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Dental Amalgam

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EXECUTIVE SUMMARY

Across the United States, many States and municipal wastewater treatment plants (publicly owned treatment works (POTWs)) are working toward the goal of reducing discharges of mercury to POTWs. Many studies have been conducted in an attempt to identify the sources of mercury entering these POTWs. According to the 2002 *Mercury Source Control and Pollution Prevention Program Final Report* prepared for the National Association of Clean Water Agencies (NACWA), dental clinics are the main source of mercury discharges to POTWs. A study funded by the American Dental Association (ADA) estimated in 2003 that 50 percent of mercury entering POTWs was contributed by dental offices (Vandeven and McGinnis, 2005). EPA estimates that dentists discharge approximately 3.7 tons of mercury each year to POTWs (see Section 6 of this document).

Sources of amalgam in dental wastewater include the placement of and removal of amalgam fillings (restorations). Of the dental amalgam constituents, mercury is of greatest concern to human health because it is a persistent bioaccumulative toxic chemical. Mercury can bioaccummulate three to ten times across each trophic level of the food chain. The major route for human exposure to mercury in wastewater discharges is through the consumption of mercury-contaminated fish.

Mercury discharged in dental wastewater is present in many forms, including elemental mercury bound to amalgam particulate, inorganic (ionic) mercury, elemental mercury, and organic mercury (monomethyl mercury (MeHg)) (Stone, 2002). The vast majority (>99.6 percent) of dental mercury discharges are in solid form (elemental mercury bound to amalgam particulate). While dissolved mercury composes a small portion of total mercury in dental office wastewater, some studies have indicated high levels of dissolved mercury in dental wastewater, and that dissolved mercury concentrations can be high enough to violate local mercury discharge limits (Stone, 2004).

Dissolved mercury is a concern because it can be converted to MeHg by bacteria, such as Desulfobacteraceae and Desulfovibrionaceae that are present in wastewater (ACS, 2008). Researchers have detected concentrations of MeHg in dental wastewater that are orders of magnitude higher than background MeHg concentrations measured in environmental samples (i.e., open oceans, lakes, and rainfall) (Stone, 2002). Although the MeHg concentrations are small compared to total mercury concentrations in dental wastewater, MeHg is particularly toxic to humans due to its ability to bioaccumulate in fish (WI DNR, 1997).

EPA estimates there are approximately 120,000 dental offices that use or remove amalgam in the United States – almost all of which discharge their wastewater exclusively to POTWs. Most dental offices currently use some type of basic filtration system to reduce the amount of mercury solids passing into the sewer system. However, best management practices and the installation of amalgam separators, which generally have a removal efficiency of at least 95 percent, have been shown to reduce discharges even further. A 2002 study funded by the National Association of Clean Water Agencies (NACWA) (See: DCN: 04225) concluded that the use of amalgam separators results in reductions in POTW influent concentrations and biosolids mercury concentrations. However, the NACWA study found that the use of amalgam separators does not always result in reductions in POTW effluent. Since the mercury in dental amalgam often reaches POTWs as larger particulates, it is likely to be removed in the grit

chambers or with the biosolids and not be discharged with the effluent. Thus, reductions in dental office amalgam discharges may result in reductions in the mercury content of POTW sludges (grit and biosolids), and may not result in reductions in mercury concentrations in POTW effluent.

ADA provides guidance documents for its members and the general public for the management and disposal of dental amalgam and amalgam waste. These include information regarding proper recycling of amalgam waste and practical guidelines for integrating best management practices (BMPs) into dental practices. On October 2, 2007, the ADA updated its BMPs to include the use of amalgam separators. ADA also provides advice for successful integration of BMPs into practices and offices, a directory of national dental waste recyclers, recommendations for safe preparation and placement of amalgam restorations, safety information for managing mercury spills, and advice on the purchase, installation and operation of amalgam separators (ADA, 2007). The ADA-defined BMPs are recognized as the industry standard. Table 4-1 of this document lists the ADA BMPs for amalgam waste.

State and local governments have implemented mandatory and voluntary programs to reduce dental mercury discharges. Specifically, 11 States and at least 19 localities have mandatory pretreatment programs that require the use of dental mercury amalgam separators. Additionally, at least four States and six POTWs have voluntary programs to reduce mercury discharges from dental offices though success rates for the voluntary programs vary greatly.

In this document, EPA has compiled information on current mercury discharges from dental offices, best management practices (BMPs), and amalgam separators. For amalgam separators, EPA has looked at the frequency with which they are currently used; their effectiveness in reducing discharges to POTWs; and the capital and annual costs associated with their installation and operation. EPA has also conducted a POTW pass-through analysis on mercury for the industry.

EPA does not think national, categorical pretreatment standards for dental mercury discharges are appropriate at this time. While this is a possibility for the future, EPA has identified a number of successful voluntary programs demonstrating that there are opportunities for pollution prevention and adoption of BMPs without federal regulation. Moreover, the dental industry is working towards voluntarily reducing its mercury discharges. Also, due to mercury-free fillings and improved overall dental health, the use of mercury in dentistry is decreasing in the U.S.

1. INTRODUCTION

Under the Clean Water Act (CWA), EPA establishes national regulations (called effluent limitations guidelines and standards) to reduce discharges of pollutants from industries to surface waters and publicly owned treatment works (POTWs). Section 304(g) and 307(b) of the CWA requires EPA to review industries consisting entirely or almost entirely of indirect discharging facilities that are not currently subject to pretreatment standards to identify potential candidates for pretreatment standards development. This includes pretreatment standards for categories of dischargers that discharge pollutants not susceptible to treatment by POTWs or that would interfere with the operation of POTWs. Using available data, EPA reviews the types of pollutants in an industry's wastewater. Then, EPA reviews the likelihood of those pollutants to pass through a POTW and finally considers whether the pollutant discharges are already adequately controlled by general pretreatment standards and/or local pretreatment limits.

Every other year EPA publishes a final Effluent Guidelines Program Plan as required by CWA Section 304(m). The plan addresses both categories with large numbers of direct discharging facilities and categories consisting entirely or almost entirely of indirect discharging facilities. EPA publishes a draft plan to give the public an opportunity to comment on the plan before it is final. EPA selected the health services industry for further analysis in the 2006 Plan (EPA, 2006), based in part on public comments concerning the discharge of mercury from dental offices and dental laboratories. EPA's study addresses the following questions:

- What are the current industry practices for disposing of dental mercury, to what extent are each of these practices applied, and what factors affect the use of these practices?
- What are the federal, state, or local requirements or guidance for disposal of dental mercury?
- How are control authorities currently limiting dental mercury discharges?
- Do POTWs report pass-through or interference problems related to dental mercury discharges?
- What technologies are available (1) as alternatives to wastewater disposal and (2) to control discharges? How effective are these technologies?
- What best management practices (BMPs) are used as alternatives to wastewater disposal and/or to control discharges? How effective are these practices?
- What are the costs of the identified technologies and/or BMPs?

This report describes EPA's analysis of dental mercury discharges and is organized into the following sections:

- Section 2 provides a preliminary profile of the dental industry that includes the number of dental offices and laboratories, the number of small businesses, discharge information, and financial characteristics;

- Section 3 discusses sources of dental mercury and environmental impacts;

- Section 4 describes national, state, and local mandatory and voluntary programs to reduce mercury wastewater discharges from dental offices;

- Section 5 describes the effectiveness and costs for dental mercury BMPs and amalgam separators; and

- Section 6 describes EPA's estimate of the potential reductions in dental mercury discharges to receiving streams following installation of amalgam separators.

2. PROFILE OF DENTAL INDUSTRY

This section presents industry profile information using the North American Industry Classification System (NAICS) codes and the Standard Industrial Classification (SIC) codes. The U.S. Census Bureau classifies information by NAICS codes and EPA classifies discharge information (TRI and PCS database information) by SIC code.

Dental laboratories fall under NAICS 339116, with the definition:

> "This U.S. industry comprises establishments primarily engaged in manufacturing dentures, crowns, bridges, and orthodontic appliances customized for individual application." http://www.census.gov/epcd/ec97/def/339116.TXT

There is 100 percent correspondence between NAICS 339116 and SIC 8072 (Census, 2007a).

Offices of dentists fall under NAICS 621210, with the definition:

> "This industry comprises establishments of health practitioners having the degree of D.M.D. (Doctor of dental medicine), D.D.S. (Doctor of dental surgery), or D.D.Sc. (Doctor of dental science) primarily engaged in the independent practice of general or specialized dentistry or dental surgery. These practitioners operate private or group practices in their own offices (e.g., centers, clinics) or in the facilities of others, such as hospitals or HMO medical centers. They can provide either comprehensive preventive, cosmetic, or emergency care, or specialize in a single field of dentistry." http://www.census.gov/epcd/ec97/def/621210.TXT

There is 100 percent correspondence between NAICS 621210 and SIC 8021 (Census, 2007b).

2.1 Number of Facilities

Table 2-1 provides a comprehensive listing of establishments by state for NAICS 339116 (Dental Laboratories) and 621210 (Dental Offices). Based on 2005 County Business Patterns data, there are 7,225 dental laboratories and 122,918 dental offices operating nationwide (Census, 2005a). According to the 2002 Census, there were 7,096 dental laboratories and 118,305 dental offices. According to the 1997 Census, there were 7,609 dental laboratories and 114,178 dental offices (Johnston, 2005). Table 2-2shows the industry changes over time.

Table 2-1. Number of Establishments by State (2005)

State	NAICS 339116 Dental Laboratories	NAICS 621210 Dental Offices
Alabama	107	1,417
Alaska	16	307
Arizona	153	2,209
Arkansas	58	933
California	1,011	19,005
Colorado	153	2,366
Connecticut	80	1,732

Table 2-1. Number of Establishments by State (2005)

State	NAICS 339116 Dental Laboratories	NAICS 621210 Dental Offices
Delaware	8	243
District of Columbia	2	315
Florida	566	6,733
Georgia	247	3,024
Hawaii	38	686
Idaho	59	656
Illinois	318	5,639
Indiana	139	2,334
Iowa	69	1,077
Kansas	55	1,016
Kentucky	73	1,586
Louisiana	97	1,527
Maine	27	478
Maryland	108	2,483
Massachusetts	113	3,050
Michigan	208	4,353
Minnesota	134	1,922
Mississippi	47	846
Missouri	144	2,153
Montana	38	414
Nebraska	49	790
Nevada	73	883
New Hampshire	32	560
New Jersey	219	4,546
New Mexico	38	593
New York	469	9,017
North Carolina	228	2,720
North Dakota	10	259
Ohio	232	4,357
Oklahoma	71	1,325
Oregon	143	1,825
Pennsylvania	216	5258
Rhode Island	30	412
South Carolina	63	1,368
South Dakota	18	267
Tennessee	128	2,110
Texas	377	7,597
Utah	117	1,418
Vermont	18	263
Virginia	177	2,845
Washington	276	3,183

Table 2-1. Number of Establishments by State (2005)

State	NAICS 339116 Dental Laboratories	NAICS 621210 Dental Offices
West Virginia	26	573
Wisconsin	135	2,023
Wyoming	12	222
Total U.S.	**7,225**	**122,918**

Source: Census, 2005a.

Table 2-2. Number of Dental Laboratories and Offices

NAICS Code	SIC Code	Number of Facilities in 1997	Number of Facilities in 2002	Number of Facilities in 2005
339116: Dental Laboratories	8072: Dental Laboratories	7,609	7,096	7,225
621210: Offices of Dentists	8021: Offices and Clinics of Dentists	114,178	118,305	122,918

Sources: Johnston, 2005; Census, 2005a and b.

2.2 Revenues and Employees

Table 2-3 lists the number of establishments, total revenues, total number of paid employees, average revenue, and average number of employees per establishment based on the 2002 Census data. Average revenue and the average number of paid employees were determined by dividing total revenue and total paid employees by the total number of establishments, respectively.

Table 2-3. Nationwide Summary by NAICS (2002)

NAICS	Number of Establishments	Revenues ($1,000)	Paid Employees	Average Revenue ($1,000)	Employees per Establishment
339116: Dental Laboratories	7,096	3,361,996	49,467	$473.79	6.97
621210: Dental Offices	118,305	71,102,922	743,628	$601.01	6.29

Sources: Census, 2004 and 2005b.

2.3 Number of Companies

Table 2-4 shows the number of establishments, total firms, and single- and multi-unit firms. For dental offices, the 2,461 multi-unit firms comprise 7,464 total establishments; specifically, there are 1,542 firms with two establishments, 402 firms with three to four establishments, 96 firms with five to nine establishments, and 41 firms with 10 or more establishments (Census, 2005c).

Table 2-4. Number of Single-Unit and Multi-Unit Firms (2005)

NAICS	Number of Firms	Number of Establishments	Single-Unit Firms	Multi-Unit Firms
339116: Dental Laboratories	6,925	7,096	—	—
621210: Dental Offices	113,302	118,305	110,841	2,461

Sources: Census, 2004 and 2005c.

2.4 Number of Small Businesses

Table 2-5 lists the Small Business Administration (SBA) size standard for each NAICS industry and the number of establishments that meet these criteria. Dental laboratories have a size standard of 500 employees, while dental offices have a size standard of $6.5 million in average annual receipts (SBA, 2006).

Table 2-5. Small Businesses (2005)

NAICS	Size Standard	Total	Definitely Small	Possibly Small	Best Estimate Small	% Small
339116: Dental Laboratories	500 employees	7,096	7,086	—	7,086	99.9%
621210: Dental Offices	$6.5 million	118,305	107,258	9,805	116,843	98.8%

Sources: Census, 2004 and 2005b.

For dental laboratories, 2004 Census data list 7,086 establishments with fewer than 500 employees and three establishments with more than 500 employees (Census, 2004).[1] Thus, EPA determined that 7,086 firms are below the SBA threshold. Therefore, 99.9 percent of dental laboratories (NAICS 339116) qualify as small businesses.

EPA used year 2005 census reporting of receipts/revenue size of firms for dental offices. EPA classified an establishment in the "definitely small" category if it operated for the entire year and was in a revenue group where the upper limit was less than $6.5 million. The SBA size standard of $6.5 million falls within the range of the $5 million to $9.99 million revenue group. As a result, some but not all of the 149 establishments in that revenue group are small. EPA assumed that the companies were evenly distributed within the revenue group and prorated the company count accordingly. EPA estimated the number of "possibly small" establishments by multiplying 149 establishments by the ratio of the number of revenue units below the SBA threshold to the total number of revenue units in the range —

($6.5 million - $5 million) ÷ ($9.99 million - $5 million) = 0.30

[1] The discrepancy in the total number of establishments can be attributed to the fact that "some payroll and sales data for small single-establishment companies with up to 20 employees (cutoff varied by industry) were obtained from administrative records of other Government agencies rather than from census report forms. These data were then used in conjunction with industry averages to estimate statistics for these small establishments. This technique was also used for a small number of other establishments whose reports were not received at the time data were tabulated." (Census, 2004)

— for a total of 45 establishments. EPA also included the number of companies that did not operate for all of 2005 (9,656) in the "possibly small" category in order not to underestimate the number of small entities. EPA assumed that the proportion of establishments that did not operate for an entire year and also qualified as small was equal to the proportion of establishments that qualified as small in the overall population: 98.8 percent, or 9,540 establishments (Census, 2005b).

Based on the census information presented in this section, dental laboratories and dental offices are nearly all small businesses.

2.5 Ownership

Among the 118,305 total dental office establishments, 2002 Census data list 62,821 corporations, 50,638 individual proprietorships, 4,778 partnerships, and 68 other forms of legal organization for dental offices. Ownership data for dental laboratories are not available at this time (Census, 2005d).

2.6 Discharge Information

Based on information contained in the TRI and PCS databases, dental facilities are small establishments, and few, if any, dental laboratories or dental offices/clinics are direct dischargers. No dental laboratories (SIC 8072) or dental offices/clinics (SIC 8021) reported releasing toxic chemicals to any media to TRI for 2004 *(TRIReleases2004_v01)*. A facility is exempt from TRI reporting if it has less than 10 employees or if its chemical releases are below the TRI reporting thresholds; the TRI reporting threshold for mercury and mercury compounds is 10 pounds per year.

EPA's *PCSLoads2004_v02* database does not include pollutant loads for dental laboratories or dental offices/clinics. EPA reviewed PCS data contained on EPA's Envirofacts Web page to verify that discharges from dental offices and dental laboratories were not reported to PCS. EPA identified nine dental offices/clinics that report to PCS (2007 Envirofacts information). Seven of these facilities were classified as minor dischargers. Permitting authorities are not required to report discharge information for minor facilities to PCS; therefore discharges for these seven facilities were not included in *PCSLoads2004_v02*. Two of the facilities that report to PCS were classified as major dischargers. However, the facilities did not have permit limits; therefore PCS does not contain measurement data for those facilities. EPA also identified one dental laboratory in PCS (2007 Envirofacts information). However, this facility is classified as a minor discharger with no discharge data in PCS, and therefore is not included in *PCSLoads2004_v02*.

The lack of information in TRI and PCS about dental industry wastewater discharges confirms that nearly all dental facilities are small, indirect dischargers. These results are consistent with EPA's 2005 review of the dental industry, which also found little information for dental laboratories or dental offices in the 2000 TRI and PCS databases (Johnston, 2005).

2.7 Financial Characteristics

This subsection describes the financial characteristics of the dental industry as measured by liquidity and profit before taxes.

2.7.1 Liquidity

Liquidity measures the ability of an industry to meet current financial obligations without having to convert assets to cash with a loss in value. A current ratio is calculated as total current assets divided by total current liabilities. Table 2-6 summarizes the current ratio for dental offices and dental laboratories for 2006 (RMA, 2007). Several differences between the groups are evident. With the exception of dental offices with sales in excess of $25 million, dental offices are illiquid. The overall current ratio for the industry in 2006 is 0.9 and the current ratio of dental offices with less than $25 million in revenues ranges from 0.7 to 0.9. This indicates that, at the time the balance sheet was constructed, the dental office owed more to its creditors than it had in assets. The historical data in RMA (2007) report a ratio of 0.8 in 2004. In contrast, the 2007 edition *Almanac Financial of Business and Industrial Ratios* indicates that dental offices are liquid and have sufficient assets to cover their current debts with a small cushion, and reports a ratio of 1.2 in 2004 (Troy, 2007). The 2007 Almanac is based on a sample of 62,347 enterprises while RMA (2007) is based on 763 income statements.

Table 2-6. 2006 Current Ratio of Assets to Liability (Liquidity)

NAICS	Revenues ($Millions)						
	All	$0–$1	$1–$3	$3–$5	$5–$10	$10–$25	>$25
339116: Dental Laboratories	1.7	—	2.7	—	—	—	—
621210: Dental Offices	0.9	0.8	0.9	0.7	0.9	0.8	1.1

Source: RMA, 2007.

RMA (2007) has data for dental laboratories, while the Almanac (2007) does not. Dental laboratories show a much healthier current ratio of 1.7, indicating a greater ability to meet current obligations. (RMA does not show data when there are fewer than 10 annual statements in the subcategory.)

2.7.2 Profit Before Taxes

Profit before taxes is calculated from an income statement, which is a one-year summary of costs and revenues. Table 2-7 shows a 10.4 percent profit before taxes for dental offices and a 5.0 percent profit for dental laboratories.

Table 2-7. 2006 Profit Before Taxes (%)

NAICS	Revenues ($Millions)						
	All	$0–$1	$1–$3	$3–$5	$5–$10	$10–$25	>$25
339116: Dental Laboratories	5.0	—	5.8	—	—	—	—
621210: Dental Offices	10.4	11.7	10.4	7.1	7.7	6.3	6.2

Source: RMA, 2007.

3. DENTAL MERCURY SOURCES AND ENVIRONMENTAL IMPACTS

The EPA Office of Compliance's Sector Notebook for the Healthcare Industry identified mercury as the major pollutant of concern (POC) for wastewater discharges from dental facilities (see EPA-HQ-OW-2004-0032-0729). Sources of amalgam in dental wastewater include the placement of amalgam fillings and removal of amalgam during restorations. Other constituents of dental amalgam include metals such as silver, tin, copper, zinc, indium, and palladium. Of the dental amalgam constituents, mercury is of greatest concern to human health because it is a persistent, bioaccumulative, toxic chemical and can bioaccumulate three to ten times across each trophic level of the food chain. For wastewater mercury discharges, the major route for human exposure is the consumption of mercury-contaminated fish.

While mercury used in U.S. dental offices accounts for only a small percentage of the total mercury discharged to air and water each year, mercury in the form of dental amalgam is among the largest sources of mercury found in wastewater influent reaching POTWs. The American Dental Association (ADA) estimates that up to 50 percent of the mercury entering POTWs originates in dental offices (Vandeven and McGinnis, 2005). Recent data compiled from across the country indicate that varying amounts of the mercury in wastewater reaching POTWs originates from dental offices:

- The East Bay Municipal Utility District (EBMUD) of Oakland, CA, estimates that dental offices account for 34 percent of the mercury influent loading to wastewater treatment plants (EBMUD, 2007);

- Dental clinics contribute 11 to 14 percent of the mercury loading to local sanitary districts in Seattle, WA (Stone, 2004);

- Dental clinics account for almost 50 percent of the mercury in wastewater in Palo Alto, CA (Palo Alto, 2007); and

- A study by the Association of Metropolitan Sewerage Agencies (AMSA) — now the National Association of Clean Water Agencies (NACWA) — found that dental offices account for an average of 35 percent of the mercury influent to POTWs (AMSA, 2002).

Due to the increased concern regarding mercury in the environment, several U.S. industries have significantly decreased mercury usage since the 1980s (Vandeven and McGinnis, 2005). Although dentists have also reduced their mercury use, as of 1999, amalgam was still widely used for restorations (66 million amalgam restorations in 1999) (Stone, 2004). ADA predicts that use of amalgam will continue to decrease due to various factors such as the introduction of improved filling material, overall decrease in tooth decay and earlier detection of tooth decay (EPA, 2007a). In 2007, TheWealthyDentist.com, a website and weekly newsletter for dentists, surveyed dentists to determine amalgam use. The survey found that 52 percent of dentists do not place amalgam fillings (The Wealthy Dentist, 2007).

The remainder of this section describes the wastewater sources of amalgam, environmental impacts of dental mercury, and treatment of dental mercury at POTWs.

3.1 Sources of Dental Amalgam in Wastewater from Dental Facilities

Amalgam used in dental practices is typically 50 percent mercury mixed with a powder of silver, tin, copper, and sometimes zinc, indium, or palladium. Raw materials for dental amalgam are liquid mercury and a metal powder mixture, often supplied in capsules. In these capsules, the mercury and metal powders are kept separate until the dentist is ready to complete a restoration. When the dentist mixes (triturates) the mercury and powder, the mercury dissolves the powdered metals and a series of intermetallic compounds (e.g., Ag_3Sn, Ag_2Hg_3, Sn_8Hg) are formed (Vandewall, 2007).

Sources of amalgam in dental wastewater include waste amalgam from fillings and amalgam removed during restorations. When filling a cavity, dentists will always overfill the tooth cavity so they can carve the filling into proper shape (Columbia, 2005). The excess amalgam is typically rinsed into a chair-side drain. In addition to filling new cavities, dentists also remove old restorations that are worn or damaged. Removed restorations are also rinsed into the chair-side drain.

3.2 Environmental Impacts of Dental Mercury Discharges

Mercury discharged in dental wastewater is present in many forms, including elemental mercury bound to amalgam particulate, inorganic (ionic) mercury, elemental mercury, and organic mercury (monomethyl mercury, or MeHg) (Stone et al., 2002). Table 3-1 presents the mean concentrations of mercury species measured in wastewater samples collected at the chair. The vast majority (>99.6 percent) of dental mercury discharges are in solid form (elemental mercury bound to amalgam particulate).

Table 3-1. Mean Concentrations of Mercury Species in Dental Wastewater

Mercury Form	Measured Concentration	Percent of Total Mercury
Total mercury	21.438 milligrams/liter (ppm)	100.0%
MeHg (monomethyl mercury)	277.74 nanograms/liter (ppt)	0.001296%
Hg0 (elemental mercury)	24.06 micrograms/liter (ppb)	0.112231%
Hg+2 (ionic mercury)	54 micrograms/liter (ppb)	0.251889%
Hg0 (elemental mercury bound to amalgam particulate)	21.360 milligrams/liter (ppm)	99.636160%

Source: Stone, 2004.

While dissolved mercury makes up a small portion of the total mercury in dental office wastewater, there is increasing interest in the causes of dissolution and the extent to which dissolved mercury is present in dental office wastewater. Some studies have indicated high levels of dissolved mercury in dental wastewater, and that dissolved mercury concentrations can be high enough to violate local mercury discharge limits (Stone, 2004).

Dissolved mercury is a concern because it can be converted to MeHg by bacteria, such as *Desulfobacteraceae* and *Desulfovibrionaceae,* that are present in wastewater (ACS, 2008). Researchers have detected concentrations of MeHg in dental wastewater that are orders of magnitude higher than background MeHg concentrations measured in environmental samples

(i.e., open oceans, lakes, and rainfall). Concentrations of MeHg in dental wastewater ranged from 0.90 to 26.77 mg/L, while concentrations in environmental samples ranged from 0.05 to 10.0 ng/L (Stone et al., 2002). Researchers have concluded that sulfate-reducing bacteria are responsible for the presence of methylmercury in dental wastewater. However, it is not clear whether methylation occurs in the patient's mouth or in the discharge stream (ACS, 2008). Although the MeHg concentrations are small compared to total mercury concentrations in dental wastewater, MeHg is particularly toxic to humans due to its ability to bioaccumulate in fish. When humans consume MeHg, it targets the nervous system and can hinder a person's ability to walk, talk, see, and hear. Extreme cases of MeHg poisoning can result in coma or death (WI DNR, 1997).

3.3 Dental Mercury Treatment at POTWs

The composition of mercury discharged from dental offices is important to POTWs because it can affect the POTWs' ability to remove mercury from influent wastewater. Solid mercury particles will likely settle out of solution and adsorb to the wastewater treatment sludge. However, dissolved mercury can pass through treatment operations and enter surface waters. EPA's 50 POTW Study (EPA, 1982) estimates that POTWs can effectively remove 90 percent of total mercury (solid and dissolved) from wastewater. However, other studies conducted by Metropolitan Council Environmental Services (MCES) in 1995 and NACWA from 2002 through 2006 have shown total mercury removals of 95 to 99 percent (Vandeven and McGinnis, 2005; AMSA, 2002; NACWA, 2007).

Mercury that partitions to wastewater sludge may be incinerated or disposed of in a landfill. Unbound mercury is highly volatile and can easily evaporate into the atmosphere. However, because the majority of dental mercury is bound to solid particles, it will not likely volatilize to the atmosphere unless the wastewater sludge is incinerated. Once in the atmosphere, mercury can be deposited into lakes and streams via precipitation (WI DNR, 1997).

4. CURRENT NATIONAL, STATE, AND LOCAL DENTAL MERCURY PROGRAMS

This section discusses national, state, and local programs to reduce discharges of dental mercury. Currently, there are no federal regulatory requirements that specifically address discharges of dental mercury to wastewater. There are, however, federal requirements to control dangers of exposure to dental mercury. The ADA has recently adopted BMP guidance that includes the recommendation that dentists use amalgam separators. Requirements for controlling discharges of dental mercury to wastewater are set at the state and local level. Currently 11 states have established mandatory state-wide programs. EPA has also reviewed requirements for 19 local mandatory programs spanning 6 states. The remainder of this section is organized into the following subsections:

- Section 4.1 discusses national programs;
- Section 4.2 summarizes state programs;
- Section 4.3 summarizes local programs; and
- Section 4.4 summarizes common elements found in state and local programs.

4.1 National Dental Amalgam Requirements and Guidance

This subsection summarizes national programs, including federal regulations and federal and non-federal guidance, for the use and disposal of dental amalgam.

4.1.1 Federal Requirements and Guidance

Federal agencies that have established regulations for dental amalgam include the Occupational Safety and Health Administration (OSHA) and the Food and Drug Administration (FDA). Both federal regulations, however, focus on aspects of dental amalgam related to employee and consumer exposure and do not address discharges of dental amalgam to wastewater. This subsection also discusses EPA's guidance and other efforts to reduce releases of mercury to the environment, including discharges of dental amalgam. EPA has not established national regulations for dental amalgam.

Occupational Safety and Health Administration

OSHA's authority regarding dental amalgam is limited to employee exposure resulting from handling or use of hazardous chemicals in the workplace. Dental amalgam is considered non-hazardous to consumers who receive dental restorations because the amalgam is considered benign once it is installed. However, workers handling amalgam have a greater potential for exposure than consumers, because dental workers handle liquid mercury while they prepare mercury amalgam restorations. For that reason, dental amalgam is classified as a hazardous chemical under OSHA's Hazard Communication Standard. Workers who handle amalgam alloy are entitled to protection under this standard, including the receipt of training and hazard information. OSHA's focus on dental amalgam is unrelated to the disposal of spent amalgam (OSHA, 1997).

Food and Drug Administration

FDA regulates dental amalgam under the Federal Food, Drug, and Cosmetic Act (FFDCA). The FFDCA classifies dental mercury as a Class I medical device and amalgam alloy

as a Class II medical device (see Title 21, *Code of Federal Regulations*, sections 872.3700 and 872.3050). Class I medical devices are subject to extensive safety regulations for use. Class II medical devices are subject to additional special controls for use (Anderson, 2007). FDA's and CDC's focus on dental amalgams is on the health risks to dentists, dental workers, and patients rather than the disposal of spent amalgam. According to FDA, dental amalgams contain mercury, which may have neurotoxic effects on the nervous systems of developing children and fetuses (FDA, 2008).

U.S. Environmental Protection Agency

There are no federal effluent limitations guidelines for mercury discharges from dental offices and dental laboratories, but EPA and its regional offices work closely with states and communities to develop strategies for reducing effluent discharges of mercury, including discharges from dental facilities. For example, EPA's Environmental Technology Verification Program studied amalgam separators to determine effectiveness (Grubbs, 2003). In addition, EPA regional offices participate in seminars and workshops with local organizations and other federal agencies to evaluate risks, develop recommendations, disseminate information, and communicate with the public regarding a wide range of mercury-associated issues. For example, EPA Region 4 participated in the Project Team on Consumption Advisories for Mercury in Gulf of Mexico Marine Fish. Also, EPA Regions 5 and 8 as well as EPA Headquarters have participated in the activities listed below to limit mercury discharge from dental facilities.

- *Region 5.* EPA and Environment Canada, working through the Great Lakes Bi-national Toxics Strategy, created a Mercury Workgroup that promotes activities that will reduce mercury releases to the Great Lakes Basin. In addition to Environment Canada EPA's Region 5, this workgroup includes representative states, environmental organizations, and the Council of Great Lakes Industries. The Workgroup's review of mercury releases in the Great Lakes area has focused on air emissions. As a result, the Workgroup has not collected trend data on mercury releases to water. The Workgroup has reviewed information on BMPs and successful voluntary and regulatory approaches used in state and local programs, including dental amalgam reduction programs in King County, WA; Toronto, ON; Duluth, MN; and Cleveland, OH (EPA, 2003). In addition, the Workgroup has not quantified reductions in mercury use or reductions in discharge of dental amalgam to wastewater.

- *Region 8.* EPA Region 8 developed a draft Mercury Control Strategy to help POTWs control mercury pollution problems from commercial, non-significant industrial users, including dental facilities. This draft Strategy includes detailed information on the development of BMPs, amalgam separators, and other removal and filtration devices, as well as other background information regarding dental amalgam control approaches (EPA, 2005).

- *EPA Headquarters (Office of Solid Waste)(OSW).* OSW recommends four specific actions to manage amalgam waste at dental facilities. The first letters of each action form the acronym *G.R.I.T.*

EPA Office of Solid Waste Recommendations for Dental Amalgam Waste Management

G	Grey Bag It	Discard any amalgam wastes into a grey bag. Never dispose of dental amalgam wastes in medical red bags or in your office trash containers
R	Recycle It	Select a responsible dental amalgam recycler who will manage your waste amalgam safely to limit the amount of mercury which can go back into the environment.
I	Install It	Install an amalgam water separator in the office to capture up to 99% of the mercury leaving a dental office through drains. This is the KEY to success.
T	Teach It	Educate and train staff about the proper management of dental amalgam in the office.

Source: David Carver, EPA/OSW

Disposal of mercury-containing waste is regulated under the Resource Conservation and Recovery Act (RCRA). A mercury-containing waste can be considered hazardous in two ways: 1) as a listed waste; or 2) as a characteristic waste. There are some source-specific hazardous wastes that are listed due to mercury; however, dental amalgam wastes are not listed in 40 CFR Part 261 Subpart D. A waste can be defined as a characteristic hazardous waste if it exhibits the toxicity characteristics for mercury. This can occur when a sample of a waste contains enough mercury to exceed the regulatory threshold of 0.2 mg/l (or 0.2 ppm) when subjected to specific leach test known as the TCLP (Toxicity Characteristic Leaching Procedure; see 40 CFR §261.24). Persons who generate hazardous waste, such as a waste that exhibits the hazardous characteristics for mercury, are subject to specific requirements for the proper management and disposal of that waste. The federal RCRA regulations differ depending upon how much hazardous waste is generated per site per month. Most dentists generate less than 100 kg of non-acute hazardous waste per month and less than 1 kg of acute hazardous waste per month, and are therefore classified as "Conditionally Exempt Small Quantity Generators" (CESQGs). CESQGs are not subject to most of the RCRA hazardous waste requirements, provided the waste is otherwise managed properly. However, some states have additional requirements for CESQGs or do not exempt CESQGs from all requirements (HERCenter, 2008).

4.1.2 American Dental Association Guidance

The most widely known national voluntary program is the "Best Management Practices for Amalgam Waste" developed and approved by the ADA Board of Trustees. This program was first published in January 2003 and updated in 2007 to include amalgam separators. All state and local voluntary programs are based on or derived from the guidance provided in the ADA BMPs.

ADA provides guidance documents for its members and the general public for the management and disposal of dental amalgam and amalgam waste. These include information regarding proper recycling of amalgam waste and practical guidelines for integrating BMPs into dental practices. ADA also provides advice for successful integration of BMPs into practices and offices, a directory of national dental waste recyclers, recommendations for safe preparation and placement of amalgam restorations, safety information for managing mercury spills, and advice on the purchase, installation, and operation of amalgam separators (ADA, 2007a). The ADA-defined BMPs are recognized as the industry standard. Table 4-1 lists the ADA BMPs for amalgam waste.

Table 4-1. ADA BMPs for Dental Amalgam

Focus	Best Management Practice
General	• Manage amalgam waste through recycling as much as possible. • Do not flush amalgam waste down the drain or toilet. • Use line cleaners that minimize the dissolution of amalgam. • Do not use bleach or chlorine-containing cleaners to flush wastewater lines. • Because amalgam waste may be mixed with body fluids or other potentially infectious material, use protective equipment such utility gloves, masks, and protective eyewear when handling it. • Check with city, county, or local waste authorities to get in touch with an amalgam waste recycler for any special requirements that may exist in the area for collecting, storing, and transporting amalgam waste. • Store amalgam waste in a covered plastic container labeled "Amalgam for Recycling" or as directed by the recycler. • Store different types of amalgam (e.g., contact and non-contact) in separate containers for recycling.
Amalgam capsules	• Do not use bulk elemental mercury, also referred to as liquid or raw mercury. • Recommend use of pre-capsulated alloys and stock a variety of capsule sizes since 1984. • Recycle used disposable amalgam capsules. • Do not put disposable amalgam capsules in biohazard containers, infectious waste containers (red bags), or regular garbage.
Non-contact amalgam	• Salvage, store, and recycle non-contact amalgam. • Do not put non-contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage. • Place unused non-contact amalgam in a silver or gray storage container or a storage container with silver or gray label (keep containers sealed at all times).
Contact amalgam	• Salvage amalgam pieces from restorations after removal and recycle the amalgam waste. • Do not put contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage. • Recycle teeth that contain amalgam restorations after confirming with the recycler that they will accept extracted teeth with amalgam restorations. • Do not dispose of extracted teeth that contain amalgam restorations in biohazard containers, infections waste containers (red bags), sharps containers, or regular garbage. • Do appropriately disinfect extracted teeth that contain amalgam restorations (e.g., 10 minutes in a 1:10 bleach-to-water solution). • Place unused contact amalgam in a silver or gray storage container or a storage container with silver or gray label (keep containers sealed at all times).
Chair-side traps	• Use chair-side traps to retain amalgam and recycle the content. • Do not rinse chair side traps containing amalgam over drains or sinks. • Disposable traps from dental units dedicated strictly to hygiene may be placed in with the regular garbage. • Place disposable chair-side traps and the contents of reusable chair-side traps in a silver or gray storage container or a storage container with a silver or gray label (keep containers sealed at all times).
Amalgam separators	• Select an amalgam separator that complies with ISO 11143. • Follow the manufacturer's recommendations for maintenance and recycling procedures.
Other amalgam collection devices	• Recycle contents retained by the vacuum pump filter, amalgam separator, or other amalgam collection device that may be used, if they contain amalgam. • Do not rinse vacuum pump filters containing amalgam, amalgam separator canisters, or other amalgam collection devices that may be used over drains or sinks. • Change the filter according to the manufacturer's recommended schedule. • Place disposable vacuum pump filters and the contents of reusable vacuum pump filters in a silver or gray storage container or a storage container with silver or gray label (keep containers sealed at all times).

Table 4-1. ADA BMPs for Dental Amalgam

Focus	Best Management Practice
Bulk elemental mercury	• Recycle bulk mercury. • Check with licensed recycler to determine if they accept it. • Do not pour bulk mercury waste in the garbage, into a red bag, or down the drain. • Check with state regulatory agency and municipality to find out if a collection program is available.

Source: ADA, 2007a.

4.2 State Dental Amalgam Requirements and Guidance

This subsection describes state mandatory and voluntary programs for amalgam discharges from dental facilities.

4.2.1 State Mandatory Programs

EPA identified the following 11 states as having mandatory program requirements for dental facilities:

- Connecticut;
- Louisiana;
- Maine;
- Massachusetts;
- New Hampshire;
- New Jersey;
- New York;
- Oregon;
- Rhode Island;
- Vermont; and
- Washington.

States typically use the voluntary BMPs developed by ADA described above as the basis for their dental mercury discharge regulations. As a result, the state requirements share several common elements. Table 4-2 summarizes the elements of the various state regulations, including the types of requirements included and the methods used to demonstrate compliance with the regulations. Table 4-3 compares the state BMP requirements to the ADA BMPs.

Table 4-2. Summary of Elements of State Requirements

Element	Examples from State Requirements
Requirements	• Install amalgam separators (CT, LA, MA, ME, NH, NJ, NY, OR, VT, WA, and only new offices in RI) • Follow state BMPs (CT, LA, MA, NH, NJ, NY, OR, RI, VT, WA). • Prohibits use of bulk mercury (LA, NJ, NY, OR).
Amalgam Separator Technology Specifications	• Meet ISO Standard 111143 (CT, ME, NH, NJ, NY, OR, RI, VT). • Operate at 95% efficiency (MA, ME, NY, VT) a. • Operate at 98% efficiency (MA if new, ME if after 3/20/03). • Operate at 99% efficiency (NY if new, RI).

Table 4-2. Summary of Elements of State Requirements

Element	Examples from State Requirements
Operation specifications for amalgam separators	• Must be operated at all times when dental procedures are performed (CT). • Must service every chair at practice where amalgam waste is generated (MA). • New offices must have separators installed prior to opening (OR).
Method for demonstrating compliance	• Submit separator certification to state environmental agency (CT, MA, ME, NJ). • Provide certification of compliance with BMPs (CT, MA, NH, NJ). • Maintain maintenance and servicing records and be able to provide upon request (CT, ME). • Provide written notice of method of disposing mercury removed by the separator (ME).
Compliance tracking	• DEP inspections (CT). • Web form for providing proof of compliance (RI).

Sources: (CTDEP, 2006; MassDEP, 2007;); (MEDEP, 2005); (MADEP, 2007); (NHDES, 2002); (NYDEC, 2007); (Oregon, 2007); (RIDEM, 2007); (VTDEC, 2006); (Walsh, 2007).
a — In several states, if a facility has an amalgam separator in operation prior to implementation of the state law, then the state will allow the facility to continue operating that separator at its current efficiency. Only newly installed separators are required to meet operating efficiencies of 98 and 99 percent.

In addition to the state requirements summarized in Table 4-2 and 4-3, New Mexico and Minnesota have proposed legislation for dental mercury controls and are awaiting approval. The bills would require all dental offices to install amalgam separators (Walsh, 2007). As of August 2008, EPA has not found any information indicating that these bills have been enacted.

Bills for dental mercury controls were proposed but not passed in the following states:

- *Alabama.* In 2004, the Alabama state legislature began debate on two bills designed to regulate the use of mercury in dental offices: HB 495, Mercury Amalgam Filling, and HB 665, Bill to Require Dentists to Provide Information about Mercury or Mercury Amalgam to Patients. It appears that both of these bills failed to clear the House and were tabled in the House Health Committee (ALISON, 2007).

- *Arkansas.* The Mercury Poisoning Reduction Act of 2003 required the Arkansas Department of Environmental Quality to develop a plan for reducing mercury pollution from dental procedures and implement a mandatory program for dental offices by July 1, 2004 (Arkansas, 2003). However, EPA could not find information to determine if this Act had been either enacted or enforced.

- *California.* In 2005, Assembly Bill 966, which would establish standards related to amalgam in dental and related services, passed the state Senate by a vote of 51 to 28 but was vetoed by the governor's office (California Legislative Counsel, 2005).

Table 4-3. Best Management Practices by State

Best Management Practice	ADA	CT	LA	MA	NH	NJ	NY	OR	RI	VT	WA
Requirement/Guidance	**G**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Initial Use											
Use only pre-capsulated alloys and/or stock a variety of capsule sizes.	T	T	T		T	T	T	T			
Do not use bulk mercury.	T		T			T	T	T			
Recycling/Disposal											
Manage amalgam waste through recycling as much as possible.	T	T	T	T	T	T	T	T	T		
Recycle used disposable amalgam capsules.	T		T		T	T	T		T	T	T
Do not flush amalgam waste down the drain or toilet.	T	T	T	T	T		T	T	T	T	T
Salvage, store and recycle non-contact amalgam (scrap amalgam).	T	T	T	T	T	T	T	T	T	T	T
Salvage amalgam pieces from restorations after removal (contact amalgam) and recycle amalgam waste.	T	T	T	T	T	T	T	T	T	T	
Recycle teeth that contain amalgam restorations.	T		T	T	T		T			T	T
Do not put used disposable amalgam capsules in biohazard containers, infectious waste containers (red bags) or regular garbage.	T	T	T		T	T	T	T	T	T	T
Do not put non-contact amalgam waste in biohazard containers, infectious waste containers (red bags) or regular garbage.	T	T	T	T	T	T	T	T	T	T	T
Do not put contact amalgam waste in biohazard containers, infectious waste containers (red bags) or regular garbage.	T	T	T	T	T	T	T	T	T	T	
Do not dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers (red bags), sharps containers or regular garbage.	T		T	T	T	T	T	T		T	
Chair-Side Traps											
Use chair-side traps to retain amalgam and recycle the content.	T		T	T	T	T	T	T	T	T	T
Do not rinse chair-side traps containing amalgam over drains or sinks.	T	T	T	T	T	T	T	T	T	T	T
Where appropriate, disposable amalgam traps are preferable to reusable traps.		T			T		T	T	T		

Table 4-3. Best Management Practices by State

Best Management Practice	ADA	CT	LA	MA	NH	NJ	NY	OR	RI	VT	WA
Requirement/Guidance	**G**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Vacuum Pumps											
Recycle contents retained by the vacuum pump filter or other amalgam collection device, if they contain amalgam.	T	T	T	T	T		T	T	T	T	T
Do not rinse vacuum pump filters containing amalgam or other amalgam collection devices over drains or sinks.	T	T	T	T	T	T	T	T	T	T	T
Use line cleaners that minimize the dissolution of amalgam.	T		T	T			T		T	T	
Do not use bleach or chlorine-containing cleaners to flush wastewater lines.	T	T	T	T		T	T		T	T	
Amalgam Separators											
Install and use amalgam separators.	T	T	T	T	T	T	T	T	T	T	T
Other											
Any dental practice using mercury should maintain a mercury spill kit on site and train all staff on mercury spill cleanup response procedure.		T		T	T				T	T	
Do not disinfect teeth or any item that contains amalgam using heat.				T	T		T	T			

Sources: ADA, 2007a; CTDEP, 2006; MassDEP, 2007; NHDES, 2002; NJR, 2007; NYDEC, 2007; RIDEM, 2007; VTDEC, 2006; and Lamperti, 2007.
G — Guidance.
R — Requirement.

4.2.2 State Dental Amalgam Guidance

EPA has reviewed guidance from five states that provide voluntary guidelines and BMPs to dental offices: Florida, Idaho, Minnesota, Washington, and the District of Columbia. Table 4-4 summarizes the state BMPs and compares them to ADA's BMPs.

4.3 Local Dental Amalgam Requirements and Guidance

This subsection summarizes mandatory and voluntary local programs for minimizing the discharge of dental mercury to wastewater. In addition, this subsection attempts to evaluate the effectives of local voluntary programs. EPA notes this subsection is not intended to be an exhaustive list of local programs.

4.3.1 Local Dental Amalgam Requirements

EPA identified and reviewed mandatory program requirements for the following 9 localities:

- King County Wastewater Treatment Division (KCWTD), WA;
- East Bay Municipal Utility District (EBMUD), Oakland, CA;
- Palo Alto Regional Water Quality Control Plant (RWQCP), CA;
- Northeast Ohio Regional Sewer District (NEORSD), Cleveland, OH;
- Several Wisconsin sewerage districts: Madison, Milwaukee, Neenah-Menasha, Oshkosh, GrandChute and Menasha West, Wausau, Fond du Lac and Green Bay-De Pere, Waukesha, Watertown, Beloit, and La Crosse (Behm, 2008);
- Fort Collins and Boulder, CO;
- San Francisco, CA;
- Solon, OH; and
- Narragansett Bay, RI.

Many elements included in the local requirements are similar to the state requirements described in Section 4.2.1. Table 4-5 summarizes the elements of the local requirements to control discharges of dental mercury. Table 4-6 compares the lists of local BMPs to ADA's BMPs.

Table 4-4. Voluntary BMPs by State

Best Management Practice	ADA	DC	FL	ID	MN	WA [a]
Initial Use						
Use only pre-capsulated alloys and/or stock a variety of capsule sizes.	T	T	T	T		
Do not use bulk mercury.	T	T	T	T		
Recycling/Disposal						
Manage amalgam waste through recycling as much as possible.	T	T	T	T	T	
Recycle used disposable amalgam capsules.	T	T		T		T
Do not flush amalgam waste down the drain or toilet.	T	T	T		T	T
Salvage, store, and recycle non-contact amalgam (scrap amalgam).	T	T		T	T	T
Salvage amalgam pieces from restorations after removal (contact amalgam) and recycle amalgam waste.	T	T	T	T	T	
Recycle teeth that contain amalgam restorations.	T		T	T		T
Do not put used disposable amalgam capsules in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T		T	T
Do not put non-contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T		T	T
Do not put contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T		T	
Do not dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers (red bags), sharps containers, or regular garbage.	T		T		T	
Chair-Side Traps						
Use chair-side traps to retain amalgam and recycle the content.	T	T	T	T	T	T
Do not rinse chair-side traps containing amalgam over drains or sinks.	T	T	T	T	T	T
Where appropriate, disposable amalgam traps are preferable to reusable traps.		T	T			
Vacuum Pumps						
Recycle contents retained by the vacuum pump filter or other amalgam collection device, if they contain amalgam.	T	T	T		T	T
Do not rinse vacuum pump filters containing amalgam or other amalgam collection devices over drains or sinks.	T	T	T		T	T
Use line cleaners that minimize the dissolution of amalgam.	T	T			T	
Do not use bleach or chlorine-containing cleaners to flush wastewater lines.	T				T	
Amalgam Separators						
Install and use amalgam separators.	T			T	T	T

Table 4-4. Voluntary BMPs by State

Best Management Practice	ADA	DC	FL	ID	MN	WA [a]
Other						
Any dental practice using mercury should maintain a mercury spill kit on site and train all staff on mercury spill cleanup response procedure.		T	T			
Do not disinfect teeth or any item that contains amalgam using heat.					T	

Sources: ADA, 2007a; FLDEP, 2001; ISDA, 2008; MDA, 2003; WA Department of Ecology, 2006.
a — According to sources at Quicksilver Caucus, the Washington program is currently a mandatory program. It is also listed in Section 4.2.1 of this report.

Table 4-5. Summary of Elements of Local Requirements

Element	Examples from Local Requirements
Requirements	• Meet a mercury discharge limit of 0.2 ppm (King County) if a separator is not installed. • Install amalgam separators (East Bay, Palo Alto, Wisconsin, Fort Collins, San Francisco, Solon, Narragansett Bay). • Alternative to installing an amalgam separator: – Facility must pay a fee of $1,770/yr and be subject to inspections and testing (East Bay). – Facility must obtain a discharge permit and monitor wastewater (San Francisco). – Follow local BMPs (King County, Palo Alto, NE Ohio, Milwaukee, Narragansett Bay).
Exemptions	• Facilities that remove amalgam no more than three days per year (King County). • Certain specialty fields (King County). • Facilities that had installed separators prior to regulation (Palo Alto).
Technology specifications	• Meet ISO Standard 111143 (King County, Madison, East Bay).
Method for demonstrating compliance	• Provide certification for separator (East Bay, Palo Alto, Madison, Milwaukee). • Provide certification of compliance with BMPs (East Bay, Palo Alto, NE Ohio, Madison, Milwaukee). • Provide documentation of mercury waste hauling (East Bay, Palo Alto, NE Ohio).
Compliance tracking	• Enforcement protocol including notice of violation, compliance schedule, and penalties for noncompliance (King County). • Inspections performed by local POTW (East Bay, Palo Alto, Madison, Milwaukee).

Sources: EBMUD, 2005; KCWTD, 2007; MMSD, 2008; NEORSD, 2007; Palo Alto, 2007; Walsh, 2007).

Table 4-6. Best Management Practices by Municipality

Best Management Practice	Municipality						
	ADA	East Bay, Oakland, CA	King County, WA	Milwaukee and Madison, WI [a]	Narragansett Bay, RI	NE Ohio, Cleveland, OH	Palo Alto, CA
Requirement/Guidance	**G**	**R**	**R**	**R**	**R**	**R**	**R**
Initial Use							
Use only pre-capsulated alloys and/or stock a variety of capsule sizes.	T	T		T	T	T	T
Do not use bulk mercury.	T			T		T	T
Recycling/Disposal							
Manage amalgam waste by recycling as much as possible.	T	T		T		T	T
Recycle used disposable amalgam capsules.	T			T	T	T	
Do not flush amalgam waste down the drain or toilet.	T	T	T	T	T	T	T
Salvage, store, and recycle non-contact amalgam (scrap amalgam).	T	T	T	T	T	T	T
Salvage amalgam pieces from restorations after removal (contact amalgam) and recycle amalgam waste.	T	T	T	T	T	T	T
Recycle extracted teeth that contain amalgam restorations.	T		T	T			
Do not put used disposable amalgam capsules in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T	T		T	T
Do not put non-contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T		T	T	T
Do not put contact amalgam waste in biohazard containers, infectious waste containers (red bags), or regular garbage.	T	T	T	T	T	T	T
Do not dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers (red bags), sharps containers, or regular garbage.	T		T	T			T
Chair-Side Traps							
Use chair-side traps to retain amalgam and recycle the content.	T	T	T	T	T	T	T
Do not rinse chair-side traps containing amalgam over drains or sinks.	T	T	T	T	T	T	T
Where appropriate, disposable amalgam traps are preferable to reusable traps.		T			T(G)	T(G)	

Table 4-6. Best Management Practices by Municipality

Best Management Practice	Municipality						
	ADA	East Bay, Oakland, CA	King County, WA	Milwaukee and Madison, WI [a]	Narragansett Bay, RI	NE Ohio, Cleveland, OH	Palo Alto, CA
Requirement/Guidance	**G**	**R**	**R**	**R**	**R**	**R**	**R**
Vacuum Pumps							
Recycle contents retained by the vacuum pump filter or other amalgam collection device, if they contain amalgam.	T	T	T	T	T	T	T
Do not rinse vacuum pump filters containing amalgam or other amalgam collection devices over drains or sinks.	T	T	T	T	T	T	T
Use line cleaners that minimize the dissolution of amalgam.	T	T			T	T(G)	T
Do not use bleach or chlorine-containing cleaners to flush wastewater lines.	T	T		T	T	T(G)	T
Other							
Any dental practice using mercury should maintain a mercury spill kit on site and train all staff on mercury spill cleanup response procedure.		T			T	T	T
Install and use amalgam separators.	T	T	T	T	T	T	T

Sources: ADA, 2007a; EBMUD, 2005; KCWTD, 2007; NEORSD, 2007; Palo Alto, 2007; Uva, 2007; WDA, 2004.
a — The Milwaukee and Madison programs reference BMPs developed by the Wisconsin Dental Association (WDA, 2004).
G — Guidance.
R — Requirement.

4.3.2 Local Dental Amalgam Voluntary Programs

This section summarizes voluntary local programs that provided information to EPA on the participation rates for their programs. All of the programs involve outreach to dentists to educate them on BMPs and use of amalgam separators. The level of interaction between the program partners and local dentists varies greatly from program to program. Follow-up activities to verify participation include surveys, visits to dental offices, and contacting amalgam separator vendors and waste haulers for lists of customers. In some cases, the available information did not give EPA enough details to determine how the participation rates were verified. Table 4-7 summarizes the voluntary programs and presents the participation rates for the programs. This table also contains some state voluntary program participation rates for comparison purposes.

4.3.2.1 Examples of Voluntary Programs with High Participation Rates

This subsection describes case studies of three voluntary programs that achieved participation rates greater than 90 percent or exceeded their goals for participation rates. It includes both local and state programs.

The Duluth program attributed its success to the following:

- High level of cooperation from local dental societies;
- One-on-one interaction with dentists; and
- Providing financial incentives to dentists.

Kansas and Massachusetts each took a two-phase approach to their programs. Phase 1 encouraged early installation of amalgam separators. Both states' programs included specific goals and deadlines for participation. The second phase of the program implemented mandatory requirements for installation of amalgam separators at dental offices. Both states reported participation rates exceeding 50 percent for the voluntary phase. Based on the success of its voluntary program, Kansas decided not to implement mandatory requirements. Massachusetts decided to continue to implement mandatory requirements under phase 2; however, the state rewarded the dental offices that voluntarily installed amalgam separators during phase 1 by allowing them to operate amalgam separators at a lower efficiency than the separators required under phase 2.

Duluth, Minnesota

In 1992, the Western Lake Superior Sanitary District ("WLSSD," i.e., Duluth) and the Northeast District Dental Society formed a public-private partnership that taught dentists how to recycle amalgam waste, made presentations at local dental society meetings, and prepared and distributed written materials. As an incentive, the WLSSD purchased and installed separators at 51 dental offices, but left the largest long-term cost (recycling the amalgam) to be paid by the dentists (Walsh, 2007). ADA attributed the success of the program to the leadership of the local dental society, peer-to-peer interaction with area dentists (including explaining the need to properly manage amalgam waste to prevent mercury from entering the environment and demonstrating the proper methods for doing so), financial incentives to install amalgam separators, and a discount waste disposal option through WLSSD's "Clean Shop" Program. Currently, all 52 of the dental offices have installed amalgam separators.

Table 4-7. Summary of Voluntary Programs for Reducing Dental Amalgam Releases to Wastewater

State (Jurisdiction)	Date	Description	Participation Rate	Verification of Participation
California (Palo Alto, San Francisco, and Central Contra Costa)	No information	Voluntary installation of amalgam separators and implementation of BMPs.	65%	Survey conducted by sanitation districts in 2000.
Kansas (City of Wichita)	April 2000	Developed a Mercury Code of Management Practices (CMP). Encouraged dentists to use technologies beyond chair side trap and vacuum filter (e.g. amalgam separator). Wichita planned to require mandatory installation of amalgam separators if participation in the voluntary program had been low, but found that a mandatory requirement was not necessary.	98% (out of 200 offices)	No information.
Massachusetts (MA Dental Society)	2004	Goals were to have 50% of dentists install amalgam separators by January 2005, 90% participation by 2006, and 100% participation by 2007. MA later implemented mandatory requirements for amalgam separators.	April 2005 — 75%	No information.
Minnesota (MN Dental Association)	2001	Voluntary installation of amalgam separators	85% of dentists have committed to installing separators.	No information.
Minnesota (City of Duluth)	2001-2003	Sanitation district purchased and installed amalgam separators in dental offices. Dentists are responsible for cost of recycling. The sanitation district and local dental society also provided education on how to recycle amalgam waste, trained dental offices, prepared written materials, and made presentations at dental society meetings.	100%	Sanitation district paid for and oversaw the installation of all amalgam separators.
Minnesota (Minneapolis, St. Paul)	2003	Voluntary installation of amalgam separators. 700 clinics participated in program. The voluntary program was accompanied by a threat of eventual regulation and an industrial permit requirement.	99% of the clinics eligible for the program installed separators	No information.

Table 4-7. Summary of Voluntary Programs for Reducing Dental Amalgam Releases to Wastewater

State (Jurisdiction)	Date	Description	Participation Rate	Verification of Participation
Missouri (Springfield)	2006	University of Missouri conducted a study to determine whether voluntary BMPs could significantly reduce mercury discharges from dental offices. Offered a half-day training course on BMPs. Also sent outreach materials via mail to local members of the dental society. Collected wastewater samples to determine mercury reductions (see Section 5.2.2).	254 members in the local dental society. 54 (21%) local dentists attended the half-day training session on BMPs. 76 (30%) dentists indicated that they had implemented BMPs as a result of outreach. Very few dentists installed amalgam separators.	UM sent a follow-up survey to the 254 members of the local dental society.
Oregon (City of Corvallis)	2003	Voluntary installation of amalgam separators and implementation of BMPs. Corvallis was awarded EPA's 2006 National First Place Clean Water Act Recognition Award for Pretreatment Program Excellence.	100%.	No information.
Washington (WA Dental Association)	August 2003	Voluntary installation of amalgam separators and implementation of other BMPs.	80% and anticipates an additional 16%	No information.
Washington (Seattle and King County)	No information	Significant outreach to dental offices on proper management of scrap amalgam, proper use of chair-side trap and pump filter waste, and amalgam separators. Participation rate was so low that King County decided to implement a mandatory program.	<50% managed scrap amalgam properly. 25% installed amalgam separators. 10% contracted with waste haulers.	King County: Made unannounced visits to 212 dental offices. Contacted separator vendors to obtain lists of dental office customers. Contacted waste haulers and mail-away firms to obtain lists of dental office customers.
Wisconsin (Madison)	1997	Encouraged use of amalgam separators through outreach to dentists. Section 4.2.1 describes the mandatory program that will be implemented in December 2008.	23 of 103 dentists in the area (22%).	Surveyed local dentists to determine how many clinics use and/or remove amalgam and how many had installed amalgam separators.

Sources: AMSA, 2002; MassDEP, 2007; MU Extension, 2007; Walsh, 2007; KCWTD, 2007; and MMSD, 2008.

Wichita, Kansas

In April 2000, the Wichita Department of Water and Sewer initiated a Mercury Code of Management Practices (CMP) for Wichita, Kansas. The CMP requires dental offices in Wichita, Kansas, to be equipped with devices to reduce the amount of amalgam discharged into the public waste streams. Phase 1 was an effort to encourage voluntary use of technologies beyond the chair-side trap and vacuum filter, e.g., a separator. Phase 2 of the program would have required mandatory separators if the voluntary effort was not successful. Phase 2 of the program was never implemented because 60 percent of dental community complied voluntarily. According to ADA, 98 percent of the 200 dental offices in the city complied with the Mercury CMP Program without a mandatory separator requirement (Walsh, 2007).

Massachusetts

In 2004, the Massachusetts Department of Environmental Protection (MassDEP) worked with the Massachusetts Dental Society to establish a voluntary program for dentists to install amalgam separators. The program used a two-phase approach:

- First, MassDEP implemented a voluntary program that encouraged dental offices to install and use amalgam separators. The program called for 50 percent participation by January 2005, 90 percent by January 2006, and 100 percent by January 2007.

- Second, MassDEP implemented mandatory requirements, described in Section 4.2.1, for operating amalgam separators, recycling amalgam waste, and certifying compliance.

The voluntary portion of the program reported a 75 percent participation rate for the first year, exceeding MassDEP's goals. In April 2006, MassDEP promulgated regulations mandating that most dental facilities install separators. Dentists who had complied with the voluntary program were rewarded with an exemption from the regulation (i.e. record keeping and reporting) until 2007 or 2010, depending on how early the dentist complied. In addition, dentists who installed separators under the voluntary program were permitted to continue operating their separators at 95 percent efficiency. The regulation required all newly installed of amalgam separators to operate at 98 percent efficiency (MassDEP, 2007).

4.3.2.2 Examples of Voluntary Programs with Low Participation Rates

This section describes case studies for two voluntary programs that had participation rates below 50 percent. These programs, similar to the programs with high participation rates, conducted extensive outreach to local dentists to educate the dentists on BMPs and the use of amalgam separators. Despite this effort, one of the two programs discussed in this section decided to implement mandatory requirements for BMPs and amalgam separators due to the low level of participation in the voluntary program.

Seattle and King County

In 1995, the Seattle–King County Dental Society set up a standing committee to work with the King County government. These partners met several times a year and pursued a number of activities, including (EPA, 2004):

- Developing a poster and a handbook for dentists;
- Writing articles for a dental journal;
- Mailing information to all members;
- Co-sponsoring a free waste pick-up event; and
- Presenting a "Green Dentistry" session at two Pacific Northwest Dental Conferences.

Other efforts undertaken independently by King County include:

- Advertisements seeking to educate dentists;
- Outreach to dental supply houses;
- Outreach to vocational/technical programs for dental assistants;
- Cash rebates for purchase of amalgam separators (up to $500);
- Technical assistance visits to dental offices; and
- Promotion of dentists as "EnviroStars."

The Seattle-King County Dental Society won a regional environmental achievement award for its efforts to educate its members concerning mercury in dental wastewater.

During the fall of 1999 and spring of 2000, King County evaluated its voluntary dental program by conducting random visits to 212 dental offices and collecting data on the disposal of amalgam scrap, trap amalgam, pump filter sludge, and fixer. King County also contacted separator vendors to obtain lists of dental offices that had purchased and installed separators, and waste haulers and mail-away firms to obtain lists of dental offices with waste management contracts.

King County's evaluation showed that the six-year voluntary program achieved the following results (EPA, 2004):

- Less than half of dentists in the King County service area properly managed scrap amalgam.

- Less than 25 percent of dentists properly managed chair-side trap and pump filter waste.

- Only 25 dental offices installed amalgam separators (2.5 percent of those estimated to place and/or remove amalgam).

- About 10 percent of dental offices contracted with waste haulers and/or mail-away firms.

- Hundreds of pounds of mercury from dental amalgams were still being disposed of annually to garbage, "red bags," sewers, and "unknown" places.

- The costs for King County's voluntary program totaled over $250,000. During 1995–2001, an estimated $4,500 was spent on advertisements, $24,000 on the production of a poster and handbook, $65,000 on equipment rebates, $63,500 on field visits, and $100,000 for staff time.

Due to the lack of immediate success of this voluntary program, King County began a mandatory program as of July 2003. The mandatory regulations are described in Section 4.3.1 (KCWTD, 2007).

Springfield, Missouri

The Springfield program included extensive outreach to local dentists and was very successful in getting dentists to follow voluntary BMPs. However, the program was unsuccessful in getting dentists to install amalgam separators. The program staff concluded that amalgam separators were not installed because they are not required.

In 2006, the University of Missouri (MU Extension) began a study to determine whether dental offices could significantly reduce their mercury discharges though voluntary BMPs. Springfield was selected for the pilot study based on interest and commitment of staff resources from the Springfield Public Works Department and the Greater Springfield Dental Society (GSDS) (MU Extension, 2007). The discussion of this study presented in this section focuses on participation rates for the voluntary program. Effectiveness of BMPs on reducing mercury concentrations at POTWs is discussed in Section 5.2.

MU distributed a questionnaire to Springfield dentists in February 2006 to collect baseline data on amalgam use and management practices. The questionnaire was sent to 123 dentists and there were 48 responses (39 percent). MU then offered area dentists a half-day training course on BMPs for dental amalgam. Eighty dentists and dental office staff representing 54 local dental offices attended the training. Participants received a DVD, a wall poster with BMPs, a brochure of other available resources, and other written materials including:

- Dental mercury hygiene recommendations;
- ADA Guidelines on Amalgam Accumulations in Dental Office Plumbing;
- Summary of Recent Study of Dental Amalgam in Wastewater;
- The Missouri Department of Natural Resources' determination of status and options for various types of dental waste; and
- A list of amalgam recyclers.

MU also sent training materials via mail to dentists who did not attend the course.

One year later, MU distributed a follow-up questionnaire to 254 members of the GSDS to measure any changes in management practices that resulted from MU's education efforts. The response rate was 76 dental offices (30 percent). The comparison of responses on reported dental amalgam management practices before and after intervention showed that the BMP training and education efforts may have succeeded in changing some practices:

- Dental amalgam use decreased 5 percent from the previous year.

- Improper disposal of capsules in regular waste decreased after the training and education, while the number of dentists reporting setting amalgam capsules aside for pickup by an amalgam recycler increased significantly.

- The collection and recycling of scrap amalgam increased significantly after BMP training while the improper disposal decreased.

- The amount of amalgam scrap disposed of as medical waste after the BMP training increased slightly. This finding may indicate a need for additional education for dental office staff and better labeling and instruction from medical waste management companies.

- Use of chair-side traps increased from the year before; the practice of disposing of trap contents with regular waste decreased.

- More of the dentists who use pump filters reported placing filter contents in a container with medical waste; also reported was a slight increase in placing filter contents in a container for pickup by an amalgam recycler. Fewer dentists reported that they place filter contents in regular office waste.

- More dentists reported that they disinfected extracted teeth with amalgam restorations and set them aside for an amalgam recycler.

- More dentists reported using an amalgam recycler and that their recycler also picks up medical waste. However, the majority of dentists reported that they were unable to recycle amalgam waste because they could not locate a recycler in their area, locate a recycler to pick up small quantities of dental amalgam waste, find a method for shipping waste, or afford recycling amalgam.

According to the results of the survey, the education efforts by MU were extremely successful in educating dentists on BMPs. However, the majority of the dentists in the Missouri/Springfield area did not use amalgam separators prior to outreach and did not install amalgam separators after MU conducted its outreach. MU concluded that very few dentists use amalgam separators because they are not required in Missouri or Springfield (MU Extension, 2007).

4.3.2.3 Summary

Participation rates in voluntary programs are highly variable, ranging from as high as 100 percent of dentists in a community to as low as around 20 percent. Several programs that experienced low participation rates conducted extensive outreach and had frequent interaction with dentists. Therefore, the level of participation does not necessarily correspond to the level of outreach and education.

The highest participation percentages were seen for voluntary programs that included the threat of a mandatory second phase. Examples of the mandatory second phase requirements include more stringent requirements for reporting or the requirement for higher amalgam separator efficiency standards. To avoid the more stringent mandatory requirements, dental facilities usually opted to comply with the voluntary requirements. Often, the mandatory second phase of the program was not ultimately implemented. Also, voluntary control programs that directly purchased amalgam separators for the dentists to install were very successful.

The level of interaction between the program partners and local dentists varies greatly from program to program. Follow-up activities to verify participation include conducting surveys, visiting dental offices, and contacting amalgam separator vendors and waste haulers for lists of customers.

According to an evaluation conducted by NACWA in 2002, participation rates in voluntary programs are highly variable, ranging from 100 percent to as low as 38 percent. NACWA also noted that during the first year of implementation regulatory programs will have higher participation rates than voluntary programs. However, over time (five to 10 years), participation rates for well-implemented voluntary programs will be similar to participation rates for mandatory programs (AMSA, 2002).

4.4 Common Elements Found in State and Local Programs

This subsection attempts to summarize commonalities of state and local dental mercury programs discussed earlier in this section. These programs encourage the use of (1) BMPs at dental facilities to reduce the amount of mercury waste generated and (2) wastewater treatment technologies to capture and recycle the mercury that is present in discharges.

Element 1 — Identify All Mercury Sources.

Several state and local programs attempt to characterize all sources of mercury in their influent. For example, East Bay implemented a program to sample wastewater at the POTW to establish baseline mercury concentrations in the influent, effluent, and biosolids. East Bay then used these data to calculate the percent contributions to the influent mercury load from residential and industrial sources (EBMUD, 2007). Similarly, King County conducted a dental office waste stream characterization study to determine baseline mercury discharges (King County, 1991).

Table 4-8 lists potential non-dental mercury sources in POTW influent.

Table 4-8. Non-Dental Mercury Sources

Commercial Activities	Residential Sources
Hospitals	Human waste (amalgam)
Laboratories	Human waste (dietary)
Universities	Laundry graywater
Secondary schools	Household products
Medical clinics	Improper disposal of mercury thermometers
Vehicle service facilities	Atmospheric deposition from coal-fired utilities
Industrial activities	Naturally occurring elemental mercury

Source: (EPA, 2005).

Element 2 — Design the Program.

State and local programs develop criteria for participation, a list of BMPs for dental facilities, incentives for participation, and goals for the program.

The usual recommended criterion for including dental facilities in a mercury reduction program is whether the dental office conducts any placement or removal of amalgam fillings. Some programs exclude dental facilities using a de minimis amount of amalgam. The King County program exempts certain specialty fields and facilities that remove amalgam no more than three days per year (KCWTD, 2007).

The ISO standards for amalgam separators are generally employed (see Section 5.1.1). Requirements beyond the ISO standards require substantial effort. Programs in King County and Narragansett Bay have also contacted separator manufacturers and suppliers for their expertise in separator selection and the development of maintenance requirements for BMPs (Chaimberlain et al, 2005 and Uva, 2007).

During the design stage, state and local officials decide on the mechanism they would use to impose standards on the dental community. The size of the community has sometimes been a key factor for selecting the appropriate control mechanism. Larger communities sometimes found that a more formal program was necessary; smaller communities found that outreach and education was more manageable.

Some programs establish specific goals for the level of participation and a timeframe for implementing BMPs. For example, the Madison, WI program set goals of 100 percent compliance with BMPs and installation of amalgam separators by December 31, 2008 (MMSD, 2008).

To provide incentives for participation, some programs issue awards recognizing positive action and subsidies for installing separators or recycling. Awards and subsidies successfully maintain rapport and speed progress. Mandatory programs also have required reporting and generally include penalties for facilities that do not comply with the requirements.

Finally, some programs have investigated opportunities to coordinate their amalgam work with other environmental or health programs. For example, amalgam management can be consolidated with work regarding lead foil, X-ray film development chemicals, radiation safety,

or medical waste (UW, 2008). The East Bay program included measures to control mercury from other industries in addition to dental facilities. (EBMUD, 2007).

Element 3 — Outreach and Education

A crucial element of any state or local program examined was effective outreach and education. Some examples are:

- Identifying all dental facilities, using sources such as: local dental society membership lists, yellow pages, state licenses, and occupancy permits (UW, 2008).

- Issuing a survey or visiting conducting site visits to local dental offices to identify current practices (program baseline) and to increase awareness of the program. Prior to implementing its program, Palo Alto visited 43 percent of dental facilities in its service area and determined baseline BMP and amalgam separator use (Palo Alto, 2007).

- Speaking to the local dental societies to introduce them to the program and to identify any work that has already been done to reduce mercury discharges. East Bay and Madison worked with their local dental societies to develop their dental programs (EBMUD, 2007 and MMSD, 2008).

- Speaking to dental and technical schools about the program.

- Maintaining a central database during the implementation of the program to track the program's progress and document other changes to the local dentist population. The Madison Municipal Sewer District developed an in-house database to track to track the mercury program. The database is designed to manage contact data, facility identification and practices, survey data, and report generation (MMSD, 2008).

Element 4 – Monitor Reductions/Measure Program Success

For voluntary programs: One method for measuring the success of a voluntary program is looking at participation rates. To do this local programs have surveyed participants at local dental society meetings and mailed out surveys to measure participation rates. The University of Missouri (MU) conducted a study to evaluate the effectiveness of a voluntary program in Springfield, MO. MU issued a survey to dental society members to measure changes in BMP use among dentists in the area. This also had the added benefit of increasing awareness of the voluntary program (MU Extension, 2007).

For mandatory programs: Mandatory programs usually have more formal reporting and monitoring to ensure that requirements are being met. The following is a list of methods used by mandatory programs:

- Reporting wastewater monitoring, certification, and/or reporting. Dentists discharging to King County's wastewater treatment division who elect not to install amalgam separators must demonstrate compliance with a 0.2 ppm mercury limit (KCWTD, 2007).

- Reporting the dates, locations, and amount of mercury waste recycled.

- Monitoring POTW influent/effluent/biosolids. East Bay monitors and analyzes mercury levels in its influent to measure the effectiveness of its program (EBMUD, 2007). King County uses biosolids monitoring data as an indicator of mercury levels in its treatment system (King County, 2008).

- Conducting inspections of dental offices. King County conducts surprise inspections at dental facilities in its service area (KCWTD, 2007).

- Requiring demonstration of amalgam separator installation. East Bay requires dentists to self certify installation of amalgam separators (EBMUD, 2007).

- Requiring demonstration/certification of adherence to other BMPs. East Bay also requires dentists to self certify adherence to BMPs (EBMUD, 2007).

- Collecting customer information from amalgam separator vendors (many manufacturers keep track for maintenance, parts replacement, and mercury recycling programs offered to their customers). King County contact amalgam separator vendors to obtain customer lists to evaluate participation rates for its voluntary program (KCWTD, 2007).

Table 4-9 presents more specific examples of how mandatory programs have monitored compliance in state and local mercury control programs.

Table 4-9. Compliance Requirements from State and Local Mandatory Programs

Element	Examples from State Programs	Examples from Local Programs
Method for demonstrating compliance	Submit separator certification to state environmental agency (CT, MA, ME, NJ).	Provide certification for separator (East Bay, Palo Alto, Madison, Milwaukee).
	Provide certification of compliance with BMPs (CT, MA, NH, NJ).	Provide certification of compliance with BMPs (East Bay, Palo Alto, NE Ohio, Madison, Milwaukee).
	Maintain maintenance and servicing records and be able to provide upon request (CT, ME).	Provide documentation of mercury waste hauling (East Bay, Palo Alto, NE Ohio).
	Provide written notice of method of disposing of mercury removed by the separator (ME).	
Compliance tracking	DEP inspections (CT).	Enforcement protocol including notice of violation, compliance schedule, and penalties for noncompliance (King County).
	Web form for providing proof of compliance (RI).	Inspections performed by local POTW (East Bay, Palo Alto, Madison, Milwaukee).

Sources: EBMUD, 2005; KCWTD, 2007; MMSD, 2008; NEORSD, 2007; Palo Alto, 2007; Walsh, 2007).

Finally, according to NACWA**,** sampling will be needed on a regular basis over a longer period of time to provide necessary trend information. This is because mercury concentrations will likely decrease slowly. For example, sewer cleaning may affect mercury concentrations, and there may be mercury deposits accumulated in the dental facility piping (NACWA, 2007a). Tracking the change in mercury concentration in the influent, effluent, and biosolids have been used to monitor mercury reductions and evaluate program success. East Bay determined that mercury levels in its influent decreased 78 percent from 1998 to 2006 and 96 percent of permitted dental facilities have installed separators (EBMUD, 2007). King County's biosolids data showed a 50 percent decrease in mercury from 2000 to 2006 (King County, 2008).

5. EFFECTIVENESS AND COSTS OF DENTAL BMPS, INCLUDING AMALGAM SEPARATORS

This section discusses the effectiveness and costs of reducing dental wastewater mercury discharges by implementing BMPs, including amalgam separators, at dental facilities. It also presents several case studies on influent and effluent POTW mercury concentrations following implementation of dental BMPs.

The remainder of this section is organized into the following subsections:

- Section 5.1 discusses standards and treatment efficiencies for amalgam separators;
- Section 5.2 presents case studies designed to demonstrate the impact of BMPs, including amalgam separators, on mercury levels in wastewater; and
- Section 5.3 discusses costs of dental BMPs.

5.1 Treatment Efficiencies and Standards for Amalgam Separators

All BMPs, including chair-side traps and vacuum filters, can reduce amalgam discharges. The use of amalgam separators as a BMP is intended to further reduce amalgam discharges. The configuration, office size, and operation of the dental office can significantly affect the choice of separator. The choice can also be affected by the operation and maintenance requirements of the selected amalgam separator. The following section describes standards for amalgam separators and separator treatment efficiencies.

5.1.1 Standards for Amalgam Separators

Two standards are used to evaluate treatment efficiencies of amalgam separators:

- The International Organization for Standardization (ISO) Standard 11143 and
- The U.S. Environmental Protection Agency's Environmental Technologies Verification (ETV) program.

ISO Standard 11143

The standard by which separators are most commonly evaluated is ISO Standard 11143 for Amalgam Separators. This standard requires that an amalgam separator remove at least 95 percent of amalgam particles by weight when subjected to a specific test method as specified in the Standard. The ISO test for removal efficiency uses 10.00 grams of amalgam particles that are composed of three portions of different sizes (ISO, 1999):

- 60 percent of the particles are 3.15 millimeters or smaller and larger than 0.5 mm;
- 10 percent of the particles are 0.5 mm or smaller and larger than 0.1 mm; and
- 30 percent of the particles are 0.1 mm or smaller.

It is important to note that certification under this Standard is based not on total mercury concentration in effluent wastewater, but on particle removal. To test the efficiency of an amalgam separator, a slurry of water and amalgam is poured into the amalgam separator and effluent water is collected. This effluent wastewater is filtered through a series of pre-weighted filters, the filters are dried and weighed, and the final weight of the filters is then compared

against the original weight (Batchu et al., 2006). By this method, an ISO Standard 11143–compliant amalgam separator will remove at least 95 percent, or 9.5 grams, of amalgam particles during laboratory testing.

EPA/ETV Standard

The EPA/ETV program has developed a standard more rigorous than ISO 11143. The EPA/ETV standard, "Protocol for the Verification of Hg Amalgam Removal Technologies," uses a concentration-based criterion and measures efficiency as a function of mercury concentration as opposed to particulate removal (NSF, 2001). EPA/ETV protocol recommends using Standard Methods 3500-Hg for sample collection, preservation, analysis, and storage. Standard Methods 3500-Hg, is a cold vapor atomic absorption method for determining the concentration on mercury in potable water (APHA, 1998). The EPA/ETV standard protocol is not used nearly as widely as the ISO Standard likely due to a larger cost and time required for analyzing samples for the mercury content. See: http://www.epa.gov/etv/pubs/04_vp_mercury.pdf

5.1.2 Treatment Efficiencies

Studies have demonstrated the ability of amalgam separators to significantly reduce the amount of mercury amalgam in dental office wastewater.

- A 1998 study tested three commercially available amalgam separators that used different separation technologies including gravity settling, settling/filtration, and mechanical centrifuge. The mercury removal efficiencies for the three technologies ranged from 95 to 99.9 percent. However, the study also noted that an effluent concentration of 0.2 parts per million could not be consistently met without chemical treatment (Boston University, 1998).

- A 2001 study found that amalgam separators were able to remove 91 to 99 percent of amalgam particles, with an average removal efficiency of 95 percent (MCES, 2001).

- EPA Region 8 has reported that a properly installed amalgam separator will achieve removal efficiencies ranging from 95 to 99.99 percent of particulate mercury (EPA, 2005).

In dental offices, amalgam separators are commonly used in conjunction with chair-side traps and vacuum pump filters. Most chair-side traps can filter particles as small as 0.7 mm and vacuum filter traps can capture particles as small as 0.4 mm, resulting in a combined removal rate of 40 to 80 percent of amalgam particles. When chair-side traps and vacuum pump filters are used upstream of amalgam separators, the combined treatment system can achieve removal rates exceeding 99 percent (Fan et al., 2002).

Table 5-1 provides a non-inclusive list of 28 commercially available amalgam separators, including manufacturer name, the type of particulate separation technologies used, and the amalgam removal efficiency based on ISO testing in a laboratory setting.[2] As illustrated, all

[2] Mention of product and vendor names does not constitute an endorsement by EPA.

separators exceeded the ISO Standard of 95 percent efficiency, 25 separators exceeded 97 percent efficiency, and 15 separators exceeded 99 percent efficiency of amalgam particle removal. The separators described in Table 5-1 achieved an average efficiency of 98.94 percent and a median efficiency of 98.7 percent.

Table 5-1. Effectiveness of Amalgam Separators

Model	Manufacturer	Treatment Technology	Percentage of Amalgam Removal Efficiency [d]
A 1000 [b]	Air Techniques	Sedimentation	96.22% [c]
A 1300 [a]	Air Techniques	Sedimentation	99.27%
Amalgam Boss [a]	Hygenitek	Sedimentation, filtration, ion exchange	99.17%
Amalgam Collector [a]	R & D Services	Sedimentation	99.40%
ARU-10 [e]	Hygenitek	Sedimentation, filtration, ion Exchange	99.99%
Asdex [b]	Avprox	Filtration	99.23% [c]
Avprox AS-9 [e]	American Dental Accessories	Sedimentation, filtration	95%–99%
BullfroHg [b]	DRNA Dental Recycling	Sedimentation, filtration	99.13% [c]
BullfroHg [e]	Dental Recycling North America	Sedimentation	98.3%–99.6%
Durr 7800/7801 [b]	Air Techniques	Centrifugation	97.86% [c]
ECO II [a]	Pure Water Development	Sedimentation	97.05%
Guardian Amalgam Collector [e]	Air Techniques	Sedimentation	>95%
Hg Separator [e]	SolmeteX	Sedimentation, filtration, ion exchange	>98%
Hg5 [a]	SolmeteX	Sedimentation, filtration, ion exchange	98.53%
Hg5 with Effluent Flow Restrictor [a]	SolmeteX	Sedimentation, filtration, ion exchange	98.03%
Hg5 HV [a]	SolmeteX	Sedimentation, filtration, ion exchange	98.88%
Hg10 [b]	SolmeteX	Sedimentation, filtration, ion exchange	99.99% [c]
Merc II [a]	Bio-Sym Medical	Sedimentation, filtration, ion exchange	98.06%
MRU [b]	DRNA Dental Recycling	Sedimentation, filtration, ion exchange	99.96% [c]
MRU 10c [a]	DRNA/ADA Technologies	Sedimentation, filtration, ion exchange	99.97%
MSS 1000 [a]	Maximum Separation Systems	Sedimentation, filtration	99.54%
MSS 2000 [b]	Maximum Separation Systems	Sedimentation, filtration	99.3% [c]
Purevac Hg [a]	Sultan Healthcare	Sedimentation	99.91%

Table 5-1. Effectiveness of Amalgam Separators

Model	Manufacturer	Treatment Technology	Percentage of Amalgam Removal Efficiency [d]
Rasch 890-1000 [a]	AB Dental Trends	Sedimentation, filtration, ion exchange	98.94% [c]
Rasch 890-4000 [b]	AB Dental Trends	Sedimentation, filtration, ion exchange	99.92% [c]
Rasch 890-6000 [a]	AB Dental Trends	Sedimentation, filtration, ion exchange	98.31% [c]
REB [e]	Rebec Simple Solutions	Sedimentation	96.90%
RME 2000 [b]	Rebec	Sedimentation	99.67% [c]
Average			**98.7%**

a — Results according to Batchu et al., 2006.
b — Results according to Fan et al., 2002.
c — Percentage of amalgam removal efficiency is calculated as the average of mean efficiency of empty separator and mean efficiency of full separator.
d — This efficiency is based on the percentage of mercury in the form of dental amalgam removed by weight, as instructed in ISO Standard 11143.
e — Results according to McManus and Fan, 2003.

As listed in Table 5-1, sedimentation, either alone or in conjunction with filtration and/or ion exchange, is used in the majority of amalgam separators. The high specific gravity of amalgam causes it to settle readily from suspension in water which allows the dental wastewater to be effectively treated by sedimentation (Fan et al., 2002). Although none of the separators listed in Table 5-1 used added chemicals, chemical and polymer additions can enhance sedimentation treatment and have demonstrated effectiveness in precipitating at least some portion of dissolved mercury out of dental wastewater. Some amalgam separator systems incorporate ion-exchange to remove dissolved mercury.

5.2 Impacts of Dental BMPs, Including Amalgam Separators, on POTW Influent

This subsection summarizes case studies demonstrating the impact of BMPs, including amalgam separators, on dental mercury discharges to POTWs. Most case studies show a decrease in the amount of mercury discharged to POTWs following installation of amalgam separators in dental offices. However, it is difficult to predict with any certainty the impact on POTW influent of the use of amalgam separators due, in part, to other mercury sources at POTWs. Also, other dental BMPS implemented at the same time as amalgam separators reduce mercury discharges to POTWs.

5.2.1 Summary of Dental BMPs

Most state and local BMPs for dental facilities are based on the ADA BMPs developed in 2003. Additionally, some municipalities require dental facilities to implement BMPs, while others have introduced voluntary BMP programs. Section 4 describes mandatory and voluntary programs.

To manage and recycle dental amalgam waste, ADA BMPs (ADA, 2007a) include the following:

- Using precapsulated alloys and stocking a variety of capsule sizes;
- Recycling used disposable amalgam capsules;
- Salvaging, storing and recycling non-contact amalgam;
- Salvaging (contact) amalgam pieces from restorations after removal and recycling the amalgam waste;
- Using chair-side traps, vacuum pump filters and amalgam separators to retain amalgam and recycle their contents;
- Recycling teeth that contain amalgam restorations;
- Managing amalgam waste through recycling as much as possible; and
- Not using bleach or chlorine-containing cleaners to flush wastewater lines.

Using bleach or chlorine-containing cleaners can mobilize mercury from amalgam that has settled in plumbing fixtures and potentially cause the dissolution of mercury from amalgam waste (EPA, 2003 and Batchu et al, 2006a). Also, some BMPs encourage dentists to use approved suction line cleaners instead of oxidizing cleaners. Some BMPs recommend avoiding the use of heat to disinfect teeth or other items that contain amalgam to minimize air releases of mercury.

5.2.2 Summary of Case Studies

Table 5-2 summarizes dental BMP effectiveness on mercury discharged to POTWs, based on several studies. The City of Corvallis, OR, believes that the implementation of BMPs is highly effective in reducing the daily mass load of mercury in the influent to the Corvallis Wastewater Reclamation Plant (Lamperti, 2007). However, a study conducted by the National Association of Clean Water Agencies (NACWA) from 2003 to 2006 concluded that influent mercury loads at POTWs were highly variable. As a result, it was difficult to collect a representative sample. Although reductions were observed for some of the POTWs included in the study, NACWA concluded that the ability of POTW influent mercury loads to measure the impact of mercury control technologies at dental offices is limited (NACWA, 2007a).

5.2.3 Considerations for Determining Impacts of BMPs on POTW Influent Mercury Levels

Although most of these studies show mercury reductions in POTW influent following the introduction of BMPs in dental offices, some studies show an increase in mercury concentrations. Thus, it is apparent that other factors can influence mercury levels and the measure of BMP effectiveness. As a result, there is uncertainty about the effectiveness of BMPs at reducing mercury at POTWs. Therefore, a POTW cannot predict with certainty that amalgam separators will decrease mercury concentrations in the influent wastewater without also exploring the other potential contributors (NACWA, 2007b). The following are examples of additional criteria that affected the mercury levels in the NACWA 2007 case studies.

- Many programs are voluntary, making BMP participation rates hard to determine.

- Dental offices are not the only source of mercury to POTWs. The next largest sources are domestic sources (human waste, household products, and laundry graywater) and hospitals (AMSA, 2002).

Table 5-2. Impact of BMPs on Mercury Discharged to POTW

BMP Program	Description	Percent of Dentists Using Amalgam Separators		Percent Mercury Load Reduction	Source
		Before Program	After Program		
California Dental Association	Voluntary installation of amalgam separators.	No information	No information	78% of amalgam to POTW	Condrin. 2004
Corvallis, OR	Voluntary installation of amalgam separators.	No information	No information	79% of POTW influent	Lamperti, 2007
Springfield, MO	BMP outreach program.	No information	No information	34% of POTW influent A [a]	MU Extension, 2007
Springfield, MO	BMP outreach program	No information	No information	96% of POTW Influent B [b]	MU Extension, 2007
Madison, WI	Voluntary installation of amalgam separators.	No information	22% (as of 2005)	No trend in POTW influent	Walsh, 2007
EBMUD	Required installation of amalgam separators.	No information	96%	No trend in POTW influent	Walsh, 2007
Wichita, KS	Voluntary installation of amalgam separators.	60%	99%	No trend in POTW influent	Walsh, 2007
Milwaukee, WI	Required installation of amalgam separators.	No information	No information	Decrease in POTW influent	Walsh, 2007
Duluth, MN	St. Louis River Beneficiary Group provided a grant to purchase amalgam separators for all offices.	No information	100%	Decrease in POTW sludge	Walsh, 2007
Palo Alto, CA	Required installation of amalgam separators.	No information	96%	No trend in POTW influent	Walsh, 2007
Narragansett Bay, RI	Voluntary installation of amalgam separators.	No information	No information	No trend in POTW influent	Walsh, 2007
MCES — Metropolitan Wastewater Treatment Plant	Voluntary installation of amalgam separators.	No information	No information	50.6% of POTW influent	Nelson, 2007
MCES — Hastings Wastewater Treatment Plant	Community-wide study. MCES established a baseline, installed the amalgam separators at dental offices, conducted sampling, and then removed the amalgam separators.	0%	100% (6 facilities total)	44% of POTW influent	Nelson, 2007

Table 5-2. Impact of BMPs on Mercury Discharged to POTW

BMP Program	Description	Percent of Dentists Using Amalgam Separators		Percent Mercury Load Reduction	Source
		Before Program	After Program		
MCES — Cottage Grove Wastewater Treatment Plant	Community-wide study. MCES established a baseline, installed the amalgam separators at dental offices, conducted sampling, and then removed the amalgam separators.	0%	87.5% (7 out of 8 facilities)	29% of POTW influent	Nelson, 2007
King County, WA	Voluntary installation of amalgam separators and mandatory implementation of BMPs.	No information	95%	50% of POTW biosolids (concentration-basis)	King County, 2008
POTW "A"	Required facilities to either install amalgam separators or demonstrate compliance with a mercury limit of 0.005 ppm.	0%	100%	No trend in POTW influent	NACWA, 2007a
POTW "B"	Mandatory BMP program began in 2002. Installation of amalgam separators was not required.	5%	9% (out of 219 facilities)	56.4% of POTW influent	NACWA, 2007a
POTW "C"	BMP program began in 2002. Some BMPs were mandatory. Installation of amalgam separators was voluntary.	6%	6% (out of 18 facilities)	43% of POTW influent	NACWA, 2007a
POTWs "D" and "E"	Program required implementation of BMPs by 2004 and installation of amalgam separators by 2008.	0.6%	38% (total number of facilities unknown)	60.5% of influent to POTW "D"; 22.0% of influent to POTW "E"	NACWA, 2007a
POTW "F"	Voluntary amalgam separator program began in 1997.	0%	20% (total number of facilities unknown)	38.0% of POTW influent	NACWA, 2007a
POTW "G"	Voluntary installation of amalgam separators.	44%	100% (100 facilities total)	90% increase to POTW influent	NACWA, 2007a
POTW "H"	Voluntary amalgam separator program began in 2002.	60%	98% (out of ~200 facilities)	No trend in POTW influent	NACWA, 2007a
POTW "I"	Mandatory amalgam separator program began in 2001.	94%	98% (total number of facilities unknown)	27.5% of POTW influent	NACWA, 2007a
POTWs "J" and "K"	Mandatory program required dentists to meet a limit of 0.2 mg/L by July 2003.	94%	98% (total number of facilities unknown)	8.9% increase to POTW "J"; 44.1% reduction to POTW "K"	NACWA, 2007a

Table 5-2. Impact of BMPs on Mercury Discharged to POTW

BMP Program	Description	Percent of Dentists Using Amalgam Separators		Percent Mercury Load Reduction	Source
		Before Program	After Program		
POTW "L"	POTW recommends installation of amalgam separators to dentists.	No information	11% (total number of facilities unknown)	50.6% of POTW influent	NACWA, 2007a

a — Northwest Treatment Plant.
b — Southwest Treatment Plant.

- The time required to flush accumulated amalgam particles from the collection system is not known.

- The time needed for mercury reductions at POTWs to be measurable after BMPs are implemented is not known.

5.3 Costs of Dental BMPs

The cost of a BMP program includes costs to state and local agencies to implement the program and costs to individual dental facilities to participate. The costs to local agencies include development of the program and costs for outreach to dentists. Depending on the program, the costs to individual dental offices will generally encompass purchasing, installing, and maintaining an amalgam separator; recycling the collected amalgam; and other costs, such as time spent educating their employees. The California Dental Association indicates that "the numerical cost of BMP implementation is low" (Condrin, 2004), and according to Bates, BMPs would cost approximately $300 per facility per year if implemented in New Jersey (Bates, 2006).

5.3.1 BMP Program Costs to State and Local Agencies

Table 5-3 shows the costs of several pollution prevention program elements estimated by AMSA and the Oregon Association of Clean Water Agencies (ACWA). These cost estimates are based on the cost of pollution prevention programs and the cost to develop pollution prevention programs in the past. All the pollution prevention/voluntary programs presented in Table 5-3 addressed only dentists.

Table 5-3. Cost of BMP Program to State and Local Agencies

Program	Description	Total Cost ($2008)	Number of Participants	Source
San Francisco, CA	Brochure/fact sheets + distribution	$80,600	900	AMSA, 2002
San Francisco, CA	Site visits	$16,100	35 visits	AMSA, 2002
Palo Alto, CA	Brochure/fact sheets + distribution	$16,100	500	AMSA, 2002
Palo Alto, CA	Outreach/advisory group	$13,400	500	AMSA, 2002
Western Lake Superior District, MN	Outreach	$40,300	100	AMSA, 2002
Salem, OR	Staff labor	$8,330	109	ACWA, 2007
Salem, OR	Inspection or other form of contact	$4,880	109	ACWA, 2007
Oregon State	All costs in 2004	$3,950	53	ACWA, 2007
Oregon State	All costs in 2005	$1,420	26	ACWA, 2007
Oregon State	All costs in 2006	$6,380	36	ACWA, 2007

5.3.2 Costs to Facilities

The major costs to dental offices for implementing mandatory or voluntary BMP programs are the costs to purchase and maintain an amalgam separator and the costs to collect and recycle amalgam waste. This subsection describes these costs.

Amalgam Separator Costs

Most BMP programs recommend, if not require, dental offices to install amalgam separators. Dentists have three options for obtaining amalgam separators:

- Purchase the unit and maintain it themselves;
- Purchase the unit and contract a company to maintain it; or
- Lease the unit, with maintenance service inclusive in the fee.

Amalgam separator life-cycle costs can include (PACE, 2007):

- Purchase or lease cost;
- Installation cost;
- Additional equipment costs;
- Maintenance costs;
- Replacement cost;
- Shipping costs; and
- Recycling costs.

Manufacturer suggested retail prices (MSRP) range from $215 to $7,450 (depending on the size of the dental office), and certain models can be installed and operated under lease arrangements for $39 to $100 per month. Table 5-4 provides a summary of costs of commercially available amalgam separator systems (non-inclusive), including specific operating and maintenance costs for each model in 2008 dollars.[3]

To verify the manufacturer estimates in Table 5-4, Table 5-5 presents amalgam separator purchase, installation, operation, and maintenance costs from information provided in other studies.

[3] Mention of product and vendor names does not constitute an endorsement by EPA.

Table 5-4. Cost of Purchasing, Operating and Maintaining Amalgam Separators ($2008) [a]

Model	Manufacturer	MSRP	Maintenance	Replacement Parts	Recycling?	First Year Cost	Other Year Costs
A1000	Air Techniques	$1,010	Replace collecting containers every 6 months	Filter: $672	Not included	$1,010	$672
A110	Air Techniques	$2,020	Replace collecting containers every 6 months	Replacement kit: $1,010	Included	$2,020	$1,010
A1200	Air Techniques	$2,020	Replace collecting containers every 6 months	Replacement kit: $1,010	Included	$2,020	$1,010
A1300	Air Techniques	$4,030	Replace collecting containers every 6 months	Replacement kit: $1,010	Included	$4,030	$1,010
A1400	Air Techniques	$4,340	Replace collecting containers every 6 months	Replacement kit: $1,010	Included	$4,340	$1,010
Amalgam Collector	R & D Services	$470–$1,680	Conduct weekly maintenance and decant treated wastewater Replace unit every 9 to 12 months Sludge removal every 2 to 5 years	Unknown	Not included	$470–$1,680	Unknown
ARU-10	Hygenitek	$671–$928 Lease: $52/mo	Replace canister every 6 months Replace sedimentation tank every 6–24 months	Filter canister: $133–$202 Sedimentation tank: $79–$101	Included	$977–$1,380	$306–$605
Avprox Asdex	American Dental Accessories	$289	Replace canister every 4–6 weeks	Canister: $47	Not included	$697–$901	$408–$612
Avprox AS-9	American Dental Accessories	$309	Replace filter every 3–8 months	Filter: $106	Not included	$468–$734	$159–$425
BullfroHg	Dental Recycling North America	Purchase: $934 Lease: $134/mo (2-year minimum)	Replace separator annually	Unknown Included in lease	$605 / year	$1,540	$605
Catch Hg 400 Series	Rebec	$1,320	Annual recycling required	Annual recycling: $531	Included	$1,860	$531

Table 5-4. Cost of Purchasing, Operating and Maintaining Amalgam Separators ($2008) [a]

Model	Manufacturer	MSRP	Maintenance	Replacement Parts	Recycling?	First Year Cost	Other Year Costs
Catch Hg 1000 Series	Rebec	$2,550–$4,030	Annual recycling required	Annual recycling: $531–$665	Included	$3,080–$4,690	$531–$665
Durr System 7800/7801	Air Techniques	$5,380	Replace cassette once per year	Cassette: $128	Included	$5,380	$128
ECO II	Pure Water Development	Purchase: $739 Lease: $73/mo	Apply recommended cleanser daily Replace separator annually	Cleanser: $101 Replacements are included under the lease	Included	$840	$101
Guardian Amalgam Collector	Air Techniques	$2,020–$4,380	Replace collection container every 6 to 12 months	Replacement kit: $1010	Included	$2,020–$4,380	$1,010
Hg5	Solmtex	$934 (1–10 chairs)	Replace cartridge every 6 months	Resin cartridge: $202–$370 Filter: $101–$202	Not included	$1,240–$1,510	$605–$1,140
Hg10	Solmtex	$10,010 (>10 chairs)	Replace cartridge every 6 months	Resin cartridge: $202–$370 Filter: $101–$202	Not included	$10,300–$10,590	$605–$1,140
Merc II	Bio-Sym Medical	$1,200–$1,740	Replace unit annually	Replacement unit installation and disposal: $665	Included	$1,200–$1,740	$665
MSS Model 1000	Maximum Separation Systems	$1300–$1,880	Replace settling tank annually	Settling tank: $222 Tank recycling: $249 Cleanser: $101	Not included	$1,300–$1,400	$571
MSS Model 2000	Maximum Separation Systems	$4,030	Replace settling tank annually	Settling tank: $222 Tank recycling: $249 Cleanser: $101	Not included	$4,030	$571
REB 1000	Rebec Simple Solutions	$2,550	Annual recycling required	Replacement parts: $531	Included	$2,550	$531
REB 5000	Rebec Simple Solutions	$2,550	Annual recycling required	Replacement parts: $531	Included	$2,550	$531
REB 7000	Rebec Simple Solutions	$2,550	Annual recycling required	Replacement parts: $665	Included	$2,550	$665
REB 9000	Rebec Simple Solutions	$4,030	Annual recycling required	Replacement parts: $531	Included	$4,030	$531
Rasch 890-1000	AB Dental Trends	$1,600	Replace canister every 12–18 months	Canister: $801	Included	$1,600	$801

Table 5-4. Cost of Purchasing, Operating and Maintaining Amalgam Separators ($2008) [a]

Model	Manufacturer	MSRP	Maintenance	Replacement Parts	Recycling?	First Year Cost	Other Year Costs
Rasch 890-4000	AB Dental Trends	$2,220	Replace canister every 12–18 months	Canister: $1,010	Included	$2,220	$1,008
Rasch 890-6000	AB Dental Trends	$895	Replace canister every 12–18 months	Canister: $801	Included	$895	$801
Average		**$2,320**				**$2,550**	**$657**

Table adapted from EBMUD, 2002 and 2004; McManus and Fan, 2003. Journal of the American Dental Association. Purchasing, Installing and Operating Dental Amalgam Separators. Volume 134, August 2003 (pp. 1054-1059).

Table 5-5. Estimated Purchase, Installation, and O&M Costs of Amalgam Separator ($2008)

Source	Purchase Cost		Installation Cost		O&M Cost	
	Low	High	Low	High	Low	High
Metropolitan Council Environmental Services and the Minnesota Dental Association (MCES, 2001)	$221	$4,840			$415	$691
Association of Metropolitan Sewerage Agencies (AMSA, 2002)	$134	$4,030			$565	$3,230
King County (WA) Department of Natural Resources and Parks (King County, 2005)	$171	$2,280	$228	$571	$228	$799
Palo Alto (CA) Regional Water Quality Control Plant (RWQCP), Amalgam Recovery Program (Palo Alto, 2007)	$181	$2,410	$60	$1,204	$301	$722
Binational Toxics Strategy Mercury Workgroup, Great Lakes National Program Office, U.S. EPA (EPA, 2003)	$393	$3,930	$262	$262		
Vandeven and McGinnis [a] (Vandeven and McGinnis, 2004)	$1,200	$2,410				
Bates (Bates, 2006)					$748	$1,070
U.S. EPA (EPA, 2003)					$98	$983
Journal of the California Dental Association (Condrin, 2004)					$361	$602
(Behm, 2008)	$600	$1,500	$200	$600		
Average [b]	**$283**	**$3,170**	**$188**	**$659**	**$388**	**$1,160**

a — The range of prices includes both the cost of purchase and installation.
b — Does not include Vandeven and McGinnis costs.

A key component in amalgam separator installation costs is labor for plumbers, pipe fitters, and steamfitters. According to the 2006 Occupational Employment and Wage survey and consistent with a MCES study, the mean hourly wage for plumbers, pipe fitters, and steamfitters is $22.03, not including benefits (BLS, 2006a). Based on the studies described above and the average MSRP for separator models included in Table 5-4 ($1,580), a conservative estimate for the cost of purchasing and installing an amalgam separator is about $2,000. Table 5-7 below shows that the average MSRP and annual O&M costs provided by manufacturers in Table 5-4 that fall within the average high- and low-cost range determined in Table 5-5 from nine regional studies.

Table 5-6. Summary of Cost Estimates

Type of Cost	Cost ($2008)
Average cost of purchase (Table 5-4)	$2,320
Average cost of purchase range (Table 5-5)	$283–$3,170
Average annual cost of O&M (Table 5-4)	$657
Average annual cost of O&M range (Table 5-5)	$388–$1,160

Cost of amalgam separators can vary, but are relative to the size of the dental operation. Table 5-7 lists prices based on information gathered by Partners for a Clean Environment (PACE) from manufacturers in September 2005. The number of amalgam separators to be installed depends on the number of chairs in an office and the amalgam separator model. The wastewater flow rate determines how often filters and traps need to be cleaned/replaced (Walsh, 2007). The costs for small dental offices are close to itemized and annual costs estimated in Tables 5-4 and 5-5.

Table 5-7. Estimated Annual Cost for Amalgam Separators by Size of Dental Office ($2008)

	Small (1–4 Chairs)	Medium (5–12 Chairs)	Large (+12 Chairs)
Purchase	$228–$1,370	$760–$2,510	$2,850–$10,000
Installation	$114–$228	$143–$297	$228–$1,140
Maintenance	$0–$228	$0–$228	$0–$228
Replacement	$57–$856	$86–$856	$571–$2,400
Estimated annual cost	$211–$1,073	$293–$1,110	$1,990–$4,630

Source: Walsh, 2007.

5.3.3 Amalgam Recycling

For 11 of the 15 separators examined (see Table 5-4), costs included recycling services and the replacement of used amalgam canisters. This recycling service included either:

- The recycler picking up amalgam waste at dental offices or
- The recycler providing packaging material, shipping labels and shipping manifests to the dentist so they can ship the collected amalgam to the recycler

Annual service and maintenance costs—including recycling—range from $95 to $750 per year. The ADA estimated a conservative (low) cost of using a recycling service to be $450 per year (Walsh, 2007). EPA estimates recycling costs are less than $600 per year (Singer, 2007b).

6. DENTAL MERCURY PASS-THROUGH ANALYSIS

This section describes EPA's analysis of the potential for dental mercury discharges to pass through POTWs. EPA determined the potential for pass-through by comparing the percentage of mercury removed by well-operated POTWs achieving secondary treatment ("baseline discharges") with the percentage of pollutant removed assuming100 percent participation in an amalgam separator program. EPA typically determines pass-through by comparing the baseline discharges with the limits for Best Available Technology Economically Achievable (BAT) for the category. EPA has not set national categorical regulations for the health services industry, however, so BAT limits do not exist for comparison. The following subsections describe EPA's assumptions and calculations for this analysis:

- Section 6.1 presents the number of dentists using amalgam;
- Section 6.2 presents calculations for mercury discharges from amalgam restorations and amalgam removals;
- Section 6.3 summarizes the baseline mercury discharge to POTWs;
- Section 6.4 presents estimates of potential reductions from the installation of amalgam separators;
- Section 6.5 summarizes the annualized costs for amalgam separators; and
- Section 6.6 summarizes the results for the assumed participation rates and associated costs.

6.1 Number of Dentists

This subsection summarizes the data and assumptions that EPA used to estimate the number of dentists in the United States who potentially install or remove amalgam restorations. A 2007 ADA survey reported a total of 163,181 active dentists in the United States in 2004 (ADA, 2007b). Although only a portion of these dentists install amalgam restorations (e.g., a 2005 study by VanDeven and McGuiness estimates that 75 percent of general dentists install amalgam restorations), all dentists have the potential to remove old amalgam when installing new, non-mercury restorations. Therefore EPA assumed that all active general dentists and specialists who work in fields that use amalgam may remove old amalgam fillings. Similarly, it was assumed that all U.S. dental offices (122,918) would be subject to mandatory amalgam separator installation programs because all offices have the potential to discharge mercury from amalgam removals even if they do not install amalgam restorations.

Calculations that use assumptions based on the number of dentists or dental offices include the mass of mercury discharged from amalgam removals and the number of facilities using chair-side traps, vacuum pump filters, and amalgam separators. The mass of mercury discharged from amalgam removals (see Table 6-3) is based on the total number of ***dentists***. For this calculation, EPA used the estimated number of specialists in fields that use amalgam (11,353) and the number of general dentists (129,745) from Table 6-1. To calculate the baseline use of chair-side traps, vacuum pump filters, and amalgam separators (see Table 6-4), EPA used assumptions based on the number of ***dental offices***. For these calculations, EPA used the total number of dental offices (122,918) from Table 6-1.

Table 6-1. Estimate of Total Number of Dentists

Description	Value	Type	Calculation	Source/Notes
Total number of active dentists	162,181	Data	None	ADA, 2007b
Number of general dentists	129,745	Estimation	80% of total dentists	ADA, 2007b
Number of specialists	32,436	Estimation	20% of total dentists	ADA, 2007b
Number of specialists in fields that use amalgam	11,353	Estimation	35% of specialists that work in fields that use amalgam	Vandevin & McGuiness, 2005
Total number of dental facilities	122,918	Data	None	ADA, 2007b

6.2 Mercury Discharge from Amalgam Restorations and Amalgam Removal

This subsection summarizes the calculations used to determine the tons of mercury discharged from amalgam restorations and amalgam removals. Table 6-2 shows detailed calculations used in this analysis to determine the total amount of mercury discharged to POTWs from amalgam restorations.

Table 6-2. Determining the Total Mercury Discharge from Amalgam Restorations

Description	Value	Type	Calculation	Source
Number of total restorations performed in US in 1999	71,000,000	Data	None	Vandeven and McGinnis, 2005
Mercury content of amalgam capsule	450 mg	Data	None	Vandeven and McGinnis, 2005
Amount of mercury used for restoration	340 mg	Data	None	Vandeven and McGinnis, 2005
Amount of mercury disposed of as non-contact scrap amalgam	110 mg	Data	None	Vandeven and McGinnis, 2005
Amount of mercury used per restoration that is discharged to wastewater	31 mg	Estimation	9% of the amount of mercury used for restorations	Vandeven and McGinnis, 2005
Total amount of mercury discharged to wastewater from restorations	**2.40 tons**	**Result**	**Product of number of restorations performed (71,000,000) and amount of mercury used per restoration that is discharged to wastewater (31 mg)**	

Table 6-3 shows detailed calculations used to determine the total amount of mercury discharged to POTWs from amalgam removals.

Table 6-3. Determining the Total Mercury Discharge from Amalgam Removals

Description	Value	Type	Calculation	Source
Total number of removals per general dentist per year	710	Data	None	Vandeven and McGinnis, 2005
Total number of removals per specialist per year	440	Data	None	Vandeven and McGinnis, 2005

Table 6-3. Determining the Total Mercury Discharge from Amalgam Removals

Description	Value	Type	Calculation	Source
Total number of removals by general dentists	92,118,808	Estimation	Product of removals by general dentists (710) and number of general dentists (129,745)	See Table 6-1
Total number of removals by specialists	4,995,175	Estimation	Product of removals by specialist (440) and number of specialists who work in fields that use amalgam (11,353)	See Table 6-1
Total number of removals	97,113,983	Estimation	Sum the number of removals by performed by general dentists and specialists	
Mercury content of amalgam removed	300 mg	Data	None	Vandeven and McGinnis, 2005 [a]
Amount of mercury per removal that is discharged to wastewater	270 mg	Assumption	90% of mercury content of amalgam removed	Vandeven and McGinnis, 2005
Total amount of mercury discharges to wastewater from amalgam removals	**27.4 tons**	**Result**	**Product of amount of mercury per removal that is discharged to wastewater (270 mg) and total number of removals (97,113,983)**	

a — Accounts for decay and deterioration of amalgam filling over time.

According to Tables 6-2 and 6-3, EPA estimates the total mercury mass present in untreated dental wastewater due to both installing and removing amalgam restorations to be **31.3 tons**. This is the mass prior to any removals from chair-side traps, vacuum filters, or amalgam separators.

6.3 Determining Baseline Mercury Discharge to POTWs

This subsection summarizes the calculations used to determine the baseline mercury discharged to POTWs. The mercury discharge is calculated for each group of dental facilities using the same type of amalgam treatment system. For estimation of baseline loads, EPA assumed that some dental facilities already had treatment in place. EPA assumed that 100 percent of dental offices had chair-side traps and that 80 percent of facilities also used vacuum filters. These assumptions are consistent with ADA's analysis (Vandeven and McGinnis, 2005). To estimate the number of dental facilities with amalgam separators installed, EPA used the following assumptions using 2005 census data for the number of dental facilities by state (presented in Table 6-8 located at the end of this section):

- 100 percent of facilities in each state have the potential to remove amalgam fillings from their patients.

- If the state had a mandatory program that required the use of amalgam separators, then 100 percent of the dental offices used amalgam separators.

- If the state had no program, then EPA assumed that 20 percent of the dental offices used amalgam separators. (EPA assumed 20 percent to account for dentists that might have installed an amalgam separator on their own and to account for local amalgam separator programs.)

Table 6-4 describes in detail the calculation used to determine the total baseline mercury discharged to POTWs.

Table 6-4. Determining the Baseline Mercury Discharge to Wastewater

Description	Value	Type	Calculation	Source
Number of facilities using only chair-side traps	24,584	Assumption	20% of all dental facilities use only chair-side traps	Vandeven and McGinnis, 2005
Number of facilities using chair-side traps and vacuum pump filters	49,167	Assumption	40% of dental facilities use only chair-side traps and vacuum pump filters	Vandeven and McGinnis, 2005
Number of facilities using chair-side traps, vacuum pump filters, and amalgam separators	49,167	Assumption	40% of dental facilities use amalgam separators, vacuum pump filters, and chair-side traps	See Table 6-8
Removal efficiency of chair-side trap	0.680	Data	None	Vandeven and McGinnis, 2005
Removal efficiency of chair-side trap + vacuum pump filter	0.810	Data	None	Vandeven and McGinnis, 2005
Removal efficiency of chair-side trap, vacuum pump filter, and amalgam separator	0.991	Data	None	Median of amalgam separator efficiencies in Table 5-1 of Section 5.1
Mercury discharges from facilities using only chair-side traps	2.00 tons	Estimation	Product of the ratio of the number of facilities using only chair-side traps to the total number of facilities; the total estimated mercury discharge; and 68% removal efficiency of chair-side traps	See Table 6-1 and Section 6.2
Mercury discharges from facilities using only chair-side traps and vacuum pump filters	2.38 tons	Estimation	Product of the ratio of the number of facilities using chair-side traps and vacuum pumps to the total number of facilities; the total estimated mercury discharge; and 81% removal efficiency for the vacuum pump and chair-side traps	See Table 6-1 and Section 6.2

Table 6-4. Determining the Baseline Mercury Discharge to Wastewater

Description	Value	Type	Calculation	Source
Mercury discharges from facilities using chair-side traps, vacuum pump filters, and amalgam separators	0.11 tons	Estimation	Product of the ratio of the number of facilities using amalgam separators, chair-side traps and vacuum pumps to the total number of facilities; the total estimated mercury discharge; and 99.1% removal efficiency for the combined treatment system	See Table 6-1 and Section 6.2
Total baseline mercury discharges to POTWs	**4.50 tons**	**Result**	**Sum of mercury discharge from facilities using only chair-side traps (2.00 tons); using chair-side traps and vacuum pump filter (2.38 tons); and using chair-side traps, vacuum pump filters, and amalgam separators (0.11 tons)**	
POTW removal efficiency	0.90	Data	None	Median POTW removal efficiency (EPA, 1982)
Total baseline mercury discharges to receiving streams	**0.45 tons**	**Result**	**Amount of mercury discharged to receiving stream after POTW removal (4.50(1-0.9))**	

6.4 Potential Reduction from Installation of Amalgam Separators

This subsection presents EPA's estimates of the potential mercury reductions due to new installations of amalgam separators. Table 6-5 shows the potential mercury reductions in discharge to POTWs as a result of a mandatory amalgam separator installation programs. This assumes that 100 percent of dental facilities will install amalgam separators.

Table 6-5. Potential Reductions of Mercury to POTWs from Mandatory Installation of Amalgam Separators

Description	Value	Type	Calculation	Source
Total baseline mercury discharges to POTWs for facilities that do not operate amalgam separators	4.38 tons	Estimation	Sum of discharges from facilities that use only chair-side traps (2.00 tons) and vacuum pump filters (2.38 tons)	See Table 6-4
Number of additional facilities that would install 99.2 percent efficiency amalgam separators	73,751	Estimation	Sum of facilities that use only chair-side traps (24,584) and vacuum pump filters (49,167)	See Table 6-4

Table 6-5. Potential Reductions of Mercury to POTWs from Mandatory Installation of Amalgam Separators

Description	Value	Type	Calculation	Source
Mercury discharges after installation of amalgam separators at these facilities	0.175 tons	Estimation	Product of the ratio of the number of facilities that would install amalgam separators to the total number of facilities; the total estimated mercury discharge; and 99.1% removal efficiency for the combined treatment system.	See Table 6-1, Table 6-4, and Section 6.2
Reduction of mercury discharges to POTWs	4.21 tons	Estimation	Difference of baseline mercury discharges to POTWs for facilities that do not operate amalgam separators (4.38 tons) and mercury discharges after installation of amalgam separators (0.175 tons)	
Total mercury discharges to POTWs following mandatory installation of Amalgam Separators	**0.29 tons**	**Result**	**Sum of mercury dischargers after installation of amalgam separators (0.175 tons) and from current facilities using chair-side traps, vacuum pump filters, and amalgam separators (0.11 tons).**	**See Table 6-4**
POTW removal efficiency	0.90	Estimation		Median POTW removal efficiency (EPA, 1982)
Total discharges to receiving stream	**0.029 tons**	**Result**	**Amount of mercury discharged to receiving stream after POTW removal (0.29(1-0.9))**	
Total reductions to receiving stream	**0.421 tons**	**Result**	**Difference of total baseline mercury discharges to receiving stream (0.45 tons) and total discharges to receiving stream (0.029 tons)**	**See Table 6-4**

6.5 Annualized Costs for Amalgam Separators

Table 6-6 summarizes the average annualized cost of installing an amalgam separators based on calculations for the first year of purchase and all subsequent years for the lifetime of the separator.

Table 6-6. Calculation of Cost

Description	Cost ($2008)	Reference
First year cost of amalgam separator unit	$2,550.00	Average cost from Table 5-4
Annual cost for amalgam separator after first year	$657.00	Average cost from Table 5-4
Lifetime of separator (years)	10	Vandeven and McGinnis, 2005
Interest rate	0.07	
Capital recovery factor	0.14	
Annualized capital investment cost	$363.06	
Total annualized cost	**$1,020.06**	

6.6 Summary and Costs

This subsection summarizes the potential reductions in mercury discharges expressed in both tons and toxic-weighted pound equivalents (TWPE). Table 6-7 presents these reductions and the costs of installing amalgam separators to demonstrate the economic impact to the dental industry.

Table 6-7. Summary of Calculations

Calculation	Baseline	100% Amalgam Separator Installation
Tons of mercury discharged to POTW from dental facilities	4.50	0.29
Tons of mercury discharged to surface water [a]	0.45	0.029
Mercury TWPE discharged to surface water (lb-eq)	105,000	6,790
Reduction of mercury discharges to POTWs (tons)	0	4.21
Reduction of mercury discharges to receiving stream (tons)	0	0.421
Reduction of mercury TWPE to receiving stream (lb-eq) [b]	0	98,200
Number of facilities to install amalgam separators [c]	0	73,800
Cost to industry ($2008) (assumes 1 separator per facility)	$0.00	$75,200,000

a — EPA assumed a POTW removal efficiency of 90 percent.
b — Toxic weighting factor for Hg is 117.
c — For baseline, EPA assumed that 122,918 dental facilities in the U.S. c (see Section 6.1) and that 40 percent of these dental facilities use amalgam separators (see Section 6.3).

Table 6-8 presents the 2005 census data used to determine the percent of dental facilities that currently have amalgam separators installed in the United States.

Table 6-8. Number of Dental Facilities and Amalgam Separator Use by State

State	NAICS 621210 Dental Offices	Assumed Percent Operating Amalgam Separators [a]	Estimated Number Operating Amalgam Separators
Alabama	478	0.2	96
Alaska	560	0.2	112
Arizona	263	0.2	53
Arkansas	3,050	0.2	610
California	412	0.2	82
Colorado	1,732	0.2	346
Connecticut [b]	9,017	1	9,017
Delaware	4,546	0.2	909
District of Columbia	5,258	0.2	1,052
Florida	4,357	0.2	871
Georgia	2,334	0.2	467
Hawaii	5,639	0.2	1,128
Idaho	4,353	0.2	871
Illinois	2,023	0.2	405
Indiana	1,922	0.2	384
Iowa	1,077	0.2	215
Kansas	2,153	0.2	431
Kentucky	259	0.2	52
Louisiana	267	0.2	53
Maine [b]	790	1	790
Maryland	1,016	0.2	203
Massachusetts [b]	243	1	243
Michigan	2,483	0.2	497
Minnesota [c]	315	0.85	268
Mississippi	2,845	0.2	569
Missouri	573	0.2	115
Montana	2,720	0.2	544
Nebraska	1,368	0.2	274
Nevada	3,024	0.2	605
New Hampshire [b]	6,733	1	6,733
New Jersey [b]	1,586	1	1,586
New Mexico	2,110	0.2	422
New York [b]	1,417	1	1,417
North Carolina	846	0.2	169
North Dakota	933	0.2	187
Ohio	1,527	0.2	305
Oklahoma	1,325	0.2	265
Oregon [b]	7,597	1	7,597
Pennsylvania	414	0.2	83
Rhode Island [b]	656	1	656
South Carolina	222	0.2	44

Table 6-8. Number of Dental Facilities and Amalgam Separator Use by State

State	NAICS 621210 Dental Offices	Assumed Percent Operating Amalgam Separators [a]	Estimated Number Operating Amalgam Separators
South Dakota	2,366	0.2	473
Tennessee	593	0.2	119
Texas	2,209	0.2	442
Utah	1,418	0.2	284
Vermont [b]	883	1	883
Virginia	3,183	0.2	637
Washington [c]	1,825	0.8	1,460
West Virginia	19,005	0.2	3,801
Wisconsin	307	0.2	61
Wyoming	686	0.2	137
Total U.S.	**122,918**		**49,021**
Percent of Total Dental Offices			**40%**

Source: Census, 2005.

a — Assumes 100 percent compliance with mandatory programs, uses Table 4-7 in Section 4 for state voluntary program participation rates, and assumes 20% for states with no information.

b — State requires amalgam separators.

c — State has voluntary program for installation of amalgam separators with information on participation rates in Section 4.

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