# TECHNICAL MEMORANDUM

TO: Kelly Moran, Palo Alto Regional Water Quality Control Plant

FROM: Bill Johnson, EIP Associates

DATE: March 2, 1999

SUBJECT: **MERCURY SOURCE IDENTIFICATION UPDATE: DENTAL OFFICES AND HUMAN WASTE**

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This technical memorandum updates the *Mercury Source Identification* prepared for the Palo Alto Regional Water Quality Control Plant (RWQCP) in August 1997 to better estimate the load attributable to mercury discharges from dental offices (EIP Associates 1997). It also revises the methodology for considering human waste from service area employees and residents, and estimates the portion of the mercury in human waste attributable to mercury amalgam fillings. Then it briefly reviews recent studies of dental discharges published by other organizations. The results and conclusions of this updated analysis are presented at the end of this memorandum.

## HUMAN WASTE

As shown by the calculations presented in Attachment A, this updated analysis employs a somewhat different approach in estimating the human waste mercury load than the approach used for the *Mercury Source Identification*. The previously completed human waste calculations were based on mercury consumption in food as roughly estimated by the Washington Toxics Coalition and reported by Larry Walker Associates (Washington Toxics Coalition 1992; Larry Walker Associates 1994). The previous calculations assumed a daily dietary mercury intake of about 0.015 milligrams per person, but a 1991 World Health Organization report estimates that a more typical daily dietary mercury intake is probably closer to 0.0066 milligrams per person (World Health Organization 1991). The human waste calculations presented in this memorandum rely on actual reported measurements of mercury in feces, not dietary intake. The value used here, 0.0022 milligrams per person, reflects measurements of the fecal mercury content for a group of study participants without mercury amalgam fillings (the same study provided data for participants with amalgam fillings, as discussed below) (Osterblad 1995). This value is closer to the World Health Organization estimate for dietary intake than to the Washington Toxics Coalition estimate. This revised methodology results in a RWQCP human waste load of about 0.45 pounds of mercury per year from dietary intake.

By relying on dietary intake data, the previous human waste estimate did not include mercury found in human waste as a result of dental amalgam fillings. As shown in Attachment A, the RWQCP human waste load attributable to amalgam fillings is estimated to be about 4.7 pounds per year. This estimate is based on actual reported measurements of mercury in feces from a group of study participants with amalgam fillings (versus measurements for participants without fillings) (Osterblad 1995). Because this mercury was not specifically included in the *Mercury Source Identification*, the human waste load attributable to these fillings was previously included among the unknown sources, including unknown residential sources.

The uncertainty in the estimated human waste load attributable to dental amalgam fillings is relatively high because few studies have tried to estimate mercury levels in human waste (Osterblad 1995; Bjorkman 1997; Skare 1995). The relevance of available data to the RWQCP service area depends, in part, on the differences or similarities between the number of filled surfaces[*] the study participants had and the number of filled surfaces typical of the RWQCP service area population. Differences in regional practices may also be meaningful, particularly since the available studies were undertaken in Sweden and Denmark.

[*] Each tooth has several surfaces, and single fillings can cover more than one surface if placed where the surfaces come together. Therefore, the number of fillings in the populace is less than the number of filled surfaces in the populace.

## DENTAL OFFICES

### Estimates of Dental Office Loads

Several studies have been performed with the intent of estimating the amount of mercury discharged to the sewer by dental offices. As shown in Table 1, the estimated mercury loads attributed to dentists span a range extending over an order of magnitude, from about 0.03 grams per day per dentist to about 0.3 grams per day per dentist. In each study, the variation among the individual measurements is reported to have been substantial. Mercury loads from the same dental office have varied over three orders of magnitude for similar activity levels (Tuominen 1998a). Therefore, in each case, the estimated loads are fairly uncertain. As discussed briefly in Attachment B, studies completed at the University of Illinois at Chicago suggest that all the results presented in Table 1 are within the range of reasonable possibilities for dental office loads. Each agency's approach in estimating dental office loads appears to be reasonable and, therefore, should result in similar conclusions. The fact that reported conclusions do not agree well with one another suggests that other factors may be at play. Possible reasons for the disparity among the results are discussed below.

***Sampling Locations***. Differences in sampling locations probably contribute to the different results, but they do not appear to be solely, or even primarily, responsible for the observed differences. For example, many of the samples were collected at similar locations (e.g., exterior clean-outs). As indicated in Table 1, data for both the Cleveland and Boulder areas were obtained at exterior clean-out locations, but the load estimated for Boulder is more than twice the load estimated for Cleveland. Sample location does not appear to be the sole determining factor in estimating dental office loads.

***Sampling Procedures and Laboratory Handling***. The manner in which samples were collected and analyzed by the various agencies is probably reflected in the results. Insufficient information is available to thoroughly review the sampling and laboratory handling procedures of each agency, but differences probably relate to how many samples were collected and how

## TABLE 1: Load Estimates for Dental Offices Around the U.S.

| Information Source | Estimated Load from Dental Offices (grams/day/dentist) | Comments |
|---|---|---|
| San Francisco, CA[a] | 0.035 | Sampled effluent from 9 buildings, one of which being occupied by 150 dentists. |
| Cleveland, OH[b] | 0.042 | Sampled effluent from 5 dental offices. Samples collected at outside locations containing dental wastewater (exterior clean-outs). |
| Seattle, WA[c] | 0.064 | Sampled wastewater from 27 patients. Collected samples just after amalgam trap and filtered them to simulate vacuum filter. |
| Boulder, CO[d] | 0.10 | Sampled effluent from 26 dentists in 4 dental clinics. Samples collected at outside locations containing dental wastewater (exterior clean-outs). |
| Boston, MA[e] | 0.043 – 0.27 | Sampled sewer manholes outside 5 dental facilities and primary sources within dental clinics. |
| Duluth, MN[f] | 0.1 – 0.3 | Sampled below dental buildings, before wet vacuum pumps, and after dry vacuum pumps. |
| Aarhus, Denmark[g] | 0.25 | Sampled effluent from about 20 dentists in 10 dental clinics. Samples collected at outside locations close to sewer outfall. Dentists did not use amalgam separators. |

[a] Rourke 1993.
[b] Linn 1998.
[c] Municipality of Metropolitan Seattle 1993. A total of 51 pounds of mercury per year was attributed to the 1,500 dentists in the metropolitan Seattle service area. EIP Associates estimated the value presented in this table by assuming each of these dentists works 48 five-day weeks per year.
[d] Buswell 1998. EIP Associates estimated the value presented in this table on the basis of average loads reported for four clinics and the number of dentists at each clinic.
[e] Massachusetts Water Resources Authority 1997. EIP Associates estimated the values presented in this table on the basis of a reported load between 0.102 and 0.601 pounds of mercury per day attributed to roughly 1,000 general practice dentists in the metropolitan Boston service area.
[f] Western Lake Superior Sanitary District 1997.
[g] Arenholt-Bindslev 1996.
*Source:* EIP Associates and references cited above.

representative composite samples are of actual discharges. Sample collection, handling, and analysis methods can also create differences in the accuracy of the reported results, especially for mercury, where positive interferences due to environmental and laboratory contamination have prompted the U.S. Environmental Protection Agency and others to move toward the use of “ultra clean” techniques.

Most agencies report using standard laboratory methods. Because mercury concentrations in dental office discharges are typically large enough that exceptional techniques are not needed to measure them, the lack of “ultra clean” techniques does not appear to explain the large range of results reported. The range of the conclusions reported by the various agencies does not suggest that any particular laboratory has reported its results inaccurately (i.e., no one result stands out as unreasonable among the others). It is unlikely that nearly all the agencies could have had problems with their sampling procedures or laboratory analyses. The substantial differences reported probably relate to other factors.

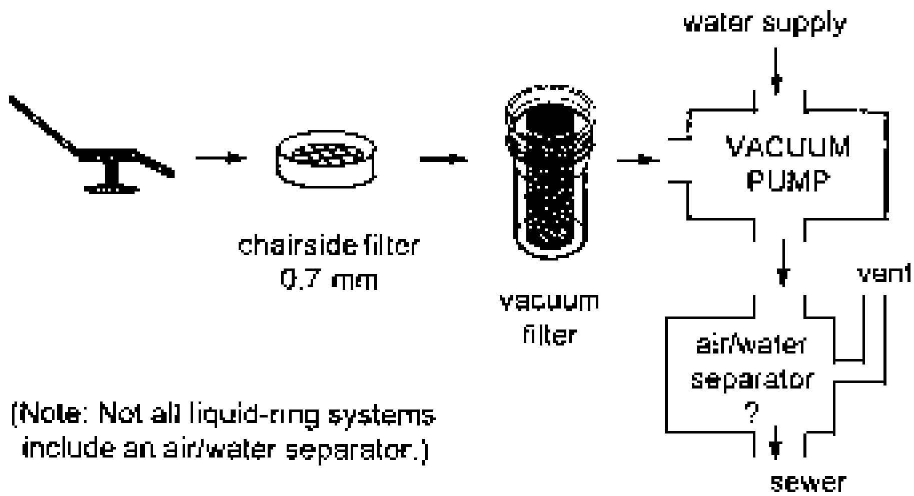
Both mercury concentrations and discharge flow rates are needed to estimate mercury loads, and while determining mercury concentrations is challenging, estimating flows is also difficult. Flows from dental offices are relatively low and can be highly variable. Uncertainties in estimating flows probably contribute to uncertainties in estimating loads. These uncertainties could explain some of the variability in the results shown in Table 1.

***Dental Equipment and Practices***. Wastewater handling practices at dental offices are known to vary widely from office to office, even within the same geographic area. There may also be regional differences in standard practices. Figure 1 presents diagrams of typical vacuum pump systems in dental offices. While using a 0.7 millimeter screen chair-side filter is standard practice for most dental offices (Berglund 1997), the other components of the system, including vacuum filters and air/water separators, may or may not be found in any particular dental office. The pore sizes of the chairside traps and vacuum filters can also vary, resulting in different mercury loads.

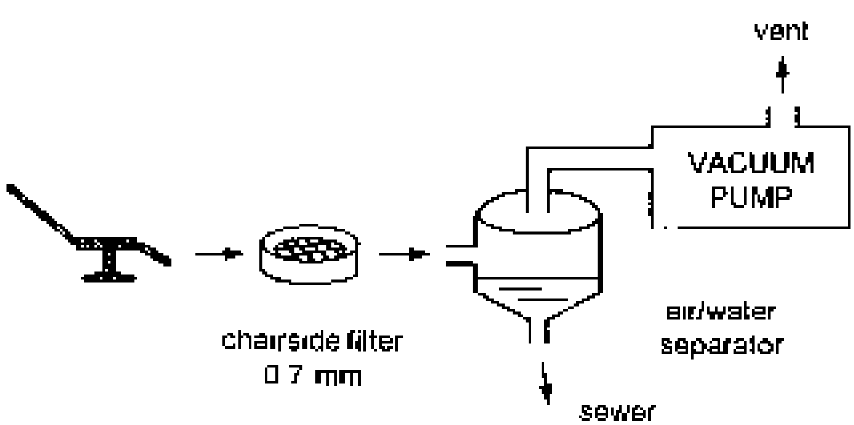
## Figure 1: Chairside Traps and Vacuum Filters

(Berglund 1997)

***Liquid-Ring* Dental Vacuum Pump System**




***Turbine (Dry)* Dental Vacuum Pump System**




(With either system, vacuum pumps may serve multiple chairs)   (MCES, 10/98, pao)

The level of awareness that individual dentists exhibit regarding the environmental concerns related to mercury can vary widely. Attitudes about releasing mercury into the environment likely affect wastewater management practices. Regular maintenance of vacuum filters is important in keeping them operational and effective. Anecdotal evidence suggests that some workers neglect to clean their vacuum filters regularly, reducing their efficiency. Because the primary purpose of the vacuum filter is to protect the vacuum from particles, not to minimize mercury discharges, some workers (apparently unaware of the mercury content of the filter waste) have been observed rinsing the filters into a sink. Some dentists have also been reported to rig primitive settling devices to keep their vacuum lines clear. On the other hand, many dental offices have installed state-of-the-art amalgam filters and treatment devices, and regularly maintain their equipment. The average mercury loads from these offices would be expected to be much less than from a less well managed office. Data available from the agencies listed in Table 1 do not include information about maintenance practices in the dental offices studied, so it is impossible to determine if such practices correlate with observed results.

How the wide variations in filtering equipment and office practices affect the results reported by the various agencies is unknown, but likely to be substantial. However, the type of dental equipment and operational practices implemented cannot explain why mercury concentrations in samples from the same clinic, collected at different times but when the clinic was operating at the same level of activity, can range over three orders of magnitude (as mentioned above). Variations in dental equipment and practices may contribute to variations in reported results, but other factors are likely responsible for variations at individual facilities.

***Build-Up and Release of Amalgam Particles***. A study of 20 Danish dental clinics found no correlation between the number of amalgam surfaces produced or removed at a clinic and the amount of mercury found in its simultaneously collected wastewater. Sampling was conducted as close to the waste pipes into the main sewer system as possible (i.e., after passage of sedimentation and filtration equipment) (Arenholt-Bindslev 1996). Agencies in the U.S. have observed similar phenomena (Tuominen 1998a). A major factor affecting mercury discharges is suspected to be the settling of mercury and amalgam particles (which are both very dense) in vacuum lines and plumbing. Studies show that more than 90% of the mercury in dental wastewater passing a 0.7 millimeter filter will settle out within about 24 hours, as discussed briefly in Attachment B (Cailas 1994).

There are many locations where dense, settlable amalgam particles can become trapped on their way to a wastewater treatment plant (Berglund 1997; Tuominen 1998b). Many dental office vacuum hoses have flexible accordion folds like a vacuum cleaner hose. The amount of amalgam released from such a hose could have more to do with how the hose is jiggled or moved, and less to do with how much mercury enters the tube at any particular time. Disturbing a vacuum line could dislodge particles and result in uneven releases. Alternatively, mercury particles could build up (along with other material) in a line until reaching a large enough mass to result in a sudden release. Such uneven releases could explain the wide range of individual sample results reported by all investigators.

Vacuum lines are not the only places dense particles can lodge. Plumbing systems contain low points, ridges, and crevices that can capture small sediments. Mercury may not readily dislodge from these areas and may build up over time. Trapped mercury particles would be expected to continually leach small amounts of mercury as time passes. Therefore, data collected outside a dental building may actually reflect historical mercury deposits more than current mercury discharges. As dental activities continue, the mercury levels in the plumbing systems could approach a steady state, where releases from mercury trapped in the pipes comprise almost the entire mercury discharge.

***Other Factors***. Other factors may pose challenges when interpreting the data in Table 1. In cases where samples were collected outside a dental building, other sources of mercury in the wastewater flow could interfere with the results. Human waste, for example, contains mercury and would be anticipated to be present in the effluent of many dental buildings. As discussed in Attachment A, however, such mercury would probably not substantially contribute to the estimated RWQCP mercury load. Mercury in the water supply could also affect the results. In the RWQCP service area, the water supply contains a relatively large portion of the mercury load at the plant, but the dental office flow is so small that the water supply does not substantially contribute to the mercury load from dental offices, as shown in Attachment A.

**RWQCP Loads**

In estimating discharges from dental offices, this analysis uses the same assumptions as were used for the *Mercury Source Identification* and, therefore, reports the same results. The load attributed to dental offices is about 2.1 pounds per year. This estimate relies on City and County of San Francisco data (see Table 1) that represent a fairly large pool of dentists (nine dental buildings, one of which houses 150 dentists). The dentists are located geographically close to the RWQCP service area (thereby best representing any regional differences in dental practices), and the data were collected by credible individuals well known by RWQCP staff (Rourke 1993). Anecdotal information from San Francisco staff suggests, however, that these San Francisco data probably understate the dental office load. More recent San Francisco data are unavailable for review and confirmation.

The data collected by the other agencies listed in Table 1 appear to support the assertion that the San Francisco data understate the dental office mercury load. Because of the wide range of mercury discharge estimates reported, the dental office load estimated here for the RWQCP is believed to be more uncertain than previously indicated in the *Mercury Source Identification*. The evidence presented in Table 1 suggests that the chances that the San Francisco data understate the mercury load from dental offices are much greater than the chances that they overstate this load. Nevertheless, the use of these data to quantitatively estimate RWQCP loads is based on a logical rationale (as stated above), and for the reasons discussed above, the data from the other agencies presented in Table 1 cannot be used to quantify how much use of the San Francisco data could understate the actual mercury discharge load from dental offices.

## UPDATED RESULTS AND CONCLUSIONS

Updated information regarding sources of mercury within the RWQCP service area are provided in Figure 2 and Table 2. The calculations on which Figure 2 and Table 2 are based are provided in Attachment A. They rely on information from various sources listed among the references at the end of this memorandum. This memorandum addresses mercury sources as of 1996. RWQCP staff will update the headworks loading calculations for the plant and will update the *Mercury Source Identification* to reflect 1998 conditions in the *Clean Bay Plan 1999*.

As shown in Figure 2 and Table 2, residential waste (excluding its water supply and human waste components) is a substantial source of mercury, contributing about 30% of the mercury found in the RWQCP influent. (If the residential human waste component were added, residential waste would account for about 47% of the total mercury load, as demonstrated by Attachment A.) The water supplied to the RWQCP service area is also a substantial source, contributing about 22% of the mercury flowing to the RWQCP. Discharges from dental offices contain about 9% of the total RWQCP mercury load, while the mercury excreted in human waste as a result of mercury-containing amalgam fillings is estimated to be about 20% of the total mercury load. The mercury in human waste attributable to dietary intake (i.e., all non-amalgam sources) is estimated to be about 2% of the total load. Permitted industries contribute about 6% of the total load, and all other known sources combined account for about 7%. The sources of about 4% of the mercury entering the RWQCP remain unknown. Therefore, this analysis accounts for 96% of the 23 pounds of mercury observed in the RWQCP's influent.

## UNCERTAINTIES

Because substantial uncertainty exists in several of the updated load calculations, the uncertainties underlying the total RWQCP load estimate are revisited here. The level of uncertainty in the updated estimates of dental office and human waste loads is considered "high"

**Figure 2: RWQCP Mercury Sources, 1996 (Updated)**

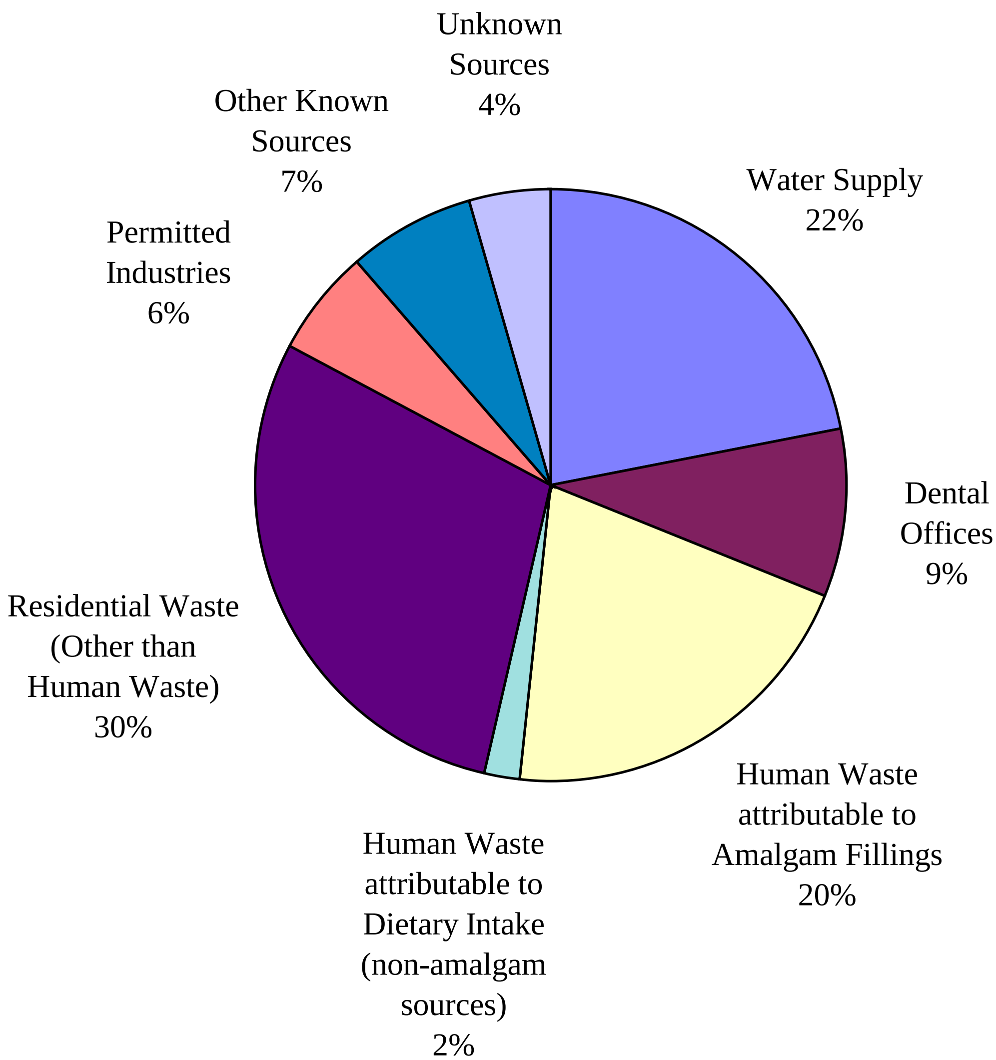


**TABLE 2: RWQCP Mercury Sources, 1996 (Updated)**

| Source | Average Hg Load (pounds/year)[a] |
|---|---|
| Water Supply | 5.1 |
| Dental Offices | 2.1 |
| Human Waste attributable to Amalgam Fillings | 4.7 |
| Human Waste attributable to Dietary Intake | 0.45 |
| Residential Waste (other than human waste) | 6.7 |
| Permitted Industries | 1.3 |
| Other Known Sources[b] | 1.6 |
| Unknown Sources[c] | 1.0 |
| TOTAL | 23. |

[a] Load data have been corrected to reflect mercury in the water supply.
[b] Other known sources include storm water inflow, Stanford University, septage haulers, commercial laundries, and portable toilets.
[c] The load attributed to unknown sources is based on the difference between the total influent load and the loads estimated for each of the identified sources.
*Source:* EIP Associates 1997, as updated by the calculations in Attachment A.

as defined in the *Mercury Source Investigation*.* Furthermore, the RWQCP may not have accurately estimated the mercury load in the plant's influent. Some portion of the mercury discharged to the sewer system in the RWQCP service area may not have been collected in the influent samples. Elemental mercury and mercury amalgam are very dense and not particularly water soluble. In all its forms, mercury tends to cling to particles in wastewater. More mercury-containing particles would be expected to exist toward the bottom of the flowing influent wastewater than toward the top of it, and sampling equipment may not have collected this material if it were not evenly suspended in solution at the sampling port. (Mercury-containing particles may be collected along with grit from the wastewater.)

The same sampling difficulties may be encountered in measuring mercury discharges from dental facilities. For example, San Francisco's sampling equipment and protocol may miss some

* The *Mercury Source Investigation* defines a high uncertainty level as follows: "Calculation is based on very limited data and numerous assumptions. Data may be obtained from a less well documented source. Treatment of 'non-detect' data probably contributes greatly to uncertainty. Error could be greater than ±100%."

of the larger, denser, and heavier particles in the waste stream. Such sampling issues could also tend to understate the mercury discharges from other sources as well, such as residential trunk lines. More study will be needed to determine whether dense mercury particles or droplets are being excluded from the influent measurements. In the meantime, the mercury load estimated here for dental offices should be treated as a lower limit, which may substantially understate the actual amount of mercury released to the environment from dental offices.

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# ATTACHMENT A

# CALCULATIONS

## HUMAN WASTE ATTRIBUTABLE TO DIETARY INTAKE
### All Non-Amalgam Sources of Exposure

Daily Hg Discharge per Human = 0.0022 mg/day (*Source:* Osterblad 1995)
Annual Hg Discharge per Human = 0.0022 mg/day x 365 days/year = 0.802 mg/year

> Fecal excretions of individuals without amalgam fillings contain about 0.061 ng Hg/mg dry feces (Osterblad 1995). Assuming a daily stool mass of about 120 g with a water content of about 70% (Bjorkman 1997), fecal excretions of individuals without amalgam fillings contain about 0.0022 mg Hg/day (i.e., daily fecal excretion = 0.061 ng Hg/mg dry feces x 0.3 mg dry feces/mg wet feces x 1,000 mg wet feces/g wet feces x 120 g wet feces ÷ 1,000,000 ng Hg/mg Hg = 0.0022 mg Hg/day).

Service Area Residential Population = 236,200
(*Source:* Association of Bay Area Governments 1995)

Service Area Employed Residents (residents of service area with jobs, whether inside the service area or not) = 115,500 (*Source:* Association of Bay Area Governments 1995)

Total Service Area Jobs (jobs in the service area, whether held by residents or not) = 163,700
(*Source:* Association of Bay Area Governments 1995)

Non-Working Service Area Residents =
Service Area Residential Population - Service Area Employed Residents =
236,200 - 115,500 = 120,700

Non-working residents are assumed to discharge 100% of their human waste at home as residential human waste.

Workers (whether residents of the service area or not) are assumed to discharge 64.3% of their human waste at home as residential human waste and 35.7% of their human waste at work as employee human waste. This assumption is based on the following:

> Each employee is assumed to work 5 days/week and stay home 2 days/week. During a typical work day, each employee is assumed to spend 8 hours sleeping, 8 hours awake at home, and 8 hours awake at work. Because during the work day half of the employee's waking hours are at home and half are at work, 50% of his or her human waste is assumed to be discharged at home and 50% is assumed to be discharged at work. Therefore, the residential discharge of a worker is 0.643 times that of a non-worker (i.e., fraction of employee discharge excreted at home = [2 days + {0.5 x 5 days}] ÷ 7 days = 0.643). Consequently, the employee human waste discharge of each worker is 0.357 times the total

amount he or she excretes both at work and at home (i.e., fraction of employee discharge excreted at work = 1 - fraction excreted at home = 1 - 0.643 = 0.357).

**Residential Human Waste from Dietary Intake**

Annual Residential Human Waste Load of Non-Workers =
Annual Hg Discharge per Human x Non-Working Service Area Residents =
0.802 mg/yr x 120,700 = $9.67 \times 10^4$ mg/yr
$9.67 \times 10^4$ mg/yr x 0.001 g/mg x 0.002205 lb/g = 0.213 lb/yr

Annual Residential Human Waste Load of Workers =
Annual Hg Discharge per Human x
Service Area Employed Residents x Fraction of Employee Discharge Excreted at Home =
0.802 mg/yr x 115,500 x 0.643 = $5.95 \times 10^4$ mg/yr
$5.95 \times 10^4$ mg/yr x 0.001 g/mg x 0.002205 lb/g = 0.131 lb/yr

Total Residential Human Waste Load =
Residential Human Waste Load of Non-Workers + Residential Human Waste Load of Workers
= 0.213 lb/yr + 0.131 lb/yr = **0.345 lb/yr**

**Employee Human Waste from Dietary Intake**

Annual Employee Human Waste Load =
Annual Hg Discharge per Human x
Service Area Total Jobs x Fraction of Employee Discharge Excreted at Work =
0.802 mg/yr x 163,700 x 0.357 = $4.68 \times 10^4$ mg/yr
$4.68 \times 10^4$ mg/yr x 0.001 g/mg x 0.002205 lb/g = **0.103 lb/yr**

**Total Human Waste Load from Dietary Intake**

Total Human Waste Load =
Residential Human Waste Load + Employee Human Waste Load =
0.345 lb/yr + 0.103 lb/yr = **0.448 lb/yr**

## HUMAN WASTE FROM DENTAL AMALGAMS
## Source In Addition to Dietary Intake

Non-Working Service Area Residents = 120,700
(see "Human Waste attributable to Dietary Intake," above)

Working Service Area Residents = 115,500
(see "Human Waste attributable to Dietary Intake," above)

Service Area Employees = 163,700 (see "Human Waste attributable to Dietary Intake," above)

Non-working residents are assumed to discharge 100% of their human waste at home as residential human waste. Workers are assumed to discharge 64.3% of their human waste at home as residential human waste and 35.7% of their human waste at work as employee human waste. (see "Human Waste from Dietary Intake," above)

Percentage of Population with Amalgam Fillings = 65% (*Source:* Bio-Probe 1992)

> National Institute of Dental Research data collected between 1988 and 1991 indicate that about 89% of the U.S. population have some teeth. Of these individuals, about 94% have some level of treated or untreated tooth decay. On a per person basis, filled surfaces account for about 86% of the total of both decayed and filled teeth (Winn 1996). On the basis of this information, about 72% of the U.S. population can be assumed to have dental fillings, but not all of these fillings consist of mercury-containing dental amalgam. The National Institute of Dental Research data appear to support the more conservative estimate of 65% published by Bio-Probe.

Non-Working Service Area Residents with Amalgam Fillings =

120,700 x 65% = 78,455

Working Service Area Residents with Amalgam Fillings =

115,500 x 65% = 75,075

Service Area Employees with Amalgam Fillings =

163,700 x 65% = 106,405

Hg in Human Waste Attributable to Amalgam Fillings = 0.0354 mg/day/person with fillings

> Fecal excretions of individuals without amalgam fillings contain about 0.061 ng Hg/mg dry feces. Fecal excretions of individuals with amalgam fillings contain about 1.044 ng Hg/mg dry feces (Osterblad 1995). The difference (the portion attributable to the amalgam fillings) is about 0.983 ng Hg/mg dry feces. Assuming a daily stool mass of about 120 g with a water content of about 70% (Bjorkman 1997), fecal excretions of individuals with amalgam fillings typically contain about 0.0354 mg <u>more</u> Hg/day (0.983 ng Hg/mg dry

feces x 0.3 mg dry feces/mg wet feces x 1,000 mg wet feces/g wet feces x 120 g wet feces ÷ 1,000,000 ng Hg/mg Hg = 0.0354 mg Hg/day).

**Residential Amalgam-Related Human Waste**

Dental-Related Human Waste from Non-Working Service Area Residents =
78,455 people x 0.0354 mg/day/person x 365 days/yr x 100% = $1.01 \times 10^6$ mg = 1,010 g/yr
1,010 g/yr x 0.002205 lb/g = 2.23 lb/yr

Dental-Related Human Waste from Working Service Area Residents =
75,075 people x 0.0354 mg/day/person x 365 days/yr x 64.3% = $6.24 \times 10^5$ mg = 624 g/yr
624 g/yr x 0.002205 lb/g = 1.37 lb/yr

Total Residential Dental-Related Human Waste Load =
Residential Dental-Related Human Waste Load of Non-Workers +
Residential Dental-Related Human Waste Load of Workers
= 2.23 lb/yr + 1.37 lb/yr = **3.61 lb/yr**

**Employee Amalgam-Related Human Waste**

Dental-Related Human Waste from Service Area Employees =
106,405 people x 0.0354 mg/day/person x 365 days/yr x 35.7% = $4.91 \times 10^5$ mg = 491 g/yr
491 g/yr x 0.002205 lb/g = **1.08 lb/yr**

**Total Amalgam-Related Human Waste Load**

Total Dental-Related Human Waste Load =
Residential Dental-Related Human Waste Load + Employee Dental-Related Human Waste Load
= 3.61 lb/yr + 1.08 lb/yr = **4.69 lb/yr**

## DENTAL OFFICES

Number of Dentists in RWQCP Service Area = 110 (*Source:* RWQCP data)

> All dentists within the RWQCP service area are assumed to provide general services, including placing and removing fillings. This assumption probably somewhat overstates the number of dentists who work with amalgam in the service area.

Daily Hg Load per Dentist = $3.47 \times 10^{-2}$ g/day (*Source:* Rourke 1993)
$3.47 \times 10^{-2}$ g/day x 0.002205 lb/g = $7.65 \times 10^{-5}$ lb/day

Gross Hg Load =
Daily Hg Load per Dentist x Number of Dentists x Number of Days of Discharge per Year (considering weekends, holidays, and vacations) =
$7.65 \times 10^{-5}$ lb/day x 110 x 250 days/yr = 2.10 lb/yr

Hg Concentration of Dental Discharge = 0.041 mg/l = $4.1 \times 10^{-5}$ g/l (*Source:* Rourke 1993)

Flow from Dentists =
(Number of Dentists x Daily Hg Load per Dentist) ÷ Hg Concentration =
(110 dentists x $3.47 \times 10^{-2}$ g/day/dentist) ÷ $4.1 \times 10^{-5}$ g/l = $9.31 \times 10^{4}$ l/day
$9.31 \times 10^{4}$ l/day ÷ 3.785 l/gal = $2.46 \times 10^{4}$ gal/day
$2.46 \times 10^{4}$ gal/day x 250 days/yr = $6.15 \times 10^{6}$ gal/yr

> This flow is estimated on the basis of the mercury concentration and load (per dentist) reported for San Francisco (Rourke 1993). Actual flow data from San Francisco are unavailable. The flow estimated here, however, appears high for dental offices. The flow probably includes some domestic wastewater that is not directly related to dental operations. Even so, the estimate appears high, and as shown below, this flow can be used to demonstrate that mercury in the water supply contributes negligibly to the mercury load estimated for dental offices.

Hg Concentration in Water Supply = $7.5 \times 10^{-5}$ mg/l
(*Source:* Montgomery Watson 1994)

Hg Load from Dentists' Water Supply =
$7.5 \times 10^{-5}$ mg/l x $8.346 \times 10^{-6}$ l-lb/mg-gal = $6.26 \times 10^{-10}$ lb/gal
$6.26 \times 10^{-10}$ lb/gal x $6.15 \times 10^{6}$ gal/yr = $3.85 \times 10^{-3}$ lb/yr

Hg Load from Dentists =
Gross Hg Load from Dentists - Hg Load from Water Supply =
2.10 lb/yr - 3.85 x $10^{-3}$ lb/yr = **2.10 lb/yr**

If human waste were present in the dental office discharges evaluated in San Francisco, this waste would need to be subtracted from this load estimate as was done for the water supply. As shown in the previous calculations for "Human Waste Attributable to Dietary Intake," the amount of mercury in human waste from sources other than amalgam fillings is about 0.0022 mg/day/person. Individuals with amalgam fillings excrete another 0.0354 mg/day/person. Assuming that 65% of the population has amalgam fillings, the average combined mercury discharge in human waste is about 0.0252 mg/day/person (i.e., average discharge = 0.0022 mg/day/person + [0.0354 mg/day/person x 65%] = 0.0252 mg/day/person).

There are 110 dentists in the RWQCP service area, and each dentist could support about 5 office staff. Because about 35.7% of each person's total human waste discharge occurs at work (see the previous calculations for "Human Waste Attributable to Dietary Intake"), each of these staff could discharge about 0.009 mg/day/person (i.e., discharge at dental office = 0.0252 mg/day/person x 35.7% = 0.00900 mg/day/person). Therefore, each dentist and his or her 5 staff (6 individuals in all) could together discharge a human waste load of about 0.0540 mg/day (i.e., load = 0.009 mg/day/persons x 6 persons = 0.0540 mg/day).

If the daily mercury load per dentist is 0.0347 g/day, or 34.7 mg/day, and the approximate human waste load from each dentist and his or her staff is about 0.054 mg/day, then correcting the dental office mercury load to account for human waste discharged from dental offices would not affect the dental office load estimate because the human waste load is about 3 orders of magnitude below the dental office load estimate. It is unlikely that the dental buildings included in the San Francisco study housed enough additional individuals to meaningfully affect the dental office load estimated here for the RWQCP.

**RESIDENTIAL WASTE**
**Other than Human Waste**

RWQCP data for residential Hg concentrations were collected from residential trunk lines located in Palo Alto. Concentration data were corrected to account for the Hg attributable to the water supply. Residential Hg loads for Palo Alto were used to estimate the proportional Hg load from all residents in the RWQCP service area.

## Total Residential Waste (Including Human and Non-Human Waste)

RWQCP Residential Flow = $14.7 \times 10^{6}$ gal/day (*Source:* RWQCP 1997)

Hg Concentration in Residential Flow = $3.13 \times 10^{-4}$ mg/l (*Source:* RWQCP data)
Hg Concentration in Water Supply = $7.5 \times 10^{-5}$ mg/l (*Source:* Montgomery Watson 1994)

Hg Concentration from Residential Activities =
Hg Concentration in Residential Flow - Hg Concentration in Water Supply
= $3.13 \times 10^{-4}$ mg/l - $7.5 \times 10^{-5}$ mg/l = $2.38 \times 10^{-4}$ mg/l

Total Residential Waste Load =
$2.38 \times 10^{-4}$ mg/l x $8.346 \times 10^{-6}$ l-lb/mg-gal = $1.99 \times 10^{-9}$ lb/gal
$1.99 \times 10^{-9}$ lb/gal x $14.7 \times 10^{6}$ gal/day x 365 days/yr = **10.7 lb/yr**

## Residential Waste Other than Human Waste

Residential Waste Other than Human Waste =
Total Residential Waste Load - (Residential Human Waste Load from Dietary Intake + Residential Dental Related Human Waste) =
= 10.7 lb/yr - (0.345 lb/yr - 3.61 lb/yr) = **6.75 lb/yr**

# ATTACHMENT B

# UNIVERSITY OF ILLINOIS AT CHICAGO DATA

## UNIVERSITY OF ILLINOIS AT CHICAGO DATA

Investigators at the University of Illinois at Chicago have studied the size fractions of amalgam in dental discharges and the behavior of these particles in typical dental equipment (Drummond 1995). As shown in the table below, the results obtained by these researchers suggest that individual dentists could discharge as much as 0.778 grams of mercury per day if they were to use only chairside traps (a typical trap is simply a 0.7 millimeter screen). Additional filtration or low-technology treatments (such as settling), if implemented consistently, could reduce discharges to as little as 0.0051 grams per day per dentist. All the data from various agencies summarized in Table 1 lie well within this range; therefore, none of these results is necessarily unreasonable.

### Amalgam Particle Distribution

| Sample Location and Treatment | Mercury Load (g/day/dentist) |
|---|---|
| Retained by Chairside Trap | 1.177 |
| Passing Chairside Trap and Settling within 24 Hours | 0.773 |
| Supernatant Above Settled Particles | 0.0051 |
| Soluble Mercury Following Centrifugation of Supernatant | 0.0033 |
| ***Total Mercury*** | ***1.96*** |
| ***Total Mercury Not Captured by Chair-Side Trap*** | ***0.778*** |

*Source:* Drummond 1995.