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Findings and recommendations of the New Jersey mercury emissions standard setting task force

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Abstract

In April, 1992, the New Jersey Department of Environmental Protection and Energy (NJDEPE) established a task force to begin the process of setting mercury emissions standards. (*Note*: In July, 1994, the NJDEPE was changed to the New Jersey Department of Environmental Protection). The task force investigated the fate and transport of mercury, generated estimates of background levels, and concentrated its initial study on municipal solid waste (MSW) incineration facilities.

In addition, the task force recommended the establishment of a mercury emissions standard of 28 μg per dry standard cubic meter (μg/dscm) by the year 2000 for MSW incinerators, with an interim standard of 65 μg/dscm to be met by 1995.

Keywords: Mercury; Solid waste; Incineration; Methyl mercury; Fish; Batteries

1. Introduction

1.1. Establishment of the task force

The Mercury Emissions Standard Setting Task Force was established with an order by the former Commissioner of the NJDEPE, Scott A. Weiner, to develop a set of recommendations for a statewide mercury emissions standard. The order also disapproved a resolution by one of New Jersey's counties, Camden County, which proposed a county-wide emissions standard of 0.024 lb/h for each source of mercury within that county. The order addressed the need for reducing mercury emissions from municipal solid waste (MSW) incinerators through implementation

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of battery separation programs and installation of new air pollution control equipment. The order mandated that the NJDEP provide an active public participation process to assist in the development of a statewide standard.

2. Task force findings: Technical and Regulatory issues

The Technical and Regulatory Issues Subcommittee was charged with evaluating the potential sources of mercury emissions, quantifying current mercury emissions in New Jersey, and evaluating methods to reduce mercury emissions in conjunction with the findings of the Environmental and Health Issues Subcommittee.

2.1. Sources

In order to develop a rough estimate of the magnitude of atmospheric emissions of mercury and mercury compounds, the task force sought information on New Jersey sources of atmospheric emissions. It did not attempt to evaluate out-of-state atmospheric sources potentially impacting New Jersey, nor did it attempt to evaluate emissions or discharges to water or land.

The data reviewed by the task force indicated that MSW incineration was the largest in-state atmospheric source, contributing approximately 3300 lb (1500 kg) of mercury emissions to the atmosphere. This is nearly half of the estimated state total. Other potentially large sources include the combustion of coal and oil and the incineration of sewage sludge. Industrial sources appeared to be at least an order of magnitude lower than municipal solid waste combustion, and other sources, including hospitals, apartment houses, and crematories, appeared to be lower still. Table 1 provides estimates of anthropogenic emissions of mercury in New Jersey, as of 1993. Where sufficient data were available, an estimated median or weighted average was calculated. High and low estimates are based on extremes of values from primary literature and other sources.

Table 1
Anthropogenic mercury emissions in New Jersey to the atmosphere estimated by source

Source type	Approximate estimates (kg/yr)		
	Mid-range[a]	High	Low
MSW incineration	1500	2100	320
Fuel oil/residential/commercial/transportation	500	1390	20
Coal (utilities)	500	2700	100
Fuel oil/utility/industrial	440	1270	10
Sludge incineration	360	410	200
Gasoline		890	120
Industrial	90	180	50
Other incineration	50	90	20
Crematories	40	60	30

[a] Estimated median or weighted average where sufficient data available.

2.2. Bases of emissions estimates

2.2.1. Municipal solid waste combustion

Approximately 1.3 million tons (1.2 million metric tons) of solid waste were incinerated per year at the four MSW incineration facilities in operation in New Jersey during the period of the task force study. Each of these is a mass-burn facility which recovers much of the heat energy contained in the trash to generate electricity [1].

A value of 0.005 lb of total mercury per ton (2.5 ppm) was used as the estimated mercury concentration of this waste. This figure was based on an evaluation performed for the USEPA by Franklin Associates [2], which in turn was based, in part, on data from the US Department of Interior, Bureau of Mines. These data were adjusted by the task force to account for a higher mercury concentration in bulky and industrial waste, which was not specifically addressed in the USEPA study.

It was assumed that the emissions controls of New Jersey's MSW incinerators, which include acid gas scrubbers and either bag house or ESP particulate collectors, collect a portion of the mercury before it is emitted to the air. Low-, mid- and high-range estimates of the degree of this control were 30%, 50%, and 90%. A mid-range estimate of about 3300 lb (1500 kg) per year was generated.

Actual stack test data from New Jersey MSW incinerators were also evaluated. Because of New Jersey's air permits, which in some cases require quarterly air monitoring for mercury, a number of such values have been obtained for each of the four facilities. The average values per facility, translated into pounds of mercury emitted per ton of waste incinerated, varied from 0.00077 lb per ton (0.32 g per metric ton) to 0.0039 lb per ton (1.5 g per metric ton). Considering the low and high estimates of the degree of mercury control (30% and 90%, respectively), these values translate into an estimated mercury content in solid waste of approximately 1 to 4 ppm.

Mean stack test values for all four facilities, where such values were available on a pounds of mercury emitted per ton of waste burned, were compiled. These were 0.0021, 0.003, 0.0039, and 0.0008 lb mercury per ton of waste. The average of these means, weighted by capacity of each facility, is 0.0025 lb per ton. When multiplied by the 1.3 million total tons of waste incinerated, this value yields approximately 3200 lb (1450 kg) of mercury per year. This number is in close agreement with the 3300 lb (1500 kg) mid-range estimate based on mercury content in waste, as described above.

2.2.2. Coal combustion

Although the combustion of coal may make a larger contribution nationally than MSW combustion, in New Jersey coal accounts for only about 3% of total energy use, as opposed to about 20% nationally [3].

There are five New Jersey utility facilities which burn coal. They burn a total of about 3.55 million tons (3.22 million metric tons) per year. A literature search performed by the task force indicated that, although there is a large range of reported mean values of mercury in coal, the mean values generally fall into a range from about 0.12 to 0.28 ppm, with an 'average' mean of 0.19 ppm.

The task force, noting a Florida Department of Environmental Regulation report [4], concluded that it was likely that the electrostatic precipitators primarily used to control particulate emissions from New Jersey utilities would reduce mercury emissions by about one-quarter. It was assumed, for the purpose of emissions estimates, that the yearly mean mercury emission rate from New Jersey coal-burning utilities would correspond to a value obtained by multiplying 3.55 million tons by approximately 3/4 of the average mean of 0.19 ppm, or 0.15 ppm, or approximately 1100 lb (about 500 kg) of mercury per year.

A stack test performed at one of the New Jersey utilities [5], provided numbers which corroborated this emissions range. In the stack test, which was performed on two of the utilities' units run at full load, one unit emitted mercury at 0.023 lb (8.6 g) per hour; the other emitted mercury at 0.03 lb (11 g) per hour. If these units were operated at full load for a year, their combined capacity would lead to the combustion of approximately 1.016 million tons (0.92 metric tons) of coal. Since, as stated above, approximately 3.55 million tons of coal are burned by New Jersey utilities yearly, emission of mercury at a similar rate by all New Jersey utilities would total about 1600 lb (about 725 kg) per year from the combustion of coal.

The task force stressed the importance of acquiring additional data, given the large range of mercury concentrations which appear to exist in coal.

2.2.3. Incineration of sludge from domestic treatment works

NJDEP data indicated that approximately 400 000 dry pounds (about 182 000 kg) of sewage sludge generated by domestic treatment works is incinerated per day in New Jersey [6]. NJDEP data also showed that the approximate median mercury content in this sludge was 4.5 ppm. Based on the use of a weighted average for all domestic treatment works, approximately 800 lb (363 kg) of mercury is emitted annually by New Jersey sludge incinerators, assuming no capture by existing emissions controls. This does not include emissions or other impacts from mercury through land application of sludge or sludge-derived products.

2.2.4. Fuel oils, gasoline, and natural gas

New Jersey is a heavily populated, industrial state which acquires most of its energy from the combustion of these fuels. Because of the possibility that even low quantities of mercury contained in such fuels could account for significant emissions given the relatively huge quantities of these fuels burned in New Jersey, the task force endeavored to acquire data on mercury content of these fuels. These endeavors met with only limited success; the task force forcefully stressed the need for more data.

The data the task force used included estimates that approximately 55 million barrels (one barrel = 42 US gallons or approximately 159 l) of fuel oils are burned yearly in the state by industries and utilities and over 61 million barrels are consumed by the residential, commercial, and transportation sectors [7]. Based on what published values were available and on personal communications with associates of task force members, the task force estimated that these fuels contained anywhere from 1.5 to 0.17 ppm mercury, with 0.06 ppm used as a mid-range estimate. For the purposes of its approximate magnitude estimates, the task force assumed that gasoline contained no more mercury than fuel oils, and that natural gas had a mercury concentration ranging from 0.02 to 0.44 μm per normal cubic meter.

The task force concluded that it was unlikely that emissions from these sources exceeded those from MSW combustion, and it acknowledged the possibility that such emissions, particularly those from natural gas, might be considerably lower. The large range of estimated concentrations of mercury in fuels indicates the need for more data. These estimates do not include potential emissions from the refining of oil and from the production and use of non-fuel petroleum-based products.

2.2.5. Industrial sources, other waste incineration, crematories, and other sources

Available data on industrial facilities included the federal Toxic Release Inventory [8] (TRI) and New Jersey's related Release and Source Reduction report [9]. Data for years 1987–1989 show only one firm reporting releases of mercury to the air in all three years. Releases from this one source, which is a manufacturer of industrial organic chemicals, totaled 500 lb (227 kg) each of these three years. 1990 data showed much lower quantities from this same facility, and indicated that only about 50 lb (about 23 kg) total mercury and mercury compounds were released to the air in 1990 from all reporting firms.

No data were available on actual emissions of industrial facilities not required to report under the TRI. However, NJDEP permit data indicated that it was highly unlikely that additional mercury emissions from these sources exceeded an additional 150 lb (68 kg) per year.

Sufficient data was acquired from NJDEP permit files and other sources to indicate that emissions from hazardous waste incinerated in New Jersey, apartment houses, hospitals, and crematories were likely to be relatively minor. However, data was not acquired for some sources which could be significant. These included potential mercury volatilization during use and disposal of fluorescent light fixtures and painted items, and electrical apparatus such as mercury-containing switches, mercury emissions from MSW landfill gas systems, and releases from industrial and other sources to water bodies and to land.

2.3. Evaluation of possible methods to reduce mercury emissions from MSW combustion

The task force found that substantial reductions in the mercury content of municipal solid waste appear feasible. In fact, source reduction and source separation were found to be capable of reducing mercury in waste by 70–90%. Measures to accomplish much of this reduction were already in place in New Jersey.

Further, it was found that there were a number of emissions control technologies capable of removing significant amounts of mercury from the flue gases. Technologies

Table 2
Mercury in discarded consumer products in the New Jersey MSW stream, 1992

Product	Mercury (metric tons)	Percent
Consumer batteries		
Alkaline	7.48	48.3
Mercury oxide	5.33	34.4
Others	0.15	0.9
Battery subtotal	12.96	83.6
Electric lighting		
Fluorescent lamps	0.95	6.1
High intensity lamps	0.03	0.2
Lighting subtotal	0.98	5.7
Paint residues	0.34	2.2
Fever thermometers	0.54	3.5
Thermostats	0.32	2.0
Pigment	0.21	1.4
Dental uses	0.12	0.7
Special paper coating	0.02	0.1
Mercury light switches	0.04	0.3
Total	15.5	100.0

such as wet scrubbers or carbon injection appeared capable of achieving between a 70–90% control efficiency.

2.3.1. Source reduction and source separation

The mercury content of waste materials as characterized in the US EPA report [10] was adjusted to New Jersey based on New Jersey's Solid Waste Assessment Task Force – Preliminary Report [11].

Table 2 presents the estimated quantity and percentages of mercury in discarded products in the New Jersey municipal solid waste stream.

Approximately 5% of the solid waste managed by New Jersey's municipal waste incinerators is considered bulky or industrial waste, and appears to contain proportionately more mercury than waste from residential and commercial sources. Much of this mercury, however, may be amenable to reductions with the same or similar measures as appear workable for residential and commercial wastes. Many of the discarded products in the municipal or industrial solid waste streams could be managed under a universal waste program.

Among the most promising measures are two programs already in place in New Jersey. In January 1992, the 'Dry Cell Battery Management Act' (NJSA 13:1E-99.59 et seq.) was signed into law. It requires the reduction of the mercury content in a variety of dry cell battery types if they are sold in New Jersey to extremely low levels, in accordance with the following schedule:

- **By 1 January 1992:**

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

(2) All button or coin shaped alkaline batteries must be equal to or less than 25 mg of mercury per battery.
(3) All carbon–zinc batteries must be equal to or less than 0.0001% mercury by weight (1 ppm).
(4) 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% mercury (250 ppm) by 1 January 1992. The exemption for hearing aid mercury oxide batteries expires on 1 January 1994. Since a mercury oxide battery cannot be produced that meets the 250 ppm standard, this effectively eliminates this battery from sale in the consumer market.

- **By 1 January 1996:**

(1) All alkaline batteries must be equal to or less than 0.0001% mercury by weight (1 ppm).

In addition, the Dry Cell Battery Management Act requires a variety of management strategies for institutional uses of batteries, consumer education, labeling, and collection and disposal. In order for institutional mercury oxide batteries to be sold in New Jersey, the mercury oxide battery manufacturers had to submit a plan which demonstrated how they would be financially liable for the establishment of a program to source separate and manage these batteries separately from the municipal solid waste disposal stream. No institutional mercury oxide batteries could be sold in New Jersey without the NJDEP's approval of such a management plan. Panasonic, Eveready, and Duracell have indicated that they are discontinuing the manufacturing of mercury oxide batteries, citing decreasing market share and environmental issues as reasons for not submitting a mercury oxide battery management plan. No other mercury oxide battery manufacturer submitted a plan by 20 October 1993, and therefore no mercury oxide batteries are available for sale in New Jersey.

As a result of this Act, two significant actions have occurred:

(1) The alkaline battery manufacturers have committed to meeting the no mercury added standard (1 ppm mercury by weight) two years ahead of schedule on 1 January 1994. This means that by 1996/97 the mercury in the MSW disposal stream from alkaline batteries will go to almost zero.

(2) Because of the mercury oxide battery manufacturers' option not to submit a battery management plan for the separate management of these batteries, no mercury oxide batteries are legally available for sale in New Jersey. This means that the mercury in the MSW disposal stream from mercury oxide batteries will be significantly reduced.

Overall, the task force estimated that this law will result in up to an 80% reduction of mercury entering MSW incinerators by 1995.

Another source reduction law was also signed into law in New Jersey in 1992. This is the 'Toxic Packaging Reduction Act' (NJSA 13:1E-99.44 et seq.) This act requires the reduction of mercury levels in packaging or in any packaging component including ink, dyes, pigments, adhesives, stabilizers, 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 in accordance with the following schedule:

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

The task force estimated that this law will result in additional reductions in the mercury content of waste materials.

The task force found that opportunities also exist to separate other mercury-containing discards from the waste stream, such as fluorescent lamps, fever thermometers, mercury switches, and thermostats. The NJDEP is currently cooperatively working with fluorescent light build manufacturers, county solid waste authorities, recycling companies and electric utility companies to develop a pilot program for the source separation of fluorescent lights from the MSW disposal stream for recycling. Overall, measures to reduce mercury in waste, if properly implemented, have the potential to reduce mercury in the MSW disposal stream and emissions from MSW incinerators by about 95% from 1992 levels.

2.3.2. Emissions controls

Several air pollution control technologies for waste combustion have also demonstrated significant reductions in mercury emissions. These include: activated carbon injection, carbon beds, sodium sulfide injection, and wet scrubbing. Testing has shown mercury removal efficiencies for these technologies are frequently in excess of 90%, and can be in the range of 99%. The task force found that minimum hourly mercury control efficiencies of 70% and average annual control efficiencies of 90% may be expected from air pollution control technologies. However, the task force noted that reductions of mercury in the waste stream may affect the removal efficiencies of mercury in the flue gas stream; this could reduce the overall control efficiency. Therefore, the task force assumed that an average annual control efficiency of 80% is achievable after implementation of an aggressive mercury waste reduction program.

2.3.2.1. Existing air pollution controls. As of June 1993, there were four large MSW incinerators operating in New Jersey; Camden, Essex, Gloucester, and Warren. (Currently, New Jersey has five operational MSW incinerators and a sixth under construction.) In order to control acid gases, all four facilities use spray dryers prior to the particulate control system. Spray dryers are not considered very effective at controlling mercury, unless carbon or sodium sulfide is injected. Although mercury removal from these systems without such injection is sometimes significant (recent tests at the Camden facility showed removal efficiencies in the range of 30–50%), there is wide variation in reported control efficiencies. The control efficiency depends on a number of factors, including the amount of carbon in the fly ash, which in turn is dependant on the type of combustion technology used and the operating conditions of the flue gas cleaning equipment. Modern MSW mass burn incinerators such as the New Jersey facilities have very good combustion efficiencies and relatively low carbon in the fly ash. The task force estimated that the existing air pollution

Table 3
Ranges of mercury emissions from New Jersey MSW incinerators based on stack tests, as of 1993

Facility	# of tests	Mean (lbs/ton)	Capacity (tons/d)
Gloucester	6	0.0008	576
Warren	N/A	0.003	400
Camden	12	0.0039	1050
Essex	13	0.002	2274

control devices on New Jersey MSW incinerators capture an average of 50% of the mercury emissions from the combustion chamber. General mass balance calculations on the average total mercury in the residual ash and average mercury emissions from stack testing of MSW incinerators, compared against the estimated mercury content of MSW, confirms this estimate (Table 3).

Overall, the task force estimated that existing air pollution control equipment in use at these MSW incinerators controls about 50% of the mercury emissions, and therefore 1993 uncontrolled emissions were estimated to be about twice those shown above, or about 700 μg/dscm. It should be noted that this represents a reduction from calculated and estimated uncontrolled emissions in previous years of 1000 μg/dscm.

2.3.3.2. Add-on mercury emissions controls. The task force reviewed several types of add-on mercury emissions control technology. These included carbon injection, carbon beds, sodium sulfide injection, scrubbing, and scrubbing with wet electrostatic precipitators (ESP).

- Carbon injection
  - It is known that mercury is adsorbed on carbon, provided there is adequate contact between the mercury and the carbon. Where there is a dry scrubber (such as a lime spray dryer absorber) and a fabric filter baghouse (SD/FF) or a dry scrubber and electrostatic precipitator (SD/ESP), carbon can be injected into the untreated gas stream at the entrance of the dry scrubber. For MSW combustion, the task force determined that carbon injection with SD/FF or SD/ESP systems usually reduces mercury emissions by 70–95%.
- Carbon beds
  - Deep beds of carbon (compared to thin layers of carbon on fabric filters) can be installed after the particulate control device, regardless of whether the particulate control is a baghouse on ESP. The task force found that testing at two pilot facilities in Germany indicated 97–99% mercury removal efficiency. However, the task force also found that carbon beds have potential operational problems.
- Sodium sulfide injection
  - Sodium sulfide has been injected prior to particulate control devices in order to control emissions of mercuric chloride and other mercury compounds. Some tests at facilities employing this technique have demonstrated mercury removal efficiencies in the same range as carbon injection. The task force found that

more testing and analysis is needed; there are indications of operational problems when sodium sulfide is injected.

- Scrubbing
  - Wet scrubbers, such as two-stage wet scrubbing and high-efficiency scrubbers, can be installed after the particulate control device to achieve additional mercury control. The task force found that three wet scrubbers in Europe have demonstrated mercury removal efficiencies in the range of 60–95%. Wet scrubbers, however, create water and sludge disposal problems which have not yet been adequately addressed.
  - All hazardous waste incinerators in New Jersey employ venturi scrubbers; stack tests of these systems indicate very low mercury emissions. Evaluation of mercury removal efficiency, however, has not been done.
- Scrubbing and wet electrostatic precipitators (ESPs)
  - A sewerage authority in New Jersey, Somerset Raritan Valley, has installed a sludge incinerator with a scrubber and a wet ESP. As of the date of the task force report, June 1993, test reports on this facility had not been completed. Three other sewerage authorities in New Jersey (Gloucester County Utilities Authority, Bay Shore Regional Sewerage Authority, and Pequannock-Lincoln Part Regional Sewerage Authority) are constructing replacement incinerators which will be equipped with wet scrubbers and wet ESPs. Testing for mercury emissions of these units should provide useful information regarding mercury removal efficiency.

2.4. Combined effects of source reduction/separation and emissions control technology

The task force found that implementation of New Jersey's 'Dry Cell Battery Management Act' will result in a 70–80% reduction of mercury in MSW incinerators by 1995. With implementation of additional mercury waste separation programs, the overall reduction in mercury could be increased to as much as 95% of 1992 levels. Adding mercury reduction air pollution control technology to MSW incinerators could provide up to 90% average annual control efficiency for mercury emissions. Table 4 indicates the overall mercury reductions expected with combinations of source reduction and separation and additional control technology (e.g., carbon injection or wet scrubbing).

Table 5 represents the average and range of possible annual mercury limitations for MSW combustion that could result if the following parameters exist:

(1) 1991 average New Jersey MSW incinerator uncontrolled mercury emission concentration of 700 ug/dscm;

(2) Aggressive mercury waste reduction programs; and

(3) Reduction in mercury emission levels through add-on mercury control technology.

The task force concluded that the average of the high and low potential reductions results in a limitation which could be reasonably achieved with significant effort. This is consistent with a combination of 80% mercury waste reduction/separation

Table 4
Potential overall mercury reductions

	70% Source reduction (%)	80% Source reduction (%)	95% Source reduction (%)
70% Control	91	94	98.5
80% Control	94	96	99
90% Control	97	98	99.5

Table 5
Possible mercury limitations for MSW combustion

Potential overall reduction (%)	Possible emission limit (μg/dscm @ 7% O_2)
91	63
96	28
99.5	3.5

and 80% control efficiency. This combined strategy results in an annual average emission limit of 28 μg/dscm at 7% oxygen.

3. Task Force recommendations

The task force recommended a two-stage standard for reducing mercury emissions from MSW incinerators. The first stage would establish a standard of 65 μg/dscm which should be achieved by 31 December 1995. It would be achieved by the implementation of source reduction and separation programs for waste materials containing significant quantities of mercury, and by the installation of new air pollution equipment. The second stage would be a mercury emissions standard of 28 μg/dscm which should be achieved by 1 January 2000 through additional and more effective source reduction and separation programs.

4. Documents released since the Task Force report was issued

The Task Force report was completed in June 1993. Since that time, two significant documents regarding mercury have been released by the NJDEP. These are: (1) new rules controlling mercury emissions from MSW incinerators, and (2) a report of a study of mercury concentrations in freshwater fish in New Jersey. Each of these is described below.

4.1. New rules

On 3 October 1994, the NJDEP adopted new rules and amendments for reducing mercury emissions. The new rules at NJAC 7:27, titled *Control and Prohibition of Mercury Emissions*, and related amendments to NJAC 7:27A-3.10, *Civil*

Administrative Penalties and Requests for Adjudicatory Hearings (the Penalty Code), apply to MSW incinerator owners and operators.

The new rules adopt the rules proposed 22 February 1994 [12] with minor modifications. They establish maximum allowable mercury emission limits for MSW incinerators. Such incinerators would be required to either reduce mercury emissions by at least 80% or achieve an emission limit that does not exceed 65 μg/dscm corrected to 7% oxygen by 1 January 1996, and an emission limit that does not exceed 28 μg/dscm corrected to 7% oxygen by 1 January 2000. The final text of the adopted rules was scheduled to be published in the New Jersey Register on 7 November 1994.

The proposed rules did not include requirements for source separation and source reduction, which would also be necessary for the numerical standards recommended by the Task Force to be achieved. In the discussion which accompanied the proposed rule as published in the New Jersey Register, however, it was stated that the NJDEP is developing a solid waste rule that would require New Jersey counties to submit specific plans and proposed time frames for the removal and separate management of consumer batteries, fluorescent light bulbs, thermometers, and thermostats.

4.2. Mercury in fish study

Also in early 1994, the NJDEP released a report titled Preliminary Assessment of Total Mercury Concentrations in Fishes from Rivers, Lakes and Reservoirs of New Jersey [13]. This report summarized a study in which a total of 313 freshwater fish were analyzed for mercury from 55 sites. Most of the specimens were largemouth bass or chain pickerel. Some smallmouth bass, catfish, trout, and bullheads were also analyzed. All specimens were above the legal catch size, and most were of moderate to large size, since these are the sizes most often used for human consumption. Mercury concentrations greater than the FDA criterion of 1.0 mg/kg wet weight were found in 50 fish, representing 15 of the 55 sites sampled. Largemouth bass ranged in concentration from 0.05 to 8.94 mg/kg. Chain pickerel ranged from 0.09 to 2.82 mg/kg.

Presently, the NJDEP is developing information and data on sources of mercury in New Jersey's environment which may not have been fully addressed in the earlier work of the task force, since it focused solely on in-state anthropogenic atmospheric sources. Potential present and historical inputs from sources including out-of-state sources, agriculture, and past industrial waste disposal practices are being investigated.

5. Additional considerations

While the NJDEP Mercury Task Force focused on control of mercury emissions from MSW incinerators, the conclusions and recommendations are transferrable to other heavy metal constituents of concern. Source reduction and source separation

Table 6
Total metals contents of bottom and combined ash of New Jersey MSW incinerators

	Cadmium (mg/kg)	Lead	Mercury
Bottom ash	21.2	1566	0.275
	(12.9–34.0)	(990–1976)	(0.00–1.0)
Combined ash	61.0	2173	6.5
	(39.0–82.0)	(1338–3500)	(4.0–8.4)

(Numbers in parentheses are ranges).

programs can help remove other heavy metal-containing products from the waste disposal stream, and thus reduce or remove impediments presented by heavy metals to the development of environmentally acceptable solid waste-derived products.

Concentrations of cadmium and lead, as well as mercury, are significant in MSW. Table 6 is a summary of a portion of a research project with which NJDEP is involved on the total metals contents of bottom and combined ash from MSW incinerators:

Bottom ash is the residue that remains on the grate after combustion. Combined ash includes bottom ash and fly ash, which is extracted from the flue gas stream through air quality control systems. As can be seen, there is a significant increase in the cadmium, lead, and mercury concentrations between the bottom and combined ash. This increase represents enrichment from the fly ash. On average, bottom ash makes up 90% of the total weight and fly ash represents 10%. Generally, MSW incineration results in a 75% by weight reduction of MSW (90% by volume reduction). Also, it can be assumed that, with the types of emissions controls in place in New Jersey, virtually all of the cadmium and lead in MSW is entrained with the fly ash or remains in the bottom ash. With mercury, as has been discussed above, present emissions technology is estimated to capture about 50% of the mercury in the waste. Thus it can be inferred that the approximate cadmium, lead, and mercury concentrations in MSW are 15, 500, and 3 mg/kg (ppm), respectively.

These numbers could serve as a base-line number for source reduction and separation programs. The second phase of the project will attempt to evaluate the efficiency of source reduction and source separation programs on this base line number.

Any use or reuse of solid waste in processes such as composting, materials recovery, or energy recovery which generates waste-derived products will result in a weight and volume reduction of the original waste, concentrating the metals. The use of such solid-waste derived products will likely be evaluated against current environmental standards. As is demonstrated in Table 7, the cadmium and lead, as well as mercury, concentrations in MSW must be decreased significantly before they can approach standards currently in place for media in which, or on which, waste-derived products might be used.

It is likely that the technology limit of source reduction will have to be identified and fully implemented to achieve the metal reductions which appear necessary. Identification and cost-assessment of the various alternatives for source separation will also be necessary if the best combination of source reduction and source

Table 7
Standards for three heavy metals in different media

	Cadmium	Lead	Mercury
Groundwater[a]	4 μg/l	5 μg/l	2 μg/l
Surface water[a]	10 μg/l	50 μg/l	2 μg/l
Drinking water[a]	5 μg/l	15 μg/l	2 μg/l
Sludge (HQ)[b]	39 mg/kg	300 mg/kg	17 mg/kg
Soils (R)[c]	1 mg/kg	100 mg/kg	14 mg/kg
Soils (NR)[c]	100 mg/kg	600 mg/kg	270 mg/kg

[a] Based on current NJDEP standards.
[b] Federal guideline; under review.
[c] NJDEP guidelines; under review.

separation is to be implemented. Such efforts will be most likely effective if costs and benefits of all significant aspects of the MSW-management are analyzed comprehensively including collection, transportation, processing, recycling, reuse, and disposal.

Acknowledgements

This report summarizes and, in some cases, restates the findings presented in the Final Report of the Task Force on Mercury Emissions Standard Setting, which was released in June 1993 by the New Jersey Department of Environmental Protection and Energy, Trenton, NJ [14]. The task force was comprised of representatives from business and industry, government, the scientific community, environmental groups, and other interested persons. It was chaired by Richard Sinding, Assistant Commissioner, and the project which resulted in the report was directed by Mary Sheil, P.P. The Environmental and Health Issues Subcommittee was co-chaired by Dr. P.H. Alan Stern and Joann Held. William O'Sullivan, P.E., and Iclal Atay, Ph.D., co-chaired the Technical and Regulatory Issues Subcommittee.

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