Association of
Metropolitan
Sewerage Agencies

December 7, 2001

W-00-31-II TMDL Comments Clerk
Water Docket (MC-4101)
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., N.W.
Washington, DC 20460

Re: *Notice of Availability of a Draft Report on Costs Associated With the Total Maximum Daily Load Program and Request for Comments, 66 Fed. Reg. 41,875 (August 9, 2001)*

Dear Sir or Madam:

The Association of Metropolitan Sewerage Agencies (AMSA) is pleased to provide comments on the U.S. Environmental Protection Agency's (EPA's) draft report entitled *The National Costs of the Total Maximum Daily Load Program* (*Draft Report*). Founded in 1970, AMSA represents the interests of over 260 of the nation's publicly owned wastewater utilities (POTWs). AMSA members serve the majority of the sewered population in the United States and collectively treat and reclaim over 18 billion gallons of wastewater every day. As key stakeholders in the total maximum daily load (TMDL) program, AMSA's member agencies have firsthand knowledge of the real costs associated with implementing the program. In fact, costs to POTWs are one of the most critical variables, requiring careful evaluation when estimating the total cost of the TMDL program.

The TMDL program seeks to achieve the attainment of water quality standards in water bodies where current, technology-based approaches have not remedied the impairment. Though envisioned as a program driven entirely by the quality of the nation's waters, the success of the TMDL program is also affected by underlying resource constraints and competing priorities at all levels of implementation. Therefore, development of an accurate estimate of the costs associated with data gathering, listing water bodies, developing TMDLs, and implementing TMDLs successfully is a critical first step in understanding and then managing this fine balance of resources.

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Since the *Draft Report* was published in August, AMSA has worked cooperatively with other clean water stakeholders to closely evaluate EPA's methodology and underlying assumptions to ensure that the *Draft Report* adequately characterizes the real costs of the TMDL program. This review uncovered a number of assumptions EPA made in the study regarding POTWs that are of concern to AMSA. AMSA's primary concerns are summarized briefly below and discussed in more detail in the attached report (See Attachment 1).

- In developing its cost estimate for TMDL program implementation, EPA inaccurately assumed two limitations on the number of POTWs that would incur additional TMDL costs:

  - First, the *Draft Report* assumes that POTWs with treatment beyond secondary treatment already in place will incur no additional TMDL costs. AMSA believes this assumption is inappropriate. The presence of advanced treatment at a POTW does not automatically mean that future upgrades will not be required to address sources of impairment. For example, a POTW with some degree of advanced treatment may remove nitrogen, but not phosphorus. If phosphorus were causing the impairment, additional potentially costly upgrades at the POTW would be required.

  - Second, the *Draft Report* assumes that any POTWs with planned upgrades associated with the 1996 Clean Water Needs Survey will incur no additional TMDL costs. Again, there is no evidence that these upgrades will be sufficient to meet TMDLs for all impairment categories. For example, these upgrades may address impairments such as nitrogen, phosphorus, and biological oxygen demand (BOD), but may not provide treatment for metals, low concentrations of phosphorus, or specific organics, which could be the reason for impairment.

Two examples will help further illustrate the effect these assumptions will have if included in the final cost estimate.

- First, consider the Saugus and Valencia Water Reclamation Plants in the Santa Clara River Watershed in California. Both of these facilities are owned and operated by the Sanitation Districts of Los Angeles County (Districts). They provide tertiary treatment for 19.1 million gallons per day of wastewater that primarily comes from residential sources. Based on the assumptions in the *Draft Report*, because these plants provide treatment beyond secondary treatment, there would be no additional costs due to TMDL implementation. However, that is clearly not the case.

  These facilities discharge into the Santa Clara River, an effluent dominated (dependent) water body that has been placed on the 303(d) list for chlorides. While the chloride TMDL has not yet been approved by the local water quality control board or EPA, a draft TMDL cites a receiving water objective of 100 mg/L for chlorides. The two primary sources of chlorides to the Districts' facilities are water supply and residential self-regenerating water softeners, neither of which is amenable to source control. In order to comply with this TMDL, the Districts would need to install a combination of microfiltration, reverse osmosis and ultraviolet radiation (disinfection) to treat the plants' effluent. The Districts would also have to construct a 46-mile brine line and a 3-

mile outfall to dispose of the brine generated by the membrane treatment processes. Based on the projected design flow for these facilities (28.1 million gallons per day), complying with the proposed chloride TMDL will cost a total of $371 million. Thus, despite the fact that these facilities provide treatment beyond secondary, they will incur substantial costs from TMDL implementation.

- Second, the City of Los Angeles, California is currently facing implementation of the Los Angeles River Trash TMDL. Estimates for meeting the zero-discharge standard have been placed at approximately $736 million dollars over a ten-year period. Total capital costs are estimated at $409 million (for installation of a full-capture unit at every City-owned outlet emptying into the river and its tributaries), with operation and maintenance over the ten year period costing $327 million. These costs will be incurred regardless of the level of treatment employed or any planned system upgrades.

AMSA believes these assumptions regarding the number of POTWs affected by the TMDL program are inappropriate and should not be included in the final cost estimate, or at a minimum examined in more detail on a case-by-case basis. Without these limiting assumptions, EPA's annual cost estimate increases by $1.0 to $1.3 billion, an increase of approximately 40 percent. (See Attachment 1, Pages 5 and 13)

- The *Draft Report* assumes that additional pretreatment controls alone will be adequate to enable POTWs to meet TMDLs for metals. The *Draft Report* addresses metals reductions solely through tighter controls for indirect dischargers. EPA used or assumed the industrial flow contribution to the affected POTW and assumed that effluent filters would be used at the industrial discharge to provide additional metals removal. Costs associated with these controls were included in the estimate. Unfortunately, this assumption does not reflect the current state of metals loadings to POTWs. For example, with mercury (which is not specifically addressed in the *Draft Report*, see below), one of the major sources of loadings to POTWs is domestic wastewater (See Attachment 2; *Evaluation of Domestic Sources of Mercury* (August 2000)). In addition, there are examples of pollution prevention programs that target metals such as copper, lead, and zinc where the programs were able to obtain substantial reductions, but were not adequate to impact influent levels (*The West County, CA Vehicle Service Program, Water Environment Research Foundation. Tools to Measure Source Control Program Effectiveness. Project 98-WSM-2*) or achieve compliance with water quality based effluent limits (*The Palo Alto Copper Reduction Program, Palo Alto Regional Water Quality Control Plant. Clean Bay Plan. 1994, 1995, 1999, 2001; and The Novato Sanitary District Copper Reduction Program, Water Environment Research Foundation. Tools to Measure Source Control Program Effectiveness. Project 98-WSM-2*). Given existing pretreatment controls and local limits established by POTWs, additional industrial effluent controls for metals may have very little effect on total metals loadings to POTWs. Accordingly, AMSA recommends that EPA's final cost estimate reflect costs associated with end-of-pipe treatment for metals at POTWs. (See Attachment 1, Page 12)

- The *Draft Report* addresses five impairment categories: nutrients, ammonia, metals, BOD/dissolved oxygen, and toxic organics. AMSA believes an accurate cost estimate must include costs for the

treatment of mercury, temperature, and salinity impairments. Although many of the existing mercury impairments may be attributable to legacy mercury or air deposition, current implementation of the TMDL program relies heavily upon point sources to reduce mercury in their discharges. The cost to treat mercury to low effluent levels is not insignificant and efforts to decrease the amount of mercury discharged, either through treatment or other means, should be reflected in the Agency's cost estimate. In addition, POTWs in the Pacific Northwest are dealing with stringent temperature guidelines that will require costly upgrades associated with the TMDL program. EPA's cost estimate must acknowledge this and other regional temperature requirements that may result in necessary upgrades. Finally, many parts of the Southwest are dealing with impairments based on salinity (e.g., chlorides or total dissolved solids) that will require costly treatment upgrades to achieve water quality standards, particularly for effluent dependent water bodies. (See Attachment 1, Pages 7-9)

The attached document provides additional explanation of these POTW-specific concerns, discusses other more fundamental assumptions of the *Draft Report*, and examines how these issues impact the overall accuracy of EPA's cost estimate for the TMDL program. AMSA feels strongly that these issues must be resolved to ensure the Agency's final cost estimate accurately characterizes the real costs of the TMDL program.

Thank you again for the opportunity to comment on this critical effort. Without an accurate cost estimate, it will be impossible for EPA to determine the most effective course for reforming and implementing the TMDL program. AMSA looks forward to continued discussions with the Agency on this matter. If you have any questions about our comments please do not hesitate to call me at 202/833-4653 or Chris Hornback at 202/833-9106.

Sincerely,

Ken Kirk
Executive Director

ATTACHMENTS

ANALYSIS AND EVALUATION OF THE EPA COST ESTIMATE FOR IMPLEMENTATION OF THE TMDL PROGRAM

Prepared for:

FEDERAL WATER QUALITY COALITION

and

ASSOCIATION OF METROPOLITAN SEWERAGE AGENCIES

Prepared by:

THE ADVENT GROUP, INC.

December 2001

Innovative solutions to environmental challenges

THE ADVENT GROUP, INC.

December 6, 2001

Mr. Fred Andes
Barnes & Thornburg
2600 Chase Plaza
10 South LaSalle Street
Chicago IL, 60603

Subject: **Analysis and Evaluation of the EPA Cost Estimate for Implementation of the TMDL Program**
ADVENT Project 01657

Dear Mr. Andes:

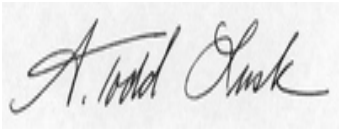
The ADVENT Group, Inc. (ADVENT) is pleased to present this draft report of the *Analysis and Evaluation of the EPA Cost Estimate for Implementation of the TMDL Program*.

Please do not hesitate to call us at (615) 377-4775 ext 133 to discuss any comments or revisions regarding this document.

Sincerely,

The ADVENT Group, Inc.

Sam E. Shelby, Jr., P.E.
Senior Vice President



Todd Lusk
Project Engineer

EXECUTIVE SUMMARY

In August 2001, the EPA issued a draft report on the estimated costs for implementation of the Total Maximum Daily Load (TMDL) program, including the basis used for determining this estimate. The EPA determined costs for three different implementation scenarios, which varied in their flexibility and cost-effectiveness. The final annual costs presented in the draft report for NPDES dischargers ranged from $625 million to $2.18 billion, depending on the scope of the TMDL program and the cost effectiveness of the implementation scenario used.

The ADVENT Group, Inc. (ADVENT), at the request of the Federal Water Quality Coalition and the Association of Metropolitan Sewerage Agencies, has reviewed EPA's cost approach. ADVENT has identified a number of significant concerns regarding the EPA's assumptions and methodology, which lead to substantial underestimation by EPA of the costs to implement TMDLs. ADVENT believes that these issues, which are detailed in this report, should be addressed in the EPA's final cost estimate. Here are some of the key findings of the report:

- EPA excluded certain POTWs from its cost estimates. If POTWs already had treatment capacity beyond secondary treatment in place or had an upgrade project underway or were planning for an upgrade, they were excluded from the TMDL cost estimate. There is no technical basis for assuming that these facilities will incur no TMDL-related costs.

- For industrial facilities with high reported flows, EPA assumed that concentrated process wastewater could be segregated from cooling water and storm water for separate treatment, and assigned an assumed "maximum" value to such flows. Also, EPA assumed that cooling water flows will not be subject to any TMDL-related control requirements. No justification was provided for the flow segregation approach, the "maximum" flow values or the cooling water assumption. These aspects of EPA's approach will likely lead to significant underestimates of TMDL-related costs.

- Capital cost functions used by the EPA do not address specific treatment technologies for the pollutants examined. Furthermore, these functions, based on costs of municipal treatment plants, were also applied to industrial facilities. ADVENT challenges the validity of using municipal cost databases for estimation of industrial upgrade costs.

- The EPA's assumption that POTWs can meet TMDL-based limits for metals by requiring pretreatment of industrial flow is inappropriate. In many cases, POTWs already have such systems in place and/or receive a majority of their influent metals from non-industrial flows. The additional treatment that would be needed in those cases to meet TMDL-based limits has not been included in EPA's estimate.

- No costs were developed for the treatment of pesticides, mercury, or PCBs, even though dischargers will likely incur substantial treatment costs due to TMDLs for these pollutants.

- The discount rate and implementation timeframe used for discounting final costs are considered excessive, leading to underestimation of TMDL costs, and should be re-evaluated.

These issues, and the others identified in the body of this report, should be addressed by EPA before it issues its final TMDL cost report, so that the estimates for TMDL implementation costs that are included in that document are technically sound, based on reasonable assumptions, and reflect a more realistic view of the costs that will be incurred by regulated parties due to TMDL-based requirements.

ANALYSIS AND EVALUATION OF THE EPA COST ESTIMATE FOR IMPLEMENTATION OF THE TMDL PROGRAM

INTRODUCTION

The Total Maximum Daily Loading (TMDL) program originated from Section 303 of the 1972 Clean Water Act. The purpose of this program is to establish the limits on discharges that reflect the maximum pollutant loading a given waterbody can receive and still meet its water quality standards. From this, loads will be allocated to the sources of those pollutants. In recent years, there has been an effort to begin developing and implementing TMDLs for the waterbodies that do not meet their water quality standards. In August 2001, the EPA issued a draft report[1] with its TMDL cost estimate and basis. These costs included the additional capital and operating costs of upgrading wastewater treatment plants to achieve compliance with new or revised effluent limitations for point source dischargers resulting from the new TMDL program. Prior to this, the ADVENT Group, Inc. (ADVENT) had been retained by the Federal Water Quality Coalition (FWQC) to develop an order-of-magnitude cost estimate for implementation of the TMDL program. This cost estimate and the basis for its development was presented to the EPA in January 2001[2] as an independent evaluation of the projected TMDL implementation costs. Recently, upon request from the FWQC and the Association of Metropolitan Sewerage Agencies (AMSA), ADVENT was also retained to review these cost estimates, compare methodologies employed by the EPA and ADVENT, and provide comments on the differences. This report will summarize ADVENT's review of the EPA draft report and its support documents.

In the original report supplied to the FWQC, ADVENT estimated a 10-year cost for all NPDES permitted direct dischargers of $20 to $80 billion in January 2001 dollars. Upon review of its original calculations, ADVENT revised its estimate to a 10-year cost of $17 to $68 billion, or an average annual cost of $1.7 to $6.8 billion. In comparison, the EPA draft report projected an annual cost estimate for point source dischargers of $0.6 to $2.2 billion in January 2000 dollars, depending on the flexibility of the TMDL approach.

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[1] *The National Costs to Implement TMDLs (Draft Report)*. U.S. Environmental Protection Agency, EPA 841-D-01-003, August 1, 2001.

[2] *Projected TMDL Compliance Costs for Point Source Dischargers*. The ADVENT Group, Inc., January 15, 2001.

In addition, the EPA reported a total cost of $0.9 to $4.3 billion for implementation of TMDLs on point sources and nonpoint sources combined. In order to ensure consistency between the two cost estimates, for this report, each estimate will be examined in terms of its average annual cost.

SUMMARY OF ESTIMATION APPROACHES

In developing their initial cost estimates for the TMDL program, both ADVENT and the EPA used the same list of 21,845 impaired water bodies, as listed in the 1998 EPA 303(d) List Fact Sheet. As shown below, both parties categorized the list of pollutant categories, defined the "next treatment step" needed to upgrade effluent quality, and developed costs for those additional upgrades. Due to time and cost limitations, ADVENT developed its cost estimates using a broad, generalized approach based on compiled nationwide flow, while the EPA developed costs on a waterbody-by-waterbody basis. Both estimates used discharge flow data taken from the Permit Compliance System (PCS) database for direct dischargers. Although similar approaches were used, there were significant differences as described herein, particularly in the specific pollutant categories addressed and the definition of the "next treatment step" and associated costs.

Cost estimates from both reports were segregated into two categories: POTWs and industrial dischargers. EPA segregated both categories into major and minor dischargers, while ADVENT segregated only the industrial dischargers to examine power plants and non-power sources. The EPA further segregated industrial dischargers into all direct discharges and indirect dischargers involving metals pretreatment for POTW discharges. To provide a range of values for their estimates, ADVENT assumed cost reduction factors of 25% for pollution prevention and source control programs, and 25% for costs which would overlap upgrades not related to TMDL compliance. ADVENT also assumed in its January 2001 report that its estimate may be as much as 50% higher or 50% lower than the calculated costs. In contrast, the EPA used alternate TMDL implementation approaches identified in the draft report as "Least Flexible," "Moderately Cost Effective," and "More Cost Effective."

Tables 1 and 2 summarize the average annual costs developed by ADVENT and the EPA for the two categories listed above. For the case of POTWs, the EPA report assumed two limitations on the number of POTWs incurring additional TMDL costs, which the ADVENT report did not. These limitations are as follows:[3]

1. Any POTWs with treatment beyond secondary treatment already in place will incur no additional TMDL costs; and
2. Any POTWs with upgrades associated with the 1996 Clean Water Needs Survey (CWNS) will incur no additional TMDL costs.

The August 2001 cost estimate reported by the EPA assumes both of these limitations are in place, although cost estimates for POTWs were reported for the case of one or both limitations being dropped. However, ADVENT believes that these limitations on POTWs are far too broad and do not reflect actual conditions. The net effect of dropping these limitations is a projected increase of $1.0 to $1.3 billion in the annual cost estimate. This correlates to an increase in the EPA estimate of approximately 40 percent.

In addition to these limitations, the EPA assumed that no TMDL implementation costs would be incurred by direct dischargers for the treatment of mercury, pesticides, or PCBs to address water bodies known to be impaired by these parameters. ADVENT believes that significant costs will be incurred by direct dischargers to address such impairments and has included these costs in its estimates. A discussion on the rationale behind these assumptions will be addressed later. For the basis of comparison, the ADVENT cost estimates are shown both with and without the costs associated for treatment of these three pollutant categories.

In addition to cost estimates by POTWs and industrial dischargers, ADVENT also reported a breakdown of average annual costs by impairment category. These estimates are shown in Table 3. For comparison with the EPA's cost estimates, total costs are shown with and without the treatment of mercury, pesticides and PCBs. The exclusion of treatment for these three categories results in a $2.9 billion decrease in average annual cost, or approximately 43% of the original ADVENT estimate.

[3] *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, pg. II-6.

In addition to developing capital and operating costs as described above, each party developed annual costs for the TMDL required upgrades in current dollars per year (January 2001 for ADVENT and January 2000 for the EPA). Although there were slight differences in the methods and factors used in annualizing the capital costs, these differences can readily be addressed. More significantly however, since the upgrades will likely be implemented over a 15-year period beginning in about 5 years, the EPA costs were discounted to reflect the "present value" of these future capital and operating costs. The net effect of this discount or adjustment was a significant reduction in annualized costs as compared to the approach utilized by ADVENT. These "economic adjustments" will be further discussed herein.

Both ADVENT and the EPA selected several impairment categories for which they each believed that further controls would not be required of point source dischargers. A brief rationale for excluding point source upgrade costs on these impairment categories is indicated in the list below:[4]

1. pH – both ADVENT and the EPA agreed it is unlikely that significant costs would be incurred by point source dischargers operating under Best Practicable Control Technology (BPT) to correct pH impairments. In fact, the EPA stated there were only 8 water bodies impaired by point sources due to pH.

2. Temperature – both parties initially agreed that any point source problems associated with temperature should be remedied by BPT. However, further review indicates that there may be additional issues to address concerning temperature control. This will be further discussed herein.

3. Clean Sediments – both parties initially agreed that it is rare to have point source process water discharges worth controlling beyond BPT. In addition, there will be additional storm water and construction technology-based requirements. However, a large number of waterbodies are listed for impairment due to clean sediment, and the technology-based requirements may not remedy all of these impairments. Therefore, control of point sources for clean sediments may require examination.

4. Pathogens – both parties agreed that pathogen impairments potentially arise due in part to wet weather discharges, such as

[4] Derived from *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, Appendix C.

combined sewer overflows (CSOs). However, a large number of waterbodies are listed for pathogen impairments, and control of CSOs may not remedy all of these impairments. Control of point sources for pathogens may require examination.

5. CSOs – both parties excluded costs for additional CSO controls from these estimates.

6. Specialized Pollutants (Chlorine, Cyanide, and Dioxins) – both parties excluded costs to address these impairments in their original cost estimates, but these items remain potential candidates for inclusion in a revised estimate.

Further details and comparative information on the basis for the cost estimates developed by both parties is presented in the following sections.

BASIS FOR COST ESTIMATION

Impairment Categories

Both ADVENT and the EPA developed costs for a list of broad impairment categories. As previously indicated, the 1998 Section 303(d) List Fact Sheet lists 21,845 impaired waters with 41,318 associated impairments in over 200 different categories. By combining similar impairments, the EPA condensed this list into 15 categories comprising 91% of the total impairments. Using this information, ADVENT devised a list of seven categories likely attributable to point source discharges, which included approximately 45% of all impairments. In comparison, the EPA chose five categories for which point sources would require further controls. The lists below show the differences in the impairment categories examined:

ADVENT Impairment Category	EPA Impairment Category
Nutrients	Nutrients
Ammonia	Ammonia
Metals	Metals
Dissolved Oxygen (DO)	BOD/DO
Toxic Organics	Toxic Organics
Pesticides	
Mercury/PCBs	

For pesticides, the EPA indicated that it considered very few point sources were worth controlling beyond Best Available Treatment (BAT), citing that there was no indication of which Standard Industrial Category (SIC) contained the majority of the point source

impairments. PCBs were considered by the EPA to be a legacy pollutant rather than an ongoing discharge requiring any control beyond BAT. A discussion with Environomics,[5] the EPA contractor who assisted in developing the EPA costs, indicated that some treatment for mercury was included in the filtration treatment technology for other metals, but that specific mercury treatment to achieve low effluent levels was not included. However, as previously mentioned in Table 3, the ADVENT cost associated with the treatment of these three impairments is substantial, particularly in the case of mercury and PCBs. As discussed below, ADVENT believes that TMDLs for mercury and PCB impairments will likely address ongoing discharges even if those sources are minor. Those TMDLs may require direct dischargers to implement costly control upgrades. ADVENT therefore believes it is critical to include these pollutants in future cost estimates.

Concerning pesticides, ADVENT believes that the number of point sources discharging into waterbodies impaired by pesticides is not insignificant. The EPA identifies 971 such point sources discharging into waterbodies impaired by both nonpoint and point sources, and an additional 24 sources discharging into waterbodies impaired by point sources only. Any facility that manufactures, formulates, or handles pesticides could be considered a potential match for treatment upgrades. In its original cost estimate, ADVENT used a combination of granular activated carbon and granular media filtration to address pesticide treatment, a system that requires substantial capital and operating costs. ADVENT believes that pesticides should be addressed in the TMDL cost estimate because of this impact.

Concerning mercury and PCBs, ADVENT again believes that the large number of point sources identified is not insignificant. Both of these pollutants can now be detected down to extremely low levels, and are now known to be present in a large number of discharges. Although a TMDL conducted on the Savannah River indicates that only 1% of the mercury loading was attributed to point-source discharges, the EPA still required these dischargers to either develop a pollution minimization plan or provide treatment to meet an effluent limit of 2.8 parts per trillion (ppt). Treatment for mercury and PCBs requires a complex and expensive treatment train. As the control requirements for these pollutants continue to become more restrictive and result in lower and lower discharge

[5] Conversation with Stuart Sessions, Environomics. November 7, 2001.

limits, treatment costs will increase dramatically. The assignment of these costs to even a small number of facilities could represent a substantial increase in the overall TMDL cost estimate.

Flow Basis

ADVENT assumed that approximately 40% of all NPDES discharged flow would require upgrades to treat the impairment causes listed above. This value is based on the EPA's determination that the approximately 22,000 waterbodies requiring TMDL determinations represent approximately 40% of the nation's waterways that were surveyed and reported in the 1998 Report to Congress. Combining this with the assumption that 45% of the impairments are due to point source discharges, approximately 18% of the total discharge flow will require additional treatment. To compute upgrade costs for POTWs, ADVENT assumed an average flow of 2.7 mgd based on a total flow of 41,794 mgd from 15,711 POTWs, as indicated in the 1996 CWNS. For industrial dischargers, ADVENT used data from the PCS database on 13 available states and assumed that this data represented 39.9% of the total industrial flow since the 13 states examined represent 39.9% of the total population. Using this data, ADVENT assumed an average flow of 444 mgd for power plants (88% of total industrial flow) and 21.9 mgd for other industrial plants (12% of total industrial flow). In summary, ADVENT developed upgrade costs for approximately 24,650 mgd of flow. This value includes 7,250 mgd of additional flow from POTWs, 12,200 mgd of additional flow from power plants, and 5,200 mgd of additional flow from other industrial plants.

In contrast, the EPA chose to evaluate costs on a waterbody-by-waterbody basis, using the same data from the 1996 CWNS and PCS databases. Apparently, a good deal of work went into identifying the direct dischargers to or within 50 miles upstream of each impaired waterbody, determining (particularly for direct dischargers) whether the discharger was a likely contributor to the cause of the impairment, and determining the flow and effluent quality of those dischargers. Limitations and gaps in these databases made this a difficult effort[6] and also required a significant number of assumptions to be

[6] *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, Appendix F.

made. An example is indicated in the support documentation for the TMDL draft report,[7] where it is reported that 2.6% of the facilities had zero reported flow, and over 55% of the facilities had no flow reported in either database. For the case of a facility with zero flow, the EPA assumed that this facility was correctly reporting its flow as zero (possibly land treatment facilities or similar). This assumption may be valid but should be verified on a case-by-case basis.

For facilities with no flow information, the EPA assigned an average flow based on all reported flows within the facility's SIC. For the case where a given SIC has no facilities with reported flow, the EPA assigned an average flow observed in its combined database for major or minor industrial plants, or major or minor POTWs. Because of the large number of facilities with no reported flow, the validity of using these average flows is considered questionable. The overall impact of these assumptions on the final EPA cost estimates cannot be easily determined.

For the "within and upstream" case, the total flow treated in the TMDL program was estimated by Environomics[8] to be approximately 14,700 mgd. This value was provided with an estimated error of +/- 20 percent. The total flow of 14,700 mgd includes treated flows of 5,400 mgd for POTWs and 9,300 mgd for industrial dischargers. The total flow treated by the EPA is considerably lower than the ADVENT flow estimate, largely due to the limitations placed by the EPA on the number of POTWs included and the decision of the EPA not to include treatment costs for cooling water at power plants. If the ADVENT flow estimate for power plant flow per facility is deleted, the total ADVENT flow is lowered to 12,500 mgd, which is within the 20% margin of error reported for the total flow treated in the EPA estimate. However, if the POTW limitations imposed by the EPA are dropped, the total flow treated in the EPA estimate may be as high as 18,400 mgd, or potentially higher.

Treatment Technology Basis

In addressing the technology requirements for TMDL implementation, both ADVENT and the EPA used the "next treatment step" approach; i.e., that a given facility would require

[7] *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, Appendix F, pg. F-1.

additional treatment technology above its current capability based on the pollutants needing treatment. Both ADVENT and the EPA determined treatment technologies based on their respective lists of impairment categories. These technologies are listed in Table 4.

As shown in Table 4, ADVENT defined a specific treatment train to upgrade current effluent quality to address specific pollutants. Although exact upgrade requirements will depend on results of each specific TMDL, the ADVENT "treatment trains" generally provide the best available treatment technology for each pollutant/impairment category. However, based upon the EPA TMDL draft report and discussions with Environomics, the EPA did not use a "treatment train" approach in defining the "next treatment step." Rather, the EPA used capital cost functions from the 1996 Clean Water Needs Survey to achieve higher effluent quality levels. For instance, to address nutrient impaired waterbodies, EPA assumed TMDL nutrient upgrade costs would be based on upgrading POTWs from secondary treatment or advanced secondary treatment to also include "nutrient removal." The CWNS includes a database of POTW upgrade costs to address known or projected upgrade needs. These costs are based on actual costs, engineering estimates if available, or can be based on less accurate cost projections. Although these functions were developed based only on cost information from POTWs, they were applied to industrial facilities as well. Based on experience in the design and costing of upgrades at both industrial and municipal wastewater treatment plants, ADVENT strongly questions whether the CWNS cost functions used by the EPA are applicable for industrial upgrades. Upgrade costs are grouped into certain categories as shown in Table 4 regardless of the technology used. Even though these cost functions do not state what specific effluent quality can be expected or what treatment approach is utilized, it was considered "representative" for upgrading plants to include "nutrient removal." Different functions were used for plants with different flow rates and O&M costs were separately determined. Nevertheless, this capital cost approach has obvious flaws. The particular items of concern regarding the use of these cost functions are discussed below.

For nutrient impairments, ADVENT selected the "next treatment step" for control of both nitrogen and phosphorus. For nitrogen, ADVENT selected a "treatment train" that

[8] Conversation with Stuart Sessions, Environomics, November 27, 2001.

includes biological nitrification and denitrification. For phosphorus, ADVENT selected a "treatment train" that includes precipitation, clarification, and filtration. In certain cases where receiving stream water quality limitations are such that point sources are now required to control phosphorus, very low effluent levels are being imposed and the advanced treatment train mentioned above is being required. We are concerned with the uncertainty regarding the treatment technologies in the EPA approach, particularly for phosphorus removal, and feel this could well lead to significantly low costs in the EPA's estimate in this area.

For ammonia-impaired waters, ADVENT selected the "treatment train" that includes biological nitrification and denitrification as the "next treatment step." For DO/BOD-impaired waters, ADVENT selected the relatively low-cost effluent reaeration technology as compared to "Advanced Treatment 1" selected by the EPA, although it is unclear exactly which treatment technologies were included or costed by the EPA. For toxic organic impairments, ADVENT selected filters and granular activated carbon column technology, whereas EPA selected "Advanced Treatment 1." Because the specific treatment technologies included in this category are unclear, ADVENT cannot determine whether such a selection is appropriate; however, we contend that additional technology beyond advanced secondary treatment is likely to be needed to address impairments caused by specific organic compounds. Many organic compounds are recalcitrant to biological treatment and require a more complex treatment train, such as carbon adsorption.

Significant differences were found in the approach used by POTWs for discharges to waters with metals impairments. For this, ADVENT selected advanced chemical precipitation, clarification and effluent filtration at POTWs as compared to the EPA approach to reduce metals discharges through tighter controls for indirect industrial dischargers. For this, EPA used or assumed the industrial flow contribution to the affected POTW and assumed that effluent filters would be required at the industrial discharge to provide additional metals removal. However, discussion with AMSA has indicated that many of its member facilities already have strict pretreatment programs for industrial metals dischargers in place. Furthermore, AMSA estimates that a significant portion of the influent metals loading (approximately 75-80% of such metals as Cu, Zn, and Cd) at such POTWs come from domestic sources rather than controllable industrial

dischargers. A study conducted by AMSA indicates that domestic wastewater is a major source of mercury loading at POTWs. Based on this information, ADVENT believes that the EPA's approach for metals control at POTWs has been incorrectly determined. We feel the correct approach is to specify the "next treatment step" to include advanced metals treatment at each POTW. The treatment train costed by ADVENT for this includes advanced chemical precipitation, clarification, and filtration.

Another item of concern is whether the EPA included costs for handling and disposing of the additional sludge that would be generated by the TMDL-related treatment upgrades. ADVENT included costs for additional sludge dewatering and landfill disposal in its estimates, and it is unclear whether such costs are incorporated into the EPA estimates.

In addition to the differences in technologies chosen for TMDL compliance, there are observable differences in the methodologies chosen by ADVENT and the EPA to implement them. As previously mentioned, the EPA placed limitations on the number of POTWs which will incur TMDL costs. However, ADVENT believes that these limitations are not plausible for several reasons. For the first limitation (no costs for facilities with treatment beyond secondary), there is no indication that the treatment system in place at these POTWs will be sufficient to meet TMDL compliance for all impairment categories examined by the EPA. Similarly, for the second limitation (no costs for facilities with upgrades in progress from 1996 CWNS), there is no evidence that these upgrades will meet TMDL requirements for all impairments. These POTW upgrades likely address such impairments as nitrogen, phosphorus, and BOD, but may not provide treatment for metals, low concentrations of phosphorus, or specific organics.

Another major difference in the implementation of treatment technologies is ADVENT's option to segregate industrial dischargers into power plants and non-power facilities. For power plants, ADVENT assumed that the only impairments requiring treatment would be metals, mercury, and PCBs. The necessity of these treatments is dependent partly on whether intake credits would be allowed for power plant discharges, particularly for mercury and other legacy pollutants. ADVENT assumed that intake credits would not be allowed for power plants and assumed that power plants may well be required to implement end-of-pipe treatment for the very large flows of one-pass cooling water. The EPA, in comparison, made the assumption that treatment would not be required for

cooling water discharges, and adjusted their flow estimates accordingly to reflect this assumption. We believe that there is no basis for the assumption that cooling water discharges will not require treatment in TMDLs. As previously shown in Table 3, treatment of these discharges represents a substantial percentage of ADVENT's original cost estimate. The EPA estimate does not include any costs for mercury or PCB treatment from any direct dischargers.

Cost Estimation Basis

In determining the costs for implementation of TMDL controls, ADVENT and the EPA used very similar approaches. ADVENT developed its costs based on January 2001 dollars, while the EPA developed costs based on January 2000 dollars. This difference is negligible and can easily be corrected based on economic cost indices. Both ADVENT and the EPA annualized capital costs using an interest rate of 7 percent. ADVENT assumed that loans for capital would be retired over 25 years, while the EPA assumed annualized capital costs would be retired over 20 years. This too, can easily be adjusted. In effect, both parties assumed these costs would continue forever, as these capital costs will be incurred each time the useful life of the necessary equipment has passed.

In addition, the EPA assumed the costs for future treatment upgrades would not be incurred until 5 years after the TMDL-based limits were developed. ADVENT questions the applicability of such an extended lag period and will address this concern in a later section. Based on this 5-year lag and the assumption that it would take 15 years to implement all 22,000 TMDLs across the nation, the EPA assumed that TMDL upgrade costs would be incurred uniformly over the 15-year period from 2006 to 2020. In order to compare the potential costs of this rulemaking effort with those for other regulations, the EPA discounted its costs and calculated "present annual value" costs in January 2000 dollars of these future capital and operating costs. This was calculated using a 7% real discount rate for costs incurred each year from 2006 to 2020. The net effect of this discount or adjustment reduced the EPA costs by approximately 45 percent[9] as compared to the actual costs in January 2000 dollars and is a significant reduction in

[9] Appendix B, page B-1, where the present value scale factor of compliance costs at a 7 % real discount rate is 0.4484 relative to the cost of $1/yr continuing forever, beginning in 2000.

annualized costs as compared to the approach utilized by ADVENT. This approach is flawed for several reasons. First, the 7% real discount rate the OMB directed the EPA to use in this analysis is not realistic in the current economic climate. Granted that interest rates for borrowing are greater than the rate of inflation, the 7% difference (equivalent to the 7% real discount rate used by the EPA) is not the current condition nor is it expected to be so for the foreseeable future. A more realistic value would be the 3% value alternatively presented in EPA cost document.[10]

However, it should be recognized that this approach is not realistic because it assumes that all point source dischargers (and others directly affected by these rules) would put aside money in the year 2000 to invest in future treatment upgrades when the TMDLs for their impaired waterbody are developed and new discharge limits become effective. The scale factor approach used allowed the EPA to develop current costs for future upgrades, to compare with other rulemaking efforts. Nevertheless, it greatly understates the real cost of this rulemaking, since future upgrade costs will be paid for with inflated dollars at the time the upgrade is made. At a minimum, a more realistic real discount rate (3 percent) should be used or costs should be presented in current dollars to express the actual current costs of this regulation. For its original evaluation, ADVENT has used costs expressed in January 2001 dollars with no discount or adjustment for future economic indices.

DETAILED ANALYSIS OF EPA COST APPROACH

After a thorough examination of the EPA draft report and multiple conversations with Environomics, ADVENT has compiled a flow chart describing the steps used by the EPA to develop its cost estimate. This flow chart, along with a table of notes providing details on each step, are presented in Figure 1 and Table 5, respectively. The steps are described in further detail below.

Beginning with 58,977 point source dischargers and 21,845 waterbodies, this list was shortened to include only those dischargers who would incur costs for the point source portion of the EPA estimate. This list of 14,668 dischargers and 4,234 associated waterbodies served as the basis for developing the “within only” and “within and

[10] *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, Appendix B.

upstream" cases examined. For both cases, each included discharger was examined to determine which pollutant categories would require upgrades for TMDL compliance. In addition, a flow was assigned to each discharger for treatment, based on the methodology previously described. Based on the list of pollutants determined, the appropriate cost functions were applied to determine the capital and O&M costs associated with the upgrades at each facility. The capital costs were amortized over 20 years using a 7 percent interest rate, and both the annualized capital and O&M costs were adjusted to 2000 dollars using the necessary cost indices. These adjusted values were added to determine a total annual cost for each facility.

Once costs for all of the facilities in each case had been determined, the list was divided into "scale from" and "scale to" sets. The "scale to" set included all facilities discharging into waterbodies for which the sources of impairment were unknown or not reported. The "scale from" set included all facilities discharging into waterbodies for which the sources of impairment had been reported by the State. Examining the "scale from" set, the EPA determined which facilities discharged into waterbodies which were reported by the States to be impaired by point sources, and determined what percentage of the "scale from" set costs fell into this category. Costs from the "scale from" set attributed to facilities discharging into waterbodies not listed as being impaired by point sources were eliminated. Using the percentage calculated for the "scale from" set, the EPA assumed that the same percentage of costs in the "scale to" set would apply to facilities discharging into point source impaired waters. Combining these portions of the "scale to" and "scale from" set, the final costs for both the "within only" and "within and upstream" cases were calculated. These costs were adjusted by a factor of 1.605 to account for incomplete georeferencing of all of the nation's dischargers and impaired waterbodies. Finally, a discounting factor of 0.4484 was applied to the costs to account for a 7 percent discount rate on future costs and a 5-year lag time before implementation costs would begin to occur.

Using the flow chart in Figure 1 as a basis for examining the EPA's methodology, ADVENT has developed a list, described in greater detail below, of specific issues which it believes should be addressed in the EPA's final report on cost estimates for the TMDL program. Included with each issue is a description of ADVENT's reasoning for expressing concern, along with recommendations, when applicable.

1. *In determining which facilities would be excluded from the TMDL cost estimate, the EPA placed unrealistic limitations on the number of POTWs to be examined.* The EPA assumed that any POTW already beyond secondary treatment or planning to improve treatment controls beyond secondary treatment in the near future would not incur any costs from the TMDL program. ADVENT believes these limitations to be inappropriate and unsupported. There is no empirical evidence presented to indicate that simply having an advanced treatment system in place will necessarily treat all of the pollutants found in the POTW discharges for which a TMDL upgrade would be required. For example, a given POTW may have an advanced treatment system to meet a low effluent limit for nitrogen, but may also have phosphorous as a pollutant, which would not be remedied by the nitrogen treatment train. For this example, the POTW would be listed as requiring upgrades to remedy a nutrient impairment, but because of the limitations selected by the EPA, no upgrades for this POTW would be taken into consideration for the report. Similarly, such POTWs would have been incorrectly excluded from metals upgrades. Based on this, ADVENT believes that both limitations imposed by the EPA on POTWs should be eliminated for the final cost estimate, or examined in more detail on a case-by-case basis.

2. *Due to a lack of available flow information, the EPA was required to estimate flows for over 50% of the facilities examined in the TMDL cost estimate*. In its protocol for estimating flows, EPA used the average flow for a facility's given SIC, when possible. If all of the facilities in a given SIC had no flow data available, the EPA chose to use the average flow for the facility's size and type classification (major or minor industrial, or major or minor POTW). Because flow was estimated for a large number of facilities, this results in a great deal of statistical variability in the TMDL cost estimates. It is impossible to determine whether the averages for a given SIC or for a given type and size of facility are truly representative of the actual average for all facilities within the given classification. This lack of information may cause the EPA costs to be grossly over- or underestimated, depending on whether the averages of the available data are actually higher or lower than the average of the entire population. Furthermore, it is unclear how many of the flows, whether estimated or used as reported, represent average actual flow as opposed to design flow. Cases where average actual flows were used would lead to significantly underestimated costs, as compared to using daily maximum flows or design flows. Each facility will have to design any upgrades to accommodate daily maximum flows rather than average flows.

3. *For cases where the EPA considered the reported flow to be incorrect, a "maximum" process flow for treatment was assumed for specific pollutant categories in each major division (major industrial, etc.)*. In an unknown number of cases, EPA considered the flows reported in the PCS database to be high and erroneous. Rather than a case-by-case review in these situations, the EPA discarded the suspect flows, citing that these high flows were likely due to cooling water or storm water rather than process wastewater. Instead, the EPA assigned a "maximum" flow of process wastewater to be considered for treatment. This could underestimate treatment costs if it is in fact necessary to treat the reported flows (whether or not they are storm water or cooling water) to adequately address the impaired waterbody. Furthermore, in its draft report, the EPA did not identify the basis for the particular maximum flows chosen. A rationale for the system of determining which

flows are "incorrect" and determining the "maximum" flow to be treated for a given pollutant category at a given type of facility should be included in the EPA's final report.

4. *For an unknown number of cases, the EPA assumed that large reported flows from industrial facilities were due to high flows of cooling water or storm water. For these cases, the EPA assumed that control technologies would be applied to small, concentrated waste streams rather than large end-of-pipe flows.* This assumption particularly impacts electric utilities (SIC 4911 and related), which often have large flows of non-contact cooling water. In making this assumption, EPA further assumes that industrial facilities will be able to isolate concentrated waste streams and apply the treatment technology at these points. However, no empirical evidence is provided to indicate that most, if any, industrial facilities will be able to isolate such waste streams. Moreover, there is no basis for the EPA's assumption that cooling water flows would not require treatment. ADVENT considers this assumption of ubiquitous flow segregation overly optimistic, and as a result, the EPA's cost estimate is likely lower than the actual amount that will be required. Because of this, ADVENT believes that the final cost estimate should include either development of costs for total end-of-pipe flow or rationale for the system of flow segregation employed by the EPA.

5. *The capital cost functions used by the EPA address generic treatment categories rather than specific treatment trains.* For example, when considering a facility with toxic organics as its only pollutant category, the EPA chose to calculate its upgrade costs based on a function for Advanced Treatment I (AT1). However, according to information obtained by ADVENT, the designation of AT1 simply refers to a facility's effluent levels of BOD and TSS. Specifically for the case of nutrient removal, ADVENT believes that the cost functions will not accurately reflect treatment costs because of the variability in the nutrient effluent limits and the wide variety of treatments that may be required for them. Treatment for nitrogen may require nitrification alone, or may require a combination of nitrification and denitrification. Depending on influent levels, treatment for phosphorus may be achievable in a biological treatment plant, or may require a system of chemical precipitation and filtration. For the case of organics removal described above, ADVENT prescribed a treatment system involving activated carbon and filtration. There is no evidence in the draft report that the cost determined by the AT1 function accurately reflects the costs associated with such a system. Based on its method of developing costs based on specific treatment trains, ADVENT believes that the cost functions used by the EPA underestimate the actual costs that will be incurred for TMDL-related upgrades. Furthermore, ADVENT believes that the EPA's final report should provide sufficient justification for the cost functions used, specifically regarding their ability to accurately estimate costs for a wide range of treatment trains and specific pollutant categories.

6. *In addressing impairments due to metals at POTWs, the EPA assumes no end-of-pipe treatment for these facilities, but instead develops costs for pretreatment of the SIU flow into the POTWs.* As previously mentioned, there is evidence from AMSA to suggest that many POTWs now receive a majority of their influent metals from commercial and residential flow rather than industrial flow. In addition, AMSA has indicated that many of its member facilities already require their SIUs to have extensive pretreatment programs in place for metals. ADVENT believes that these

assumptions cause the EPA to underestimate the amount and extent of treatment that POTWs will be required to do for metals, and therefore underestimate the costs associated with addressing metals at POTWs. Based on this information, ADVENT recommends that the EPA's final report should include costs developed for end-of-pipe treatment for metals at POTWs.

7. *The EPA estimate does not include any costs developed for the treatment of pesticides, mercury, PCBs, or temperature*. Specifically for the temperature impairment, it now appears that stringent temperature guidance will be implemented for the Pacific Northwest (WA, OR, and ID) which would require treatment upgrades associated with the TMDL program. Other regional temperature limits may also result in upgrade requirements. Reports on temperature control upgrades indicate that the costs associated with such control systems are not insignificant. For instance, it has been estimated that the cost to cool the 40 mgd flow of treated effluent from a pulp and paper mill in the Pacific Northwest to comply with its proposed effluent temperature criterion of 20 °C will involve a capital cost of approximately $25 million and an annual operating cost of $1.3 million. Another study on a POTW in the Pacific Northwest discharge of approximately 30 mgd indicated capital costs of $12.5 million and an annual operating cost of $0.5 million to achieve similar effluent temperatures.

   For pesticides, ADVENT believes that the large number of impairments due to pesticides justifies its inclusion in developing TMDL costs. PCBs are cited as an impairment cause in a large number of waterbodies. Treatment for PCBs requires an expensive treatment train, and therefore should be included in some form for the final cost estimate.

   In addition, mercury is a unique heavy metal that we believe should be examined independent of other metals. This is due to the low analytical detection levels, lower criteria requirements, the widespread presence of mercury in waterbodies and discharges, and the elaborate treatment train required for mercury removal. Again, we feel that the costs for these parameters should be included in the final EPA estimate.

8. *In amortizing capital costs, the EPA assumes loan retirement over 20 years at a rate of 7%*. Due to the recent trends in interest rates, ADVENT believes a 6% interest rate may be more appropriate.

9. *In determining the sources of impairment for a given waterbody, the EPA assumes that information reported by the States is complete and accurate*. However, as explained in the draft report, States use hundreds of different terms or codes to describe impairment causes, ranging from generic to specific.[11] Furthermore, a uniform set of instructions or guidance for reporting impairment causes was not given to the States. As a result, the standards for reporting this impairment information are not clearly defined. The variability in the reporting system may result in improperly including or excluding facilities from the TMDL cost estimate. In fact, only about half of the states provided information on impairment causes. The ultimate impact on the final costs for the TMDL program is unclear.

[11] *The National Costs to Implement TMDLs (Draft Report): Support Document #2*, Appendix G, pg. G-2.

10. *The EPA determined the percentage of costs in the "scale from" set resulting from cost upgrades for point sources discharges to waters impaired by point sources. In determining costs for the "scale to" set of dischargers, the EPA assumed that the same percentage of these discharges would discharge to point source impaired waters, and therefore the same percentage of the costs from this set were included.* Similar to the available flow information, a large percentage (over 43%) of the waterbodies examined had no impairment information reported, or reported only unknown impairment sources. Because of this, it is impossible to determine whether the percentage of costs calculated from the "scale from" set will accurately reflect the actual percentage across all examined waterbodies. This may result in substantial errors in the final costs developed.

11. *In its economic analysis, the EPA uses a real discount rate of 7 percent and a 5-year lag period before any facilities would begin to incur costs.* Both the discount rate and the lag period used are considered by ADVENT to be excessive. The combination of these assumptions ultimately reduces the final EPA cost estimate by over 55%. A real discount rate of 7 percent would correspond to a nominal rate of 9-10 percent, depending on inflation. Under the current economic conditions, a nominal rate of 9-10 percent is considered excessive. A real discount of 3 percent would be more realistic. In addition, State-issued compliance schedules typically require facilities to come into compliance within 3 years, rather than the 5 years assumed in the draft report. Also, facilities will incur costs associated with upgrades throughout this 3-year period rather than at the end of it, as was assumed by the EPA in developing its discounting factor. ADVENT believes that a 2-3 year lag period, coupled with a real discount rate of 3 percent, would provide a more reasonable estimation.

SUMMARY

In conclusion, ADVENT believes that there are several areas of concern where the EPA must provide further explanation or change their initial assumptions in order to provide a more accurate final estimate on the costs for implementing the TMDL program. The basis for the procedures used in the steps listed below are of greatest concern:

- Including and excluding facilities from the cost estimate
- Unsupported assumptions concerning flow determination and flow assignment
- Undefined technologies covered in capital cost functions
- Impairment categories included and the assumed treatment for each
- Determination of impairment sources
- Economic assumptions, particularly discount rate and lag time

ADVENT believes that many of the changes needed to reflect an accurate accounting of TMDL implementation costs will cause the overall estimate to be significantly higher than

the existing EPA estimate. In particular, the concerns listed above should be addressed in the final EPA cost report.

TABLE 1. COMPARISON OF ADVENT AND EPA TMDL AVERAGE ANNUAL COSTS BY SEGMENT

Item	Range	ADVENT Costs (10^6/yr), Jan. 2001 Dollars		EPA Costs (10^6/yr), Jan. 2000 Dollars		
		With Mercury, PCBs, Pesticides	Without Mercury, PCBs, Pesticides	Least Flexible	Moderately Cost Effective	More Cost Effective
POTWs	**Low Estimate**	$ 911	$ 618	$ 396	$ 297	n/a
	High Estimate	$ 3,644	$ 2,473	$ 697	$ 523	n/a
	No Limitations [a]	$ 3,644	$ 2,473	$ 2,009	$ 1,506	n/a
Industrial	**Low Estimate**	$ 777	$ 351	$ 676	$ 507	n/a
	High Estimate	$ 3,107	$ 1,402	$ 1,465	$ 1,099	n/a
Indirect (Metals)	**Low Estimate**	none [b]	none [b]	$ 10	$ 8	n/a
	High Estimate	none [b]	none [b]	$ 16	$ 12	n/a
TOTAL	**Low Estimate**	$ 1,688	$ 969	$ 1,082	$ 812	$ 625
	High Estimate	$ 6,751	$ 3,875	$ 2,178	$ 1,634	$ 1,321
	No Limitations [a]	$ 6,751	$ 3,875	$ 3,490	$ 2,617	n/a

(a) The EPA imposed 2 limitations on the number of POTWs to be included in the TMDL cost estimates. (Exhibit II-1, pg. II-6). The costs presented in these rows reflect estimates on POTW costs without these limitations. ADVENT did not impose any limitations comparable to those made by the EPA.

(b) ADVENT included costs for metals treatment from indirect dischargers to POTWs as costs to be incurred by POTWs rather than by the dischargers.

TABLE 2. SUMMARY COMPARISON OF ADVENT AND EPA TMDL AVERAGE ANNUAL COSTS BY SEGMENT

Item	Range	ADVENT Costs (10^6/yr), Jan. 2001 Dollars		EPA Costs (10^6/yr), Jan. 2000 Dollars		
		With Mercury, PCBs, Pesticides	Without Mercury, PCBs, Pesticides	Least Flexible	Moderately Cost Effective	More Cost Effective
POTWs	**Low Estimate**	$ 911	**$ 618**	**$ 396**	**$ 297**	n/a
	High Estimate	$ 3,644	$ 2,473	$ 697	$ 523	n/a
	No Limitations [(a)]	$ 3,644	**$ 2,473**	**$ 2,009**	**$ 1,506**	n/a
Industrial (total)	**Low Estimate**	$ 777	**$ 351**	**$ 686**	**$ 515**	n/a
	High Estimate	$ 3,107	**$ 1,402**	**$ 1,481**	**$ 1,111**	n/a
TOTAL	**Low Estimate**	$ 1,688	**$ 969**	**$ 1,082**	**$ 812**	$ 625
	High Estimate	$ 6,751	$ 3,875	$ 2,178	$ 1,634	$ 1,321
	No Limitations [(a)]	$ 6,751	**$ 3,875**	**$ 3,490**	**$ 2,617**	n/a

(a) The EPA imposed 2 limitations on the number of POTWs to be included in the TMDL cost estimates. (Exhibit II-1, pg. II-6). The costs presented in these rows reflect estimates on POTW costs without these limitations. ADVENT did not impose any limitations comparable to those made by the EPA.

(b) ADVENT included costs for metals treatment from indirect dischargers to POTWs as costs to be incurred by POTWs rather than by the dischargers.

TABLE 3. ADVENT TMDL COMPLIANCE COST ESTIMATES w/ and w/o PESTICIDES, MERCURY, AND PCBs

POLLUTANT/IMPAIRMENT	ANNUAL COSTS, All Pollutants (10^6, Jan. 2001 Dollars)				
	POTWs	INDUSTRY (NON-POWER)	INDUSTRY (POWER)	INDUSTRY TOTAL	TOTALS
Nutrients	$ 1,261 (a)	$ 393	$ -	$ 393	$ 1,655
Ammonia	$ 64 (a)	$ 14	$ -	$ 14	$ 78
Metals	$ 748	$ 263	$ 594	$ 858	$ 1,606
Dissolved Oxygen	$ 50	$ 17	$ -	$ 17	$ 66
Pesticides	$ 470	$ 161	$ -	$ 161	$ 631
Mercury, PCBs	$ 700	$ 405	$ 1,139	$ 1,544	$ 2,244
Organics	$ 351	$ 120	$ -	$ 120	$ 471
TOTALS by PS	$ 3,644	$ 1,374	$ 1,734	$ 3,107	$ 6,751
SUBTOTAL, All pollutants					$ 6,800
COST REDUCING FACTORS					
Pollution Prevention Reduction					25%
Other Upgrade Requirements					25%
NEW TOTAL					$ 3,400
MINIMUM (TOTAL - 50%)					$ 1,700
MAXIMUM (TOTAL +50%)					$ 6,800

POLLUTANT/IMPAIRMENT	ANNUAL COSTS, no Hg, PCB, Pesticide Treatment (10^6, Jan. 2001 Dollars)				
	POTWs	INDUSTRY (NON-POWER)	INDUSTRY (POWER)	INDUSTRY TOTAL	TOTALS
Nutrients	$ 1,261 (a)	$ 393	$ -	$ 393	$ 1,655
Ammonia	$ 64 (a)	$ 14	$ -	$ 14	$ 78
Metals	$ 748	$ 263	$ 594	$ 858	$ 1,606
Dissolved Oxygen	$ 50	$ 17	$ -	$ 17	$ 66
Organics	$ 351	$ 120	$ -	$ 120	$ 471
TOTALS by PS	$ 2,473	$ 808	$ 594	$ 1,402	$ 3,876
SUBTOTAL, no Hg, PCBs, Pesticides					$ 3,900
COST REDUCING FACTORS					
Pollution Prevention Reduction					25%
Other Upgrade Requirements					25%
NEW TOTAL					$ 1,950
MINIMUM (TOTAL - 50%)					$ 975
MAXIMUM (TOTAL +50%)					$ 3,900

(a) The original estimate for these cost were $2.4 (nutrients) and $0.4 billion (ammonia).
An error was discovered in the original calculations which caused the O&M costs to be high.

TABLE 4. COMPARISON OF TREATMENT TECHNOLOGIES FOR TMDL COST ESTIMATES

Point Source	Impairment Category	ADVENT Technology	USEPA Technology [(a)]
POTWs	Nutrients	Biological Nitrification/Denitrification for ammonia	ST w/ nutrient removal or
		Precipitation/Clarification/Filtration for phosphorous	AT1 w/ nutrient removal
	Ammonia	Biological Nitrification/Denitrification	ST w/ nutrient removal or
			AT1 w/ nutrient removal
	Metals	Precipitation/Clarification/Filtration	Pretreatment w/ filtration at dischargers
	DO/BOD	Effluent Reaeration	AT1 or AT1 w/ nutrient removal
	Organics	Filtration/Granular Activated Carbon (GAC)	AT1 or AT1 w/ nutrient removal
	Pesticides	Filtration/GAC	none
	Mercury/PCBs	Filtration/GAC/Reverse Osmosis for water Electrodialysis/Crystallization/Dewatering/Landfill for sludge	none
Industrial	Nutrients Ammonia Metals DO/BOD Organics Pesticides Mercury/PCBs	Same technologies as POTWs	Same technologies as POTWs (except Metals) Filtration
Indirect (Metals)	Metals	Precipitation/Clarification/Filtration	Filtration

(a) The acronyms listed in the USEPA treatment technologies are as follows:

ST = Secondary Treatment

AT1 = Advanced Treatment 1

FIGURE 1. EPA COST APPROACH FLOW CHART

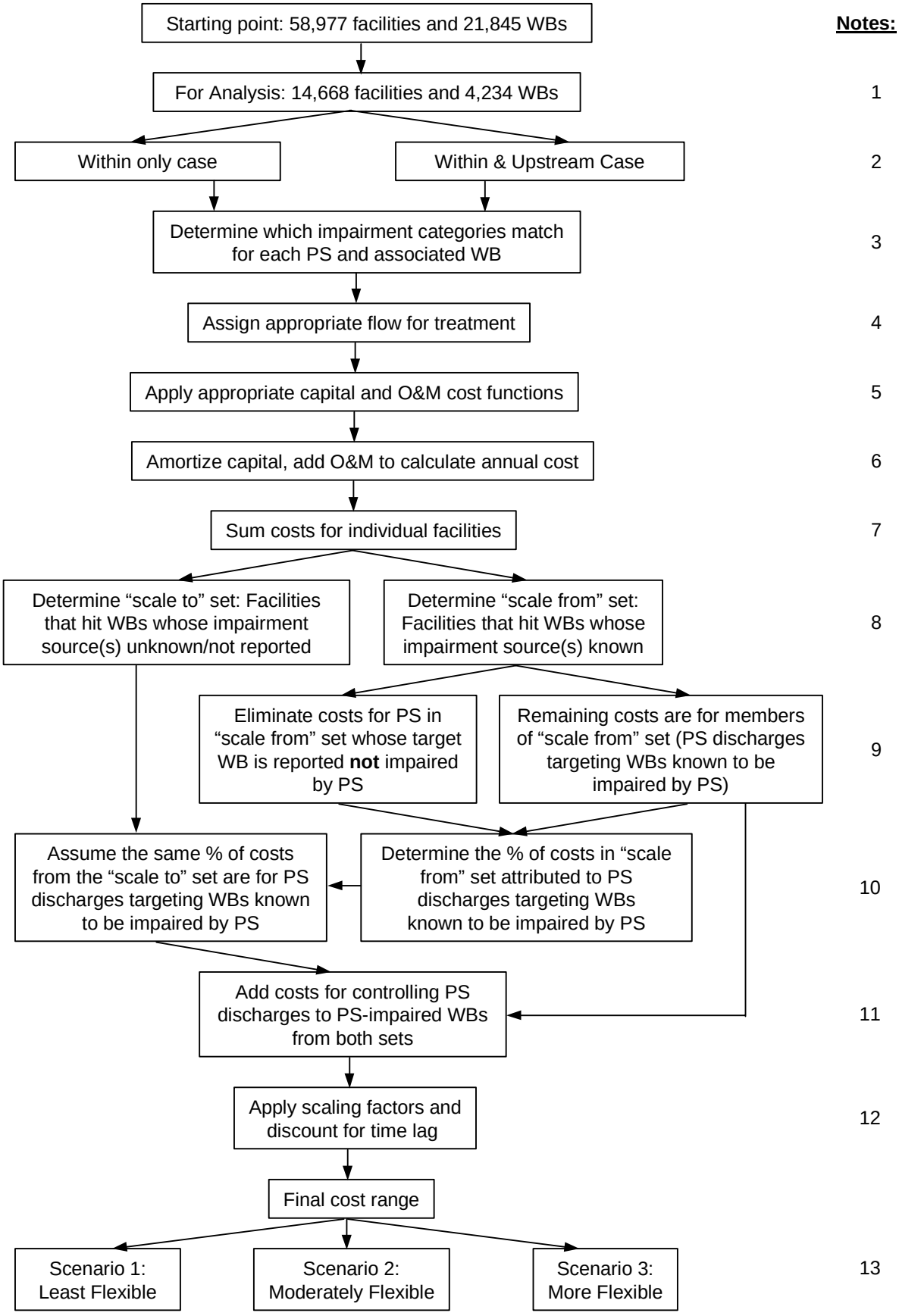

TABLE 5. NOTES ON EPA COST APPROACH FLOWCHART

Note #	Notes	Reference for Note
1	The original list of 21,000+ impaired waters, from the 1998 303(d) List Fact Sheet, was condensed to 4,234 WBs which where impaired specifically by the impairments examined. For these WBs, a list of 14,668 PS discharged within or upstream of the WB and discharged at least one impairment for which the associated WB is impaired.	Information from Stu Sessions, Environomics
2	"Within only" case eliminates all facilities that do not discharge directly to an impaired WB Both cases eliminate the following: -149 facilities with zero reported flow -116 POTWs have matches for metals only but have zero SIU flow -803 POTWs already have or plan beyond secondary treatment	Information from Stu Sessions, Environomics
	In the tables presented in the TMDL report, a range for each scenario is given. The low value represents the "within only" case. The high value represents the "with and upstream" case.	
3	Determined by CWNS	
4	Flow data taken from PCS and CWNS databases Average flows assumed for the cases of missing flow Maximum flows assumed for cases of flow considered to be "inaccurate"	TMDL Support Doc. 2, Appendix F
5	Function determined based on impairment categories for each PS Capital functions taken from 1996 CWNS O&M functions taken from regression of AMSA data All costs adjusted to January 2000 dollars using appropriate cost indices	TMDL Support Doc. 2, Appendix E
6	Capital amortized over 20 years, 7% real discount rate Annual cost determined by adding annualized capital and annual O&M	TMDL Support Doc. 2, pg. ES-3 Information from Stu Sessions, Environomics
7	"Scale from" and "scale to" sets were determined because EPA did not have complete information on the sources of impairment from each WB. Regulations concerning state reporting of impairment sources are questioned. The "scale from" set is used as a pre-screening baseline because information on the WB impairment source is available.	TMDL Support Doc. 2, Appendix G
8	Costs eliminated in the "scale from" set for these PS because their target WBs are not reported as being impaired by PS. Standards concerning state reporting of impairment sources are questioned.	TMDL Support Doc. 2, Appendix G, Exhibit G-1
9	From the "scale from" set, a certain percentage of calculated costs are attributed to PS discharges targeting WBs known to be impaired by PS. It is assumed for PS in the "scale to" set, where the WB impairment is not reported or unknown, that a similar percentage of these PS discharges will actually create PS-related impairments in their target WB. Therefore, this percentage (64% for the "within only" case) is applied to the "scale to" set.	TMDL Support Doc. 2, Appendix G (also info from Stu Sessions, Environomics)
10	Since PS TMDL costs will only be incurred for PS discharges targeting WBs impaired by PS, these costs in the "scale from" and "scale to" sets are combined to calculate the total cost.	TMDL Support Doc. 2, Appendix G, Exhibit G-2

TABLE 5. NOTES ON EPA COST APPROACH FLOWCHART

Note #	Notes	Reference for Note
11	Scaling factors are employed because of the shortfalls in analytical coverage. Two scaling factors are used: 1.427 to compensate for incomplete georeferencing of point sources, and 1.125 to compensate for incomplete georeferencing of impaired waters (1.605 overall scaling factor) Final costs are discounted to account for the time lag associated with TMDL implementation. EPA originally used a 7% real discount rate to calculate this discount factor, though the option to change this is being considered. The final discount factor is 0.4484	TMDL Support Doc. 2, pgs. I-13, I-14 TMDL Support Doc. 2, Appendix B
12	Final cost range represents the calculated annual costs for the "within only" case (low value) and the "within and upstream" case (high value)	
13	Scenario 1 is Least Flexible - no further calculations Scenario 2 is Moderately Flexible - assumed at 75% of Scenario 1 Scenario 3 is More Flexible - assumes additional savings from WLA	 TMDL Support Doc. 2, Exhibit II-4 TMDL Support Doc. 2, Exhibit II-6

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Evaluation of Domestic Sources of Mercury
Association of Metropolitan Sewerage Agencies
August 2000

1.0 INTRODUCTION

The U.S. Environmental Protection Agency's (EPA's) actions to control and eliminate mercury sources to the environment emphasize the need for controlling point sources to publicly owned treatment works (POTWs). There have been claims made that elimination/minimization of mercury from industrial sources such as dental facilities and hospitals would result in "zero discharge" or at least enable POTWs to meet extremely low aquatic life and wildlife water quality criteria for mercury. In fact, in its proposed mixing zone ban for mercury and other bioaccumulative pollutants in the Great Lakes, EPA noted that there were several documented instances in the Great Lakes Basin and elsewhere where the development and implementation of aggressive source control programs had resulted in the virtual elimination of bioaccumulative pollutants.[1] This approach, however, assumes that there is no background mercury concentration in domestic wastes. Until recently there has been very little information on domestic waste concentrations, mainly due to a lack of monitoring at a sufficiently low level.

To better understand the relative contributions of mercury in domestic wastes and potential source control options, a study was initiated to collect information on concentrations of mercury in domestic wastewater, to identify the sources of mercury in domestic wastewater, and to evaluate the feasibility of controlling those mercury sources. This report presents the results of the investigation and recommendations on future courses of action.

2.0 DOMESTIC WASTEWATER DATA

When we began this project, we identified several AMSA members that had collected mercury data for residential wastewater using sensitive sampling and analytical methods. Our goal was to see what kinds of mercury concentration ranges existed in domestic wastewater without inputs from industry, dentists, or other commercial sources. The participating agencies were geographically distributed (east coast, midwest, west coast) and represented different sizes and types of POTWs. It should be noted that while the purpose of this evaluation was not to provide a statistically valid national sample, it was considered to be statistically *significant* as a national sample set to provide insight on solutions for regulating mercury in wastewater discharges

Domestic wastewater data presented in this report were collected by the following four POTWs: the Massachusetts Water Resources Authority (MWRA) in Boston, Massachusetts, the Metropolitan Council Environmental Services (MCES) in St. Paul, Minnesota, the Hampton Roads Sanitation District (HRSD) in Virginia Beach, Virginia and the City of Palo Alto, California. The sampling locations were carefully screened in all areas to ensure that only residential wastewater flows were sampled with no commercial or industrial inputs. Age of the sampled residential service areas ranged from <10 to ~125 years old.

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[1] October 4, 1999 *Federal Register*, pp. 53641-53642.

Mercury data were produced using analytical methods sensitive enough to generate results that could be compared to the current EPA water quality criteria. Statistical evaluations were performed on the quantifiable data. Some of the samples were collected and analyzed using clean techniques. The remaining data were collected using semi-clean protocols with measures employed to control contamination.

2.1 Scope of Data Evaluation

- Three hundred and eighty three (383) data points were obtained from samples collected from residential areas; of these, 263 had detectable results based on the detection limits (MDLs) of the analytical methods used by the participating POTWs.

- The list of analytical methods used and the corresponding MDLs are presented in Table 1.

- Mean and median mercury concentrations for each residential neighborhood/service area and for all areas combined were calculated using all detectable results.

- Since a few of the results appeared to be outliers, a test was performed to determine which data points were indeed statistical outliers. The calculations of mean and median values were then performed excluding from the data sets those few measurements that were determined to be outliers.

- Additional statistical calculations were performed with inclusion of all detectable and non-detectable values, with non-detectable values reported as concentrations at the MDL.

- Trends in mercury concentration as related to an age of each residential area were assessed statistically.

- Seasonal changes, (on a quarterly basis) in mercury concentrations were also statistically evaluated.

Table 1. Summary of Analytical Methods and Detection Limits

POTW	Analytical Method	MDL – ng/L
MWRA	EPA 245.1	50
MCES	EPA 245.7	15
HRSD	EPA 245.7	2
Palo Alto	Hydride by FIAS/AA[1]	100
Palo Alto	Hydride by FIAS/Gold Amalgamation/AA[2]	10
Palo Alto	Hydride by FIAS/ICP-MS[3]	10
[1] Samples collected between 7/83-2/96 [2] Samples collected between 3/96-8/97 [3] Samples collected between 9/97-Present		

2.2 Statistical Methods

- The data were normalized ($\log_{10}$) before statistical analyses were performed. Outliers were determined using Box-and-Whisker and Normal Probability Plots (*Statgraphics Plus for Windows 4.0* used for statistical evaluations).

- After normalizing the data, standard skewness and kurtosis values were obtained. (Skewness measures the symmetry or shape of the data. The flatness or steepness of the data distribution, with respect to a normal or Gaussian distribution, is measured by kurtosis). The results indicated that the data significantly departed from normality for the sets including outlier concentrations. Therefore, any statistical evaluations regarding standard deviation (e.g., ANOVA) tend to be invalidated.

- Normalized data sets excluding outliers returned standard skewness and kurtosis values indicating that the data had a normal distribution.

- Mean and median mercury values and standard deviations were calculated for each neighborhood and for all areas studied.

- Seasonal changes in mercury concentration were assessed using ANOVA on the normalized data set.

- The MCES data were generated on split samples by two different laboratories, using different analytical methods. The Student's t-test performed on these data sets indicated the sets were not statistically different, therefore a mean value for each sample split was used in the statistical evaluations. One sample split with the RPD of >100% was rejected.

2.3 Results

Table 2 presents a summary of all results, and also provides information on the approximate age of each neighborhood and average total suspended solids (TSS) concentrations, where available.

- Using all of the mercury data, the mean and median values for all of residential areas were:

Mean	178 ng/L
Median	110 ng/L

- The normalized data set, with an exclusion of extremely high values, which were considered outliers, provided the following mercury mean and median values:

Mean	138 ng/L
Median	104 ng/L

- Using the data sets that included non-detected values at the MDL concentrations, the mean and median mercury values for all of the residential areas were:

Mean	143 ng/L
Median	88 ng/L

Table 2. Summary of Mercury Concentrations for All Service Areas

Service Area	Number of Samples	Dates of Sampling	Age of area (yrs)	Avg Hg Conc. All Data (ng/L)	Avg Hg Conc Excl. outliers (ng/L)	Avg Hg Conc. NDs at MDL (ng/L)	Avg TSS Conc. (mg/L)
MCES							
Colby Lake	7	11/97, 4/98	NA	61	61	69	NA
Weir Drive	9	11/97, 4/98	NA	32	32	35	NA
Juliet St.	6	11/97, 4/98	NA	51	51	46	NA
Lilac-Men. Heights	5	6/98	NA	239	239	239	NA
Navajo-MH	6	6/98	NA	53	53	53	NA
So. St. Paul	6	6/98	NA	70	70	70	NA
MWRA							
DEDH	63	1/96 – 1/99	36	157	110	126	NA
WALT	63	1/96 – 1/99	26	149	110	139	NA
WEYM	63	1/96 – 1/99	47	102	102	122	NA
WINC	63	1/96 – 1/99	12-124	89	79	110	NA
HRSD							
Courthouse Estates	1	3/12/99	<10	17	17	17	143
Lago Mar	1	3/12/99	15	31	31	31	58
Hunt Club	1	3/12/99	15	86	86	86	245
Monroe Place	1	3/19/99	60	47	47	47	69
Elmhurst	1	3/19/99	50	284	284	284	176
Powhatan	1	3/19/99	50	58	58	58	120
Palo Alto							
Pulgas (mainly apartments)	45	5/95 – 2/99	37	292	172	192	NA
Waverly (upscale houses)	41	5/95 – 2/99	37	165	149	193	NA
Mean				**178**	**138**	**143**	
Median				**110**	**104**	**88**	
St. dev.				**258**[2]	**112**	**223**	

[1] NA – the data are not available.

[2] The results for the full data set indicated that the data significantly departed from normality including outlier concentrations. Therefore, any statistical evaluations regarding standard deviation (e.g., ANOVA) tend to be invalidated.

- There were seasonal differences in mercury concentrations in the sampled areas with higher concentrations observed during the second and third quarter of the calendar year. Application of an ANOVA test (99% confidence level) to the data sets that were considered to have a normal distribution determined that the seasonal trend was statistically significant.

- No clear correlation could be established between the age of the collection system/neighborhood and the mercury concentrations. Based on the Palo Alto data, population density may have a greater impact on mercury concentrations than the age of the service area.

- As can be seen from Table 2, a high level of variability was observed for the different locations sampled, with means for different locations varying from 17 to 284 ng/L and a number of non-detects and outliers. There are a number of reasons that this type of variability could occur as discussed in Sections 5.3 and 6.0 of the report.

3.0 PORTABLE TOILET WASTES

For comparison purposes, data were obtained and evaluated for portable toilet wastes, including chemical toilet wastes and septage. The intent of presenting these data was not for use in a mass balance, but to provide anecdotal support that levels of mercury in human excrement, independent of the contribution from discharged household products, are substantial.

3.1 Chemical Toilet Waste Results

Chemical toilet waste samples were collected and analyzed by the Northeast Ohio Regional Sewer District (NEORSD), in Cleveland, Ohio. Because these wastes do not contain household products, the data collected should provide an indication of the fecal/urinary contribution of mercury to domestic wastewater. Eight samples of portable toilet wastes were collected in March and April 2000, along with a sample of the chemical treatment solution to evaluate its potential contribution to the toilet waste mercury concentrations. The results, which are shown in Table 3, yielded mean and median mercury concentrations of 3,737.5 ng/L and 800 ng/L. Although mercury was detected at 410 ng/L in the chemical treatment solution added to portable toilet waste, the solution volume is very small relative to the total waste volume, and cannot account for the total mercury measured in the waste.

Table 3. Summary of Mercury Concentrations in Portable Toilet Waste

Date	Detection Limit (ng/L)	Mercury Conc. (ng/L)	Assumed Mercury Conc. ng/L
3/17/00	1600	5800	5800
3/21/00	1600	ND	800
3/22/00	1600	3100	3100
3/29/00	1600	18000	18000
4/03/00	1600	ND	800
4/04/00	50	710	710
4/05/00	50	290	290
4/06/00	50	400	400
Mean			**3737.5**
Median			**800**

3.2 Septic Waste Results

NEORSD also collected and analyzed 34 samples from 12 different waste hauler services to determine concentrations of mercury in exclusively domestic septage. The results, which are presented in Table 4, yielded mean and median mercury concentrations of 12,918 ng/L and 6,950 ng/L.

Table 4. Summary of Mercury Concentrations in Septic Hauler Waste

Date	Detection Limit ng/L	Mercury Conc. ng/L	Assumed Mercury Conc. ng/L
2/15/00	200	5,400	5,400
2/16/00	200	3,900	3,900
2/16/00	200	2,700	2,700
2/16/00	1,600	1,300	13,000
2/21/00	1,600	1,900	1,900
2/21/00	1,600	6,700	6,700
2/22/00	1,600	4,100	4,100
2/22/00	1,600	17,000	17,000
2/23/00	1,600	7,800	7,800
2/23/00	1,600	4,600	4,600
2/24/00	1,600	11,000	11,000
2/24/00	1,600	6,000	6,000
2/25/00	1,600	120,000	120,000
2/24/00	1,600	9,400	9,400
2/28/00	1,600	7,200	7,200
2/29/00	1,600	6,000	6,000
2/29/00	1,600	2,600	2,600
3/01/00	1,600	5,100	5,100
3/01/00	1,600	13,000	13,000
3/02/00	200	19,000	19,000
3/02/00	200	11,000	11,000
3/07/00	1,600	26,000	26,000
3/07/00	1,600	4,600	4,600
3/08/00	1,600	7,700	7,700
3/08/00	1,600	1,700	1,700
3/11/00	1,600	5,100	5,100
3/11/00	1,600	ND	800
3/14/00	1,600	43,000	43,000
3/14/00	1,600	4,100	4,100
3/15/00	1,600	10,000	10,000
3/15/00	1,600	ND	800
3/15/00	1,600	35,000	35,000
3/16/00	1,600	11,000	11,000
3/16/00	1,600	12,000	12,000
Mean			**12,918**
Median			**6,950**

4.0 MERCURY IN HOUSEHOLD PRODUCTS

Some literature sources report commonly used detergents and toiletries as potentially contributing to mercury in residential wastewater. HRSD performed mercury determinations on several common household and toiletry items. The products analyzed were selected to represent those commonly used by the average consumer. The intent of these analyses was not to look at specific products, but to provide a snapshot of a group or category of products. To completely characterize a product, it would be necessary to analyze different brands, lot numbers, manufacturing facilities, etc., which was beyond the scope of this project. In addition, it was implicitly understood that a bias might result from analyzing the products only one time. Because these biases may be positive or negative, the average result of the biases were considered negligible to the final outcome of the calculations. The results of the analysis are presented in Table 5 according to product type.

Table 5. Mercury in Common Household Products and Toiletries

Product Type	Number Products Tested	Range of Concentration (ng/L)	
		Minimum	Maximum
Toothpaste	5	490	3,800
Shaving Cream	4	90	670
Deodorant/Antiperspirant	2	1,010	1,350
Soap/Shampoo	5	835	25,000
Toilet Tissue	3	220	1,510
Laundry Detergent	6	560	2,490
Bleach	2	<200	6,170
Dish/Dishwasher Detergent	4	560	1,320
Drain Cleaners	2	2,970	5,490
Soft Drinks/Drink Mixes[1]	3	25	6,070
Fruit Juices	3	789	3,560
Fruit/Vegetables[2]	4	116	874
Rice/Grains	2	26	<200
Processed Meats	6	<100	290
Beef/Chicken	2	29	<40
Condiments[3]	4	133	1,956
Food Coloring[4]	4	96	137,000

[1] With yellow or red dyes.
[2] Fresh, frozen and canned.
[3] Salt and sugar.

5.0 MASS BALANCE FOR DOMESTIC SOURCES OF MERCURY

Mass balance calculations were performed using the mercury data for the domestic products evaluated to determine the relative contribution of these products to domestic mercury loadings to POTWs. In addition, mercury data for processed foods, meats, seafoods, vegetables, fruits, and seasonings were obtained and utilized in the calculations.

5.1 Assumptions

Because product and food consumption can vary widely, a number of assumptions were used in developing these calculations.

- The average household consists of four people (2 adults and 2 children).
- The average flow per household is 12,000 gal/month (45,420 L/month) (*Wastewater Engineering Treatment, Disposal, and Reuse Third Edition," Metcalf & Eddy, 1991*; *Sanitation Districts of Los Angeles County, Final Joint Outfall System Master Facilities Plan, June 1995*).
- Product use or consumption per month was determined using information from the American Dietetic Association *(ADA Food Pyramid and Website)*, USDA recommended portions *(USDA Website)*, and other estimates, which are presented in Appendix A.
- The contribution from fish and shellfish consumption is based on estimates cited in the USEPA *Mercury Study Report to Congress (EPA-452/R-97-006, Vol. IV, Tables 4-73 and 4-74)*. Children were estimated to have the same contribution rates as adults: a worst case scenario.
- Similar products (e.g., ground beef and chicken) with like concentrations were combined for the calculations.
- These analyses provide a snapshot of those products used by the average consumer. Samples selected represent only a cross-section of commonly used products.
- Since the entire product list was used in calculating the mass balance, it was understood that any biases would be negligible to the final result.
- Usage rates are *overall* averages and may vary from person to person.

5.2 Calculations

Mercury contributions from each product were calculated by multiplying the estimated quantity of product used per month by the average mercury concentration in the product. Using shaving cream as an example:

Usage	0.24 kg/month
Mercury Conc.	340 ng/kg

Mercury Contribution	=	Usage x Conc.
	=	0.24 kg/month x 340 ng/kg
	=	81.6 ng/month

Fish and shellfish consumption calculations were based on information found in Tables 4-73 and 4-74, Volume IV of the *Mercury Study Report to Congress*. The 50th percentiles for total U.S. mercury exposure from fish and shellfish of marine, estuarine, and freshwater origin are 110 ng/kg/day and 100 ng/kg/day for men and women, respectively.

Exposure Men 110 ng/kg bw/day
Exposure Women 100 ng/kg bw/day
Weight Men 70 kg
Weight Women 65 kg

$$\text{Mercury Contribution}_{(M)} = \text{Exposure} \times \text{Weight}$$
$$= 110 \text{ ng/kg bw/day} \times 70 \text{ kg} \times 30 \text{ day/month}$$
$$= 231{,}000 \text{ ng/month}$$

$$\text{Mercury Contribution}_{(W)} = 100 \text{ ng/kg bw/day} \times 65 \text{ kg} \times 30 \text{ day/month}$$
$$= 195{,}000 \text{ ng/month}$$

5.3 Results

Table 6 lists the products used in calculations, the estimated quantity of each product used per month, and the average mercury contribution from each source per household.

Table 6. Mass Balance for Domestic Sources of Mercury

Product	Usage per Month kg/month	Avg. Hg Conc. ng/kg	Hg Household Contribution ng/month
Shaving Cream	0.24	340	82
Deodorant	0.06	1180	71
Soap	0.12	7908	949
Shampoo	2.04	835	1,703
Toothpaste	0.42	1230	517
Mouthwash	0.91	15	14
Dishwashing Detergent	0.91	1320	1,201
Dishwasher Detergent	2.00	1478	2,956
Laundry Detergent	4.00	1478	5,912
Bleach	0.90	6170	5,553
Toilet Paper	1.00	827	827
Drain Cleaners	0.18	4230	761
Soft Drinks:			
Powdered Mix	0.14	6070	850
Premixed	5.52	25.1	139
Carbonated	8.16	142	1,159
Fruit Juice	14.7	2570	37,779
Rice/Grains	33.6	26.4	887
Hot Dogs/Sausage	3.64	100	364
Processed Lunch Meat	1.82	200	364
Fish and Shellfish [1]			852,000
Ground Beef, Chicken	7.23	30	217
Fresh, Frozen and Canned Vegetable and Fruit	27.6	400	11,040
Sugar[2]	6.00	1602	9,612

Product	Usage per Month kg/month	Avg. Hg Conc. ng/kg	Hg Household Contribution ng/month
Salt[2]	1.20	1,956	2,347
Total All Products			937,303

[1] Monthly consumption in a four person household.
[2] Includes quantities found in prepared foods.

To determine the average domestic contribution per household, the sum of the mercury contribution for all of the domestic and food products was divided by the flow for each household.

Total Mercury Contribution 937,303 ng/month
Average Household Flow 45,420 L/month

Average Household Contribution = Mercury Contribution ÷ Average Flow
= 937,303 ng Hg/month ÷ 45,420 L/month
= **20.6 ng/L**

Based on the estimated average household mercury contribution of 20.6 ng/L and the mean mercury domestic wastewater concentration of 138 ng/L (data set excluding outliers), approximately **15 % *of the total domestic contribution can be attributed to food, toiletry and household products***. With this information, it is apparent that at least ***85% of the mercury in domestic waste comes from other sources***.

One explanation is that a significant source of mercury comes from human wastes. Information in the literature indicates that after mercury is released from human tissues, fecal excretion becomes the predominant route for elimination of mercury from the body, and that the rate of excretion correlates with the number of amalgam fillings *(Lorscheider, et al., Mercury Exposure From Silver Tooth Fillings: Emerging Evidence Questions a Traditional Dental Paradigm, The FASEB Journal, 9: 504-508, 1995)*. Engqvist has shown that the amalgam particles are formed when a person chews aggressively, and the amount of particles originating from fillings can be estimated from a fecal sample, with at least 80% of the ingested particles excreted *(Engqvist et al., Speciation of Mercury Excreted in Feces from Individuals With Amalgam Fillings, Archives of Environmental Health, 53: 205-213, May/June 1998)*. This same study showed that mercury vapor dissolved in water and swallowed was only excreted to about 40% in feces.

Measurements by Skare *(Water, Air, and Soil Pollution 80: 59-67, 1995*; see Appendix B) have indicated that dental amalgam-loaded individuals excrete mercury at average rates of 64 ug/day in feces and 4.5 ug/day in urine. The individuals studied were selected to represent a broad range in amalgam loadings, and none normally ate fish from lakes or smoked. The control from the Skare study, representing dental amalgam-free individuals, had measured mercury excretion rates of 1 ug/day in feces and 0.4 ug/day in urine. Subtracting the control measurements, the total rate of dental amalgam mercury excreted by the average dental amalgam-loaded individual through feces and urine would be 67 ug/day (67,000 ng/day).

In the *Mercury Study Report to Congress* it was reported that the individuals with dental amalgams are exposed to elemental mercury vapor released by these fillings. Mercury vapors are almost entirely re-absorbed by the lungs and eventually excreted in urine at the rate of 1-5ug/day *(Vol. IV, 5-1)*. The 1-5 ug/day "general" range presented in represents urinary excretion only, and is not inconsistent with the 1995 Skare study.

It should also be noted that some mercury is excreted in hair. In Table 6-3, Volume IV, of the *Mercury Study Report to Congress*, the average mercury concentration in hair from studies in various U.S. communities is approximately 1 to 2 ug/g. It is difficult to estimate the average growth rate of hair in order to calculate the average rate at which mercury is excreted through hair. However, this source is believed to be quite small[2].

Assuming a daily wastewater generation rate of 100 gallons per day per individual (378 L/day; *Sanitation Districts of Los Angeles County, Final Joint Outfall System Master Facilities Plan, June 1995*) and an estimate that 65% of the population has dental amalgam fillings (*September 1992 Bio-Probe*), a domestic sanitary sewage mercury concentration attributable to excreted dental amalgam mercury can be predicted from the Skare data as follows:

Rate of mercury excretion		67,000 ng/day
Water usage		378 L/day
Percentage of amalgam population		65%
Mercury conc. from excreted wastes	=	0.65 x 67,000ng/day ÷ 378 L/day
	=	**115.2 ng/L**

Using the mean mercury domestic wastewater concentration of 138 ng/L, this ***loading from feces and urine could account for 83 % of the total domestic loading***. Considering the variability in domestic waste concentrations and uncertainties in the percentage of the population with amalgam fillings, this percentage could be higher or lower than this estimate, but this source of mercury is certainly significant.

Applying the Skare data to the NEORSD service area population of 1.1 million, the human-excreted dental amalgam mercury loading to the NEORSD sewerage system can be estimated:

Amalgam loading	=	populations affected x excretion rate
	=	1,100,000 x 0.65 x 67,000 ng/day ÷ 10^9 ng/gram
	=	**48 grams/day**

Based on the average NEORSD total treated flow of one billion L/day and a treatment plant mercury removal efficiency of 97 percent, ***48 grams/day of human-excreted dental amalgam mercury is, by itself, enough mercury to exceed the 1.3 ng/L water quality criterion*** at the NEORSD plant effluents:

Effluent concentration	=	removal x loading ÷ flow
	=	(1 - 0.97) x 48 grams/day x 10^9 ng/gram ÷ 10^9 L/day
	=	**1.4 ng/L**

Due to the limited number of individuals studied by Skare as well as uncertainty about how representative these individuals may be, some questions remain concerning numeric values derived from the Skare study data. Nonetheless, the Skare study results indisputably indicate that the contribution to domestic wastewater from excreted dental amalgam mercury is substantial. At the very least, these results demonstrate that further consideration of this mercury source is imperative.

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[2] For comparison purposes, to equal the estimated 67 microgram/day rate through feces and urine excretion, hair would have to grow at a rate of 45 grams/day or 3 pounds/month.

Another potential source of mercury in domestic wastewater is the improper disposal of thermometers. A study performed by Larry Walker Associates *(Davis, CA 1994)* estimated that on an annual basis, 1.6% of households discarded 1 thermometer to the sewer, with each thermometer contributing 0.5 g. Using our original assumption of 4 individuals per household, the NEORSD service area could be contributing 6 grams/day based on improper disposal of thermometers.

Thermometer disposal	=	discard rate x households x therm. contrib.
	=	0.016 x 275,000 households x 1 therm/household/yr x 0.5 gram/thermometer ÷ 365 days/year
	=	**6 grams/day**

Other potential sources could include infiltration and inflow from rain or rising groundwater, the drinking water sources, ritualistic uses and vaccinations for children.

Infiltration and inflow contributions will vary depending on location, geology[1] and climate. Indeed, the impacts from infiltration and inflow may explain why the domestic mercury wastewater data showed statistically significant differences in concentrations. This observation has been validated by other POTWs, including biosolids data provided by the Western Lake Superior Sanitary District in Duluth, Minnesota. The data show lower mercury concentrations in the winter when the ground is frozen, in comparison to spring and summer conditions *(Personal communication, data collected August 1985 – February 2000, Tim Tuominen).*

Some limited data were available on the levels of mercury in the tributary drinking water sources for the agencies studied using sensitive mercury methods. For the HRSD service area, five tap water samples were collected to characterize the five treatment facilities in the service area. The average concentration was 0.7 ng/L. In the Minneapolis area, 8 samples were collected from the service area in March 2000 with an average mercury concentration of 0.4 ng/L. It should be noted that in order fully characterize drinking water from these areas, it would be necessary to conduct multiple sampling capturing seasonal changes. The City of Palo Alto collected 12 water samples during the period March 1999 - April 2000 with an average mercury concentration of 0.9 ng/L. These data confirm other information that shows that drinking water is a relatively minor contribution to the POTW mercury loadings. The range in concentration depends on whether the source is surface water (3 - 4 ng/L for some Great Lakes communities; *Personal communication, Keith Linn, NEORSD*) to groundwater (2 ng/L) for Wisconsin. In these cases, the relative contribution from drinking water to total wastewater mercury appears to be small (2 to 4%)

Studies conducted by the Chicago Department of Public Health have shown that mercury is used in religious rituals and folk medicines in Chicago's Hispanic community *(Potential Dangers of Using Mercury in Religious Rituals and Folk Medicines, US EPA Region 5, September 1997).* Ritual mercury users obtain mercury from *botánicas*, friends and folk healers.

Thimerosal is a mercury-containing preservative that has been used as an additive to biologics and vaccines since the 1930's to kill bacteria used in vaccines and in preventing bacterial contamination.

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[1] The average abundances for common geological materials are: (I) igneous rocks—0.004 mg/kg, ultramafic; 0.01 mg/kg, mafic; 0.04 mg/kg, granitic; (ii) sedimentary rocks---0.04 mg/kg, limestone; 0.03 mg/kg, sandstone; 0.02 to 0.40 mg/kg, shale; (iii) soils---0.056 mg/kg. *Rose, J.A., H.E. Hawkes, and J.S. Webb. 1979. Geochemistry in mineral exploration. 2nd ed. Acad. Press, New York.*

Some, but not all of the vaccines recommended routinely for children in the U.S. contain thimerosal. The U.S. Public Health Service and the American Academy of Pediatrics are working collaboratively to assure that the replacement of thimerosal-containing vaccines takes place as expeditiously as possible *(Centers for Disease Control and Prevention Website, Bulletins: Thimerosal, May 15, 2000)*. Manufacturers have been asked for a clear commitment and a plan to eliminate or reduce the mercury content of their vaccines.

6.0 CONCLUSIONS

The results of this study offer some important observations for sources of mercury in domestic wastewater and the feasibility of effective control options.

- Significant amounts of mercury at the average concentration of 138 ng/L were consistently found in strictly domestic wastewater in various parts of the country.

- An important finding in the statistical data evaluation is that regardless of the approach used (excluding outliers and including non-detectable values) the mean mercury concentrations were not significantly affected.

- A correlation between the age of the neighborhood and the mercury concentrations was not substantively meaningful. It appears that the more significant factor may be the density of population in the neighborhoods. Unfortunately, only very limited information regarding the population density was available.

- Statistically significant differences were found when the data were grouped by quarters. The mercury concentrations in residential wastewater appear to be higher in second and third quarter of the calendar year. This can potentially be explained as impacts resulting from infiltration and inflow to sewers during rainy seasons.

- The variability in the levels of mercury observed in the domestic wastewater samples may also be the result of differences in the number of amalgam surfaces per individual, fish/shellfish consumption rates, water usage, water source, and rates of mercury settling/resuspension in sewers.

- Several common household and toiletry items were found to contain substantial concentrations of mercury when examined using sensitive analytical techniques. Although these products individually do not contribute a lot to a total concentration in wastewaters, their cumulative effect accounts for approximately 15% of the mercury concentration in domestic wastewater. The feasibility of controlling these sources would require a national effort.

- Although several sources contributing to the domestic mercury concentrations have been identified, human wastes (feces and urine) from amalgam loaded individuals are believed to be the most significant source (> 80%).

- These results were corroborated by the results from the chemical toilet and septic wastes that showed that a significant portion of the mercury in domestic wastewater is from uncontrollable sources such as dental amalgam fillings.

- While controlling human wastes is impractical, the long-term outlook is promising inasmuch as

the trend in dental health is for fewer cavities and resulting in smaller and smaller populations of amalgam-loaded individuals over time.

Based on this information, domestic waste contributes appreciable concentrations of mercury to POTW influent wastestreams and must be considered when addressing mercury control strategies and the likelihood of virtual elimination of mercury. Background mercury concentrations averaging more than 100 ng/L can be expected in POTW wastewater influents, even if complete elimination of industrial point source discharges is accomplished.

In EPA's cost analysis for the Great Lakes Water Quality Initiative, and in subsequent discussions with wastewater representatives, the Agency has supported the use of pollutant minimization programs as a way for achieving compliance. AMSA strongly endorses and promotes pollution minimization efforts, but is concerned that these efforts may not be adequate to produce the desired level of permit compliance sought by regulatory authorities, highlighting the need for a national compliance strategy for POTWs.

APPENDIX A
Assumptions Used to Determine Usage for Consumer Products

The assumptions used to determine usage quantities per month for mass balance of household products, toiletries and food items found in Table 5 are detailed below. The number of events per month are based on a four family member household, such that:

Number events per month= 4 people x 1 event/person x 30 days/month
= 120 events/month

Usage was determined using specific quantities used per person per event or based on the amount of product routinely purchased per month. The monthly usage was calculated as follows:

Monthly usage = Usage per event x Number of Events
= Usage per month

The following are specific items that were used in the mass balance calculation:

Shaving Cream

Usage/Event	0.002 kg
No. of Events	120
Usage/Month	0.24 kg

Deodorant

Usage/Event	0.0005 kg
No. of Events	120
Usage/Month	0.06 kg

Soap

Usage/Event	0.001 kg
No. of Events	120
Usage/Month	0.12 kg

Shampoo

72 oz/month	
Usage/Month	2.04 kg

Toothpaste

15 oz/month	
Usage/Month	0.42 kg

Mouthwash

32 oz/month	
Usage/month	0.91 kg

Dishwashing Detergent

32 oz/month	
Usage/Month	0.91 kg

Dishwasher Detergent

Usage/Event	0.10 kg
No. of Events	20
Usage/Month	2.00 kg

Laundry Detergent

Usage/Event	0.10 kg
No. of Events	40
Usage/Month	4.00 kg

Bleach

32 oz/month	
Usage/Month	0.90 kg

Toilet Paper

4 Rolls/month (0.25 kg/roll)	
Usage/Month	1.00 kg

Drain Cleaners

36 oz/month	
Usage/Month	1.00 kg

Soft Drinks

Powdered Mix	
Usage/Event	0.007 kg (~0.25 oz. pack)
No. of Events	20 packs/month
Usage/Month	0.14 kg
Premixed	
Usage/Event	0.23 kg (~8 oz. bottle)
No. of Events	24 bottles/month
Usage/Month	5.52 kg
Carbonated Drinks	
Usage/Event	0.34 kg (12 oz. Can)
No. of Events	24 cans/month
Usage/Month	8.16 kg

Fruit Juice

Usage/Event	0.12 kg (~4 oz. Serving)
No. of Events	120
Usage/Month	14.7 kg

Rice/Grains

Usage/Event	0.28 kg (~10 oz. Serving)
No. of Events	120
Usage/Month	33.6 kg

Hot Dogs/Sausage

Usage/Event	0.11 kg (~4 oz. Serving)
No. of Events	32
Usage/Month	3.64 kg

Processed Lunch Meat

Usage/Event	0.11 kg (~4 oz. Serving)
No. of Events	16
Usage/Month	1.82 kg

Ground Beef Chicken

Usage/Event	0.11 kg (~4 oz. Serving)
No. of Events	64
Usage/Month	7.23 kg

Fresh, Frozen, and Canned Fruits and Vegetables

Usage/Event	0.23 kg (~8 oz. Serving)
No. of Events	120
Usage/Month	27.6 kg

Sugar

Usage/Event	0.01 kg (~4 teaspoons)
No. of Events	600
Usage/Month	6.00 kg

Salt

Usage/Event	0.01 kg (per ADA website)
No. of Events	120
Usage/Month	1.20 kg

APPENDIX B

Mass Balance and Systemic Uptake of Mercury Released From Dental Amalgam Fillings

I. Skare

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MASS BALANCE AND SYSTEMIC UPTAKE OF MERCURY RELEASED FROM DENTAL AMALGAM FILLINGS

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(Received 10th July 1994; accepted 10th October 1994)

Abstract. The release of mercury (Hg) from dental amalgam fillings has been verified by several authors. In this study, the emission rate of Hg^0-vapor from the oral cavity (O-Hg) and the urinary Hg-excretion rate (U-Hg) have been studied with 34 healthy individuals. In ten cases, the urinary excretions of silver (U-Ag) and the fecal excretions of Hg and Ag (F-Hg, F-Ag) were also monitored. All variables, except U-Ag, were significantly related to the load of amalgam. According to this study, an individual with a moderate load of amalgam, i.e. 30 restored surfaces, is predicted to exhibit the following emission rates: O-Hg=22, U-Hg=3, F-Hg=60 and F-Ag=27 μg/d (d=24 hours), consistent with a gross mass balance for Hg of approximately 60 μg/d. The corresponding systemic uptake of Hg was estimated to 12 μg/d based on external data relating air Hg^0-exposures to urinary Hg-excretions. The worst case individual showed a gross mass balance of 200 μg Hg/d connected to a systemic uptake of 70 μg Hg/d. These values were compared to the average intake of total-Hg by a Swedish diet (2 μg/d) and to the WHO's tolerable value for intake of total-Hg by food (45 μg/d). Upscaled to the entire Swedish population (8 mill.), the data suggests a fecal/urinary emission to the environment of 100 kg Hg yearly originating from a population load of amalgam fillings containing 90,000 kg of Hg.

1. Introduction

Before the beginning of the 1980's, the stability of dental amalgam with respect to the release of mercury (Hg) was generally not very much questioned. The release of Hg from amalgam has, however, since then been described and verified by several authors (Aronsson, 1989; Berglund, 1988, 1990; Björkman, 1992; Brune, 1985; Frykholm, 1957; Jokstad, 1992; Patterson, 1985; Pleva, 1992; Skare, 1994; Svare, 1981; WHO, 1991; Vimy, 1985a, 1985b).

For individuals with a moderate load of amalgam, i.e. approximately 30 restored surfaces, a basic release rate of elemental Hg^0 from the oral cavity of 20 μg/d (d=24 hours) is normally averaged, reaching about 100 μg Hg^0/d for such individuals most heavily loaded. By chewing and by drinking hot beverages the Hg^0-emission may temporarily be increased by three to tenfold.

One part of the released elemental Hg^0 is exhaled, and one part is retained in the saliva and swallowed together with amalgam particles and corrosion products, giving a gastrointestinal inorganic-Hg flow from which, however, only a smaller fraction is supposed to be systemically absorbed (WHO, 1991).

The remaining part of the released Hg^0 should be systemically absorbed through the lungs or by resorption through the oral mucosa. Being uncharged and monoatomic, elemental Hg^0 is a highly mobile species capable of entering most of the body compartments. The systemic uptake of Hg is, in addition to the present number of amalgam fillings, also influenced by the mean ratio of the oral-to-nasal breathing and to the actual chewing pattern.

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For risk assessment of a long-term inorganic-Hg exposure, biological monitoring of the urinary Hg-excretion is normally applied. Several authors have significantly related elevated urinary Hg-levels to the load of amalgam (Aronsson, 1989; Berglund, 1990; Jokstad, 1992; Langworth, 1991; Olstad, 1987; Skare, 1990, 1994; WHO, 1991; Åkesson, 1991).

Other common biological monitoring indices used are the total-Hg plasma concentration and the level of inorganic-Hg in whole blood - designed for minimizing the confounding influence from MeHg present in the blood. Some authors have used the blood matrix when studying the Hg-exposure from amalgam (Jokstad, 1992; Langworth, 1991; Snapp, 1989; Svare, 1981; Åkesson, 1991).- Only few studies have been published where the monitoring of fecal Hg-excretion is attentioned (Frykholm, 1957; Stock, 1934).

In the present study, *the gross mass flow balance of Hg* and *the systemic uptake of Hg* have been estimated for individuals with different load of amalgam fillings, based on data from the monitoring of oral air Hg-emissions and excretion rates of Hg/Ag by urine and feces. In addition, the Hg-excretion data has been upscaled to represent the entire Swedish population, thus obtaining an estimate of the Hg-emission from amalgam fillings to the sewage systems and to the environment.

2. Subjects and methods

2.1. TEST SUBJECTS AND MEASUREMENTS

Basic monitoring of the emissions of oral air Hg and urinary Hg were performed with 34 healthy adult individuals of both sexes, occupationally unexposed to Hg or Ag. In ten cases, the urinary excretions of silver (U-Ag) and the fecal excretions of Hg and Ag (F-Hg, F-Ag) were also monitored. The individuals were selected to represent a broad range in amalgam loading. None of them normally eat fish from lakes and none was a present smoker. The number of restored amalgam surfaces (N) was examined by a dentist.

2.2. ANALYTICAL METHODS

2.2.1. Elemental Mercury Vapor Emission into the Oral Cavity

As amalgam surfaces are very easily influenced by all kinds of mechanical and chemical actions, the oral environment should be properly normalized prior sampling. Two different methods for monitoring of the emisssion of oral air Hg^0 have been used in the study (Skare, 1994).

By one method, a well-defined flow of oral air (1.5 l/min) was continously sampled through a mouth-piece and passed into a gas cell of a UV-instrument until a steady-state reading was established, from which the oral emission rate of Hg^0 was calculated. The lowest quantifiable Hg^0 vapor concentration in the cell, i.e. 1 $\mu g\ Hg^0/m^3$, corresponds to a oral Hg^0 emission rate of approximately 2 $\mu g/d$ (d=24 hours).

The other oral air Hg^o-method was based on the covering of all amalgam surfaces with a 25-ml portion of water for a fixed period of time (2.0 min) by that collecting all Hg^o-vapor emitted into the aqueous phase. The content of total-Hg in the aqueous sample was determined, after a wet-digestion step at room temperature with an acidified potasssium permanganate ($KMnO_4$) solution, by using a standard cold AAS-technique (D.L.= 0.2 ng Hg/ml) implying a releasing step to Hg^o-vapor by Sn[II]-reduction (Skare, 1972).

The detection limits, equal for the two oral air Hg^o-methods, correspond to a Hg^o-rate expected from 2-3 restored amalgam surfaces, i.e. 1-2 μg O-Hg/d.

2.2.2. Total Mercury and Silver Excretions by Urine

The individuals were requested to collect all their urine voided during a 24-hour period. Sub-samples were wet-digested at room temperature by the addition of an acidified $KMnO_4$-solution.

The total content of U-Hg was determined by using the standard cold AAS- technique. The detection limit, expressed as excretion rate, was on the average 0.2 μg U-Hg/d.

The total content of U-Ag was determined using a graphite furnace AAS- technique. The detection limit, expressed as excretion rate, was on the average 0.6 μg U-Ag/d.

2.2.3. Total Mercury and Silver Excretions by Feces

The individuals were requested to deliver two consequtive fecal voidings while recording the duration intervals. The contents of Hg and Ag in the samples were, after digestion with warm concentrated HNO_3, determined by using an ICP-technique (external laboratory). After relating the results to the sampling times, the results were converted to excretion rates for Hg and Ag (Skare, 1994).

The lowest quantifiable excretion rates were approximately 3 μg F-Hg/d and 0.8 μg F-Ag/d, respectively.

2.3. MASS BALANCE CALCULATIONS ON MERCURY

In estimating the total exposure from Hg, i.e. the gross balance of Hg passing the body, for individuals occupationally unexposed to Hg, the following Hg-containing sources should initially be considered: air, food and water supply, and amalgam fillings.

Urban air may contain 5 ng Hg^o/m^3. If the mean breathing rate during the day is limited to 15 l/min and an uptake efficiency of 80% is assumed, then, the contribution to the systemic Hg-uptake by breathing environmental air may not exceed 0.1 μg Hg/d.

The mean contribution of total-Hg from a Swedish dietary (for normal fish consumers) has recently been determined to approximately 2 μg Hg/d, about 2/3 of which are present as MeHg species (Becker, 1991). The systemic uptake of Hg from the intestines is considered to be 90% for MeHg and 5 to10% for inorganic Hg-species (WHO, 1991).

The purpose of monitoring the fecal Ag-excretion was the possibility to make an indirect estimation of the fraction of Hg contained in the released and swallowed particles and corrosion species. At time of insertion, amalgam restorations contain Hg and Ag in a ratio of approximately 1:0.7 by weight. If the composition of the surface layers is

assumed to be constant for years, a rough estimate of Hg contained in particles and corrosion products can be calculated from the F-Ag rate after correction for food-Ag in feces (obtained from the F-Ag excretion with the amalgam-free individual).

The estimation of the systemic uptake of Hg is a more elusive task. However, since the systemic input and output of Hg, at equilibrium, by definition is the same, the systemic uptake of Hg should be more adequately estimated by using urinary excretion data than by using data related to intake patterns.

After entering the blood, most of the body-burden of Hg (90%) is stored in the kidneys, the Hg-content of which is reflected by the U-Hg excretions. A minor part part of the systemic-Hg is expected to be stored in other tissues exhibiting very long halftimes for Hg-clearance (i.e. years), where the equilibrium is very slowly attained. This latter fraction is, however, not predictable from urinary data (WHO, 1991).

In equilibrium with a long-term inorganic Hg-exposure, the daily urinary Hg-excretion has been shown to be rather constant (Skare, 1994). By mathematical integration of the kidney-clearance decay curve to infinity, assuming $t_{1/2} = 45$ days, a first order of kinetics and by using the monitored U-Hg rate as input data, the kidney-burden can be estimated by the equation:

$$\text{Kidney-burden } (\mu g \text{ Hg}) = \text{U-Hg}(\mu g/d) * 45(d) / \ln 2.$$

For example, an individual with a moderate load of amalgam, exhibiting at equilibrium a daily urinary excretion of 3 μg Hg should have a kidney-burden of approximately 200 μg Hg. Individuals, very heavily loaded with amalgam, may in extreme cases show urinary Hg-excretions (and kidney-burdens), which are tenfold higher.

The body-clearance of Hg is not accomplished only by urine but also by feces, sweat, exhalation and by storage in hair and nails. However, only the excretions by urine and feces are large enough to be considered. The fecal excretions contain Hg-species (maybe biotransformed), which partly have been swallowed and partly originate from Hg systemically absorbed and excreted through the bile.

To estimate the excretion rate of Hg through the bile, again, U-Hg excretion rate data might be helpful. Referring to the report by WHO 1991, an occupational air concentration of 25 μg Hg°/m^3 is, on group level, consistent with a urinary excretion of 45 μg U-Hg/d (≈30 μg U-Hg/g creatinine). As a daily 8-h Hg°-exposure is consistent with a systemic uptake of 175 μg Hg/d [calculation: 25(μg/m^3) * 18(l/min (worker)) * 8(h) * 60(min/d) * * 80%(retention efficiency)], the difference between this total-Hg uptake rate and the U-Hg rate (45 μg/d) should be the averaged bile-Hg rate.

If this relationship between the urinary and the bile Hg-excretion is also valid at lower levels of exposure, then an equation can be made up for estimating the total systemic uptake of Hg for individuals loaded with amalgam:

$$\Sigma \text{ Hg}_{\text{uptake}} (\mu g/d) = 4 * \text{U-Hg } (\mu g/d)$$

This formula is not inconsistent with results from human Hg°-exposure studies reported by Cherian, 1978.

3. Results and discussion

3.1. BIOLOGICAL MONITORING OF MERCURY AND SILVER

The results obtained from the ten individuals concerning oral air Hg°-emissions and urinary and fecal excretions of Hg and Ag are summarized in Table I.

As seen from Table I, the flow rates of Hg/Ag for the amalgam-free individual were, with one exception, i.e. U-Ag, very low compared to the corresponding rates for the nine amalgam loaded individuals. In spite of this group of nine individuals, on average, was somewhat heavier loaded with amalgam (mean: N=40 surfaces) than is normally expected from a Swedish middle-age group (i.e. N=30), the results still clearly indicate that man's exposures to total Hg and Ag predominatly originate from the presence of dental amalgam fillings.

TABLE I

Emission and excretion rates of Hg and Ag from individuals loaded with amalgam fillings (Data from ten individuals; Hg = mercury, Ag = silver and d = 24 hours)

Variable	Symbol	Amalgam loaded individuals		Control individual
		Md-value	Range	
Number of amalgam surfaces	N	40	18 - 82	0
Oral air Hg° emission	O-Hg	29 µg/d	20 - 124 µg/d	0 µg/d
Urinary Hg excretion	U-Hg	4.5 µg/d	1.8 - 19 µg/d	0.4 µg/d
Urinary Ag excretion	U-Ag	1.7 µg/d	1.4 - 6.0 µg/d	1.3 µg/d
Fecal Hg excretion	F-Hg	64 µg/d	27 - 190 µg/d	1 µg/d *
Fecal Ag excretion	F-Ag	33 µg/d	11 - 97 µg/d	4 µg/d *

* Mean value based on a homogenized sample from ten consecutive days

In this study, the emission rate of Hg°-vapor from the oral cavity has been determined by using two entirely different methods. The close accordance in the results by the two methods gives support for assuming the averaged O-Hg rates to be reliable. The method, in which only a simple water trap is used for sampling, might, because of simplicity, be the method choice for out-of-laboratory purposes. This does not say that the determination of the unstimulated O-Hg rate should be the most appropriate way in assessing an amalgam Hg-exposure.

According to several studies, urinary excretions do not often exceed 1 μg Hg/d for amalgam-free individuals occupationally unexposed to Hg. Our control individual did apply to this prediction. Urinary excretions, due to amalgam, exceeding 15 μg Hg/d are also rare. Our worst case individual, having 82 restored amalgam surfaces, many of which in a bad condition, showed a urinary excretion of 19 μg Hg/d.

The content of Hg in feces was about twice the content of Ag in feces. The extremely high coefficient of correlation for F-Hg *vs* F-Ag (Table II) should be a strong evidence for the fecal Hg-excretions being connected to the bearing of dental silver-amalgam. For individuals with a moderate load of amalgam (N=30 surfaces), their fecal Hg-excretion rate was predicted to be about 20 times the urinary Hg-excretion rate and about 30 times the total-Hg intake by food (2 μg Hg/d) consuming an average Swedish diet. This food-Hg value, reported by Becker and Kumpulainen 1991, was consistent with the fecal Hg-excretion value exhibited by the amalgam-free control individual.

TABLE II

Correlation coefficients (Pearson, r) among N, O-Hg, U-Hg, U-Ag, F-Hg and F-Ag
See Table I for explanation of symbols. The number of observations (n) used and the adherent statistical p-values are also displayed

	N	O-Hg	U-Hg	U-Ag	F-Hg	F-Ag
O-Hg	r= 0.82 p< 0.0001 n = 34	--				
U-Hg	r= 0.80 p < 0.0001 n = 34	r= 0.91 p < 0.0001 n = 34	--			
U-Ag	r= - 0.20 p = 0.59 n = 10	r= - 0.23 p = 0.53 n = 10	r= - 0.23 p = 0.53 n = 10	--		
F-Hg	r= 0.67 p = 0.033 n = 10	r= 0.85 p = 0.001 n = 10	r= 0.81 p = 0.003 n = 10	r= 0.12 p = 0.75 n = 10	--	
F-Ag	r= 0.74 p = 0.02 n = 9	r= 0.93 p < 0.0001 n = 9	r= 0.90 p = 0.0003 n = 9	r= 0.16 p = 0.69 n = 9	r= 0.97 p < 0.0001 n = 9	

Referring to Table II, significant levels of interplay were, excl. U-Ag, seen among all the emission/excretion variables and the number of amalgam surfaces. The deviating behavior of the U-Ag variable, e.g. no significant correlation to N, indicates that Ag from amalgam is not, or only to a very low extent, systemically absorbed.

The following linear regression line equations have been calculated:

O-Hg = 0.1 + 0.73 * N;	(based on 34 observations)
U-Hg = 0.4 + 0.08 * N;	(based on 34 observations)
F-Hg = 15 + 1.45 * N;	(based on 10 observations)
F-Ag = 4 + 0.77 * N;	(based on 9 observations)

3.2. MASS BALANCE CALCULATIONS ON MERCURY

3.2.1. Gross mass balance of Hg

After a long-term Hg-exposure, the input and output flows of Hg should, at equilibrium equalize. The two main pathways for man's excretion of inorganic Hg are through urine and feces. Thus, a satisfactory estimate of the mean daily input of total-Hg should be the sum of the daily U-Hg and the F-Hg excretion rates. With a load of amalgam scored to be 30 restored surfaces, i.e. the average load of amalgam for middle-age people in Sweden, the predicted excretion rates (see regression equations above) should make up a gross mass balance being approximately 60 μg Hg/d.

In Figure 1, the intake, uptake and excretion flows of Hg for this average individual are outlined. As seen from Figure 1, the intake of amalgam-Hg is the most dominant origin to the Hg-exposure.

The elimination of all amalgam fillings should result in a very rapid decay of the F-Hg rate level. The U-Hg rate and some part of the bile-Hg rate, both reflecting the body-burden of Hg, should decline more slowly, i.e. during months.

The fecal Hg-excretions may consist of Hg-species as amalgam particles, corrosion products (oxidized Hg), bile-Hg (probably Hg connected to SH-groups in low-molecular weight proteins), biotransformed MeHg from food (mineralized by bacterial action) and species originating from the swallowing of elemental Hg^0-vapor with the saliva. Some of these Hg-species may have passed the gastro-intestinal tract without any interactions at all, whereas other Hg-species have had a systemic past.

Upscaled to the entire Swedish population (8.5 mill.), the fecal-urinary excretions contain about 100 kg Hg/year originating from a population load of dental amalgam restorations containing approximately 90,000 kg of Hg.

3.2.2. Systemic uptake of Hg

The systemic uptake for an individual moderate loaded with amalgam (N=30 surfaces) has here been calculated to 12 μg Hg/d based on urinary excretion data and assumptions concerning the relationship between air-Hg^0 exposure and U-Hg data (see 2.3). This amalgam Hg-exposure should be equivalent to a daily 8-hour occupational Hg^0-exposure of 2 μg Hg^0/m^3, and corresponds to a total body-burden of 200 to 250 μg Hg.

Our worst case individual was suggested to exhibit a systemic uptake of 70 μg Hg/d, which value might be compared to a food standard by WHO stating the daily "tolerable" intake of total-Hg and MeHg should not exceed 45 and 30 μg Hg/d, respectively (WHO, 1972). The "acceptable" intake should be *none* according to the same report.

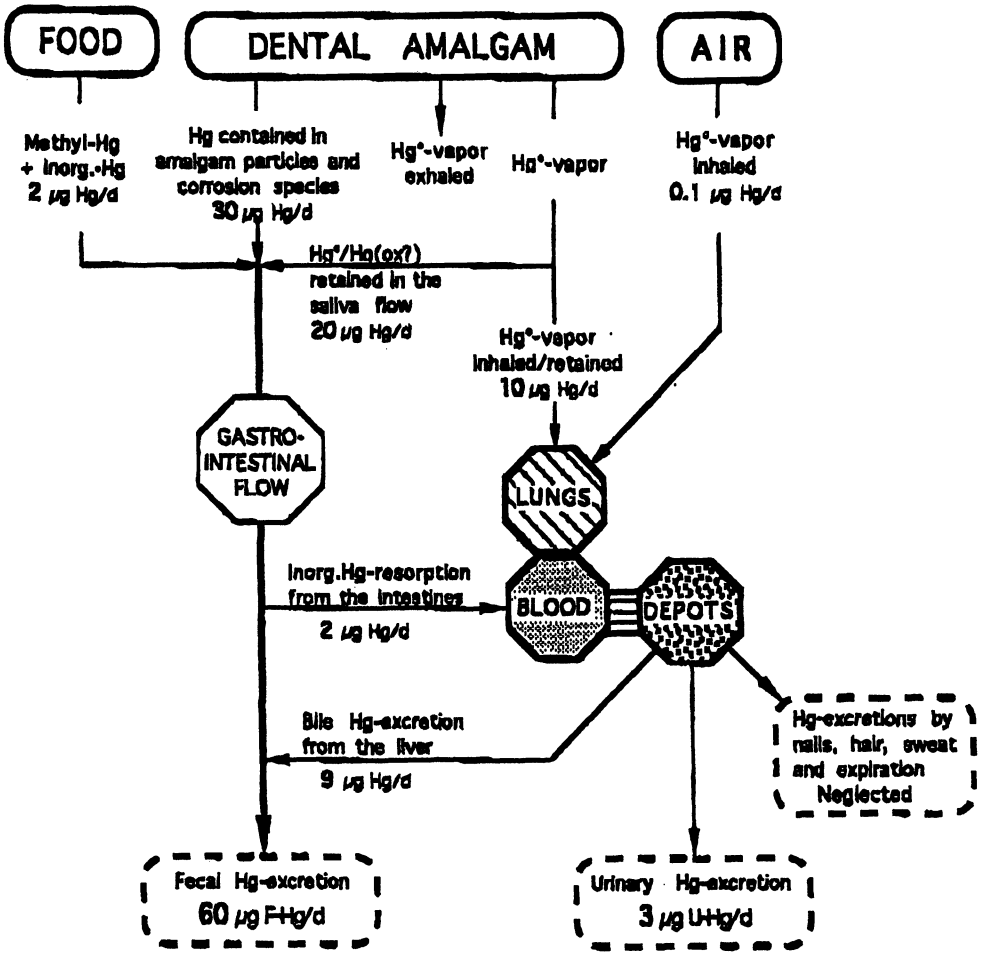

Figure 1. Flow chart exhibiting the intake, uptake and excretions of Hg originating from environmental air, food and dental amalgam.. Applicable to individuals with a moderate load of amalgam , i.e. 30 surfaces.

(For lucidity, the enterohepatic recirculation of MeHg is not outlined)

4. Conclusions

The study has confirmed that human emissions of oral air Hg^0 and excretions of urinary Hg are significantly related to the present load of dental amalgam fillings. In addition, even the fecal excretions of Hg and Ag were shown to exhibit a significant relationship to the number of amalgam fillings.

For an individual with a moderate load of amalgam, the predominating part of the gross mass balance of Hg originates from the fillings. At comparison, a normal contribution to the Hg-exposure from air, water and food should be neglectable.

The daily systemic absorption of Hg was, for individuals heavily loaded with amalgam, predicted to be close to or even exceeding the WHO's recommendation for "tolerable" intake of total-Hg by food.

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ACKNOWLEDGMENTS

The AMSA Mercury Workgroup would like to acknowledge the contributions made by the following individuals:

Patty Lee, Anna Rule, Cynthia S. Bato, Sandra J. Williams, Hampton Roads Sanitation District, Virginia Beach, VA

Keith Linn, Northeast Ohio Regional Sewer District, Cleveland, OH

Stephanie Hughes, City of Palo Alto Regional Water Quality Control Plant, Palo Alto, CA

Kevin McManus, Massachusetts Water Resources Authority, Boston, MA

Rebecca Flood, Metropolitan Council Environmental Services, St. Paul, MN

Margie Nellor, Sanitation Districts of Los Angeles County, Whittier, CA

AMSA MERCURY WORKGROUP

AMSA's Mercury workgroup was formed in 1998 to address issues related to the discharge of mercury into the environment and the impact of anticipated mercury effluent limits and sensitive analytical methods to publicly-owned treatment works (POTWs). The workgroup has performed significant work to ascertain the low levels of mercury in POTW discharges and the sources of mercury into the POTW collection system. The workgroup is also working with U.S. EPA to improve the range of analytical methods used to detect mercury in wastewater, and is seeking appropriate modifications to mercury criteria using best available science.

The workgroup plans further study to evaluate the effectiveness of source control/pollution prevention programs to achieve anticipated regulatory compliance levels and plans to explore potential national compliance strategies for mercury so that every individual POTW does not have to come up with an individual compliance solution. Agencies represented on AMSA's Mercury Workgroup include:

Sanitation Districts of Los Angeles County, CA
Orange County Sanitation District, CA
Sacramento Regional County Sanitation District, CA
City of San Diego Metropolitan Wastewater Department, CA
City of Palo Alto Regional Water Quality Control Plant, CA
San Francisco Public Utilities Commission, CA
City of Los Angeles Department of Public Works, CA
City of San Jose Environmental Services Department, CA
Central Contra Costa Sanitary District, CA
Metropolitan Water Reclamation District of Greater Chicago, IL
Massachusetts Water Resources Authority, MA
Wayne County Department of Environment, MI
Western Lake Superior Sanitation District, MN
Metropolitan Council of Environmental Services, MN
Onondaga County Department of Drainage and Sanitation, NY
City of Lima Utilities Department, OH
Metropolitan Sewer District of Greater Cincinnati, OH
City of Akron - Public Utilities Bureau, OH
City of Toledo Department of Public Utilities, OH
Northeast Ohio Regional Sewer District, OH
Hampton Roads Sanitation District, VA
Green Bay Metropolitan Sewer District, WI
Milwaukee Metropolitan Sewerage District, WI