

T A S K F O R C E O N

M E R C U R Y
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S E T T I N G

FINAL REPORT ON
MUNICIPAL SOLID WASTE
I N C I N E R A T I O N

VOLUME III
T E C H N I C A L A N D
R E G U L A T O R Y I S S U E S

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**TASK FORCE
ON
MERCURY EMISSIONS STANDARD SETTING

FINAL REPORT
ON
MUNICIPAL SOLID WASTE INCINERATION**

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list of Task Force Members**

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VOLUME III
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CHAPTER 1.

OVERALL SOURCES OF MERCURY

SUMMARY:

Data from the literature, NJDEPE files, and personal communications were gathered in an attempt to develop an order-of-magnitude estimation of anthropogenic sources of air emissions of mercury in New Jersey.

This search revealed that, overall, the combustion of municipal solid waste appears to be the largest source of air emissions of mercury in New Jersey. Other potentially large sources include the combustion of coal and oil and the incineration of sewage sludge. Industrial sources appear to be at least an order of magnitude lower than municipal solid waste combustion, and other sources, including hospitals, apartment houses, and crematories, appear to be lower still.

The large range of estimated concentrations of mercury in fuels indicates the need for more data.

TASK DESCRIPTION:

Order-of-magnitude estimates of emissions of mercury and mercury compounds to the air in New Jersey were made.

HOW TASK WAS ACCOMPLISHED

Data from the literature, DEPE files, and personal communications were gathered. Additional data was received from public task force members. The tight time frame for this effort, coupled with the exacting requirements for state-of-the-art analysis, precluded direct testing by the NJDEPE for mercury in fuels at this time. Unless specific sources were known to employ control technology capable of capturing some mercury emissions, such as for municipal solid waste combustion and some industrial sources, it is assumed in this analysis that no controls are utilized, and that all the mercury in the material being burned is emitted.

RESULTS

Results appear in graphic form in Figure 1.1

DISCUSSION

Municipal Solid Waste

Approximately 1.33 million tons of solid waste are incinerated annually in New Jersey. A value of 0.005 pounds of total mercury per ton of waste was used (1). This represents a weighted average of concentrations of 0.0048 and 0.0089 pounds of mercury per ton of municipal solid waste and bulky/industrial solid waste, which make up 95% and 5%, respectively, of the waste incinerated in New Jersey. For the low, mid, and high range estimates, 90%, 50%, and 30% control of the emission of this mercury during combustion of the waste was assumed. Multiplying the total tons of waste by the pounds of mercury per ton of waste, and multiplying by 0.10, 0.50, and 0.70 generates approximately 700, 3300, and 4600 pounds per year total mercury for the low, mid, and high ranges estimates, respectively. It should be noted that this mid-range assumption translates to an emission rate of approximately 0.0025 pounds of mercury per ton of waste incinerated, which is in close agreement with actual stack test data for one of New Jersey's resource recovery facilities noted by a task force member (2).

Combustion of solid waste appears to be the largest source of atmospheric mercury emissions in New Jersey. Nationally, coal may be a larger contribution. In New Jersey, however, coal accounts for only about 3% of total energy use, as opposed to about 20% nationally (3).

Coal-Burning Utilities

There are five New Jersey utility facilities which burn coal (3). They burn a total of about 3.55 million tons per year. There is a large range of values for the mercury concentration of coal reported in the literature and received through personal communications from committee members and others. This large range may reflect, in part, differing sampling and/or analytical procedures. It is also very likely that coal, a natural material, varies widely in its mercury content, much as it varies in content of sulfur and other constituents.

In an effort to shed more light on the mercury content of coal, additional references were gathered (4), (5), (6), (7), (8), (9). The values reported in these references were added to those already acquired (10), (11), (12), (13), (14), and then all values were compared. Averages were taken of the high values and the low values, where reported, and of the mean values. All reported mean values fall within a range from 0.12 ppm to 0.28 ppm. The lowest low value reported is 0.004 ppm, and the highest high value reported is 1.93 ppm. The average of the low values is 0.03 ppm, and the average of the high values is 0.84 ppm. The average mean value is 0.19 ppm. One especially relevant reference is the recent Florida Department of Environmental Regulation Report (9), which compares mercury emission rates from utilities without any emissions controls with those with ESP controls. The report indicates that ESP reduces the emission rate by about one quarter.

Since most New Jersey utilities employ ESP controls, it is assumed for the purpose of emissions estimates that the mean mercury emission rate from utilities would correspond to a value obtained by multiplying 3.55 million tons by approximately 3/4 of the average mean of 0.19 reported above, or 0.15 ppm, yielding 1064 pounds. Low and high estimates were obtained by multiplying 3.55 million by 0.03 ppm and 0.84 ppm respectively, yielding quantities of 213 pounds and 5956 pounds, respectively.

A stack test performed at Atlantic Electric's B. L. England units (Table 9.4) provides numbers which tend to corroborate this emissions range. In the test, one unit emitted mercury at an average rate of .023 pounds per hour; the other emitted it at .03 lbs/hr. These quantities, multiplied by 24 hours x 365 days total 464 pounds per year. According to an Atlantic Electric spokesman (15), the full load capacity of these units totals approximately 116 tons of coal per hour, or approximately 1.016 million tons per year, and the stack tests were run at full load. The B. L. England plant normally runs at approximately sixty percent of full capacity, so its mercury emissions would be estimated to be approximately 278 pounds per year (464 x 0.6). However, the rate of mercury emitted per ton of coal burned should be independent of the capacity utilization. So, since New Jersey burns 3.55 million tons of coal per year, 464 pounds multiplied by 3.55/1.016 should equal the total mercury emitted by New Jersey utilities. This quantity equals approximately 1600 pounds per year, a number well within the estimated range based on mercury concentration of coal, as described above.

When more data specific to New Jersey is obtained, and analyzed with state-of-the-art procedures which avoid mercury contamination, which has perhaps caused unrealistically high volumes in the past, the range of estimated emissions of mercury from this source can be narrowed.

Sludge Incineration

Reference (16) indicates that an average of about 400,000 dry pounds of sewage sludge is incinerated per day in New Jersey. This reference also reports that median mercury concentrations in sludge in 1985 ranged from approximately 3 ppm to nearly 6 ppm. Multiplying 400,000 lbs. by 365 days, by 3 ppm, 4.5 ppm, and 6 ppm gives low, mid, and high range estimates of approximately 450, 650, and 900 pounds total mercury emissions per year from this source. Based on the use of a weighted average for all domestic treatment works, approximately 800 pounds of mercury is emitted per year by New Jersey sludge incinerators.

Industrial Sources (Other than fuel combustion)

Firms large enough to meet the reporting thresholds must report releases of mercury and other hazardous substances pursuant to the federal Toxic Release Inventory (TRI) and New Jersey's Release and Source Reduction report. Data for years 1987, 1988, and 1989 show only one firm reporting releases of mercury to the air in all three years. Releases from this source, a manufacturer of industrial organic chemicals, totaled 500 pounds each of these three years. 1990 data (17), show much lower quantities from this facility, and indicate that only about 50 pounds total mercury and mercury compounds were released to the air in 1990 from all reporting firms.

No data was available on actual emissions of facilities not required to report under the TRI. However, DEPE permit data (18) indicates that only very few facilities are permitted for release of mercury, and that the maximum quantity of mercury released from all firms is roughly double the releases (50 pounds) reported on the TRI. Personal communication with the largest potential emitters has revealed very low levels of actual mercury emissions (18). Thus the overall total would appear to be in the order of magnitude of 100 pounds per year, or less.

As a further check on the possible range of mercury emissions, information on quantities of mercury and mercury-containing compounds stored on site in New Jersey reported through the Right-to-Know Program on Form 094 (17) was reviewed. Inventoried quantities of 100 pounds or larger were totaled. The one firm which reported air releases on the TRI accounted for about one third of this total. If the remaining two-thirds of the inventory would be likely to result in air emissions similar to that of the one TRI facility, then a total emission from these sources of approximately 150 pounds per year could be assumed.

For the purposes of this analysis, low, mid, and high range estimates of total mercury air emissions from industrial sources (other than fuel combustion) were estimated as 100, 200, and 400 pounds per year.

Natural Gas and Gasoline

Although data on the mercury content of these fuels remains sparse, information recently obtained considerably augments the data obtained previously and reported earlier by the Task Force. The new information indicates that emissions of mercury from natural gas are likely to be very small, and that emissions from gasoline, while not insignificant, are not likely to be larger than those emissions from other fuel combustion.

Natural gas from the North Sea has been reported by a task force member to have a concentration of 0.16 micrograms per cubic meter (19). Another report (20) indicates a range of mercury concentration from 0.02 to 0.44 micrograms per normal cubic meter. These latter quantities, when multiplied by the quantity of natural gas burned in New Jersey, yield a total emission rate of from less than one pound per year to 11 pounds per year. It is assumed for this analysis that an earlier reported value of 200 micrograms per cubic meter (21) is unrealistically high. Additional data could clarify the picture.

Gasoline, according to (22) as reported in the Florida DER Report (9), has approximately 0.02 ppm mercury. Reference (9) also assumes that on-road diesel fuel contains about 0.12 ppm. A task force member's letter (23) reports calculations based on other data from (9) which indicates that mercury associated with the particulate fraction emitted from automobiles might total from 260 to 1870 pounds per year. This 260 pound figure is based on an emission factor of 2×10^{-7} pounds mercury per pound of fuel. In fact, this is the highest of three emission factors presented in (9); the lowest is two orders of magnitude lower.

For the purposes of this analysis, the earlier reported range of 1 to 20 ppm (24) is assumed to be incorrect, and it is estimated that emissions from gasoline consumption fall between 260 and 1870 pounds per year. As with natural gas, additional data is needed to accurately predict these emissions.

Crematories

According to (25), the average corpse cremated contains about 3 grams of mercury in dental fillings. This study also indicates that virtually all of this mercury would be vaporized upon cremation. Personal communication (26) indicates that 14,427 cremations took place in 1990 in New Jersey's 16 crematories. Calculations based on data on the projected quantity of mercury used in dental preparations in 1985 (27) yields an estimated quantity of 2.2 grams mercury per corpse. For the low, mid, and high range estimates, values of 2.2 grams, 3 grams, and 4 grams per corpse were multiplied by 14,427 to obtain source emissions of 70, 95, and 125 pounds of mercury per year.

Other Incineration

Data was obtained on the amount of hazardous wastes manifested for mercury or mercury compounds which were incinerated in New Jersey in 1990 and 1991. These quantities were approximately 7 pounds in 1991 and 74 pounds in 1990. Moreover, it is likely that only a small portion of these wastes is actually mercury or mercury compounds, as such. Thus the quantities of mercury which appear to be emitted from this source appear to be relatively small.

Likewise, quantities of mercury emitted from hospitals and apartment house incinerators as indicated by data from (18) also appear to be relatively small. For this analysis, low, mid, and high estimates of 50, 100, and 200 pounds of mercury were assumed from the other incineration source.

Fuel Oil Combustion

Data from (3) indicates that over 55 million barrels of fuel oils are consumed yearly in New Jersey by industries and utilities, and that over 61 million barrels are consumed by the residential, commercial, and transportation sectors. Recent analytical data (28) indicates concentrations of mercury in heavy fuel oils ranges from 1.5 ppb to 4.8 ppb. Older data (29) gives values of 0.066 ppm for middle and light distillate oils and 0.13 ppm for residual oil. Recent EPRI PISCES data, as reported by (12) for 11 residual oil samples indicates a mercury content ranging from 0.01 ppm to 0.17 ppm, with a median value of 0.06 ppm; for two samples of number 6 oil, the values were 0.01 and 0.09 ppm. In another recent study, as reported by (14), the Oak Ridge National Laboratory used a value for all oils of 0.05 ppm. For this analysis, 1.5 ppb was used for the low estimate, 0.17 ppm was used for the high estimate, and 0.06 ppm was used as the mid-range estimate.

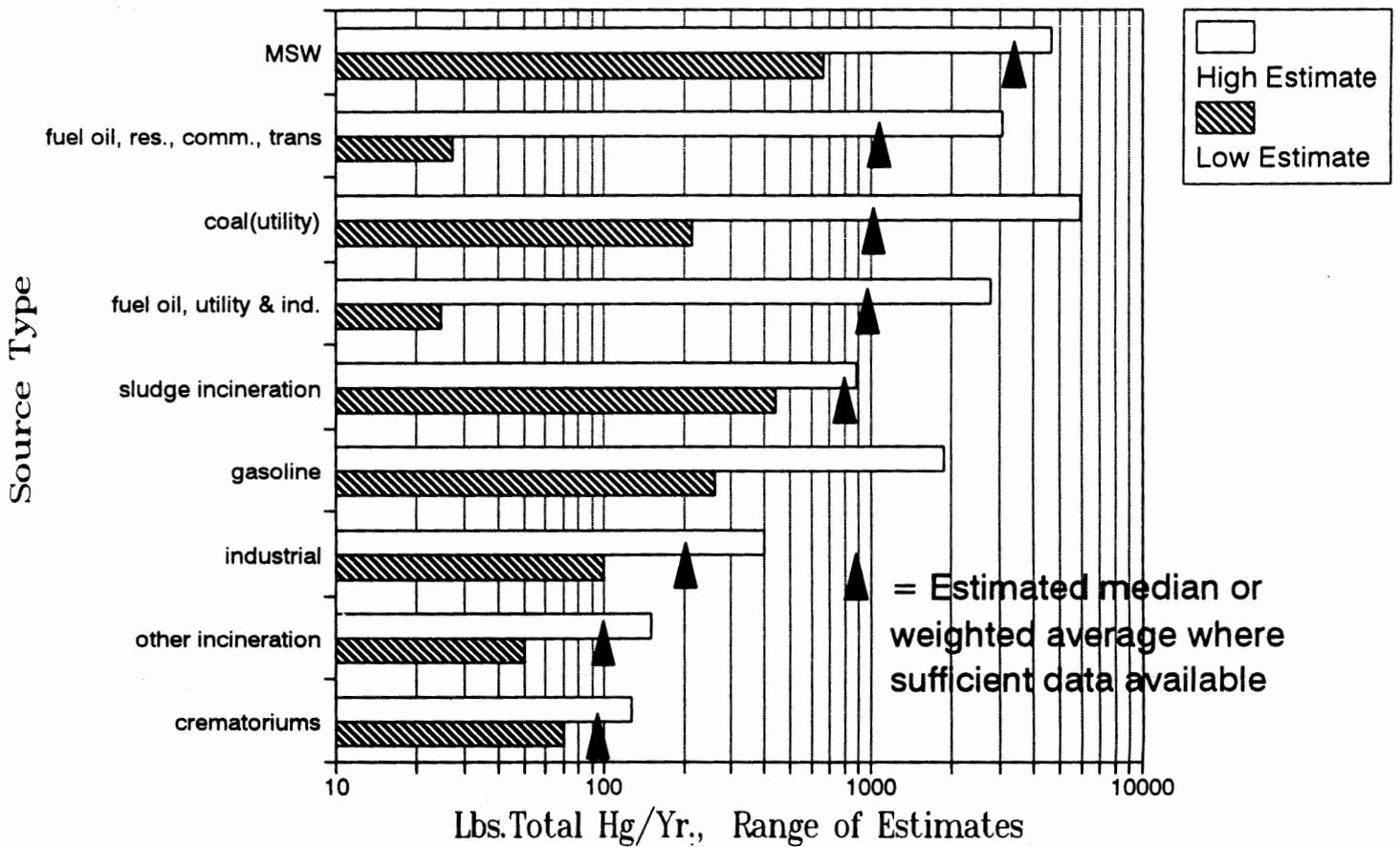
It should also be noted that some recent stack test data (30) show mercury emissions from utility boilers in that study which fired residual fuel oil were all below the detection limit of 0.4 to 2.0 micrograms mercury per cubic meter.

Emissions from Other Sources

Other sources of mercury emissions to the atmosphere and to other media have not been considered in this chapter because available data is insufficient. Potentially large sources include volatilization during use and disposal of light fixtures and electrical apparatus in addition to batteries, and releases from industrial and other sources to water bodies. Another potential source which should be investigated further is landfill gas.

Figure 1.1

Anthropogenic Mercury Emissions in NJ to the atmosphere; estimated, by source



NOTE: Ranges of mercury emissions to the atmosphere from other potential sources are not given because available data was considered insufficient.

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CHAPTER 2
MERCURY IN SOLID WASTE
METHODS OF PREVENTION AND REDUCTION

SUMMARY:

This chapter of the report addresses the issue of the quantity of mercury in the solid waste stream and the processible waste stream of MSW incinerators. The first section estimates the quantity of mercury in the current solid waste stream and evaluates this quantity in terms of the potential flue gas concentrations (uncontrolled emissions) in New Jersey MSW incinerators. The second section calculates the reduction in the quantity of mercury in the solid waste stream as a result of source reduction and source separation programs that are currently being implemented and developed by the Department. The reduction in the mercury content in solid waste is then evaluated in terms of its potential flue gas concentration in New Jersey MSW incinerators.

In New Jersey solid waste is comprised of different types of waste: municipal ID type 10, bulky ID-type 13, vegetative ID type 23 and industrial ID type 27. Since one objective of this section is to evaluate the quantity of mercury in the processible solid waste stream in MSW incinerators, the focus of this chapter is on municipal solid waste (MSW). MSW makes up 95 percent of the processible waste stream in New Jersey facilities. The other five percent is composed of bulky/industrial solid waste (B/ISW). New Jersey's MSW generation rate is on average equivalent to the United States MSW generation rate. The mercury content in municipal solid waste stream is quantified in the USEPA Report "Characterization of Products Containing Mercury in the Municipal Solid Waste in the United States 1970 to 2000," dated April, 1991, prepared by Franklin Associates, Ltd. (USEPA Mercury Report). Since municipal solid waste is primarily comprised of discarded consumer products the USEPA Mercury Report utilizes a material flow methodology developed by Franklin Associates Ltd. This methodology estimates the generation of materials and products in the municipal solid waste stream on a product-by-product basis. The USEPA Mercury Report calculates the 1988 mercury quantity in the United States MSW stream at 709 tons and projects the quantity in the 1995 U.S. MSW stream at 245.3 tons. From these quantities the 1992 quantity is projected to be 477 tons. This quantity represents a 33 percent reduction in the mercury content in the MSW stream since 1988.

Since the USEPA Mercury Report is limited to municipal solid waste it is necessary to quantify the amount of mercury in the bulky/industrial that is also processed in part by the NJ county MSW incinerators. This quantity is derived by subtracting the mercury content in municipal solid waste from the total United States consumptive use of mercury reported by the U.S. Bureau of Mines. In order to derive this quantity the average lifetime of a consumer product is needed. From the data presented in the USEPA Mercury Report it is estimated that the 1992 average lifetime of a consumer product from the time it is manufactured to the time it is used and finally disposed is 4 years.

According to the US Bureau of Mines the consumptive use of mercury in products and processes in 1988 was 1755 tons. This use of mercury, on average,

generated approximately 477 tons of mercury in the 1992 MSW stream. The remainder of the mercury in products, 1278 tons of the 1988 consumptive use of mercury, is disposed of as liquid waste into a treatment works, as hazardous waste or as bulky/industrial solid waste. It was estimated from evaluating the US Bureau of Mines consumptive use data for mercury, that 30 percent of the products and process waste would be managed as hazardous waste. The remaining 895 tons of mercury in discarded products is assumed to be disposed of in the bulky/industrial solid waste stream.

The mercury content in the U.S. municipal solid waste stream and the bulky/industrial solid waste stream is then apportioned to the New Jersey solid waste streams. Based on the 1988 New Jersey solid waste generation rates the quantity of mercury in the New Jersey MSW stream is 0.0048 pounds/ton and in the B/ISW stream it is 0.0089 pounds/ton. Based on a review of the solid waste disposal records for the operating county MSW incinerators, the processible solid waste stream is, on average, comprised of 95 percent municipal solid waste and 5 percent bulky/industrial solid waste. This quantity is apportioned to the processible solid waste in the four county facilities. The potential flue gas concentration from this quantity of mercury in the solid waste is presented in Table 2.1 below.

Table 2.1

MERCURY CONTENT IN NEW JERSEY RRF's

FACILITY	PERMIT LIMITS	STACK* TEST	POTENTIAL FLUE GAS** CONCENTRATIONS
	(pounds/hour/unit)		
Camden MSWI	0.08	0.0446	0.074
Essex MSWI	0.053	0.0564	0.155
Gloucester MSWI	0.12	0.0014	0.063
Warren MSWI	0.05	0.0394	0.043

* Data from Chapter 6

**nominal throughput operating at 100% on-line availability with 100% mercury volatilization without controls.

New Jersey is currently in the process of implementing programs that will reduce the quantity of mercury, as well as other heavy metals in the solid waste stream. These programs are mandated in two amendments to the Solid Waste Management Act which were passed by the Legislature and signed into law by Governor Florio on January 20, 1991. The amendments are the "Dry Cell Battery Management Act" N.J.S.A. 13:1E-99.59 et seq and the "Toxic Packaging Reduction Act" N.J.S.A. 13:1E-99.47 et seq.

Table 2.2 quantifies the mercury content in the processible solid waste stream in the four county facilities and illustrates the potential reduction in mercury concentration that could occur over time as source reduction and source separation (SR & SS) programs are implemented.

Table 2.2

**POTENTIAL FLUE GAS CONCENTRATIONS IN NEW JERSEY MSWI
WITH MERCURY SR & SS REDUCTION PROGRAMS**

FACILITY	PERMIT LIMIT pounds/hr/unit	POTENTIAL FLUE GAS* CONCENTRATIONS pounds/hr/unit			
		YEAR			
		1992	1993	1994	1995
Camden MSWI	0.08	0.074	0.031	0.025	0.022
Essex MSWI	0.053	0.155	0.063	0.053	0.044
Gloucester MSWI	0.012	0.063	0.028	0.023	0.019
Warren MSWI	0.05	0.043	0.017	0.013	0.090

Table 2.3 quantifies the mercury content in the processible solid waste stream in the four county facilities and illustrates the additional reduction in mercury concentration that could occur over time with additional source reduction and source separation efforts inplace.

Manufacturers of alkaline batteries have accelerated their source reduction efforts and plan to have all added mercury out of their alkaline batteries by January 1, 1994, which is two years ahead of schedule. Other product manufacturers are redesigning their products to source reduce the mercury in their products. The fluorescent light bulb manufacturers have committed to an approximate 50 percent reduction in their product by 1995. Other product manufacturers that cannot remove the mercury because of product or technology limitations are working with federal, state and local governments to develop source separation programs to remove their products from the solid waste disposal stream. The successful implementation of these programs could result in a greater than 95 percent reduction of mercury in the municipal solid waste stream.

Conservatively, this reduction of mercury in the municipal solid waste stream may not be fully realized until the year 2000. A number of factors impact on the scheduling for implementation, including the following:

1. The time required to develop and implement source reduction programs by manufacturers;
2. The time required to develop and implement source separation collection programs;

3. The time required to develop and implement recovery/reclamation/reuse facilities; and
4. The average lifetime of the products.

However, the major factor in the overall timeframe in which a mercury reduction program can be implemented is funding. This factor, who pays, at what cost, and at what point is the key to any program. It is the one factor that will take the most amount of time resolving and should be determined upfront in the program.

Table 2.3

POTENTIAL EMISSIONS FROM NEW JERSEY MSWI WITH ADDITIONAL SOURCE REDUCTION PROGRAMS					
FACILITY	PERMIT LIMIT pounds/hr/unit (pounds/hr/fac)	POTENTIAL FLUE GAS* CONCENTRATIONS pounds/hr/limit			
		YEAR			
		1992	1993	1994	1995
Camden MSWI	0.08	0.074	0.025	0.018	0.015
Essex MSWI	0.053	0.155	0.053	0.0341	0.028
Gloucester MSWI	0.12	0.063	0.024	0.017	0.014
Warren MSWI	0.05	0.043	0.014	0.009	0.007

TASK DESCRIPTION:

This chapter of the report addresses the issue of mercury in products, the quantity of mercury these products impart to the solid waste stream and the current and future source reduction potential for these components. In summary the following topics are discussed:

- 1• Definition of solid waste and the various types of solid waste in the New Jersey system;
- 2• The relationship between state and federal definitions of municipal solid waste;
- 3• The consumptive use of mercury in the United States;

- 4• The mercury in discarded consumer products in the United States municipal solid waste stream;
- 5• The mercury in discarded consumer products in the New Jersey municipal solid waste stream;
- 6• The mercury in discarded products the New Jersey bulky/industrial solid waste streams;
- 7• The mercury in the processible solid waste stream of the New Jersey MSW incinerators;
- 8• The current and potential source reduction programs for discarded products containing mercury;
- 9• The reduction of mercury in the solid waste stream over the next three years resulting from source reduction; and
- 10• The reduction of mercury in the processible solid waste stream of the New Jersey MSW incinerators.

Chapter 3 of the report will address issues relative to mercury in discarded products in hospital solid waste.

DISCUSSION AND RESULT:

DEFINITION OF SOLID WASTE

In New Jersey, solid waste is defined primarily by the following waste types:

1. Municipal solid waste (ID type 10): Waste originating from household, commercial and institutional sources;
2. Bulky solid waste (ID type 13): Large noncompactable waste originating mainly from construction and demolition operations. Included in this category are white goods, furniture, tree trunks and stumps, and discarded automobiles;
3. Vegetative solid waste (ID type 23): Waste originating from farms, plant nurseries and greenhouses. Included in this category are leaves, grass clippings, tree parts, shrubbery and garden waste; and
4. Dry industrial solid waste (ID type 27): Waste originating from manufacturing, industrial and research and development processes and operations.

The above waste types define the majority of solid waste managed in New Jersey. Other types of waste are animal and food processing waste (ID 25), dry sewage sludge (ID 12), bulk liquid and semi liquids (ID 72) , septic tank clean out waste (ID 73) and liquid sewage sludge (ID 74). The definitions for these types of wastes are set forth at N.J.A.C. 7:26-2.13(g) and (h).¹

The USEPA defines municipal solid waste (MSW) as solid waste generated by residential, commercial and institutional sources.² This is essentially similar to New Jersey's definition for MSW. The federal and state definitions do not include sewerage sludge, industrial waste and process residues, construction and demolition waste, agricultural waste, oil and gas production waste and mining waste.

For purposes of this report, vegetative solid waste (ID type 23) is included in the calculation of the total New Jersey municipal solid waste stream since it is defined as MSW under the federal definition. The inclusion of this solid waste type with municipal solid waste does not change the calculations of mercury in the New Jersey municipal solid waste and total waste stream. Over the last 18 years mercury and mercury compounds in ID type 23 solid waste have been greatly reduced and limited by regulations limiting mercury in pesticides.³ Mercury pesticides were eliminated for use in food crops in 1972.³ The inclusions of ID type 23 within the calculations of municipal solid waste is a conservative assumption. A recent article in Biocycle Magazine reported the range of mercury in yard waste and yard waste compost to be 0.2 to 0.8 mg/kg (0.0004 to 0.0016 pounds per ton) on a dry basis.⁴

This chapter of the report will focus on the sources of mercury in discarded consumer products found in the municipal waste stream. It is important to note that the consumptive use of mercury is not equal to the mercury in discarded consumer products for two reasons. One, because mercury is used in products and manufacturing/industrial processes that are not discarded as municipal solid waste but as liquid waste to sewer system and treatment works, as process losses to the atmosphere or in other waste streams such as bulky/industrial solid waste or hazardous waste. Two, there is a lag time or lifetime of a product between when it is produced, purchased, used and discarded into the solid waste stream.

The quantity of mercury in the total solid waste stream will be estimated from the evaluation of the quantity of mercury in discarded consumer products in the municipal solid waste. Municipal solid waste, ID 10, is solid waste generated by households, commercial and institutional sources and primarily consists of discarded consumer products and packaging.

MERCURY IN THE CURRENT SOLID WASTE STREAM

This section of the report evaluates the mercury content currently in the solid waste stream in both the municipal and bulky/industrial solid waste streams. In addition this section of the report evaluates the mercury content currently in the processible solid waste stream in New Jersey's MSW incinerators.

Methodology

The methodology for this section of the chapter is as follows:

1. Quantify the total U.S. consumptive use of mercury in products in the U.S.;

2. Quantify the mercury content in discarded consumer products in the U.S. municipal solid waste stream;

3. Determine the average lifetime of discarded consumer products from the estimate of time between production, purchase, use and disposal for individual discarded consumer products; and

4. Using the average life of products to estimate the mercury in discards in other solid waste streams in the U.S.;

5. Using the data on mercury in the U.S. municipal solid waste and total waste stream to estimate the quantity of mercury in the New Jersey solid waste streams; and

6. Using the mercury in the New Jersey municipal and total solid waste streams calculate the quantity of mercury in discarded products processed by the four operating MSW incinerators.

Natural and Anthropogenic Sources of Mercury

Table A1 in the Appendix summarizes the worldwide annual anthropogenic sources of mercury, as cited in the USEPA report "Characterization of Products Containing Mercury in Municipal Solid Waste in the United States 1970 to 2000", dated June 1990, prepared by Franklin Associates, Ltd. (USEPA Mercury Report).³ The basis for this summary is the Nriagu and Pacnay article "Quantitative Assessment of Worldwide Contamination of Air, Water and Soils by Trace Metals" in the May 1988 issue of Nature. Nriagu and Pacnay estimated that the anthropogenic quantity of mercury in the biosphere at 12,000 short tons per year.⁵ It is important to note that mercury is also available from non-anthropogenic or natural sources. The Nature article estimates the ratio of natural sources of mercury for atmospheric releases to the anthropogenic sources of mercury at approximately 1:1 while some studies have reported this ratio as high as 2:1 and 4:1.⁵ More recent studies indicate that there is a shift to the anthropogenic side of the equation. The reader is referred to Volume II of this report for a more detailed discussion of the sources of mercury in the biosphere. The anthropogenic sources of mercury come from the combustion of fossil fuel (gas, oil and coal) municipal solid waste, sewage sludge and wood; metal production including mining and smelting; and manufacturing processes. The natural sources of mercury are mainly from volatilization of mercury from soils, vegetation and water bodies. However, one issue in regard to the ratio of natural sources versus the anthropogenic sources of atmospheric release is that the volatilization of mercury from soils and peat may be from atmospheric deposition rather than from geologic sources.⁶ The mercury in peat and vegetation (grasses and sugar cane) that are released when they are burned, may also likely have originated from anthropogenic sources.⁶ As cited in the Nature article the total atmospheric deposition to the water and soil from all anthropogenic atmospheric emission sources represents approximately 20 and 25 percent respectively of the total mercury input to the aquatic and soil ecosystems.

According to the Nriagu and Pacnay article the range of the quantity of mercury emitted in the atmosphere from municipal solid waste combustion is 154 to 2,315 short tons per year (conversion from metric units to short tons by Franklin Associates, Ltd.). The total emissions to the atmosphere from all sources is reported as 910 to 6200 short tons with a medium value of 3560 tons. This is a range of 17 to 37 percent of the sources of mercury resulting in atmospheric emission with a medium value of approximately 32 percent. Worldwide this is the second largest source of atmospheric emission of mercury with coal combustion—industry/domestic, 48.8 percent, being ranked first and coal combustion—electric utilities ranked a distant third at 9.8 percent. However, this article fails to address mercury emissions from other fossil fuel sources such as oil, its product derivatives and natural gas. While the concentration of mercury in these sources may be low, the sheer volume of their use depending on the concentration makes them a source of atmospheric emissions for consideration as discussed in chapter 1. The reader is referred to chapter 1 for a detailed discussion of the ranking of mercury emissions in New Jersey.

The Nature article overlooks some other anthropogenic sources of mercury into the environment which the department and the USEPA are just beginning to evaluate. They are mercury emissions from sewage sludge digestors and flares, crematoriums and solid waste landfills. These additional anthropogenic sources of mercury to the environment, which may be small, highlights why the first or preferred option in mercury control technology is to reduce or eliminate, were possible, the mercury in products that we use and not just finding the most appropriate management system for their disposal. The mercury in the products that we use and eventually discard will end up in one of the environmental control and management systems that we design and operate. While these systems can be made environmentally sound they can contribute, however small, to the total load of mercury to the environment. Therefore, it is more appropriate to remove or reduce mercury from the products we use and eventually discard.

Consumptive Use of Mercury

According to the U.S. Bureau of Mines, the 1989 consumptive use of mercury in U.S. products and processes was 1338 short tons.⁷ This quantity has decreased by over 50 percent over the last 20 years and by over 75 percent over the last 10 years. According to the figures maintained by the U.S. Bureau of Mines, the consumptive use of mercury in the United States has decreased on average by approximately 3 percent annually over the last twenty years. In recent years there has been on average, an 8 percent annual decrease in the consumptive use of mercury, with a 24 percent decrease between 1988 and 1989.

Table A2 in the Appendix (which is a summary from the USEPA Mercury Report) presents the U.S. Bureau of Mine's reporting statistics for the consumption use of mercury in the U.S. from 1967 to 1989. The current primary uses for mercury are in manufacturing of chlorine and caustic soda, batteries, paints, wiring devices and switches, measuring and control instruments, dental equipment and supplies, electrical lighting, pigments, catalysts, pharmaceuticals and laboratory uses. It should be noted that over the last several years mercury use in agricultural chemicals, paints and paper have

been reduced or eliminated. ³ Newly added to this list of reduced or eliminated sources of mercury in consumer products are batteries and pigments. ^{8,9}

Mercury in Discarded Products in Municipal Solid Waste

Tables A3 and A4 in the Appendix present the products, the tonnage and the percentage of mercury annually discarded into the MSW stream from 1970 to 2000. These Tables were developed by the Franklin Associates, Ltd. as presented in the USEPA Mercury Report utilizing a material flow methodology developed by Franklin Associates Ltd.. Franklin Associates, based on this methodology, calculate the quantity of mercury in the 1989 U.S. municipal solid waste stream at 709 short tons ³. From the data in Table A3, the 1992 quantity of mercury in the U.S. municipal solid waste stream (US_{Hg.M}) is projected to be 477 tons.

Over the last several years a number of pollution prevention, source reduction and source separation programs have been and are in the process of being implemented by industry to lower the mercury use in their products and in the disposal stream. Most notable of these programs is the battery manufacturers which have been recognized for their pollution prevention programs in this area. These programs resulted in a 33 percent reduction in mercury in the municipal solid waste stream over the last four years and will significantly reduce the mercury in the municipal solid waste stream over the next four years. The alkaline battery manufacturers have committed to eliminating all added mercury in their product by January 1, 1994. This will result in a 99.9 percent reduction of mercury from batteries over the current level in the 1992 municipal solid waste disposal stream.

Mercury in Bulky/Industrial Solid Waste

From the data presented in the USEPA Mercury Report it was determined that the average product lifetime between production, use and disposal in the municipal solid waste stream is four years. This number is calculated by the summation of the life of the individual products multiplied by the percentage of mercury that product represented in the municipal solid waste stream as follows as Equation 1:

$$\sum_{i=1}^n L_i * Hg_i \quad (\text{Eq.1})$$

where

- i = discarded consumer product
- L = lifetime of the ith product
- Hg = percentage of mercury of the ith product in MSW stream

This means that, on average, the consumptive use of mercury in consumer products versus the time they appear in the municipal solid waste stream is

four years or the 1992 total mercury in the municipal solid waste stream was generated from a 1988 mercury consumptive use (US_c). The 1988 consumptive use of mercury according to the U.S. Bureau of Mines was 1755 short tons. It should be noted that the average lifetime of mercury containing consumer products from consumptive use to disposal was dominated by batteries. As the mercury content in batteries is reduced, the average lifetime for mercury containing consumer products will increase. From the 1988 mercury consumptive use of 1755 short ton of mercury, the quantity of mercury in the 1992 MSW discarded consumer products, 407 short tons is subtracted resulting in a remaining quantity of 1278 short tons. This represents the quantity of mercury in discards in other than the municipal solid waste stream.

As an equation, the above discussion can be presented as follows:

$$\text{U.S. Consumptive Use} - \text{Hg in MSW} = \text{Hg in other waste streams.} \\ \text{(Eq. 2)}$$

In evaluating the consumptive use categories defined by the U.S. Bureau of Mines it was determined that 30 percent would be managed as hazardous waste and would not be managed within the solid waste system. These categories are all of chlorine and caustic soda manufacturers, catalysts and laboratory uses and a small percentage of other uses (the other category includes chemical uses, catalysts for plastics which would be managed as hazardous waste). This results in 895 short tons of mercury in discards in the bulky ID 13 and industrial waste ID 27 portions of the solid waste streams. It is important to note that this figure is more than double the quantity of mercury in the municipal waste stream, the majority of which is disposed of in solid waste landfills.

As an equation, the above discussion can be presented as follows:

$$\text{Hg in other waste streams} - \text{Hg in discarded products managed as hazardous} \\ \text{waste} = \text{Hg in bulky/industrial solid waste stream.} \\ \text{(Eq. 3)}$$

Mercury in the Processible Solid Waste Stream of MSW Incinerators

Based on an analysis of the department's solid waste disposal records for the operating MSW incinerators in Camden, Essex, Gloucester and Warren counties, it was determined that, on average, 95 percent of the total throughput of these facilities was municipal solid waste and 5 percent was processible bulky and industrial solid waste.¹⁰ The range of processible bulky and industrial solid waste is from 3 to 10 percent of the total throughput. A summary of the results is presented in Table 2.4.

TABLE 2.4
RRF THROUGHPUT
BY MSW and BULKY/INDUSTRIAL
IN TONS AND PERCENTAGE

	MSW tons	%	B/ISW tons	%	TOTAL
Camden Co. RRF	165,039	93.9	10,743	6.1	175,782
Adjusted*	323,885		21,040		344,925
Essex Co. RRF	809,964	96.1	33,004	3.9	842,968
Gloucester Co. RRF	157,960	90.0	17,487	10.0	175,447
Warren Co. RRF	134,714	97.2	3,895	2.8	138,609
TOTAL	1,267,677	95.1	65,114	4.9	1,332,806

* Camden RRF tonnage was adjusted to reflect an annual throughput of 1050 TPD at the referenced higher heating value (HHV) with a 90% on-line availability at the MSW - B/ISW ratio reflected above. The Camden facility began operations in May 1991.

The next factor in determining the quantity of mercury in the New Jersey municipal and total solid waste stream was to determine the relationship of New Jersey's MSW generation rate to the US MSW generation rate.

Based on the USEPA Report "Characterization of Municipal Solid Waste in the United States 1960 to 2000 (1990 update)" dated June 1990, prepared by Franklin Associates, Ltd. it was estimated that the U.S. per capita generation rate for MSW is 4.00 pounds per person.¹¹ Based on New Jersey's "Solid Waste Reassessment Task Force-Preliminary Report" dated June 1990, the New Jersey per capita generation for MSW is 4.61 pounds per person.¹² After accounting for recycling the discard rate for the US MSW stream is 3.48 pounds per capita and the New Jersey rate is 3.57 pounds per capita. A summary of results is presented in Table 2.5. The ratio of US MSW per capita rate to NJ MSW per capita rate prior to recycling will be used to normalize the mercury quantity in discarded consumer products in the New Jersey MSW stream to the US rate.

TABLE 2.5
RATIO OF U.S. MSW RATE
TO N.J. MSW RATE

	(pounds/person/day)		
	US	NJ	Ratio US:NJ
MSW Generation Rate	4.00	4.61	1.153
MSW Recycling Rate	0.52	1.04	0.500
MSW Disposal Rate with Recycling	3.48	3.57	1.026

The final factor in converting the mercury in discarded consumer products in the US MSW stream to the New Jersey MSW stream is to calculate the percentage of New Jersey's population to the total US population. Based on the latest census the New Jersey population is 3.1 percent of the total U.S. population¹³.

The equation to calculate the mercury content in the New Jersey municipal solid waste stream is as follows:

$$\text{NJ Hg.M} = \text{US Hg.M} * 1.153 * 0.031 \quad (\text{Eq.4})$$

where

NJ Hg.M = Mercury in the NJ Municipal Solid Waste (1992)
 US Hg.M = Mercury in the United States Municipal Solid Waste (1992)
 1.153 = waste ratio of New Jersey MSW to U.S. MSW; and
 0.031 = the percentage of New Jersey population in the U.S.

Table 2.6 presents the results of mercury in discarded products in the New Jersey municipal solid waste stream using equation 4 above.

TABLE 2.6

**MERCURY IN DISCARDED CONSUMER PRODUCTS IN
 THE NEW JERSEY MSW STREAM**

PRODUCT	1992	
	TONS	PERCENT
Consumer Batteries*		
Alkaline	8.23	48.3
Mercury Oxide	5.86	34.4
Others	<u>0.16</u>	<u>0.9</u>
Battery subtotal	14.25	83.6
Electric Lighting		
Fluorescent Lamps	1.05	6.1
High Intensity Lamps	<u>0.03</u>	<u>0.2</u>
Lighting Subtotal	1.08	6.3
Paint Residues	0.37	2.2
Fever Thermometers	0.59	3.5
Thermostats	0.35	2.0
Pigment	0.23	1.4
Dental Uses	0.13	0.7
Special Paper Coating	0.02	0.1
Mercury Light Switches	<u>0.04</u>	<u>0.3</u>
TOTAL	17.05	100.0

*Consumer batteries in the municipal solid waste disposal stream are generated by residential, commercial and institutional sources. The majority of alkaline batteries are from residential uses while the majority of mercury-oxide batteries are from institutional uses.

Equation 5 calculates the mercury content in the bulky/industrial (B/ISW) solid waste stream is as follows:

$$NJ \text{ Hg.I} = 0.031(US_{c, \text{year } 0} - US \text{ Hg.M}^{\text{Year } 4}) * 0.70 * 1.153 * (\text{Eq. } 5)$$

where

$NJ \text{ Hg.I}$ = mercury in the bulky/industrial solid waste stream

$US_{c, \text{year } 0}$ = US consumptive use of mercury (1988)

$US \text{ Hg.M}^{\text{year } 4}$ = Mercury in US MSW (1992)

The mercury content in the New Jersey bulky/industrial solid waste (B/ISW) stream is approximately 32 short tons. The total mercury content in the solid waste stream is 49 short tons. The mercury content in discarded consumer products, represents 35 percent of the mercury in the solid waste stream, while the remaining 65 percent is in discards in the bulky/industrial solid waste portion. The possible sources of mercury in products and processes in the bulky/industrial waste stream will be discussed later in this chapter.

Table 2.7 presents the New Jersey solid waste generation rate for municipal and bulky/industrial solid waste.¹² Using Table 2.7 and the total mercury content in the municipal solid waste stream and the bulky/industrial waste stream from Equations 4 and 5, the mercury content in pounds per ton of municipal solid waste and industrial solid waste were calculated as follows:

$$NJ_{\text{Hg.M}} * 2000 / \text{MSW} = 0.0048 \text{ \#/Ton} \quad (\text{Eq. } 6)$$

$$NJ_{\text{Hg.I}} * 2000 / \text{BISW} = 0.0089 \text{ \#/Ton} \quad (\text{Eq. } 7)$$

where

$$\begin{aligned} \text{MSW} &= \text{Total municipal and vegetative solid waste} \\ &= 7,171,000 \text{ tons}^{12} \end{aligned}$$

$$\begin{aligned} \text{BISW} &= \text{total bulky and industrial solid waste} \\ &= 7,184,000 \text{ tons}^{12} \end{aligned}$$

TABLE 2.7

**NEW JERSEY SOLID WASTE BASELINE
GENERATION RATE**
(thousands of tons/year)

	Generated	Recycled	Disposal
MSW and Vegetative Waste	7,171	2,130	5,041
Bulky and Industrial	7,184	3,998	3,186
Total	14,355	6,128	8,227

Table 2.8 presents the estimated average annual mercury content in the Camden, Essex, Gloucester, and Warren County MSW incinerators. Table 2.8 was developed utilizing the information from Table 2.4 and the results of Equations 6 and 7.

TABLE 2.8

**1991 MERCURY CONTENT IN SOLID WASTE PROCESSED
BY OPERATIONAL RRF's**

Facility	Municipal		Industrial		Total mercury content (pounds)
	thru-put (tons)	mercury content (pounds)	thru-put (tons)	mercury content (pounds)	
Camden RRF*	323,885	1,554.65	21,040	187.26	1,741.91
Essex RRF	809,964	3,887.83	33,004	293.74	4,181.57
Gloucester RRF	157,960	758.21	17,487	155.63	913.84
Warren RRF	134,714	646.63	3,895	34.67	681.30

* Adjusted for annual throughput

Table 2.9 presents the average daily mercury content in the Camden, Essex, Gloucester and Warren County MSW incinerators. Table 2.9 was developed utilizing the information from Table 2.5, the results of Equations 6 and 7 and the nominal throughput of each facility. The quantity in Tables 2.8 and 2.9 will differ because of differences in actual on-line availability of the facility and the actual higher heating value (HHV) of the solid waste processed by the facility. A lower HHV of the fuel means more solid waste is needed to be processed by the facility to maintain an equivalent total heat release and conversely an increase in the HHV means less solid waste is needed to maintain an equivalent total heat release.

TABLE 2.9

**DAILY MERCURY CONTENT IN SOLID WASTE PROCESSED
BY OPERATIONAL MSWI**

	Nominal Daily Mercury Capacity (tons/day)	Estimated Average Content (pounds/day)
Camden MSWI	1050	5.30
Essex MSWI	2250	11.16
Gloucester MSWI	575	3.00
Warren MSWI	400	2.04

Table 2.10 presents a summary of the average potential concentrations in the flue gas from the estimated mercury content in the processible solid waste

stream generated in Table 2.8 and 2.9. It should be noted that Table 2.10 is an estimate of the potential concentrations of mercury in each facility's flue gas stream. It is only an estimate of the uncontrolled emissions within the facility based on the Franklin Associates materials flow methodology for mercury in the solid waste stream. The data was calculated by assuming an on-line availability of 100 percent and 100 percent volatilization of the mercury in the solid waste processed by the facility. The actual mercury emissions from a facility will differ from that reported in Table 2.10 based on a number of factors including: the range of mercury content in the waste, the on-line availability and the facility's mercury control. The reader is referred to Chapter 6 for a detailed description of each facility's actual mercury emissions data.

TABLE 2.10

**POTENTIAL FLUE GAS CONCENTRATION FROM NEW JERSEY
MSW INCINERATORS AT CURRENT MERCURY CONTENT
IN PROCESSIBLE SOLID WASTE STREAM***

FACILITY	PERMIT LIMITS		POTENTIAL FLUE GAS*	
	(#/hr/unit)	(#/hr/facility)	(#/hr/unit)	(#/hr/facility)
Camden MSWI	0.08		0.074	
		0.24		0.221
Essex MSWI	0.053		0.155	
		0.159		0.465
Gloucester MSWI	0.12		0.063	
		0.24		0.125
Warren MSWI	0.05		0.043	
		0.10		0.085

* Assuming operations 24 hour, 365 day/year with 100% volatilization of mercury in the solid waste.

Mercury Mass Balance

As can be seen from Table 2.10, except for Essex County, the county MSW incinerators operate approximately at their permit limits without air quality control systems. To check these numbers Table 2.11 through 2.13 presents a summary of a mercury balance for the Warren and Camden facilities using stack testing data presented in Chapter 6 and total mercury analysis of the combined ash stream presented in Chapter 11.

Table 2.11 presents a summary of the total mercury analysis of the combined residual ash stream for both the Camden and Warren County facilities. These facilities are the only facilities in New Jersey at which total metal analysis is being performed because of their initial or current disposal situation.

New Jersey does not currently require total metals analysis of the residual ash. The data is presented for the range of values, the average value and the number of samples in the database. The results are presented in mg/kg and pounds/ton as ppm.

TABLE 2.11

	TOTAL MERCURY IN MSWI RESIDUAL ASH*			
	Min	Max (mg/kg) (#/ton)	Avg	n
Camden Co. MSWI	0.035** 0.00007	7.7 0.0154	3.05 0.0061	114
Warren Co. MSWI	0.01** 0.00002	0.81 0.0016	0.041 0.00008	130

* The total metal results are effected by the sample preparation (particle size), the evasiveness of the mineral acid used and the analytical instrument.

** One half of the minimum detection limits was used for all values that were reported as below minimum detection level.

The results of Table 2.11 demonstrates the log distribution nature of metals in the environment. Several orders of magnitude are reported for both facilities between the maximum and minimum values of the total mercury in the residual ash. Any system that is developed to statistically monitor the mercury (or any metal) in the residual ash or emissions should account for this fact. Table 2.12 present the data for the allowable emissions and the actual emission from the latest stack testing at the Camden and Warren County MSW incinerators from Chapter 6.

TABLE 2.12

	allowable emissions (#/ton)	actual emissions
Camden Co. MSWI	0.0055	0.0037*
Warren Co. MSWI	0.006	0.003

* represents an average of test data

Table 2.13 combines the total mercury in the residual ash and the actual emission data to develop a mass balance for the facilities.

TABLE 2.13

MERCURY BALANCE IN MSW INCINERATORS

	Residual Ash (#/ton)	Emission	Total
Camden Co. MSWI	0.0061	0.0037	0.0098
Warren Co. MSWI	0.00008	0.003	0.00308

The above data is presented as a rough check on the materials flow method presented in this chapter for calculating the mercury contain in solid waste processed by New Jersey MSW incinerators. It is not a full mass balance of the mercury in the processible solid waste streams in these facilities. Additional data on the standardization of the mercury sampling and analytical procedures for both the air emissions and residual ash must be developed before drawing direct conclusions. Of particular concern is the timeframe for sampling of the air emissions and the residual ash which may result in a high degree a variance in the data. Two areas for further evaluation before fully assessing this approach, given the above data are:

1. The total metals analysis and overall removal efficiencies of the facilities. The Camden County facility has shown a removal efficiency range of 40 to 70 percent while the Warren County facility indicates only a 3 percent removal. However data from the Department's residual ash sampling at the Warren County facilities shows a total mercury in the residual ash of 4.1 to 4.2 mg/kg. This would result in a removal efficiency of 71 percent and a total mercury balance of 0.011 pounds per ton; and
2. Warren County has implemented and operated a battery separation program for over two years. The effect of this program may be the reason for the low total mercury in the facility. As programs are implemented to source reduce or source separate mercury containing products from the solid waste stream, the total metals in the residual ash should be monitored to evaluate the efficiencies and recovery rates of these programs.

One possible explanation for the difference in mercury content from the mass balance method and the materials flow method may be the specific uses for mercury containing consumer products that are particular to New Jersey compared to the national average. This possibility was explored by Florida DER and Broward County in their mercury study and will be unique to all coastal states.¹⁴ Each boat in the marinas across New Jersey has a bilge pump. That bilge pump operates on a mercury switch. The mercury switch, because of the corrosive nature of the salt water may require replacement on average, annually. These discarded consumer products would probably be managed in the municipal solid waste stream and would increase the mercury content in the solid waste stream.

When evaluating the mercury containing products in the USEPA Mercury Report, the only mercury switches calculated within the municipal solid waste stream were from light switches and thermostats. This category of mercury containing products was under evaluated in the USEPA Mercury Report. Almost all safety appliances that automatically switch off when tipped over, like irons or kerosene heaters have a mercury switch. Almost all automatic pumps operate with a mercury switch. However, the USEPA Mercury Report does not include these switches within the municipal solid waste stream.

To confirm the conclusions developed by Florida, the Department contacted mercury switch manufacturers and evaluated the U.S. Bureau of Mines data on consumptive use of mercury in products. The U.S. Bureau of Mines data indicates that mercury switches are in fact the fourth largest product use of mercury, following chlorine and caustic soda manufacturing, batteries and paints (mildew-proofing). Since mercury in chlorine and caustic soda manufacturing is not managed in the solid waste stream and mercury in paints and batteries is, being reduced, mercury in switches will probably be the largest source of mercury in the municipal solid waste stream. This was confirmed by Comus International, a mercury switch manufacturers.¹⁵

Further support for this explanation may be found in comparing the uncontrolled mercury emissions reported by the MSW incinerators. Evaluation of the mercury content in the processible solid waste stream developed by the mass balance method is more in line with the MSW incinerators uncontrolled emissions for mercury reported by the industry in 1992 of 1000 to 1300 ug/dscm.

However, as stated above, this method for calculating and checking on the total mercury content in the processible waste stream needs to be more accurately implemented through modification of the MSW incinerators permits. When a facility is monitored for mercury emissions, the total mercury content in the residual ash should be monitored. This will allow for a check on the overall effectiveness of the mercury source reduction and source separation programs.

Another method of determining the mercury content in the solid waste stream is to perform an actual weighing/composition study in which the solid waste is sampled and analyzed for total mercury. The methodology for a weighing/composition study is to segregate a number of solid waste vehicles that represent a percentage of the incoming solid waste by type (approximately 10 percent of the incoming vehicles). From these vehicles a sample of approximately 300 pounds is taken and sorted into components such as glass, paper, plastic, etc. To evaluate the total mercury content in the waste a subsample of the sorted component waste is collected and analyzed. Attached in Appendix B are summaries of three weighing/composition study which sampled the solid waste stream for total metals analysis. It is difficult to perform an accurate waste composition analysis by type of solid waste due to the variety of material in the solid waste stream. This problem is compounded when trying to sample for total metals analysis as demonstrated by the results in the Appendix B. The data is supplied for informational purposes only. With the current limited data it can not be used as a balance of the total metals in the solid waste stream.

SOURCE REDUCTION

This section of the report will evaluate the source reduction potential for mercury in the solid waste stream. The data generated in the first section of the report will be evaluated in terms of current and future potential source reduction programs in New Jersey.

Methodology

The methodology for this section is as follows:

1. Quantify the mercury reduction in the solid waste stream as a result of source reduction/source separation programs currently being developed and implemented;
2. Estimate the resultant reduction of mercury in the processible solid waste stream in New Jersey MSW incinerators;
3. Estimate the future potential source reduction/source separation programs for mercury content in solid waste; and
4. Estimate the future potential reduction of mercury in the processible solid waste stream in New Jersey MSW incinerators.

Current Source Reduction Programs

Two amendments to the New Jersey Solid Waste Management Act relating to the reduction of mercury in solid waste were passed by the Legislature and signed into law by Governor Florio on January 20, 1992. They are the used Dry Cell Battery Management Act and the Toxic Packaging Reduction Act. The Dry Cell Battery Management Act will have the greater impact in reducing the quantity of mercury in the solid waste stream.

"Dry Cell Battery Management Act"

The "Dry Cell Battery Management Act" actually addresses all types of batteries including alkaline, carbon/zinc, mercury oxide, nickel/cadmium, seal lead acid, lithium and silver oxide but specifically requires battery management plan for only mercury oxide, nickel/cadmium and sealed lead acid. Mercury oxide, nickel/cadmium and sealed lead acid dry cell batteries will be prohibited from disposal in the solid waste stream upon approval and implementation of the battery management plans. This section of the report details the "Dry Cell Battery Management Act" as it relates to mercury oxide batteries and mercury content in alkaline and carbon/zinc (usually referred to as general purpose or heavy duty) batteries.

This act requires the reduction of the mercury content in different dry cell battery types if they are to be sold in New Jersey, as follows:

1. All alkaline batteries must be equal to or less than 0.025 percent mercury by weight (250 ppm), except for button or coin shaped, by January 1, 1992.

2. All button or coin shaped alkaline batteries must be equal to or less than 25 mg of mercury per battery by January 1, 1992.
3. All carbon - zinc batteries must be equal to or less than 0.0001 percent mercury by weight (1 ppm) by January 1, 1992;
4. All alkaline batteries must be equal to or less than 0.0001 percent mercury by weight (1 ppm) by January 1, 1996;
5. All consumer mercury oxide batteries except those sold by licensed hearing aid dispensers for use in hearing aids, must be equal to or less than 0.025 percent mercury (250 ppm) by January 1, 1992. The exemption for hearing aid mercury oxide batteries expires on January 1, 1994. Since a mercury oxide battery can not be produced that meets the 250 ppm standard, this effectively eliminates this battery from sale in the consumer market;
6. Institutional generators of mercury oxide batteries, must source separate their batteries on-site for collection and management in accordance with a DEPE approved mercury oxide battery management plan. Within one year of the effective date of the Act, and approvable and implementation of the mercury oxide battery management plans, the disposal of mercury oxide batteries are prohibited from disposal in the solid waste stream and must be managed in accordance with the approved plan;
7. The act further restricts the sale of institutional mercury oxide batteries unless the manufacturer has obtained approval from the department for a battery management plan. The act holds the manufacturers liable, at their expense, for the environmentally sound collection, transportation, recycling or proper disposal of every used mercuric oxide battery produced and sold in New Jersey; and
8. Each battery management plan, to be prepared and submitted by each mercury oxide battery manufacturer, must:
 - i. Designate a collector, transporter, processor or collection system for the specific batteries;
 - ii. Designate the funding source or mechanism to defray the cost to implement the plan;
 - iii. Develop a strategy for informing the consumer at the point of sale about the availability of a convenient mechanism for managing batteries;
 - iv. Develop a statewide consumer education program for disseminating information on the environmental impact of improper disposal and the type of batteries that the battery manufacturers are liable for their environmentally sound management; and

- v. Develop a strategy for establishing an industry - wide uniform coding system for identification and labeling.
9. The Department as a condition of any permit or approval may require the owner or operator of any MSW incinerator, in conjunction with the County, to implement a countywide used dry cell battery source separation and collection program. The program, as approved by the Department must ensure that any used dry cell battery found to be of particular concern is removed from the solid waste stream prior to acceptance at the facility; and
10. The Commissioner may find that continued disposal of a specific used dry cell battery as solid waste presents a threat to the environment or public health and safety and order every manufacturer of the specific battery to:
 - i. Prepare and submit a battery management plan for the environmental sound collection, transportation, recycling or proper disposal of that used dry cell battery; or
 - ii. Require every manufacturer to reduce the mercury concentration in the dry cell battery to environmentally acceptable and technologically feasible levels as a condition of sale or distribution of the dry cell battery in the State.

"Toxic Packaging Reduction Act"

This act requires the reduction of mercury levels in packaging or in any packaging component including ink dyes, pigments adhesives, stabilizes or any other additives if the package or packaging component or the product contained in a package is sold in New Jersey. The act requires that the mercury content be reduced to the following levels:

1. Equal to or less than 0.06 percent mercury by weight or 600 ppm by January 1, 1993;
2. Equal to or less than 0.025 percent mercury by weight or 250 ppm by January 1, 1994; and
3. Equal to or less than 0.01 percent mercury by weight or 100 ppm by January 1, 1995.

Reduced Mercury Content in Discarded Products and MSW

The following conditions are used to calculate the reduced mercury level in MSW and the total solid waste stream as a result of the Dry Cell Battery Management Act and the Toxic Packaging Reduction Act:

1. The mercury levels established in the USEPA Mercury Characterization Report for alkaline batteries in 1995 will be achieved in New Jersey in 1993;⁸

2. Over the next three years alkaline batteries increase at a rate of 6.6 percent annually;³
3. Consumer mercury oxide batteries are no longer sold in New Jersey. This supply in the MSW stream will decrease to zero over the next three years;⁸
4. The institutional mercury oxide battery management plan will be implemented in 1993. Because of focused markets and the accessibility to a reserve distribution system, the participation rate will be 80 percent in the first year and increase to 95 over three years. This portion of the mercury oxide battery stream makes up 60 percent of total mercury oxide battery discards;¹⁶ and
5. The mercury in pigments in packaging will be reduced by greater than 85 percent over the next three years.⁹

Tables 2.14 and 2.15 present a summary of the predicted result of New Jersey's mercury source reduction programs in MSW over the next three years.

Table 2.14

**REDUCTION OF MERCURY IN DISCARDED
CONSUMER PRODUCTS IN THE NJ MSW STREAM
RESULTING FROM CURRENT SOURCE REDUCTION PROGRAMS**

Product	Years		
	1993	1994	1995
		(tons)	
Consumer Batteries			
Alkaline*	1.49	1.58	1.69
Mercury-Oxide**	2.17	1.06	0.14
Others	<u>0.15</u>	<u>0.14</u>	<u>0.13</u>
Battery Subtotal	3.81	2.78	1.96
Electric Lighting			
Fluorescent Lamps	1.09	1.13	1.17
High Intensity Lamps	<u>0.03</u>	<u>0.03</u>	<u>0.04</u>
Lighting Subtotal	1.12	1.16	1.21
Paint Residue	0.27	0.18	0.08
Fever Thermometers	0.59	0.59	0.60
Thermostats	0.33	0.31	0.29
Pigments	0.17	0.11	0.05
Dental Uses	0.12	0.11	0.10
Special Paper Coating	0.01	0.01	0.00
Mercury Light Switches	<u>0.05</u>	<u>0.06</u>	<u>0.06</u>
Total	6.47	5.31	4.35

*Majority disposed in the residential waste stream.

**Majority disposed in the institutional waste stream.

Table 2.15

**REDUCTION OF MERCURY IN DISCARDED CONSUMER PRODUCTS IN THE NJ MSW STREAM
RESULTING FROM CURRENT SOURCE REDUCTION STRATEGIES**

Product	Years		
	1993	1994	1995
	(percent)		
Consumer Batteries			
Alkaline	23.0	29.8	38.9
Mercury-Oxide	33.5	20.0	3.2
Others	<u>2.3</u>	<u>2.6</u>	<u>3.0</u>
Batteries Subtotal	58.9	52.4	45.1
Electric Lighting			
Fluorescent Lamps	16.8	21.3	26.9
High Intensity Lamps	<u>0.5</u>	<u>0.6</u>	<u>0.9</u>
Lighting Subtotal	16.3	21.8	27.8
Paint Residue	4.1	3.4	1.8
Fever Thermometers	9.1	11.1	13.8
Thermostats	5.1	5.8	6.7
Pigments	2.6	2.1	1.5
Dental Uses	1.9	2.1	2.3
Special Coating	0.2	0.2	0.0
Mercury Switches	<u>0.8</u>	<u>2.1</u>	<u>1.4</u>
Total	100	100	100

According to the above calculations the mercury content in discarded consumer products in the 1992 New Jersey municipal solid waste stream will decrease by 62.1 percent in 1993, by 68.9 percent in 1994 and by 74.5 percent in 1995. This reduction is predominantly a result of the efforts of the battery manufacturer to reduce the amount of added mercury in their products.

It should be noted that the alkaline battery manufacturers have committed to removing all added mercury from their batteries by January 1, 1994.¹⁷ In New Jersey, this is defined as the "1 ppm" alkaline battery. This means that by the end of 1995 mercury from alkaline batteries will contribute approximately 0.01 ton of mercury in municipal solid waste. This represents a 99.9 percent reduction of mercury from alkaline batteries from the 1992 solid waste disposal stream.

Further the mercury-oxide battery manufacturers have elected to comply with the New Jersey Dry Cell Battery Management Act, by not offering their batteries for sale in New Jersey instead of assuming the liability for their separate management from the disposal stream. To continue to allow for the sale of their batteries in New Jersey, the mercury oxide battery manufacturers were to submit a plan which established a convenient system of collection, transportation, processing and reuse or disposal of their batteries at their

cost separate from the solid waste stream. They have chosen not to assume this responsibility, electing instead to discontinue their sale only in the State of New Jersey. Mercury-oxide batteries will continue to be available for use in other States and will continue to be disposed of through the solid waste stream in those States. This means that the mercury content from mercury-oxide batteries in the New Jersey solid waste stream will go to approximately zero in 1993.¹⁷.

In total, the mercury content in the solid waste stream from batteries will be reduced by 99 percent by the end of 1995 as a result of the above actions. This will result in a 42 percent reduction in the mercury content in the 1995 municipal solid waste disposal stream. Overall, the mercury content in the municipal solid waste stream should be reduced by 85 percent by the end of 1995 over the mercury content in the 1992 municipal solid waste disposal stream. However, the more conservative numbers will continue to be used in the report.

Table 2.16 presents the results of the mercury content in discarded consumer products in the municipal solid waste stream on a pound per ton basis. The municipal solid waste generation rate was kept constant over the three years.¹² Equation 4 from the first section of this chapter was used to calculate the pound per ton rate in the MSW stream.

Table 2.16

MERCURY CONTENT IN MUNICIPAL SOLID WASTE

Year	(pounds/ton)
1993	0.0018
1994	0.0015
1995	0.0012

Reduced Mercury Content in the Bulky/Industrial Solid Waste

In determining the mercury content in the bulky/industrial solid waste stream, the following assumptions have been made:

1. The consumptive rate of mercury in the U.S. is decreasing at an 8 percent rate annually;³
2. The exports of mercury containing products in this waste stream equals the imports of mercury containing products;³
3. There are no production losses. (This is a conservative assumption since the USEPA documents at minimum 6 percent processing losses in products in the municipal solid waste stream);³ and
4. The percentage of products and process waste managed as hazardous waste increases to 36% over the next 3 years.³

Table 2.17 represents the results of the mercury content in discarded products in the bulky/industrial solid waste stream. The bulky/industrial solid waste generation waste was kept constant over the next three years¹². Equations 5 and 7 from the first section of this chapter were used to calculate the mercury content on a pound per ton basis for the bulky/industrial waste stream.

Table 2.17
MERCURY IN #/TON IN B/ISW

Year	US _C (tons)	US _{Hg.M} (tons)	NJ _{Hg.I} (tons)	NJ _{Hg.I} (#/ton)	YEAR
1989	1338	400	22.80	0.0063	1993
1990	1231	323	21.42	0.0060	1994
1991	1133	245	20.31	0.0056	1995

Using the same distribution as presented in Table 2.8, Tables 2.18, 2.19 and 2.20 present the average annual mercury content in the Camden, Essex, Gloucester and Warren County MSW incinerators (MSWI) as a result of mercury source reduction programs currently in place.

Table 2.18
MERCURY FROM MSW

Facility	Year		
	1993	1994	1995
	(pounds/ton)		
Camden MSWI	582.99	485.83	388.66
Essex MSWI	1457.94	1214.95	971.96
Gloucester MSWI	284.33	236.94	189.55
Warren MSWI	248.48	202.07	161.66

Table 2.19
MERCURY FROM B/ISW

Facility	Year		
	1993	1994	1995
	(pounds/year)		
Camden MSWI	132.55	126.24	117.82
Essex MSWI	207.93	198.02	184.82
Gloucester MSWI	110.17	104.92	97.93
Warren MSWI	24.54	23.37	21.81

TABLE 2.20
TOTAL MERCURY IN SW

Facility	Year		
	1993	1994	1995
	(pounds/year)		
Camden MSWI	715.54	612.07	506.48
Essex MSWI	1665.87	1412.97	1156.78
Gloucester MSWI	394.59	341.86	287.48
Warren MSWI	267.02	225.44	183.47

The above calculations for mercury content in the total waste stream in the operational county facilities are conservative in that it makes no significant account for reduction in the bulky and industrial solid waste stream, other than what is being accomplished through reduction of the consumptive use of mercury. It is clear from the requirements of the "Dry Cell Battery Management Act", that there will be other reductions in the mercury content in the industrial solid waste stream as evident from the separate management of industrial mercury-oxide batteries through the manufacturer's battery management plans. Additional source reduction and source separation options for other products in the municipal and bulky/industrial waste stream are discussed in the next section.

Table 2.21 presents the overall reduction of mercury in the solid waste stream processed by the four county MSW incinerators over the next three years as a result of current source reduction and source separation programs. Table 2.21 has been generated by comparing the data in Table 2.20 to the mercury content in discarded consumer products in the solid waste stream per facility as presented in Table 2.8.

**TABLE 2.21
MERCURY REDUCTION IN PROCESSIBLE SOLID WASTE FROM 1992**

Facility	Year (percent reduction)		
	1993	1994	1995
Camden MSWI	57.4	64.9	70.9
Essex MSWI	60.2	66.2	72.3
Gloucester MSWI	56.8	62.6	68.5
Warren MSWI	60.8	66.9	73.1

Table 2.22 presents a summary of the mercury content on a pound per ton basis in the waste stream processed by the four operational facilities over the next three years as a result of source reduction and source separation programs currently being implemented by the department. Again, these numbers will be further reduced as a result of the actions to be taken by the battery manufacturers as described above. However, the more conservative numbers, those required in the statutes, were used in this report.

**Table 2.22
MERCURY IN THE PROCESSIBLE SOLID WASTE STREAM
BY FACILITY**

Facility	Year (pounds/ton)		
	1993	1994	1995
Camden MSWI	0.0021	0.0018	0.0015
Essex MSWI	0.0020	0.0017	0.0014
Gloucester MSWI	0.0023	0.0019	0.0016
Warren MSWI	0.0020	0.0016	0.0011

Table 2.23 uses the data generated in Table 2.22 to calculate the potential emission from the four operational county facilities over the next three years. From Table 2.23, relying solely on the level of projected mercury reduction described above, the operational county facilities can achieve significant reduction in potential mercury concentration in the flue gas stream. The Camden Co. MSWI could potentially experience a 73 percent reduction, the Essex Co. MSWI a 18 percent reduction, the Gloucester Co. MSWI a 87 percent reduction and the Warren Co. MSWI a 82 percent reduction over current permit limits for mercury over the next three years. It should be noted that the calculations in Table 2.23 are very conservative. It assumes 100 percent on - line availability, 100 percent of the mercury in the solid waste as volitalized and no controls for mercury within the system. Further, the small percent reduction in the Essex County MSWI is because this facility already has a relatively low (140 ug/dscm) allowable emission limit.

Table 2.23

**POTENTIAL EMISSIONS FROM NEW JERSEY MSWI *
WITH SOURCE REDUCTION PROGRAMS**

FACILITY	PERMIT LIMITS (#/hr/unit) (#/hr/facility)	SOURCE REDUCTION FLUE GAS* CONCENTRATIONS		
YEAR				
		1993	1994	1995
Camden MSWI	0.08	0.031	0.025	0.022
	0.24	0.092	0.074	0.066
Essex MSWI	0.053	0.063	0.053	0.044
	0.159	0.188	0.159	0.131
Gloucester MSWI	0.12	0.028	0.023	0.019
	0.24	0.055	0.046	0.038
Warren MSWI	0.05	0.017	0.013	0.009
	0.10	0.033	0.027	0.018

* Assuming nominal through - put operating 24 hours per day 365 days per year with 100% mercury volitalization without control.

EXPANDED SOURCE SEPARATION PROGRAMS FOR MERCURY REDUCTION

In evaluating Tables 2.14 and 2.15 and the result of potential flue gas concentrations in Table 2.23, it is clear that in order to further reduce the mercury content in the solid waste stream over that which can be accomplished through existing source reduction and source separation programs several options need to be evaluated.

Batteries

While the provisions of the Dry Cell Battery Management Act will significantly reduce the mercury in the municipal and solid waste streams it will not be immediately effective because of the lag time between production, sale, use and disposal of the 99.975 percent mercury-free batteries. Even with the commitment by the alkaline battery manufacturers to accelerate the "1 ppm" battery which is more appropriately termed the "no added mercury" alkaline battery to January 1, 1994, two years ahead of the requirements, the effect of this commitment will not be fully realized in the solid waste disposal stream until the end of 1995.¹⁷ In addition, as opposed to the USEPA Mercury Report prepared by Franklin Associates, Ltd., the mercury content in alkaline and other battery categories will not become zero by the year 2000. The Department calculates approximately 0.01 tons of mercury in the municipal solid waste stream from alkaline batteries by the end of 1995. This represents the trace or background concentration of mercury in the zinc and other metals in the battery.

A report funded by the department and other state environmental agencies and prepared by Recoverable Resources/Boro Bronx 2000 (R2B2), Inc. entitled "Feasibility Study for the Implementation of Consumer Dry Cell Battery Recycling As An Alternative to Disposal-Getting a Charge Out of the Wastestream Final Report" dated March 6, 1992, indicates that batteries marketed as mercury free will still have some background or naturally occurring quantity of mercury in trace concentrations in the zinc.¹⁶ The New Jersey standard for these batteries is 0.0001 percent by weight (1 ppm) to be implemented by January 1, 1994. However, while most alkaline batteries will be at or below this concentration in the 90 percentile for compliance with the "Dry Cell Battery Management Act", the range of the maximum concentration could be as high as 4 ppm.¹⁸ In addition, the R2B2 report calculated the quantity of mercury in other types of batteries such as the silver oxide, zinc air and alkaline button cell, all of which are replacements for the consumer mercury oxide batteries and some institutional mercury oxide batteries. Table 2.24 summarizes these results. This quantity of mercury will still be available in the municipal solid waste stream.

Table 2.24

MERCURY IN OTHER BUTTON CELLS¹⁶

Battery Type	% mercury by weight	mercury (ppm) content/battery
Alkaline	0.40	3,648
Zinc Air	2.07	20,680
Silver Oxide	1.10	10,947

Several options in this category are under consideration:

1. Include all batteries in the battery manufacturers' battery management plan in County's with MSW incinerators or which are sending their solid waste to be processed in MSW incinerators. If

there is to be a further reduction of mercury, the manufacturer's battery management plan implemented by the MSWI, in conjunction with the county, should include a program to collect consumer mercury oxide batteries until 1995 when these batteries are no longer in the solid waste disposal stream. Additionally, manufacturer's battery management plan implemented, by the MSWI in conjunction with the county, should include alkaline batteries in counties with MSWI until 1996 when the 1 ppm alkaline batteries are the predominant alkaline battery in the MSW disposal stream;

2. Promote the use of rechargeable dry cell batteries as substitutes for primary disposable dry cells, **where feasible**. These batteries have a longer life than primary batteries. In addition, and more importantly rechargeable batteries are part of a closed loop system of production, sale, use, source separation collection, and reuse as part of the battery manufacturers management plan for collection and separate management of rechargeable batteries. As pointed out by Ray Balfour of Rayovac in his comments on the preliminary report, "(The) decisions about whether to purchase Ni-Cd or alkaline batteries should be made on the basis of performance, characteristics and cost, while disposal decisions should be made on the basis of battery contents."¹⁹ However, the department's position, in terms of its pollution prevention and source reduction policies are that the manufacturing process to make a product and the disposal requirements after that product has served its intended use should be factored into making a purchasing decision. Once the rechargeable battery is spent it will be collected and the metals that make up the battery will be reclaimed and recycled to make new products and possible new batteries. This system is being developed, implemented and managed by the rechargeable battery manufacturers at their cost²⁰. It is this positive response by industry that should be recognized and rewarded. This program may be the most cost effective method for managing these materials in the front end of the process instead of managing them as waste at the back end. In addition to being a cost effective method of managing these materials it also serves to start the process of reducing government regulations; and
3. Promote the use of zinc-air batteries as substitutes for mercury oxide in institutional uses, where feasible.

The following assumptions have been made if the conditions in option 1 above are implemented within the battery manufacturer's management plan by MSW incinerators owner/operators in conjunction with the Counties:

1. Over the next three years counties with MSW incinerators implement a battery collection program to manage all batteries separately⁸;
2. The participation rate begins at 45 percent and increases to 85 percent over the next three years¹⁶; and
3. This program is in operations until 1996 when the "1 ppm" alkaline battery is the predominant battery in the solid waste disposal stream¹⁷.

Table 2.25 presents the results of the mercury content in discarded consumer products in the municipal solid waste stream as a result of an increased battery separation program.

Table 2.25

MERCURY IN THE SOLID WASTE STREAMS BY TYPE

Year	MSW	B/ISW	AVERAGE
	(pounds/ton)		
1993	0.0015	0.0063	0.0017
1994	0.0009	0.0060	0.0012
1995	0.0007	0.0056	0.0009

Utilizing the distribution of MSW and B/ISW to the County facilities reported in Table 2.4, Table 2.26 presents the mercury content in the processible waste stream at the four county MSW incinerators.

Table 2.26

MERCURY IN THE PROCESSIBLE SOLID WASTE STREAM BY FACILITY

FACILITY	YEAR (pounds/year)		
	1993	1994	1995
Camden MSWI	618.38	417.74	334.54
Essex MSWI	1422.88	926.99	751.80
Gloucester MSWI	947.11	247.08	208.50
Warren MSWI	226.61	194.61	116.11

Table 2.27 present a summary of the mercury content on a pound per ton basis in the waste stream processes by the four MSW incinerators over the next three years as a result of additional source reduction programs for batteries.

Table 2.27

MERCURY IN THE PROCESSIBLE SOLID WASTE STREAM BY FACILITY

FACILITY	1993	1994	1995
		(pounds/ton)	
Camden MSWI	0.0018	0.0011	0.0010
Essex MSWI	0.0017	0.0011	0.0009
Gloucester MSWI	0.0020	0.0014	0.0011
Warren MSWI	0.0017	0.0012	0.0009

Utilizing the data in Table 2.27 above, Table 2.28 presents a summary of the total potential concentration in the flue gas stream using the conservative assumption described above in Table 2.23.

Table 2.28

POTENTIAL EMISSIONS FROM NEW JERSEY MSWI WITH ADDITIONAL SOURCE REDUCTION PROGRAMS

FACILITY	PERMIT LIMITS (#/hr/unit) (#/hr/facility)	SOURCE REDUCTION FLUE GAS CONCENTRATIONS		
		(#/hr/unit)	(#/hr/unit)	(#/hr/facility)
		YEAR		
		1993	1994	1995
Camden MSWI	0.08	0.025	0.018	0.015
	0.24	0.078	0.053	0.044
Essex MSWI	0.053	0.053	0.034	0.028
	0.159	0.158	0.103	0.084
Gloucester MSWI	0.12	0.024	0.017	0.014
	0.24	0.047	0.034	0.029
Warren MSWI	0.05	0.014	0.009	0.007
	0.10	0.027	0.017	0.014

Table 2.23 demonstrates that the operating county facilities can achieve additional reduction of mercury at relatively low costs. With additional source separation programs the Camden MSWI could experience an 82 percent reduction, the Essex MSWI a 47 percent reduction, the Gloucester MSWI an 88 percent reduction and the Warren MSWI an 86 percent reduction in mercury over the current permit limits over the next three years.

The results presented in Tables 2.25, 2.26, 2.27 and 2.28 are based on assumptions of participation and recovery rates for batteries managed within a collection program. The quantity of mercury that can be removed from the municipal solid waste stream and the MSWI processible waste stream is a direct relationship between the program implementation timeframe and the participation rate.

Clearly, the quicker a program is implemented the sooner the results, in terms of mercury reduction, will be experienced at facilities. On this point, the provisions in the "Dry Cell Battery Management Act" clearly establish the responsible parties, those entities with the expertises and resources to most cost effectively and efficiently implement the program.^{8,20}

The second point, the participation rate is a function of convenience. The Department's experience is that the more convenient the collection system the

higher the participation rate.²¹ In this regard there are two ways to manage consumer batteries:

1. As a fully source separated stream sorted by each battery chemistry; or
2. As a commingled stream of mixed battery chemistries.

This factor is an issue because of the number of different battery types available on the market and the lack of product labeling and consumer information. The requirement of the "Dry Cell Battery Management Act" addresses both of these issues.

There are two main types of dry cell batteries. They are primary or single use disposal batteries and secondary or rechargable batteries. Within the primary battery category there are six different types of batteries which are distinguished by battery chemistry. They are alkaline, carbon/zinc (general purpose or heavy duty), mercury oxide, silver oxide, zinc air and lithium. Within the secondary battery category there are primarily two different battery types. They are nickel cadmium and sealed lead acid batteries. Table 2.29 presents a percent distribution of the amount of batteries sold in New Jersey.^{3,16,23}

TABLE 2.29

BATTERY TYPES IN NEW JERSEY

Battery	Percent	Tons	Batteries/Person
PRIMARY			
Alkaline	61.6	2929	8.01
Carbon Zinc	24.3	1145	3.16
Silver Oxide	2.8	3	0.37
Zinc Air	2.1	4	0.27
* Mercury Oxide	1.7	3	0.22
Lithium	0.2	6	0.02
SECONDARY			
* Nickel Cadmium	6.2	231	0.80
* Sealed Lead Acid	1.2	18	0.16

* Part of mandatory battery management program required to be separately managed as set forth in the Dry Cell Battery Management Act NJSA 13:1E-99.59 et seq.

The issue, in terms of convenience, is that there are eight different types of batteries and only three battery types that are specifically addressed by the "Dry Cell Battery Management Act". The batteries required by the "Dry Cell Battery Management Act" to be managed separately makes up only 9.1 percent of the total battery stream. The question that needs to be answered is, What is the more convenient and most cost effective system for managing the batteries, fully source separated by chemistry or commingling all batteries?

This point is highlighted by the fact that the available reclamation or recycling option for batteries are chemistry specific. A reclamation operation for nickel cadmium batteries will reject a load, as unacceptable, if lead acid batteries are mixed with the load. This situation is basically similar for all the battery types. Therefore, in order to recycle batteries the commingled stream must be separated at some point.

The department has been quoted an estimated cost for managing a commingled stream of batteries at \$1.25 per pound of batteries.²² This cost includes collection and transportation to a sorting facility, processing into specific battery chemistry types and then processing at a metals recovery facility. This cost does not include the cost of transportation to the metals recovery facility which would be an additional freight charge.

Table 2.30 presents the number of batteries available in the four counties with operating MSW incinerators and the cost to manage them in a commingled process at \$1.25 per pound.

TABLE 2.30

COST FOR MANAGING COMMINGLED BATTERIES

County	No. of Batteries	Tons	Cost*
Camden	7,042,586	283	\$705,880
Essex	10,892,906	437	\$1,091,800
Gloucester	3,220,268	129	\$322,770
Warren	1,280,107	52	\$129,110

* plus FOB for shipment to the metal processing facility

New Jersey consumers dispose of approximately 108,000,000 batteries annually.²³ These discarded batteries have a total weight of approximately 4300 tons. On average this represents approximately 13 batteries per person per year or on average a total weight of approximately one pound per person per year. The cost to manage the total commingled battery stream would be approximately \$10,800,000. This translates to a cost of approximately \$0.10 per battery per year. This cost is approximately the same as the cost projected in the R2B2 Report.¹⁶

The cost of managing batteries separately in the front end of the process at \$1.30 per person per year (13 batteries at \$0.10 per battery per year per person) should be compared with the cost to incorporate additional air quality control systems to manage the mercury at the back of the MSW incinerator, as discussed in Chapter 6 of this Report.

The advantages of managing a commingled stream of batteries are basically, its convenience to the consumer; and operations within existing collection system. The disadvantages are: the safety of managing large volumes of commingled battery type which could electrically short across the terminals if the batteries are not fully discharged; and the requirements to separate the batteries before transportation to the end-use market. The advantages of

managing a fully source separated stream of batteries by chemistry type are: its direct availability to an end use market. However, the disadvantages are: the need to set up separate collection systems and the need for an extensive consumer education program.

As with all recycling programs, the best system, commingled or fully source separated is a function of site specific conditions. The department will remain flexible on the implementation of a program provided the participation and recovery rates are acceptable. Based on the R2B2 Report United States battery collection programs have achieved a recovery rate of 12 to 18 percent and European program have achieved rates in the range of 10 to 35 percent with rates as high as 60 percent.¹⁶ It should be noted that in European programs the batteries are commingled and these programs have not experienced major problems with the shorting of batteries.²⁴ As reported by the Pollution Control Financing Authority of Warren County, the Warren County battery curbside collection program is at a 30 percent recovery rate for its curbside commingled collection program. This is a significant increase over the drop off centers that were previously in use throughout the county.²⁵ The drop off program was averaging approximately between a one to four percent recovery rate. The Warren county curbside program collects commingled batteries.

One argument against initiating a collection program for all batteries is that it only has a limited useful life. Since mercury levels in alkaline batteries will go to "1 ppm" by 1994 and will be the predominant battery in the municipal solid waste stream by the end of 1995, alkaline batteries will no longer need to be collected. However, the reverse may actually be true. The more mercury that is removed from the alkaline battery, the more readily recoverable is the zinc and manganese. One of the limiting factors to implementing a zinc recovery program for alkaline batteries is the current level of mercury that was added to the battery to control the generation of hydrogen off gases and increase the battery's performance. As the mercury is reduced, more end-use markets may be available for the zinc and manganese and may actually increase the alkaline battery's value as a recyclable commodity.^{22,26}

FUTURE POTENTIAL SOURCE REDUCTION AND SOURCE SEPARATION PROGRAMS

At this point in order to achieve any further reduction of mercury in the solid waste stream, it is important to focus on strategies that target other mercury-containing products. As noted in Tables A1, 2.6, 2.14 and 2.15, the other major categories of mercury-containing products are electric lighting specifically fluorescent lamps, thermometers and mercury switches. The following section briefly describes options for further management of other major mercury containing products.

In addition, possible sources of mercury in the bulky/industrial solid waste stream were evaluated to determine their potential for source reduction and/or source separation from the solid waste disposal stream.

Fluorescent Lighting

Discarded fluorescent bulbs will represent one of the largest quantities of mercury in the municipal solid waste stream after the implementation of the "1 ppm" alkaline battery and the source separation of institutional mercury oxide batteries. While the mercury content to the MSW stream from this discarded product is only increasing at a rate of 3.6 percent per year, its impact on the mercury content in MSW, because of the decrease of mercury in batteries, increases by almost 300 percent over three years. Therefore, this discarded consumer product should be one of the next products for which the DEPE and the USEPA, working along with the manufacturers, develop source reduction and source separation recycling or disposal options. The two management paths available to implement this program are:

1. The development of a legislative/regulatory program similar to the "Dry Cell Battery Management Act" in which the manufacturers will be designated as the responsible entity; or
2. Through policy positions developed as part of the Statewide Solid Waste Management Plan to designate this material as a waste for separate management.

The Department is actively working with the New Jersey chapter of the National Electrical Manufacturers Association (NEMA) to discuss the establishment of a program for fluorescent tubes similar to the battery management program.²⁷ NEMA's national policy is that a Subtitle D landfill (New Jersey Class I sanitary landfill) is a proper management facility for fluorescent bulbs.²⁹ The goals, in terms of risk management, should be to develop the most cost effective and environmentally sound collection and management systems for this discarded product. In this manner a private sector management system can be developed without prescriptive statutory and regulatory requirements.

NEMA fluorescent bulb manufacturers produce a 4-foot bulb that on-average contains 40 mg of mercury per bulb.²⁸ The fluorescent bulb manufacturers have committed to a source reduction goal of approximately 50 percent by 1995.²⁸ This mercury source reduction goal for fluorescent bulbs is currently a technology limitation on the design of the bulb.²⁹ With increased research and development of different bulb design, glass and phosphor, the fluorescent bulb manufacturer may be able to reduce the mercury in their bulbs into the single digit of mg of mercury per 4-foot bulb.^{27,29} Given that all the mercury can not be source reduced from the bulb, the next management option would be to require them to be source separated from the disposal stream to be managed separately.

Currently, on average 4-foot fluorescent bulbs may fail the Toxicity Characteristic Leaching Procedure (TCLP) for mercury. The USEPA and NEMA are evaluating the TCLP methodologies to determine if the test method is accurately applied by the testing laboratories.³⁰ On average, disposal of approximately 350 bulbs would exceed the small quantity generator (SQG) exclusion.²⁷ In New Jersey, the small quantity generator limits are not more than 100 kilograms of a hazardous waste per month or 1 kilogram of acutely hazardous waste per month.¹ In addition, SQG waste must be managed in a

facility permitted to accept solid waste type-ID 27 industrial waste, unless the waste is prohibited from final land disposal in accordance with N.J.A.C. 7:26-9.2(d). The land ban exemption for TCLP mercury waste D-009 expires in 1993.

The issue in the context of this report is not whether the bulbs pass or fail the TCLP test but the total quantity of mercury in the bulb and the fate and transport of the mercury into the environment. Currently spent 4-foot fluorescent bulbs contain on-average 40 mg of total mercury which should be managed properly. On average, 15,000 bulbs contain one pound of mercury.²⁷ This is the critical issue as it relates to MSW incinerators.

In order to evaluate the impact of mercury in fluorescent bulbs one needs to evaluate the entire life cycle of the bulb from production through use to disposal. As determined by both Green Seal and the USEPA's Green Lights program, which utilized a mercury balance approach, including the mercury emissions from electrical generation utilities, there is less mercury emitted to the environment when using fluorescent bulbs. This is because of the energy saving derived from the use of fluorescent bulbs.

As documented in Chapter 1 of this Report, there is mercury in the fossil fuel used to generate electricity. The use of fluorescent bulbs saves energy and electrical generation capacity (referred to as demand side management, DMS). Therefore, ultimately less mercury is emitted to the environment because of the reduction of mercury in the overall mercury balance when using fluorescent bulbs for lighting. However, the analysis to date has not focused on the mercury emission or the total mercury balance when disposal or recycling of the bulb is added to the overall calculations. Does the mercury savings between use of fluorescent bulbs and electrical generation carry over when calculating the disposal/recycling impacts of the mercury in the fluorescent bulbs?

As discussed previously, the issue of disposal or recycling/reuse of a product should be factored into the overall evaluation of a product's impact on the environment. This aspect of a product's impact is beginning to be factored into life cycle analysis. The department has performed two research projects that evaluate life cycle disposal or recycling impacts and costs.^{31,32} The USEPA is currently evaluating the appropriate mechanisms and procedures to evaluate life cycle impacts including disposal and recycling impacts. The issue with life cycle impact assessment is how to evaluate a pound of one particular chemical versus another since, toxicologically not all chemicals are equal. The department's "Tellus Life Cycle Analysis for Packaging" suggests and evaluates one possible ranking system.³¹ The USEPA is currently evaluating the overall lifecycle impacts of fluorescent bulbs including recycling/reuse or disposed. The department will have input into this process and will ultimately develop and implement its overall program for fluorescent bulbs based on that evaluation.

It is clearly evident from this Report and other State Environmental Agency mercury reports, that mercury containing discarded products should be removed from the processible solid waste stream of MSW incinerators, where feasible.^{33,34} The impacts of mercury in sanitary landfills and recycling/reclamation facilities are less clear.

Sanitary landfills are predominantly in an anaerobic state. In this state they generate methane as well as other gases. Sanitary landfills therefore, have a potential for methylation of mercury (as described in Volume 2 of this report). However, the environment in a sanitary landfill is a reducing environment, which suggests that mercury in the landfill should result in the formation of mercury sulfides, which are highly insoluble and immobile. This is probably the reason that the mercury content in sanitary landfill leachate is relatively low. However, under certain conditions, there could be a minor shift in the sulfide/sulfate balance to sulfates, as in the recirculation of leachate or from the mining of landfill gases. In this case the mercury would be more soluble and mobile.

As described in Volume II of this Report, mercury chemistry is highly complex. The solubility of mercury is a function of pH, temperature redox potential and the salt (sulfate/chloride) concentration, which is not constant in a landfill environment. The partitioning coefficients of mercury would suggest that the landfill gas condensate is the likely fate and transport mechanism for mercury in the landfill environment. While the USEPA Report on fluorescent bulbs documents very low gas and condensate concentrations, a report performed for the USEPA by SCS Engineer suggests a higher value.^{30,35} The department has evaluated the range of numbers documented by SCS Engineers (0.034 to 0.00069 mg/l) through the use of the USEPA Landfill Air Emissions Estimation Model (version 1.1).³⁶ The model indicates a range of values from 6 to 10 pounds per landfill per year on the low side.³⁷ However, this rate is an annual generation rate per landfill which could occur over 50 years of gas production.

New Jersey has a total universe of 578 landfills, 410 that were pre-1982 closures, 131 that were post-1982 closures, and 37 that are presently active. The 1981 "New Jersey Sanitary Landfill Closure Act", NJSA 13:1E-100 et seq., required all sanitary landfills to upgrade and obtain financial closure plan approval or close by 1982. Individually sanitary landfills are probably not a major source of atmospheric mercury emission. Cumulatively, they may be another source that needs to be properly managed, particularly in landfills with active gas venting or leachate recirculation. However, to ascribe or partition this emission to one discarded product versus another is not feasible, at this time.

While the sanitary landfill is one end point for mercury, the entire system including collection, transportation and recycling processes should be evaluated in detail. The department presents the following qualitative analysis for this portion of the mercury balance system. In general, the mercury impacts are in the collection, transportation, disposal facility, recycling facility and its end use products.

In collection for disposal, a majority of the bulbs will be crushed or broken in the packer truck or roll off, since they are not handled or stored in any special method. A percentage of the mercury in the bulb would be emitted to the environment at this point. In collection for recycling, bulbs are packaged to minimize breakage. Therefore, in terms of collection, recycling would be less of an impact.

Transportation for disposal would result in less distance traveled. There are currently more disposal facilities for bulbs in closer proximity to their point of generation than recycling facilities. Therefore, in terms of transportation, disposal would be less of an impact.

In the disposal facility, if the facility is recovering materials (composting facility) or energy (MSW incinerator) some of the mercury could be available as emissions or discharges to the environment. As stated previously, this is clearly not acceptable. In terms of energy recovery, the facility can be retrofitted to remove a percentage of the mercury from the flue gas stream. In that case the resultant residual ash would be the end point management. The issue of mercury in the residual ash or the finished compost is the same. The larger the quantity of mercury, the smaller the available markets for their potential reuse. Ultimately landfill disposal may be the only acceptable option for these recoverable/reusable products with high mercury content. This too is clearly not acceptable. In the landfill disposal environment there may be a small percentage of mercury that may be available, through gas production, in particular in the water condensate phase in the gas. This fate and transport mechanism is probably more available in mixed solid waste landfills as opposed to residual ash monofills. However, one research has documented mercury methylation potential with residual ash.³⁸

In terms of recycling a small percentage of the mercury in the bulb will be in the aluminum and the glass. The recycling for these components of the bulb will have to manage the mercury. However, since making aluminum and glass from recycled aluminum and glass uses less energy there is probably less mercury emitted to the environment from this overall process. This is the same argument for using fluorescent bulbs over incandescent bulbs. Less energy use, therefore less overall mercury emissions to the environment. In addition, a recycled aluminum or a recycled glass product would probably not be made with 100% fluorescent bulb aluminum end caps or glass.

Finally, reusing recovered mercury means less mercury would be mined and processed from mercury-containing ore. In a life cycle analysis less mercury would probably be available when you calculate the energy requirements to mine, and process the ore and to transport the mercury to the manufacturing facilities to be utilized in products. In a qualitative analysis the use of fluorescent bulbs is an environmental sound option. The recycling of these bulbs would probably make this product more environmentally sound.

The Minnesota Office of Waste Management in its draft report on Fluorescent and HID Lamp Management dated November 10, 1992 estimated that reclaiming the mercury in the lamps saves roughly 140,000 times as much mercury as the energy required for reclaiming it.³³ This mercury savings is only derived if the fluorescent lamps or bulbs are source separated from the solid waste disposal stream and managed separately through a recovery or reclamation process. This back end saving of mercury coupled with the savings in mercury emissions from electrical utility emissions makes fluorescent bulbs an overall mercury reducing product even with the mercury within the product.

The major issue in putting together a recovery program for fluorescent bulbs as with any recovery/reuse/recycling program is financing. Preliminary

information indicates that the cost of managing the fluorescent bulbs as hazardous waste appears to be approximately equal to the cost of managing the bulbs source separated from the disposal stream and through a recovery/reclamation process. NEMA estimates the cost of managing fluorescent bulbs for recycling at approximately \$0.51 to 0.56 per 4-foot bulb, including transportation.²⁸ Advanced Environmental Recycling Corporation (AERC), a facility permitted in Pennsylvania to receive and recycle fluorescent bulbs quoted a cost between \$0.40 to 0.60 per 4-foot bulb plus transportation.³⁹ This cost must be compared against disposal costs as solid waste or as hazardous waste. AERC stated that the cost would probably be lower if they did not have to strictly comply with manifesting the bulbs into their facility. This issue could be addressed in the USEPA proposed Universal Waste Rule at 40 CFR Part 273.⁴⁰

There are a number of funding mechanisms which must be evaluated to determine the most cost effective management programs. The key in establishing this type of program is flexibility. The spent bulbs will be generated from a number of different sources including households, commercial, institutional and industrial users. Each user category has a different need for the bulb, a different operation and maintenance routine for managing the bulb and a different distribution network. All these factors need to be evaluated and factored into any program.

There are a number of companies that have developed technologies to manage discarded fluorescent bulbs and to recover the mercury. The recycling/recovery technologies are divided into two basic process technologies, a wet or dry process. The wet process uses a sulfide solution or dilute acid to rinse the mercury from the bulb or crush bulb. The dry process uses air to strip the mercury, which is recovered with activated carbon or the dry phosphor is collected separately. The following is a list of companies involved in processing fluorescent bulbs.

RECYCLING TECHNOLOGY	EQUIPMENT USED	LOCATION	COMPANY
De-manufacturing	Prolux	Germany	Rundholz Thur USRAM
De-manufacturing	MRT	Hungry Switzerland Sweden Minnesota	TUNGSRAM SONAG MRT Recyclights
De-manufacturing	dry lamp disassembly	California	Lighting Resources
Wet Crushing	Aqua Control	Germany	Aqua Control
Dry Crushing	Mercury Technologies	California	Mercury Technologies
Dry Crushing	Kusters	Netherlands	Lumen ^E x Phillips
Shredding/washing	Recytec	Switzerland	Recytec

There are a number of companies in North America that are planning constructing or operating recycling/recovery facilities for fluorescent bulbs. The following is a list of companies:

1. Mercury Technologies - Pine City Minnesota
underconstruction
2. Resource Recovery, Inc. - Hennepin Co Minnesota
planning
3. Lighting Resources - Pomona California
operational
4. Mercury Recovery - Monrovia California
operational
5. Midwest Recycling & Mercury Recovery Services
Dubuque Iowa
6. Advanced Environmental Recycling Corp. - Allentown Pa.
construction/operational
7. Nine West Technologies - Nashville Tennessee
construction/operational

8. Lighting Recycling, Inc. - Boston Mass
planning/construction
9. American Lighting - Sandy Utah
planning
10. Salesco Systems - Phoenix Arizona
planning
11. Tallon Metal Technologies - Guelph Ontario
planning

There are two companies in the United States which accept fluorescent and HID lamp phosphor for refining and recovery of mercury as follows:

1. Mercury Refining - Latham New York
2. Bethlehem Apparatus - Hellertown Pa.

The above information was developed by the Minnesota Office of Waste Management and appears in their Draft Report on Fluorescent and HID Lamp Management, November 10, 1992³³

Fever Thermometers

This category of consumer products will represent the second largest percentage of mercury in the municipal solid waste stream. According to industry representatives digital thermometers particularly in hospitals. However, mercury thermometers will always be the standard for the measure of temperature.⁴¹ In this area, the Department should support the replacement of mercury thermometers with digital units. The department will work with the New Jersey Hospital Association to establish a cooperative program to recover this portion of mercury in the waste stream. The Department has contacted the Hospital Instrument Manufacturers Association to bring the development of a management program for mercury thermometers.

Thermostats - Electrical Switches

This category of consumer products, (particularly electrical switches) in the municipal waste stream has been underestimated. While the USEPA Mercury Report indicates it is a relatively small source, it is probably the second largest source of mercury in discarded products in the municipal solid waste stream as reported by Florida Department of Environmental Regulation's Mercury Emissions to the Atmosphere the Florida dated August 1992 prepared by KBN Engineering and Applied Sciences, Inc. and confirmed by Comus International a New Jersey based mercury switch manufacturer.^{34,42} It is also a relatively large percentage of the bulky and industrial waste stream. The department will be working with the Builder's Association to evaluate a special waste category for this waste stream for its separate management.

The above referenced recommendations are long term projects which need to be developed with the department in conjunction with a number of other agencies and associations. However, their implementation will have a dramatic impact on the continued reduction of mercury in the solid waste stream. The above programs could reduce the mercury content in municipal solid waste by approximately 95 percent by the year 2000.

It is clear from the evaluation of Table 2.17 that the mercury content in the bulky and industrial solid waste streams should be reduced to improve the operations and emissions from all solid waste facilities. The major impact to these facilities other than that found in municipal solid waste will be from thermostats, electrical switches and painted wood that contains mercury pigments and fungicides. The department will be evaluating programs to reduce and eliminate this quantity of mercury from this solid waste stream.

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Table A-1

WORLDWIDE ANNUAL ANTHROPOGENIC SOURCES OF MERCURY
(In thousand kilograms per year and short tons per year)

Mercury source	Thousand kg/year	Short tons/yr (1)
Atmospheric emissions		
Coal combustion-electric utilities	155 - 542	171 - 597
Coal combustion-industry/domestic	495 - 2,970	546 - 3,274
Lead production	8 - 16	9 - 18
Copper-nickel production	37 - 207	41 - 228
Municipal refuse incineration	140 - 2,100	154 - 2,315
Sewage sludge incineration	15 - 60	17 - 66
Wood combustion	60 - 300	66 - 331
Total emissions	910 - 6,200	1,003 - 6,834
Median value	3,560	3,925
Inputs into aquatic ecosystems (2)		
Domestic wastewater-central	0 - 180	0 - 198
Domestic wastewater-non-central	0 - 420	0 - 463
Steam electric	0 - 3,600	0 - 3,968
Base metal mining/dressing	0 - 150	0 - 165
Smelting/refining-nonferrous metals	0 - 40	0 - 44
Manufacturing processes-metals	0 - 750	0 - 827
Manufacturing processes-chemicals	0.02 - 1,500	22 - 1,653
Manufacturing processes-petroleum products	0 - 20	0 - 22
Atmospheric fallout	0.22 - 1,800	243 - 1,984
Dumping of sewage sludge	0.01 - 310	11 - 342
Total Input, water	0.3 - 8,800	276 - 9,667
Median value	4,600	5,070
Emissions into soils (2)		
Agricultural and food wastes	0 - 1,500	0 - 1,653
Animal wastes, manure	0 - 200	0 - 220
Logging/other wood wastes	0 - 2,200	0 - 2,425
Urban refuse	0 - 260	0 - 287
Municipal sewage sludge	0.01 - 800	11 - 882
Solid wastes-metal manufacturing	0 - 80	0 - 88
Coal fly ash and bottom fly ash	0.37 - 4,800	408 - 5,291
Peat (agricultural and fuel uses)	0 - 20	0 - 22
Wastage of commercial products	0.55 - 820	606 - 904
Atmospheric fallout	0.63 - 4,300	694 - 4,740
Total Input, soils	1.6 - 15,000	1,720 - 16,512
Median value	8,300	9,150
Mine tailings	0.55 - 2,800	606 - 3,086
Smelter slags and wastes	0.05 - 280	55 - 309
Total discharge on land	2.2 - 18,000	2,425 - 19,841

Mercury into biosphere = approximately 12,000 short tons per year (3).

(1) Conversion from metric units to short tons by Franklin Associates, Ltd.

(2) Units in data source given in million kg/year. Converted to thousand kg/year by Franklin Associates.

(3) Man-induced mobilization of trace metals into the biosphere equals median values of the terrestrial plus aquatic inputs minus atmospheric emissions (Reference 1).

Source: Nriagu and Pacyna (1).

Source: USEPA Mercury Report Franklin Associates

Table A-2
MERCURY CONSUMED IN THE UNITED STATES, 1967 TO 1989
(In short tons and percent of total)

Year	Chlorine and Caustic Soda Manufacture		Pigments		Catalysts for Plastics		Catalysts, Misc.		Laboratory Uses		Pharmaceuticals		Paints, Antifouling	
	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total
1967	543.6	20.6			a		94.6	3.6	73.7	2.8	10.8	0.4	5.8	0.2
1968	663.2	23.1			a		72.7	2.5	75.6	2.6	16.1	0.6	14.9	0.5
1969	787.4	26.8			a		112.4	3.8	73.6	2.5	27.1	0.9	9.3	0.3
1970	570.4	24.4			a		85.0	3.6	68.6	2.9	26.2	1.1	7.5	0.3
1971	461.9	23.3			a		38.5	1.9	68.3	3.4	25.9	1.3	15.7	0.8
1972	437.7	21.8			a		30.4	1.5	22.6	1.1	22.0	1.1	1.2	0.1
1973	496.7	24.1			a		25.6	1.2	25.0	1.2	23.0	1.1	1.2	0.1
1974	642.1	28.4			a		49.3	2.2	18.1	0.8	22.7	1.0	0.2	0.0
1975	578.4	29.9			a		31.8	1.6	12.7	0.7	16.9	0.9		
1976	610.1	24.7			a		48.0	1.9	22.6	0.9	2.3	0.1		
1977	408.3	17.5			a		58.7	2.5	15.4	0.7	W			
1978	424.3	22.9	W		a		63.3	3.4	16.0	0.9	W			
1979	462.8	26.8	W		27.1	1.6	20.8	1.2	15.6	0.9	W			
1980	359.9	16.1	W		W		29.1	1.3	13.8	0.6				
1981	278.3	12.4	W		W		31.0	1.4	12.5	0.6				
1982	237.2	12.8	W		W		19.0	1.0	10.7	0.6				
1983	306.1	16.4	W		W		18.4	1.0	10.6	0.6				
1984	279.2	13.4	W		W		13.6	0.7	10.2	0.5				
1985	258.6	13.7	W		W		18.5	1.0	15.7	0.8				
1986	285.0	16.3	W		W		19.6	1.1	21.7	1.2	W			
1987	342.5	21.5	W		W		15.3	1.0	22.4	1.4	W			
1988	490.0	27.9	W		W		12.2	0.7	28.1	1.6	W			
1989	420.0	31.4	c		c		c		19.8	1.5	c			

Source: Bureau of Mines, 1989 and earlier

W - Withheld to avoid disclosing company proprietary data: included in Other from 1969 through 1980; all other years included in Unknown.

a - Included in Catalysts, Miscellaneous

b - Included in Other Instruments and Related Products

c - Included in Other Chemicals

d - Included in Other

e - Included in Electrical and Electronic Uses

Note - Through 1979, Other total included mercury used for installation and expansion of chlorine and caustic soda plants

Source: USEPA Mercury Report Franklin Associates

Table A-2 (continued)
MERCURY CONSUMED IN THE UNITED STATES, 1967 TO 1989

Year	Paints, Mildew-proofing		Agricultural Chemicals		Amalgamation		Pulp and Paper Manufacture		Other Chemicals		Electrical and Electronic Uses	
	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total
1967	267.0	10.1	141.8	5.4	8.3	0.3	16.9	0.6			616	23.3
1968	386.6	13.5	130.3	4.5	10.1	0.4	15.8	0.6			746	26.0
1969	360.5	12.3	102.2	3.5	7.4	0.3	21.2	0.7			703	23.9
1970	385.7	16.5	68.8	2.9	8.3	0.4	8.6	0.4			606	25.9
1971	311.3	15.7	56.1	2.8			0.1	0.0			642	32.3
1972	311.2	15.5	69.8	3.5			0.0	0.0			591	29.4
1973	287.7	13.9	69.5	3.4							684	33.2
1974	258.7	11.4	37.2	1.6							748	33.1
1975	263.3	13.6	22.8	1.2	0.3	0.0					645	33.4
1976	298.1	12.1	23.1	0.9	0.4	0.0					1,045	42.4
1977	317.9	13.7	22.2	1.0	W						1,109	47.6
1978	340.3	18.4	W						W			
1979	379.2	22.0	W						W			
1980	327.6	14.6	W						W			
1981	267.9	11.9	3.0	0.1					W			
1982	258.2	13.9	1.4	0.1					W			
1983	229.8	12.3							W			
1984	176.7	8.5							W			
1985	185.9	9.8							18.2	1.0		
1986	196.8	11.2							W			
1987	218.7	13.7							W			
1988	217.4	12.4							W			
1989	211.7	15.8							44.1	3.3		

Source: Bureau of Mines, 1989 and earlier

W - Withheld to avoid disclosing company proprietary data: included in Other from 1969 through 1980; all other years included in Unknown.

a - Included in Catalysts, Miscellaneous

b - Included in Other Instruments and Related Products

c - Included in Other Chemicals

d - Included in Other

e - Included in Electrical and Electronic Uses

Note - Through 1979, Other total included mercury used for installation and expansion of chlorine and caustic soda plants

Table A-2 (continued)
MERCURY CONSUMED IN THE UNITED STATES, 1967 TO 1989

Year	Electrical Lighting		Wiring Devices and Switches		Batteries		Other Electrical Uses		Measuring and Control Instruments		Dental Equipment and Supplies	
	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total	Short tons	% of total
1967	e		e		e		e		b		90.7	3.4
1968	e		e		e		e		b		117.0	4.1
1969	e		e		e		e		b		109.4	3.7
1970	e		e		e		e		b		86.9	3.7
1971	e		e		e		e		b		89.7	4.5
1972	e		e		e		e		b		113.4	5.6
1973	e		e		e		e		b ¹		101.8	4.9
1974	e		e		e		e		b		114.9	5.1
1975	e		e		e		e		b		88.9	4.6
1976	e		e		e		e		b		75.6	3.1
1977	e		e		e		e		b		46.7	2.0
1978	34.5	1.9	120.8	6.5	525.4	28.3	1.6	0.1	132.6	7.2	19.5	1.0
1979	19.4	1.1	122.1	7.1	303.5	17.6	40.4	2.3	136.9	7.9	30.1	1.7
1980	39.4	1.8	116.4	5.2	1,057.5	47.2	5.5	0.2	115.9	5.2	67.6	3.0
1981	39.6	1.8	100.4	4.5	1,118.8	49.7	W		215.5	9.6	61.3	2.7
1982	31.4	1.7	76.2	4.1	945.4	50.8	W		116.4	6.3	38.7	2.1
1983	48.4	2.6	88.0	4.7	887.3	47.5	W		93.7	5.0	60.7	3.3
1984	56.5	2.7	103.7	5.0	1,128.6	54.3	W		108.5	5.2	54.4	2.6
1985	43.6	2.3	105.0	5.5	1,049.6	55.4	W		87.4	4.6	54.9	2.9
1986	45.5	2.6	113.3	6.5	827.0	47.3	8.2	0.5	69.2	4.0	57.3	3.3
1987	49.4	3.1	144.8	9.1	587.6	36.9	W		65.3	4.1	61.3	3.8
1988	33.9	1.9	193.9	11.0	493.5	28.1	W		84.9	4.8	58.2	3.3
1989	34.2	2.6	155.4	11.6	275.6	20.6	d		95.9	7.2	43.0	3.2

Source: Bureau of Mines, 1989 and earlier

W - Withheld to avoid disclosing company proprietary data: included in Other from 1969 through 1980; all other years included in Unknown.

a - Included in Catalysts, Miscellaneous

b - Included in Other Instruments and Related Products

c - Included in Other Chemicals

d - Included in Other

e - Included in Electrical and Electronic Uses

Note - Through 1979, Other total included mercury used for installation and expansion of chlorine and caustic soda plants

Table A-2 (continued)
MERCURY CONSUMED IN THE UNITED STATES, 1967 TO 1989

Year	Other Instruments		Other		Unknown		Total Short tons
	Short tons	% of total	Short tons	% of total	Short tons	% of total	
1967	283.4	10.7			488.5	18.5	2,641.6
1968	303.2	10.6			314.5	11.0	2,866.0
1969	252.9	8.6	347.1	11.8	27.2	0.9	2,940.1
1970	183.6	7.9	222.6	9.5	8.6	0.4	2,337.1
1971	185.1	9.3	91.5	4.6	0.1	0.0	1,985.8
1972	248.6	12.4	161.8	8.0	0.8	0.0	2,010.5
1973	271.9	13.2	72.7	3.5	3.6	0.2	2,062.8
1974	235.7	10.4	93.2	4.1	40.4	1.8	2,260.2
1975	174.7	9.0	66.5	3.4	30.6	1.6	1,931.8
1976	192.5	7.8	110.5	4.5	36.9	1.5	2,465.1
1977	198.4	8.5	98.4	4.2	53.0	2.3	2,327.8
1978	20.1	1.1	154.9	8.4			1,853.1
1979	33.4	1.9	135.4	7.8			1,726.8
1980	7.2	0.3	30.0	1.3	71.6	3.2	2,241.4
1981	9.6	0.4	9.2	0.4	104.3	4.6	2,251.3
1982	7.4	0.4	37.4	2.0	80.5	4.3	1,859.8
1983	W		51.5	2.8	72.8	3.9	1,867.2
1984	W		53.4	2.6	92.5	4.5	2,077.4
1985	W		10.1	0.5	46.7	2.5	1,894.1
1986	W		13.3	0.8	93.6	5.3	1,750.3
1987	W		16.0	1.0	70.6	4.4	1,593.8
1988	W		28.5	1.6	115.0	6.6	1,755.4
1989	d		38.6	2.9			1,338.2

Source: Bureau of Mines, 1989 and earlier

W - Withheld to avoid disclosing company proprietary data: included in Other from 1969 through 1980; all other years included in Unknown.

a - Included in Catalysts, Miscellaneous

b - Included in Other Instruments and Related Products

c - Included in Other Chemicals

d - Included in Other

e - Included in Electrical and Electronic Uses

Note - Through 1979, Other total included mercury used for installation and expansion of chlorine and caustic soda plants.

Table A-3
DISCARDS* OF MERCURY IN PRODUCTS
IN THE MUNICIPAL SOLID WASTE STREAM, 1970 TO 2000
(In short tons)**

Products	1970	1975	1980	1985	1989	1995	2000
Household Batteries							
Alkaline	4.1	38.4	158.2	352.3	419.4	41.6	0.0
Mercury-Zinc	301.9	287.8	266.8	235.2	196.6	131.5	98.5
Others	4.8	4.7	4.5	4.5	5.2	3.5	0.0
Subtotal Batteries	310.8	330.9	429.5	592.0	621.2	176.6	98.5
Electric Lighting							
Fluorescent Lamps	18.9	21.5	23.2	27.9	26.0	32.6	39.7
High Intensity Lamps	0.2	0.3	1.1	0.7	0.8	1.0	1.2
Subtotal Lighting	19.1	21.8	24.3	28.6	26.7	33.6	40.9
Paint Residues	30.2	37.3	26.7	31.4	18.2	2.3	0.5
Fever Thermometers	12.2	23.2	25.7	32.5	16.3	16.9	16.8
Thermostats	5.3	6.8	7.0	9.5	11.2	8.1	10.3
Pigments	32.3	27.5	23.0	25.2	10.0	3.0	1.5
Dental Uses	9.3	9.7	7.1	6.2	4.0	2.9	2.3
Special Paper Coating	0.1	0.6	1.2	1.8	1.0	0.0	0.0
Mercury Light Switches	0.4	0.4	0.4	0.4	0.4	1.9	1.9
Film Pack Batteries	2.1	2.3	2.6	2.8	0.0	0.0	0.0
TOTAL DISCARDS	421.8	460.5	547.5	730.4	709.0	245.3	172.7

* Discards before recovery.

** Weights in this report are converted to short tons of 2000 pounds.

Source: Franklin Associates, Ltd. USEPA Mercury Report

Table A-4
DISCARDS* OF MERCURY IN PRODUCTS
IN THE MUNICIPAL SOLID WASTE STREAM, 1970 TO 2000
(In percent of total discards)

Products	1970	1975	1980	1985	1989	1995	2000
Household Batteries							
Alkaline	1.0	8.3	28.9	48.2	59.2	17.0	0.0
Mercury-Zinc	71.6	62.5	48.7	32.2	27.7	53.6	57.0
Others	1.1	1.0	0.8	0.6	0.7	1.4	0.0
<i>Subtotal Batteries</i>	73.7	71.9	78.4	81.1	87.6	72.0	57.0
Electric Lighting							
Fluorescent Lamps	4.5	4.7	4.2	3.8	3.7	13.3	23.0
High Intensity Lamps	0.0	0.1	0.2	0.1	0.1	0.4	0.7
<i>Subtotal Lighting</i>	4.5	4.7	4.4	3.9	3.8	13.7	23.7
Paint Residues	7.2	8.1	4.9	4.3	2.6	0.9	0.3
Fever Thermometers	2.9	5.0	4.7	4.4	2.3	6.9	9.7
Thermostats	1.3	1.5	1.3	1.3	1.6	3.3	6.0
Pigments	7.7	6.0	4.2	3.5	1.4	1.2	0.9
Dental Uses	2.2	2.1	1.3	0.8	0.6	1.2	1.3
Special Paper Coating	0.0	0.1	0.2	0.2	0.1	0.0	0.0
Mercury Light Switches	0.1	0.1	0.1	0.1	0.1	0.8	1.1
Film Pack Batteries	0.5	0.5	0.5	0.4	0.0	0.0	0.0
TOTAL DISCARDS	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Discards before recovery.

Details may not add to totals due to rounding.

Source: Franklin Associates, Ltd. USEPA Mercury Report

Table B-1

Ultimate Analysis for Residential MSW

<u>Parameter</u>	<u>Unit</u>	<u>Paper</u>	<u>Plastics</u>	<u>Organics [1]</u>	<u>Wood</u>	<u>Textiles</u>	<u>Rubber</u>	<u>Ceramics</u>	<u>Glass</u>	<u>Metal</u>	<u>Inorganics</u>
Arsenic	ppm	3.80	3.10	10.53	3.97	7.60	4.57	4.00	5.07	31.47	2.30
Barium	ppm	27.07	41.27	110.40	34.80	24.13	20.80	113.80	108.87	24.87	73.00
Cadmium	ppm	4.83	1.69	5.84	0.78	1.94	1.52	0.90	0.89	1.33	1.38
Chromium	ppm	8.82	17.85	34.37	7.46	395.17	66.63	12.92	120.93	45.91	38.72
Lead	ppm	28.80	58.57	532.43	72.17	15.03	16.37	767.33	32.40	2066.83	384.67
Mercury	ppm	0.68	0.74	0.63	0.66	0.47	0.41	0.06	0.05	0.13	1.14
Selenium	ppm	7.17	1.83	1.87	1.47	4.40	41.40	1.37	1.40	1.70	8.37
Silver	ppm	0.88	0.93	0.77	0.97	1.50	0.51	0.87	0.47	0.77	0.97
Carbon	%	34.57	45.17	19.40	42.73	46.27	37.87	6.63	1.15		12.77
Hydrogen	%	7.30	7.60	7.47	6.10	6.00	4.57	1.73	1.13		2.70
Nitrogen	%	0.22	0.11	0.47	0.51	2.38	0.24	0.15	0.15		1.74
Oxygen	%	50.80	49.53	56.00	48.80	42.43	16.83	0.00	0.00		14.73
Sulfur	%	0.12	0.15	0.34	0.06	0.16	0.55	0.05	0.08		2.03
Chlorine	%	0.30	1.26	0.15	0.13	0.37	2.79	0.06	0.07		2.30

[1] Brush, grass, food waste, and miscellaneous organic wastes.

Source: SCS Engineers, "NYC Solid Waste 'Ultimate Analysis,'" 1990.

Table B-2
ROCKLAND COUNTY INTEGRATED SOLID WASTE MANAGEMENT PLAN

**SUMMARY OF LABORATORY ANALYSIS ON MIXED HOUSEHOLD
 SOLID WASTE SAMPLES AND COMBINED YARD WASTE
 AND FOOD WASTE SUBSAMPLES**

ANALYSIS ¹	PARAMETER	AVERAGE OF MIXED WASTE SAMPLES ²	AVERAGE OF COMBINED YARD AND FOOD WASTE SUBSAMPLES ³
MOISTURE CONTENT ⁴		26.51	58.00
PROXIMATE (%) ⁴	Volatile Material	59.14	N/A
	Fixed Carbon	8.38	N/A
	Ash	5.89	14.93
ULTIMATE (%) ⁴	Sulphur	0.15	0.14
	Carbon	34.08	14.93
	Hydrogen	5.23	1.80
	Nitrogen	0.54	0.80
	Oxygen	27.53	9.38
HIGHER HEATING VALUE (BTU/LB) ⁵		63.13	NA
TRACE METALS (ppm) ⁶	Mercury	0.42	1.54
	Lead	59.9	116.9
	Cadmium	< 0.05	< 0.05
	Nickel	14.4	51.0
	Chromium	6.1	< 0.25
	Copper	30.5	131.8
	Zinc	235.7	229.1
ORGANICS (ppb) ⁷	PCB	ND (< 85)	ND (< 47)
	Captan	N/A	ND (< 0.05)
	Carbaryl	N/A	ND (< 30.00)
	Diazinon	N/A	ND (< 6.00)
	Malathion	N/A	ND (< 6.00)

¹Higher heating value, proximate and ultimate analysis are defined in Section 5.1 - Glossary

NOTES: NA = Not analyzed

ND = Not detectable at the threshold detection limit () stated

²Average of composite field samples taken in June 1990 at the Ramapo Transfer Station and the Haverstraw and Clarkstown Landfills from the mixed residential waste fraction as disposed

³Average of composite field samples of the combined yard waste and food waste subfraction which remained after hand sorting from the mixed residential waste fraction as disposed

⁴Percent by weight

⁵BTU/LB = British Thermal Units per pound, a measure of the potential as fired fuel value of the waste

⁶Parts per million

⁷Parts per billion

Table B-3
FOUR SEASONS
AVERAGE METAL CONCENTRATIONS DETECTED IN TYPE-10 WASTE--DRY BASIS (a)
 (in parts per million)

Category	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Newspaper	0.2	ND (b)	ND	25	ND	0.41	ND	83
Corrugated cardboard	0.3	ND	ND	17	24	0.22	8	73
Kraft paper	0.4	ND	7	15	22	0.19	ND	43
Office paper	0.7	ND	ND	8	ND	0.12	ND	31
Magazines	0.5	ND	4	52	ND	0.10	ND	99
Other paper	0.8	ND	7	79	14	0.10	ND	88
Yard waste	1.7	ND	8	18	26	0.26	5	165
PET bottles	ND	ND	16	31	61	0.08	ND	22
HDPE containers	0.2	ND	57	15	229	0.11	ND	63
LDPE bags and film	0.6	ND	125	31	565	0.15	ND	157
Other plastic	0.5	10	8	10	23	0.05	ND	83
Food waste	0.3	ND	ND	25	ND	0.05	6	56
Text./rubber/leath.	1.0	23	469	30	58	0.33	6	806
Wood	40.3	ND	62	38	129	2.58	ND	246
Disposable diapers	0.3	ND	4	5	ND	0.05	ND	83
Other combustibles	2.4	2	17	186	54	7.94	25	274
Glass containers	ND	ND	ND	ND	84	0.19	ND	ND
Tin cans	4.4	16	527	375	350	0.78	133	145
Batteries (d)	7.0	53	45	8,400	236	2,900	NA (c)	180,000
Other ferrous	11.4	14	5,998	157	163	0.68	320	1,100
Aluminum cans	ND	ND	72	107	30	0.74	54	80
Other aluminum	ND	ND	62	251	23	0.87	43	109
Other nonferrous (e)	7.3	391	128	223,300	38,529	ND	5,126	26,700
Other noncombust.	1.2	ND	21	13	50	0.93	5	21
Fines	4.3	2	24	303	462	0.31	30	596
Overall type 10 (f)	3.3	4.5	377	534	152	5.8	34	579

- (a) If a given metal was detected in a given material in any season, average was calculated based on substitution of detection limit for "ND" in other seasons.
- (b) In this table, "ND" indicates that the metal was not detected in the material in any season.
- (c) NA = not analyzed for the metal indicated.
- (d) Concentrations for copper and zinc are literature values.
- (e) Averages for cadmium, lead, and nickel have been adjusted to account for the presence of a nickel-cadmium battery pack weighing 1.5 ounces and a sealed lead-acid battery weighing 3.7 pounds in the waste sorted in the spring. Battery pack estimated to be 17.5 percent cadmium and 24 percent nickel. Lead content of sealed lead-acid battery estimated at 60 percent.
- (f) Based on composition in table 2-3e. Zero substituted for "ND" in calculated overall values.

Soucre: Cape May County MSW Composting Facility Permit Application

Table B-3 (continued)
FOUR SEASONS
DISTRIBUTION OF DETECTED METALS AMONG TYPE-10 WASTE CATEGORIES (a)
 (by percentage)

Category	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Newspaper	0.2%	0.0%	0.0%	0.2%	0.0%	0.3%	0.0%	0.6%
Corrugated cardboard	0.4%	0.0%	0.0%	0.1%	0.6%	0.2%	0.9%	0.5%
Kraft paper	0.3%	0.0%	0.0%	0.1%	0.3%	0.1%	0.0%	0.1%
Office paper	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Magazines	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%
Other paper	4.3%	0.0%	0.4%	3.3%	2.1%	0.4%	0.0%	3.5%
Yard waste	2.0%	0.0%	0.1%	0.1%	0.7%	0.2%	0.6%	1.1%
PET bottles	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
HDPE containers	0.0%	0.0%	0.1%	0.0%	0.9%	0.0%	0.0%	0.1%
LDPE bags and film	0.6%	0.0%	1.2%	0.2%	12.9%	0.1%	0.0%	0.9%
Other plastic	1.4%	20.8%	0.2%	0.2%	1.5%	0.1%	0.0%	1.4%
Food waste	0.8%	0.0%	0.0%	0.4%	0.0%	0.1%	1.6%	0.8%
Text./rubber/leath.	2.0%	32.8%	8.0%	0.4%	2.5%	0.4%	1.2%	9.0%
Wood	58.0%	0.0%	0.8%	0.3%	4.0%	2.1%	0.0%	2.0%
Disposable diapers	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Other combustibles	2.7%	1.9%	0.2%	1.3%	1.3%	5.0%	2.6%	1.7%
Glass containers	0.0%	0.0%	0.0%	0.0%	3.0%	0.2%	0.0%	0.0%
Ferrous cans	2.6%	7.1%	2.7%	1.4%	4.5%	0.3%	7.5%	0.5%
Batteries	0.4%	2.1%	0.0%	2.8%	0.3%	88.9%	0.0%	55.0%
Other ferrous	18.8%	16.4%	85.4%	1.6%	5.8%	0.6%	49.8%	10.2%
Aluminum cans	0.0%	0.0%	0.2%	0.2%	0.2%	0.1%	1.3%	0.1%
Other aluminum	0.0%	0.0%	0.2%	0.6%	0.2%	0.2%	1.6%	0.2%
Other nonferrous	0.5%	17.9%	0.1%	85.4%	51.7%	0.0%	30.4%	9.4%
Other noncombust.	1.7%	0.0%	0.3%	0.1%	1.5%	0.7%	0.7%	0.2%
Fines	2.6%	1.0%	0.1%	1.1%	6.1%	0.1%	1.8%	2.1%
Total	100.0%							

(a) Based on the overall composition in table 2-3e and the metals concentrations from table 4-6e.

Source: Cape May County MSW Composting Facility Permit Application weighing/composition study

CHAPTER 3

MERCURY IN HOSPITAL WASTE: METHODS OF PREVENTION AND REDUCTION

SUMMARY

The municipal waste stream includes residential, commercial and institutional waste. Solid waste generated in hospitals is a component of this waste stream, although it is a relatively minor component of the municipal solid waste stream, representing only 1.1 percent of the total municipal disposal rate.

The main discarded products in hospital waste that contain mercury are batteries, particularly mercury oxide batteries, fever thermometers and other mercury-containing instruments. Statewide mercury oxide batteries from hospitals account for 20 percent of the mercury loading in the municipal solid waste stream. In some counties, because of the number of hospitals located in the county, mercury oxide batteries from hospitals could represent approximately 60 percent of the total mercury oxide batteries disposed of in the municipal solid waste stream. Fever thermometers, as a source of mercury, are decreasing in hospitals. Their use is being replaced with digital thermometers. Presently, mercury thermometers from hospitals represent a 93 percent increase over the quantity of mercury present, on average, in the municipal solid waste stream on a pound per ton basis.

Hospitals could be a significant contributor to mercury in the municipal solid waste stream. However, this impact is magnified when disposal of hospital waste occurs in an on-site incinerator. Given that this waste stream is a captive waste stream (the hospital has direct control over purchasing, use and disposal), source reduction strategies may be implemented in a cost-effective manner. The USEPA estimates 98 percent of the mercury containing products are noncombustible. These products should be prohibited from disposal in hospital incinerators.

Specifically in regard to mercury oxide batteries, the "Dry Cell Battery Management Act", N.J.S.A. 13:1E-99.59 et seq, prohibits the disposal of mercury-oxide batteries in the solid waste stream. The act establishes the battery manufacturers as the responsible entity and holds them liable, at their expense, for their proper management, separate from the solid waste stream. Mercury oxide battery use in hospitals can be performed in a close loop system through a reserve distribution network. This system would be highly effective in eliminating mercury oxide batteries from the solid waste disposal stream. Another option would be to replace mercury oxide with zinc-air. The advantages of either option are basically equivalent.

TASK DESCRIPTION

This task has two objectives:

1. To evaluate the mercury content in the hospital solid waste stream in terms of on-site disposal and solid waste facilities (off-site) as part of the municipal solid waste stream; and
2. To evaluate the source reduction potential to reduce the quantity of mercury in the hospital waste stream.

METHODOLOGY

The mercury containing products in municipal solid waste were evaluated to determine their use in hospitals and their potential quantity in the hospital waste stream. Source reduction programs currently in place were evaluated in terms of the hospital solid waste stream in both the on-site disposal mode or off-site disposal to solid waste facilities.

DISCUSSION/RESULTS

Current Mercury in Hospital Waste

Exclusive of regulated medical waste, hospital solid waste is part of the municipal solid waste stream. Municipal solid waste is defined as containing residential, commercial and institutional solid waste. Unless disposed of on-site through incineration, hospital waste is disposed of at solid waste facilities. Hospital solid waste has been estimated to account for approximately 4.3 percent of the commercial and institutional portion of the municipal solid waste stream. It has been estimated that commercial and institutional waste accounts for approximately 50 percent of the municipal solid waste stream.¹ The Bureau of Residual and Special Waste Planning within the department has estimated that regulated medical waste is 30 percent of the total hospital waste stream.² The department does not require the reporting of the individual components of the ID 10 municipal solid waste stream. However, according to the department's Medical Waste Tracking System, 17,000 tons of regulated medical waste was generated in 1991.² Therefore, the total hospital waste stream would be approximately 56,667 tons annually. If all hospital waste were disposed at off site facilities, hospital waste would account for 1.12 percent of the municipal solid waste disposal stream.

In terms of quantity, hospital solid waste in the municipal solid waste stream is very small. However, in terms of specific loading of mercury, this waste stream has the potential to have a significant impact on mercury emissions. According to the New Jersey Hospital Association, 8.4 volt mercury oxide batteries account for approximately 1191 kilograms or 2626 pounds of mercury annually in the hospital waste stream.³ This number was determined through evaluation of the purchasing records of the Middle Atlantic Services Corporation (MASC). MASC is the vendor through which 36 of the state's hospitals purchase their batteries. This quantity represents eight percent of the total New Jersey mercury loading into the 1992 municipal solid waste stream, nine percent of the mercury loading represented by all batteries and 22 percent of the mercury loading represented by mercury oxide batteries. This quantity is averaged across New Jersey. However, on a county basis, this mercury loading is dependent on the number of hospitals within a particular county.

Batteries

As outlined in Table 2-6 of Chapter 2, batteries account for 83.6 percent by weight of mercury in the 1992 solid waste stream. Hospital use and disposal of alkaline and carbon zinc batteries are within the average ranges within the municipal solid waste stream.¹ However, hospitals are a major source of mercury resulting from mercury-oxide batteries. These batteries are used in remote telemetry beds, fetal heart monitors and EKG meters. In one county it has been estimated that mercury oxide batteries account for 20 percent of the mercury load to the municipal solid waste stream.⁴ As determined in Table 2-6 in Chapter 2, mercury-oxide batteries account for 34.4 percent by weight of the mercury in the New Jersey municipal solid waste stream. Hospitals however, contribute approximately 60 percent of the mercury-oxide batteries in the municipal solid waste stream.

Electric Lighting

Fluorescent lighting is the second largest source of mercury in the municipal solid waste stream. According to the Table 2-6 above, they represent 8.3 percent of the mercury in the 1992 municipal solid waste stream.

Since the hospitals are operated 24 hours a day, they are significant users of fluorescent lighting.¹ However, since institutional and commercial sources are the major contributors of fluorescent lighting, this source is not out of average with the overall input in the municipal solid waste stream.

In their report "Cadmium, Lead and Mercury in Hospital Solid Waste: A Scoping Study," prepared by Tufts University for NEWMOA, the authors selected a case study hospital to evaluate. The case study hospital has 305 beds and a patient occupancy rate approximately 75 percent. The purchasing records for thermometers, CAT scan film, waste disposal bags and fluorescent light bulbs were evaluated to estimate the quantity of mercury in the hospital waste stream. The NEWMOA report cites the use of 3000 fluorescent light bulbs and estimates an annual loading of 0.3 pounds of mercury resulting from fluorescent lighting. The quantity of waste generated during the year was 824 tons. This results in a 0.00036 pounds per ton loading resulting from fluorescent lighting. This figure is consistent with the loading from fluorescent lighting in the municipal solid waste stream of 0.00030 pounds per ton.

Fever Thermometer

The NEWMOA report cites the purchase of 1470 rectal and oral fever thermometers during the year. These thermometers contain two percent mercury by weight and results in a 2 pound load of mercury in the hospital waste stream.¹ The loading from fever thermometers in the hospital solid waste stream was 0.00243 pounds per ton of solid waste. This loading is compared to the mercury loading from fever thermometers in the 1992 municipal solid waste stream of 0.00016 pounds per ton of solid waste. This is a 93.4% increase over the average loading of mercury in the municipal solid waste stream. This discarded product in the hospital waste stream and as a component of the

municipal solid waste stream is a significant contributor of mercury. Mercury thermometers are being rapidly replaced by digital thermometers in hospital use. However, mercury thermometers will not be fully replaced but digital thermometers since the standard for temperature measurement is mercury thermometers.⁵

Other Sources of Mercury

Other small sources of mercury in the hospital solid waste stream are from mercury compounds, such as thimerosal in pharmaceutical antiseptics, diuretics and skin preparations, pigments in plastics, such as red plastic bags, and CAT scan paper.²

While these sources of mercury-containing products are small, they are predominant in the combustible fraction of the hospital solid waste stream.

SOURCE REDUCTION

The USEPA has estimated that 98 percent of the mercury-containing product are in the non-combustionable fraction of the municipal solid waste stream.⁶ This ratio is more significant in the hospital solid waste stream for on-site incineration and disposal. However, it is also more controllable. An overall source reduction strategy for the on-site incinerators would be to prohibit the acceptance of batteries, fluorescent lights, thermometers, all other mercury-containing instruments, electrical switches and thermostats in the hospital incinerator. These mercury-containing discarded products should be required to be managed separately, as a special waste. Recovery of the mercury, where feasible should be considered. While this report focuses on the incinerator of hospital waste containing mercury-containing, discarded products should be managed from other on-site hospital disposal facilities such as sterilization and chlorination processes.

Mercury oxide batteries will be prohibited from disposal as solid waste upon approval of the manufacturers' battery management plans. The battery manufacturers will be financially liable for their separate management as a special waste. Management of mercury oxide batteries as part of the battery management plan will eliminate this product in the municipal waste stream. As discussed in Chapter 2, currently, there are no approved mercury oxide battery management plans in New Jersey. Therefore, as set forth in the "Dry Cell Battery Management Act", N.J.S.A. 13:1E-99.65, no mercury oxide battery can be sold in New Jersey. Hospitals have the option to replace the use of mercury oxide batteries with zinc air batteries. **In cases where there is no technologically feasible alternative to mercury oxide batteries, and for health and safety reasons, the department will allow the use of mercury oxide batteries.** It should be noted that zinc-air batteries are not mercury-free and contain a background quantity of mercury in trace amounts in the zinc.

Hospitals ultimately control the purchasing, use and disposal of the products. Therefore, source reduction practices can substantially reduce the mercury content in the hospital solid waste stream. The department will be working with the New Jersey Hospital Association to develop data on the

potential for recycling and source reduction with the hospital solid waste stream.

REFERENCE

1. Northeast Waste Management Officials' Association (NEWMOA) "Cadmium, Lead and Mercury in Hospital Solid Waste: A Scoping Study," Prepared by Tufts University, November 1991.
2. Confer, Robert Chief, Bureau of Residual and Special Waste Planning, Division of Solid Waste Management, NJDEPE, June 1992, Personal communication.
3. Hickey, Tim, Memorandum N.J.H.A. Hospital Mercury Generation Through Battery Disposal dated July 14, 1992.
4. Cooper, Laurie Environmental Scientist, American Ref-Fuel Company, June 1992, Personal communication.
5. Barbie, Glenn, Director of Safety, Becton Dickinson, Franklin Lakes, NJ, November 1992 Personal communications.
6. USEPA "Characterization of Products containing Mercury in Municipal Solid Waste in the United States" 1970 to 2000 OSW EPA 530-R-92-013 prepared by Franklin Associates, Ltd., April 1992.
7. NJHA/NJDEPE Developing a Recycling Program: "A Guide for Hospitals, New Jersey Hospital Association", Council on Management Practices, Task Force on Recycling, February 1991.

CHAPTER 4

MERCURY IN SLUDGE: METHODS OF PREVENTION AND REDUCTION

SUMMARY:

This section of the report was prepared to provide information relative to the content of mercury in sewage sludge. Various database sources maintained under the New Jersey Pollutant Discharge Elimination System (NJPDDES) were investigated to obtain information on the mercury content of sewage sludge and possible sources for the presence of mercury in sewage sludge. Data submitted by domestic treatment works (DTW) under the Sludge Quality Assurance Regulations (SQAR) indicate a worse case of 3.0 to 6.0 mg/kg of mercury. Based on information obtained on industrial NJPDDES discharge permits, as well as industrial and domestic sludge quality data, a wide variety of industrial, commercial and domestic activities could be potential sources for the discharge of mercury.

TASK DESCRIPTION:

It is important to understand that each DTW must evaluate the level of mercury, as well as other constituents, in sewage sludge generated by their facility on a case-by-case basis which is contingent on the specific method of sludge management. This report does not attempt to identify problem sources of mercury discharges to the environment nor problem levels for mercury in sewage sludge, but is only meant to be used as a starting point to understand the potential sources for the presence of mercury in sewage sludge and potential strategies which could be used to decrease mercury contributions where necessary.

HOW TASK WAS ACCOMPLISHED:

Information required to be submitted under the New Jersey Pollutant Discharge Elimination System (NJPDDES) was reviewed to obtain data on mercury in sewage sludge. Specifically, sludge quality data submitted by domestic and industrial treatment works was reviewed for the presence of mercury. In addition, NJPDDES permit files were reviewed to identify pretreatment technologies currently used by industries required to monitor for mercury in their discharges.

DISCUSSION:

SEWAGE SLUDGE MERCURY CONTENT

There are currently 451 DTWs in the state of New Jersey which generate an average of 1,800,000 dry pounds of sewage sludge per day. Table 4.1 indicates sewage sludge production by sludge management method. Currently, about 400,000 dry pounds per day of sewage sludge, or 23 percent of the total sludge production, is currently incinerated at ten authorities with sewage sludge incinerators located in the state of New Jersey. Based on the use of weighted average for all DTWs, approximately 800 pounds of mercury is incinerated a

year in sewage sludge incinerators. This is a conservative estimate since it is based on using the worse case reported mercury concentration for each domestic treatment works. Worse case reported mercury concentrations are used because facilities must monitor and conform to limitations for mercury on a monthly basis. In addition, those domestic treatment works which utilize a sludge management alternative with a mercury limitation (e.g. incineration or beneficial use) will tend to have lower mercury concentrations.

Of the 451 DTWs, each may have various combinations of wastewater or sludge treatment which could effect the fate of pollutants entering the treatment plant. These facilities vary in size from 1,200 gallons per day (GPD) to 330 million gallons per day (MGD) of wastewater treated. However, as stated in Table 4.2, 97 percent of the sludge generated is produced by the 106 largest DTWs in excess of 1 MGD; thus, the average mercury content of sewage sludge is skewed by the larger DTWs.

All DTWs are required to report information on sludge quality, including mercury, pursuant to the Sludge Quality Assurance Regulations (SQAR), N.J.A.C. 7:14-4. SQAR was originally adopted and became effective on October 18, 1979. The rules require the routine analysis and reporting on all sludge produced by domestic and industrial treatment works. As previously stated, Table 4.2 presents information on DTWs according to size and percentage of industrial users. These categories are utilized under SQAR to determine the degree of reporting necessary by DTWs. Table 4.3 summarizes information on the past and present mercury content of sewage sludges by category. As described above, the mercury content presented is conservative, since it is based on the worse case reported concentrations at each domestic treatment works.

Since 1985, there has been a reported 38 percent improvement in sludge quality relative to mercury concentration. Part of the documented improvement is related to the standardization of sampling and analytical procedures which were adopted in May 1989, as part of SQAR. Thus, more reliable and consistent data is now being obtained for all categories of treatment works. However, the most significant contribution to real sludge quality improvement came with the adoption of the Statewide Sludge Management Plan (SSMP) in November 1987. The SSMP set forth the Department's "clean" sludge policy and established a limit of 10 mg/kg for the beneficial use of sewage sludge. In addition, more recently, permits issued for sewage sludge incinerators now include sludge quality limitations. The existing limits for sewage sludge incinerators range from 5 to 20 mg/kg based on site specific considerations. All of these factors have contributed to DTWs paying closer attention to sludge quality and taking a more proactive stance to protect sludge quality.

A majority of DTWs do not have excessive mercury concentrations in their sludge when compared to existing limitations (See Table 4.3). However, it can also be noted from the range of concentrations shown that mercury contamination of sewage sludge must be addressed on a case-by-case basis.

SOURCES FOR THE PRESENCE OF MERCURY IN SEWAGE SLUDGE

Mercury present in the raw sewage entering DTWs could have several fates. Mercury could potentially partition to sewage sludge, volatilize, or remain in

the discharge water. Since mercury entering DTWs is generally in an inorganic, less soluble form, mercury is likely to adhere to sludge particles.

New Jersey Pollutant Discharge Elimination System (NJPDDES) permits are issued to protect two media: receiving waters and sewage sludge. To comply with its NJPDDES permit and meet other environmental criteria, a DTW must limit the receipt of any pollutants which are not amenable to treatment. Typically, DTWs receive a mixture of two types of waste: domestic sewage from residential and commercial sources, and industrial wastewaters discharged into the sewer. Industrial users of sanitary sewer systems are usually monitored much more closely than the other sources.

Existing Categorical Standards For Mercury

Currently, 4 industrial categories are subject to categorical standards for mercury (1) as indicated below:

1. Battery manufacturing (40 CFR Part 461);
2. Inorganic chemicals (40 CFR Part 415);
3. Nonferrous metals manufacturing (40 CFR Part 421); and
4. Steam electric power generating (40 CFR Part 423).

Industries in each of the above categories are potential dischargers of mercury into DTWs and are required to meet technology-based effluent standards. However, it should be noted that categorical standards may not be sufficient to protect a specific DTW's sludge quality; therefore, prohibited discharge standards and local limits provide additional controls.

Additional, Potential Industrial Dischargers Of Mercury Include:

1. Wood manufacturing and refinishing industries where mercury concentrations ranging from 0.0007 to 18.0 mg/l have been reported (2);
2. The paint manufacturing industry where mercury based bactericides are used in solvent and water-based paints (3). (See Chapter 2 for a discussion of mercury reduction in paint;) and
3. The commercial printing industry that uses mercury salts as an intensifier to increase the blackness and change the image contrast (4).

Future Categorical Standards

Categorical pretreatment standards are currently being revised for existing and new sources in the organic chemicals, plastics, and synthetic fibers category (1993), the pharmaceutical manufacturing category (1994), and the pulp, paper, and paperboard category (1995) because some toxic pollutants discharged from these industries are not regulated by current pretreatment standards. Furthermore, EPA is assessing the need to revise categorical pretreatment standards for petroleum refining, the processing of timber products, and the operations of textile mills. Finally, EPA plans to study the following industrial categories to determine the merit of developing effluent guidelines (including categorical standards): drum reconditioning,

hospitals, industrial laundries, paint formulating, solvent recycling, stripper oil and gas extraction, transportation equipment cleaning and used oil reclamation and refining (5). Additional information is needed on many of these categories to assess if they are a potential source of mercury.

Industrial Treatment Works

In addition to the 451 domestic treatment works previously cited, 41 industrial treatment works have reported detectable concentrations of mercury in sludge generated by these facilities. Furthermore, an additional 27 industrial facilities, including 22 landfills, were identified as having mercury effluent limitations. This information is also available to be used to determine potential sources of mercury discharges.

Industrial Discharge to DTW'S

Currently, only 71 DTWs have collection systems with known industrial users. Table 4.4 compares the mercury concentration in the sewage sludge generated by these 71 DTWs to the mercury concentration in the sewage sludge generated by those DTWs with no known industrial users. As can be seen, there is little correlation between industrial connections to a treatment plant and high mercury concentrations. In fact, the highest reported mercury concentrations have been found in domestic treatment works with no known industrial users or which service single users (e.g. hospitals and schools). Therefore, additional explanations for the presence of mercury in sewage sludge must be identified. (Based on Chapter 3, it is not surprising that hospitals have high concentrations of mercury in waste water discharge. Also, Chapter 7 indicates that schools do generate hazardous waste.)

To date, the highest concentrations of mercury reported in sewage sludge have been the result of unique occurrences: discharge from a municipal solid waste incinerator scrubber and breakage of mercury seals in biological trickling filters. Nevertheless, 66 DTWs have reported mercury concentrations in excess of 10 mg/kg. Table 4.5 identifies these 66 DTWs based on the type of user area that is serviced. Based on this information, additional potential sources for the discharge of mercury into DTWs can be identified as summarized below:

1. Hospitals: the primary source of mercury waste at most hospitals include broken or obsolete equipment (6). SQAR testing has identified levels of mercury exceeding 10 mg/kg at 6 DTWs which exclusively serve health care facilities (see Table 4.5);

2. Educational institutions: mercury is often used in general chemistry experiments or is found in equipment used at educational facilities (e.g. thermometers, barometers, switches) (7). In addition, SQAR testing from DTWs which serve educational institutions has identified elevated mercury levels above 10 mg/kg at 11 such treatment works (Table 4.5);

3. Domestic wastewater: traditionally, domestic discharges to Publicly Owned Treatment Works (POTWs) have been considered simply a source of suspended solids and degradable organic materials, as compared to industrial

and commercial sources. For many domestic treatment works, however, domestic flows make up a large part of the total flow received. The reported range of mercury in domestic wastewater is .0001 mg/l to .054 mg/l (8). Reports have suggested that as much as 60 percent of the discharged mercury could come from dental clinics (9);

4. Stormwater: stormwater runoff collected by combined sewer systems may contain toxic pollutants that may ultimately be discharged into DTWs. Toxic pollutants in stormwater runoff come primarily from urban roadways and parking lots, runoff from industrial facilities, agricultural runoff of pesticides, and air pollutants washed to the ground by precipitation. EPA during the Nationwide Urban Runoff Program, initiated in 1978, found mercury in only 9% of the samples taken (10);

5. Infiltration/Inflow Sources: infiltration and inflow may also contribute a diverse load of toxics to POTWs. Infiltration is the passage of groundwater into a collection system through breaks and leaks in the system. Inflow, the uncontrolled entrance of water into the system from surface sources, typically occurs when surface water passes over unsealed manhole access points. Because infiltration is difficult to detect and is rarely analyzed for the presence of pollutants, the extent of infiltration as a source of toxics is generally unknown. However, there are a few case studies where contaminated groundwater infiltrated into the sewer system ultimately affecting sludge quality (11);

6. Septage: DTWs whose influents comprise a relatively large proportion of hauled septage may find that these wastes contribute significant loadings of certain pollutants, specifically copper. Although the concentration of mercury in typical septage delivered to DTWs is expected to be low, the quality of the septage is dependent on the source where the septage was generated (12). Therefore, DTWs which receive septage are encouraged to have quality control procedures in place to avoid sludge quality problems.

7. Solid Waste Facilities: as previously described, a majority of the facilities required to monitor for mercury under the NJPDES system are landfills. In addition, there is a case history where a discharge from a municipal solid waste incinerator caused concentrations in excess of 100 mg/kg in the receiving DTW's sludge.

PRETREATMENT AND SOURCE REDUCTION

Pursuant to SQAR, DTWs must comply with the sludge quality criteria applicable to the method of sludge management selected. As previously stated, most DTWs have a mercury sludge content that would not limit the selection of sludge management alternatives. Essentially, there are two primary methods to prevent excessive levels of mercury from being discharged to DTWs: reduction at the source of generation or end-of-pipe treatment prior to discharge. It is important to emphasize that mercury reductions, when necessary, must take place prior to discharge to a DTW. Many pretreatment technologies provide for reclamation of lost raw materials by industrial users, or are substituted by pollution prevention practices that eliminate the need for end-of-pipe treatment.

1. Pollution Prevention: reductions in toxic pollutants can be achieved through pollution prevention techniques. These general techniques include:

a. Source Reduction reduces the volume of waste generated or transferred to the environment. Reduction techniques include waste segregation, materials handling and housekeeping, process modifications, equipment replacement, employee training, and development of corporate strategies.

b. Waste Recycling/Recovery reduces the amount of waste that must be ultimately disposed of, such as:

*Closed-Loop Recycling is alteration of production line to include reuse of materials as part of the manufacturing process.

*Reuse of the Original Product is the reuse of waste materials in their original form; for example, bottles that are sterilized and reused.

*Primary Recycling is the remanufacturing of waste materials into new materials such as conversion of waste bottles to cullet (13).

In October 1988, Congress passed the Pollution Prevention Act of 1990, which states as national policy that pollution should be prevented or reduced at its source wherever possible. To date, EPA has published pollution prevention guidance manuals for the seven industrial categories listed below: (14)

- * Pesticide formulating industry
- * Commercial Printing industry
- * Selected hospital waste streams
- * Fabricated metal products industry
- * Printed circuit board manufacturing
- * Research and educational institutions
- * Paint manufacturing

Specific applications involving the reduction of mercury waste were identified for four of the above categories as follows:

• The Paint Manufacturing Industry: bactericide substitutes have been found to replace mercury in solvent-based paints. No similar success for water-based paints was identified (15). (However, mercury in water based paint was also prohibited. See discussion in Chapter 2;)

• Hospitals: mercury wastes are decreasing in quantity due to the substitution of solid state electronic sensing instruments (thermometers, blood pressure gauges, etc.) for those containing mercury. Mercury from broken equipment can also be controlled by use of spill cleanup kits and recycling uncontaminated mercury to appropriate vendors (16);

• Educational Institutions: eliminate the drain disposal of all toxic and hazardous waste (17); and

Commercial Printing Industry: nonhazardous substances are available as substitutes as photographic intensifiers (18).

Some industrial facility operators have implemented pollution prevention technologies as a cost-effective method of managing waste. It has been found to be less costly to reformulate products, modify processes, redesign equipment, or reuse waste materials than to implement traditional end-of-pipe controls. The implementation of pollution prevention measures at industrial facilities has been shown to reduce the amounts of pollutants in air, water, solid waste, wastewater, and sludge (19).

2. Pretreatment: pretreatment technologies are used to treat waste prior to discharge to a domestic treatment works. Pretreatment requirements cannot be imposed on industrial users without a technical basis. The technical basis must be tied to at least one of 3 criteria: treatment plant protection, worker safety and compliance with permit limits (effluent, sludge or air). The most commonly used pretreatment technologies for removal of mercury based on a file review of 11 NJPDES permitted facilities are summarized below:

*Chemical precipitation and sedimentation or filtration: heavy metals are generally not very soluble in water and can therefore be removed by physical means, such as settling or filtration. Removal normally requires adjustment of the pH to the proper level to precipitate solids by coagulation and gravity settling and/or filtration. Common precipitation reagents include lime, caustic and sulfide. Also, calcium and sodium carbonate are used for metals where solubility within a pH range is not sufficient to meet a specific treatment standard (20). Chemical precipitation was used in 10 of the 11 industries surveyed.

*Activated carbon: mercury has been shown to have good adsorption potential; thus, activated carbon could be well suited for removal of mercury. Pretreatment is necessary to secure column effectiveness and to minimize regeneration time and expense (21). Therefore, carbon adsorption is usually preceded by other pretreatment technologies such as neutralization and/or precipitation. Activated carbon was used at 4 of the 11 industries surveyed.

*Ion exchange: ion exchange differs from other systems of waste treatment as it is a process for substituting other ions for certain ions in the waste stream. Ion exchange resins are relatively insoluble granular materials that have acid or basic radicals exposed on parts of their surface which can be exchanged for ions of the same positive or negative charge in the wastewater. Strong acid resins (e.g. analogous to sulfuric acid) are effective in removing mercury (22). Ion exchange was used at one of the industries surveyed.

*Reverse osmosis: reverse osmosis has several applications for industrial water pollution control and involves the concentration of dissolved solids into a much smaller volume for separate treatment or disposal. However, extensive pretreatment is needed to protect the

unit from excessive suspended solids loads, extreme pH values, oil and grease and other wastewater characteristics that may impede operation or even damage or dissolve the membrane. Currently, cost significantly limits the use of reverse osmosis for wastewater treatment (23). Reverse osmosis was used at one of the industries surveyed.

*Oxidation-reduction: chemical oxidation-reduction reactions are used to reduce toxicity or solubility or to transform a substance to one more easily handled. Chemical reduction has been employed for treatment of wastes containing mercury. Common reducing agents include sulfur dioxide, sulfite salts and ferrous sulfate (24). Oxidation-reduction was used at one of the industries surveyed.

The above list by no means should be considered to be all inclusive, but merely demonstrates the practical application of some pretreatment technologies based on a limited review of available information. In addition, it should be noted that amalgam separators have been reported to be from 99.5 percent (25) to 98.6 percent (26) effective in removing mercury from dental clinic discharges.

FATE OF MERCURY FROM CONTROL TECHNOLOGY

Pretreatment technologies are available for removing excessive mercury from wastewaters prior to discharge. However, pretreatment also creates additional sludge which must then be managed by the industrial treatment works. A total of 41 industrial treatment works have reported detectable concentrations of mercury in sludge generated by their treatment works. A summary of the management methods employed by industrial treatment works appears in Table 4.6.

Mercury which does enter DTWs is generally in its inorganic, less soluble form (27); thus, mercury is more likely to adhere to sludge particles. However, removal efficiencies vary between DTWs; therefore, the fate of mercury through a DTW must be evaluated on a case by case basis. In addition, questions were raised by committee members as to the "cycle" of mercury at DTWs which utilize incineration. Specific information was requested on ash and scrubber water mercury concentrations. Each of the 10 existing sewage sludge incinerators were contacted for information. Table 4.7 is a summary of the data collected.

In addition, questions have been raised regarding the potential for sludge digesters at domestic treatment works to act as an additional emission source for mercury. Although mercury is the most volatile of the metals in sewage sludge, the temperatures during sludge digestion (ambient to 55 degrees C) must be questioned as being conducive to significant mercury volatilization. However, the lowest temperature studies for mercury volatilization were found to be performed was 350 degrees C. Pursuant to Kistler (1987) mercury was completely evaporated at the lowest investigated pyrolysis temperature of 350 degrees C (28). To properly evaluate sludge digesters as a source for mercury emissions, studies on the volatilization of mercury at lower temperatures as well as data on changes in the mercury content of sewage sludge before and after digestion must be obtained. The Department will consider future investigation of this issue.

TABLE 4.1

SUMMARY OF EXISTING SEWAGE SLUDGE MANAGEMENT METHODS

SLUDGE MGT. METHOD	AVERAGE SLUDGE PROD. (DRY LBS./DAY)	% OF TOTAL SLUDGE PROD.	LBS. Hg PER YEAR
Beneficial Use	388,334	21.6%	776.7
Incineration	404,307	22.5%	808.7
Out-of-state	965,752	53.8%	1,931.7
Other	36,764	2.1%	73.5
TOTALS	1,795,159	100.0%	3,590.6

TABLE 4.2

SUMMARY OF SEWAGE SLUDGE PRODUCTION BY CATEGORY

CATEGORY	TOTAL STP'S	% OF TOTAL SLUDGE PROD.
1 = Design flow LT 0.099 MGD	259	1%
2 = Design flow 0.1 to 0.999 MGD	86	2%
3 = Design flow 1.0 to 4.999 MGD	51	8%
4 = Design Flow GT 5.0 MGD (except 5)	31	29%
5 = GT 10% industrial users	24	60%
TOTALS	451	100%

TABLE 4.3

SUMMARY OF THE MERCURY CONTENT OF SEWAGE SLUDGE

CATEGORY	MEDIAN MERCURY CONCENTRATION (mg/kg)		RANGE
	YEAR-1985	YEAR-1992	YEAR-1992
1	22.0	3.05	ND - 100
2	19.0	5.46	ND - 130
3	6.0	4.88	0.42 - 36
4	10.0	5.06	0.5 - 27
5	7.0	5.81	1.3 - 52
WEIGHTED AVG.		5.48	

TABLE 4.4

MERCURY CONTENT OF SEWAGE SLUDGE AT DTWS WITH AND WITHOUT INDUSTRIAL USERS

CATEGORY	MERCURY CONCENTRATION (mg/kg)	
	MEDIAN	RANGE
DTWs without industry	3.83	ND - 130
DTWs with industry	4.89	0.63 - 52

TABLE 4.5

SUMMARY OF TYPES OF DTWS WITH SLUDGE MERCURY CONCENTRATIONS IN EXCESS OF 10 MG/KG

CATEGORY	# DTW'S
Commercial/Small Residential	22
Publicly Owned Treatment Works	21
Research/Educational	11
Hospitals	6
Transportation	4
Military	2
TOTAL	66

TABLE 4.6

SUMMARY OF INDUSTRIAL SLUDGE MANAGEMENT METHODS

SLUDGE MGT. METHOD	AVG. SLUDGE PROD. (DRY LBS/DAY)	RANGE OF Hg CONC. (mg/kg)	LBS. Hg PER YEAR
Landfill (Haz)	171,472	0.26 - 4.54	42.0
Landfill (Nonhaz)	40,720	0.10 - 110.0	747.9
Out of State (Haz)	17,160	0.13 - 29.0	11.3
Incineration (Haz)	6,334	0.17 - 3.36	0.5
Incineration (Nonhaz)	3,200	0.01 - 0.97	0.1
Other	37,318	0.04 - 25.8	16.5
TOTALS	276,204	0.01 - 110.0	818.3

TABLE 4.7

SUMMARY OF ASH, SCRUBBER WATER AND SLUDGE MERCURY CONCENTRATIONS AT SEWAGE SLUDGE INCINERATORS

FACILITY	SLUDGE (mg/kg)	SCRUBBER WATER (ug/l)	ASH (mg/kg)
ACUA	0.25	--	--
BRSA	2.31	--	0.14
CCMUA	1.5	--	--
GCUA	1.2	--	--
NWBCUA	3.61	--	0.30
ParTroy	5.29	--	ND
SBRSA	3.2	--	0.24
SRVSA	5.95	--	--
TBSA	5.9	--	0.67
Wayne	2.64	0.625	ND

ND = Not Detected

FOOTNOTES:

- (1) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), pp. 5.6-5.8.
- (2) Ibid., p. 3.50.
- (3) USEPA, Guides to Pollution Prevention: The Paint Manufacturing Industry, EPA/625/7-90/005 (June 1990), pp. 1-10.
- (4) USEPA, Guides to Pollution Prevention: The Commercial Printing Industry, EPA/625/7-90/008 (August 1990), pp. 3-11.
- (5) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), p. 5.10.
- (6) USEPA, Guides to Pollution Prevention: Selected Hospital Waste Streams, EPA/625/7-90/009 (June 1990), pp. 4-5.
- (7) USEPA, Guides to Pollution Prevention: Research and Educational Institutions, EPA/625/7-90/010 (June 1990), pp. 2-10.
- (8) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), p. 3.52.
- (9) Alpha International Management Group LTD., Written Correspondence, March 18, 1992), p.3.
- (10) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), p. 3.65-3.71
- (11) Ibid., pp. 3.73-3.74.
- (12) Ibid., pp. 3.74-3.76.
- (13) Ibid., p. 3.88.
- (14) Ibid., p. 3.85.
- (15) USEPA, Guides to Pollution Prevention: The Paint Manufacturing Industry, EPA/625/7-90/005 (June 1990), pp.1-10.
- (16) USEPA, Guides to Pollution Prevention: Selected Hospital Waste Streams, EPA/625/7-90/009 (June 1990), pp. 4-8.
- (17) USEPA, Guides to Pollution Prevention: Research and Educational Institutions, EPA/625/7-90/010 (June 1990), pp. 2-10.
- (18) USEPA, Guides to Pollution Prevention: The Commercial Printing Industry, EPA/625/7-90/008 (August 1990), pp. 3-11.

- (19) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), p. 3.85.
- (20) Robert A. Corbitt, Standard Handbook of Environmental Engineering (New York: McGraw-Hill Publishing Company, 1990), p. 6.170.
- (21) Ibid., p. 9.20.
- (22) Ibid., p. 6.202.
- (23) Ibid., p. 9.28.
- (24) Ibid., pp. 9.27-9.28.
- (25) Alpha International Management Group LTD, Written Correspondence (March 18, 1992), p.1.
- (26) Laqua Dental Equipment Limited, Written Correspondence, (July 29, 1992), p.2.
- (27) USEPA, National Pretreatment Program: Report to Congress, 21W-4006 (July 1991), pp. 5.6-5.8.
- (28) University of Washington, "Air Emissions and Ash Resulting From Incineration of Sewage sludge: Abstracts", In Literature Reviews on Environmental Effects of Sludge Management, ed. Charles L. Henry, Ph.D., and Robert B. Harrison, Ph.D., (July 1991), p. 49.

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4. U.S. Environmental Protection Agency. Guides to Pollution Prevention: The Fabricated Metal Products Industry. EPA/625/7-90/006. July 1990.
5. U.S. Environmental Protection Agency. Guides to Pollution Prevention: The Printed Circuit Board Manufacturing Industry. EPA/625/7-90/007. June 1990.
6. U.S. Environmental Protection Agency. Guides to Pollution Prevention: Research and Educational Institutions. EPA/625/7-90/010.
7. U.S. Environmental Protection Agency. Guides to Pollution Prevention: The Paint Manufacturing Industry. EPA/625/7-90/005. June 1990.
8. U.S. Environmental Protection Agency. National Pretreatment Program: Report to Congress. 21W-4004. July 1991.
9. NJDEPE. Sludge Quality Assurance Regulations, N.J.A.C. 7:14-4, October 1979 (amended May 1989).
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13. Alpha International Management Group LTD., Written Correspondence (March 18, 1992).
14. Laqua Dental Equipment Limited, Written Correspondence (July 29, 1992).

CHAPTER 5

MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATORS, HOSPITAL WASTE INCINERATORS, AND MUNICIPAL SOLID WASTE INCINERATORS AND MERCURY EMISSION CONTROLS

SUMMARY:

Information in Tables 5.1 to 5.3 and 6.2 collected on mercury emissions from sewage sludge incinerators, hospital waste incinerators, and municipal solid waste incinerators in the State of New Jersey indicates that the permitted and actual mercury emissions are in the following ranges:

	<u>Permitted</u>	<u>Actual</u>
Sewage Sludge Incinerators:	200 - 9200	300 - 2284
Hospital Waste Incinerators:	0.33 - 900	0.145 - 1011
Municipal Solid Waste Incinerators:	140 - 750	4 - 1170

All above values are in microgram per dry standard cubic meter at 7% oxygen.

The test data indicates that mercury emission levels from the above mentioned incinerators vary significantly from site to site. Factors such as waste composition, combustion efficiency, air pollution control device type, and operation may affect mercury removal.

Following is a list of the mercury control technologies that have been identified for the following types of incinerators currently existing in the State of New Jersey:

Sewage Sludge Incinerators:	Venturi-Scrubber, Wet Electrostatic Precipitators (ESP), and Wet Scrubber
Hospital Waste Incinerators:	Activated carbon injection (with spray dryer/fabric filter (SD/FF) system) and Waste Separation.
MSW Incinerators:	Sodium Sulfide injection, Activated carbon or modified activated carbon injection, wet scrubbing, and waste separation. These Mercury Control Technologies are discussed in Chapter 6.

TASK DESCRIPTION:

The goals of this task were: (1) to determine mercury emissions from sewage sludge incinerators, hospital waste incinerators and municipal solid waste incinerators in the State of New Jersey; and (2) to identify

feasible technologies that are available for the control of mercury, the control efficiencies that are achievable with these control technologies and discuss the retrofit potential of these technologies to existing incinerators.

HOW TASK WAS ACCOMPLISHED:

This task was accomplished by obtaining information from the files of the four Regional (Metro, Central, Northern, and Southern) Enforcement offices of the NJDEPE and the following references:

1. A September 30, 1991 report prepared by EPA for development of standards of performance for new hospital waste incinerators. The Office of Air Quality Planning and Standards (OAQPS) of the U.S. Environmental Protection Agency is conducting a regulatory development program for air emissions from medical waste incinerators under Section 129 of the Clean Air Act Amendments of 1990. The regulatory program includes the development of new source performance standards (NSPS) based on the maximum achievable control technology (MACT), and the development of emission guidelines for existing sources.
2. Four technical papers on hospital waste incinerators (See Reference list 1, 3, 4, and 6) .
3. Information received from Marjorie Clarke and Steven Krivanek during the NJDEPE public work group meetings held on April 15, May 8, and June 9, 1992.

The information collected has been arranged in the following tables:

Table 5.1. Mercury Emissions from Sewage Sludge Incinerators in New Jersey;

Table 5.2. Mercury Emissions from Hospital Waste Incinerators in U.S.;

Table 5.3. Mercury Emissions from Hospital Waste Incinerators in New Jersey;

Table 6.2 in Chapter 6 presents information on allowable mercury emissions and actual emissions (if tested) from MSW incinerator facilities that are operating or licensed in New Jersey;

The tables include the name of the facility, type of incinerator, size of the incinerator, allowable mercury emission limit, and actual emissions (if tested), type of mercury control (if any), and any other type of air pollution control devices.

DISCUSSION OF CONTROL TECHNOLOGIES:

This section presents information on the air pollution control technologies applicable to sewage sludge incinerators (SSI) and hospital waste incinerators:

Sewage Sludge Incinerators:

Wet ESP, wet scrubbers, and venturi-scrubbers used for particulate control, also control mercury emissions from SSI. Mercuric chloride present in the flue gas is removed by acidic water in the first stage of a wet scrubber. Rest of the mercury exhausts as elemental mercury vapor unless it is absorbed by activated carbon (injection or carbon filter bed). Some of mercuric chloride in the second stage of a wet scrubber converts to elemental mercury vapor. To prevent revolatilization of mercury from the scrubber effluent solution, liquid chelating agents can be used to enhance the coagulation, sedimentation, and the fixation of mercury compounds in the sludge. No operating or test data are available to determine mercury control efficiency for sewage sludge incinerators.

Hospital Waste Incinerators:

Activated carbon injection technology has been demonstrated to reduce mercury emissions from hospital waste incinerators. Large internal pore surface area of activated carbon can adsorptively or chemisorptively bond a very broad range of substances. Additionally, activated carbon is a catalyst which converts elemental mercury to mercuric oxide. Mercuric oxide is then adsorbed on the large inner pore surfaces of the activated carbon, and is captured in the particulate control device. (Ref. 1 of Chapter 6)

Powdered activated carbon can be injected into the flue gas in the spray absorption chamber, in the lime slurry, or downstream of the spray absorption chamber and upstream of the particular matter (PM) control.

Injection of powdered activated carbon was tested at Morristown Memorial Hospital (facility M) located in New Jersey, with the addition of carbon at the rate of 2.6 Lb/hr to 3.0 Lb/hr. The hospital waste feed was continuous and in the range of 672 Lb/hr to 749 Lb/hr. The Morristown Memorial Hospital (facility M) is a rotary type incinerator equipped with a spray dryer and fabric filter (SD/FF). The carbon was mixed with the lime slurry for injection into the spray dryer. Mercury control efficiency was approximately 89%.

Borgess Medical Center Kalamazoo, Michigan (Facility A) equipped with dry sorbent injection/FF was tested with activated carbon injection. The carbon was injected into the duct to the FF (after the waste heat boiler) just prior to the point where the lime is injected. At the carbon injection rate of 1 Lb/hr, a 92% mercury control efficiency was observed, and at the carbon injection rate of 2.5 Lb/hr, a 96% mercury control efficiency was observed.

The above results are summarized in the following table.

MERCURY EMISSION CONTROL EFFICIENCY FOR HOSPITAL WASTE INCINERATORS

CARBON	W/O CARBON INJECTION	WITH INJECTION
FACILITY M (SD/FF)	23.6 %	89.2 %
FACILITY A (DI/FF)	0.0 %	95.9 %

SD/FF: Spray Dryer/Fabric Filter
DI/FF: Dry Injection/Fabric Filter

Dioxin removal for the SD/FF system increased from 83% without carbon injection to over 98% with carbon injection. Dioxin removal for the DI/FF system increased from 44% without carbon injection to about 99% with carbon injection. (Ref. 6.)

The above results lead to a conclusion that this technology can be retrofitted to the existing hospital waste incinerators. Morristown memorial hospital plans to install permanent activated carbon injection to reduce mercury emissions.

Stack test results at two hospital waste incinerators (see Elizabeth General and St. Francis Medical Center in Table 5.3) indicate very low mercury emissions with no air pollution control. Successful waste segregation programs have been implemented at those hospitals which resulted in low mercury emissions. The January 20, 1992, provisions of the Dry Cell Battery Management Act, N.J.S.A. 13:1E-99.59 et seq., and Toxic Packaging Reduction Act, N.J.S.A. 13:1E-99.44 et seq., will significantly reduce the mercury in hospital waste streams.

Municipal Solid Waste Incinerators:

Mercury Control technologies for these incinerators are discussed in Chapter 6.

TABLE 5.1

MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION *****	TYPE OF FACILITY *****	SIZE OF FACILITY *****	APC EQUIPMENT *****	EMISSIONS ALLOWED *****		ACTUAL EMISSIONS (AVERAGE OF THREE TESTS) *****	
				lb/hr	ug/dscm	lb/hr	ug/dscm
		Dry TPD					
Gloucester CUA	* FBI ⁽¹⁾	17	Venturi Scrubber	0.013	1414	0.021	2284
Gloucester CUA	FBI	36	Venturi Scrubber & Wet ESP	0.005	246	(Under Construction)	
Camden County UA	* FBI	36	Venturi Scrubber	0.04	9165		
Pequannock Lincoln Park Fairfield SA	* FBI ⁽²⁾	36	Venturi-Scrubber	0.023	878	0.0003	323
Pequannock Lincoln Park Fairfield SA	FBI ⁽²⁾	36	Venturi-Scrubber & Wet ESP	0.0285	1404	(Under Construction) Permit approved 8/91	
Somerset RVSA	* FBI ⁽¹⁾	14	Venturi-Scrubber, Wet scrubber	0.0162		0.0067	
Somerset RVSA	FBI	35.6	Venturi Scrubber, Wet scrubber & Wet ESP	0.011			
Bayshore RSA	* FBI ⁽¹⁾	27	Venturi Scrubber				

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TABLE 5.1

MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION *****	TYPE OF FACILITY *****	SIZE OF FACILITY *****	APC EQUIPMENT *****	EMISSIONS ALLOWED *****	ACTUAL EMISSIONS (AVERAGE OF THREE TESTS) *****
		Dry TPD		lb/hr ug/dscm	lb/hr ug/dscm
Bayshore RSA	FBI	27	Venturi- Scrubber, Tray Towers & Wet ESP	1.43E-2 744	(Under construction permit approved 11/91)
Parsippany- Troy Hills Twp.	* Multiple Hearth Inc.	2x26	Venturi Scrubber & Afterburner		
Twp. of Wayne	* Multiple Hearth Inc.	2x20	Venturi Scrubber Wet ESP and After burner		
Northwest Bergen CUA	* FBI	24	Venturi Scrubber	0.01 759	
Atlantic CUA	* Multiple Hearth Inc.	56	Venturi scrubber, Wet scrubber & mist eliminator	35.93	
Stony Brook RSA	* 2 Existing Incinerators	2X24	Venturi Scrubber & Afterburners	0.06 1795	
Twp. of Wayne	* Multiple Hearth Inc.	20	Venturi- Scrubber		
Linden RSA	2 FBI	2x18.3	Dry ESP, Venturi- Scrubber & Tray Scrubber	0.012 646	(Not under construction as of 5/14/93) Permit approved 9/91

TABLE 5.1

MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION *****	TYPE OF FACILITY *****	SIZE OF FACILITY *****	APC EQUIPMENT *****	EMISSIONS ALLOWED *****	ACTUAL EMISSIONS (AVERAGE OF THREE TESTS) *****
		Dry TPD		lb/hr ug/dscm	lb/hr ug/dscm
Joint Mtg. of Essex & Union Counties	Multiple Hearth Inc.	54.4	Venturi-Scrubber, Wet ESP & Afterburner	(Application pending. Expect to be cancelled)	
Bergen CUA	FBI	46.8	Venturi and tray Scrubber, Wet ESP	(Application has been cancelled)	
PVSC	FBI	8x113	SNCR, Dry ESP, Wet ESP, Venturi Scrubber, and Wet tray scrubber	(Application pending)	
IWT	FBI	8x112	SNCR, DSI, Dry and Wet ESPs, Venturi-Scrubber, tray-Scrubber	(Application pending)	
Hoboken Weehawken Union SA	1 Gasifier 1 Boiler	22.8	Bag House Wet Scrubber	0.006 518	

FBI: Fluid Bed Incinerator
ESP: Electrostatic Precipitator

* Existing incinerators

- (1) Existing incinerator will not operate except as backup when new incinerator becomes operational.
- (2) Only one incinerator may operate at a time.

TABLE 5.2

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP. (F) AT THE		STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS				WASTE LOAD DURING STACK TESTING Lb/hr	
			lbs/hr/unit	ug/dscm 7% O ₂	INLET OF BH or ESP	OUTLET OF STACK		AT THE INLET OF BH or ESP		AT THE OUTLET OF STACK			
								Lb/hr	ug/dscm 7% O ₂	Lb/hr	ug/dscm 7% O ₂		
1. EPA Facility M New Jersey (e)	1 x 9.6	Spray Dryer & FF	6.3x10 ⁻³	706.83			EPA's multi-metal test	(a) Without Carbon Injection - 2591 - 1979				672 to 749	
							EPA's multi-metal test	(b) With Carbon Injection @ 3lb/hr - 2627 - 284					
2. EPA Facility A (e)	1 x 7.8	Dry Lime Injection & FF					EPA's multi-metal test	(a) Without Carbon Injection - 6883 - 7407					
							EPA's multi-metal test	(b) With Carbon Injection @ 1.0 lb/hr - 7380 - 587				449 to 522	
							EPA's multi-metal test	(c) With Carbon Injection @ 2.5 lb/hr - 9503 - 389					
3. Medigen Babylon Long Island, NY (a)	4 x 11 (Batch)	Dry Scrubber & Baghouse	-	N/A	N/A	Not Available	255°F	EPA'S multi-metal test	N/A	N/A	.08	266	
4. St. Lukes Hospital Utica, NY	1 x 9.6 (a)	Wet Scrubber	-	N/A	N/A	N/A	174°F	EPA multimetal test	N/A	N/A	1.76x10 ⁻⁷	0.029	

TABLE 5.2

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP (F) AT THE		STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS				WASTE LOAD DURING STACK TESTING Lb/hr	
			lbs/hr/unit	ug/dscm 7% O ₂	INLET OF BH or ESP	OUTLET OF STACK		AT THE INLET OF		AT THE OUTLET OF STACK			
								BH or ESP	ug dscm 7% O ₂	Lb/ hr	ug/ dscm 7% O ₂		
5. Hamot Medical Center Erie, PA (b)	1 x 12	Scrubber	-	N/A	N/A	-	123°F	-	N/A	N/A	5.77x10 ⁻⁴	2.08	
6. EPA Facility B (c)	1 x 18	Venturi/ Packed bed Scrubber							N/A	338	N/A	288	902
7. EPA Facility K (c)	1 x 3.6	None							N/A	-	N/A	139 to 2060 (3 tests)	300
8. EPA Facility S (c)	1 x 3.0	None							-	-	-	8 to 182 (3 tests)	175 to 250
9. EPA Facility W (c)	1 x 3.6	None							-	-	-	184 to 2640 (3 tests)	300
10. EPA Facility J (c)	750 lb/ batch	Fabric filter/ Packed bed							-	2326	-	824	750 batch

TABLE 5.2

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP. (F) AT THE		STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS				WASTE LOAD DURING STACK TESTING Lb/hr
			lbs/hr/unit	ug/dscm 7% O ₂	INLET OF BH or ESP	OUTLET OF STACK		AT THE INLET OF BH or ESP		AT THE OUTLET OF STACK		
								Lb/hr	ug/dscm 7% O ₂	Lb/hr	ug/dscm 7% O ₂	
11. Hospital Center at Orange New Jersey (d, f)	1 x 6.7	None	Not specified in the permit				EPA Multi-metal Test	Not test- ed	Not test- ed	2x10 ⁻⁴ to 0.013	17.7 to 2964 (3 tests)	560

FF: Fabric Filter
N/A: Not Available

SOURCES

- (a) May 18, 1992 fax from Mr. Raj Rao of New York State Department of Environmental Conservation, Albany, New York to Mr. Ketan Bhandutia, of BAQEng/NJDEPE.
- (b) May 4, 1992 fax from Dr. B.J. Lerner of BECO Engineering Company to Ms. Sunila Agrawal of BAQEng/NJDEPE.
- (c) A copy of September 30, 1991 Draft report on Medical Waste Incinerators - Background information for proposed standards and guidelines - Control Technology Performance Report for New and Existing Facilities.
- (d) A copy of April 14, 1992 report on Mercury Stack Emission Data, prepared by the Bureau of Technical Services of NJDEPE.
- (e) May 7, 1992 fax from Mr. Jim Eddinger of Office of Air Quality Planning and Standards of USEPA to Mr. Ketan Bhandutia or BAQEng/NJDEPE.
- (f) Permit file.

TABLE 5.3

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP (F) AT THE		STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS*		WASTE LOAD DURING STACK TESTING
			lbs/hr/unit	ug/dscm 7% O ₂	INLET OF BH or ESP	OUTLET OF STACK		AT THE INLET OF BH or ESP	AT THE OUTLET OF STACK	
1. Rahway Hosp., Rahway (Log # 1-89-4195)	1 x 7.2	Scrubber - (Two Stage Atomizer Packed Tower)	1.08×10^{-6}	0.333	-----Under Construction-----					
2. Helen Fuld Medical Center, Trenton (Log # 1-91-4228)	1 x 9.36	Baghouse & Packed Tower	2.1×10^{-5}	4.35	-----Permit issued in June 1992-----					
3. Raritan Bay Medical Center (P/C # 052063)	1 x 9.6	None	Mercury Emission Rates not specified in the permit issued on 10/8/81							
4. Elizabeth General Elizabeth (C-225-A) (Log #1-88-1950)	1 x 8.4	None	2.6×10^{-4}	38.52	-	-	-	-	1.08×10^{-5} lb/hr (1.42 ug/ dscm)	
5. Elizabeth General Elizabeth (C-75-P)	1 x 2.1	None	6.0×10^{-5}	16.00	-	-	-	-	-	
6. Mercer Medical Center, Trenton (Log #1-90-1005)	1 x 8.16	None	2.3×10^{-4}	16.70	-----Under Construction-----					

TABLE 5.3

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP (F) AT THE INLET OF BH or ESP	AT THE OUTLET OF STACK	STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS*		WASTE LOAD DURING STACK TESTING
			lbs/hr/unit	ug/dscm 7% O ₂				AT THE INLET OF BH or ESP	AT THE OUTLET OF STACK	
7. Sandoz Pharma- ceutical East Hanover Log #1-89-2407	1 x 9.36	Dry Scrubber & BH	7.0×10^{-3}	868.54	—Under Construction, Permit issued on 1/3/92—					
8. St. Peter's Medical Center, New Brunswick Log # 1-88-1758	1 x 9.0	Scrubber & After- burner	1.3×10^{-3}	171.09	—Under Construction, Permit issued on 1/30/91—					
9. St. Joseph's Hosp., Patterson Log #1-89-1528	1 x 18	Venturi Scrubber	1.13×10^{-8}	7.36×10^{-4}	—Permit issued on 1/28/93—					
10. Pascacak Valley Hosp., Westwood Log #1-90-3208	1 x 7.8	BH & Dry Scrubber	4.40×10^{-4}	127.27	—Under Construction, Permit issued on 11/15/91—					
11. Morristown Memorial Hospital Log #1-90-4001	1 x 9.6	BH & Dry Scrubber	6.3×10^{-3}	706.83		EPA's Multi- metal test	9503	389 (with carbon injection) @ 2.5 lb/hr		
12. Hospital Center at Orange	1 x 6.7	None	1.0×10^{-3}	265.7		EPA Multi- metal Test	Not tested	0.00441b hr (1011.43 ug/dscm at 7% O ₂)	560 lb/ hr	

TABLE 5.3

MERCURY EMISSIONS FROM HOSPITAL WASTE INCINERATORS IN NEW JERSEY

FACILITY & LOCATION	SIZE OF FACILITY UNIT X TPD	APC EQUIPMENT	ALLOWED EMISSIONS		FLUE GAS TEMP (F) AT THE		STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS*		WASTE LOAD DURING STACK TESTING
			lbs/hr/unit	ug/dscm 7% O ₂	AT THE INLET OF BH or ESP	OUTLET OF STACK		AT THE INLET OF BH or ESP	AT THE OUTLET OF STACK	
13. St. Francis Medical Center, Trenton (1, 3)	1 x 6.7	Modulating burner control	.00028	14.05			EPA Multi- metal Test	Not tested	0.29 E-5 to 0.36E-5 lb/hr (0.145 to 0.180 ug/ dscm at 7% O ₂)	700 lb/ hr

Sources

1. Bureau of New Source files and Engineers working on projects.
2. April 14, 1992 report on Mercury Stack Emission Data, Bureau of Technical Services of NJDEPE.
* Status as of June 1992.
3. October 7, 1991 memo from Ed Choromanski to Chief of Enforcement with test results conducted on 5/31/91.

REFERENCES

1. "Emission of Volatile Heavy Metals from Medical Waste Incinerators" by Mr. Craig Volland dated June 21, 1992;
2. "Waste Management and Treatment or Disguised Disposal?" by Dr. Donald Drum and Jack Lauber dated June 21, 1992;
3. "Dioxin/Furan Removal: Negative Efficiency Behavior Causes and Effects" by Dr. Lerner dated June 21, 1992;
4. "Best Control Technologies for Regional Biomedical Waste Incineration" by Mr. Lauber dated June 27, 1990;
5. Written testimony by Marjorie Clarke dated April 6, 1992;
6. Technical paper prepared by Dr. Kenneth Durkee and Mr. James Eddinger of the EPA on the Status of the EPA Regulatory Development Program for Medical Waste Incinerators, Results of Emission Test Program dated June 3, 1992.
7. September 30, 1991 draft report prepared by the EPA on Medical Waste Incinerators, Background Information for Proposed Standards and Guidelines
8. April 14, 1992 report prepared by the Bureau of Technical Services on Mercury Stack Emission Data
9. May 18, 1992 fax from Mr. Rao of the New York State Department of Environmental Conservation to Mr. Ketan Bhandutia of NJDEPE
10. May 4, 1992 fax from Dr. Lerner of BECO Engineering to Ms. Sunila Agrawal of NJDEPE
11. July 3, 1990 letter from Dr. Lerner to Mr. Craig Volland
12. June 3, 1992 fax from Mr. Jim Eddinger of the EPA

CHAPTER 6
MERCURY EMISSION CONTROLS
FOR
MUNICIPAL SOLID WASTE INCINERATORS

SUMMARY

The following methods were found to be useful for reducing mercury emissions from municipal solid waste (MSW) incinerators:

1. Sodium Sulfide (Na_2S) Injection
2. Activated Carbon or Modified Activated Carbon
3. Wet Scrubbing
4. Waste Separation

1. Sodium Sulfide (Na_2S) Injection:

With Na_2S injection, the reported mercury removal efficiencies range from 7 to 99 percent. Some MSW incinerators operating with duct sorbent injection (DSI) for acid gas control and a fabric filter (FF) for particulate control have been retrofitted with (Na_2S) injection.

2. Activated Carbon or Modified Activated Carbon etc.:

Activated carbon injection has been retrofitted to twelve MSW incinerators in Europe operating with a semi dry scrubber (SD) or duct sorbent injection (DSI) or wet scrubber (WS) and electrostatic precipitators (ESP) or fabric filter (FF). The reported mercury removal efficiencies range from 40 to 93 percent depending on carbon feed rate. Additionally, test programs were conducted at three MSW plants operating with DSI/FF or SD/FF in Europe and one MSW plant operating with SD/FF in British Columbia. In U.S.A., pilot tests were conducted on facilities at Stanislaus, California (Ref. 51), Camden, New Jersey MSW, and Charleston, South Carolina.

Fixed carbon bed has been tested on two MSW plants in Germany. Mercury removal efficiency rates of greater than 98% have been reported for these two plants.

3. Wet Scrubbing:

With wet scrubbing, the reported mercury removal efficiencies range from 57 to 96 percent. Wet scrubbing systems have been retrofitted to MSW incinerators operating with ESPs.

4. Waste Separation:

With separation of mercury containing waste from MSW, mercury reductions in the stack tested mercury emissions have been reported to be in the range of 54-82 percent. The January 20, 1992, provisions of the Dry Cell Battery Management Act, N.J.S.A. 13:1E-99.59 et seq., and Toxic Packaging Reduction Act, N.J.S.A. 13:1E-99.44 et seq., will significantly reduce the mercury in the municipal and solid waste streams. According to the calculations given in Chapter 2 of this report the mercury content in discarded consumer products in the 1992 New Jersey municipal solid waste stream will decrease by 62.1 percent in 1993, by 68.9 percent in 1994 and by 74.5 percent in 1995.

TASK DESCRIPTION:

The goal of this task was to determine all the technologies that are available for the control of mercury, the control efficiencies that are achievable with these control technologies and the retrofit potential of these technologies to existing MSW incinerators.

HOW TASK WAS ACCOMPLISHED:

The 1990 Clean Air Act Amendments require the U.S. Environmental Protection Agency (USEPA) to promulgate mercury emission limits for MSW incinerators. Therefore, the USEPA is in the process of developing a mercury New Source Performance Standard for MSW incinerators. A report prepared by Radian Corporation for USEPA which provides information on mercury emission rates and control technologies applicable to MSW incinerators has been reviewed. More than twelve technical papers concerning different types of mercury control technologies have also been reviewed.

Information was also received from Mike Cooper of Foster Wheeler Environmental Services, Don Elias of RTP Environmental Associates, Inc., Marjorie Clarke (Environmental Consultant), and Steven Krivanek (Private Consultant) during our public work group meetings held on April 15, May 8, and June 9, 1992.

On June 1, 1992, presentations on mercury control technologies were given by the following air pollution control vendors:

- BELCO Technology on wet scrubbing.
- Von Roll on activated carbon and wet scrubbing.
- AS-NIRO Inc., Joy Technology on activated carbon.

On July 22, 1992, Dr. Mick Greenbank of Calgon Carbon Corporation presented a seminar on deep bed carbon filter technology for the removal of mercury from flue gas streams.

Two vendors (Beltran and DeGussa) gave presentations on July 29, 1992, concerning wet scrubbing technology.

RESULTS:

The information collected is summarized in the following tables:

Table 6.1	List of MSW incinerators operating with mercury control;
Table 6.2	Mercury emissions from MSW incinerators operating or permitted in New Jersey;
Table 6.3	Existing mercury emission standards;
Table 6.4	Comparison of mercury air pollution controls;
Table 6.5	Pilot studies in the USA for mercury control;
Table 6.6	to
Table 6.10	Summarized description of Mercury control technologies

DISCUSSION:

The following technologies have been identified as potential air pollution control technologies that may reduce emissions of mercury from municipal solid waste incinerators. However, it should be noted that some European test methods do not capture all of the mercury in the flue gas, therefore mercury removal efficiencies are questionable. Many of the potential mercury control technologies have not been evaluated with U.S. test methods. Therefore, claimed mercury removal efficiencies can not be substantiated. (See Ref. 65)

1. Injection of Sodium Sulfide:

An aqueous solution of 2 to 4 percent sodium sulfide (Na_2S) in demineralized water is sprayed into the flue gas prior to the acid gas control device. Mercury vapor reacts in the presence of water and oxygen to form mercuric sulfide and sodium hydroxide. Mercuric chloride reacts in the presence of water and Na_2S to form sodium chloride and mercuric sulfide. Mercuric sulfide is a very stable solid, and is collected in the baghouse. (Ref 1. & 55).

Injection of Na_2S has been used at three plants in Sweden, two plants known in Germany, and one plant in British Columbia, Canada. All of these plants are equipped with duct sorbent injection (DSI) for acid gas control and a fabric filter (FF) for particulate matter (PM) control. Table 6.1 gives the mercury concentrations at the inlet and outlet of mercury control equipment of these plants. Mercury removal efficiencies range between 7-99 percent as shown in Table 6.4. Na_2S injection has not

been tested on plants installed with spray dryer (SD) or electrostatic precipitators (ESP's). (Ref. 1)

The Institute of Resource Recovery sponsored two days of mercury testing using Na_2S injection for mercury control at the Stanislaus plant. During these tests, Na_2S was injected upstream of the spray dryer. The injection location was also upstream of the inlet flue gas sampling location. Offgassing of hydrogen sulfide (H_2S) was prevented by controlling the pH of the Na_2S solution. Actual in-plant testing did not show any detectable H_2S around the plant. (See Pages 10 & 11 of Ref. 52) The Na_2S test data indicated less than 50% mercury removal efficiency (See ref. 72).

Factors Concerning Use of this system include:

- Formation of hydrogen sulfide - Sodium sulfide in the presence of air reacts to form hydrogen sulfide. To avoid emissions of hydrogen sulfide to the atmosphere, several of the facilities simply vent the sodium sulfide storage/mixing area to the incinerator where the hydrogen sulfide is destroyed. Also, offgassing H_2S may be prevented by controlling the pH of Na_2S solution.
- Corrosion - The potential for corrosion. Sodium sulfide is a corrosive material which could cause corrosion in the ductwork.
- System clogging - Clogging and plugging in screw conveyor due to solidification of Na_2S . This problem was encountered at the Hogdalen plant in Sweden.
- Flyash - Sodium sulfide injection adds sodium ions to the fly ash disposal product (pre-baghouse injection scenario) which increases fly ash solubility and leachability. (Ref. 55).
- Sludge - If demineralized water is not used, a sludge tends to form. (Page 2-20 Ref. 55).
- Increase in hydrated lime - There is an apparent 50 percent increase in the use of hydrated lime. There are SO_2 spikes at the outlet suggesting that Na_2S may be affecting the sorbent use in some way, or some unknown factor may be involved, although average emissions have remained constant. (Ref. 19)

- Unknown factors - The effects of flue gas temperature, lime or ammonia injection on reactions between Na_2S and mercury are unknown.
- Costs - The capital cost for such a system is estimated to be \$150,000 to \$250,000 for an 800 tons per day (tpd) incinerator. Annualized costs are estimated to be \$0.50 - \$1.00./ton of MSW. (Ref. 1)

2. Activated Carbon or Modified Activated Carbon:

Two primary alternatives, operating on the basis of carbon adsorption, are described below:

(a) Injection of Activated Carbon -

Activated carbon, or activated coke, functions as a very effective adsorbent due to the fact that its particles or fibers contain an extraordinarily large internal pore surface area which can bond adsorptively to a very broad range of substances. The internal surface area of the active coke/carbon used on large scale applications today are between 300 - 800 m^2 per gram of activated carbon. (Ref. 8) Grains having an internal surface area of up to approximately 300 m^2 /gram are referred to as activated cokes; above this value, and as high as 1500 m^2 /g, the material is called activated carbon.

In addition to having large internal pore surface area on which to bond impurities in gases, some activated carbons also possess catalytic properties. When activated carbon is a catalyst, elemental mercury converts to mercuric oxide which adsorbs on the large inner pore surfaces of the activated carbon.

Powdered activated carbon can be injected into the flue gas ahead of the spray dryer, into the spray absorption chamber or downstream of the spray absorption chamber, in the lime slurry, and upstream of the particulate matter control.

Injection of powdered activated carbon has been commercially used on a MSW plant operating with SD/ESP system in Zurich, Switzerland. Mercury control efficiencies at the Zurich Switzerland plant range between 40-94 percent. It is reported that fluctuating mercury inlet levels did not affect performance when activated carbon was used. The effect of increasing activated carbon injection rate from 9 ug/dscm to 20 ug/dscm to 39 ug/dscm did not have a significant impact on mercury outlet levels or removal efficiency. The average inlet mercury concentrations were between 148 to 462 ug/dscm at 7% O_2 and outlet mercury concentrations were between roughly 30 and 90 ug/dscm. (Ref. 1)

Injection of powdered activated carbon at a feed rate from 0.25 -0.45 gram per normal cubic meter is being commercially used on two MSW incineration plants operating with SD/FF system in Germany. Mercury removal efficiencies at these plants are greater than 90%. A table with data from these two commercial - sized facilities show: (References 54,62, and August 4, 1992, telecon of Sunila Agrawal with Mr. Jack Riley of Lurgi Corporation)

<u>Plant</u>	<u>Hg Concentration in ug/dscm</u>		<u>Hg Removal Efficiency</u>	<u>Dioxin Removal Efficiency</u>
	<u>Inlet of FF</u>	<u>Outlet of FF</u>		
MVA 1	717	11.2	98.4%	97.7%
	357	32.48	90.9%	
MVA 2	1652	34.16	97.9%	98.5%
	263	28.0	89.0%	
	533	34	93.1%	

Pilot test programs at MSW plants operating with SD/FF were conducted in Amager, Denmark; Kassel, Germany; and Burnaby, British Columbia. Test results indicate that mercury removal efficiencies were in the range of 48%-97%. Table 6.1 gives the mercury concentrations of the inlet and outlet of mercury control test equipment at these plants. No operational problems have been reported with this technology when used with SD/FF. (Ref. 1)

"Stanislaus Tests"

Pilot tests were also conducted at MSW plant in Stanislaus, CA operating with SD/FF/Thermal DeNO_x and Camden, N.J. operating with SD/ESP. At the Stanislaus Plant, CA, the following three carbon types were used to investigate the impact of the carbon surface area and composition:

- a. Thermally activated carbon made from coal;
- b. Thermally activated carbon made from lignite; and
- c. Chemically activated carbon made from wood.

The study was also conducted to determine the effects of activated carbon feed location and feed rate on mercury removal. Based on the results of the testing and the statistical analysis of the data, varying the carbon type and feed location did not significantly influence the results. The statistical analysis did indicate, however, that the carbon feed rate had a significant impact on mercury removal for all carbon feed locations and types. Increasing the feed rate from 3 to 12 lb/hr increased mercury removal from 53 to 80% and lowered stack mercury concentrations. (See Figure 4 of Ref. 51 on Page 6.17) At a carbon feed rate of 12 lb/hr an average outlet

mercury concentration of less than 80 ug/dscm was achieved over the entire range of uncontrolled mercury levels (300-1300 ug/dscm at 7% O₂). Higher feed rates greater than 12 lb/hr also decreased the variability of mercury control performance. Low carbon feed rates (3 lb/hr), resulted in both lower mercury control efficiency and greater run-to-run variability in mercury reduction performance. (Ref. 51)

The impact of ammonia injection on mercury removal, both with and without carbon injection, appeared to be minor. The limited data obtained for these conditions did not permit a statistical verification of this finding. (Ref. 51)

Finally, no correlation between mercury removal, lime feed rate, and FF temperature was reported within the range tested. (Ref. 51).

"Camden, N.J. Tests"

Pilot tests were conducted at MSW facility in Camden, New Jersey operating with spray dryer and ESP. The following two carbon types were used to investigate the impact of the carbon surface area and composition:

- a. FGD Darco Lignite activated carbon; and
- b. PC-100 coal activated carbon

It has been observed that with no carbon injection, mercury removal efficiencies were in the range of 40 to 82.7%. Based on the results of the pilot testing, increasing the feed rate from 12 lbs/hour to 60 lbs/hour increased mercury removal from approximately 82 to 97.5%. Varying the carbon type did not significantly influence mercury removal efficiency. (Ref. 73)

"Activated Carbon and Wet Scrubbing"

A test was also conducted by Von-Roll at a full scale plant using activated carbon with a wet scrubber/FF. Activated carbon was injected upstream of the FF. Partially saturated carbon captured in the FF was discharged from the FF, slurried with the scrubber make-up water, and fed into the scrubber. The activated carbon in the scrubber reduced mercury emissions to 40 ug/dscm. Information concerning percent oxygen, inlet mercury concentration, percent mercury reduction, and stack test methods is not available. (Ref. 59)

Some variations of activated carbon are discussed below:

• Counter - Current Adsorber: (Ref. 54)

The adsorber operates according to the counter-current principle and is equipped with a double-funnel type distribution bottom to allow the gas to flow upwards through the activated-lignite coke bed while the adsorbent passes the reactor in a downward flow. Controlled coke withdrawal, that is discharge of the lowest coke layer only, which carries the maximum pollutant burden, also contributes towards minimizing coke consumption. A pressure drop in the system of approximately 10mm is the result of higher particulate concentration in the lower bed layer is ususally signals a withdrawal of coke. Pollutant concentration may be used as further reference to ensure the withdrawal of larger coke quantities when present limit value is reached.

• Transport Reactor: (Ref.54)

In this technology, activated pulverized lignite coke at a feed rate from 0.25 to 0.45 gram per normal cubic meter is injected into a duct at almost the same velocity as the flue gas. Separation of particulate in the fabric filter produces a filter cake on the latter. The carbon present in the filter cake resulted in high mercury removal rates of greater than 96%.

• Circulating Fluid Bed (CFB): (Ref. 54)

The adsorbent mixture is continuously fed to the reactor, where it is mixed with the flue gas at a relatively high velocity, separated in the subsequent fabric filter and recycled to the reactor. Repeated recycling of the adsorbent permits total residence times of up to 30 minutes to be set. A small part of the used adsorbent is continuously withdrawn from the process and replaced by fresh material.

CFB system has been used for approximately 10 months at a hazardous waste incinerator in Schwabach, Germany.

Following is a mercury emission concentration reported with use of these variations of activated carbon:

	<u>Fixed Bed</u>	<u>TR</u>	<u>CFB</u>
Hg ug/Nm ³	10	15	10
Injection of HCL or chloride salts treated Activated Carbon:			

Experiments were conducted to study the behavior of activated carbon impregnated with chloride salts. The objective of the study was to test the increasing adsorptive capacity of the activated carbon impregnated with chloride salts and the ability to recover the mercury or mercuric chloride at high temperatures from the activated carbon.

Carbon treated with HCl has a 300 times greater capacity for mercury removal compared to untreated carbon. Activated carbon treated with solutions of chloride salts offer even greater mercury removal compared to HCl treated carbon. The nature of the chloride salt and the concentration of salt on the carbon affect the mercury removal capacity. Mercury can be removed from carbon treated with chloride salts by simple heating using reasonable temperatures (300 °F to 375 °F). Treated carbon adsorbents that have been desorbed of Hg are suitable for landfill application or can be recycled as a mercury adsorbent. (Ref. 13)

Activated carbon impregnated with chloride salts has not been demonstrated on an actual operation to date. (Ref. 55)

- Injection of Sodium Sulfide Plus Activated Carbon Plus Dry Hydrated Lime:

This process consists of the injection of sodium sulfide, activated carbon, and lime into a reactor upstream of a baghouse. The mercury is either adsorbed by the carbon or reacted with the sodium sulfide. A portion of the solids collected in the baghouse are recycled to reduce reagent usage.

This system is currently in use at a hazardous waste incinerator in East Germany. No data is available on this method of mercury control. (Ref. 61).

- Injection of Tesisorb, Calcium Hydroxide, and Activated Carbon:

This process consists of the injection of Tesisorb, calcium hydroxide, and activated carbon into a dry venturi upstream of the baghouse. This system has been tested on two hospital incinerators, one in Wisconsin and the other in Skovde, Sweden.

At the Skovde hospital, this process was capable of reducing mercury levels from as high as 10,000 ug/Nm³ to a level of 25 ug/Nm³. Although data indicates good mercury control the tests were conducted only on hospital waste incinerators, which have significantly higher HCL and Hg concentrations in the waste stream. (Ref. 13 and 61)

"Cost"

The amount of carbon injected is dependent upon the size of the facility, the amount of uncontrolled mercury, and the potential removal efficiency. List prices for activated carbon range from \$0.50 - 1.00 per pound depending on the raw material used to produce the carbon and the available surface area. Based on a carbon feed rate of 1 to 2 kg/hr these costs correspond to \$0.15-0.35/ton of MSW. Estimates of capital costs for the construction of an activated carbon injection system at the Burnaby MWC are on the order of \$200,000 (1990 dollars). With this information, the annualized costs (based on a capital recovery factor of 0.1315 and 8000 hours of operation per year) for Burnaby are estimated at \$0.30 - 0.50 /ton of MSW. (Ref. 1) The total cost at the Burnaby Plant would be in excess of \$0.50/ton of MSW and would be closer to \$1.00/ton MSW at plants sized and equipped similarly to the Burnaby plant. This includes cost of the storage, injection equipment, license to the patent holder (AS/NIRO), permitting, siting, and insurance, etc. (Ref. 65)

The vendors of New Jersey Resource Recovery Facilities (RRFs) provided the following list of the estimated costs of installing and operating activated carbon injection systems at NJRRFs:

Mercer County RRF:	\$2.35 per ton of MSW (Ref. 79)
Essex County RRF:	\$2.84 per ton of MSW (Ref. 80)
Camden County RRF:	\$1.37-3.78 per ton of MSW (Ref. 81)
Warren County RRF:	\$3.88-5.59 per ton of MSW (Ref. 82)
Gloucester County RRF:	\$1.10 per ton of MSW (Ref. 83)
Union County RRF:	\$1.14 per ton of MSW (Ref. 70)

(b) Fixed Carbon Bed:

An activated carbon filter bed system can be positioned after all auxiliary air pollution control devices. The flue gas exiting the baghouse/ESP passes through the filter bed, where mercury is adsorbed. Inner pore surfaces of the carbon particles in the bed can adsorptively bond a broad range of substances. Two resource recovery facilities currently under construction in Europe will be using activated carbon filtration. Several other European hospital waste and hazardous waste incinerators are also planning to use this system. Activated carbon beds have been tested on two resource recovery facilities in Germany, one at Duesseldorf - Flingern MSW plant using hearth type furnace coke, and another at Hamburg-Stapelfeld using catalytic formation coke. A mercury removal efficiency of over 98% has been reported. (Ref. 17) Based on the information presented by Mick Greenbank of Calgon Carbon Corporation, deep bed carbon systems have been demonstrated to achieve mercury emissions as low as 0.01 ug/m³. (Ref. 66)

The possible disadvantages of this system include:

- The size of the filter bed - It was calculated that an incinerator processing 300,000 tons per year of waste would require a filter bed of 40,000 cubic meters in size. (Ref. 61 Warren Mercury Study Report) This would be equivalent to 40 foot high building the size of a football field.
- The ignition point of the furnace coke is at least 730 °F and of the formation coke is roughly 660 °F, so in back end installations, where the operating temperature of the bed is usually less than 284 °F and sometimes as low as 230 °F, the risk of ignition would seem to be small under normal operating conditions. In addition, activated carbon beds can be monitored for temperature and the difference in CO before and after the reactor. However, Activated carbons are naturally flammable and may self-ignite at temperatures as low as 175 °F when oxygen and impurities such as organic substances are present. Therefore, fires may occur. (Ref. Presentation by Calgon Carbon Corporation on 7/22/92)
- The regeneration or disposal of the filter bed. The most common method for dealing with the used formation coke is regeneration by mechanical cleaning and furnace coke disposal by on-site incineration. (Ref. 17)

Currently, the spent coke from Duesseldorf waste to energy plant in Germany is being burned in a coal fired electric power plant (Ref. 71).

- A disadvantage of the coarse and granulated carbon bed technology also includes lower adsorption capacity than powdered activated carbon. (Ref. 49)

Fixed Bed of Sulfur-impregnated Activated Carbon:

According to the paper dated June 16, 1991 prepared by K. Nebel (page 3 of Ref. 14), Dr. Turk of the City College in NY provided information on potential mercury revolatilization and the use of sulfur-impregnated carbon to control mercury emissions. He stated that with the use of sulfur-impregnated carbon, very insoluble, non-volatile mercuric sulfide is formed. In the presence of chlorine

sulfur-impregnated carbon would preferentially form HgS over HgCl₂. Dr. Turk said that HgS is more stable than HgCl₂, especially at ambient temperatures. Since the reactivation energy needed to liberate the Hg would be very high, volatilization of HgCl₂ is also not a problem.

It is concluded in the report that the mercury compounds that adsorb onto carbon in the fly ash are very stable and will not revolatilize with normal waste disposal practices. (Ref. 14).

Calgon Carbon Corporation offers a type HGR granulated activated carbon impregnated with sulfur in a fixed bed application. It has been used to remove elemental and organic mercury from natural gas, air, and by-product hydrogen streams. It has been demonstrated on the following processes to reduce mercury: natural gas feed stocks to liquified natural gas (LNG) and liquified petroleum gas (LPG) plants; exhaust air from mercury cell chloride plants or metallurgical processing equipment; and by product hydrogen streams from mercury cell chloralkali plants. It has been used to control mercury emissions from industrial processes; however, it has not been demonstrated at a municipal solid waste combustor installation. (Ref. 55).

S-impregnated carbons have been reported to lose mercury adsorption capacity in the presence of moisture. Therefore, incinerators equipped with wet APC system can not be effectively controlled with this type of fixed carbon bed. The spent mercury-laden carbon sulfur impregnated creates a disposal problem because it can not be regenerated. (Ref. 55)

Regeneration/Disposal of Activated-Carbon:

The total amount of charged or used-up coke represents about 1% by weight in relation to the total amount of solid waste processed. A method for regeneration involves separate thermal treatment in a moving bed desorber, where the carbon is brought into contact with a circulating gas whose temperature lies in the range of 660 °F to 932 °F. This process desorbs the mercury and catalytically reduces the dioxins, with subsequent condensation at 68°F at which point the mercury precipitates.

3. Wet Scrubbing:

Flue gas is contacted with H₂O to remove HCl in the first stage and an alkaline solution containing calcium hydroxide [Ca(OH)₂] or NaOH in the second stage to remove SO₂. Mercuric chloride present in the flue gas is removed by acidic water in the first stage of a wet scrubber. Rest of the mercury exhausts as elemental mercury vapor unless it is absorbed by activated carbon (injection or carbon filter bed). Some of mercuric chloride in the second stage of a wet scrubber converts to

elemental mercury vapor. (Ref. 68 and 69). To prevent revolatilization of mercury from the scrubber solution, liquid chelating agents are used that enhance the coagulation, sedimentation, and the fixation of mercury compounds in the sludge.

Both a liquid chelating agent injection system and a sodium hypochlorite solution injection system at a wet scrubber reportedly have achieved more than 90% removal of mercury in Japan. (Page 20 Ref. 38). Following is the description of these technologies:

a. Liquid Chelating Agent Injection System:

According to reference 38, this system is designed with a caustic soda-based gas scrubbing line, into which liquid chelating agent and cupric chloride are injected for absorption of atomic mercury contained in the flue gas. In general, mercury in the flue gas at the wet scrubber entrance occurs in three forms: water soluble mercury, slightly water soluble mercury, and atomic mercury. Water soluble mercury is assumed to be identified as $HgCl_2$ formed by reaction between atomic mercury and HCl in the flue gas. Therefore, this form of mercury can be absorbed even in a conventionally-used wet scrubber, which, however is not capable of absorbing the other two forms of mercury: atomic and slightly water soluble mercury. The scrubbing waste water containing mercury is subjected to coagulating sedimentation with the addition of a liquid chelating agent at a concentration several times the amount of copper, followed by fixation in the sludge. (Ref. 38) No test results were reviewed by the Department.

b. Sodium Hypochlorite Injection System:

This system is designed with a wet scrubber, to which sodium hypochlorite is injected for reaction with mercury to form mercury chloride for absorption. This system reportedly provides a mercury removal efficiency of 90-95%, and also, the system features concurrent removal of nitrogen oxides achieved by addition of bromine at an efficiency of 30-50%. (Ref. 38) The Department did not review any test results.

c. Calvert Collision Scrubber

A calvert collision scrubber has been permitted at the Bayfront Medical Center in Tampa Florida. (Ref. 56) This device removes fine particulates from flue gas stream with greater efficiency than conventional wet scrubbing. (Ref. 55)

d. Wet Electrostatic Precipitator

WESP's use an electrostatic field to charge particulate matter contained in the flue gas stream and then attract and collect the particles on a collection surface of opposite charge. They can vary in shape; WESP's can be concentric, tube-type or square. The WESP is intermittently washed with water sprays to remove collected particles from the collection surface.

e. Other Wet Scrubbing

Wet scrubbing has been used at two plants in France, one in Switzerland, and a few in Japan. Mercury emissions from the plants in France and Switzerland are in the range of 13-62 ug/dscm at 7% oxygen and mercury removal efficiencies are in the range of 57-96 percent. A Large quantity of water is required with this technology. (Ref. 28) No stack test reports were provided.

The existing wet scrubber system at Fort Dix was designed for the removal of acid gases not for mercury emissions. Stack tests were conducted to evaluate reduction of mercury. Based on the permitted emission limit for mercury and outlet mercury measurements, the mercury removal efficiency ranged from 0 to 74.9%. (Ref. 55 and 84)

The control efficiency that can be achieved by the scrubbers depends on the type of scrubber used and also the types and quantities of various mercury compounds present at the inlet of the scrubber. If the mercury in the flue gas entering the scrubber is mostly in the form of soluble mercury compounds, mercuric chloride for example then a high removal efficiency could be expected. However, if the mercury is mostly in the form of elemental mercury or some other insoluble form then a high removal efficiency cannot be expected. A better assessment could be done if the flue gas was tested to determine the quantities and types of various mercury compounds.

"Removing Mercury From Waste Water"

Once the Mercury is removed from the flue gas and is in the waste water, it must be removed from the waste water before the water discharge.

The potential disadvantages of wet scrubbing technology are as follows (Ref. 65):

- A large quantity of waste water containing mercury is generated. This water may be treated to achieve mercury removal prior to discharge to surface water or sewage treatment plant.

- Treatment of a large quantity of scrubber waste water may generate hazardous sludge. Disposal of this sludge in a landfill may impact soil or ground water quality.
- Wet flue gases may need to be reheated. Reheating would produce additional air contaminant emissions.
- Dioxin toxic equivalencies may increase when wet scrubbing is used.

4. Waste Separation:

As indicated in Table 6.4, with separation of mercury containing waste from MSW, reductions in the stack tested mercury emissions has been reported to be in the range of 54-82 percent. The January 20, 1992, provisions of the Dry Cell Battery Management Act, N.J.S.A. 13:1E-99.59 et seq. and Toxic Packaging Reduction Act, N.J.S.A. 13:1E-99.44 et seq. will significantly reduce the mercury in the municipal and solid waste streams. According to the calculations given in Chapter 2 of this report the mercury content in discarded consumer products in the 1992 New Jersey municipal solid waste stream will decrease by 62.1 percent in 1993, by 68.9 percent in 1994, and by 74.5 percent in 1995.

5. Other Emerging Mercury Control Technologies:

(a) Selenium Filters:

The selenium filter consist of a cylindrical shell which contains graded porus material impregnated with selenium. The selenium filters are used in metallurgical smelting operations. Flue gas passes through the filter prior to the stack. At temperatures upto 365 °F mercury reacts with selenium to form mercuric selenide. Mercury control efficiencities range between 85-90%. The filter element is sensitive to liquids. The moisture in the flue gas inactivates the selenium element. No operating or test data is available for the use of these filters on MSW plants.

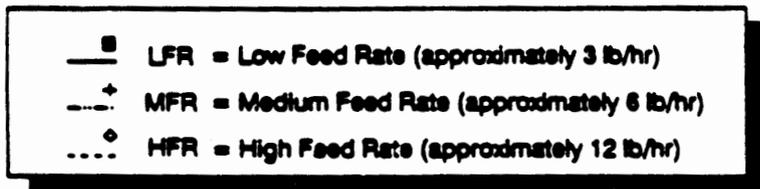
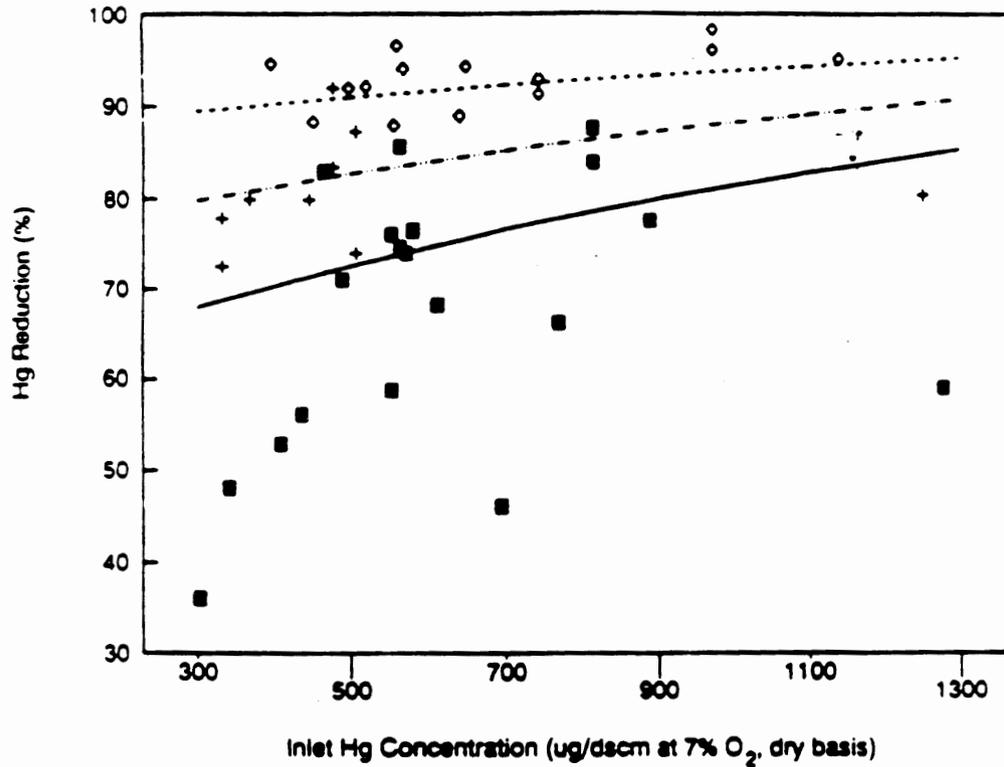
It is possible to use thermal or wet chemical means to remove the mercury and surplus selenium from an exhausted filter element and then reuse the selenium. (Ref. 4)

(b) Sulfidic Complex: (Ref. 54)

Two different types of sulfidic complexes are added to the quenching water in a system working according to the semi-dry process. A mercury removal efficiency rate of greater than 80% has been reported. The test method used was wet-chemical absorption. The analysis method was atomic absorption spectrometry. The sulfide complexes have been tested on MSW incinerators. No test data has been provided. (Ref. 74)

(c) Surface Filtration: (Ref. 30)

An absorbent layer builds up on the microporous Poly Tetra Fluoro Ethylene (PTFE) membrane which reduces an already low particulate matter (PM) emission to the lowest level achievable by means of PTFE membrane filter media. PTFE membrane allows longer and more efficient utilization of the filter coke (second reaction/adsorption) leading to more than 10% savings in Ca(OH)_2 and coke consumption.



Stanislaus RRF test results equipped with spray dryer/fabric filter

Figure 4. Effect on Carbon Feed Rate on Mercury Removal

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS XTPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS TEMP (F)		MERCURY EMISSION RATE AT				STACK TESTED EFFICIENCY %	STACK TEST METHOD FOR Hg	OPERAT- INC PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR ESP
						AT THE INLET OF BH OR ESP	AT THE STACK	INLET OF BH lbs/hr	OUTLET OF STACK lb/hr	ug/dscm 7 % O ₂	ug/dscm 7 % O ₂					
Avesta, Sweden (Ref. 1)	1 unit 45,000 Tons per year (Ref 37)	Injec- tion of sodium sulfide	DSI/FF	1989 (Ref 42)	N/A	N/A	200	N/A	100-1000 (Ref. 42)	N/A	2-100 (Ref. 42)	N/A	N/A	*Possib- ility of reactions between Na ₂ S & acid gas control sorbent. *When Na ₂ S is injected in to hot flue gas (450°F), dry Na ₂ S particle forms, which is less reac- tive to Hg & removal effici- ency drops. *Gas-side corros- ion of cool sur- faces (such as Na ₂ S piping and nozzles) by con- densation of HCl from the humid flue gas.	N/A	N/A
Koping, Sweden (Ref. 1)	2 units 50,000 Tons per year (Ref. 37)	Injec- tion of sodium sulfide	DSI/FF	1989 (Ref. 42)	N/A	N/A	N/A	N/A	100-1000 (Ref. 42)	N/A	2-100 (Ref. 42)	N/A	N/A		N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS KIPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS AT THE INLET OF BH OR ESP	TEMP (F) AT THE STACK	MERCURY EMISSION RATE AT				STACK TESTED EFFIC- IENCY %	STACK TEST METHOD FOR Hg	OPERAT- ING PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR ESP
								INLET OF BH OR ESP	OUTLET OF STACK	lb/hr	ug/dscm 7 % O ₂					
Hogdalen, Sweden (Ref. 1)	3 units 265 TPD	Injec- tion of sodium sulfide	DSI/FF	1986	13	313	302	N/A	102-463	N/A	3-168	7 to 99		*Clogging and plugging in screw conveyor *Solidification of Na ₂ S *Sludge buildup	N/A	N/A
6.19 Kempten Germany (Ref. 1)	210 TPD	Injec- tion of sodium sulfide	DSI/FF	1989	N/A	N/A	400	N/A	100-1000	N/A	2-100	65 - 90			N/A	N/A
Munich (South) Germany (Ref. 1)		Injec- tion of sodium sulfide	DSI/FF	1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A
Burnaby, British Columbia (Ref. 1)	265 TPD	Injec- tion of sodium sulfide	DSI/FF	1989	11	N/A	N/A	N/A	400-1400	N/A	84-750	53 - 86		(Intending to switch to activated carbon inj.)	N/A	N/A
Zurich, Switzerland MWC (Ref. 1 & 49)	400 TPD	Activ- ated Carbon Injection	SD/ 2 field ESP single pass SCR	1986	12	230-284°F	N/A	N/A	148-462	N/A	14-58	40 - 94			N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS XTPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS AT THE INLET OF BH OR ESP	TEMP (F) AT THE STACK	MERCURY EMISSION RATE AT				STACK TESTED EFFICIENCY %	STACK TEST METHOD FOR Hg	OPERATING PROBLEMS	AMOUNT OF CARBON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR ESP
								INLET OF BH OR ESP	ug/dscm 7 % O ₂	OUTLET OF STACK	lb/hr ug/dscm 7 % O ₂					
Berlin-Ruhleben Germany (Ref. 57 & 29)	7x168 stoker	Activated Carbon/Lime Injection	DSI/FF	1990	N/A	N/A	329	N/A	420	N/A	93	78	N/A		N/A	N/A
Wurzburgy Germany (Ref. 57 & 29)	2x300	Activated Carbon/Lime Injection	DSI/FF	1990	N/A	N/A	464	N/A	300	N/A	45	>80	N/A		N/A	N/A
Schweinfurt Germany (Ref. 57 & 29)	60	Activated Carbon/Lime Injection	SD/FF	1991	N/A	N/A	230	N/A	2750	N/A	18	99.3	N/A		N/A	N/A
Schweil-Brenn Analage, Germany (Ref. 57 & 29)	(Siemens-KWU) 12	Activated Carbon/Lime Injection	WS/DSI FF	1990	N/A	N/A	464	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A
Bonn, Germany (Ref. 57 & 29)	3x144	Activated Carbon/Lime Injection	FF/WS/DSI	1992	N/A	N/A	230	N/A	N/A	N/A	22 (Ref. 77)	N/A	N/A		N/A	N/A
Marktobendorf, Germany (Ref. 57 & 29)	72	Activated Carbon/Lime Injection	FF/WS	1990	N/A	N/A	320	N/A	N/A	N/A	35	N/A	N/A		N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS XTPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS TEMP (F)		MERCURY EMISSION RATE AT				STACK TESTED EFFIC- IENCY %	STACK TEST METHOD FOR Hg	OPERAT- ING PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR ESP
						AT THE INLET OF BH OR ESP	AT THE STACK	INLET OF BH OR ESP	OUTLET OF STACK	lbs/hr	ug/dscm 7 % O ₂					
Coburg Plant (Ref. 54)	300 TPD	Activ- ated Carbon Injection	SDA/FF 2 Stage WS/WESP	1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zirndorf, Germany (Ref. 57, 29, & 78)	2x96	Activ- ated Carbon/Lime Injection	WS/DSI/ FF	1991	N/A	N/A	230	N/A	N/A	N/A	12	N/A	N/A	N/A	N/A	N/A
Burgau, Germany (Ref. 57 & 29)	2x85	Activ- ated Carbon/Lime Injection	DSI/FF	1991	N/A	N/A	374	N/A	N/A	N/A	60	N/A	N/A	N/A	N/A	N/A
MVA1 Germany (Ref. 54, 62)		Activ- ated Carbon Injection	SD/FF	N/A	N/A	N/A	N/A	N/A	N/A	N/A		94.6	N/A	N/A	N/A	N/A
MVA2 Germany (Ref. 54, 62)		Activ- ated Carbon Injection	SD/FF	N/A	N/A	N/A	N/A	N/A	N/A	N/A		93.3	N/A	N/A	N/A	N/A
Lyon-Nord France (Ref. 28)	2x350 TPD Stoker	Wet Scrub- bing	ESP/WS	1989	6	464	145	N/A	165-345	N/A	49-62	57-91	N/A	N/A	N/A	N/A
Lyon-Sub France (Ref. 28)	3x288 TPD Stoker	Wet Scrub- bing	ESP/WS	1990	4	446	151	N/A	406-513	N/A	59-61	84-91	N/A	N/A	N/A	N/A
Basel Switzer- land (Ref. 28)	550 TPD	Wet Scrub- bing	ESP/WS	1989	16	N/A	N/A	N/A	75-513	N/A	13-32	82-96	N/A	N/A	N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS XTPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS TEMP (F)		MERCURY EMISSION RATE AT				STACK TESTED EFFIC- IENCY %	STACK TEST METHOD FOR Hg	OPERAT- ING PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BE OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BE OR ESP
						AT THE INLET OF BH OR ESP	AT THE STACK	INLET OF BH OR ESP	OUTLET OF STACK	lbs/hr ug/dscm 7 % O ₂	lb/hr ug/dscm 7 % O ₂					
Spittelau Plant at Vienna, Austria (Ref. 38, 75, 76)	2x	2 Stage WS/ Electro dynamic VS/DENO _x (SCR) Plant		1990 (Ref. 58 green book)	N/A	N/A	N/A	N/A	N/A	N/A	5.19	N/A	N/A	N/A	N/A	N/A
TEST PROGRAMS:																
Amager, Denmark (Ref. 1 & 49)	4X300 TPD Volume Rotary Single Pass	Activ- ated Carbon Injection	SD/FF	N/A	10	356-446	274	N/A	209-303	N/A	7-50	82-97	N/A	N/A	N/A	N/A
Kassel, Germany (Ref. 1 & 49)	2X300 TPD United Kassel Works Grate	Activ- ated Carbon Injection	ESP SD/FF	1989	4	460	279	N/A	234-1175	N/A	25-762	48-89	N/A	N/A	N/A	N/A
Burnaby, British Columbia (Ref. 12)	3x240 TPD	Activ- ated Carbon Injection	ESP SD/FF	6/90 to 1/91	N/A	307-325	N/A	N/A	637	N/A	87	84	N/A	N/A	N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS KIPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS TEMP (F)		MERCURY EMISSION RATE AT				STACK TESTED EFFIC- IENCY %	STACK TEST METHOD FOR Hg	OPERAT- ING PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR E
						AT THE INLET OF BH OR ESP	AT THE STACK	INLET OF BH OR ESP	OUTLET OF STACK	lb/hr ug/dscm 7 % O ₂	lb/hr ug/dscm 7 % O ₂					
Geisel- Bullach, Germany (Ref. 57 & 29)	3x144	3-5% Activ- ated Carbon with 95-97% Lime Injection	DSI/FF	1/89	N/A	428	N/A	N/A	488	N/A	35	93	N/A	N/A	N/A	N/A
Duessel- dorf Flingern Germany (Ref. 17)		Two-stage SD fixed carbon bed using hearth-type furnace coke		1989 (Ref. 58 green book)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	98-99	N/A	N/A	N/A	N/A

TABLE 6.1

LIST OF COMMERCIAL MUNICIPAL WASTE INCINERATOR PLANTS OPERATING WITH MERCURY CONTROL

FACILITY & LOCATION	SIZE OF FACILITY # OF UNITS XTPD/UNIT	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	Hg CONTROL SINCE	NO OF STACK TEST	FLUE GAS TEMP (F)		MERCURY EMISSION RATE AT				STACK TESTED EFFIC- IENCY %	STACK TEST METHOD FOR Hg	OPERAT- ING PROBLEMS	AMOUNT OF CAR- BON TESTED IN FLY ASH COLLECTED IN BH OR ESP	AMOUNT OF Hg TESTED IN FLY ASH IN BH OR ESP
						AT THE INLET OF BH OR ESP	AT THE STACK	INLET OF BH OR ESP	OUTLET OF STACK	lbs/hr	ug/dscm 7 % O ₂					
Hamurg- Stapelfeld, Germany (Ref. 17)		Act. Carbon bed using catalytic formation coke		1988 (Ref. 58 green book)	N/A	284	N/A	N/A	108	N/A	2.6	97.4	N/A	N/A	N/A	N/A
Flotzersteg (Ref. 17, 75)		Selective catalytic reduction system and electro-dynamic -Venturi system		1992	N/A	N/A	N/A	N/A	N/A	N/A	40	N/A	N/A	N/A	N/A	N/A

- Source: 1. Summary of Mercury Emissions and Applicable Control Technologies for Municipal Waste Combustors Radian Report, September, 1991
 2. Control of Mercury and Dioxin Emissions From United States and European Municipal Solid Waste Incinerators By Spray Dryer Absorption Systems, Joy Technologies, Inc. Report
 3. Summary of Information Related to Mercury Emission Rates and Control Technologies Applied to Municipal Waste Combustors, Radian Report, Sept. 1990.
 4. Ref. 17, 28, 29, 38, 58, 75, 57, 12, 49, 76, 54, 62, 1, & Presentation by 3 vendors (BELCO, VON-ROLL, AS-NIRO) on June 1, 1992 in the NJDEPE.

MWC: Municipal Waste Combustor
 DSI: Duct Sorbent Injection
 ESP: Electrostatic Precipitator
 WS: Wet Scrubber
 SD: Spray Dryer
 FF: Fabric Filter
 VS: Venturi Scrubber
 N/A: Information Not Available

TABLE 6.2

MERCURY EMISSIONS FROM MSW PLANTS OPERATING OR PERMITTED IN NEW JERSEY

FACILITY & LOCATION	TYPE OF FACILITY	SIZE OF FACILITY TONS PER DAY	APC EQUIPMENT	OPERATING SINCE	ALLOWED EMISSIONS*			FLUE GAS TEMP (F) AT THE INLET OF BH or ESP	(F) AT THE OUTLET OF STACK	STACK TEST METHOD FOR MERCURY	ACTUAL EMISSIONS*		WASTE LOAD DURING STACK TESTING TPD
					lbs/hr/unit	lbs/ton MSW	ug/dscm				AT THE INLET OF BH or ESP	AT THE OUTLET OF STACK	
Camden County	MWC MB/WW	3 x 350	SD/ESP	1991	0.08	0.0055	520	266	240	USEPA 101A	911 710 680	PLEASE	
Essex County	MWC: MB/WW	3 x 758	SD/ESP	1990	0.053	0.0017	140	302	290	USEPA 101A	N/A	SEE	
Fort Dix	MWC: MOD/SA	4 x 20	WS/FF	1986	0.0009	0.0011	214	450		" "	N/A	ATTACHMENTS	
Gloucester County	MWC: MB/WW	2 x 288	SD/FF	1990	0.12	0.01	723	250		" "	N/A	TO	
Warren County	MWC: MB/WW	2 x 200	SD/FF	1988	0.05	0.006	356 500***	240		" "	N/A	TABLE	
Union County	MWC: MB/WW	3 x 480	SD/FF		0.076	0.0038	220	280		" "	N/A	6.2.	

*** - At maximum fuel BTU value

MWC - Municipal Waste Combuster

MB/WW - Mass Burn Waterwall

SD/ESP - Spray Dryer/Electrostatic Precipitator

SD/FF - Spray Dryer/Fabric Filter

MOD/SA - Modular Starved Air

* Hg Emissions are based on 3-one hour average and are at 7% O₂

N/A - Information not available

ATTACHMENT 1 FOR TABLE 6.2
ESSEX COUNTY RRF MERCURY EMISSION DATA

DATE	HOUR	UNIT	STEAM (LBS/HR)	TONS/HR	MERCURY (LBS/HR)	MERCURY (LBS/TON)	MERCURY ug/dscm @ 7%O ₂
4/03/91					0.077		
to					0.044		
4/11/91					0.052		
7/19/91	1130-1336	1	218,000	34.44	7.20E-02	2.09E-03	182
7/19/91	1421-1637	1	220,500	34.83	4.80E-02	1.38E-03	117
7/19/91	1705-1911	1	217,400	34.34	7.20E-02	2.10E-03	184
10/17/91	1803-2028	1	213,900	33.79	7.10E-02	2.10E-03	163
10/17/91	2133-2352	1	220,200	34.78	7.10E-02	2.04E-03	173
10/18/91	1100-1320	1	215,200	33.99	6.10E-02	1.79E-03	141
1/18/92		1	219,300		0.086		252
1/19/92		1	207,700		0.068		206
1/20/92		1	215,600		0.045		130
2/13/92	0915-1119	1	240,000	37.55	2.22E-01	5.91E-03	
2/13/92	1208-1422	1	221,400	34.64	5.30E-02	1.53E-03	
2/13/92	1621-1901	1	238,900	37.38	4.00E-02	1.07E-03	
2/13/92	1914-2121	1	213,100	33.34	7.50E-02	2.25E-03	
4/03/92	0815-1025	1	215,400	34.00	7.18E-02	2.11E-03	
4/03/92	1040-1248	1	220,900	34.87	4.07E-02	1.17E-03	
4/03/92	1305-1513	1	215,600	34.03	4.83E-02	1.42E-03	
8/17/92		2			0.116		264
8/18/92		2			0.110		251
8/19/92		2			0.119		261
8/20/92		2			0.062		142
8/21/92		2			0.129		291
8/22/92		2			0.080		183
9/08/92		3					351
9/09/92		3					180
9/10/92		3					208
9/11/92		3					178
9/12/92		3					152
9/13/92		3					240
10/12/92		1			0.100		
10/13/92		1			0.054		
10/14/92		1			0.049		
10/15/92		1			0.043		
10/16/92		1			0.108		

ATTACHMENT 1 FOR TABLE 6.2
 ESSEX COUNTY RRF MERCURY EMISSION DATA

DATE	HOUR	UNIT	STEAM (LBS/HR)	TONS/HR	MERCURY (LBS/HR)	MERCURY (LBS/TON)	MERCURY ug/dscm @ 7%O ₂
10/17/92		1			0.031		
11/16/92		2	193,500		0.053		168
11/17/92		2	196,500		0.016		48
11/18/92		2	197,600		0.028		85
11/19/92		2	201,700		0.035		107
11/20/92		2	210,000		0.036		104
11/21/92		2	197,000		0.041		127
12/14/92		3	210,500		0.042		122
12/15/92		3	210,500		0.047		143
12/16/92		3	197,800		0.098		298
12/17/92		3	204,700		0.056		169
12/18/92		3	211,300		0.049		150
12/19/92		3	199,100		0.033		105
1/21/93		1	212,000		0.125		373
1/22/93		1	211,600		0.057		164
1/23/93		1	205,800		0.042		116
3/15/93		3			0.059		181
3/16/93		3			0.072		216
3/17/93		3			0.072		240
3/18/93		3			0.088		288
3/19/93		3			0.045		154
3/20/93		3			0.049		143

6.27

ATTACHMENT 2 FOR TABLE 6.2

CAMDEN COUNTY RRF MERCURY EMISSION DATA

DATE	HOUR	UNIT	STEAM LB/HR	MSW PER UNIT TONS/HR	MERCURY LB/HR	MERCURY LBS/TON OF MSW	MERCURY ug/M3 @ 7% O2
6/18/91	0810-1025	UNIT 1	93904	13.71	7.36E-03	5.37E-04	54.7
6/18/91	1100-1345	UNIT 1	93904	13.71	3.94E-02	2.87E-03	296
6/18/91	1446-1715	UNIT 1	93904	13.71	3.98E-02	2.90E-03	301
9/25/91	0930-1220	UNIT 2	98700	14.41	2.90E-02	2.01E-03	243
9/25/91	1340-1601	UNIT 2	98700	14.41	2.45E-02	1.71E-03	213
9/25/91	1725-1942	UNIT 2	98700	14.41	4.84E-02	3.36E-03	411
12/18/91	0800-1013	UNIT 2	82500	12.04	8.00E-02	6.64E-03	584
12/18/91	1040-1255	UNIT 2	82500	12.04	7.11E-02	5.91E-03	586
12/18/91	1420-1704	UNIT 2	82500	12.04	5.29E-02	4.39E-03	407
3/18/92	1000-1246	UNIT 2	95300	13.92	6.10E-02	4.38E-03	463
3/18/92	1335-1550	UNIT 2	95300	13.92	4.72E-02	4.38E-03	381
3/18/92	1855-2110	UNIT 2	95300	13.92	3.44E-02	2.47E-03	265
AVERAGE			92601	13.52	4.46E-02	2.71E-03	350.39

ATTACHMENT 3 FOR TABLE 6.2

WARREN ENERGY RESOURCE COMPANY MERCURY EMISSION DATA

DATE	TIME	UNIT #	STEAM FLOW (LBS/HR)	MERCURY EMISSION	
				(LB/HR)	(UG/DSCM @7% O2)
12/1/88	1016-1225	2	63,000	0.0231	192
12/1/88	1310-1540	2	64,000	0.0130	110
12/1/88	1645-1850	2	46,000	0.0302	254
6/20/90	0833-1038	1	not available	0.0299	363
6/20/90	1144-1349	1	not available	0.0308	417
6/20/90	1523-1729	1	not available	0.0503	523
9/17/90	1330-1535	1	51,200	0.0185	247
9/18/90	1000-1205	1	50,700	0.0959	1165
9/19/90	0935-1137	1	51,000	0.0270	356
9/20/90	1000-1205	1	56,300	0.0430	590
9/21/90	0915-1118	1	49,100	0.0293	400
9/22/90	1020-1350	1	51,300	0.0525	678
1/14/91	1330-1535	1	50,900	0.0420	474
1/15/91	1145-1400	1	50,300	0.0412	459
1/16/91	1155-1400	1	50,600	0.0396	414
1/17/91	1045-1655	1	49,700	0.0527	588
1/18/91	1005-1210	1	50,900	0.0537	653
1/19/91	1015-1219	1	51,600	0.0285	286
4/25/91	1125-1411	2	54,400	0.014	121
4/26/91	1040-1245	2	54,500	0.038	381
4/25/91	0935-1139	2	54,500	0.074	876
		Average =	52,800	0.0394	455

ATTACHMENT 4 FOR TABLE 6.2

**GLOUCESTER COUNTY RESOURCE RECOVERY
STACK TESTS FOR MERCURY**

DATES OF TESTS	UNIT TESTED	STREAM FLOW KLBS/HR	WASTE CHARGED TONS/HR	STACK TESTS FOR MERCURY EMISSIONS		
				LBS/HR	LBS/TON	UG/DSCFM
4/30/91	1	69.2	11.08	14.8E-3	13.4E-4	121
5/01/91	1	68.5	11.08	17.4E-3	15.7E-4	143
5/02/91	1	68.8	11.08	15.6E-3	14.1E-4	126
9/11/91	2	68.1	11.41	0.83E-3	0.73E-4	6.6
&	2	68.1	11.41	0.57E-3	0.50E-4	4.4
9/12/91	2	67.6	11.70	2.00E-3	1.71E-4	14.6

TABLE 6.3

EXISTING MERCURY EMISSION STANDARDS

COUNTRY *****	STANDARD *****	BASIS OF STANDARD *****	TEST METHODS *****	ONLY Hg Std or TOTAL METALS *****	TYPE OF SOURCE STD. APPLY TO *****	STD FOR NEW OR EXISTING SOURCES *****	MERCURY CONTENT OF THE WASTE *****
Sweden July (1991) (ref. 37)	65 ug/dscm at 7% O ₂ (39 ug/dscm at 7% O ₂ as annual goal)	Reductions, reuse, recycling and heightened public awareness, Health effects and availa- ble technology	Filter Absorption	Only Hg standard ^{#*}	MSW, Haz. waste Hospital waste, and sewage sludge incinerators	For New Sources	0.0011 lbs per ton of MSW
Austria for plants with capacity greater than 400 TPD (Ref. 38)	65 ug/dscm at 7% O ₂ 1/2 hr. avg.	same as above	Filter Absorption	Only Hg std ^{#*}	Waste incinerators	N/A	N/A
For smaller plants with capacity Less than 400 TPD (Ref. 38)	130 ug/dscm at 7% O ₂ 1/2 hr. avg.	same as above	Filter Absorption	Only Hg std ^{#*}	Waste incinerators	N/A	N/A
Netherlands (ref. 33)	65 ug/dscm at 7% O ₂ 1 Hour average	same as above	N/A	Only Hg standard ^{#*}	N/A	N/A	N/A
Germany (ref. 34, 58, & 17)	65 ug/dscm at 7% O ₂	Based on the information that sufficient technology exists now for new plants to meet the standard. See page 4, (Ref. 17.)	N/A	Only Hg and Hg compounds	MSW, Haz. waste Hospital Waste, and sewage sludge incinerators	Effective 12/1/90 for new sources & 3/1/96 for existing sources (Ref. 17)	0.00066-0.0011 lbs per ton MSW

TABLE 6.3

EXISTING MERCURY EMISSION STANDARDS

COUNTRY *****	STANDARD *****	BASIS OF STANDARD *****	TEST METHODS *****	ONLY Hg Std or TOTAL METALS *****	TYPE OF SOURCE STD. APPLY TO *****	STD FOR NEW OR EXISTING SOURCES *****	MERCURY CONTENT OF THE WASTE *****
Switzerland	120 ug/dscm at 7% O ₂	Reductions, reuse, recycling and heightened public awareness.	N/A	N/A	N/A	N/A	N/A
European Community (ref. 41)	260 ug/dscm at 7% O ₂ Hg and Cd	Based on available means such as source reduction, reuse, recycling and control technology.	N/A	Hg and Cd	Municipal waste incineration plants	For New Sources effective 12/1/90	N/A
Canada	300 ug/dscm at 7% O ₂	N/A	N/A	N/A	N/A	N/A	N/A
Denmark (Ref. 33)	65 ug/dscm at 7% O ₂	N/A	N/A	Only Hg standard**	N/A	N/A	N/A
Italy (Ref. 33)	65 ug/dscm at 7% O ₂	N/A	N/A	Only Hg standard**	N/A	N/A	N/A

Ref. 1, 31, 33, 34, 37, 38, 41, & 58

N/A - Information not available

** - Information could not be obtained concerning whether this is only elemental mercury standard or total mercury standard. The New Jersey Department of Environmental Protection and Energy assumes that this is a total mercury standard.

Hg - Mercury

TABLE 6.4

COMPARISON OF MERCURY AIR POLLUTION CONTROLS

TYPE OF CONTROL *****	CONTROL EFFICIENCY RANGE *****	RETROFIT POTENTIAL TO EXISTING APC EQPT *****	OPERATIONAL CONCERNS *****	COSTS \$/TON OF MSW FOR Hg REMOVAL—O&M AND CAPITAL EXCLUDED *****	COMMENTS/OTHER ENVIRONMENTAL CONCERNS *****
1. Injection of sodium sulfide	7 to 99	-suitability observed with DSI/FF systems -Uncertainly exists with other APC Eqpt (SD/FF and SD/ESP)	Possibility of: -Corrosion of cool surfaces of HCL by condensation -Clogging of conveyor -Solidification of sodium sulfide	\$0.20 to \$0.60 per ton of MWS	-Possible reactions between Na ₂ S and acid gas control sorbents -Possible health risk to employees caused by off- gassing of H ₂ S
2. Injection of activated carbon/modified activated carbon	17 to 97	-suitable with SD, DSI, WS, FF, and ESP	None	\$1.00 to \$5.50 per ton of MSW (Ref. 70, 79, 80, 81, 82, 83)	-Data is available to confirm that capture of Hg by this technique is permanent. Two and a half year old samples have been tested for this purpose.
Final Stage Activated Carbon Bed	98%	N/A	-Possibility of fires—self ignition temp. 80–400oC in in presence of O ₂ and impurities such as organic substances	N/A	-Special Precautions needed to prevent mercury emissions during regeneration -may be classified as hazardous waste

TABLE 6.4

COMPARISON OF MERCURY AIR POLLUTION CONTROLS

TYPE OF CONTROL *****	CONTROL EFFICIENCY RANGE *****	RETROFIT POTENTIAL TO EXISTING APC EQPT *****	OPERATIONAL CONCERNS *****	COSTS \$/TON OF MSW FOR HG REMOVAL-O&M AND CAPITAL EXCLUDED *****	COMMENTS/OTHER ENVIRONMENTAL CONCERNS *****
3. Wet scrubbing	57 - 91	N/A	-Potential difficulty with waste handling -Quantity of water required	N/A	-Use of additives (sch as TMT-Trimercapto-s-triazine) is required to stabilize condensed mercury -Control of organic emissions may be Lower -Lower plume rise due to moisture in the flue gas doubles the ground level concentrations
4. Use of Selenium Filters	N/A	N/A	-Filter need to be replaced.	N/A	-Emerging technology
5. Waste Separation					
A. Warren New Jersey	54	Not applicable	Not applicable	N/A	NONE
B. Fort Dix New Jersey	82	Not applicable	Not applicable	N/A	NONE
C. Salem Virginia	76	Same as above	Same as above	N/A	NONE
D. Nashville Tennessee	70	Same as above	Same as above	N/A	NONE

N/A - Information not available

6.34

TABLE 6.5
PILOT STUDIES IN USA FOR MERCURY CONTROL

FACILITY & LOCATION	TYPE OF FACILITY	SIZE OF FACILITY Tons/Day	TYPE OF Hg CONTROL	OTHER APC EQUIPMENT	PILOT TEST DATES/DURATION	TEST METHOD	EMISSION RATE of Hg lb/hr at 7% O ₂		TEMP. (F) AT THE INLET OF OUTLET OF BH/ESP STACK		STACK TESTED EFFICIENCY %	OPERATING PROBLEMS
Stanislaus California	MWC MB/WW	2x400	Activated Carbon	SD/FF and Thermal de Nox	7&8/1991 1 hour- 50 tests	USEPA Method 101A + 29	(See page 6.16)		290-295	276-290	68-96	None
Camden CRRF New Jersey	MWC MB/WW	1050	Activated Carbon	SD/ESP	special tests during spring/summer 1992	Multi-Metals method 29	N/A	N/A	N/A	N/A	82-97.5	N/A
Charleston South Carolina		2x300	Activated Carbon	SD/ESP	4/29/91 5/31/91	USEPA Method 101A	0.0219 to 0.0361	166 to 287	283-290	281-287	50-75	Possible act carbon deposition on electrodes of ESP

Ref. 35, 36 & 49

N/A - Information not available

TABLE 6.6

Na₂S INJECTION

- o Physical Equipment
 - mix tank, pump, piping, atomizer, air compressor, Na₂S.
- o Na₂S Properties
 - Crystalline solid; soluble in water.
Corrosive
Offgases H₂S
- o Collection Mechanism
 - Na₂S solution is sprayed into the hot flue gas (e.g. 450°F) prior to the acid gas control device at a feed rate from 0.1 to 1 pound per ton of MSW. Mercury vapor reacts in the presence of water and Na₂S to form sodium chloride and mercuric sulfide. Mercuric sulfide is a very stable solid, and is collected in the baghouse.
- o Chemistry
 - $\text{Hg (gas) + Na}_2\text{S}\cdot\text{H}_2\text{O} = \text{HgS (solid) + NaOH}$
 $\text{HgCl}_2 \text{ (gas) + Na}_2\text{S}\cdot\text{H}_2\text{O} = \text{HgS (solid) + NaCl. H}_2\text{O}$

Effects of flue gas temperature, lime or ammonia injection on these reactions are uncertain.

Ref. 1 and 12.

TABLE 6.7

ACTIVATED CARBON OR MODIFIED ACTIVATED CARBON

- o Activated Carbon or Modified Activated Carbon Properties
 - Large inner pore surfaces, which can adsorptively or chemisorptively bond a broad range of substances and which, moreover, possess catalytic properties. The mercury or mercuric chloride can be recovered later. Modified activated carbon (activated carbon impregnated with chloride salts) has 300 times greater capacity for mercury removal for temperatures of 300-500°F.

- o Collection Mechanism of Activated Carbon or Modified Activated Carbon
 - Powdered activated carbon or modified activated carbon is a catalyst, which is injected into the flue gas ahead of particulate control device. Large internal pore surface area of these carbons can bond adsorptively or chemisorptively a broad range of mercury or mercury compounds. Also activated carbon acts as a catalyst to convert elemental mercury mercuric oxide which is then adsorbed. The carbon particles laden with adsorbed mercury vapor compounds are then captured in the particulate control device. (Ref. 1 and 17)

TABLE 6.8

WET SCRUBBING

- o Physical Equipment
 - Two stage absorber
- o Collection Mechanism
 - Flue gas is contacted with H₂O to remove HCl in the first stage and an alkaline solution containing sodium hydroxide (NaOH) or calcium hydroxide [Ca(OH)₂] in the second stage to remove SO₂. Mercuric chloride present in the flue gas is removed by acidic water in the first stage of a wet scrubber. Rest of the mercury exhausts as elemental mercury vapor unless it is absorbed by activated carbon (injection or carbon filter bed). Some of mercuric chloride in the second stage of a wet scrubber converts to elemental mercury vapor. (Ref. 68 and 69). Failure to stabilize and remove Hg compounds from the scrubber solution can result in revolatilization of Hg from the scrubber solution. To prevent revolatilization of mercury from the scrubber solution, liquid chelating agents are used that enhance the coagulation, sedimentation, and the fixation of mercury compounds in the sludge.
 - Use of sodium hypochlorite injection in wet scrubbers has achieved 90% removal of mercury in Japan.

Ref. 1, 15, and 38.

TABLE 6.9

SELENIUM FILTERS

- o Physical Equipment
 - Cylindrical shell which contains graded porous material impregnated with selenium.
- o Selenium Properties
 - Selenium has a strong affinity for mercury.
- o Collection Mechanism
 - Flue gas exiting a particulate control device would pass through the filter prior to the stack.
- o Chemistry
 - At temperatures up to approximately 365°F mercury reacts with selenium to form mercuric selenide.
- o Operating Experience
 - Such filters are used in metallurgical smelting operations and are not tested on MSW incinerators.

Ref. 1, Page 3 - 19

TABLE 6.10

SURFACE FILTRATION

- o Physical Equipment
 - A microporous Poly Tetra Fluoro Ethylene (PTFE) membrane.
- o PTFE Membrane Properties
 - Superior particle collection efficiency of microporous PTFE.
- o Collection Mechanism
 - An absorbent layer builds up on the filter medium which further reduces an already low particulate matter (PM) emission to the lowest level achievable by means of PTFE membrane filter media.
- o Chemistry
 - PTFE membrane allows longer and more efficient utilization of the filter coke (secondary reaction/adsorption) leading to more than 10% savings in $\text{Ca}(\text{OH})_2$ and coke consumption.

Ref. 30

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CHAPTER 7
MERCURY EMISSIONS
FROM
HAZARDOUS WASTE INCINERATORS
IN NEW JERSEY

SUMMARY:

At the present time, there are a total of nine hazardous waste incinerators approved by the New Jersey Department of Environmental Protection and Energy. Six are currently in operation, two are under construction and one has received draft approval of the permit to construct. Five of the six operating units were stack tested for mercury. For these five units, the total annual mercury emissions to the atmosphere that are allowed by permit are 1814.7 pounds. The actual air emissions determined by stack emission tests and calculated on the same basis is 19.66 pounds per year.

The air pollution control (APC) devices and combinations thereof vary considerably among the hazardous waste incinerators. Six of the nine utilize wet APC's only, one of which includes a wet electrostatic precipitator (ESP). The other three, which coincidentally were the last three to receive approval or draft approval of the air permit applications, will employ a combination of dry and wet APC devices. This combination represents the latest advances in the art of air pollution control technology and has the additional benefit of collecting the heavy metals in a dry state. The dry fly ash may then be disposed of in a secure landfill or other treatment methods may be utilized if necessary. Scrubber effluent on the other hand is much more difficult to treat. Heavy metals, including mercury, are not easily removed to acceptable levels in the final effluent discharge.

In calendar year 1990, the hazardous waste manifest reports show that 188,653 pounds of waste containing mercury were generated, but that only 74 pounds of these wastes were incinerated in New Jersey. For 1991, the incinerated amount dropped to 5 pounds of the 318,644 pounds generated. Most hazardous wastes containing mercury were sent out of state to other treatment, storage or disposal facilities (TSDFs).

TASK DESCRIPTION:

The purpose of this phase of the study was to:

1. Determine the potential and actual emissions of mercury to the atmosphere from the hazardous waste incinerators operating in New Jersey.

2. Review the air pollution control systems for the incinerators and determine, if possible, the best systems for controlling mercury emissions.
3. Conduct a file search to determine the amount of hazardous waste containing mercury that is generated in the state of New Jersey and the amount of these wastes that are incinerated in the state.
4. Recommend a maximum allowable air emissions rate and/or concentration of mercury from hazardous waste incinerators, if appropriate based upon accumulated information.

HOW TASK WAS ACCOMPLISHED:

Permit applications and supporting documentation for the listed hazardous waste incinerators were reviewed for allowable amount of mercury in the waste feeds, total feed rates, air pollution control devices, control efficiency for mercury and the allowable stack emission rates for mercury; stack emission test results were reviewed to determine the actual emissions of mercury to the atmosphere; and a computer search of hazardous waste manifests for mercury-containing wastes was conducted.

DISCUSSION:

To date, the New Jersey Department of Environmental Protection and Energy has approved and permitted a total of nine hazardous waste incinerators. This number represents facilities in operation (6), under construction (2) and those that have received draft approval (1).

The Rollins Environmental Services (NJ), Inc., located in Logan Township is the only operating commercial hazardous waste incinerator in the state. E.I. duPont deNemours & Co., Inc., has received draft approval for the installation of a commercial hazardous waste incinerator at its Chambers Works Facility in Deepwater. DuPont has 4 other hazardous waste incinerators at this site two in operation and two under construction. The Ensco Company, under a subcontract, has installed a portable rotary kiln-type incineration system at the Bridgeport Rental and Oil Services Company in Bridgeport for the purpose of cleaning up this federally-funded Superfund site. It is in operation now and will continue for about three years. Two other incinerators are company owned and operated for the purposes of incinerating company generated hazardous wastes. They are the Ausimont, USA facility in Thorofare and the ICI Americas facility in Bayonne.

For all nine incinerators, the total permitted maximum emission rate of mercury is 2,178.3 pounds per year. This number is based upon the allowable hourly emission rate and the assumption that all units will operate 8,760 hours per year. Five of the six operating units have had stack emission tests conducted for air contaminants, including mercury. The permitted maximum allowable emission rate of mercury, on an annual basis, is 1,814.7 pounds per year for these five units and the stack emission test results showed an annual emission rate of mercury of 19.66 pounds per year. Based upon the results so far and if this trend continues for the other incinerators, mercury emissions to the atmosphere are low, compared to other mercury sources.

The hazardous waste incinerators listed employ a variety of air pollution control devices or combinations thereof, for control of the type and amount of air contaminants emitted, including heavy metals. Five of the units in operation use wet scrubbing devices and one uses a wet scrubber and a wet electrostatic precipitator (ESP) combination. The wet scrubbers include packed tower, reverse jet, tray/froth column, Venturi, Hydrosonics (steam eductor type), and Calvert (hybrid Venturi) type systems. These systems have a wide range of collection efficiencies for particulates and, therefore, heavy metals, including mercury. Although the high pressure drop Venturi and Calvert systems and the Hydrosonics steam jet scrubber with a good M/Q ratio (mass of steam in pounds per hour over air flow rate in thousands of actual cubic feet per minute) have good control efficiencies for particulates in the small particulate size distribution range, there is a problem with the heavy metals that are collected. It is difficult and expensive to remove mercury and other heavy metals from the scrubber effluent prior to discharge to any waterway.

The combination of dry/wet APC systems provide the best overall control for particulates and heavy metals. Baghouses do provide the best collection efficiencies (99 plus) for particulates, including those in the submicron range. Most of the mercury, however, is removed in wet scrubbing systems that absorb or condense mercury and are designed for small and especially submicron particulate removal. Examples of these are: high pressure drop venturis, ionizing wet scrubbers, calvert scrubbers, hydrosonics scrubbers. Two separate tests conducted by the Federal Environmental Protection Agency (EPA) show that although wet scrubbers do remove mercury, the collection efficiency is affected by the chemical form of mercury and the temperature of the gas inlet to the scrubber. Mercuric chloride is known to be very soluble in acidic water (pH 5) as compared to mercury metal and mercuric oxide. To promote condensation and nucleation of mercury, the flue gases to the scrubber must be saturated and subcooled to less than 130F. The mercury control efficiencies that are shown on Table 7.1 are overall incineration system efficiencies and not the control efficiency of only the air pollution control devices.

Other technologies that are now emerging such as powdered activated carbon and other activities are not included in this report because of the lack of information on their application to hazardous waste incineration systems.

The Division of Hazardous Waste Management provided a computerized summary of all mercury containing wastes that were manifested in the years 1990 and 1991. In 1990, a total of 188,653 pounds of mercury containing wastes were manifested and shipped off property. Only 74 pounds of these wastes were incinerated in New Jersey. The remainder was shipped out of state to other treatment, storage and disposal facilities (TSDFs). In 1991, the total manifested wastes were 318,644 pounds and only 5 pounds were incinerated in New Jersey. Although the mercury containing wastes generated between 1990 and 1991 shows an increase of about 70%, there is a corresponding 93% reduction in the wastes incinerated in New Jersey. There are four questions that arise from this information:

1. Do these numbers actually represent within reason the total amount of mercury containing wastes that are generated in New Jersey and is there an explanation for the significant increase in mercury wastes reported in 1991 as compared to 1990?
2. Manifest reports show that most of the hazardous waste that contain mercury are shipped out of state. What is the fate of these wastes and the ultimate impacts of the mercury, after treatment, if any, on the environment?
3. What would happen if the generators of these wastes in New Jersey would no longer be able to ship the wastes out of state?
4. Could some of these wastes be directed to hazardous waste incinerators, especially in view of the low actual emissions compared to the allowable emission rates?

Table 7.1

MERCURY EMISSIONS FROM HAZARDOUS WASTE INCINERATORS IN NEW JERSEY

FACILITY LOCATION	PERMIT NUMBER	TOTAL FEED RATE	TOTAL MERCURY FEED RATE LB/HR	MERCURY CONTROL DEVICES	ESTIMATED* MERCURY CONTROL EFFICIENCY	ALLOWABLE MERCURY AIR EMISSIONS (LB/HR)	ACTUAL EMISSIONS (LB/HR)	(ug/m ³)**
1. Ausimont, USA, Thorofare	72825	1880 lb/hr (850 lb/hr of which is hazardous)	0.0001	Venturi Scrubber, Packed Tower Scrubber	54%	0.000046	0.0000049	1.25
2a. E.I. DuPont Carbon Regen- eration Furnace Deepwater	67148-Appl.# 1-89-0893	5600 lb/hr, dry basis	0.28	2 Reverse Jet Scrubbers, Tray/Froth Scrubber	99%	0.0028	0.0022	32.7
2b. E.I. DuPont Rotary Kiln Incinerator, Deepwater	Draft Appv. Stage Appl. # 1-89-3366	Kiln Section 26954 lb/hr, Afterburner Section 7,500 lb/hr, Total 34,454 lb hr.	0.35	Quench, Baghouse, Saturator, Condenser, Venturi Scrubber	95%	0.0175	Construction not started.	
2c. E.I. DuPont Multipurpose Incinerator, Deepwater	41627	2500 lb/hr	None	Reverse Jet Scrubber, Wet ESP	N/A	None	Unit tested, but not for mercury	
2d. E.I. Dupont Sludge Inciner- ators, Deepwater	Approved APC Permit Appl. #s, 1-89- 4916 and 1-90-3715	9000 lb/hr dry and 32,150 lb/hr wet/each incinerator	0.12 each incinerator	Packed bed scrubber, baghouse	90%	0.012 each incinerator	Under construction.	
3. ICI Americas, Bayonne	Appl. # 1-89-1927 Approved	160 lb/hr still tops (gaseous waste), 160 lb/hr still bottoms liquid waste	0.00032 (1 ppm in waste)	Packed tower scrubber	0%	0.00032 lb/hr	0.00000424	1.13

Table 7.1 (con't)

MERCURY EMISSIONS FROM HAZARDOUS WASTE INCINERATORS IN NEW JERSEY (cont'd)

FACILITY LOCATION	PERMIT NUMBER	TOTAL FEED RATE	TOTAL MERCURY FEED RATE LB/HR	MERCURY CONTROL DEVICES	ESTIMATED* MERCURY CONTROL EFFICIENCY	ALLOWABLE MERCURY AIR EMISSIONS (LB/HR)	ACTUAL EMISSIONS (LB/HR)	ACTUAL EMISSIONS ($\mu\text{g}/\text{m}^3$)**
4. Rollins Environmental Services (NJ), Bridgeport	68328	15000 lb/hr	0.18	Venturi Scrubber (Calvert), Packed Column	0%	0.18 lb/hr	0.000035	0.04
5. Bridgeport Rental Oil Services (BROS), Bridgeport	Superfund Site- Federally Funded	48,000 lb/hr	0.048	Hydrosonics (eductor) scrubber	50%	0.024	0.00002	0.864

* - Control efficiencies estimated over the entire incineration system.

** - At standard conditions, dry basis, and corrected to 7% oxygen.

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CHAPTER 8

MERCURY EMISSIONS AND CONTROLS FOR SMALL, INCINERATORS (CREMATORIUMS AND APARTMENT INCINERATORS)

SUMMARY:

Review of information collected on mercury emissions from small incinerators (human and animal crematoriums and apartment incinerators) in New Jersey indicates that up to about 238 pounds of mercury could be emitted from these sources. The actual emissions are probably about half of this. Apartment incinerators are shutting down as a result of enforcement actions taken by the Department. Animal crematoriums are not a source of mercury emissions. The mercury emissions from human crematoriums may be decreasing due to a decrease in the quantity of mercury used in the amalgams and improved oral hygiene, but this needs to be quantified before a final recommendation can be made.

TASK DESCRIPTION:

The purpose of this task was:

- to determine mercury emissions from small incinerators in the State of New Jersey,
- to identify air pollution control methods by surveying the actual number of small incinerators by type, and
- to determine the amount of material burned in those incinerators.

HOW TASK WAS ACCOMPLISHED:

This task was accomplished by obtaining information from: the four New Jersey Department of Environmental Protection and Energy Regional (Metro, Central, Northern, and Southern) enforcement offices, the Air Pollution Enforcement Data Systems (APEDS); the President of the New Jersey Funeral Directors' Association; and references listed below.

RESULTS:

The information summarized in the Table 8.1 lists the number of different types of small incinerators, the average size of the incinerators, the average mercury content, the estimated annual emissions of mercury, and potential methods of reducing mercury emissions.

DISCUSSION:

1. Human Crematoriums

Information provided by the President of the New Jersey Funeral Directors' Association, indicated, that in 1990, there were a total of 14,427 cremations at New Jersey's 16 crematoriums. According to one report, an average person has five amalgam fillings (1). Each filling contains about 0.6 gm of metallic mercury. Five amalgam fillings of average size would therefore contain about 3 gm of mercury. Assuming each body cremated emits 3 gm of mercury to the

air, approximately 96 pounds of mercury per year would be emitted by crematoriums. There are no crematoriums with mercury emission controls. One possible way of preventing mercury emission from crematoriums is removal of teeth prior to cremation. However, according to a report submitted to the Department by the New Jersey Cemetery Association, the percentage of mercury used in the amalgams is decreasing. It is also reported that reduction is observed in the number of dental cavities in the last twenty years due to improved dental hygiene and the use of fluoride (6). A decrease in mercury emission that can be expected needs to be quantified before it may be determined if a control system is necessary.

2. Animal Crematoriums

There are 47 permitted animal crematoriums in New Jersey. Many of these are no longer operating. There are no identifiable sources of potential mercury emissions from these facilities. Accordingly, these incinerators are not expected to emit mercury, if only animal cadavers are incinerated.

3. Small Apartment Incinerators

There are approximately 130 operating apartment incinerators in New Jersey (2). These incinerators operate an average of 5 to 8 hours a day, with an average combustion rate of 1000 pounds per day (3). The waste combusted in these small apartment incinerators is similar to municipal solid waste. This type of household waste contains an average of 0.006 pounds of mercury per ton of waste (4).

Assuming all these incinerators operate 365 days a year, there would be 142 pounds of mercury emissions per year. However, the department expects that the number of operating apartment incinerators will decline to less than 20 within the next 18 months, and eventually to zero. These anticipated reductions are a result of enforcement activities and the cost of better air pollution controls. All incinerators coming due for 5 year renewal of the certificate to operate are being required to stack test as a condition of renewal. Rather than stack test, most small apartment incinerator owner/operators are electing to cease operation. They then develop recycling programs and contract for waste collection by private haulers. (2)

TABLE - 8.1

MERCURY EMISSIONS FROM SMALL INCINERATORS

NO. TYPE OF INCINERATORS	NUMBER OF INCINERATORS	AVERAGE SIZE	AVERAGE MERCURY CONTENT OF WASTE	CALCULATED ANNUAL EMISSIONS OF MERCURY LBS/YEAR	FEASIBLE AIR POLLUTION CONTROL
1. Human crematoriums	16	906 <u>Bodies</u> Year	3 <u>gm</u> Body	96	Remove teeth prior to incineration
2. Animal crematoriums	47	?	None	None	N/A
3. Apartment Incinerators	130	1000 pounds/day	0.006 pound	142	Shut-down these incinerators

REFERENCES:

1. Allan Mills; "Mercury and crematorium chimneys", Nature, Vol 346, Page 615, August 1990.
2. Memo from John Walsh, Acting Chief, Bureau of Enforcement operations to Iclal Atay, Chief, Bureau of Air Quality Engineering (BAQEng), dated June 12, 1992.
3. Phone conversation between Mr. B. Sullivan, REO, Metro office and Yogesh Doshi, BAQEng.
4. Information provided by Mr. Mike Winka, Chief, Division of Solid Waste Management.
5. Detail report generated by Air Pollution Enforcement Data Systems (APEDS).
6. Report submitted by the New Jersey Cemetery Association, August 30, 1991.

CHAPTER 9

MERCURY EMISSIONS AND CONTROLS FOR COAL, NATURAL GAS FUEL OIL AND GASOLINE

SUMMARY:

A review of the available literature on mercury content and consumption of various fuels (coal, natural gas, fuel oil and gasoline) revealed that estimates of concentrations of mercury in the fuel vary greatly. The data on coal is not sufficient to make more than rough estimates on potential mercury emissions. There appears to be wide variations in the mercury content of coal. There is also no reliable or actual test data available on the mercury content of fuel oil or gasoline. Mercury emissions from fuel combustion may be reduced by increasing the energy efficiency of the combustion equipment, fuel cleaning, fuel switching, and installing auxiliary air pollution controls. This report did not address the feasibility of any of these systems.

TASK DESCRIPTION:

The purpose of this task is to determine mercury emissions from coal, natural gas, fuel oil and gasoline combustion by collecting information on mercury content, finding yearly consumption of these fuels in New Jersey and identifying mercury control measures.

HOW TASK WAS ACCOMPLISHED:

Data was obtained from Atlantic Electric, Public Service Electric and Gas (PSE&G), Electric Power Research Institute (EPRI), the American Petroleum Institute (API), and other listed references. Table 9.4 lists specific information on type of coal and stack test results from Atlantic Electric's B.L. England Generating Units No. 1 and 2.

DISCUSSION:

COAL:

Essentially 100% of the mercury contained in coal is volatilized during combustion. Some mercury will condense on the fly ash due to reduced vapor pressure at lower temperatures and react with chloride in the flue gas to form the less volatile mercuric chloride. The data available on partitioning and forms of mercury is insufficient to draw any conclusions regarding how much mercury is being emitted into the air. Much of the mercury is emitted in vapor form, although some mercury condenses and is associated with the fine particulate fractions of the fly ash (1). The proportion of mercury measured in particulate versus vapor phase varies greatly. The form of mercury present in the flue gas is dependent on temperature and fly ash characteristics. Little information is available on the percentage of various mercury species in total mercury emissions. Speciation is important to identify environmental impacts and potential for control.

Table 9.1 presents the ranges of mercury concentration in coals by coal type. According to the information provided by Dr. B. Jensen of PSE&G, an article in EPRI Journal of December 1991 recommends extraordinary precautions to ensure that samples are not contaminated with even tiny amounts of mercury. As stated in the same paper, as sampling techniques have improved, the estimates of mercury concentrations in one lake have dropped by a factor of 500 (11). In the likely event that a positive bias exists for the data presented, then the possible range and mean as presented in Table 9.1 could be lower, resulting in a smaller possible range of mercury emissions in New Jersey from combustion of coal.

Recent studies show that sampling and analytical conditions can result in significant contamination and inaccuracy in the data, especially at low levels, unless "clean" procedures are followed. This puts much of the literature data on mercury in question since clean techniques were not available until recently (15).

TABLE - 9.1

CONCENTRATION OF MERCURY IN COAL BY COAL TYPE

Coal Type	Number of Samples	Mercury Concentration (ppm by wt.)		
		Range	Mean	Reference
Bituminous	120	0.004 - 1.9	0.12	6
Subbituminous	117	0.01 - 1.6	0.1	6
Anthracite	52	0.16 - 0.3	0.23	3
Lignite	183	0.03 - 1.0	0.15	3

B. Fuel Oil:

The concentration of mercury in fuel oil depends on the type of oil. The reported mercury concentrations in crude oil range from 0.023 ppm to 30 ppm, while the range of concentrations in residual oil is reported to be 0.007 to 10 ppm (3). Table 9.2 presents the summary of data for mercury in oil.

A study published by Booth and McDannel (10) presents a summary of air toxic emission values from utility boilers firing fuel oil or natural gas. This study reports that every emission sample from fuel oil firings contained mercury below the detection limit of 0.4 ug/cubic meter. As discussed earlier, it is true that significant contamination and inaccuracy in the data exist, unless "clean" laboratory procedures are followed.

TABLE - 9.2

SUMMARY OF DATA FOR MERCURY IN OIL (3)

Type of Oil	No. of Samples	Mercury Concentration (ppm)	
		Range	Mean
Residual No. 6	11	0.007 - 10	0.06
Distillate No. 2	1		0.4 *
Crude Oil	46	0.023 - 30	6.86

* - Based on single sample, may not be representative

Natural Gas

Natural gas contains trace amounts of mercury, with concentrations varying 2 to 4 orders of magnitude. One report suggests mercury concentrations in natural gas typically range from one to 200 micrograms per cubic meter (5). In the Netherlands the mercury content of natural gas varies from "non detectable" to approximately 300 micrograms per cubic meter. 250 micrograms per cubic meter is considered to be a high concentration (8).

The values reported here for mercury content in natural gas were derived from analyses of natural gas at the well. Studies have found that the mercury content in natural gas decreases significantly during transmittal from the well to the combustion source because of chemisorption onto steel pipe walls. It is reported that for one 68 mile pipeline, the mercury content decreased by 60% and similar reductions are also experienced on pipe and vessel walls in facilities and plant (11). Since mercury corrodes aluminum, producers which use aluminum heat exchangers also take active steps to remove mercury from the natural gas stream. A study published by Bingham (4), reported that activated carbon is used to reduce mercury prior to such heat exchangers to 0.1 ug/m³.

According to the information provided by Dr. B. Jensen of PSE&G, the head of Environmental Sciences at a United Kingdom Electric Utility indicated a concentration of mercury less than 0.16 ug/cubic meter in gas from the Southern North Sea. Additional information provided by PSE&G reports a range of 0.019 to 0.44 ug/cubic meter in Eastern US natural gas pipelines (13). Based on this data it is calculated that 0.5 pound to 11 pounds of mercury emissions from natural gas combustion in New Jersey annually.

EPA's "Handbook - Control Technologies for Hazardous Air Pollutants (HAP)", lists mercury as a potential HAP from coal, oil and gasoline combustion but not from natural gas combustion (17).

The Department is continuing investigation to obtain more reliable sources of data.

Gasoline

The data on mercury content in gasoline is sparse. One reference mentioned the range of 1 to 20 ppm of mercury content in gasoline (5).

The May 1992 Florida Department of Environmental Regulation report on Mercury Emissions to the atmosphere in Florida, describes measurements conducted in California on particulate matter emissions in the exhaust gases of an unleaded-gasoline-fueled vehicle. While one test resulted in no detectable levels, another test showed amounts of mercury of 0.002 percent by weight of the total particulate emitted (14). Using the 0.002 value, and applying EPA's Air Pollutant Emission factors of 0.6 gram per mile, and assuming 20 miles per gallon, the result is approximately 5×10^{-7} pound per gallon. Multiplying this figure by the number of gallons of gasoline consumed in New Jersey annually results in 1870 pounds of mercury per year. The calculation accounts for mercury which is part of the particulate matter, the volatilized mercury component must be added to this.

The Florida report uses a conservative mercury emission factor for gasoline of 0.7×10^{-7} pound per gallon. This is an average emission factor calculated from the average of the high and low values. Using this estimate for New Jersey, results in annual emissions of 260 pounds of mercury due to gasoline combustion. The same document also reports mercury emissions from diesel-fueled vehicles, as well as aircraft.

RESULTS:

MAGNITUDE OF EMISSIONS:

Table 9.3 are estimates of mercury emissions from fuel burning in New Jersey. Annual mercury emissions have been estimated using the quantities of each fuel burned annually in New Jersey from the 1991 New Jersey Energy Master Plan (1) and the mercury content of different fuels reported in listed references (2, 3).

TABLE - 9.3

SUMMARY OF FUEL CONSUMPTION AND MERCURY CONCENTRATION

Fuel	Consumption Annual	Concentration	Annual Emission Pounds
Coal	3.55 E06 tons	0.004 - 0.84 ppm	30 - 5040
Natural gas	3.96 E11 ft3	0.019 - 0.44 ug/m ³	0.5 - 11
Waste Oil	260,525 tons	Unknown	
Gasoline	3.74 E09 gal	<1 - 20 ppm?	260-1870
Fuel Oil	5.91 E09 gal	Unknown	-

Table 9.3 provides the summary of consumption of different fuels in the state of New Jersey, its mercury content ranges and estimated annual emissions ranges.

OPTIONS FOR REDUCING MERCURY EMISSIONS

This section examines options for reducing utility emissions of mercury through energy efficiency improvements, coal cleaning, fuel switching, conventional control technologies (particulate controls and scrubbers) and developing control technologies.

Energy efficiency as a mercury emission prevention tool

Fuel reductions through energy efficiency improvements offer the best option for reducing mercury emissions. Increasing the efficiency of electricity generation and end-use will reduce the amount of coal and oil that is burned, thereby reducing the amount of mercury emitted to the atmosphere.

The amount of reduction in mercury emissions achieved through fuel reductions and energy efficiency improvements will vary depending on the fuels displaced. Efficiency improvements will reduce more mercury per KWH of electricity from utilities that rely heavily on high mercury fuels than from utilities that rely on lower mercury fuels. Efficiency improvements that displace electricity generated by nuclear power will not provide any mercury emission reduction benefits since plants using this energy source do not emit mercury.

Fuel-switching as a mercury emission prevention tool

The effectiveness of fuel switching as a mercury emission prevention tool depends upon the particular fuels. It also involves site, technical and economical constraints. Switching from coal to nuclear or renewable energy will yield a 100% reduction in mercury emissions. Understanding the impacts of switching from coal to natural gas or from one coal to another, is more complex.

As mentioned earlier, the estimated mercury content of natural gas (at the high end) may be comparable to low mercury coals. The low end of the range may be more than two orders of magnitude lower than the concentration in low mercury coals. Thus, fuel-switching to natural gas may provide some mercury emission reduction benefits, but the magnitude of the benefit is uncertain. Since mercury concentrations can vary within, as well as between, regions, fuel switching within regions may also affect mercury emissions. The average mercury concentration of Pennsylvania coals (10.83 mg/mmBTU), for example, is nearly 20% higher than the Northern Appalachian regional average (9.13 mg/mmBTU) (3).

In summary, fuel switching, from one coal to another coal or to another fuel may provide mercury emission reduction benefits for individual plants, but present data does not allow reaching this conclusion with certainty. More information is necessary.

Mercury removal potential of coal cleaning

Although removal of mercury is not currently a specific goal of coal cleaning, removal of ash and sulfur also results in some mercury removal. Studies by Bituminous Coal Research (BCR) and the National Committee for Geochemistry, which examined a number of different coals, suggested that existing coal-cleaning techniques may remove approximately 30% of mercury on average. EPRI has research underway that may shed light on the future mercury removal potential of coal cleaning.

It should be recognized that the cleaning of coal adds additional uncertainty to the analysis. For example, literature data for Pittsburgh seam coal includes both cleaned and uncleaned coal. Since most Pittsburgh seam coal is cleaned prior to use, the mercury levels in the feed coal may run, on average, less than that shown in the literature. Also, the natural variability of mercury content in coal is not controllable.

Mercury removal potential of gasoline cleaning:

While mercury content of gasoline is relatively low, the quantities of gasoline consumed, may result in significant mercury emissions. Better data on mercury content is necessary, and the feasibility of cleaning the gasoline to reduce its mercury content also needs to be investigated.

Mercury removal potential of existing control technologies

Most coal fired utility power plants, in New Jersey are equipped with electrostatic precipitator (ESP). There are also 3 coal fired boilers in Atlantic Electric's Deepwater facility equipped with fabric filters. At lower temperatures, some mercury may adsorb on to fly ash particles which are then removed by pollution controls. Requiring the retrofitting of scrubbers on power plants equipped with only an ESP or fabric filters may reduce mercury emissions about 50%. It should be noted, however, that currently there are no scrubber vendors who are willing to guarantee mercury reductions from a wet SO₂ scrubber, since there is no reliable data. Most of the data supplied from the vendors of scrubbers for mercury suggest that physically capturing mercury, requires a high energy system, i.e. one with a significantly higher pressure drop than is encountered in wet SO₂ scrubbers.

Developing Control Technologies

Sodium hypochlorite technology

This technology was developed in Japan by NKK. The NKK mercury removal process involves adding the sodium hypochlorite to a wet scrubber to solubilize mercury in flue gas. In MSW operations, this technology is capable of mercury removal efficiencies greater than 95%. The average mercury removal efficiency during one and a half years of operation at Kyoto MSW incinerator was 96.6%. (1) This technology has not been tested on any coal fired boilers.

Lignite Coke Technology

This technology was developed by Stadtwerke Dusseldorf in Germany. It was originally developed for NOx removal, but tests on MSW incinerators showed that the lignite coke catalyst also adsorbed mercury and other heavy metals. Removal efficiencies of these pollutants was nearly 100% (1). This technology however, was never used in coal fired boiler.

Sulfur-Activated Technology

Japanese scientists at Kanazawa University studied the impacts of passing flue gas containing mercury through a sulfur-impregnated active alumina bed and then a sulfur-impregnated activated carbon bed. This experiment led to conclusion that the technology could accomplish "complete removal of mercury vapor for a long period of time." No data for the potential application of this technology to a coal burning power plant is available.

CONCLUSION:

There is wide variations in the data reported on mercury content of various coals from different geographic origins. One New Jersey coal fired power plant reported 0.021 ppm of mercury concentration in coal by actual testing (16). Also, two New Jersey coal fired power plants were stack tested for their mercury emissions. The average mercury emissions were found to be 0.03 and 0.024 lb/hr for Atlantic Electric, B.L. England facility (Unit 2) and PSE&G, Mercer Generating Station, respectively (18). More test data on mercury content of the coal used by New Jersey utilities is needed to provide better estimates of emissions of mercury.

Similarly, a mercury content range for different types of fuel oil is reported in the literature. More recent test data on different types of fuel is needed. This is particularly true in the case of gasoline. The Department is continuing to investigate to obtain more reliable sources of data. Depending on the actual mercury content, these could be the highest or the lowest sources of mercury.

Finally, developing technologies could provide an extremely important breakthrough in controlling mercury emissions. At present, however, conclusions regarding applications of these technologies to coal fired power plants are speculative.

Title III of the Clean Air Act Amendments (CAAA), signed into law on November 15, 1990, addresses emissions of hazardous air pollutants (HAP). The law requires that 189 HAPs (including mercury) from various categories of sources be regulated by EPA. Title III requires EPA to conduct a study of emissions of HAPs emitted by utilities, including mercury, and based on the results of the study, to promulgate any necessary regulations. EPA in concert with EPRI is presently conducting this congressionally mandated study. Title III of the CAAA provides that this study must be completed by November 15, 1993. We expect that more reliable data will become available at the conclusion of the EPA study.

REFERENCES

1. Electric utilities and Long range transport of mercury: Center for clean air policy, Washington, DC.
2. 1991 New Jersey Energy Master Plan
3. Estimating Air toxics emissions from coal and oil combustion sources: USEPA
4. M. Bingham; "Field Detection and Implications of Mercury in Natural Gas", SPE Production Engineering, May 1990.
5. J. Paasivirtov; "Chemical Ecotoxicology" 1991 Edition, Page 110.
6. R. Meij; "The fate of mercury in coal-fired power plants and the influence of wet flue gas desulphurization", Water, Air and Soil Pollution Journal, Vol 56, 1991.
7. H. Knauer and G. Milliman; "Analysis of petroleum for trace metals - Determination of petroleum and petroleum products", Analytical Chemistry, Vol 47, July 1975.
8. P. Gijselman; "Presence of mercury in natural gas: An occupational health program", First international conference on health, safety, and environment, The Netherlands, November 1991.
9. J. Leeper; "Mercury - LNG's problem", Hydrocarbon Processing, November 1980.
10. R. Booth and M. McDannel; "Summary of air toxics emission values from utility boilers firing residual fuel oil or natural gas", Air & Waste Management Association 85th Annual meeting, Kansas City, June 21-26, 1992.
11. Correspondence between PSE&G and the Department, dated July 10, 1992.
12. Correspondence between PSE&G and the Department, dated September 4, 1992.
13. Correspondence between PSE&G and the Department dated November 10, 1992. "Mercury in Natural Gas" Proceedings of the American Gas Association (Operating Section), 1976.
14. "Mercury emissions to the Atmosphere in Florida", A Report by the Florida Department of Environmental Regulation, May 1992.
15. Correspondence between Atlantic Electric and the Department dated November 13, 1992.

16. "Estimate of selected air contaminants at Mercer Generating Station", Report by PSE&G, December 1990.
17. "Handbook of Control Technologies for Hazardous Pollutants (HAP)", USEPA, June 1991.
18. "Mercury stack emissions data", Bureau of Technical Services, July 1992.

CHAPTER 10

NON-COMBUSTION SOURCES OF MERCURY EMISSIONS IN NEW JERSEY

SUMMARY:

Information was obtained from the Air Pollution Enforcement Data System (APEDS) and the DEPE's Right-To-Know Program (RTK). The information obtained from APEDS indicates very little permitted mercury emission to the atmosphere. Analysis of the data obtained from the RTK section has shown that many facilities may store mercury, such as laboratories in schools, hospitals or research departments but do not emit mercury as an air contaminant.

TASK:

To identify sources of mercury emissions other than Fuel Combustion and Incineration.

PROCEDURE:

Information was requested from the DEPE's Right-To-Know Bureau as to what companies have reported the storage of mercury or compounds of mercury. Several reports were obtained from the APEDS system to include all companies that report an emission of mercury or mercury containing compounds and those that reported the use of mercury or related compounds as raw materials. These reports were compared against one another to ensure consistency.

RESULTS:

Tables 10.1 thru 10.3 illustrate the data contained in the APEDS reports. Table 10.1 shows the active sources of mercury emissions. Table 10.2 shows all sources of mercury containing compounds that are emitted. Table 10.3 shows all permitted sources that indicate the use of mercury in a process. Data obtained from the RTK program indicate that a very large number of the reports were an inventory of stored materials and did not contribute to atmospheric releases.

DISCUSSION:

The total permitted emission of all sources of mercury is approximately 3.7 tons per year. Of this amount approximately 2.9 tons are emitted from non-combustion sources. Sources of mercury emissions that do not show on the data base (non-permitted) can be estimated to be very low, since any source handling mercury, because of its density, would meet the de minimus level of processing 50 lbs in any one hour.¹ Basically, the emission of mercury from permitted sources come from two storage tanks, air stripping of waste water, two reaction vessels, the production of radio-active pharmaceuticals, paint production at one facility, glassware calibration and fluorescent bulb manufacturing.² Information obtained from the DEPE's Pesticide Section has indicated that no pesticide user has registered any mercury containing compounds for application in New Jersey.³

TABLE 10.1

**COMPANIES THAT REPORT EMISSIONS OF MERCURY IN AIR
QUALITY PERMIT APPLICATIONS OTHER THAN FUEL COMBUSTION
AND INCINERATION REMAIN ACTIVE**

NAME & LOCATION	STACK ID	SOURCE TYPE	EMISSIONS LBS/HR		
			WO/CONT	W/CONT	
COSAN CHEMICAL CARLSTADT	00076-049	STORAGE TANKS	.82	.002	CARB
	00076-054	REACTOR	.002	.002	NONE
	00076-058	REACTOR	.001	.001	NONE
	00076-087	AIR STRIP. TANK	0	0	NONE
	00076-088	AIR STRIP. TANK	0	0	NONE

NOTE: These sources have since become inactive

E. R. SQUIBB NEW BRUNSWICK	15026-066-01	RADIO-ACT.PHARM.	5	.5	FILTERS
	-02	"	5	.5	&
	-03	"	5	.5	CARBON
	-04	"	5	.5	
	-05	"	5	.5	

NOTE: These sources have since become inactive

DUROTEST CORP. CLIFTON	30051-042-03	EXHAUSTER	.0006	.0006	NONE
	30051-043-02	EXHAUSTER	.0006	.0006	NONE

TABLE 10.2

**COMPANIES THAT REPORT EMISSION OF MERCURY CONTAINING
COMPOUNDS IN AIR QUALITY
PERMITS OTHER THAN THAT OF FUEL COMBUSTION OR INCINERATION.**

NAME & LOCATION	COMPOUND	STACK ID	EMISSION RATE (lbs/hr)
SMITHKLINE BEECHAM PISCATAWAY	MERCUDERAMIDE	15083-225	.66
COSAN CHEMICAL CARLSTADT	MERCURIC ACETATE	00076-053	.0001
MCGRAW EDISON BELLEVILLE	MERCURIC CHLORIDE	05054-011*	.0001
TROY CHEMICAL NEWARK	MERCUROUS CHLORIDE	05459-013*	.001
JOHNSON MATTHEY WEST DEPTFORD	MERCUROUS CHLORIDE	55270-035*	.004

* DENOTES SOURCE IS NO LONGER ACTIVE

TABLE 10.3

COMPANIES THAT REPORT THE USE OF MERCURY AS A RAW MATERIAL IN AIR
QUALITY PERMIT APPLICATIONS

NAME & LOCATION	STACK ID	SOURCE TYPE(IF ACTIVE)	TONS/YEAR USED
COSAN CHEMICAL CO. CARLSTADT	00076-049-01	STORAGE TANK	30879
	00076-049-02	STORAGE TANK	258
	00076-054	REACTOR	261
	00076-061	REACTOR	119
	00076-087	AIR STRIPPER TANK	546
	00076-088	AIR STRIPPER TANK	546
MCGRAW EDISON BELLEVILLE	05054-013*		1248
	05054-016*		>1
	05054-057*		1
	05054-058*		2
TROY CHEMICAL NEWARK	05459-012*		1400
	05459-013*		4950
	05459-014*		840
	05459-015*		4788
	05459-020*		313
E. R. SQUIBB NEW BRUNSWICK	15026-066-01	RADIO-ACTIVE PHARMACEUTICAL	.34
	-02	MANUFACTURING	.34
	-03		-
	-04		.34
	-05		.34
PENWALT CORP. HOLMDEL TWP.	20020-028-02*		.75
	20020-046-01*		87
	-02*		6.5
	-03*		6.5
	20020-047-01*		6.5
	-02*		6.5
	-03*		6.5
20020-052-02*		50	
DUROTEST CLIFTON	30051-042	FLUORESCENT BULB MANUFACT	3
	30051-043	" " "	3
AMERICAN CYAN. BRIDGEWATER	35001-579-01*		71
HULS AMERICA ELIZABETH	40196-005-01*		20

TABLE 3 (CONTINUED)

NAME & LOCATION	STACK ID	SOURCE TYPE(IF ACTIVE)	TONS/YEAR USED
J & J	60049-009-01*		29
EAST WINDSOR		-02*	29
		-03*	.1
		-04*	1.6
		-05*	1.6
		-06*	.1
	60049-010-01*		21
MERCURY TRADING	70199-002*		1000
BELLCO GLASS, INC.	75049-002*		8
VINELAND	75049-006*		.2
KONTES GLASS CO.	75082-004	GLASS CALIBRATION	.78
VINELAND			
CIBA-GEIGY CORP.	78001-011*		6

* DENOTES SOURCE HAS BEEN DELETED

Most of the data in this chapter was taken from the APEDS permit data base which indicates the amount of emissions that are allowed under any permit. Although this may not be the actual emission rate of mercury it does show what types of non-combustion sources are presently operating. To get a total emission of mercury, some type of reporting mechanism needs to be implemented by the Department. The Department must review how many companies may be sources of mercury but do not indicate this material on their permits. This is basically the case for permits that were issued prior to 1980. Requiring companies to test for mercury during permit renewal time would help address this issue. In this way the existing permit data bases could be updated, providing a better correlation between industrial data and permit data.

REFERENCES

1. N.J.A.C. 7:27-8.2(a) 7
2. APEDS data base reports: Mercury Emissions, Mercury Raw Materials, Mercury Compounds Emissions. Further discussions with plant personnel at these facilities have shown that many of these sources are no longer active.
3. Telecon with Ray Ferrarin - Pesticide Program.

CHAPTER 11

ENVIRONMENTAL EFFECTS OF MERCURY CONTROL ON THE SOLID WASTE STREAM

SUMMARY:

This chapter of the report evaluates the environmental impacts on the residual ash stream of additional mercury controls, including both air pollution control technology and source reduction programs. The total mercury content and the TCLP (Toxic Characteristic Leaching Procedure) leachable mercury content are also evaluated. This evaluation is performed for both the current mercury solid waste loading and with additional mercury control to the solid waste stream.

The average range of values for total mercury is between 0.041 and 3.0 mg/kg (ppm) and the average range of values for TCLP leachable mercury is between 0.0006 and 0.0011 mg/l (ppm). Approximately between 0.02 to 2.68 percent of the total mercury may be available, or TCLP leachable from the residual ash. In evaluating ash-only landfill leachate data from New Jersey landfills and from the USEPA ash research projects, the actual concentration of mercury in landfill leachate is less than this percentage, and in most cases is in the non-detectable range.

Within the residual ash management context the two options for mercury control tend to have cancelling effects. The mercury control technology within the air quality control system will increase the amount of total mercury in the residual ash. While the source reduction and source separation programs will decrease the amount of total mercury in solid waste, the flue gas stream and ultimately the residual ash. Therefore, given these cancelling effects, the current TCLP leachable quantity from the residual ash over time will probably decrease.

TASK DESCRIPTION:

With the implementation of additional mercury controls into the overall system of combustion facilities there may be an increase in mercury concentrations into the solid residual phases and the liquid discharges (quench water). This chapter of the report focuses on the potential impacts to the solid phase, primarily in the area of combustion of solid waste, and the management of the residual ash stream.

HOW THIS TASK WAS ACCOMPLISHED:

First, the current total and TCLP leachable mercury content in the residual ash from operating New Jersey MSW incinerators is quantified based on data reported by the facility operators. The data from these facilities is for the range and average values and the ratio of total to leachable values. This data is further evaluated using the current mercury emissions test data and the information on mercury removal from the MSW incinerators in Chapter 6 to determine the current maximum potential concentrations. Finally, the residual

ash management systems were evaluated in terms of future mercury control. The impacts of the implementation of mercury controls on the overall quantity of mercury within the residual ash management system are evaluated. All evaluations are performed on the combined residual ash stream (i.e. the combination of the facility's fly ash and bottom ash within an enclosed system).

DISCUSSION/RESULTS:

New Jersey does not require total metals analysis for residual ash monitoring. Only two of the MSWI incinerators (MSWI) have tested for total metals. Based on an analysis of this data, the range of mercury in the residual ash is from non-detectable, with a detection limit of 0.02 mg/kg, to concentration ranging from 0.02 mg/kg to 8.6 mg/kg. Table 11-1 presents a summary of the total mercury data as measured at these two facilities.¹

TABLE 11-1

TOTAL MERCURY IN MSWI RESIDUAL ASH*

Facility	Min	Max	Average	number
		mg/kg (ppm)	(#/ton)	of samples
Camden Co. MSWI	<0.07	8.6	3.00	114**
	1.39	5.7	3.00 (0.006)	19**
Warren Co. MSWI	<0.02	0.81	0.041 (0.0000082)	131***

* Total metal analysis is effected by the sample prep (particle size), the evasiveness of the mineral acid and the analytical instrumentation.

** Camden Co. RRF collects and analyzes six individual composite samples. The first row are the individual composite sample results and the second row is the average of the batch (weekly or monthly) results.

*** Warren Co. RRF collects ten individual composite samples and analyzes one for total metals.

Table 11-2 presents a summary of the TCLP leachable mercury data for the range of values and the overall average properties.¹ The range for mercury results of the TCLP data (The TCLP test replaced the previous E.P. Toxicity test) is either in the non-detectable range or on average, two orders of magnitude below the regulatory threshold for mercury. The regulatory threshold, as set forth at N.J.A.C. 7:26-8.12, for mercury (D-009) is 0.2 mg/liter.

The methodology for evaluating TCLP is to collect a representative sample which is indicative of the average properties of the waste to be disposed.

The sample is analyzed and the statistical average of the results is compared to the regulatory threshold. The average property must be below the regulatory threshold with a confidence interval of 80 percent, utilizing a two-sided Student-t test. Since the only result that is evaluated is a positive pass/fail, the 80 percent two-sided Student-t test is actually a 90 percent one-sided Student-t test. This means that the average property of the waste must be below the regulatory threshold with a 90 percent confidence interval to be classified as passing the TCLP characteristic or non-hazardous solid waste.

The department requires, as set forth at N.J.A.C. 7:26-2B.8 and by permit condition, the sampling and analyses of the residual ash of MSW incinerators for TCLP parameters and 2, 3, 7, 8 TCDD. The sampling and analysis is performed in a two-phase approach, defined as start-up performance monitoring and on-going or operational performance monitoring. The first phase is initiated when the facility is in a steady state condition and occurs for a minimum of eight weeks. In this phase, the residual ash is sampled at a point representative of the average properties of the residual ash for disposal. At a minimum, one grab sample is collected every hour. This sample is composited into a daily sample and further composited into a weekly sample. The weekly composited sample is segregated, at a minimum, into four individual piles. From each individual pile a sample of a minimum of 1000 grams is collected for TCLP analyses. The average of these samples must be below the regulatory threshold with a 90 percent confidence interval (one-sided Student-t test) for all parameters for at least eight consecutive weeks for the facility to be classified as generating non-hazardous waste. The department may extend the eight week start-up performance monitoring period in order to more adequately assess the characteristics of the residual ash and the facility. This is probably the most stringent residual ash monitoring program in the United States. All New Jersey district MSW incinerators have passed the performance monitoring phase and have been operating in the on-going monthly monitoring phase.

After the successful completion of the start-up performance monitoring, the facility enters into on-going or operation monitoring. During this phase, the sampling and analysis is performed on a monthly basis and the residual ash is disposed of as generated. If there is a failure in the monthly test, or if an unacceptable trend in results begins to develop, the facility is required to implement the start-up performance monitoring phase for reclassification of the residual ash and facility. No New Jersey district MSW incinerator has been required to re-enter the start-up performance monitoring phase since initially passing this phase of monitoring.

TABLE 11-2

TCLP LEACHABLE MERCURY IN MSWI RESIDUAL ASH

Facility	Min	Max	Average	No. of samples
		mg/l (ppm)		
Camden Co. RRF	<0.0002	0.0053	0.0006	114
	<0.0002	0.0022	0.0006	114*
Warren Co. RRF		0.130***	0.0011	1360**
	<0.002	0.061	0.0011	1360

- * Camden Co. RRF collects and analyzes six individual composite samples. The first row is the individual composite sample results and the second row is the average of the batch (weekly or monthly) results. Camden currently as of June 1992 has run 8 weekly and 11 monthly analysis.
- ** Warren Co. RRF collects and analyzes ten individual composite samples. The first row is the individual composite sample results and the second row is the average of the batch (weekly or monthly) results. Warren currently as of June 1992 has run 110 weekly and 23 monthly analysis.
- *** This value is the only value out of 1360 analysis in this range. For most of the values (1310 analyses) the value is less than the minimum detection limit of 0.002 mg/l.

Table 11-3 presents a summary of the ratio between total mercury and TCLP leachable mercury from the Camden and Warren County facilities. As can be seen from Table 3, only 0.02 percent of the mercury is TCLP leachable in the Camden Co. residual ash and 2.68 percent of the mercury is TCLP leachable in the Warren Co. residual ash (See Chapter 2 of this report - section "Mercury Balance" for a discussion of these results). These figures are above the USEPA rule of thumb 20:1 ratio for requiring TCLP classification testing, yet they only leach a small fraction of the mercury that is present.

TABLE 11-3

**PERCENT OF LEACHABLE MERCURY TO
TOTAL MERCURY IN MSWI RESIDUAL ASH ***

FACILITY	TOTAL (ppm)	LEACHABLE (percent)	RATIO
Camden Co. RRF	3.00	0.0006	0.02
Warren Co RRF	0.041	0.0011	2.68

* Based on average values

A number of factors are involved in controlling the leachability of mercury or any metal from a solid waste matrix. The most significant factors are the pH and total alkalinity that is present and available in the waste. For the most part, except in amphoteric metals, the higher the pH the more insoluble and immobile the metal. The high pH, in turn, is controlled by the total available alkalinity of the solid waste matrix. For MSWI combined residual ash, the alkalinity is supplied by the excess lime carried over from the spray drier of the air quality control system. The lime is added to control acid gases in the flue gas stream. The total alkalinity of the combined ash is in the range of 100,000 mg/kg as CaO and the pH is in the range of 10 to 12.

There are two options in terms of mercury control for the combustion of solid waste, mercury source reduction and source separation programs and additional control technology within the air quality control system. These technologies have been termed "upfront control" and "end-of-the pipe control" because of the location in the process line or facility in which they operate. "Upfront controls," or mercury source reduction/source separation programs, address the mercury in the solid waste before processing in the RRF, as discussed in Chapter 2. This control can occur in three methods: minimizing or eliminating the mercury in the product; by developing separate systems to manage the products before they are collected as commingled solid waste; or by pre-processing of the solid waste prior to processing in the MSW incinerator to minimizing or eliminating mercury-containing products in the solid waste stream.

According to the National Recovery Technologies (NRT) Report, dated December 31, 1981, the preprocessing of solid waste can result in a significant reduction of heavy metals.² In particular, Table 11-4 presents a summary of the reduction in air emission and mercury in the bottom ash from two of the facilities that participated in the NRT project. As can be seen from Table 4, there is a 25 to 30 percent reduction in air emission, although this reduction does not appear to be transferred to the ash (Report only cites testing for bottom ash). The NRT report states that the removal of metals and batteries during waste stream presorting may be the primary factors in reducing heavy metals in the emissions and ash.² (The reader is referred to the EPA rulemaking on the New Source Performance Standards rulemaking for a more detailed discussion of this report.)

The questions raised in this regard, as it relates to mercury reduction, is the cost-effectiveness of removing the batteries in the waste stream by preprocessing rather than source separation or source reduction. Based on the department's report on "Cost Reduction Opportunities in New Jersey Curbside Recycling Programs" it is clear that source separation programs are more cost effective than commingled program for recyclables.³ This effect is more pronounced with batteries, since batteries represent approximately 0.05 percent by weight or 0.002 percent by volume of the total solid waste disposal stream. They would be the proverbial needle in the haystack. Therefore, the same reduction, if not a greater reduction in mercury emission and total mercury content in the residual ash can be achieved through a source separation program which manages the batteries, and other mercury containing product discards, separate from the solid waste disposal stream, rather than collect these discarded products with other solid waste and to try to remove them after collection through a processing facility, such as a materials recovery facility.

In terms of source reduction versus source separation the more effective mercury control is a product specific evaluation. In some cases, almost all, except for background mercury, can be removed from the product. In other cases, there will be a technological limit on this reduction and source separation program, will need to be implemented if additional mercury reduction in the solid waste stream is to be achieved. The reader is referred to Chapter 2 of this Volume for a more detailed discussion of the various effects and impacts of source separation versus source reduction for effective mercury control.

TABLE 11-4
MERCURY REDUCTION FROM PRE-PROCESSING OF SOLID WASTE

	Nashville (pounds per 1000 ton of MSW processed)	Salem
Air Emission as received MSW	12.2	0.032
Air Emission pre-processed MSW	3.6	0.008
Total Mercury Bottom Ash as received MSW	<0.023	<3.8E-04
Total Mercury Bottom Ash pre-processed MSW	0.016	<2.4E-04
EP Tox Bottom Ash as received MSW in ppm	<0.0020	<0.0020
EP Tox Bottom Ash pre-processed MSW in ppm	0.0028	<0.0020

"End-of-the pipe controls" manage the mercury in the emission or discharge points at the facility after the solid waste has been processed. There are a number of different technologies to control mercury emissions and discharge. Their efficiencies and effectiveness are discussed in Chapter 6.

From the standpoint of residual ash management these options, up-front controls or end-of-the pipe controls, will tend to have cancelling effects. The implementation of additional air quality control technology within the MSW incinerators will increase the mercury removal efficiencies of the incinerators and thereby increase the concentration of total mercury in the residual ash. The implementation of source reduction and source separation options by product manufacturers and counties will decrease the total amount of mercury in the processible solid waste stream going into the MSW incinerators, and thereby decreasing the concentration of total mercury in the residual ash.

Table 11-5 presents a summary of the range of mercury emission removal efficiencies of add-on air quality control technology from Chapter 6 and the range of mercury reduction in the solid waste from source reduction from Chapter 2. As can be seen from the data, these three mercury control options have cancelling effects as it relates to the mercury in the residual ash. For the purpose of this table, we have lumped source reduction and source separation programs from Chapter 2 into one option. From the standpoint of MSW incinerators that utilize the solid waste, any programs that removes mercury could generally be viewed as source reduction. However, from a definitional and solid waste management viewpoint, these two options, source reduction and source separation, are distinctly different in the implementation and impacts.

TABLE 11-5
MERCURY REDUCTION AFTER IMPLEMENTATION OF MERCURY CONTROL

Mercury Control	percent reduction		
	low	medium	high
Air Quality Control Systems (Chapter 7)	40	67	94
Source Reduction (year) (Chapter 2)	1993	1994	1995
Current Requirements (CR)	57	68	74
Expanded Program (EP)	70	75	83

Utilizing the data presented in Table 11-5, Table 11-6 presents a summary of the potential mercury on a pound per ton basis that could be available on average in the residual ash. Table 11-6 assumes a mercury content in the solid waste of 0.0050 pounds per ton in 1992 and that the air quality control system can be implemented in less than six months. For the purposes of this calculation, the removal efficiency has been assumed constant across a decreasing mercury content in the solid waste. This conservative assumption has been made for the purpose of evaluating the worst case scenario in terms of mercury content in the residual ash. It is not an evaluation of when or how mercury controls will be implemented in MSW incinerators. It should be noted that the decrease in mercury content in products and the solid waste stream will have an impact on the removal efficiencies of mercury air quality control technologies (See Chapter 6 for a discussion of this issue).

As can be seen from the data in Table 11-6, as compared to Tables 11-1 through 11-3, the addition of mercury control within an MSW incinerator should not result in an exceedance of the TCLP characteristic for mercury. With the implementation of source reduction, even at high mercury emission removal efficiencies, the total quantity of mercury available in the residual is significantly reduced over the next three years.

TABLE 11-6
MERCURY IN THE RESIDUAL ASH AFTER
IMPLEMENTATION OF MERCURY CONTROL

Air Quality Control Systems	Source Reduction	mercury removal efficiencies		
		low	medium	high
		(pounds/ton)		
	1992	0.0020	0.0034	0.0047
	1993 CR	0.0009	0.0014	0.0020
	EP	0.0006	0.0010	0.0014
	1994 CR	0.0006	0.0011	0.0015
	EP	0.0005	0.0008	0.0012
	1995 CR	0.0005	0.0009	0.0012
	EP	0.0003	0.0006	0.0008

*Removal efficiency is held constant with a decreasing mercury content in the solid waste. At lower mercury content in the solid waste, this assumption may not be correct.

Based on the current data for total mercury and TCLP leachable mercury in the residual ash, a higher mercury removal efficiency of the flue gas stream is not expected to result in an exceedance of the TCLP regulatory threshold for mercury. In addition, it is expected that with a source reduction programs in the municipal solid waste stream, as cited in Chapter 2, the total quantity of mercury in the residual ash will decrease significantly.

In addition to the total quantity and TCLP leachability of mercury in the residual ash stream, there is a question of the stability or immobilization of the mercury in the residual ash. This issue has in part been addressed by the USEPA which concluded that the re-volatilization of mercury that is absorbed onto carbon in the fly ash are very stable and will not re-volatilize upon disposal in the landfill.⁴

The question raised is whether the mercury in the residual ash or any mercury-containing product in the solid waste stream disposed of in a landfill can be released to the environment. Normal conditions in Class I solid waste landfills result in relatively low pH, an elevated internal temperature and an anaerobic methane generating atmosphere. These are factors that may contribute to the methylation of mercury from the residual ash or solid waste in a landfill environment. The department is evaluating the requirement that all residual ash generated from the combustion of solid waste be monofilled within a Class II ash-only landfill. This would minimize and control the factors that contribute to the re-volatilization.

Nagase et al (1985), in their paper entitled "Mercury Methylation by Ash Refuse Incineration," suggested the potential of methylation of inorganic mercury from ash at landfill sites.⁵ Further, Nagase reports that Takizawa,

et al (1984), detected 16.3 milligrams of methyl mercury per gram of soil from a landfill site as highest value. The paper appears to indicate that this reported value of methylmercury was from "refuse dumping sites with high inorganic mercury concentrations," suggesting a mixed municipal solid waste landfill or even a hazardous waste facility. The reader is referred to Chapter 2, section - Future Potential Source Reduction - (fluorescent bulbs), for a more detailed discussion of this issue.

In municipal solid waste landfills the potential pathway for mercury emission would be from gas production within the landfill. The mercury would probably exist in the landfill gas condensate. As described in Chapter 1, insufficient data is available at this time to fully evaluate this impact. The department will be initiating a sampling program at MSW landfills and residual ash monofills to measure both point and non-point emissions.

The potential environmental impacts of wet scrubbing technology (discussed in detail in Chapter 6) are as follows:⁶

1. Large quantities of mercury containing waste water generated through a wet scrubbing system should be treated prior to discharge to surface water of sewage treatment plant to remove mercury;
2. Treatment of large quantity of waste water from scrubbers may generate hazardous sludge. Disposal of sludge in landfills may impact soil or ground water quality;
3. Wet flue gases may need to be reheated. Reheating would produce additional air contaminant emissions; and
4. Dioxin toxic equivalencies may increase when wet scrubbing is used.

REFERENCES

1. NJDEPE Division of Solid Waste Management--Bureau of Resource Recovery RRF residual ash monitoring results.
2. Sommer, Ed J., et al, "Effect of MSW Preprocessing on Thermal Conversion of MSW in Massburn Incineration, National Recovery Technologies, Inc." prepared for the US Department of Energy, December 31, 1987.
3. "Cost Reduction Opportunities in New Jersey Curbside Recycling Programs", Richard Bishop Consulting, Ltd. prepared for the New Jersey Department of Environmental Protection, October 1990.
4. Memorandum from Kris Nebel, Radian to Walt Stevenson, SDB and Mike Johnston, ISB "Mercury Revolatilization", dated June 16, 1991.
5. Nagase, Nisamitso, et. al., "Mercury Methylation by Ash Refuse Incineration" The Science of Total Environment, Elsevier Science Publishers B.V. Amsterdam 53 (1986) pp 133-138.
6. Ferraro, Frank, Director, Environmental Engineering letter to Mary Sheil, Project Manager, NJDEPE/DSWM dated September 10, 1992. comments on the Preliminary Mercury Task Force Report.

CHAPTER 12

EVALUATION AND COMPARISON OF MERCURY STACK EMISSION TEST METHODS AND EUROPEAN STANDARDS

SUMMARY:

A review of European and United States test methods indicate that while some similarities exist, the manner in which these methods are implemented differ significantly. European projects also back dated information which makes it difficult to draw valid comparisons.

TASK DESCRIPTION:

The purpose of this task was to determine if the method used to evaluate mercury emission values in the European community could be a basis for establishing limits in the United States.

HOW TASK WAS ACCOMPLISHED:

This task was accomplished by reviewing available literature on European and U.S. test methods and interviewing experts on mercury from the U.S.E.P.A.

DISCUSSION:

Development of a mercury emission standard is contingent upon the method of determining compliance with that standard. Mercury and related Hg compounds can exist in both particulate and vapor states in stack exhaust gases. The purpose of this chapter is to evaluate the sampling and analytical methodologies currently in use to test various stack sources for compliance with existing mercury emission limits. U.S.EPA sampling and analytical procedures were compared to known European stack sampling procedures.

Techniques for mercury sampling include both batch and instantaneous methods. Batch sampling involves extracting exhaust gases for an extended period of time (usually one hour or more) and filtering, absorbing or adsorbing the contaminant of interest in a suitable reagent or media for subsequent analysis. Results are reported as time weighted averages.

Instantaneous or instrumental methods measure the contaminant at the source and consequently give a more detailed picture of emission fluctuations.

A batch sampling method for mercury can be conducted isokinetically, as required by U.S.EPA reference methods, or as a single point gas sample as favored by the European community; while instantaneous methods are typically single point non-isokinetic samples.

The necessity for isokinetic sampling is two fold. First, isokinetic sampling is required to extract particulate matter from the gas stream at a rate proportional to its total mass emission. In addition, the multi-point isokinetic sampling technique eliminates potentially erroneous contaminant measurements due to stratification within the exhaust duct.

The non-isokinetic sampling utilized in the European mercury methods is based on the premise that sources equipped with effective flue gas cleaning systems will remove virtually all particulate mercury compounds from the exit stack gas. This concept is supported by data collected from the multi-metals sampling train which provides analysis of the particulate mercury and the gaseous mercury compounds. (Typically, a source with controls will exhibit only 1 or 2% of the total mercury collected as particulate from the outlet gases). U.S. standards, if adopted for MSW incinerators, will probably include an efficiency requirement mandating the need for inlet/outlet isokinetic sampling. Since, the inlet gas stream controls a significantly higher percentage of particulate mercury, isokinetic sampling will be necessary.

Stratification, however, cannot be summarily dismissed. The problem is source specific and independent of the type of controls. Even gas samples can be adversely affected by poor mixing and air leaks.

While the methods described here are primarily designed to determine total mercury emissions, much of the emphasis on developing new sampling methodology is concerned with speciation of the mercury compounds emitted from point sources. It was not the purpose of this report to attempt to critique experimental methods. The need for speciation is of primary concern for developing control technologies and determining risk assessments. Enforcement and standards development should be based on established methodology.

TEST METHODS COMPARISONS

SAMPLING ANALYTICAL METHOD	ISOKINETIC	PARTICULATE Hg	GASEOUS Hg	DETECTION LIMIT
EPA RM 101A	YES	YES	YES	5.5 ug/DSCM ⁽²⁾
DRAFT EPA RM 29	YES	YES	YES	5.6 ug/DSCM ⁽²⁾
CVASS ⁽³⁾ and Stanous Chloride (Continuous Sampling)	NO	NO	YES	3.04 ug/DSCM
DOAS ⁽⁴⁾ (Continuous Method)	NO	NO	YES ⁽⁵⁾	0.02 ug/DSCM

Persulfate Method	NO ⁽⁶⁾	NO ⁽⁶⁾	YES	(7)
European Permanganate	NO	NO ⁽⁸⁾	YES	5.5 ug/DSCM
Potassium Chloride and Iodized Carbon	NO	NO	YES	0.04 ug/DSCM

- 1) Particulate defined as capture by filtration during sampling
- 2) A lower detection limit can be achieved by increasing sample volume. Example: By doubling the sample time the detection limit is twice as sensitive.
- 3) Cold vapor atomic absorption spectrophotometry.
- 4) Differential optical absorption spectroscopy.
- 5) Elemental Hg only.
- 6) May be adapted to isokinetic sampling and to collect particulate Hg. However, data which was evaluated for this report indicates that this method was not used isokinetically.
- 7) Data not found in literature search.
- 8) European methods are non-isokinetic assuming control technology captures particulate Hg.

DETERMINATION OF PARTICULATE AND GASEOUS MERCURY EMISSIONS FROM SEWERAGE SLUDGE INCINERATORS REFERENCE METHOD 101A

Principle -

"Particulate and gaseous Hg emissions are withdrawn isokinetically from the source and collected in acidic potassium permanganate ($KMnO_4$) solution. The Hg collected (in the mercuric form) is reduced to elemental Hg, which is then aerated from the solution into an optical cell and measured by atomic absorption spectrophotometry."

Sensitivity -

The method is capable of detecting Hg as low as 20 ng/ml. A one hour sample (approximately 45 DSCF) could determine Hg stack concentrations around 5.5 ug/DSCM. Increased detection limits are possible by lengthening the sample time/volume.

Comments -

Revised method will include additional filter digestion and analysis for increased mercury detection.

Even with additional filter analysis the results may be approximately 10% lower than the multi metals sampling train. Additional studies are planned to corroborate this difference.

POTASSIUM PERSULFATE METHOD

Principle -

A gas sample is withdrawn from the source and passed through two impingers containing an Hcl solution for absorbing oxidized mercury compounds followed by two additional impingers containing an acidified potassium persulfate solution for collection of elemental mercury.

Sensitivity -

Detection limit is believed to be almost equal to the permanganate methods. The detection limit may be lowered by increasing sampling time/volume.

Comments -

European comparative studies have shown lower results with this method, probably due to higher Hg carry over in the impingers.

**DETERMINATION OF METALS EMISSIONS FROM STATIONARY COMBUSTION SOURCES
DRAFT REFERENCE METHOD 29**

Principle -

Particulate and gaseous Hg emissions are withdrawn isokinetically from the source and collected in impingers containing $\text{HNO}_3/\text{H}_2\text{O}_2$ and $\text{KMnO}_4/\text{H}_2\text{SO}_4$ respectively. The impingers and rinse solution as well as the digested filter solution are analyzed for mercury using cold vapor atomic absorption spectroscopy.

Sensitivity -

The method is capable of detecting Hg at concentrations of approximately 5.5 ug/DSCM at stack concentrations for a one hour sample of 45 DSCF. Increased sensitivity is possible by increasing sample time/volume.

Comments -

The method can be used to determine trace metals emissions.

CONTINUOUS COLD VAPOR ATOMIC ABSORPTION (CVAA) SPECTROSCOPIC METHOD

Principle -

A continuous gas sample is withdrawn from the source at a flow of 1 liter/min via a teflon tube to a refrigerated gas/liquid separator where condensed water is separated from the flue gas. The dry gas is transferred to the absorption cell where elemental mercury is measured directly. Total mercury is measured via another sample line where the flue gas is brought in contact with acidic stannous chloride (SnCl_2) solution and oxidized compounds of mercury are reduced to elemental mercury. The stannous chloride solution and condensed stack water vapor are removed in a second gas/liquid separator prior to analysis of the elemental mercury vapor.

Sensitivity -

The detection limit of the continuous CVAA method is approximately 3 ug/DSCM.

Comments -

- Single Point Sample
- Stannous Chloride will not reduce stable Hg compounds (e.g. HgS) thus these compounds will not be counted in total mercury.
- Oxidized Hg compounds can condense in the sampling line also reducing total Hg emissions.

DIFFERENTIAL OPTICAL ABSORPTION SPECTROSCOPY (DOAS)

Principle -

An in-situ method of elemental mercury analysis consisting of a light source transmitting a beam of parallel rays from a high pressure xenon lamp across the flue gas duct to a receiver which transmits the light over a fiber-optic cable to the central unit. The measurement is performed by scanning the part of the spectrum where the gas in question is absorbing.

Sensitivity -

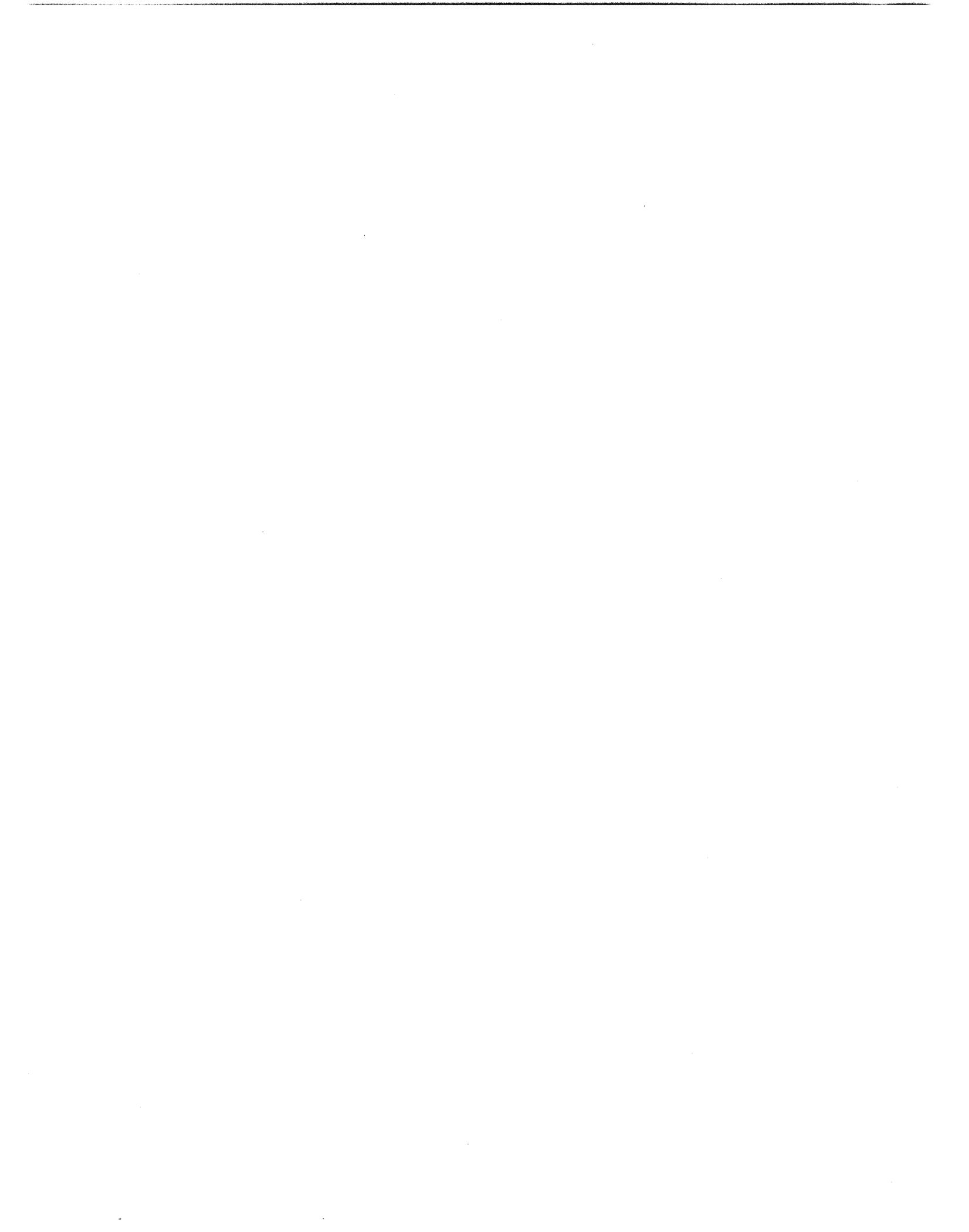
The method is capable of detecting elemental mercury levels in the PPT range (<1 ug/DSCM).

Comments -

- Measures only elemental Hg
- Measures entire cross sectional path length for a more integrated sample.
- Can measure additional contaminants (SO₂, NO, NO₂, specific organics, etc.)

REFERENCES:

- 1) Code of Federal Regulations - 40 CFR - Part 61 - Appendix B - Reference Method 101A - July 1, 1992
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