EXECUTIVE SUMMARY

Introduction

The effects of mercury exposure on human health and wildlife are driving a number of efforts to significantly reduce the level of this toxic, persistent, and bioaccumulative metal in the environment. Exposure to mercury, a neurotoxin, affects the brain and nervous system. The consumption of fish from waters contaminated with mercury offers the greatest risk of exposure to this pollutant. [TriTAC, 2001]

Increased monitoring of mercury in the water column and fish tissue and the application of more stringent standards (ranging from the California Toxics Rule (CTR) Saltwater Criterion (25 ng/L) to the proposed Maine Criteria (0.2 ng/L)) has led to increasingly stringent mercury effluent limits in NPDES permits.

Currently, approximately 6% (253 of 4307) of the major publicly owned treatment works (POTWs) in the United States have NPDES permits with mercury effluent limits and approximately 10% of the major POTWs (423 of 4307) have monitoring requirements (Morris, 2001). As more monitoring for mercury is conducted, the number of agencies with effluent limits is likely to significantly increase. Of the agencies with limits, several (particularly in the Great Lakes region) have limits based on the Great Lakes Initiative (GLI) Wildlife Criteria (i.e., 1.3 ng/L) and have had difficulty meeting these limits (EPA, 2001).

In order to comply with permit requirements, POTWs with effluent limits for mercury have investigated a variety of strategies, including non-regulatory approaches such as pollution prevention and source control, in an effort to achieve mercury reductions. National efforts to reduce mercury releases to the environment have already used source control and pollution prevention to target incineration of medical and dental wastes, disposal of consumer products (i.e., fever thermometers, thermostats, switches, fluorescent light bulbs) and dental office wastewater discharges.

In addition to source control and pollution prevention programs, mercury has also been the target of legislation. Legislation to restrict mercury use in consumer products and in certain other applications has been introduced at the federal level as well as in many states throughout the country.

While pollution prevention and source control are effective tools for reducing the amount of a pollutant entering the environment, several factors influence a POTW's ability to achieve mercury reductions and permit compliance using pollution prevention and source control. These factors include:

- Initial influent mercury levels;
- Percentage of the influent loading that can be attributed to specific sources;
- Ability of the POTW to control a particular source;

- Potential effectiveness and cost of the source control strategies employed;
- Form of mercury present in the influent (i.e., particulate vs. dissolved);
- Treatment plant removal efficiencies; and
- Final effluent limit that must be achieved and corresponding reduction needed to achieve this limit.

The purpose of this project was to,

1. Determine the extent to which pollution prevention and source control programs can achieve measurable reductions in POTW influent and if these reductions will enable POTWs to comply with new, lower effluent limits based on the criteria mentioned above. (Note: The term pollution prevention program, as used in this report, refers to a source control program that uses only voluntary approaches); and

2. Identify the beneficial impacts of wastewater source control programs on other pathways by which mercury enters the environment.

The following steps were taken to complete this assessment:

- Estimate mercury reduction achievable through source control;
- Assess ability of POTW to comply with effluent limits based on these reductions;
- Compare impact of implementing source control programs (cost) with impact of additional POTW treatment costs; and
- Identify benefits of source control programs in addition to impacts on wastewater treatment.

The procedure used and the results of this assessment are described in the following sections.

Procedure. This section describes the process, the assumptions and the data sources used in the analysis.

Results. The results of this analysis are presented with respect to estimated mercury influent loadings for each plant, reductions that may be achievable through pollution prevention, resulting effluent mercury levels and potential for each case study candidate to comply with future effluent limits. The impacts of the various assumptions made are also discussed in this section.

Findings. The implications of the results with respect to the potential effectiveness of mercury pollution prevention programs and regulatory impacts are discussed. The impacts on other media in addition to water are also considered. Limitations of the study are presented.

Conclusions and Recommendations. Overall conclusions are summarized. Recommendations for source control programs are presented. Areas requiring future study are identified.

Findings

The purpose of this project was to determine if pollution prevention and/or source control programs have the potential to achieve the reductions necessary to enable POTWs to comply with current and proposed NPDES permit effluent limits for mercury. The analysis conducted was based on the use of existing data. A variety of assumptions were necessary to apply the collected data to the POTWs used as case studies. As a result, this analysis has certain limitations. The findings regarding the effectiveness of mercury pollution prevention programs, the assessment of potential compliance, the impact of the assumptions made, and the limitations of the analysis are discussed below.

Effectiveness of Mercury Pollution Prevention and Source Control Programs

The effectiveness of mercury pollution prevention and source control programs may be considered with respect to the direct benefit of achieving reductions in wastewater influent. Mercury pollution prevention and source control programs may also achieve significant reductions in other waste streams resulting in overall reductions in mercury entering the environment. The benefits to other environmental media were not evaluated quantitatively in this study but several reduction opportunities were identified during this analysis.

Potential for Wastewater Reductions

Using the basic scenario described in this report (i.e., setting dental discharges to 0.056 g/dentist/day and human waste from amalgam to 17.2 µg/person/day), the analysis presented a number of findings with respect to wastewater mercury pollution prevention programs.

Influent load reductions for mercury achievable through pollution prevention activities for the POTW case studies on average ranged from 12% to 90% depending on the agency's existing pollution prevention efforts and the extent of additional pollution prevention conducted (i.e., pollution prevention or source control programs). For agencies like the Palo Alto Regional Water Quality Control Plant, Palo Alto, California and the Western Lake Superior Sanitary District (WLSSD), Duluth, Minnesota with mature pollution prevention programs, there is not much additional reduction available because most strategies have already been implemented. For example, both agencies have worked extensively with dentists and have high rates of participation/cooperation from the dental community with respect to implementation of recommended amalgam management practices. WLSSD has close to 100% cooperation from the dental community, so their influent and effluent concentrations used in the analysis reflect this level of participation. To project any further mercury reduction, source control strategies other than voluntary implementation of best management practices (BMPs) would have to be considered (i.e., regulation, and use of amalgam separators).

Average influent mercury concentrations for the POTW case studies prior to the pollution prevention considered in this analysis ranged from 106 ng/L to 323 ng/L. Average effluent concentrations prior to the pollution prevention considered in this analysis ranged from 3.1 ng/L to 9 ng/L. Maximum effluent concentrations ranged from 5 to 29

ng/L. Influent load reductions from pollution prevention resulted not only in effluent reductions but also in biosolids reductions, which may also have positive implications for POTW operations.

The largest source of mercury in wastewater influent is discharges from dental offices. The next largest sources are domestic sources (human waste, household products, and laundry graywater) and hospitals. Of the domestic sources, human waste is considered uncontrollable and laundry graywater is considered very difficult to effectively control. Household products are controllable to the extent that residents can be persuaded to stop using them or to the extent that their availability can be restricted through product bans. Legislative efforts to restrict the availability of certain mercury containing products may prove effective in reducing discharges from household products. The sources with the greatest potential for achieving measurable reductions in wastewater influent are dental offices and hospitals.

Benefits to Other Media

Another important benefit of pollution prevention programs, although not quantified in this report, is their beneficial impact on other media. Restriction or elimination of mercury-containing products (e.g., thermometers, thermostats, blood pressure cuffs) will also reduce the amount of mercury released to the environment through improper disposal as solid waste or medical waste (and then to landfills, incinerators, or steam autoclaves). Similarly, educating the dental community regarding proper disposal of amalgam wastes will reduce the amount of these wastes that are transferred to solid waste or infectious waste (which gets incinerated or autoclaved).

Other indirect benefits of wastewater source control and pollution prevention programs include increasing public awareness of mercury pollution issues and the potential to create partnerships with other agencies that have more direct control over certain waste streams and established communication vehicles. Increased public awareness may result in more successful legislative activity at both the state and federal level. Working with other agencies and businesses (i.e., health departments, solid waste programs, air programs, recycling companies, environmental organizations, etc.) may result in more widespread communication to both the general public and the business community that may result in behavior changes that achieve reductions in environmental releases.

Compliance Assessment

While measurable reductions are expected as a result of mercury pollution prevention programs, these reductions do not appear to have a significant impact on a POTW's ability to comply with the more stringent effluent limits evaluated in this study. However, pollution prevention or source control may result in adequate reductions to achieve permit limits under certain circumstances (i.e., reduction needed is reasonable, as in the case of achieving the 7.8 ng/L limit developed from the fish tissue criterion using default values). For limits based on the CTR (i.e., 25 ng/L), or other less stringent criteria (i.e., based on fish tissue criterion for rivers and streams, 17-18 ng/L), the case study POTWs could generally comply prior to implementing pollution prevention. For the Great Lakes Criteria (i.e., 1.3 ng/L), none of the POTWs were able to comply even

after the estimated reductions based on pollution prevention (all voluntary) efforts were calculated. One agency was able to comply on the basis of a source control/semi-regulatory program. For the intermediate standard of 7.8 ng/L, the two POTWs that could not comply prior to pollution prevention were projected to be able to achieve that level after the implementation of a source control/semi-regulatory program.

One of the limitations of this study is that it is theoretical in nature. There are very few examples of mercury source control programs that have been in place long enough to yield measurable results. However, some examples that may give an indication of the potential effectiveness of mercury pollution prevention and source control programs include the programs implemented by the Palo Alto Regional Water Quality Control Plant, Palo Alto, California, the Western Lake Superior Sanitary District (WLSSD), Duluth, Minnesota, and Metropolitan Council Environmental Services (MCES), St. Paul, Minnesota, and experiences in Denmark.

As noted previously, WLSSD and Palo Alto have both implemented most, if not all, of the recommended pollution prevention strategies described in this analysis. Source control strategies that have not been implemented include regulating dentists and requiring amalgam separators. Neither of these POTWs is able to consistently achieve effluent concentrations below 3.1 ng/L. Palo Alto's reported maximum and average effluent concentrations were 18.3 ng/L and 5.5 ng/L respectively and WLSSD reported maximum and average effluent concentrations of 29 ng/L and 4.7 ng/L respectively. Therefore, in these two communities pollution prevention has not been able to achieve very low mercury effluent levels.

MCES conducted a study, in cooperation with the Minnesota Dental Association, to assess the reduction of mercury levels in biosolids resulting from the installation and operation of amalgam removal equipment in dental clinics (Anderson, 2001). MCES obtained baseline data for mercury loadings in biosolids for two treatment plants (Hastings and Cottage Grove). Amalgam removal equipment was then installed in all the dental clinics in the Hastings service area and all but one dental clinic in the Cottage Grove service area. Mercury biosolids levels dropped 44% and 29% for the Hastings and Cottage Grove treatment plants respectively during the period when the removal equipment was in operation at the dental clinics. Because influent and effluent monitoring were not conducted for this study, no information is presented regarding the impact of amalgam removal equipment on treatment plant effluent levels of mercury. However, operation of amalgam removal equipment by dentists appears to have the potential to reduce biosolids mercury levels.

In Denmark, several POTWs have required dentists in their service area to install amalgam separators (Arenholt-Bindslev, 1999). Agencies were surveyed in 1999 to assess the effectiveness of this strategy with respect to mercury reductions. Out of 273 counties surveyed, 174 indicated that amalgam separators had been installed in all dental offices in the service area. Of these counties, 45 provided adequate data to calculate reductions in mercury levels in treatment plant biosolids after the separators had been installed. Approximately half of the agencies observed no statistically significant change

in biosolids levels after the installation of amalgam separators. Reductions ranged from 14% to 80% for those agencies experiencing measurable reductions (other than the one value at 14%, the range of the data was 32% to 80%). The Danish results indicate that the effectiveness of regulation and amalgam separators is highly variable. While significant measurable reductions were achieved in some cases, other cases resulted in no significant change.

The inability to achieve adequate mercury reductions to meet the more stringent effluent limits can be attributed to the uncontrollable influent sources (e.g., residential) and the effectiveness of voluntary programs. As noted previously, pollution prevention is voluntary. While regulatory approaches may be available for commercial sources they are labor-intensive and therefore only cost effective for the largest sources (i.e., dentists). Regulatory approaches are not available for residential activities because POTWs lack the legal authority to regulate domestic users. In addition, some domestic sources are essentially uncontrollable (i.e., human waste). Product bans are one approach that is being explored in several states, but their impact on wastewater levels of mercury remains to be seen. Overall there is a limit to the potential effectiveness of pollution prevention for residential sources. On average, residential sources accounted for approximately 25% of the influent loading. Therefore, even if commercial and industrial mercury discharges could be completely eliminated, the maximum reduction achievable is about 75%. For the more stringent effluent limits, reductions greater than 75% are needed for most agencies to consistently meet these levels.

The estimated annual cost of the pollution prevention program ranged from $250,000 to $350,000 depending on the size of the service area. The estimated annual cost of the source control program ranged from $300,000 to $700,000. Because pollution prevention was not adequate to achieve consistent compliance with a 1.3 ng/L standard, additional POTW treatment would also be necessary. The annual total cost of this additional treatment would range from $1.2 to $226 million per POTW depending on the size of the POTW and the reduction needed. Interestingly, the cost of treatment without pollution prevention was not all that different, ranging from $4.8 to $300 million annually.

Impact of Assumptions

The assumptions that influenced the results most heavily were the values assumed for dental discharges and human waste associated with amalgam. While the values assumed for these two parameters had a significant impact on the estimated load reductions and resulting effluent concentrations, they did not have a significant impact on the ability of POTWs to comply with effluent limits or the estimated cost to comply with these limits. Regardless of the values chosen, dental discharges accounted for the largest portion of influent loadings and, therefore, represent the source for which pollution prevention and source control efforts would be expected to be most effective with respect to measurable reductions.

Limitations of Analysis

Several assumptions were incorporated into the estimate of effluent mercury reductions achievable through pollution prevention. These limitations are listed below:

- Dental discharge data is primarily the liquid fraction of mercury measured in the lateral leaving the dental facility. While these values were measured as total mercury, they may underestimate the amount of mercury that leaves the dental facility each day because some of the mercury (as amalgam) will settle out and may leach back into the wastewater at a later date. Other studies have estimated that larger amounts of mercury may be discharged from dental offices. However, for the purposes of this calculation a conservative estimate of the amount of mercury that reaches the treatment plant was used. It was assumed that this quantity was best represented by the mercury in the liquid fraction (both smaller amalgam particulates and dissolved) leaving the dental facility, but this would need to be confirmed by further monitoring and research.
- The mercury levels from human waste are based on measurements of the human waste itself rather than the amount in the wastewater stream. These measurements are for total mercury, which may overestimate the amount that reaches the treatment plant influent.
- There is some uncertainty regarding total and dissolved mercury measurements and analytical techniques used for the measurements made both by the case study POTWs and by the agencies conducting analyses of sources that were used in this report. These uncertainties may decrease the confidence level associated with the mass balances. For instance, the 7470 digestion method, typically used for wastewater analysis, does not dissolve larger particles of amalgam and, therefore, would not generate an accurate measure of the mercury content. This is a concern for samples that are high in amalgam solids. However, the digestions used for wastewater dental samples (if they have relatively low solids content) are aggressive enough to dissolve the amalgam in the particles in these samples.
- The uncertainties regarding the form of mercury (i.e., particulate vs. dissolved) may also impact the levels of mercury estimated in the POTW influent and effluent and may, therefore, affect the mass balance determinations. These uncertainties will also impact the effectiveness of source control programs and other efforts seeking to reduce mercury effluent levels. If mercury is reaching the plant as larger particulates, it is likely to be removed in the grit chambers or it will enter the biosolids, not the effluent. Source control efforts that remove larger solids will not necessarily have much impact on influent and effluent levels. However, removal of larger particles still meets the goal of reducing the release of mercury into the environment. Overall, the form of mercury and how this affects its movement through the treatment plant requires further study to accurately predict the relationship between source control and effluent reductions.

Regardless of these limitations, discharges from dentists appear to represent the largest contributor to mercury influent levels. Human waste, while a significant source, represents a smaller contribution relative to dentists.

Another limitation of this analysis is the use of average removal efficiencies when calculating effluent concentrations based on influent reductions. There is some indication that POTW removal efficiencies will decrease as influent concentration decreases. The probability-based model, for example, predicts much lower effluent reductions than

influent reductions. A better correlation between removal efficiency and influent concentrations could increase the accuracy of this analysis.

This report only attempts to quantify mercury reductions in effluent and, to some extent, in biosolids. Other reductions in environmental releases of mercury were only evaluated qualitatively. It is possible that the reductions in releases to other media are equally significant and may merit further evaluation.

It must be recognized that this study was geared towards creating an 'average' community, in terms of size and potential sources of mercury. Some communities, especially smaller ones, may be more heavily influenced by sources such as schools and laboratories that were considered to be a small influence in the 'average' community approach.

This report is a theoretical study on the impacts of mercury source control efforts on POTW effluents. As noted above, there is very little experimental verification of predicted results because few POTWs have conducted extensive mercury source control programs over a long enough time period to determine the level of reduction that is achievable. For other pollutants, POTWs have found that, over a period of years, pollution prevention and source control can achieve significant reduction under the right circumstances (WERF, 2000).

Conclusions

The results of this study indicate that mercury source control and pollution prevention programs have the potential to achieve measurable reductions in POTW influent and to have positive impacts with respect to reducing other environmental releases of mercury. Source control and pollution prevention may also be effective in helping POTWs achieve effluent limits, assuming the required reduction falls within a reasonable range. The results of this study indicated that, based on the assumptions made, pollution prevention or source control are potentially effective in achieving sufficient reductions to enable POTWs to meet effluent limits that are 7.8 ng/L or greater. However, if more stringent effluent limits are in effect, such as the 1.3 ng/L limit that has been imposed on POTWs in the Great Lakes Region, pollution prevention or source control with no treatment process modifications will not be effective in achieving these limits.

Regardless of the potential for meeting effluent limits through pollution prevention and source control alone, these efforts have many benefits as described in this report and should be an essential tool in any mercury reduction effort. Reduction of mercury at its sources will have positive impacts for wastewater influent and biosolids and for other media.

Pollution prevention efforts targeting sources of mercury should focus on dental offices and medical facilities (hospitals) to have the greatest potential for achieving measurable reductions. With respect to dental offices, implementation of BMPs on a voluntary basis is recommended as the initial approach. However, if additional reductions are needed, regulatory approaches and the required installation of treatment should be considered.

For hospitals and medical facilities, implementation of BMPs and purchasing policies promoting non-mercury-containing items has proven effective.

Recommendations

Additional study of the relationship between influent mercury concentrations and removal efficiencies through the treatment plant would help clarify the relationship between influent reductions and resulting effluent concentrations. Additional study is also needed with respect to the portion of mercury present in wastewater in solid form and in liquid form. The form of mercury present in wastewater will have a significant impact on its travel through the treatment process and the reductions that are ultimately achievable as a result of source control and pollution prevention efforts.

To gain a more complete understanding of mercury sources in wastewater treatment plant influent, a more comprehensive effort to assess total mercury discharges from dental offices should be conducted. In addition, research that more directly measures mercury in wastewater resulting from human wastes should be conducted.

To further assess the feasibility of reducing mercury levels in laundry graywater, research could be conducted to ascertain the origin of mercury in the graywater (i.e., does it come from dirt or clothing dyes).

Recommended practices for larger sources such as dentists may have a significant impact on the magnitudes of reductions achievable by these sources. Certain practices will have greater impacts than others will. For example, there is a lot of improper screen disposal/handling at dental offices. It would be helpful to have a standard protocol for disposal/handling and to get cooperation from state agencies to aid in disposal to facilitate implementation of BMPs by dentists and other sources.