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Regulating Use
Health Impact
Alternatives

Amalgam and Dental Wastewater

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OF THE CALIFORNIA DENTAL ASSOCIATION
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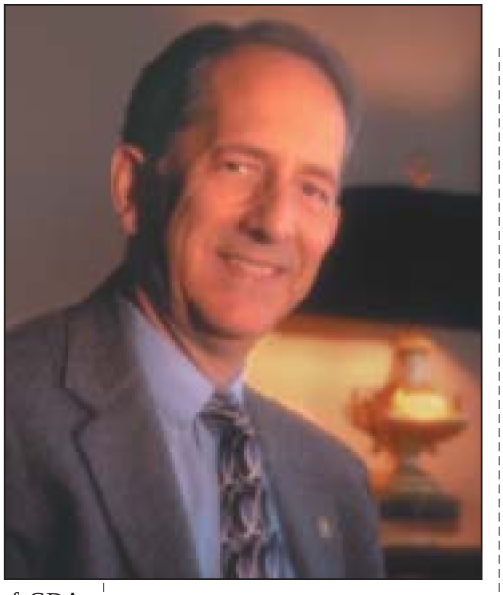
DEPARTMENTS

FEATURES

Jack F. Conley, DDS

A Time of Progress



While listening to the proceedings of the recent California Dental Association Board of Trustees meeting, we came to one inescapable conclusion. The first five months of the 2004 administrative year of CDA have been marked by remarkable progress and achievement.

The day-to-day activities continue, as they always have, to place a priority on providing outstanding membership services to CDA members. For example, not only is there a continuing effort to improve the quality of the educational programs provided at Scientific Sessions, but there have been efforts to improve one hurdle every registrant encounters, the amount of time it has taken, waiting in line, to obtain registration credentials at the meeting. This was a major dissatisfier for a member arriving with little time to spare before attending a C.E. session. This procedure was markedly improved this year. Trustees were also informed that continuing improvements would be made to a new C.E. credit entry procedure for each course that was initiated this year and at times required substantial waiting to access a computer.

Modifications to these Sessions procedures, while relatively minor in importance in the big picture of service to CDA members, nonetheless illustrate the commitment of CDA staff and volunteers to continually improve the quality of service provided to the membership.

However, the most significant achievements have not been directly related to immediate service to members. Rather, many have been part of a growing need for the profession to build its reputation in the communities we serve. While it may not always seem important to the individual member that the association encourage and coordinate programs that improve access to care, dentistry does have an extremely important role to play. If CDA fails to make meaningful contributions to public initiatives in the 21st century, it will fail to fulfill the CDA mission ...*"To be the recognized symbol of excellence in education, advocacy and innovation, serving its members and assisting the dental community in fulfilling their responsibility to the public."*

We previously reported in this space some of the accomplishments of the CDA Foundation. As many members of the association know, the Foundation, as well as TDIC and 1201, entities that were formerly considered "subsidiaries" of CDA, have been integrated into the organizational structure of CDA. Every function in which the Foundation engages is now linked to the association's Strategic Plan and Goals.

The CDA Foundation Mission is *"Improving the health of Californians by promoting total health, disease prevention, risk assessment, and treatment of oral health-related diseases through strategic partnerships with allied organizations." Specific purposes include, "To improve the health of Californians by linking the dental profession to community needs,"* and *"To collaborate with public and private organizations and leverage partner funding, expertise, and knowledge."*

The latter purpose is clarified by one of its long-range goals. *"To be a credible, unbiased health organization working with key philanthropic and private organizations to garner interest and leverage external (non-CDA) financial support for initiatives important to dentistry."* A good example of early success in achieving this goal is the First 5 Oral Health Initiative funding award to the Foundation that was previously mentioned in this column. The $7 million grant is

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designed to provide training and education to dental and medical providers and consumers in the prevention of dental disease in children from birth to age 5.

Another way in which the dental profession will carry out its mission to influence the improvement of oral health care is through collaboration with other organizations. Here again, the CDA Foundation is at the center of an exciting new initiative now underway. A grant application is currently under development to the National Institute of Dental and Craniomandibular Research (NIDCR). It involves the five California dental schools as well as the new dental school in Nevada and the Nevada Dental Association. Referred to as the California/Nevada Clinical Research Collaborative (or Practice-Based Research Network), this will be a significant clinical research project in which California and Nevada dental practitioners (not dental faculty) will engage. The role of schools and faculty will be to provide consultation on project protocols and design.

Whether or not the grant is funded by NIDCR, it will be administered or coordinated by the CDA Foundation. If the NIDCR grant funding does not become available, there remains a strong commitment within the association to develop or leverage other sources of funding in order that this first-of-a-kind clinical research project by the profession can be launched.

The Foundation has made a great deal of progress in a very short time. Based on the accomplishments to date, much more can be expected in the future. While Foundation initiatives and efforts to identify external funding partners are critical, support from within the profession is also vital to their success and to the image of the profession. Thus, support from within the profession is encouraged.

Those who may have been critical of the time-intensive procedures of policy development by traditional standing councils of the association will be pleased to know that the structure of the association, in line with the strategic plan has been changing. Groups of individuals with expertise in the policy areas of concern are now being appointed to make timely decisions. Two task forces are currently in place. One is charged with bringing the Code of Ethics up to contemporary standards and make it more user friendly, and those who have been regularly reading the association publications should be well aware of the issues and concerns confronting the Task Force on Licensure. A Policy Development Council and a Government Affairs Council that will combine and replace five existing councils are under development with final approval to come at the 2004 House of Delegates. An important objective of these groups is to consider important public policy issues in a timely fashion.

The product of the described activities and accomplishments (and many others that would form a list too lengthy to include here) is a membership association that is well positioned "to make a difference" on programs and issues important to dentists and the future of the dental profession here in California. Association structure (and staffing) has been streamlined; there is excellent staff and volunteer leadership, and a good financial support base. Others in the profession outside of California will be watching CDA efforts closely to consider similar initiatives to advance dentistry in their states or districts.

Some volunteer leaders have expressed criticism that the implementation of CDA's Applied Strategic Plan has been slow to kick in. To this observer, recent developments, as well as recent decisions by the Board of Trustees, confirm that a "new" CDA has indeed been launched and that the year 2004 is without question, *a time of progress!* CDA

Groups of individuals with expertise in the policy areas of concern are now being appointed to make timely decisions.

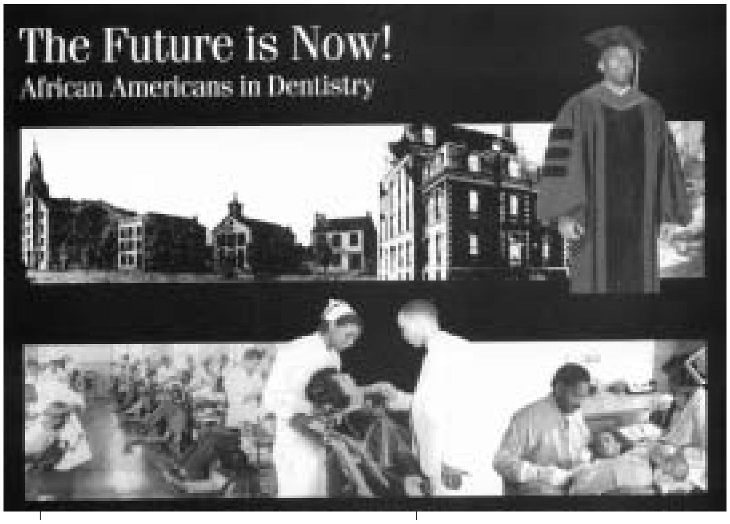
Photos: The National Museum of Dentistry/Collage:Matt Mullin

National Museum of Dentistry Exhibit Comes to California

This summer, California residents won't have to travel far to get a glimpse of an extraordinary exhibit from the Samuel D. Harris National Museum of Dentistry in Baltimore.

Los Angeles is the first stop on a national tour of "The Future is Now! African Americans in Dentistry," a comprehensive exhibit paying tribute to the movers and shakers who paved the way for African Americans' success as dental professionals.

The exhibit, which includes dramatic portraits, moving memoirs and inspirational stories of individual and collective achievement of African Americans in dentistry, will open July 30 at the California African American Museum in Los Angeles. Of particular interest is "Standing on the



Shoulders of Giants" focusing on 10 prominent achievers in the dental field. This section includes an audio component sharing the stories of Clifton O. Dummett, DDS, pre-eminent dental historian and educator, and Jeanne Craig Sinkford, DDS, PhD, the first female dean of a dental school.

Unique to each host city is the "Hometown Heroes" panel designed to highlight local individuals who have made a significant contribution or impact in organized dentistry, dental education, a dental specialty area or service to the dental profession. For the Los Angeles showing, four exceptional leaders will be highlighted: John Alexander Somerville, Vada Watson Somerville, Alva C. Garrott and H. Claude Hudson. *(See historical accounts below.)*

"Through this exhibit, we have been able to forge new relationships and create a learning tool that helps our young people understand the important roles African Americans have played and continue to play in the dental community," said Rosemary Fetter, executive director of the National Museum of Dentistry.

"The Future is Now!" opened in September at the National Museum of Dentistry, which is affiliated with the Smithsonian Institution. During a high-spirited reception, guests enjoyed a book-signing opportunity with Dr. Dummett. His book *NDA II: The Story of America's Second National Dental Association* was used as a source of information for the exhibit.

"Dr. Dummett is credited with the research and documentation of African Americans in dental history," said Scott Swank, DDS, curator of the National Museum of Dentistry. "Until now, there has not been an exhibit that demonstrates such a comprehensive overview of the history of African Americans in dentistry, brought to life in a contemporary museum setting."

The National Museum of Dentistry and the National Dental Association collaborated to bring "The Future is Now!" to regions across the U.S. The mission of the NDA is to continually enhance the skills of its members, recruit under-represented minorities into the profession, and create opportunities for research among its members and the communities they serve. After leaving Los Angeles, the exhibit will continue on to numerous other high-traffic museums and universities. The exhibit is made possible by the generous support of the NDA Foundation in partnership with Colgate-Palmolive and the American Dental Association Foundation.

"Until now, there has not been an exhibit that demonstrates such a comprehensive overview of the history of African Americans in dentistry, brought to life in a contemporary museum setting."

Scott Swank, DDS
Curator of the National Museum of Dentistry

Local Historical Leaders Highlighted in Los Angeles Display

John Alexander Somerville: Civic Leader

John Alexander Somerville, DDS, (1882-1973), was a native of Jamaica. He came to the United States in 1902 in order to obtain an education, which culminated in him becoming the first African American graduate of the University of Southern California College of Dentistry in 1907. By 1913, Dr. Somerville had become a U.S. citizen and assisted in organizing the Los Angeles Chapter of the NAACP. He built an apartment building and hotel so persons of color could more easily secure lodgings in those days of segregation. His civic leadership did not go unnoticed. In 1953, he was awarded the title of Officer of the Order of the British Empire by Queen Elizabeth II.

Photograph, circa 1910, reproduced from: Dummett, C.O. & L.D. Dummett. NDA II: The Story of America's Second National Dental Association. Washington, DC: National Dental Association Foundation, 2000.

Vada Watson Somerville: Social Welfare Leader

Vada Watson Somerville, DDS, (1885-1972), a native Californian, was the first African American woman graduate of the University of Southern California College of Dentistry in 1918. She retired after 12 years of practicing dentistry with her husband John in order to devote her time and energy to social welfare and civic work. Dr. Somerville helped found the Los Angeles Chapter of the National Council of Negro Women and became a vice president of the national organization. She served on the executive board of the Los Angeles League of Women Voters and become the first president of the Los Angeles Chapter of Links, Inc.

Photograph, circa 1920, reproduced from: Dummett, C.O. & L.D. Dummett. NDA II: The Story of America's Second National Dental Association. *Washington, DC: National Dental Association Foundation, 2000.*

Alva C. Garrott: Los Angeles Dental Pioneer

Alva C. Garrott, DDS, (1866-1952), graduated from the Howard University College of Dentistry in 1899. Two years later, he made a bold decision to move west and became the first African American to practice dentistry in Los Angeles. Dr. Garrott became a member of the Chamber of Commerce, served as first president of the Los Angeles Urban League and Director of the Unity Finance Company.

Photograph, circa 1901, Dr. Garrott and family, reproduced from: On the Move for Seven Decades & Still Going Strong. *Los Angeles, CA: Los Angeles Urban League, 1991, Miriam Matthews photo.*

H. Claude Hudson: A Life of Community Service

H. Claude Hudson, DDS, (1886-1989), graduated from the Howard University College of Dentistry in 1913. Born and raised in Louisiana, he returned there to open a dental practice and became the first president of the Shreveport branch of the NAACP. Dr. Hudson moved to Los Angeles in 1923 and established a dental practice. The next year he was elected president of the Los Angeles Branch of the NAACP and held that position for 10 years. Dr. Hudson was thrown into the civil rights struggle by being jailed for swimming at a segregated beach. Understanding the need for a law degree to enhance his fight, he enrolled at Loyola College of Law in Los Angeles and became their first African American graduate in 1931. He co-founded Broadway Federal Savings and Loan to provide loans for minorities, becoming the institution's president in 1949 and holding that position until 1972. Dr. Hudson was instrumental in the fight for fair housing in California through his position on the national board of the NAACP, a position he held until his death. Dr. Hudson received many accolades, awards and honors throughout his life.

Photograph, circa 1960, courtesy of the H. Claude Hudson family.

For more information on the Samuel D. Harris National Museum of Dentistry, visit www.dentalmuseum.org or call (410) 706-0600.

For more information on the California African American Museum, call (213) 744-7432.

"The best way to remove decay-causing plaque and help prevent gum disease is by brushing and cleaning between your teeth every day."

Matt Messina, DDS
ADA consumer adviser

Poll Results: Oral Hygiene Foremost on Patients' Minds

Maintaining good oral hygiene ranked first among patients, according to 32 percent of dentists polled recently in the American Dental Association/Colgate Oral Health Trend Survey.

Tooth decay followed at 28 percent as the next most pressing consideration. Dentists, however, cited lax oral hygiene habits and the most common modifiable risk factor contributing to caries. Third place, at 25 percent, went to periodontal disease. Left untreated, it can result in tooth loss.

"The best way to remove decay-causing plaque and help prevent gum disease is by brushing and cleaning between your teeth every day," said Matt Messina, DDS, ADA consumer adviser. "Brushing your teeth twice a day with fluoride-containing toothpaste, cleaning between your teeth once a day with floss or interdental cleaners and seeing your dentist regularly are essential for good oral hygiene."

Tooth Whitening Tops List

The survey also revealed that tooth whitening was the No. 1 requested procedure (63.7 percent) by patients between the

ages of 40 and 60, according to dentists who were polled. Veneers, bonding or crowns were the second-most requested procedure (58 percent) by baby boomers. Also on the list, periodontal disease treatment ranked third at 55 percent; prevention advice, 35.4 percent; and dental implants, 34.7 percent.

Fastest Growing Segment of Practice

An estimated 27 percent of dentists chose restoring teeth with natural-colored fillings as the fastest growing segment of their practices. Tooth whitening followed with 21 percent.

"Spa" or Office Amenities

Nearly half of those dentists surveyed offer office or spa amenities to patients. Typical items of comfort range from headphones and neck rests to warm towels and free beverages and snacks. Only five percent offer massages, facials, pedicures and manicures.

Additional Survey Results

Ninety-two percent of dentists responded they routinely screen their patients for oral cancer.

Fifty-six percent of dentists said their patients are not adequately concerned about gum disease, followed by oral cancer, 33.7 percent.

Approximately two-thirds of dental professionals have volunteered for community outreach events in the past five years, with the most popular being child-specific oral health programs.

The 12th annual survey, sponsored by Colgate Oral Pharmaceuticals, polled 427 U.S. dentists on general oral care trends at ADA's 144th Annual Session last October.

Programs to Honor Dental Hygienists

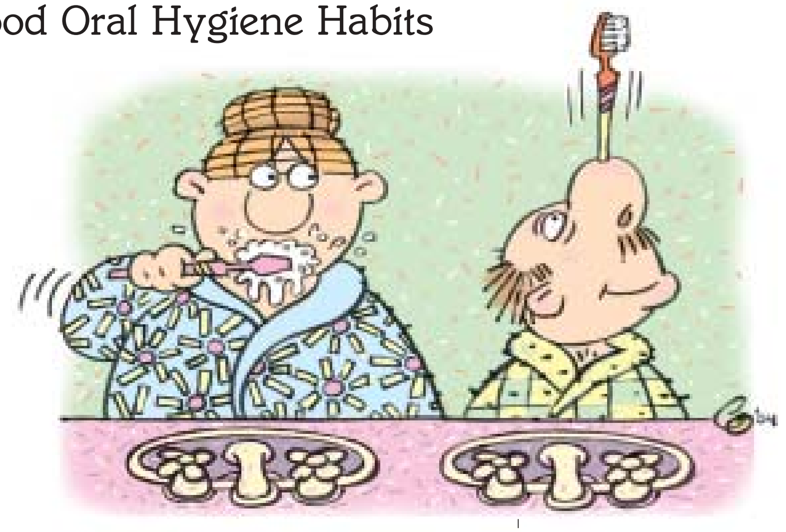
Furthering its commitment to dental hygienists, Oral-B Laboratories, together with the American Dental Hygienists Association, has created three initiatives recognizing the importance of the profession. The programs include broad community outreach, continuing education course and a print ad campaign acknowledging and honoring the dental hygiene community.

The community outreach program, Smiles Within Reach, promotes oral health and encourages professional support, as well as access to oral care education within the community. A recent *Surgeon General's Report on Oral Health*, noted that proper preventative oral health care may reduce the risk of oral cancer, diabetes, heart disease and premature, low-birth weight babies.

A unique educational experience for dental hygienists and the communities in which they work, the outreach program fosters a link between hygienists' invaluable work and the oral health needs of their community.

For more information regarding the Oral-B programs or products, call (800) 44-ORALB or go to www.oralb.com.

Women Outpace Men in Good Oral Hygiene Habits



The results of the recent ADA's *Public Opinion Survey: Oral Health of the U.S. Population* are in: Women are better when it comes to oral health care.

Conducted by Zogby International last December, the survey consisted of telephone interviews with a nationally representative sample of 1,014 adults aged 18 years and older who identified themselves as the head of household.

In the poll, women were more likely than men to brush their teeth following each meal (28.7 percent of women to 20.5 percent of men); or twice a day (56.8 percent to 49 percent). Also revealed: Women are more likely to have a dentist than their counterparts (89.2 percent to 74.6 percent).

American adults recorded an increase among those brushing their teeth twice daily or after each meal, 78 percent in 2003 compared with 75.4 percent in 1997. The most notable jump in brushing frequency occurred in the number of respondents who replied they brushed following every meal, 24.8 percent in 2003, which more than doubled 1997's figure of 11.5 percent.

Using a dental floss or an interdental cleaner every day rose from 48.2 percent in 1997 to 50.5 percent in 2003.

"Being thorough in your daily oral hygiene lays the groundwork for a healthy smile," explains Dr. Kimberly Harms, DDS, ADA consumer adviser. "A daily routine of brushing and flossing, in addition to regular dental checkups, can be enough in most cases to help prevent tooth decay and gum disease."

Save Face — Wear Protective Gear

The American Association of Orthodontics, the American Academy of Pediatric Dentistry and the American Association of Oral and Maxillofacial Surgeons strongly recommend that athletes don protective gear for their faces.

"Oral and facial injuries are a significant public health issue with significant impact, financially and emotionally, on American families," said Daniel M. Laskin, DDS, MS, D.Sc, editor of the *Journal of Oral and Maxillofacial Surgery*.

The dental specialists, which sponsored the fifth annual National Facial Protection Month last April, recently compiled a list of safety tips. Among them:

Wear mouth guards for contact sports: soccer, yes; chess, likely no. Mouth guards may prevent injuries to one's teeth, jaw and mouth. The devices are less costly than recovering from an injury.

Wear protective eyewear. Remember the warning about getting your eye poked out.

Wear a face shield to guard against scratched or bruised skin. Racquetballs, basketballs and hockey pucks can inflict serious damage.

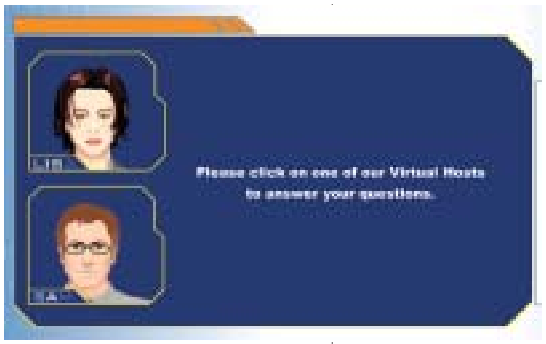
Don a helmet, which absorbs the energy of an impact from a rollerblading or bike accident.

Don't stray from common sense. Gear up if the activity has a remote possibility of injury. Pickup basketballs games have landed numerous players in the emergency room.

Watch out. Alert spectators can avoid injury by being aware of foul baseballs and incoming hockey pucks.

Redesigned Web Site Introduces Animated Guides

Recently re-launching its Web site, 1-800-Dentist added virtual reality guides to assist Internet visitors.



"Lisa," who anticipates and answers questions, guides visitors through the matching process of patient-to-dentist. Once matched, "Sam" takes over introducing the patient to the dentist and informing them of the unique features and benefits particular to that dental office.

"In redesigning the Web site, our objective was to engage the consumer long enough to show how important it is to be "matched" to a dentist rather than selecting a dentist from a list," said Fred Joyal, chief executive officer for 1-800-Dentist.

"It is our comprehensive matching process that differentiates our service from directory listings available on other Web sites."

The Web site, 1800Dentist.com, matches visitors with a pre-screened dentist based on several criteria including geographics, who meets their dental needs, and will accept their preferred method of payment. Additionally, the site provides the dentist's practice hours, philosophy, credentials, years of practice, special treatments offered and technical advances to ensure the patient is comfortable.

All dentists who apply for membership with 1-800-Dentist are meticulously screened and not all are accepted. The company promotes and supports regular dental office visits as part of each consumer's regimen for health care.

Upcoming Meetings

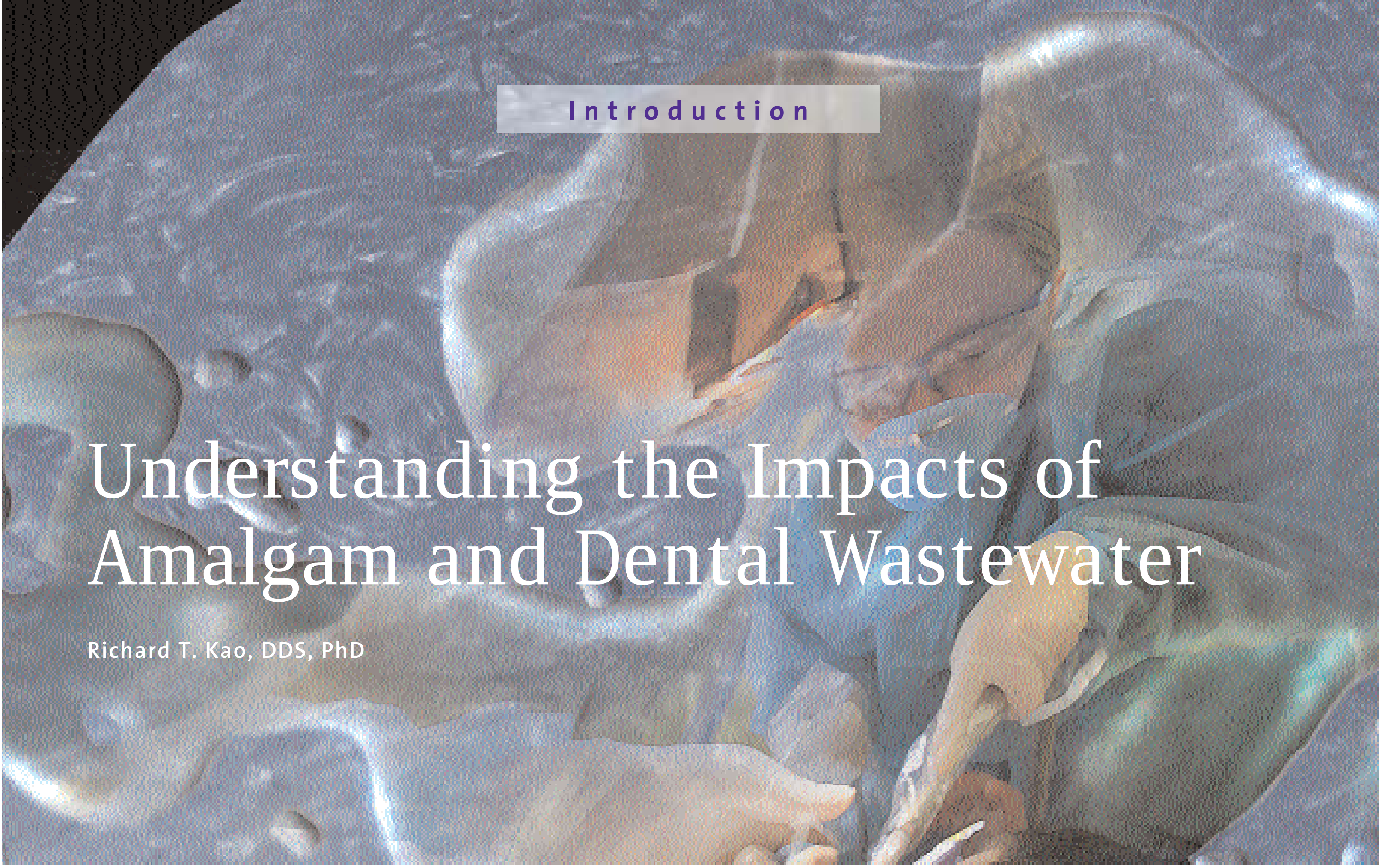
2004

July 7-11	Academy of General Dentistry's 52nd annual meeting, Anaheim, (888) 243-3368, ext. 4339; www.agd.org/annual.meeting/Anaheim/index.html
Aug. 11-14	Fifth annual World Congress of Minimally Invasive Dentistry, San Francisco, (800) 973-8003
Sept. 8-11	International Federation of Endodontic Association's sixth Endodontic World Congress, Brisbane, Queensland, Australia, www.ifea2004.im.com.au.
Sept. 10-12	CDA Fall Scientific Session, San Francisco, (866) CDA-MEMBER (232-6362).
Sept. 29-Oct. 2	American Association of Oral and Maxillofacial Surgeons 86th annual meeting, Scientific Session and Exhibition, San Francisco, www.aaoms.org
Sept. 30-Oct. 3	ADA Annual Session, Orlando, Fla., (312) 440-2500.
Nov. 7-13	U.S. Dental Tennis Association Annual Meeting, Palm Desert, (800) 445-2524, www.dentaltennis.org

2005

April 6-9	Academy of Laser Dentistry 12th annual Conference and Exhibition, New Orleans, (954) 346-3776.
April 12-16	International Dental Show, Cologne, Germany, www.koelnmesse.de

To have an event included on this list of nonprofit association meetings, please send the information to Upcoming Meetings, *CDA Journal,* P.O. Box 13749, Sacramento, CA 95853 or fax the information to (916) 554-5962.



Introduction

Understanding the Impacts of Amalgam and Dental Wastewater

Richard T. Kao, DDS, PhD

Recently, there has been an increasing level of attention given to the sources, environmental behavior, and impacts of mercury in the environment. Though the mercury contained in amalgams is not a major source of mercury release to the environment, the dental profession has been under both public and regulatory scrutiny on the issue of amalgam and dental wastewater.

For dental practitioners, these public sentiments and regulations may be disconcerting, but the realities are that it is important for the practitioners to understand these issues and various options to address these concerns. This edition will address the following issues:

Why has dental amalgam become a wastewater issue? What is the environmental impact of dental amalgam in wastewater? What are the specific concerns regarding our situation here in California? In the first two articles, Thomas Barron and ENVIRON report on both the anthropogenic and natural sources of mercury and its effect on the environment. Of particular interest is ENVIRON's assessment of the impact of mercury contributed due to amalgam use in California and its effect on publicly owned treatment works.

What are the toxicologic concerns regarding mercury? Kao et al. reviews the toxicology of mercury and its impact on health and environment.

Don't environmental regulations have to be based on sound science? Teresa Pichay reviews the regulatory responsibilities for various governmental organizations and the premise by which regulations are developed. This article will provide important insight as to how the interpretations and implementations of environmental laws will impact our dental practices.

Is there anything dental practitioners can do to prepare for possible regulatory activities? Are Best Management Practices (BMP) and amalgam separator approaches effective? And if mandated, are they easy to implement? In the articles by Amy Knepshield Condrin and Mark Stone, the two most popular approaches toward addressing mercury in dental wastewater are reviewed. Ms. Condrin reviews the CDA- and ADA-recommended BMP protocols and discusses practical strategies for how practices should manage dental amalgam waste. In both articles by Condrin and Stone, the use of amalgam separators to reduce the amount of mercury reaching wastewater treatment plans is discussed.

Lastly, if the use of dental amalgam will result in more regulatory mandates, are there any restorative alternatives? Will they work just as well in function and durability? Drs. J.R. Mackert and Michael Wahl address these issues. In an evidence-based discussion, the evaluation of dental amalgams as compared to the various restorative alternatives is reviewed. This article will provide the restorative practitioners a scientific base for discussing the clinical implication in using alternative restorative materials.

As the practice of dentistry becomes more complicated, regulatory and public pressure requires that dental practitioners become more versed on controversial topics. This issue will provide the readership a sound fundamental background on the issue of amalgam and dental wastewater. CDA

Mercury in Our Environment

Thomas Barron, civil engineer

ABSTRACT

Mercury is a very useful metallic element that, while not particularly abundant in nature, can play an important role in the overall health of humans and animals. This article discusses the benefits and toxicological consequences of society's use of mercury. It also will focus upon the mining, processing, and uses of mercury in the United States, and then highlight the amounts of mercury that are released as wastes. Along the way, three important questions are addressed:

- How much mercury is released by human activities and by natural events?
- Do these releases pose a risk either to humans or to the environment in general?
- How does this information apply to dentistry?

Mercury • Hg[1]

- Atomic Number: 80
- Atomic Weight: 200.59
- 68th most abundant element
- Typical Adult Body Load: 6 mg total
- Dietary Intake: 3µg/day (can be more with high fish diet)
- Typical uses: Switches, thermometers, dental amalgam, biocide, disinfectant, religious observance, batteries and laboratory reagents
- Toxic to humans and animals

Mercury has a number of chemical forms, with inorganic salts and other compounds being the most common. Mercury is usually mined from cinnabar, or mercuric sulfide, which may occur either by itself or in association with gold deposits.

Table 1 highlights three common forms of mercury, together with their relative solubilities in water and lipid fats. These solubilities are important because they determine how the mercury compounds move and accumulate within the body of a human who has been exposed.

Mercury Toxicology

Throughout history, humans have used mercury for a number of medical and religious purposes. Since the 1800s, these uses have expanded to include dental amalgam restorations, electrical

Author / Thomas Barron is a civil engineer specializing in environmental and wastewater issues including evaluations of chemicals used in electronics manufacturing, architecture, and building maintenance. He currently is working on a project sponsored by the CDA and the EPA examining potential health, safety and environmental implications of chemicals used in dentistry.

Acknowledgements / This article is the result of projects undertaken by the author for the cities of Palo Alto and San Francisco, Union Sanitary District, and the U.S. Environmental Protection Agency. The author wishes to thank the staff of these agencies for their important contributions to the body of knowledge underlying this article. The opinions and conclusions expressed here are those of the author, and do not necessarily reflect those of any agency.

Mercury has the potential to harm animals and humans exposed to it. However, the risk of actual harm requires that three independent factors occur together.

switches, lamps, thermometers, paints, and process catalysts.

In contrast to its beneficial uses, mercury has the potential to harm animals and humans exposed to it. However, the risk of actual harm requires that three independent factors occur together:

Risk of Harm = Hazard + Exposure + Susceptibility

Hazard is the term for the inherent characteristics that mercury or any other chemical has and the way those characteristics interact with humans or animals. These hazards are different for elemental mercury and the various mercury compounds. Of particular concern is methylmercury, an organic compound with the structural formula CH_3-Hg+ (e.g., dimethylmercury is: CH_3-Hg-CH_3). Methylmercury is toxic in very small amounts with neurologic or teratogenic effects starting when blood levels reach a fraction of a microgram of CH_3-Hg per liter of blood serum (µg/l).

Exposure is a combination of dose (i.e., how much of the chemical is present), duration, and pathway. Three common exposure pathways for humans are: dental amalgam restorations, inhalations by industrial workers, and ingestion by people who eat fish.

Mercury bound in silver amalgam restorations is one obvious form of human exposure, but one that most studies to date suggest is relatively benign. For example, Litvak and her coworkers recently reported that patients with modest numbers of mercury-containing amalgam restorations have an average total mercury level of only 1.7 µg/l in their blood, and that this level does not produce detectable neurologic effects.[3] The Environmental Protection Agency health guidelines suggest that serum mercury levels should be less than 5 µg/l of total Hg for the average adult, and that the daily intake of mercury from all sources be less than 0.1 µg/Kg of body weight.

However, other mercury compounds are volatile. Therefore, workers exposed for long periods to mercury vapor or airborne mercury particles may have more significant exposures. It is interesting to note that the Litvak study mentions observable diminishment of neurologic function in dental workers themselves. The blood mercury levels reported in these workers ranged up to 9 µg/l, nearly twice the EPA health guidelines.

Table 1

Common Mercury Compounds

	Example Forms		
	Mercuric Sulfide (Cinnabar)	**Mercuric Chloride (Calomel)**	**Mercuric Chloride Methylated**
Formula	HgS	$HgCl_2$	CH_3HgCl
Structure	Hg - S	Cl - Hg - Cl	CH_3 - Hg - Cl
Water Solubility	Low	High	Low
Lipid Solubility	Med	Low	High

Sources: Goyer[2]; Emsley[1]

In addition, people who eat significant amounts of large fish (e.g., shark, halibut, and tuna) are reported to have serum mercury levels up to 90 µg/l, leading to the conclusion that the dietary pathway can be particularly significant.[4]

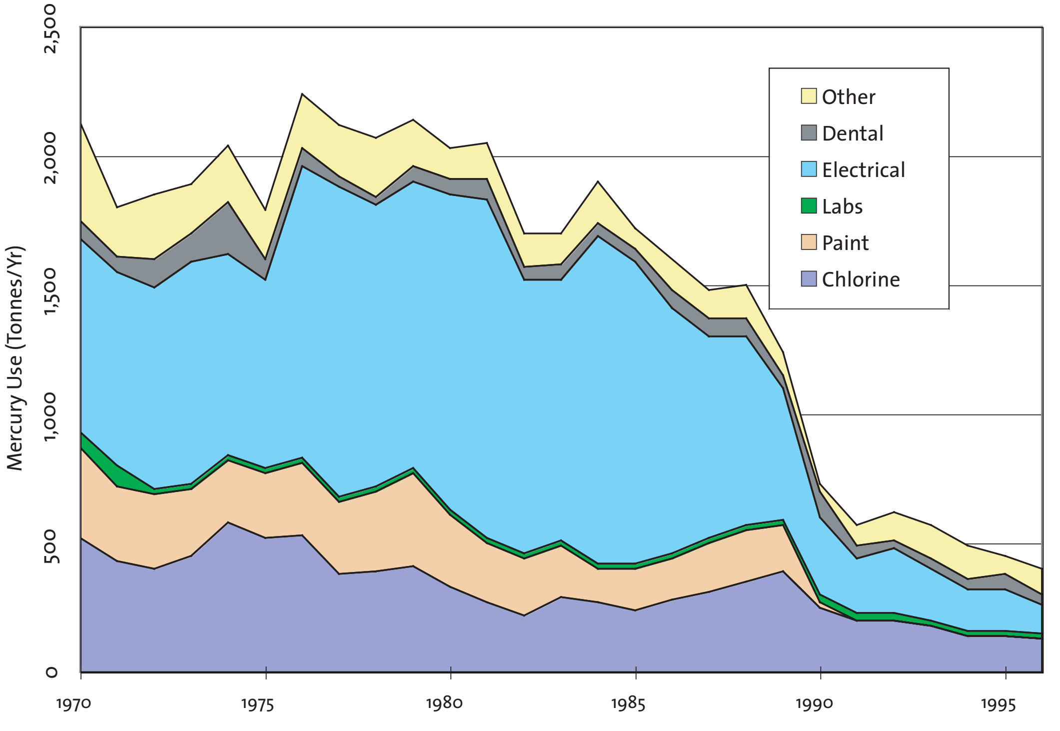
Susceptibility is the tendency of specific individuals or groups to experience the potential hazards presented by the chemicals to which they are exposed. As mentioned before, EPA health guidelines for adult daily intake of mercury from all sources is less than 0.1 µg/Kg of body weight. However, pregnant women, a susceptible population, should work toward a somewhat lower daily intake. Hence, EPA issues fish advisories for Hg in most states.

Human Uses of Mercury

In 1997, about 400 metric tonnes of mercury were ‘consumed’ in the United

Table 2

U.S. Mercury Consumption (1970-1997)



Source: EPA[5] and Sznopek.[6]

States. Approximately one-third of this amount was imported, while the balance was produced by recycling or as a byproduct of gold mining. There are currently no active mercury mines in the United States.

Table 2, obtained from the EPA's 1997 Report to Congress,[5] shows a downward trend in domestic mercury use since 1970. At the start of this period, annual mercury use in the U.S. totaled about 2,000 tonnes (2,200 tons), with the largest applications being batteries, chlorine production, and paints. By 1997, annual mercury use had decreased to just over 400 tonnes (440 tons), with dental amalgam, lighting, and switches each comprising about 10 percent of that total.

Dental Mercury Use

Recent studies published by the American Dental Association[7] indicate there are about 165,000 dentists of all types actively practicing in the United States. General dentists make up the largest subgroup within this total, numbering approximately 120,000.

Most general dentists, as well as an additional 10,000 specialists in pediatrics, prosthodontics, and endodontics, encounter and remove existing amalgam restorations in their patients. In 1999, these professionals are believed to have removed about 92 million amalgams. A somewhat smaller number of dental professionals, perhaps 100,000 in all, also placed new amalgam restorations. Berthold[8] estimates that dentists placed about 70 million amalgam restorations in 1999, compared to 100 million in 1990.

Table 3 summarizes the mercury content of these restorations.

Mercury Releases to the Environment

Our exposure to mercury arises in part from volcanic eruptions and other natural processes. The United Nations Global Mercury Assessment[9] concludes that, once released by these processes, mercury is persistent and cycles globally:

"The most significant releases of mercury pollution are emissions to air, but mercury is also released from various sources directly to water and land. The largest man-made source of mer-

Table 3

Dental Amalgam Restorations in the United States (1999)

Amalgam Removals		**Amalgam Placements**	
No. of Dentists	**130,000**	**No. of Dentists**	**100,000**
Removals/Yr	710 per dentist	Placements/Yr	700 per dentist
	92 million total		70 million total
Hg/Removal	300 mg each	Hg/Placement	450 mg each
Total Hg/Yr	27,600 Kg	Total Hg/Yr	31,500 Kg
	30 tons		35 tons
			8% of U.S. Total

Source: Interpreted by author (from ENVIRON[7]).

cury to the environment is the combustion of fossil fuels, which release Hg found within oil and coal. Once released, mercury persists in the environment where it circulates between air, water, sediments, soil and biota in various forms. Current emissions add to the global pool – mercury that is continuously mobilized, deposited on land and water, and remobilized."

"The form of mercury released varies depending on source type and other factors. The majority of air emissions are in the form of gaseous elemental mercury, which is transported globally to regions far from the emissions source. The remaining emissions are in the form of gaseous inorganic ionic mercury forms, such as mercuric chloride, or bound to emitted particles. These forms have a shorter atmospheric lifetime and will deposit to land or waterbodies within roughly 100 to 1000 kilometers of their source.

Elemental mercury in the atmosphere can undergo transformation into ionic mercury, providing a significant pathway for deposition of emitted elemental mercury."

"Once deposited, the mercury form can change, primarily by microbial metabolism, to methylmercury which has the capacity to collect in organisms (bioaccumulate) and to concentrate up food chains (biomagnify), especially in the aquatic food chain (fish and marine mammals). Methylmercury is therefore the form of greatest concern. Nearly all of the mercury in fish is methylmercury." [Source: UNEP[9]]

The transformations in nature of mercury from one form to another, for example conversions of ionic mercury into methylated mercury, are not fully understood. Nancy Beckvar summarized what is known about these chemical dynamics in the final report of her research project sponsored by the National Oceans and Atmospherics Administration:[10]

"In both freshwater and saltwater environments, mercury is converted from inorganic bivalent mercury (Hg[II]) to methylmercury primarily by microorganisms, although chemical methylation also occurs. Methylmercury production depends on both the availability of Hg[II] for methylation and microbial activity."

"Methylation is usually greatest at the sediment/water interface, but also occurs in the water column. Net methylmercury production is a function of both the rate of methylation and the rate of demethylation. Methylmercury is not readily decomposed so the methylation rate is usually higher than the demethylation rate. Degradation of methylmercury is also primarily a microbial process."

"Methylation is influenced by the availability of Hg[II], oxygen concentration, pH, redox potential (Eh), presence of sulfate and sulfide, type and concentrations of complexing inorganic and organic agents, salinity, and organic carbon." [Source: Beckvar[10]]

Mercury is typically found as an ore, such as cinnabar (HgS), or as a trace ingredient in coal and other hydrocarbons. Processing the ore in a heated retort, using the recovered mercury, and burning fossil fuels are examples of human activities that release this mercury into the air and water around us. In 1995, human-related mercury releases in the United States totaled an estimated 585 tons, with the majority coming from coal-fired boilers and waste incinerators.[6]

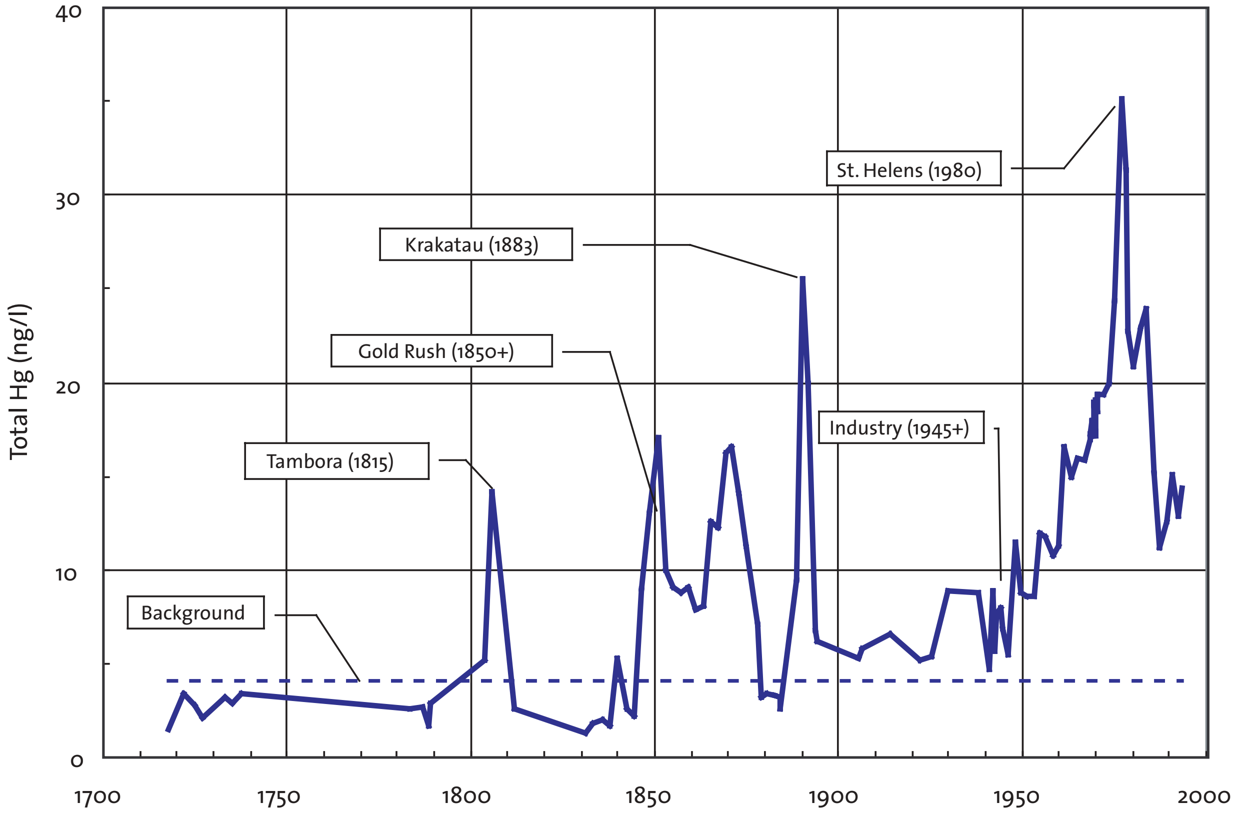
Amounts released to the air can be carried great distances. Therefore, some of our stack emissions reach Europe, while we in turn receive airborne mercury from Asia. The United Nations Environmental Programme estimates that annual worldwide mercury emissions to the air are 2,000 tonnes (2,200 tons), with stationary coal combustors in Asia contributing 40 percent of this total and being by far the largest sources.[9]

Volcanoes, hot springs, and forest fires are natural processes that also release large but not precisely known amounts of mercury. Geophysicists are starting to develop detailed estimates of this natural release. Initial results suggest that mercury released from human activities exceeds that from nature, except for during short-lived natural events such as the 1980 eruption of Mt. Saint Helens in Washington state.

Work by Paul Schuster and other researchers with the U.S. Geological

Table 4

Glacial Ice Mercury Concentrations (1700-2000)



Source: Schuster[13]

Survey give an interesting picture of the relative amounts of mercury released from human and natural sources.[11,12] **Table 4** is a chart of mercury concentrations that Schuster's team measured in boreholes drilled into a glacier in Wyoming. This particular ice deposit has been steadily increasing for about 300 years, making it possible to assign dates to samples obtained from various depths below the surface. These dates appear along the horizontal axis of **Table 4**.

The Wyoming ice deposit reveals that during the past three centuries, sufficient mercury particles landed upon the glacier's surface to leave a background residue of mercury in the ice of about 3.5 nanograms to 4 nanograms per liter (ng/l). Large volcanic eruptions, three of which are noted on the chart, caused yearlong peaks in the mercury concentration that are up to 20 ng/l above this background.

From 1850 to 1880, Schuster's glacier observations show that these natural processes were over-shadowed by the mining and retorting of mercury for the California gold rush and other western mining operations. These historical events added an average of perhaps 5 to 10 ng/l of mercury to the glacial ice that Schuster's team studied, or about twice the natural background. Sediment samples from California rivers and bays show similar peak accumulations of gold rush mercury working its way downstream toward the Pacific Ocean.[14]

The 20th century saw significant industrialization take place in Asia and the western U.S., i.e., upwind of the Wyoming glacier. Power plants, waste boilers, and other industrial processes added from 5 ng/l to 15 ng/l of mercury to the glacial ice from about 1940 onward.

Also significant are the as-yet unexplained decreases that Schuster's chart

Table 5

Estimated Dental Office Mercury Releases to Environment

	Typical Mercury Releases		
	Solid Waste [2]	Sewer Waste [3]	Airborne Waste
Remove One Restoration [1]	210 mg	90 mg	
Place One Restoration [4]	30 mg	15 mg	
Daily Total per Dentist [5]	0.85 g	0.38 g	
Annual Total per Dentist [5]	170 g	75 g	Unknown
Annual Total for United States	20,000± Kg Total [6]	9,000± Kg lost	5,000± Kg lost

[1] One procedure involving a restoration that contains 0.3 grams of Hg.

[2] Optimally sent to a certified mercury recycler.

[3] Sewer waste = amounts swallowed by patient plus amounts discharged via office vacuum system. Vacuum system assumed to not have an amalgam separator unit installed.

[4] Most of the triturated amalgam ends up in the restoration. These estimates are the unused excess plus the amount carved during placement.

[5] Assumes 200 work days per year.

[6] An estimated 75 percent of this total is recycled. The remaining 5,000± Kg/yr is released via the trash or from incinerated medical waste.

Source: Barron[18]; also see **Table 3**; ENVIRON[7], and Sznopek.[6]

reveals in the glacier's mercury levels from about 1990 onward. The author speculates that this downward trend may be from diversion of batteries, lights, thermometers, dental amalgam, and other mercury-containing wastes from municipal and medical incinerators. Alternatively, the decreases are perhaps from air pollution control measures recently installed at coal-fired power plants in states just west of the Wyoming glacier.

Conclusions

How much mercury is released to the environment by human activities and by natural events?

Dental Offices

Table 5 summarizes the author's estimate that 13 tonnes per year of mercury are released by dental offices that remove or place amalgam restorations. Careful attention to collecting this waste amalgam and shipping it to certified mercury recyclers are important steps dental offices should take to mitigate these releases. Details of these mitigating measures are discussed in other articles in this *Journal* (Johnson and Pichay[15]) and in fact sheets issued by the ADA (McManus[16]) and various local governmental agencies (CCSF[17]).

Other Releases

Table 6 shows the author's estimate that 1,350 tonnes of mercury are released each year in the United States from both natural sources and human activities. Worldwide amounts are thought to be perhaps 10 times these domestic levels. Circulation of mercury in the atmosphere is such that part of the releases in Asia reach across the Pacific to the United States, while some fraction of our domestic releases migrate eastward toward Europe.

Do these mercury releases pose a risk either to humans or to the environment in general?

Studies to date show that people in general, including those with modest numbers of amalgam restorations, have blood mercury levels that are below EPA health risk guidelines. However, dental workers and people who eat significant amounts of fish may have much higher levels.[4] Some researchers also report that they see a connection between these high mercury levels and decreased neurologic function.[3]

Regulatory agencies that focus upon water quality issues have determined that human releases of mercury (from both current and historical activities) can pose a significant risk to fish and[19] invertebrates, as well as to birds that feed upon them. These agencies are setting lower regulatory limits upon the

Table 6

Estimated Total Mercury Releases to Environment (1990s)

Source	Tonnes/yr	
Power Plants & Other	160	(1)
Mining & Processing Losses	80	(2)
Dental Restorations — Solid/Medical Waste	5	(3)
— Lost to Sewer	9	(4)
Other Industrial Processes	340	(5)
	594	
Natural Processes	750	(6)
Total Released	1,344	

Notes
(1) Releases in the United States only. Sznopek,[6] Figure 6.

(2) Sznopek,[6] Figure 7.

(3) Loses to either medical or municipal wastes, excluding recycled amounts. Barron;[18] Sznopek,[6] Figure 7.

(4) See Exhibit 5.

(5) Sznopek,[6] Figure 7.

(6) Author's estimate based upon Sznopek,[6] Figure 7, which estimates 1,000 and implication of Schuster,[12] Figure 3, that shows natural Hg is about 40 percent of total airborne Hg.

levels of mercury that businesses, industries, and sewage treatment plants may release into the environment.

In the Great Lakes area, many municipal wastewater treatment plants have received mercury discharge limits in the single parts-per-trillion (ppt) range. These limits are forcing municipalities to review their options for additional controls on all incoming mercury sources.

How Does this Information Apply to Dentistry?

It is suggested that dental professionals follow the various ongoing studies that focus upon potential health impacts of amalgam in patients. So far, the results of published studies appear to be negative. However, as with any area of public concern, it is better to be knowledgeable on the latest developments and prepared for questions that arise.[20,21]

Another issue that deserves careful review is the potential exposure of dental workers to amalgam dust. It is suggested that a close reading be made of both the referenced Litvak study,[3] and other reports of potential mercury impacts upon dental occupational health.

Another important issue relates to the management of amalgam waste materials in the dental office. In California, state regulations designate solid amalgam as a hazardous waste unless it is recycled for the metals that it contains. This regulation applies to all forms of waste amalgam, including non-contact scrap, as well as the residual found in empty capsules, chairside traps, and vacuum system screens. The ADA has published a set of recommended best management practices (BMPs) for managing these materials. These BMPs are intended to keep amalgam waste out of the medical waste and solid waste streams where incineration can release and redistribute mercury great distances.

At the local level, additional regulations are emerging for the closer control of amalgam waste contained in dental office sewer discharges. Restricted by tighter limits at their own outfall, local sewer agencies are asking dental offices to implement amalgam BMPs, and in some cases are requiring offices to install amalgam removal equipment on their vacuum systems. An example of such a program is described on the Web site set up by the City of San Francisco.[17] CDA

Web sites of interest

City of San Francisco Dental Amalgam Program
<http://sfwater.org/main.cfm/MC_ID/4/MSC_ID/85>

Palo Alto Regional Water Quality Control Plant
<http://www.city.palo-alto.ca.us/cleanbay/ dental.html>

United Nations Environmental Programme
<http://www.chem.unep.ch/mercury>

Water quality limits on mercury discharges
<http://www.swrcb.ca.gov/rwqcb2/sfbaymercury tmdl.htm>

References / Most of these references can be downloaded from the Internet. It may be helpful to correspond directly with the authors of each reference and ask for other recommended studies. In addition, the American Dental Association has specialists who focus on the subject of mercury, its beneficial uses in dentistry, and patient or regulatory concerns about these uses.

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Cost-Effectiveness of Removing Amalgam From Dental Wastewater

Jay A. Vandeven and Steve L. McGinnis

ABSTRACT

Mercury in the form of amalgam is commonly introduced into dental wastewater as a result of amalgam placements and removals. Dental wastewater is primarily discharged to municipal sewers that convey industrial and residential wastewater to publicly owned treatment works (POTWs) for treatment prior to discharge to surface waters. In some localities, the sewage sludge generated by POTWs from the treatment of wastewater is incinerated, resulting in the emission of mercury to the atmosphere. Some of the mercury emitted from the incinerators is deposited locally or regionally and will enter surface waters.

An assessment was conducted of the use of mercury in amalgam in California and the discharge of that mercury from dental facilities to surface waters via the effluent from POTWs and air emissions from sewage sludge incinerators (SSIs). The annual use of mercury in amalgam placements conducted in California was estimated to be approximately 2.5 tons. The annual discharge of mercury in the form of amalgam from dental facilities to POTWs as a result of amalgam placements and removals was estimated as approximately one ton. The discharge of mercury to surface waters in California via POTW effluents and SSI emissions was estimated to total approximately 163 pounds. A cost-effectiveness analysis determined that the annual cost to the California dental industry to reduce mercury discharges to surface waters through the use of amalgam separators would range from $130,000 to $280,000 per pound.

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Table 1

Overview of Geographic Regions

Northern California		Southern California
Alameda	Northern California	Central Coast
Berkeley	Redwood Empire	Harbor
Butte-Sierra	Sacramento	Kern County
Contra Costa	San Francisco	Los Angeles
Fresno-Madera	San Joaquin	Orange County
Humboldt	San Mateo	San Diego
Marin	Santa Clara	San Fernando
Mid-Peninsula	Southern Alameda	San Gabriel
Monterey	Stanislaus	Santa Barbara-Ventura
Napa-Solano	Yosemite	Tri-County
		Tulare-Kings
		Western

Amalgams have been the primary restorative material used by dentists in the United States for more than 150 years, and have historically contained approximately 50 percent by weight mercury.[1,2] Mercury in the form of amalgam is commonly introduced into dental wastewater during amalgam placement and removal procedures. Due to the growing concern regarding mercury as a persistent, bioaccumulative and toxic substance, the use of mercury in many industries and products in the United States has decreased substantially over the past two decades.[3,4] Although the use of dental amalgams has also declined, the dental industry remains one of the largest consumers of mercury, and is facing regulatory scrutiny regarding the mercury content of dental wastewater.[4-6]

Since 2001, ENVIRON International Corporation has worked with the American Dental Association to develop a model of the quantity and fate of mercury in the form of amalgam introduced into dental wastewater. At the request of the California Dental Association, ENVIRON used this model to evaluate a number of issues related to the use of mercury as amalgam by the dental industry in California. Specifically, the objectives of the assessment were to evaluate: (1) the quantity of mercury used in amalgam by the California dental industry, (2) the amount of mercury from amalgam in dental wastewater that ultimately reaches surface waters in California; and (3) the cost-effectiveness of reducing these discharges through the installation and use of amalgam separators in dental facilities throughout the state.

The assessment was limited to the discharge and deposition of mercury to surface waters via the primary pathways consisting of the effluents from publicly owned treatment works (POTWs) and the emissions from sewage sludge incinerators (SSIs). It was recognized that additional pathways may exist for the discharge of mercury to surface waters, including:

- Amalgam present in biosolids managed via methods other than incineration (e.g., land application and landfilling);
- Non-contact and contact amalgam managed via methods other than recycling (e.g., in solid and infectious waste streams);
- Amalgam present during cremation; and
- Mercury in human waste which may, in part, be associated with amalgam.

For the purposes of the assessment, California was divided geographically into the northern and southern halves of the state. The geographic regions included in the definitions for both of these areas are summarized in **Table 1**.

Characteristics of the Dental Industry in California

The assessment focused on identifying and evaluating the mercury discharges to surface waters in California resulting from the use of amalgam by general dentists and specialists in private practice. According to the CDA, there are currently 25,222 such practitioners in California.[7] During the assessment, it was considered some general dentists and many specialists do not use amalgam in their practices. Although statewide surveys for California were not available, a survey recently conducted by the Sacramento Regional County Sanitation District (SRCSD) reported that approximately 72 percent of general dentists in Sacramento County use amalgam.[8] This percentage generally agreed with the results of nationwide surveys recently conducted by dental products manufacturers, which indicated that approximately 76 percent of general dentists throughout the United States reported using amalgam in 2001.[9] During the assessment, the percentage identified by the SRCSD of 72 percent was assumed for general dentists throughout California.

According to the ADA, pediatric dentists, prosthodontists, and endodontists are the only types of specialists using amalgam.[5] Due to a lack of data, it was assumed all of these specialists use

Table 2

Summary of Dentists in California and Estimates of Dentists Who Use Amalgam

Type	Northern California	Southern California	Statewide
Number of General Dentists	7,776	11,293	19,069
Using amalgam – 72%	5,600	8,100	13,700
Specialists	2,447	3,706	6,153
Using amalgam – pediatric dentists, prothodontists, and endodontists.	630	872	1,502

amalgam in their practices. The numbers of practitioners in California as provided by the CDA and the estimates of those using amalgam based on the assumptions discussed above are summarized in **Table 2**.

Estimate of Annual Amalgam Placements

Based on its 2003 survey, the SRCSD reported general dentists in Sacramento County conduct an average of eight placements per week.[8] From nationwide surveys, the ADA has estimated the average dentist in the United States works 48 weeks per year.[10] This work schedule was assumed for general dentists in Sacramento County to estimate that, on average, these dentists each perform 384 amalgam placements per year. The Central Contra Costa Sanitary District (CCCSD) conducted a similar survey in August 2000, and reported dentists within its service area perform an average of 449 amalgam placements per year.[11] Based on recent studies of dentists in areas serviced by the Union Sanitary District (USD) and the Palo Alto Regional Water Quality Control Plant (RWQCP), Barron estimated dentists in these two areas perform an average of 240 placements per year.[12,13] The amalgam placement rates identified for the SRCSD, CCCSD, USD, and Palo Alto RWQCP service areas were averaged to estimate the general dentists in these areas perform approximately 328 amalgam placements per year. This average rate was assumed for general dentists using amalgam throughout California. This rate is less than half the average rate identified by the ADA for general dentists in the U.S. of approximately 713 amalgam placements per year.[14]

None of the 23 specialists who responded to the 2003 SRCSD survey reported conducting amalgam placements, and no additional data was available regarding the use of amalgam by specialists in California. As noted, the ADA has conducted nationwide studies of the use of amalgam by specialists, and concluded that only pediatric dentists, prosthodontists, and endodontists use amalgam. According to the ADA, these specialists performed 4.7 million amalgam placements nationwide in 1999, for an average of approximately 440 amalgam placements per specialist.[14] Due to the limited data regarding the use of amalgam by specialists in California, this placement rate was assumed for the pediatric dentists, prosthodontists, and endodontists practicing in California. Considering the significantly lower amalgam placement rate identified for general dentists in California as compared to the national rate, the use of the national rate for specialists in the state was considered to be conservative. The amalgam placement estimates are summarized in **Table 3**. The estimates presented in **Table 3** and the following tables have been rounded to reflect the number of significant digits used in the underlying calculations.

Estimates of the Use and Disposition of Mercury in Amalgam

The amalgam placement rates identified above for general dentists and specialists were combined with the number of each type of dentist using amalgam in California in order to estimate the total number of amalgam placements conducted. Stone et al. reported the average mercury content per double spill of amalgam to be approximately 450 mg Hg.[15] This mass was combined with the estimated number of placements conducted in order to estimate the amount of mercury used in amalgam by the California dental industry.

Excess amalgam (i.e., "non-contact" amalgam) is commonly triturated during each amalgam placement to ensure that sufficient mixed amalgam is available to complete the restoration. The Florida Center for Solid and Hazardous Waste Management, Arenholt-Bindlsev, and Barron estimated that 15 percent to 50 percent of the amalgam triturated for placement becomes non-contact amalgam.[13,16,17] Barron's estimate of 25 percent was used as an approximate average of the percentages reported in the literature in order to estimate the mass of non-contact amalgam generated in California and the mass of amalgam actually used in placements. The calculations of the use and disposition of mercury in amalgam are summarized in **Table 4**.

When the units of the estimates presented in **Table 4** are converted to tons,

Table 3

Estimates of Annual Amalgam Placements

	Northern California	Southern California	Statewide
Number of General Dentists	5,600	8,100	13,700
Placement rate	328	328	328
Placements	1,800,000	2,700,000	4,500,000
Number of Specialists	630	872	1,502
Placement rate	440	440	440
Placements	280,000	380,000	660,000
Total Placements	2,100,000	3,100,000	5,200000

Table 4

Summary of the Annual Use and Disposition of Mercury in Amalgam

	Northern California	Southern California	Statewide
Total Placements	2,100,000	3,100,000	5,200,000
Mass Hg Per Placement	450 mg	450 mg	450 mg
Total Mass Hg Used	2,100 lbs	3,100 lbs	5,200 lbs
Hg in Non-Contact Amalgam	530 lbs	770 lbs	1,300 lbs
Hg Placed in Amalgam	1,600 lbs	2,300 lbs	3,900 lbs

it was estimated approximately 1 ton of mercury is used in amalgam in Northern California and 1.5 tons in Southern California, for a statewide total mercury use of approximately 2.5 tons. This corresponds to approximately 7 percent of the estimated 35 tons of mercury used in amalgam nationwide.[18] Approximately 15 percent of the nation's dentists practice in California, indicating that amalgam use in California may be significantly lower than the national average.

Estimate of Mercury Removed as Amalgam

The 2003 SRCSD study identified an average removal rate of about 22 amalgams per general dentist per week.[8] In 1993, researchers estimated that general dentists in the San Francisco area averaged 1.79 amalgam removals per day.[19] The aforementioned work schedule identified by the ADA (228 days and 48 weeks per year) was assumed for these general dentists to estimate that, on average, the dentists in the SRCSD and San Francisco Service areas perform 1,056 and 408 amalgam removals per year, respectively. The CCCSD, USD, and Palo Alto RWQCP studies identified amalgam removal rates of 857, 312, and 300 removals per general dentist per year, respectively.[11-13] The results of these studies were averaged to estimate that general dentists in California each remove approximately 587 amalgams per year. This average is somewhat lower than the average of the amalgam removal rates identified by the Municipality of Metropolitan Seattle; the Western Lake Superior Sanitary District in Duluth, Minn.; the Metropolitan Council Environmental Services (MCES) in St. Paul, Minn.; and the Massachusetts Water Resources Authority in Boston.[20-23] The average of the amalgam removal rates from these studies was 785 removals per dentist per year.

During its 2003 survey, the SRCSD reported that endodontists, periodontists, orthodontists, and oral surgeons in Sacramento County removed an average of 18 to 19 amalgams per week.[8] Based on the average work schedule discussed above, it was estimated these dentists conduct an average of 888 amalgam removals per year.

It was assumed that all general dentists and specialists in California remove amalgam, even if they do not regularly place amalgam in their practices. The amalgam removal rates discussed above were combined with the numbers of general dentists and specialists to estimate the total number of amalgam removals conducted in California.

The mass of mercury in an amalgam originally placed in a tooth is greater than that ultimately removed from the tooth due to losses over the life of the amalgam. Barron estimated these losses at 10 percent.[13] This estimate generally

Table 5

Summary of Annual Amalgam Removals and Mercury Removed as Amalgam

	Northern California	Southern California	Statewide
Number of General Dentists	7,776	11,293	19,069
Removal rate	587	587	587
Removals	4,600,000	6,600,000	11,200,000
Number of Specialists	1,350	1,762	3,112
Removal rate	888	888	888
Removals	1,200,000	1,600,000	2,800,000
Total Removals	5,800,000	8,200,000	14,000,000
Mass Hg Per Removal	300 mg	300 mg	300 mg
Hg Removed as Amalgam	3,800 lbs	5,400 lbs	9,200 lbs

agrees with that predicted from annual mercury loss rates reported by Skare and the United States Agency for Toxic Substances and Disease Registry and with the average amalgam life estimated by the USGS of about eight to nine years.[4,24,25] When applied to the average mass of mercury originally placed in a typical amalgam (i.e., that which is not discharged in wastewater during the placement), Barron's 10 percent estimate indicated that the average amalgam contains about 280 mg of mercury when removed from the tooth. This estimate was slightly lower than the results of a study conducted by Watson et al., which indicated an average of about 320 mg of mercury in each removed amalgam.[26] From the results of these studies, it was assumed the average removed-amalgam contains 300 mg of mercury. This mass was combined with the number of amalgam removals conducted in California to estimate the mass of mercury removed as amalgam in the state each year. The amalgam removal calculations are summarized in **Table 5**.

Estimate of Mercury in the Form of Amalgam Released to Dental Wastewater

During the Palo Alto RWQCP study, Barron estimated the fraction of amalgam particles that are released to dental wastewater during amalgam placements and removals as approximately 9 percent and 90 percent, respectively.[13] These percentages were applied to the mass of mercury placed in amalgams and removed in the form of amalgam estimated as part of this study. The calculations of the release of mercury in the form of amalgam to dental wastewater from amalgam placements and removals are summarized in **Table 6**.

Capture of Mercury in the Form of Amalgam in Dental Facilities

Dental wastewater generated from restorative procedures flows through a chairside trap and, in the majority of dental facilities, a filter that protects the vacuum pump, prior to discharge.[27] Drummond et al. identified a capture efficiency for chairside traps of 60 percent based on sampling data, while Naleway et al. estimated that chairside traps capture 75 percent of amalgam in dental wastewater based on particle size distribution studies.[28,29] An average chairside trap capture efficiency of 68 percent was selected based on the capture efficiencies reported by these studies.

No data was available regarding the percentage of dental facilities in California that are equipped with vacuum filters. Based on studies conducted in Minneapolis-St. Paul, Minn., the MCES and MDA reported that approximately 71 percent to 88 percent of the surveyed dental facilities were equipped with vacuum filters.[22,27] These estimates are similar to those reported in a study conducted by Watson et al., which estimated that approximately 90 percent to 95 percent of dental facilities in Ontario, Canada, were equipped with vacuum filters.[26] Approximately 80 percent of the dental facilities in California were estimated to be equipped with vacuum filters based on the average of the results of the MCES and MDA studies.

In 2001, the MCES and MDA conducted a detailed evaluation of the efficiency of vacuum filters in capturing amalgam particles that pass a chairside trap, and identified an overall capture efficiency of 42 percent. Particle size distribution studies conducted by Batchu et al. and Cailas et al. indicated that capture efficiencies for vacuum filters range from 25 percent to 50 percent.[30,31] An average vacuum filter capture efficiency of 40 percent was estimated based on the average of the capture efficiencies identified from these studies.

A statewide capture efficiency of mercury in the form of amalgam was calculated using the data identified in the literature for the capture of chairside traps and vacuum filters. Dental facilities equipped with both a chairside

Table 6

Summary of the Release of Mercury in the Form of Amalgam to Dental Wastewater

	Northern California	Southern California	Statewide
Placements			
Hg Placed as Amalgam	1,600 lbs	2,300 lbs	3,900 lbs
Release to Dental Wastewater	9%	9%	9%
Hg Released from Placements	140 lbs	210 lbs	350 lbs
Removals			
Hg Removed as Amalgam	3,800 lbs	5,400 lbs	9,200 lbs
Release to Dental Wastewater	90%	90%	90%
Hg Released from Removals	3,400 lbs	4,900 lbs	8,300 lbs
Total	3,500 lbs	5,100 lbs	8,600 lbs

trap and vacuum filter were estimated to capture approximately 81 percent of the amalgam particles in dental wastewater due to the combined capture of both devices, while dental facilities equipped with only a chairside trap were estimated to capture 68 percent of the amalgam particles. Based on studies conducted by the MCES and MDA, it was estimated that 80 percent of the dental facilities in California are equipped with both chairside traps and vacuum filters and 20 percent are equipped with chairside traps only.[22,27] A weighted average was utilized to estimate a capture efficiency for dental facilities in California of approximately 78 percent.

Capture of Mercury in the Form of Amalgam in POTWs

The wastewater generated by dental facilities is discharged to either POTWs or septic systems. The Maine Dental Association recently conducted a survey of its constituents, and estimated that 86 percent of the dentists in Maine discharged wastewater to POTWs and that the remainder is discharged to septic systems.[32] No data regarding this distribution in California was identified from a review of the literature. In order to provide a conservative estimate of mercury loading to POTWs in California, it was assumed that all dental facilities discharge to POTWs.

A review of the open literature was conducted to identify POTW capture efficiencies for mercury and mercury in the form of amalgam. Although substantial data was identified regarding the capture of mercury by POTWs, little data was identified for the capture of mercury in the form of amalgam. Although POTWs are not designed to capture mercury, a number of recent studies have reported mercury capture efficiencies for POTWs ranging from 95 percent to 99 percent. The most comprehensive of these studies was conducted by the Association of Metropolitan Sewerage Agencies (AMSA), and included of a review of 15 POTWs ranging in capacity from approximately 4 million gallons per day (MGD) to 375 MGD.[6] The AMSA study identified an average mercury capture efficiency for POTWs of 95 percent. Independent studies conducted by the MCES in 1995 and 1998 identified mercury capture efficiencies for three POTWs of 96 percent, 98 percent, and 99 percent, respectively.[33,34] Based on the comprehensive data reported in the AMSA study, an average POTW capture efficiency of 95 percent for mercury and mercury in the form of amalgam was used in the present assessment.

Incineration of Mercury in the Form of Amalgam with POTW Biosolids

Particles captured in POTWs are either transferred to the grit solids or biosolids. Grit solids are typically removed from the wastewater stream through the use of either horizontal-flow, aerated, or vortex grit chambers.[35] A study conducted by the MCES in 1998 identified mercury capture efficiencies for aerated and vortex grit chambers of 7 percent and 48 percent, respectively.[34] The data was compared with a theoretical capture analysis for amalgam of approximately 20 percent in a horizontal-flow grit chamber based on design specifications reported by Tchobanoglous and Burton and the amalgam particle size distribution identified in studies conducted by the International Organization for Standardization (ISO).[35,36] It was estimated that 25 percent of mercury in the form of amalgam captured by POTWs is transferred to the grit solids, and that 75 percent is transferred to the biosolids.

The California Association of Sanitation Agencies (CASA) conducted a survey of biosolids management practices in California in 1998 and reported that approximately 6.7 percent of biosolids generated were managed via incineration in sewage sludge incinerators (SSIs) at that time. The CASA study

Table 7

Summary of the Discharge of Mercury from Dental Facilities to POTWs and Surface Waters

	Northern California	Southern California	Statewide
Hg Released to Dental Wastewater	3,500 lbs	5,100 lbs	8,600 lbs
% Captured in Dental Facilities	78%	78%	78%
Hg Captured in Dental Facilities	2,700 lbs	4,000 lbs	6,700 lbs
Hg Discharged to POTWs	800 lbs	1,100 lbs	1,900 lbs
% Captured in POTWs	95%	95%	95%
Hg Discharged via POTW Effluents	40 lbs	55 lbs	95 lbs
Hg Captured in POTWs	760 lbs	1,040 lbs	1,800 lbs
% Transferred to Biosolids	75%	75%	75%
Hg Transferred to Biosolids	570 lbs	780 lbs	1,400 lbs
% Incinerated with Biosolids	5%	5%	—
Hg Incinerated with Biosolids	29 lbs	39 lbs	68 lbs
% Capture by Emissions Controls	0%	0%	0%
Hg Emitted from SSIs	29 lbs	39 lbs	68 lbs
Total Hg Discharged to Surface Waters	69 lbs	94 lbs	163 lbs

indicated that the mass of biosolids incinerated in Northern and Southern California was relatively equal. Additional information indicates that the fraction of biosolids managed via incinerations has dropped to 5 percent.[37,38] From approximately 1988 to 1995, the United States Environmental Protection Agency (EPA) developed representative emissions factors for SSIs, commonly referred to as AP-42 factors, the average of which represented a mercury capture efficiency for SSI emission controls of about 79 percent.[38] However, some of the scrubber water utilized in these control systems is recycled through the POTW. As a result, at least some of the captured mercury will be released via POTW effluents through this cycle. For the purposes of this assessment, the overall capture efficacy was assumed as 0 percent.

Estimate of the Discharge of Mercury to Surface Waters

The mercury capture efficiency of chairside traps and vacuum filters in dental facilities (78 percent) was applied to the mass of mercury in the form of amalgam released to dental wastewater during amalgam placements and removals to estimate the mass of mercury captured in dental facilities and released to POTWs in California. The POTW capture efficiency (95 percent) was then applied to the mass of mercury released to POTWs to estimate the mass of mercury entering surface waters in California via POTW effluents. The percentage of mercury in the form of amalgam transferred to biosolids (75 percent) and the biosolids incineration rate (5 percent) were used to estimate the mass of mercury from amalgam that is released from SSIs. Although some fraction of the mercury emitted from SSIs will be deposited on land and become bound to soils, all of this mercury was assumed to enter surface waters. The discharge calculations are summarized in **Table 7**.

Cost of Using Amalgam Separators to Reduce Mercury Discharges

Amalgam separators are the primary technology currently being considered to reduce the content of mercury in the form of amalgam in dental wastewater prior to discharge from dental facilities. The cost of implementing the use of amalgam separators and their effectiveness in reducing mercury discharges from dental facilities was considered as part of the assessment.

From 2000 to 2002, the ADA, the MCES and MDA, and the Palo Alto RWQCP conducted studies of the costs associated with utilizing amalgam separation equipment in dental facilities.[27,39,40] The results of these studies were reviewed and supplemented with commercial vendor quotes to estimate the cost of purchasing and operating an amalgam separator for the average dental facility in California. The separator purchase and operating costs identified during the assessment are summarized in **Table 8**.

Based on a review of the cost studies and vendor quotes, it was estimated the cost to purchase and install an amalgam separator(s) would typically range from roughly $1,000 to $2,000 per dental facility. It was estimated the cost to operate the separator(s) would typically range from $700 to $1,000 per dental facility per year.

In order to prepare a conservative estimate of the costs associated with amalgam separators, the installation and operation of separators in only those dental facilities operated by general dentists were considered. During a 1997 survey, CDA identified that approximately 73 percent of all dentists in California maintained a solo private

Table 8

Summary of Amalgam Separator Purchase and Operating Costs

Vendor	Model	Type	Purchase Price	Annual Operating Costs
AB Dental Trends, Inc.	890-1000	Sedimentation, Filtration, Ion exchange	$1,190	$476
	890-4000	Sedimentation, Filtration, Ion exchange	$1,650	$610
	890-6000	Sedimentation, Filtration, Ion exchange	$667	$441
Air Techniques, Inc.	A 1000	Sedimentation	$750	$1,150
	Durr 7800/7801	Centrifuge	$4,000	$495
Avprox, Inc.	Asdex Filter	Filtration	$215	$1,360
	BullfroHg	Sedimentation	$0	$1,200
DRNA	MRU	Sedimentation, Filtration, Ion exchange	$0	$1,800
Maximum Separation Systems, Inc.	MSS 2000	Sedimentation	$3,000	$596
Metasys	ECO II	Sedimentation	$260	$428
R&D Services	Amalgam Collector	Sedimentation	$350	$540
Rebec Environmental	RME 2000	Sedimentation	$1,895	$474
SolmeteX	Hg5	Sedimentation, Filtration, Ion exchange	$695	$496

practice.[7] Although the CDA survey did not identify the typical size of group practices in California, the ADA has reported that such practices are staffed by an average of 2.9 dentists per facility nationwide.[10] These percentages were assumed for the general dentists throughout California to estimate the number of dental facilities in the state. The calculations of the number of dental facilities and costs of using amalgam separators are presented in **Table 9**.

Effectiveness of Using Amalgam Separators to Reduce Mercury Discharges

The effectiveness of separators was evaluated as the incremental capture attained by the separator beyond that already attained by chairside traps and, where present, vacuum filters. The behavior of the amalgam fraction not captured by the separators in the receiving POTWs was also evaluated in order to determine the actual reduction in discharges to surface waters via the POTW effluent and SSI emission pathways.

The MCES and MDA recently completed a two-year study on the capture efficiency of amalgam separators in several dental facilities located in Minnesota. This study identified incremental capture efficiencies for amalgam separators of approximately 94 percent beyond the capture already achieved in facilities equipped with chairside traps and 89 percent beyond the capture achieved in facilities equipped with both chairside traps and vacuum filters.[27]

The ADA recently conducted a bench study of the amalgam capture efficiency of 12 amalgam separators in accordance with ISO Standard 11143. From the study, the ADA identified an average overall amalgam capture efficiency of 99 percent.[41] However, the amalgam sample utilized in these studies was prepared in accordance with the ISO standard, and consisted of amalgam particles ranging up to 3,150 mm in size, 60 percent of which were greater than 500 mm in diameter.[36] As noted, dental facilities are equipped with chairside traps that have pore sizes of 700 mm, and many are also equipped with vacuum filters that have pore sizes ranging from 210 mm to 400 mm. Therefore, had the ADA's tests been conducted in actual dental facilities, much of the ISO amalgam sample uti-

Table 9

Summary of the Number of Dental Facilities and Costs of Using Amalgam Separators

	Northern California	Southern California	Statewide
General Dentists	7,776	11,293	19,069
% Solo practitioners	73%	73%	73%
Number of Solo Practitioners/Facilities	5,700	8,200	13,900
Number of Practitioners Sharing Facilities	2,100	3,100	5,200
Density of Practitioners per Facility	2.9	2.9	2.9
Number of Shared Facilities	720	1,100	1,800
Total Number of Dental Facilities	6,400	9,300	15,700
Separator Capital Cost per Facility	\$1,000 – \$2,000	\$1,000 – \$2,000	\$1,000 – \$2,000
Total Separator Capital Cost	\$6.4 – \$13 million	\$9.3 – \$19 million	\$16 – \$31 million
Separator Operating Cost per Facility	\$700 – \$1,000	\$700 – \$1,000	\$700 – \$1,000
Total Separator Operating Cost	\$4.5 – \$6.4 million	\$6.5 – \$9.3 million	\$11 – \$16 million
Total Cost of Using Separators[1]	\$5.1 – \$7.7 million	\$7.4 – \$11 million	\$13 – \$19 million

[1] The separator capital cost was spread over an assumed separator life of 10 years and added to the annual operating and maintenance costs in order to estimate the total annual cost of using amalgam separators.

lized in the tests would have been captured by the chairside traps and vacuum filters prior to entering the amalgam separators. Upon consideration of the capture of these devices, the incremental separator capture efficiency identified by the ADA bench tests was estimated to range from 95 percent to 97 percent.

Based on the MCES and MDA study and the ADA bench tests, an average incremental capture efficiency for the use of amalgam separators of approximately 95 percent was used in the assessment. At this efficiency, amalgam separators would reduce the estimated discharge of 1,900 pounds of mercury in the form of amalgam to POTWs in California to approximately 95 pounds. The 95 pounds would consist of the smallest and most difficult amalgam particles to capture. Amalgam separators primarily employ the same physical processes to remove amalgam particles as the processes utilized at POTWs to remove particulates (i.e., sedimentation and centrifugation) and can generally be expected to remove the same types of amalgam particles. Indeed, the amalgam capture efficiencies identified for both POTWs and separators from the open literature are both approximately 95 percent. Therefore, it is unlikely a significant amount, if any, of the 95 pounds of mercury in the form of amalgam particles not captured by amalgam separators would subsequently be captured by the downstream POTWs (i.e., the 95 pounds of mercury in the form of amalgam not captured by the separators would consist of the same 95 pounds that is already estimated not to be captured by POTWs). Under this scenario, the only benefit attained through the use of separators would be the virtual elimination of the deposition to surface waters of an estimated 68 pounds of mercury from the incineration of amalgam in SSIs in California, at an estimated annual cost of reduction of approximately \$190,000 to \$280,000 per pound (\$380 million to \$560 million per ton).

A second scenario of the potential reductions in mercury discharges from the use of amalgam separators was considered for the purposes of the assessment. AMSA is currently conducting a study to evaluate whether separators have an effect on the mercury discharged in POTW effluents. From this study, AMSA has generated some preliminary data regarding average mercury concentrations in the effluent from the POTWs operated by the City of Wichita, Kan.[42] Although the data appears relatively inconclusive, AMSA has reported that the use of amalgam separators reduced mercury effluent concentrations from the City of Wichita's POTWs by approximately 29 percent. Despite the preliminary nature of this data, a hypothetical situation was considered during the assessment in which the use of amalgam separators decreased the mercury concentrations in the effluent from POTWs in California by approximately 30 percent. Assuming this hypothetical situation, the mercury discharges from POTWs to surface waters in California would be reduced by at most 97 pounds per year, at an annual cost of reduction of approximately $130,000 to $200,000 per pound ($260 million to $400 million per ton).

Conclusions

An assessment was conducted of the use of mercury in dental amalgam in California and the discharge of mercury in the form of amalgam from dental facilities to surface waters via the effluent from POTWs and air emissions from sewage sludge incinerators. The annual use of mercury in amalgam placements in California was estimated to be approximately 2.5 tons. The annual discharge of mercury in the form of amalgam from dental facilities to POTWs as a result of amalgam placements and removals was estimated as approximately one ton. The discharge of mercury to surface waters in California via POTW effluents and SSI emissions was estimated to total approximately 165 pounds per year. A cost-effectiveness analysis determined that the annual cost to the California dental industry to reduce mercury discharges to surface waters through the use of amalgam separators would range from $130,000 to $280,000 per pound. CDA

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Understanding the Mercury Reduction Issue: The Impact of Mercury on the Environment and Human Health

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ABSTRACT

Mercury has been used in both medicine and dentistry for centuries. Recent media attention regarding the increased levels of mercury in dietary fish, high levels of mercury in air emissions, and conjecture that certain diseases may be caused by mercury exposure has increased public awareness of the potential adverse health effects of high doses of mercury. Dentistry has been criticized for its continued use of mercury in dental amalgam for both public health and environmental reasons. To address these concerns, dental professionals should understand the impact of the various levels and types of mercury on the environment and human health.

Mercury is unique in its ability to form amalgams with other metals. Dental amalgam — consisting of silver, copper, tin, and mercury — has been used as a safe, stable, and cost-effective restorative material for more than 150 years. As a result of this use, the dental profession has been confronted by the public on two separate health issues concerning the mercury content in amalgam. The first issue is whether the mercury amalgamated with the various metals to create dental restorations poses a health issue for patients. The second is whether the scraps associated with amalgam placement and the removal of amalgam restorations poses environmental hazards which may eventually have an impact on human health. Despite the lack of scientific evidence for such hazards, there is growing pressure for the dental profession to address these health issues.

In this article, the toxicology of mercury will be reviewed and the impact of amalgam on health and the environment will be examined.

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Human exposure to mercury is from three major sources: dental amalgams, fish consumption, and vaccines.

Several reviews of the toxicology of mercury have appeared recently.[1-3] Liquid mercury (quicksilver) has largely been eliminated from homes and work environments. However, rare incidents of poisoning are still reported due to cultural and religious uses of mercury. Human exposure to mercury is from three major sources: dental amalgams, fish consumption, and vaccines. Dental amalgams emit mercury vapor that can be potentially inhaled and absorbed into the bloodstream. However, this amalgam-associated mercury vapor poses a very limited risk to dentists and those with amalgam restorations. The major toxicology concerns about mercury are related to its two organic forms, methylmercury (CH_3Hg^+) and ethylmercury ($CH_3CH_2Hg^+$). Fish consumption is the main source of methylmercury intake in humans. Exposure to ethylmercury is mainly through thimerosal, a preservative used in vaccines.

Each form of mercury has its own characteristic, distinctive toxicologic profile, and clinical symptoms. **Table 1** summarizes the clinical toxicologic features of the various forms of mercury.

Mercury Vapor from Dental Amalgams

An ambient atmospheric level of mercury is negligible. Health risks can occur with occupational exposure to high concentration of mercury vapor. Mercury vapor is a monatomic gas that evaporates from liquid metallic mercury. Historically, occupational exposures were associated with cinnabar mining, extraction of gold and silver with quicksilver, mirror-making, hat-making, and accidental mercury spills from, for example, blood pressure cuffs. Mercury has been used in manufacturing paints, pesticides, and batteries, but is no longer used for these products. Mercury continues to be used in the manufacture of chlorine and fluorescent lamps. Non-occupational exposures to mercury vapor have occurred in the past due to mercury's use in science classes and easy public access to the product. Recreational gold miners are known to use elemental mercury today. Exposures can also occur when devices containing mercury, such as thermostats and thermometers, break. Today, given modern occupational standards and safety precautions and greater awareness of mercury vapor toxicity, human exposure to high concentrations of mercury vapor are rare in the U.S.

Amalgam fillings are the chief source of exposure to low levels of mercury vapor for the general population.[4] How much vapor is absorbed by the body or is breathed out is not known. Brain, blood, and urinary concentration of mercury are proportional with the number of amalgam restorations present. Estimates indicate that 10 amalgam surfaces would raise urinary concentration by 1 µg of mercury per liter, which is twice the normal environmental background concentration.[5] Heavy mastication and prolonged chewing will elevate urinary concentration close to the recommended health limits.[6] A temporary elevation in mercury vapor can be observed with amalgam removal. [7]

Historically, reports of high concentration of mercury vapor inhalation have been characterized by tremor, gingivitis, and erethism (bizarre behavior such as excessive shyness and/or aggression).[8] In today's occupational environment, the risks are low and reversible. With a short half-life of 60 days, mercury is usually cleared from the body with no significant health effects. In extreme cases, reversible kidney changes, mild cognitive changes, and memory loss may occur.

Occupational exposure associated with working with dental amalgam can result in a 10- to 25-fold elevation in urinary output of mercury.[7] Though this is well below recommended health limits, some have speculated that long-term exposure to low concentrations of mercury vapor may cause or contribute

Table 1

Toxicological Features of Mercury*

Variables	Mercury Vapor	Methylmercury	Ethymercury
Route of exposure	Inhalation	Oral ingestion (primarily from fish consumption)	Parenteral (through vaccines)
Target organ	Central and peripheral nervous system; kidney	Central nervous system	Central nervous system; Kidney
Local clinical signs			
Lungs	Bronchial irritation; pneumonitis		
GI	Stomatitis; gingivitis; metallic taste; increase salivation		
Skin			
Systemic clinical signs			
Kidney	Proteinuria (>500 µg/m_3 of air)		Tubular necrosis
Peripheral nervous system	Peripheral neuropathy (>500 µg/m_3 of air)		Acrodynia
Central nervous system	Erethism; tremor (>500 µg/m_3 of air)	Paresthesia, ataxia, visual and hearing loss (>200 µg/l of blood)	Paresthesia; ataxia; vision and hearing loss
Approximate half-life	60 days	70 days	20 days in adult 7 days in infants
Treatment	Meso-2,3-dimercaptosuccinate	Chelators not effective	Chelators not effective

*Data was adapted from Clarkson.[1]

to the development of degenerative diseases such as amyotrophic lateral sclerosis, Alzheimer's disease, multiple sclerosis, and Parkinson's disease. Most of the speculation has been associated with Alzheimer's disease, but epidemiologic studies have failed to correlate this association.[9-11]

With increased public awareness of "anti-amalgamist" claims, some patients have questioned whether they should have all amalgams removed. These patients should be reminded there is no evidence supporting amalgam removal for supposed health benefits. Additionally, patients should be cautioned that removal of amalgams prior to the need for replacement will result in increased exposure to mercury vapor and a transient increase in blood mercury concentration.

Methylmercury from Fish Consumption

The main source of human exposure to methylmercury is the consumption of fish. Mercury vapor (Hg^0) is a stable monatomic gas that evaporates from soil and water and is emitted by volcanoes. The major anthropogenic sources of mercury vapor emissions are coal-burning power stations and municipal incinerators. Eventually, mercury vapor converts to a soluble form (Hg^{2+}) and returns to the earth surface with rainwater. This soluble form may attach itself to aquatic sediments and be microbially converted into methylmercury (MeHg). Methylmercury then enters into the aquatic food chain. Methylmercury becomes concentrated at the top of the aquatic food chain, with the highest concentrations found in long-lived predatory fish such as tuna, swordfish, shark, and bass. The classic case of aquatic contamination is the excessive industrial release of methylmercury into Minamata Bay and the Agano River in Japan, which resulted in two large epidemics of mercury poisoning related to fish consumption.[12]

The brain is the primary target tissue of mercury poisoning, with regional destruction of neurons in the visual cortex and cerebellar granule cells. This is clinically manifested by a latent period with paresthesias of the limbs followed by visual field constriction and ataxia. Some have suggested that MeHg contributes to cardiovascular disease, but epidemiologic evidence does not support this.[13-16] Additionally, it is not clear how this may contribute to this multi-factorial disease.

The main concern about methylmercury is prenatal exposure. The fetal brain is more susceptible to mercury-induced damage. Methylmercury inhibits neuronal cell division and migration, which disrupts brain development. Due to this concern and epidemiologic data,[17-19] the Environmental Protection Agency reduced the allowable intake of MeHg from 0.5 to 0.1 µg of mercury per kilogram per day.[20] This translates into a weekly consumption of one 7-ounce can of tuna for an adult. For pregnant women, nursing mothers, and young children, the Food and Drug Administration is more stringent in recommending these populations avoid eating fish with a high mercury content [>1 parts per billion (ppb)], such as those levels found frequently in shark, swordfish, tilefish, and king mackerels. California Department of Fish and Game regulation guidelines include public health advisories on consumption of sport fish from various water bodies including San Francisco Bay and the Delta region. Due to elevated levels of mercury, PCBs, and other chemicals in these areas, consumers are advised against eating more than two meals per month of certain fish, eating any striped bass or sharks more than 24 inches to 35 inches long, and eating any fish from certain water bodies.

Ethylmercury from Thimerosal in Vaccines

Thimerosal has been used as a vaccine preservative since 1930.[2,21] It contains ethylmercury, which kills microorganisms and fungi. The presence of ethylmercury in vaccines became a concern as a result of a study suggesting infants undergoing the recommended U.S. program of vaccinations from birth to six months of age would be exposed to more than 0.1 µg of mercury per kilogram per day.[2] Utilizing MeHg epidemiologic data on prenatal exposure, the EPA ordered post-natal exposure to ethylmercury to be lowered. This resulted in a rapid change in the U.S. vaccination program whereby thimerosal was completely eliminated from use by switching to vaccines in single dose vials without any preservative.

The main concern about methylmercury is prenatal exposure. The fetal brain is more susceptible to mercury-induced damage.

The toxicology pattern of ethylmercury has some similarities to methylmercury. They have similar tissue-organ distribution and damage patterns; however, ethylmercury is metabolized more rapidly than MeHg.[22] Whereas the typical half-life of MeHg is 70 days, it is only seven days to 10 days in children receiving thimerosal-containing vaccines. Due to this rapid turnover, there is minimal if any risk for accumulation. It has been postulated that EPA extrapolation of the MeHg data in developing regulatory policies for the U.S. vaccination program is not scientifically sound. Echoing this sentiment, the World Health Organization (WHO) advisory committee recently concluded it is safe to continue to use thimerosal in vaccines.[23]

Amalgam and Human Health

As for the safety of dental amalgam in individuals with fillings, amalgam has a long track record of safety and durability. The U.S. Food and Drug Administration, Public Health Service, National Institutes of Health, WHO, ADA, and Academy of General Dentistry have all stated that no valid scientific evidence shows that the mercury in amalgam has any negative health effect. In the oral environment, the mercury is amalgamated with the various metals and is rendered inert. With chewing, it is possible to have mercury vapor released, but the amount is thousands times lower than the amount considered safe by various scientific studies and the National Institutes of Health. Some experts have calculated that one would need to have approximately 500 fillings to face any toxic effect from this mercury vapor.[4] Despite the preponderance of information that supports the use of amalgam, many have advocated its replacement with alternative restorative materials. This approach may pose greater health risks due to the temporal elevation of mercury, the endodontic risk associated with premature restorative procedures, and the unclear longevity of service for certain categories of restorative materials.

Amalgam and Wastewater

The recent focus of regulatory agencies has not been on the safety of amalgam but rather on amalgam waste. The concern is that the mercury within the amalgam may contribute to the environmental load of mercury, resulting in higher concentration of mercury deposited into our food chain. Whether this is true has been a source of controversy. Nevertheless, regulatory agencies dictate regulations and policies based upon certain assumptions. Since these regulations will have a significant impact on restorative dentists, it is important to understand the issues involved.

With the passage of the Federal Clean Water Act, agencies have imposed regulations in an attempt to protect the nation's water bodies by limiting the concentration and loading of chemicals discharged from various sources including, but not limited to, dental offices, industrial facilities, and sewage treatment plants. Mercury is of particular interest to these regulatory agencies because it is a persistent bioaccumulative toxic chemical.

Environmental regulations and policies on mercury are based on a series of assumptions that are overestimated and not based on scientific evidence. Despite empirical uncertainties, this preventive regulatory approach has been taken to protect human health and the environment. The EPA and other regulatory agencies have made the assumption that all mercury (whether bound or unbound) from dental offices will be converted into methylmercury once released into the environment. Though there is no scientific evidence to support this conversion, this is the fundamental basis for this regulatory scheme. Environmental regulations for mercury do not take into consideration the different forms of mercury. Therefore, as a result of these assumptions, regulations have been imposed to minimize the concentration of total mercury levels in water bodies. In the Great Lakes region, for example, the EPA has dictated a maximum concentration of mercury allowed in the surface water of 0.0013 micrograms of mercury per liter [0.0013µg/l or ppb] as a result of all discharges along this water body.

The EPA, many states, and several municipalities have specifically identified dental offices as a major source of mercury discharge into sewer systems. However, the dental industry is not a major source of mercury release into the environment. The most significant sources to the environment are from air emissions from electric power and chloralkali industries. Mercury has been detected in sewage sludge at concentrations that range between 0.38 mg/kg and 3.0 mg/kg. This mercury is the result of the cumulative impact of all mercury entering the sewage system, including human waste and industrial sources. In addition, the leakage of mercury from silver mining and other industries no longer functioning may continue to contribute to the mercury discharge. Though a large percentage of mercury in dental amalgam is bound, it is not known if any of this mercury is readily bioconverted into methylmercury. Nevertheless, dental amalgam discharge into sewer systems is highly scrutinized by regulatory agencies.

> While dentists' offices are an identifiable source of amalgam waste discharge, there is no evidence that these discharges are converted to methylmercury in the sewer system or during the waste treatment process.

While dentists' offices are an identifiable source of amalgam waste discharge, there is no evidence that these discharges are converted to methylmercury in the sewer system or during the waste treatment process. There are few reliable quantitative data about the environmental impact of amalgam in wastewater. A study based on dental wastewater discharge suggested that dentists discharge an average of 35 milligrams of mercury in the amalgamated form into the sewer per day.[24] Studies conducted by POTWs in San Francisco and Seattle estimated that dental office wastewater constitutes between 8 percent and 14 percent of the total mercury load.[25,26] However, these findings are based on waste accumulation sampling, and not on how much amalgam or how much free mercury dental offices actually discharge. It is clear that the amount of amalgam discharged can be minimized by 40 percent to 80 percent with the use of chairside and vacuum pump traps.[27-29] This can be further improved to 96 percent to 99 percent with the use of amalgam separators.[30] Nevertheless, research has not determined what effect, if any, dental discharges have on mercury loading at a given POTW.

In one ADA-commissioned study, a simulated treatment model was used to determine whether amalgam would degrade to its individual components with wastewater treatment. Using an assay method that could detect 1 ppb, no soluble mercury was detected when amalgam particulate was subjected to wastewater treatment procedures.[31]

Although regulatory assumptions resulting in higher calculated water quality impacts for amalgam discharges may not be scientifically sound, it is unlikely that regulations will be modified by the EPA or the states. The inherent toxicity of methylmercury is such that the National Academy of Sciences reviewed the EPA's daily limit on exposure to methylmercury (0.1 µg/kg of body weight per day) and concluded it was scientifically justified.[32] The issue is not only concern for water quality, but also for the amount of methylmercury that bioaccumulates in fish, a part of our food chain. The maximum amount of methylmercury allowed in fish tissue by the EPA is 0.3 ppm. The FDA limit is 1 ppm. Both the EPA and the FDA have issued advisories recommending that pregnant women, nursing mothers, and young children, not to eat shark, swordfish, king mackerel, canned tuna, or tile fish. The California Department of Fish and Game, California EPA, and Office of Environmental Health have various advisory warnings recommending limited fish consumption for fish caught in San Francisco Bay, Clear Lake, and other water bodies in California. Many of these concerns are due to the high level of methylmercury in the fish.

Conclusion

Mercury toxicity is not a significant issue when one examines the mercury vapor levels associated with dental occupational exposure and dental amalgams in patients. Health concerns about mercury exposure increase significantly when one examines the levels of mercury associated with fish consumption. Does dental amalgam contribute to this problem? It is not clear. Despite the lack of scientific evidence to support that the mercury associated with dental amalgam readily converts into methylmercury, regulatory agencies act on the assumption that it is completely converted and that it contaminates the food chain. As federal and state regulatory goals to lower the maximum level of mercury allowable in water bodies become more pronounced, it is likely that regulations will become more stringent. Though the regulations may appear unduly harsh and non-scientific, it is unlikely the EPA nor Congress will make any fundamental policy changes. Likewise, an attempt by the dental profession to refute the EPA regulatory assumptions would be both complex and costly, and a heavy burden of proof will be required. **CDA**

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Dental Amalgam: Regulating Its Use and Disposal

Teresa J. Pichay

ABSTRACT

Although dental amalgam has been a restorative material for more than 150 years, government regulation of its use and disposal came much later with the creation of new federal laws and agencies. None of the federal laws regulating dental amalgam today were written specifically to regulate amalgam. Instead, these new laws and agencies were created to address broad public safety concerns, where little or no regulation existed before, in the areas of medical devices and drugs and environmental pollution. It is the interpretation and implementation of environmental laws that recently have had the greatest impact on dental practices.

Dental amalgam and its components are medical devices regulated by the U.S. Food and Drug Administration (FDA) under the authority of the 1976 Medical Device Amendments to the Federal Food, Drug, and Cosmetic Act. Dental amalgam was already in use at the time of the 1976 amendments, so it and other existing medical devices were assigned to one of three "classes." Class I devices pose the lowest risk and are subject to the least level of controls. Class II devices are subject to additional special controls because they are devices that pose incrementally greater risk and their safety and effectiveness cannot be adequately controlled by Class I controls. Class III devices are the riskiest devices and have the most controls placed upon them.

Dental mercury is regulated as a Class I device. Dental amalgam alloy (silver, tin, copper and sometimes, other metals) is regulated as a Class II product because of "potential risks that could result from variations in chemical formulation related to percent composition and types of materials."[1] Amalgam in capsules (alloy and mercury that are separately sealed and sold in single-use capsules) has never been classified, but is regulated as a Class II device because one of its components is regulated as such.

In February 2002, the FDA proposed a rule to bring all amalgam products

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The CWA is a 32-year-old law that relies on the concept that "preventive" regulation is the best method to address environmental concerns.

into Class II. The FDA wants to require ingredient labeling and conformance to international standards.[2] Two public comment periods were provided for the proposed rule. The FDA has analyzed the comments, but the rulemaking has been placed on hold until after a forthcoming scientific literature review related to the health effects of dental amalgam in humans is completed.[3] In conjunction with the U.S. Public Health Service and the National Institute of Dental and Craniofacial Research, the FDA has contracted with an independent firm to conduct the literature review, which is expected to be completed in 2004.[4]

Environmental

Wastewater

Dental office wastewater regulations are enforced primarily by state and local agencies in accordance with authority delegated to them under the federal Clean Water Act (CWA). If the EPA finds that a state or local authority has not carried out its responsibilities under the CWA, then the EPA can promulgate or enforce the necessary regulations. The EPA also has the authority to review state water quality programs to ensure compliance with the CWA. States and their subdivisions can also regulate wastewaster under independent state and local laws. However, state regulations must be at least as stringent as federal regulations, and can be more stringent.

The CWA is a 32-year-old law that relies on the concept that "preventive" regulation is the best method to address environmental concerns. This law was enacted during a time when public concern about environmental pollution was very high, and there was strong political consensus for broad environmental legislation. The CWA allows the EPA to set wastewater discharge limits for industries, to set water quality standards for lakes, rivers, and bays, and to manage federal funding for construction of sewage treatment plants. Amendments to the law and recent implementation strategies have led to an evolution from a source-by-source, pollutant-by-pollutant approach to one that is more holistic, considering the physical and biological integrity of the surface waters and not just chemical characteristics.[5]

The EPA uses a series of assumptions or policy judgments that collectively can be referred to as "precautionary principles." These policy judgments may have strong theoretical rationale, but may or may not be supported strongly by scientific data. The EPA's regulatory approach is based on these policy judgments, and recognizes that there are financial and technical limitations, on acquiring the scientific data necessary to ensure the policy judgment is valid. Many industries have mounted well-financed legal challenges to the EPA's regulatory approach, but the courts have held that the agency is not required to support its findings with a high degree of scientific certainty.

With regard to dental amalgam and mercury, the EPA assumes all forms of mercury have the potential to convert to the more toxic and bioavailable methylmercury. This has not been scientifically proven, but it is the basis for the EPA's actions to eliminate or reduce the use of mercury, and to set limits on mercury discharges to the environment. The EPA then sets the standard that state and regional water boards must enforce against local sanitation agencies and other dischargers.

According to the ADA, "EPA's aggressive pollution prevention initiative and CWA implementation measures are the driving forces for the increased regulatory scrutiny ... Neither EPA nor Congress is likely to change a fundamental pillar of its regulatory scheme even if the impact of the regulatory framework is unduly harsh and inefficient in achieving the statutory goals when applied to dentists. There is no simple, cost-effective research project that is likely to convince EPA to exempt dental offices from this regulatory scheme ... Literally hundreds of millions of dollars have been or are being expended by EPA, the states, and industry on many of these issues. Therefore, ADA is unlikely to prevail by simply presenting a new study."[6]

State and regional water quality boards must establish policy and regulations consistent with federal law. The EPA has established a limit of 0.05 mg/l or ppb for surface waters in most states, but as noted, states and local agencies can set more stringent limits. Examples of current discharge limitations are:

- EPA 0.05 mg/l or ppb
- California Toxics Rule 0.025 mg/l or ppb
- Great Lakes 0.0013 mg/l or ppb
- Maine (proposed) 0.0002 mg/l or ppb

It is widely believed that the California Toxics Rule limit will be lowered in the near future.

To provide a sense of how low these numbers are, one part per million is roughly equivalent to a pinch of salt in one ton of potato chips. One part per billion is roughly equivalent to a pinch of salt in one thousand tons of potato chips.

The EPA encourages pollution prevention and source reduction. Source reduction typically involves efforts to eliminate the use of mercury-containing products. Sanitation agencies view pollution prevention and source control as the most cost-effective methods to meet their treatment plant permit limits. Dentists have asked if treatment plants have considered implementing other systems or processes to improve their plants' ability to capture mercury. Plant operators have responded that options have been explored, and that reverse osmosis systems could be effective. However, those systems cost in the millions of dollars, generate their own hazardous waste streams that must be managed and require the use of more land than treatment plants generally have available.

In the past year, the cities of Los Angeles, San Francisco, and Palo Alto have formalized regulatory programs for dental office wastewater. Other communities, especially in the San Francisco Bay Area, are considering the implementation of regulatory programs. For other communities that do not face further restrictions on mercury, an educational campaign on best management practices for dental waste is a likely alternative to regulation.

Regulated Waste

California's hazardous waste laws and regulations, unlike their federal equivalents, apply to dental amalgam. Prior to the adoption of "universal waste" regulations effective March 2003, amalgam waste that could be classified as scrap metal could be recycled and exempted from hazardous waste regulation. Other amalgam wastes that contained very fine particles, such as sludge from the vacuum filter and chairside traps, were regulated as hazardous waste. Hazardous waste regulation limited options for waste disposal and increased regulatory paperwork and oversight.

Under the universal waste Regulations, all amalgam waste can be managed as universal waste, that is, it should be recycled.

Under the universal waste regulations, all amalgam waste can be managed as universal waste, that is, it should be recycled. If the amalgam waste is not recycled, it is considered hazardous waste subject to hazardous waste regulatory requirements. The California Department of Toxic Substances Control determined that amalgam waste meets the criteria to be designated universal waste. These criteria include: (1) the waste is generated by a large number of businesses frequently and in relatively small quantities by each generator; (2) there are systems in place to ensure close stewardship of the waste; (3) the risk posed by the waste is relatively low compared to other hazardous wastes, and (4) regulation as universal waste will promote safe and effective collection and recycling.[7]

The universal waste regulations require adherence to specific amalgam waste management practices. They are:

- Do not rinse amalgam-containing traps, filters, or containers in the sink.
- Do not place amalgam, or amalgam-containing traps and filters with medical waste or regular solid waste.
- Recycle or manage as hazardous waste non-contact and contact amalgam (including extracted teeth with amalgam).
- Recycle or manage as hazardous waste amalgam-containing waste from traps and filters.
- Keep amalgam waste in an air-tight container.

Dental offices should be aware that other mercury-containing products may also be managed as universal waste, such as thermometers, lamps, batteries, and switches in some appliances. CDA

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The Use of CDA Best Management Practices and Amalgam Separators to Improve the Management of Dental Wastewater

Amy Knepshield Condrin, MPH

ABSTRACT

Concerns over the persistence and effects of mercury in the environment, particularly in wastewater, have increased significantly over the past decade. Because mercury is a component of dental amalgam, comprising about 50 percent of amalgam among other metals, in recent years the concern has affected dental practices and even educational curricula in the dental schools. While numbers vary widely from area to area, on average, it is estimated dentistry contributes less than 1 percent of the mercury generated from human activity to the environment.[1] Despite dentistry's low contribution to the environmental mercury load, organized dentistry's position is that dentistry's role as a public health profession includes environmental stewardship, as well as patient safety, and that dental professionals must act responsibly by taking steps to prevent amalgam waste or any potentially harmful materials from entering the environment, no matter how small the amount. In support of this belief, both the California Dental Association and the American Dental Association have developed recommendations for best practice that dental offices should follow when handling dental amalgam waste.[2,3] Many dental schools and auxiliary programs have shown their commitment to minimizing detrimental effects to the environment, evidenced by the fact that most, if not all, have incorporated safe work practices including mercury hygiene procedures as part of clinical coursework. Some local jurisdictions hardest hit by the effects of mercury in wastewater have gone even further to recommend, or even require, the installation of amalgam separators in dental offices. This article will describe the history of BMPs and amalgam separators usage in California, and examine the practical aspects of their usage in reducing the discharge of dental amalgam into waste streams.

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The idea of controlling amalgam waste disposal is not a new one to California. Both the CDA and ADA have recommended environmentally responsible management of amalgam waste for many years.[3] In the early 1990s, the City of San Francisco considered making mandatory the installation of amalgam separators in dental offices. The CDA, in conjunction with the local dental society, worked diligently to encourage San Francisco to promote BMPs instead of separators. More recently, as municipal wastewater treatment facilities, also termed local publicly owned treatment works (POTWs), are facing more stringent discharge limits, they have been forced to look "upstream" for controllable sources of mercury. Although its relative contribution to the environmental mercury load is low, dentistry has been identified as a controllable mercury source. Especially in areas with impaired water bodies, such as the San Francisco Bay Area and Los Angeles, dental offices are facing more rigorous regulatory control programs, some even having to install amalgam separators.

In Los Angeles, a BMP permit program has been implemented which requires regular reporting and a written plan.

In San Francisco, dentists are required to either install an amalgam separator or opt for a strict monitoring protocol. One of the concerns regarding separators in San Francisco involves the massive presence of mercury in the SF Bay from gold mining and mercury mining in the 19th century. The New Almaden mine in San Jose was the largest mercury mine in North America and the tailings leached into the bay. (Almost no mercury was mined east of California.) For this reason, the SF Bay is considered a special body of water, yet EPA regulations make no recognition of this.

Throughout California, local jurisdictions are, at a minimum, starting to require voluntary BMP programs. CDA continues to proactively collaborate with many local dental societies and POTWs in order to ensure consistency and fairness as POTWs enforce stricter discharge requirements on dental facilities connected to the municipal sewer systems.

Additionally, from a different regulatory perspective, in March 2003, the Department of Toxic Substances Control, the state agency in charge of administering and enforcing hazardous waste laws, reclassified dental amalgam waste as a universal waste, which also made mandatory across the state some best management practices recommended by CDA (see BMPs in **Table 1**).[4]

> The key to successful recycling of dental amalgam waste depends on effective collection of the material.

Similar trends to eliminate mercury discharge to the environment have been occurring on the national level. Regional and statewide initiatives in the north, northeast, and northwest have consisted of regulatory approaches to minimizing dental amalgam discharges. The states of Maine, Connecticut, and New Hampshire have enacted laws requiring amalgam separators. Similar legislative attempts have been made and failed in California, New York, and Oregon, but could resurface again. Dental practices in Vermont, Massachusetts, and Rhode Island are being encouraged but are not required to install separators. Massachusetts is enacting regulations on installation which will kick in 2005 or 2006 depending upon the success of voluntary programs. On the regional level, Wichita, Kan., and King County in Washington state have implemented strict regulatory control programs including a separator requirement.

Best Management Practices — What Are They?

Recycling is the preferred method of disposal for many consumer and industrial waste streams — paper and wood products, plastic, metals, chemicals, etc. Like most heavy metals, elemental mercury and silver can be easily collected and recycled in most industrial settings, including dentistry. If not to be recycled, these metals must be disposed as hazardous waste. The key to successful recycling of dental amalgam waste depends on effective collection of the material. Best management practices for amalgam waste disposal, as well as amalgam separator technologies, target amalgam's efficient collection and removal both from wastewater and in solid form. Simply put, best management practices for amalgam waste disposal incorporate both environmental and occupational health control strategies into routine work procedures.

CDA has compiled a list of recommended best management practices for amalgam waste management.[2] These BMPs are designed to eliminate the use of bulk mercury in the dental office, to reduce amalgam waste generated and discharged to the environment, and to provide dental office personnel with practical, concise, and easy-to-follow procedures for handling amalgam waste. Perhaps the most effective and widespread BMP in dentistry has been the increased use of precapsulated dental amalgam over bulk mercury, which has remarkably lowered the amount of waste amalgam generated during a restorative procedure. This one control strategy has resulted in significant improvement in occupational health and environmental impacts.[5] Other BMP strategies include utilizing and maintaining chair and sink traps and filters properly, collecting scrap and contact amalgam for recycling, and training dental personnel. Additionally, CDA recommends the use of amalgam removal technologies, such as sedimentation systems or amalgam separators, in areas where mercury in wastewater discharges is a serious concern. Practices to avoid include placing amalgam waste of any kind (including extracted teeth with amalgams) in the biohazard (red) bag, the trash, or the sharps container; rinsing traps, filters, or screens over or down the drain, or into a wastebasket; disinfecting teeth or any item containing amalgam with any method that uses heat. Refer to **Table 1** for a complete list of CDA's recommended best management practices for amalgam waste management.

Table 1

Best Management Practices for Amalgam Waste

- Do not rinse amalgam-containing traps, filters, or containers in the sink.*
- Do not place amalgam, elemental mercury, broken or unusable amalgam capsules, extracted teeth with amalgam, or amalgam-containing traps and filters with medical waste or regular solid waste.*
- Recycle, or manage as hazardous waste, amalgam, elemental mercury, broken or unusable amalgam capsules, extracted teeth with amalgam, amalgam-containing waste from traps and filters.*
- Keep amalgam waste in an airtight container.*
- Separate excess contact dental amalgam that is retrieved during placement and place in an appropriate container.
- Use chairside traps to capture dental amalgam.
- Change, or clean, chairside traps frequently. Flush the vacuum system before changing the chairside trap.
- Change vacuum pump filters and screens at least monthly or as directed by the manufacturer.
- Check the p-trap under your sink for the presence of any amalgam-containing waste.
- Eliminate all use of bulk elemental mercury and use only precapsulated dental amalgam for amalgam restorations.
- Limit the amount of amalgam triturated to the closest amount necessary for the restoration. Keep a variety of amalgam capsule sizes on hand to ensure almost all triturated amalgam is used.
- Train staff who handle or may handle mercury-containing material on its proper use and disposal.
- Consider the use of amalgam removal technologies, such as sedimentation systems or amalgam separators if you practice in an area where mercury in wastewater discharges is a serious concern.

*Mandatory per California Code of Regulations Title 22.

Efficiency of BMPs and Amalgam Separators

The efficiency and cost-effectiveness of BMPs by themselves has been shown to range up to about 78 percent. In a September 2002 evaluation for the ADA, ENVIRON International Corporation found that a well-managed dental office adhering to CDA's recommended BMPs could reduce amalgam being discharged to the municipal sewer system by as much as 78 percent.[6,7] EPA has estimated that utilization of the chairside traps and vacuum pump filters captures approximately 70 percent of the mercury generated during an amalgam restoration procedure.[8] The numerical cost of BMP implementation is low; however, time and discipline must be devoted to ensure their effectiveness in the dental office.

Amalgam separators target the capture of remaining amalgam particles that escape the traps and filters. Certification by the International Organization for Standardization (ISO) 11143 requires that amalgam separators be capable of reducing the amalgam concentration by 95 percent. Most ISO-certified separators on the market even reduce the levels by 99 percent.[9] Even for dental offices that choose to install a separator, which is considered the best available control technology now, they still may end up with water quality that does not meet the local discharge limits. Some local areas with severely impaired water bodies have initiated either zero-mercury discharge limits or limits which are unattainable by even separator technology. This creates a conundrum for both dental offices and regulators. Water quality regulators in these areas acknowledge that an amalgam separator is the best available technology for controlling mercury discharges in dental facilities. In California, those POTWs which are looking to require an amalgam separator or equivalent recognize amalgam separators as the current best available control technology, and accept that adherence to BMPs and the installation of a separator will exempt a dental facility from any additional requirements.

Table 2

Questions to Ask Your Amalgam Recycler

- What kind of amalgam waste do you accept?
- Do your services include pickup of amalgam waste from dental offices? If not, can amalgam waste be shipped to you?
- Do you provide packaging for storage, pickup or shipping of amalgam waste?
- If packaging is not provided, how should the waste be packaged?
- What types of waste can be packaged together?
- Do you accept whole filters from the vacuum pump for recycling?
- Is disinfection required for amalgam waste?
- How much do your services cost?
- Do you pay for clean noncontact ("scrap") amalgam?
- Do you accept extracted teeth with amalgam restorations?
- Does your company have an Environmental Protection Agency, license or applicable state license to recycle/reclaim this material?
- Does the company use the proper forms required by the EPA and state agencies?
- To whom do you sell recovered mercury and silver from the amalgam waste?

McManus KR, Purchasing, installing and operating dental amalgam separators: practice issues. JADA 134(8):1054-65, Box 2, 2003.

BMPs and Amalgam Separators — Putting Them into Practice

The types of amalgam wastes are defined as the following by the ADA:[3]

Non-contact amalgam (scrap) is excess mix left over at the end of a dental procedure. Many recyclers will buy this clean scrap.

Contact amalgam is amalgam that has been in contact with the patient. Examples are extracted teeth with amalgam restorations, carving scrap collected at chairside, and amalgam captured by chairside traps, filters, or screens.

Chairside traps capture amalgam waste during amalgam placement or removal procedures (traps from dental units dedicated strictly to hygiene may be placed in the regular garbage).

Vacuum pump filters or traps contain amalgam sludge and water. Some recyclers will accept whole filters while others will require special handling of this material.

Amalgam sludge is the mixture of liquid and solid material collected within vacuum pump filters or other amalgam capture devices.

Empty amalgam capsules are the individually dosed containers left over after mixing precapsulated dental amalgam.

When following recommended BMPs or when performing maintenance on the amalgam removal equipment, it is very important to use proper personal protective equipment as necessary such as utility gloves, masks, protective eyewear, and gowns to minimize exposures to the body fluids mixed with the amalgam waste and the amalgam waste itself. Additionally, all personnel should be trained on the proper procedures to follow when performing this work, including cleaning up spills. The procedures should be documented in a written plan.

As previously mentioned, BMPs target the efficient collection and recycling of dental amalgam waste. The first step in this process is to identify a state-approved recycler and then follow any instructions he or she may have in the collection and removal procedures. For example, some recyclers do not accept contact amalgam waste, or if they do, they require it be collected separately from scrap amalgam. Others may accept all forms of amalgam waste in the same container. Therefore, it is very important to follow the recycler's instructions. Consider keeping different types (e.g., contact and non-contact) of amalgam wastes in separate containers as required by your recycler. Refer to **Table 2** for more questions to ask amalgam recyclers.

Amalgam materials should be stocked in many capsule sizes in order to better select the right amount of material for a particular restoration. Non-contact (scrap) amalgam and amalgam capsules should be placed in a wide-mouth, airtight dry container marked "Scrap Dental Amalgam for Recycling." The container lid should be well sealed. When the container is full, it should be sent to the recycler. If there is a spill of amalgam from a capsule, contain it and clean it up immediately with a commercially available mercury spill kit; follow the instructions on the spill kit.

When collecting contact amalgam from disposable or reusable chairside traps, first open the chairside unit to expose then trap. Then, if it is disposable, remove the trap and place it directly into a wide-mouthed, airtight container marked "Contact Dental Amalgam for Recycling." If the trap is reusable, remove the trap and empty the contents into the wide-mouth, airtight container marked "Contact Dental Amalgam for Recycling." Replace the trap into the chairside unit.

(Do *not* rinse the trap under running water as this could introduce dental amalgam into the waste stream). Make sure the container lid is well sealed and when the container is full, send it to a recycler. Traps from dental units dedicated strictly to dental hygiene procedures may be placed with the regular garbage.

Vacuum pump filters should be changed according to the manufacturer's recommended schedule. First, remove the filter and while holding the filter over a tray or other container that can catch any spills, decant as much of the liquid as possible without losing any visible amalgam. Then, put the lid on the filter and place the sealed container in the box in which it was originally shipped labeled "Contact Dental Amalgam for Recycling." When the box is full, the filters should be recycled.

Once the amalgam waste has been collected, it must be removed. As previously indicated, some amalgam waste recyclers have special requirements for collecting, storing and transporting amalgam waste. If you need to find a recycler, check with your city, county or local waste authority to see whether they have an amalgam waste recycling program. Additionally, the ADA has compiled a national directory of amalgam recyclers for reference. **Table 2** provides a list of questions to ask potential recyclers.[10]

The implementation of amalgam separators in a dental office is a very complex process and involves four major steps: purchase, installation, maintenance, and recycling. Amalgam separators come in many different sizes, shapes, and technologies. One size does not fit all. Refer to **Table 3** which contains a listing of ISO-certified amalgam separator models compiled by the ADA.[10] The basic premise of the separator technology is to effectively handle flow without clogging and to allow sufficient time for the amalgam particles to be separated out of the water and into a collection device. The removal technologies available on the market are sedimentation, filtration, ion exchange, centrifugation, or a combination of these. Sedimentation is used in the majority of amalgam separators, which relies on a settling tank which allows solid materials to settle out of the wastewater. These types of separators tend to be larger and require more space than other units. In addition to size constraints, other practical issues to consider when choosing a separator unit include cost, maintenance, reliability, ease of operation, utility requirements, capacity, dental office/building constraints, and regulatory factors. **Table 4** contains a buyer's checklist which outlines many of these considerations.[10]

It is very important to use proper personal protective equipment as necessary such as utility gloves, masks, protective eyewear, and gowns.

The installation of the amalgam separator should only be conducted by a licensed plumber. If the unit is downstream of the vacuum system and requires power, a licensed electrician also should be contracted. Depending on the local area, special permitting under the building code may be required. Consultation with the building owner also is recommended. Oftentimes, dental supply companies can help to initiate and facilitate the installation process. The location of the separator in the office will likely be either chairside or more commonly, as close as possible to the vacuum pump. If the unit is a gravity-fed unit, then it should be installed below grade.

Some difficulties to avoid with field installations include insufficient space or access to preferred installation location; compatibility with and condition of existing piping, local plumbing code interpretations, impact of vacuum system operation, and warranty impacts of existing in-situ equipment. For many offices in large buildings sharing a single vacuum system, the decisions become more complex. In all of these scenarios, replumbing may become necessary. In rare cases, separately plumbed cuspidor units may be required to be replumbed through a separator system.

Each amalgam separator requires ongoing maintenance and recycling to remove the collected amalgam. Maintenance factors, which consist of cost, frequency, ease, impact on treatment, and recycling methods vary significantly depending on the inherent characteristics of the individual amalgam separator unit as well as the individual office activities. For example, amalgam separators that utilize filtration will require filter replacement, and sedimentation units will require the collection tank or canister to be replaced. Annual maintenance costs typically range from $300 to $500, which generally includes the costs to recycle the contact amalgam waste (see **Table 3**). Amalgam waste collected by the amalgam separator should be recycled as described above for contact amalgam, or disposed according to California DTSC hazardous waste requirements.

Summary

In summary, as regulatory initiatives to minimize dental amalgam in wastewater become more widespread,

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Table 3

Amalgam Separator Models by Technology

Brand Name and Manufacturer	Purchase Or Lease Price*	Cost Replacement Parts	Recycling Included	Size in Inches (Depth x Width x Height)	Installation Site	Efficiency† (Certification‡)	Maintenance
Sedimentation							
Guardian Amalgam Collector models Air Techniques 1-800-AIRTECH www. airtechniques.com	Dry vacuum A110 (with Air Technique vacuum system): $1,500; A1200 (with Air Technique vacuum system): $1,500; wet vacuum A1300 (single pump system): $2,995; A1400 (dual pump system): $3,225	Replacement kit: $750	Yes	6.25x1.5 x7.5	In-line at out of air/ water separator (requires air/water separator); drains by	>95% (ISO 11143-certified)	Clean daily; replace collection container after one pound waste collection (usually six months)
Amalgam Collector models R&D Services 1-800-816-4995 1-206-525-4995 www.theamalgam collector.com	CH9 or CH12; $459; CE15 or CE18: $695; CE24: $1,250	Not applicable (canister replacement optional)	No	CH9: 6x6 x9 CH12: 6x6x12 CE15: 6x6x15 CE18: 6x6x18 CE24: 8x8x24	CH9 or CH12: chair-side in-line; CE15, CE18, CE24: in-line	>95% (ISO-11143-certified; King County [Washington] Industrial Waste Program-approved)	Adjust two external valves weekly; monitor liquid level and decant as needed to keep tubing 3 inches above sediment; add sterilant two to three times/week; sludge removal after two to five years depending on workload
BullfroHg Dental Recycling North America 1-800-360-1001 www.drna.com	$50/month lease (two year minimum; $695 purchase	Included in lease	Yes (lease); $450 (purchase) annual kit cost	8.5x8.5 20.5	In-line; AC power supply needed to pump settled effluent	98.3%-99.6% (ISO 11143-certified)	Replace separator annually

Table 3 continued

Brand Name and Manufacturer	Purchase Or Lease Price*	Cost Replacement Parts	Recycling Included	Size in Inches (Depth x Width x Height)	Installation Site	Efficiency† (Certification‡)	Maintenance
ECO II (Economy System Type II) Pure Water Development 1-877-638-2797 1-305-663-2989 www.ecotwo.com	$550 plus $54/month service fee	—	Yes	8.7x8.7x13.8	Chairside or in-line	>95% (ISO 11143-certified; King County [Washington] Industrial Waste Program - approved)	Apply cleaner daily (recommended); replace separator annually
REB models Rebec Simple Solutions 1-800-569-1088 www.rebecsolutions.	REB 1000: $1,895; REB 5000: $1,895; REB 7000: $1,895; REB 9000: $2,995	REB 1000: $395; REB 5000: $395; REB 7000: $495; REB 9000: $395	Yes	REB 1000: 8x22x23.5 REB 5000: 6x9.5x6.5 REB 7000: 6x20x6.5 REB 9000: 10x26x24	In-line	96.9% (ISO 11143-certified; King County [Washington] Industrial Waste Program-approved)	Annual recycling should be scheduled with the manufacturer
Sedimentation/Filtration							
Avprox AS-9 American Dental Accessories 1-800-331-7993	$229.95	Replacement filter: $78.95	No	5.5x5.5x16	In-line	95%-99% (ISO 11143-certified)	Replace every three to eight months depending on workload
MSS models Maximum Separation Systems 1-800-799-7147 www.amalgam separators.com	MSS Model 1000 (ﬃ11 chairs): $968; MSS Model 2000 (12-22 chairs) includes two settling tanks: $1,395	Settling tank: $165; tank recycling fee: $185	No	1000: 15x18.5x24 2000: 15x18x28	In-line AC power supply needed for control panel	>95% (ISO 11143-certified; King County [Washington] Environmental Choice Program certificate§)	Replace settling tank annually; nonfoaming cleanser (recommended)
Sedimentation/Filtration/Ion Exchange							
ARU-10 Hygenitek 1-866-494-3648 www.hygenitek.com	$499 (Service plan option: $39/month	Media filter canister¶: $99; sedimenta-tank: $59	Yes	12x12x21	In-line	99.99% (ISO 11143-certified; King County [Washington] Industrial Waste Program-approved)	Apply cleanser daily; service plan: six-month cycle; replace media filter canister: six months; replace sedimentation tank: six-24 months depending on workload

Table 3 continued

Brand Name and Manufacturer	Purchase Or Lease Price*	Cost Replacement Parts	Recycling Included	Size in Inches (Depth x Width x Height)	Installation Site	Efficiency† (Certification‡)	Maintenance
Hg separator models SolmeteX 1-508-393-5115 www.solmetex.com	Hg5 (one-10 chairs): $695; Hg10 (>10 chairs): $7,450	Hg5 filter resin cartridge; $150; Hg10 filter: $150; Hg10 resin cartridge: $275	No	Hg5: 10x13x29 Hg10: 48x24x48	Hg5: in-line line; hg10: after vacuum and sewer drain AC power supply needed	Hg5: >98% King County [Washington] Industrial Waste Program - approved): Hg10: <.02 parts per billion mercury in effluent	Hg5: Replace filter resin cartridge every six months; Hg10: weekly oxidizer tablet treatments; replace filter and resin cartridge quarterly
Merc II Bio-Sym Medical	$1,295	Replacement ment unit installation and disposal: $495	Yes	13x7x8	Chairside or in-line	>95% (ISO 11143-certified; King County [Washington] Industrial Waste Program-approved)	Replace unit annually
MRU models Dental Recycling North American	MRU 10c; MRU 100v	Costs included in lease fee	No	10c: 12x16x24 100v: 12x16x24	In-line In-line	>95% (ISO 11143-certified; King County [Washington] Industrial Waste Program-approved)	Replace separator, filter and absorbant column every six-12 months depending on workload
Rasch 890 models AB Dental Trends 1-360-354-4722 www.amalgam separation.com	890-1000: $1,190; 890-6000: $666	Canister: $596	No	890-1000 12.75x10.25 x28.5 890-6000: 12.25x9.0 x5.12	In-line	>95% (ISO 11143-certified; King County [Washington] Industrial Waste Program-approved)	Replace canister every 18 months depending on workload

*Manufacturer's suggested retail price as of 2003.

†According to manufacturer.

‡ International Organization for Standardization Specification 11143 reuqires 95 percent removal.[9]

§ Canadian program.

¶ Costs apply only to customers who do not take the service plan option.

McManus KR, Purchasing, installing and operating dental amalgam separators: practice issues. JADA 134(8):1054-65, Table 1, 2003.

Table 4

Amalgam Separator Buyer's Checklist

Factor	Comments
Office Considerations	
Operatories (number of chairs)	Offices with four or more chairs should consider central, not chairside, units
Number of amalgam restorations placed or removed per day Office operations (number of days per week)	Offices that perform more than 40 amalgam-related activities per week may need a unit with a large storage capacity
Dental practices located in your building Number and type Do you own or lease your space? Would lease stipulations affect installation of a separator? What terms are included for utilities maintenance?	Consider combining similar flows with other offices if possible to share or reduce costs Confirm that plumbing system modifications are consistent with lease provisions
Do you operate wet/dry cuspidors?	Wet cuspidors should be plumbed to a separate line if possible; if not possible, separator should have a holding or surge tank with sufficient capacity
Building Configuration	
Is sufficient space available to the air/water separator drain-line and sewer-line connection? Access to electrical power (voltage) Size and material of existing sewer connection	Certain separators rely on gravity flow and require adequate space from the air/water separator line to connect to the drain system Check the power supply needs for each model under consideration Separator installation should not constrict existing vacuum or drain-line requirements
Vacuum System	
Do you operate a wet or dry vacuum system?	Wet-ring vacuum pumps generate additional water flow that will require greater storage capacity
Will any warranty be affected by third-party installations?	Some warranties may be invalidated if parts of the system are modified by third parties
Is the vacuum system dedicated to your office?	Group practices that share vacuum systems may wan to replumb or split costs associated with amalgam separator
Location of the vacuum system Basement or office?	Office-level systems may require smaller units
Space available adjacent to vacuum system (height, length and width)	Access to upstream piping is critical for maintenance and inspection of systems
Separator Specifications	
Recommended installation location Capacity (in chairs) Maximum flow rate Life-cycle cost	Evaluation model information against the specific conditions for the practice (such as space, plumbing, access, workload, regulatory considerations)
Other considerations	
In your group practice, who is responsible for Equipment servicing and maintenance? Water/sewage/utilities? Amalgam collection/recycling?	Group practices that share vacuum lines may need to discuss how the addition of an amalgam separator will affect allocation of cost and responsibilities, as well as make arrangements for access to the unit

McManus KR, Purchasing, installing and operating dental amalgam separators: practice issues. JADA 134(8):1054-65, Box 1, 2003.

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dentistry needs to heed the growing concerns about mercury coming from dental offices. All dentists should at a minimum follow CDA's best management practices, some of which are required by state law. Also, in areas hardest hit by the environmental mercury problem, it is recommended dentists put their environmental concerns into action by proactively installing an amalgam separator and ensuring that all amalgam waste is collected and sent to a reputable recycling facility. These actions send a great message to patients and to the public, demonstrating dentists care about the environment. CDA

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The Effect of Amalgam Separators on Mercury Loading to Wastewater Treatment Plants

Mark E. Stone, DDS

ABSTRACT

Mercury (Hg) release from dental offices has become an acute issue for the dental profession and has resulted in efforts by regulators to mandate both the use of Best Management Practices (BMPs) as well as the installation of amalgam separators. Concern has been expressed by some regarding the efficacy of amalgam separators in reducing the Hg loads to wastewater treatment plants (WWTPs). Data from several Publicly Owned Treatment Works (POTWs) serving areas with installed bases of separators suggest these devices can substantially reduce Hg burdens to WWTPs. The data consists of Hg levels in sewer sludge (biosolids) and in some cases includes Hg concentrations in WWTP influent and effluent. Data comes from various geographical locations, and suggest separators can have a positive effect in reducing the amount of Hg reaching WWTPs.

The Mercury (Hg) content of dental-unit wastewater has become increasingly important to the dental profession and regulations limiting its release into the environment are becoming more pervasive. Hg is a toxic element that persists in the environment and bioaccumulates in the food chain. It remains among the top 20 hazardous substances listed on the Agency for Toxic Substances and Disease Registry (ATSDR)/United States Environmental Protection Agency (EPA) priority list. An EPA conference on Hg in the Midwest[1] highlighted the need to keep Hg out of medical waste and out of the wastewater stream. Hg is present in rain, water, soil, and fish,[2] and the consumption of fish contaminated with Hg represents the single most important source of human

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Disclaimer / The views expressed herein are those of the author and do not necessarily reflect the official policy or position of the Departments of the Navy or Defense, nor the U.S. government.

exposure.[2-4] The recently implemented Great Lakes Water Quality Guidance criteria[5] call for an ambient Hg water level of 1.3 ng/liter (parts per trillion, ppt) for the protection of wildlife. Such guidelines have become a force for lowering the release of pollutants into WWTPs.

While dentistry has been identified as a source of anthropogenic Hg emissions to the environment, by far the largest anthropogenic releases come from combustion sources.[2] The burning of coal to produce electricity is responsible for 33 percent of U.S. Hg emissions.[2] Hg released from the combustion of coal is deposited into lakes, rivers and streams where microorganisms in the sediments, especially sulfate-reducing bacteria, transform it into methyl Hg. In this way, Hg from coal enters the food chain. The planned regulation of Hg releases from coal-fired power plants under the "Clear Skies Initiative" leaves dentistry as one of the few unregulated sources remaining.

The regulatory authority for the management of wastewater arises from the Clean Water Act (CWA), signed into law by President Nixon in 1972. This act created the National Pollution Discharge Elimination System (NPDES) which issues permits to entities that discharge into receiving bodies of water. POTWs are issued permits that impose discharge limits for a number of pollutants including Hg. POTWs retain the ability to set their discharge limits at or below those set forth in NPDES permits.

A survey conducted by the Association of Metropolitan Sewerage Agencies (AMSA) taken at the 1998 AMSA/EPA Pretreatment Coordi-nator's meeting showed the average local discharge limits for industrial discharge of Hg to be 0.0875 mg/liter (n=42, range=0.00002-to-2 mg/liter). Two agencies did not have local limits for Hg. One agency had a narrative pollution prevention standard for Hg, and one agency had a tiered Hg limit based on flow rates from facilities. The variability in local regulations governing wastewater has the potential to create confusion for dental treatment facilities attempting to conform to regulatory requirements.

The goal of sewage treatment is to separate harmful material from the water that carries it. WWTPs are designed to remove organic wastes, not toxic chemical pollutants including Hg and other heavy metals. WWTPs use microorganisms to digest organic wastes in an "activated sludge" process, and the microorganisms are vulnerable to effects of toxic chemicals. Chemicals that disrupt the microbial breakdown of organic wastes impair the operation of the plant. Sludge produced from WWTPs has economic value and in many facilities is sold for use as a soil conditioner or fertilizer. Sludge containing high concentrations of toxic material cannot be used for agricultural application and must be disposed of as hazardous waste, a costly and burdensome process.

The goal of sewage treatment is to separate harmful material from the water that carries it.

Human health concerns are the primary force driving lower discharge limits for Hg. Several large-scale longitudinal studies have shown that even chronic low-dose exposure may be harmful, especially to the fetus and the developing nervous systems of children.[6,7] The primary mode of exposure to humans is through the consumption of fish and the human brain is the organ most critically affected.[8-10] The number of states that have issued fish consumption advisories due to the Hg content of fish has risen from 27 in 1993 to 45 in 2002. Additionally, 19 states have issued statewide fish consumption advisories for all their lakes and rivers.[11] The Hg in fish is almost entirely in the form of methyl Hg which has a bioconcentration factor of 10 million. Moreover, Hg in the environment is able to bioconcentrate three-to-10 times across each trophic level of the food chain.[12] The EPA has determined the reference dose for methyl Hg to be 0.1 µg/kg body weight/day.13 A reference dose is defined as an estimate of a daily exposure to humans that is not likely to produce adverse effects on health when exposure occurs over a lifetime.

Historically, allowable Hg limits tend to be adjusted downward as analytical methods become more sensitive. Until recently, the method of choice for the analysis of Hg in water was EPA Standard Method 245.1.[14] This cold vapor atomic absorption spectrometry technique is based on the ultra-violet light absorption by Hg vapor (253.7 nm) to determine Hg levels. The typical detection limit for this method is 0.2 µg/liter (parts per billion, ppb). NPDES discharge limits for Hg were, until recently, based upon the detection limit of this standard method. In May 1999, the EPA Office of Water promulgated a new standard method for the analysis of Hg in wastewater. Method 1631 Revision E[15] is for the low-level measurement of Hg in filtered and unfiltered water by oxidation, purge and trap, desorption, and cold vapor atomic fluorescence spectrometry. Method 1631 allows for the determination of Hg at 0.5 ng/liter (parts per trillion, ppt), and has improved accuracy and precision at low Hg levels when compared to previous methods. In addition, it allows for Hg determinations at ambient water quality criteria levels for the first time. Method 1631 has four components: Sample preparation involves a chemical "cleaning" step (oxidation-reduction) to produce volatile elemental Hg in an aqueous solution. The Hg is purged from the aqueous solution onto a gold-coated sand trap. The trapped Hg is thermally desorbed into the cell of a cold-vapor atomic fluorescence spectrometer. The 400-fold decrease in the detection limit for Hg achieved with standard Method 1631 has resulted in dramatically lower discharge limits for POTWs. As a result, POTWs have "gone upstream" to look for ways to decrease the Hg levels that reach their plants. An unintentional consequence of this regulatory design is that local POTWs have become de facto regulators.

It is estimated that dental facilities in the United States used 40 metric tons of Hg in 1997.[16] As other industrial sectors cut back on the use of Hg, dentistry becomes a larger target for regulatory scrutiny. Although the number of amalgam restorations continues to decrease, driven largely by the desire for esthetic tooth-colored restorations, amalgam is still a very widely used restorative material: 66 million amalgam restorations were placed by U.S. dentists in 1999.[17] The Seattle Metro Study[18] and a later study by Barruci et al.[19] reported that 11 percent to 14 percent of the Hg load to local sanitary districts originates from dental clinics. Other studies have estimated the contributions to be as high as 80 percent.[20] Several studies have examined the environmental aspects of Hg release from dental-unit wastewater. Collaborative efforts by Naleway et al.[21] and Cailas et al.[22] were the first to systematically characterize the dental amalgam-wastewater stream. A related study demonstrated the presence of significant levels of dissolved (<0.45 µm) Hg in dental-unit wastewater, and established that dissolved Hg concentrations can be high enough to violate some local Hg discharge limits.[23]

Industrial wastewater-treatment technologies have been developed to address specific manufacturing applications.[24] However, the development and implementation of waste-treatment technologies for dental-operatory wastewater is a relatively new field. Developing effective, non-toxic, and cost-effective treatments has been difficult due to the small quantity of dental-operatory wastewater generated and its heterogeneous nature.

The International Organization for Standardization (ISO), a network of the national standards institutes of 148 countries, is a non-governmental organization

As other industrial sectors cut back on the use of Hg, dentistry becomes a larger target for regulatory scrutiny.

and the world's largest developer of standards. The ISO developed standard for amalgam separators,[25] ISO 11143, is being used increasingly by POTWs as a minimum requirement of separator performance. ISO 11143 requires amalgam separators to remove at least 95 percent of amalgam particulate when the separator is subjected to the test method specified in the standard. The ISO test for amalgam removal efficiency uses 10.00 gram samples of amalgam particles made from three different particle size ranges. Sixty 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. An important caveat to this standard is that certification is based on removal of particles and not on the concentration of Hg in the effluent. Therefore, the installation of an ISO certified separator does not necessarily mean a dental clinic will meet POTW discharge limits. The state of Minnesota and the Narragansett Bay Commission of Rhode Island have gone one step further by requiring separators to remove 99 percent of the ISO amalgam test sample. The American Dental Association has published an evaluation of 12 commercial separators utilizing the ISO 11143 protocol.[26] The separators in the ADA study have efficiencies ranging from 96.06 percent to 99.99 percent, and all have passed the ISO certification protocol. The EPA has developed a more rigorous standard, Protocol for the Verification of Hg Amalgam Removal Technologies[27] that uses a concentration-based criterion. However, only one vendor has used this protocol to certify their separator as of this date.

This paper has two objectives. First, to give an overview of the properties and composition of dental-unit wastewater and secondly, to gauge the effectiveness of separators in lowering Hg levels at WWTPs.

Characterization of Dental-Unit Wastewater

Wastewater produced in the dental office is a heterogeneous mixture of nearly all the materials used by dentists and their staffs together with tissue, blood, saliva, and microorganisms. Hg in dental-unit wastewater ranges from large sized amalgam particles to submicron Hg containing colloidal particulates. Particle size distribution experiments have shown that 90 percent of the Hg is located in particles larger than 10 microns.[21,22] Ninety-seven-point-three percent of the Hg in settled wastewater samples taken directly from the dental chair is in the form of elemental Hg (Hg^0) bound to particulate. Hg is also present in the following forms: ionic Hg (Hg^{+2}), dissolved elemental Hg (Hg^0) and monomethyl Hg (MeHg).[28,29] Mean concentrations from settled wastewater taken directly at the chair (**Table 1**) are: Total Hg 21.438 mg/liter (ppm), MeHg 277.74 ng/liter (ppt), Hg^0 24.06 µg/liter (ppb), Hg^{+2} 54.00 µg/liter (ppb) and Hg^0 bound to amalgam particulate 21.360 mg/liter (ppm).[28]

Table 1

Concentrations of different forms of mercury in chairside dental-unit wastewater samples. Hg(T) is total mercury, MeHg is monomethylmercury, Hg(°) is elemental mercury, $Hg(^{+2})$ is ionic mercury, and Amalgam bound Hg(°) is elemental mercury bound to amalgam particulate.

Sample ID	Hg(T), mg/liter	MeHg, ng/liter	Hg(0) µg/liter	Hg(+2), µg/liter	Amalgam bound Hg(0), mg/liter	% Amalgam Bound Hg(0)
#1	43.081	444.54	17.22	144.96	42.918	99.62
#2	0.828	96.19	28.31	13.97	0.786	94.88
#3	79.751	583.58	21.34	84.22	79.645	99.87
#4	3.010	225.85	27.87	54.09	2.928	97.27
#5	1.005	167.40	22.43	12.14	0.970	96.54
#6	0.953	148.91	27.22	14.65	0.911	95.59
Mean	21.438	277.74	24.06	54.00	21.360	97.30
SD	33.08	192.76	4.46	53.08	33.04	2.07

(mg/liter equals parts per million,µg/liter equals parts per billion, and ng/liter equals parts per trillion.)

Table 2

Residual mercury levels and Toxicity Characteristic Leaching Procedure (TCLP) analysis of dental wastewater vacuum lines

Location	Pipe Type	Pipe Size ID	Residual Hg	TCLP Hg
Virginia	Copper	¾ inch	1.1 g/kg (n=5, SD=0.4)	0.019 mg/L (n=2, SD=0.002)
Maryland	PVC	2 inch	139 g/kg (n=4, SD=27)	0.304 mg/L (n=3, SD=0.087)
Maryland	PVC	1½ inch	8.1 g/kg (n=3, SD=0.132)	0.035 mg/L (n=4, SD=0.019)
Maryland	PVC	½ inch	N/A	0.129 mg/L (n=3, SD=0.068)
Illinois	PVC	1 inch	3.3 g/kg (n=9, SD=0.9)	0.089 mg/L (n=4, SD=0.029)

To help determine if a waste is hazardous, the EPA designed a laboratory analysis called Toxicity Characteristic Leaching Procedure (TCLP) which determines the mobility of analytes in an acetic acid buffer solution. The concentration of regulated analytes in the extract determines the toxicity characteristic of a sample, and therefore whether it is subject to disposal regulations under the Resource Conservation and Recovery Act (RCRA). The test was designed to predict whether landfill wastes might leach dangerous levels of chemicals into ground water. TCLP regulatory levels exist for 40 different toxic chemicals. The TCLP limit for Hg is 0.2 milligrams per liter, mg/liter.

In one documented case, concentrations of dissolved Hg species collected from the entire clinic were high enough to exceed POTW discharge limits.[23] Total Hg levels in the dental wastewater from this large 117-chair dental treatment facility averaged 3.905 mg/liter (n=6, SD=0.274) with dissolved Hg levels averaging 0.368 mg/liter (n=6, SD=0.64), almost 7.4 times higher than the POTW mandated discharge limit of 0.05 mg/liter. As a result, the clinic was disconnected from the sanitary district sewer lines and forced to collect its dental-unit wastewater in 55-gallon drums. The clinic spent $900 to dispose of each 55-gallon drum of dental wastewater as hazardous waste for an estimated annual cost to the facility of more than $150,000.

The average daily Hg loading to dental-unit wastewater is exceedingly variable and in one study was seen to average 0.484 grams per chair per day (n=25, SD=0.420). Mean Hg loadings from a dental chair at one clinic were seen to average over 2 grams of Hg per day. The high density of amalgam (the specific gravity of dental amalgam being 11.6) results in average settling velocities ranging from 16.56 to 65.7 cm/hour, with more than 90 percent of amalgam particulate settling in two hours.[22]

A critical consequence of this swift settling is deposition of amalgam particulate in the wastewater lines leaving the dental chair. Determination of residual Hg levels in dental vacuum lines (**Table 2**) demonstrated Hg levels averaging 29.6 grams/kg of pipe (range=0.710 grams/kg to 177 grams/kg, SD=55.4).[30] Toxicity Characteristic Leaching Procedure analysis (defined in EPA Method 1311 and used to help determine if a waste is hazardous[31,32]) demonstrated substantial levels of Hg leaching out of the lines (**Table 2**). Hg levels in the leachate of one sample were high enough to meet the criteria of hazardous waste and suggest that dental wastewater lines might serve as a reservoir of Hg that can leach over time. Oxidizing line cleaners used in some offices to disinfect wastewater lines can mobilize Hg from amalgam particulate[33,34] and this may be true for the Hg in amalgam sludge present in wastewater lines.

Amalgam Separator Studies

Data demonstrating the efficacy of amalgam separators in reducing Hg influent into WWTPs comes from studies at five different locations and are summarized below. The locations include: (1) Toronto, Ont., (2) Minneapolis/St. Paul, Minn., (3) Duluth, Minn., (4) Great Lakes, Ill. and (5) Denmark.

> The average daily Hg loading to dental-unit wastewater is exceedingly variable.

Toronto, Ont.

Toronto lies on the northwestern shores of Lake Ontario and is the largest city in Canada. It became the fifth largest city in North America on Jan. 1, 1998, with the amalgamation of the six former municipalities into a metropolitan area with a combined population of more than 2.4 million. This "new" city has dental practices numbering more than 1,100. On July 6, 2000, the Toronto city council adopted a new sewer use bylaw. As originally passed, the bylaw required dental offices to submit a pollution prevention plan by Dec. 31, 2001, install and maintain amalgam separators by Jan. 1, 2002, and mandates an Hg discharge limit of 0.01 mg/liter effective June 30, 2002, (later extended to Nov. 1, 2002).

The Pollution Prevention Plan submission required in the bylaw is to include information on the type of separator to be installed, frequency of maintenance and service, plumbing schematics, standard operating procedure for handling the waste generated from the separator, and the storage, handling, disposal of scrap amalgam.

Since the installation of separators and the use of "Dental Amalgam Best Management Practices," there has been a 58 percent reduction in Hg levels in WWTP sludge in the four plants.[35] The total average monthly mass of Hg in the combined sludge at all four plants had been reduced from 17 Kg to 7 Kg per month. Plant by plant reduction rates varied from 44.8 percent to 74.3 percent. Data was obtained at a time when compliance with the bylaw was estimated to be 800 out of the 1,100 or so dental clinics.[35] Full compliance with the bylaw is estimated to produce a 79.9 percent reduction in the Hg in sewer sludge on a monthly basis.[35] Applying the Toronto Sewer District Hg removal rate data to the 133,000 dental clinics in the U.S. implies that universal implementation of amalgam separators would prevent the 22.1 tons of Hg from ending up in sludge at WWTPs.[35]

Minneapolis and St. Paul, Minn.

The Metropolitan Council of Environmental Services (MCES) is the POTW that serves the Minneapolis/St. Paul metropolitan area of Minnesota. MCES collects and treats wastewater at eight regional treatment plants, processing more than 300 million gallons of wastewater every day from more than two million residents in 103 communities. MCES WWTPs operate at 99 percent compliance with their permit requirements. In 2001, MCES collaborated with the Minnesota Dental Association (MDA) in two related studies: A community-wide dental Hg investigation and an evaluation of amalgam separators and dental

Table 3

Western Lake Superior Sanitary District (WLSSD) Hg data for years 1995 to 2003

The top half of the table is concentration data in nanograms (ng) per liter for wastewater and milligrams per kilogram for sludge. The bottom half of the table is load data in grams/day. (Data courtesy of Tim Tuominen, chemist for the WLSSD.)

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003
Influent Hg in ng/liter	180	160	150	160	120	100	90	80	106
Effluent Hg in ng/liter	20.6	15.3	11.2	10.1				1.9	2.3
% Removal	88.6	90.4	92.5	93.7				97.6	97.8
Sludge Hg in mg/kg dry	1.3	0.99	0.75	0.84	0.64	0.45	0.47	0.32	0.32
Separators installed		3				11	11	20	6
YEAR	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Influent Hg in grams/day	28	26	22	24	18	15	13	12	14
Effluent Hg in grams/day	3.1	2.2	1.5	1.3				0.27	0.30
% Removal	89.3	91.2	93.3	94.4				97.8	97.9
Sludge Hg in grams/day	44.6	44.5	24.0	29.5	22.2	16.3	10.9	11.35	10.7
Separators installed		3				11	11	20	6

Hg loading to sanitary sewer study.[36,37]

The community-wide studies evaluated Hg loading from dental clinics with and without amalgam separators. It took place in the cities of Hastings and Cottage Grove and included the participation of 24 of 25 dentists in these communities. Amalgam separators were in place for three months. The second study, evaluation of amalgam separators, took place in seven general dental practices and looked at five separator models. There were 87 cumulative weeks of testing with 275 days of wastewater monitoring. The community-wide study was able to demonstrate Hg reductions of 29 percent and 44 percent and is based on reductions of Hg in WWPT sludge when separators were installed at community dental practices.[36] The second study determined the discharge of Hg per dentist to be 234 mg/day. Separators removed substantial quantities of Hg from dental clinic wastewater ranging from 91 percent to 99 percent removal efficiencies, measured as Hg not already captured in the chairside traps.[37]

Duluth, Minn.

Duluth is a growing metropolitan area of 87,000 people located on the shores of Lake Superior. Duluth has a thriving seaport hosting more than 1,000 ships per year. The Western Lake Superior Sanitary District (WLSSD) serves the Duluth area and together with Seattle, was one of the first POTWs to look seriously at ways to limit the amount of Hg coming into their WWTPs. Duluth is home to roughly 50 general dental practices with a 100 or so dental professionals. The WLSSD program is voluntary and relies on the good will of dental professionals and staff, state (MDA) and local dental societies. The program began as an educational effort to train personnel in proper disposal of dental Hg from chairside traps and vacuum pump filters. Later, WLSSD installed amalgam separators in 35 of the regional dental practices. Additionally, a small business waste collection system was set up to recycle photographic fixer, all types of amalgam and lead foils from radiographic films. The fruits of the WLSSD effort (**Table 3**) include Hg reductions in WWTP influent from a high of 0.18 pounds per day in 1993 to less than 0.02 pounds per day in 2002.[38] Hg concentration in the treated wastewater leaving their plant decreased from 20.6 ng/liter in 1995 to 1.9 ng/liter in 2002.[38] Hg levels in biosolids decreased from over 2.5 mg/kg sludge to a low of 0.19 mg/kg sludge.[38] Credit for these dramatic decreases goes to Tim Tuominen, a chemist for the WLSSD, who has toiled diligently in this area for more than 10 years.

Great Lakes, Ill.

The Naval Training Center at Great Lakes, Ill., is home to the Navy's only recruit in-processing facility (boot camp) and trains more than 50,000 recruits per year. In addition, the base houses an advanced training center within the Service School Command. Many recruits hail from areas where access to dental care is limited, and some require extensive restorative work, most of which is completed utilizing amalgam. The base has five clinics and more than 200 dental treatment rooms and utilizes 5,063 double spill amalgam capsules per month, which amounts to approximately 27 kg of Hg per year.

Like many other large military installations, the base at Great Lakes has a history of environmental issues, Hg exceedances being just one. The base has assiduously worked to correct past inadequacies and continues to labor closely with its POTW, the North Shore Sanitary District (NSSD), which operates the wastewater treatment plant serving the base. An estimated 20 percent of the influent to the plant comes from the base. NSSD enforces an "end of pipe" discharge limit for Hg of 0.5 µg/liter (parts per billion, ppb). This limit is expected to drop to 0.1 µg/liter in the near future. In an effort to determine the cause of the Hg exceedances, Hg spikes in excess of POTW discharge limits, (up to 54 exceedances per year) upstream and downstream composite sampling was completed by the base engineering department. Sampling data showed Hg levels in excess of the 0.5 µg/liter discharge limit were frequently measured in manholes downstream of dental treatment facilities. NSSD then required the base to install Hg pretreatment systems (amalgam separators) in all clinics.

As required by the EPA, NSSD routinely monitors Hg levels in the sludge produced by its WWTPs. WWTP sludge is applied to land as a fertilizer and the sale of sludge can generate revenue for the POTW. The EPA sets limits for various pollutants in sludge, and POTWs are required to keep detailed data on the amount of pollutants, including Hg. Our research institute obtained the database of Hg levels for POTW sludge and compared them to the date when the amalgam separators were installed in naval base dental clinics. Since 1996, when the first system was installed at the largest clinic, there has been a 52 percent decrease in Hg levels. The Hg levels in the biosolids, when plotted in a graph, trend downward and may reflect the gradual dissolution of Hg in the sewer lines. Over the years, Hg exceedances have fallen from a high of 54 per year down to three.

While data showing the effect of amalgam separators on Hg loadings to WWTPs cannot yet be seen as categorical, it strongly suggests that separators can play an important role in decreasing the amount of Hg reaching POTW facilities.

Denmark

Denmark, a country roughly twice the size of Massachusetts, has been active in the environmental aspects of dental amalgam for many years. Dr. Dorthe Arenholt-Bindslev, a faculty member at the University of Aarhus Dental School, published one of the earliest papers to define the role on dental amalgam in Hg contamination of the environment.[39] Hg accumulation in Danish WWTPs has raised concern and led to the adoption of Hg reduction policies across all industries including dentistry. A Danish sampling study measuring Hg release from 20 dental offices demonstrated that in dental clinics without separators, a mean of 250 mg of Hg was being discharged per dentist per day.[40] Dental clinics with amalgam separators showed a mean Hg discharge to the sewer system of 35 mg of Hg per dentist per day — an 86 percent reduction.[40] Seventy-three percent of Danish counties responding to surveys reported that separators have been installed in all dental offices.[40] Twenty-eight percent of the responding counties had no plans to mandate separators, and 12 percent of the counties did not respond to the survey.[40] In half of the wastewater treatment plants surveyed in her study, a statistically significant decrease in the Hg levels in sludge from 14 percent to 80 percent was shown.[40] In a number of WWTPs, data showed a gradual decline in Hg loads in WWTP sludge.

Conclusion

While data showing the effect of amalgam separators on Hg loadings to WWTPs cannot yet be seen as categorical, it strongly suggests that separators can play an important role in decreasing the amount of Hg reaching POTW facilities. More definitive evidence may soon be available with the completion of an ongoing effort conducted by the Association of Metropolitan Sewerage Agencies (AMSA). AMSA is a trade organization representing the interests of wastewater treatment agencies that serve the majority of the sewered population in the United States. The AMSA Hg working group committee is undertaking a multi-center investigation of separator efficacy that is characterizing Hg levels in both the influent and effluent of wastewater treatment plants, and also is quantifying Hg levels in primary and secondary sewer sludge. The AMSA effort will help provide further evidence for the efficacy of amalgam separators.

In several areas of the country, state and local dental societies are working closely with local POTWs to control the release of heavy metals into sanitary sewer systems. The ADA has taken a proactive role with the publication of Best Management Practices for the dental office. Dentistry has a long and storied history of preventive care and service to the community. Fluoride, sealants, outreach and education are but a few examples of dentistry's contributions to society. This spirit of prevention and community service can now be seen extending to the environment. CDA

To request a printed copy of this article, please contact / Mark E. Stone, DDS, Naval Institute for Dental and Biomedical Research, 310A B St., Building 1-H, Great Lakes, Ill., 60088.

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Are There Acceptable Alternatives to Amalgam?

J. Rodway Mackert, Jr., DMD, PhD, and Michael J. Wahl, DDS

ABSTRACT

Amalgam has been the material of choice for restoring posterior teeth for more than 100 years. The past 25 years have witnessed significant advances in restorative materials themselves and in the bonding systems for retaining a restoration in the prepared tooth. As a result, there has been a shift toward resin composite materials during this same period because of concerns about the esthetics and biocompatibility of dental amalgam. In addition, other materials such as glass ionomer cements, ceramic inlays and onlays, and gold alloys have been used as alternatives to amalgam. This article will review recent studies on the longevity and biocompatibility of these alternatives to dental amalgam.

For more than 100 years, amalgam has been the material of choice for the filling of posterior teeth. More than 75 percent of dentists surveyed in 2001 placed amalgam.[1] Dentists in the United States placed about 71 million amalgam restorations versus only about 46 million posterior composite restorations in 1999, about a 60 percent amalgam to 40 percent composite resin ratio.[2]

Data is limited, but glass ionomer, gold, and ceramic restorations combined probably comprised about 1 percent of all fillings placed by United States dentists in 1999.[2] Still, the use of resin composites and other amalgam alternatives was up sharply over the last decade, and these are likely to surpass the use of amalgam in coming years both because of perceived cosmetic, clinical, or health issues, or a combination of these. The amalgam alternatives we will focus on are resin composite, glass ionomer, ceramic, and gold restorations.

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Restoration Longevity

Assessment of Longevity

When comparing restoration choices, the issue of restoration longevity must be addressed. Ironically, assessing restoration longevity is not as straightforward as it might first appear, because there are many variables and various ways of addressing this issue. Two major systematic reviews of the literature on restoration longevity that have been published in the past few years[3,4] (the Chadwick et al. report[4] has been summarized in several other publications[5,6,7]). A systematic review is a special type of review article that methodically seeks out all the relevant studies on a particular subject of interest, evaluates the design and methodology of each study according to predetermined criteria, and summarizes the results of the highest quality studies. The authors of both of these systematic reviews have discussed the challenges encountered in synthesizing and drawing conclusions from the available literature.[3,8]

The types of studies that are useful in assessing restoration longevity are called "cohort studies." A cohort study is designed to obtain information about a conceptual population — such as "all individuals that have restorations in one or more of their teeth" — over a long follow-up period. Cohort studies are also called "longitudinal studies." A cohort study is conducted by sampling a subset of such individuals and drawing inferences about the entire population. Studies in which the study groups, or cohorts, are identified prior to the follow-up period and data are collected at intervals during the follow-up period, are referred to as prospective. Studies in which the cohorts are identified after a conceptual follow-up period and data are collected by recall on one occasion, are called retrospective. A prospective longitudinal study is generally referred to simply as a cohort study,[9] while a retrospective longitudinal study is referred to as a historical cohort study.[10]

Another type of epidemiologic study is the cross-sectional study. In contrast to cohort (longitudinal) studies, a cross-sectional study involves information pertaining to a single point in time. A cross-sectional study, as usually defined, provides a "snapshot" of conditions at a particular point in time.[11] A cross-sectional study would be useful in assessing, for example, numbers of restorations of a given type are present in the mouths of people in different age groups — i.e., how many amalgams, how many resin composites, etc.[12] The line between cross-sectional studies and retrospective (historical) cohort studies is blurred when retrospective longitudinal data are collected in a cross-sectional survey.[13] The key factor that distinguishes whether such a study should be considered cross-sectional or historical cohort is whether records are available (as opposed to participants' mere recollections) for the retrospective identification of study participants, the classification of the exposures of interest, and the follow-up of the participants for the relevant outcomes.[10] If such records exist and are used in the study, it is considered a historical cohort (retrospective longitudinal). Many studies on restoration longevity that are classified (even by their authors) as cross-sectional, are perhaps more properly classified as historical cohort (retrospective longitudinal) studies. This distinction is important, because retrospective longitudinal studies are considered of greater validity and higher quality than cross-sectional studies in assessing restoration longevity.[3] In fact, it would be virtually impossible to use a true cross-sectional study, as properly defined, to assess restoration longevity.

Restoration size has been shown to affect longevity, with smaller restorations lasting longer.

An example of a cohort (prospective longitudinal) study would be the study of restorations placed by one or a few practitioners, usually under controlled conditions (e.g., size of the restoration, placement technique, type of material). The restorations are then evaluated at periodic intervals thereafter. The advantage of prospective studies is the ability to control variables, including variables in placement and preparation techniques, types of materials, and variations in operators. One of the most important aspects of a prospective study is the ability to make random assignments of subjects to treatment group to avoid selection bias. In a prospective comparison of amalgam and composite materials, for example, the selection of the type of material to restore a given tooth would best be determined randomly. The reason is that restoration size has been shown to affect longevity, with smaller restorations lasting longer.[3] If, for example, operators in a study of restoration longevity consciously or unconsciously tend to select amalgam rather than composite for larger cavities, then the study results will be biased against amalgam, because larger restorations tend to fail sooner than smaller ones. Random assignment of restoration type ensures that selection bias does not affect the study results. The disadvantages of prospective studies include the difficulty in recruiting and managing the large numbers of study subjects required, the expense of conducting a large clinical study, and the high dropout rate —which is typically more than 50 percent during a 10-year study. In addition, the controlled methods of restoration placement without time constraints may not mirror a typical private practice situation.

An example of a historical cohort (retrospective longitudinal) study would be the study of a large number of failed restorations at a particular time, possibly in one or more private practices or dental schools. An analysis is typically done of the causes of restoration failure and the age of the restorations, based on patient records. A retrospective study would generally include large numbers of failed restorations of different sizes, placed by various operators and with various materials. An advantage is the ability to look at large numbers of restorations relatively simply and inexpensively at their actual failure date. Since the analysis is done retrospectively, a disadvantage is that these studies typically lack control over material selection and placement techniques. A retrospective study of restoration longevity almost always suffers from the effects of selection bias as described above, unless the study is specifically designed to compare materials based upon restorations of similar size and complexity. Another problem with retrospective studies is that often only failed restorations are analyzed and not restorations that are still functioning in the patient's teeth.

Resin composite

Retrospective Studies

Most studies have shown that resin composite restorations do not last as long as amalgam restorations. A 2001 study showed the median age of over 1,800 failed amalgam restorations was nearly 12 years but slightly less than five years for more than 1,500 failed resin composite restorations.[14] A 2000 study of 6,761 replaced restorations showed that the median age of replaced amalgam was 10 years, but that of composite was only eight years, with amalgam outlasting composite for Class 1, 2, 3, 4, and 5 restorations.[15] A 1999 study of more than 9,000 restorations showed that amalgam outlasted resin composite for Class 1, 2, and 5 restorations,[16] and a 1998 study showed the median age of a replaced amalgam restoration was 15 years versus only eight years for a replaced resin composite.[17] A group of researchers in 2002 used an insurance claims database to study more than 207,000 replaced amalgam and more than 93,000 replaced composite restorations and found that resin composite restorations were significantly more likely to fail than amalgam restorations, but observed that "composite fared almost as well as amalgam."[18]

Most studies have shown that resin composite restorations do not last as long as amalgam restorations.

Prospective Studies

In a 2001 prospective study of 194 small Class 1 and 2 hybrid composite fillings, 46 fillings were available for review after 10 years.[19] Failures were the result of total or partial filling loss, bulk fracture, or secondary caries. A minimum of 53.5 percent (and a maximum of 74.2 percent, based on the dropout of some patients in the study over the years) were clinically acceptable, confirming "the clinical safety of posterior composite restorations." In a 1998 prospective study of 90 posterior resin composite restorations, Mair reported 56 were available for 10-year review, and none failed.[20] Raskin et al. reported on 100 posterior resin composite restorations placed and reviewed afterward.[21] At 10 years, 37 were available for review and 32 had failed, mostly because of loss of occlusal anatomic form or proximal contacts. The authors estimated the actual failure rate to have been between 40 percent and 50 percent.

Review Articles

Hickel and Manhart, in an 2001 comprehensive review article on longevity of posterior restorations, described annual failure rates of 0 to 7 percent for amalgam restorations, 0 to 9 percent for direct composites, 1.4 to 14.4 percent for glass ionomers, 0 to 5.9 percent for cast gold inlays and onlays, and 0 to 11.8 percent for ceramic or composite inlays.[22] These results were similar to a 2000 review article they also published.[23] The problem with pooled studies that give annual failure rate ranges for various restorations is that they tend to favor materials with shorter-term and/or smaller studies versus longer-term and/or larger studies. For example, a three-year study of 10 resin composite restorations with no failures will give a perfect 0 percent annual failure rate, even if three restorations failed over the following two years (30 percent failure after five years), which would have given a 6 percent annual failure rate. If five of the restorations fail over the following seven years (50 percent failure after 10 years), then the annual failure rate would have been 10 percent. On the other hand, a much larger, longer-term 10-year study of 100 amalgam restorations with 10 failures (10 percent failure after 10 years) would give a higher annual failure rate of 1 percent versus the perfect 0 percent failure rate of the short-term three-year study of 10 resin composite restorations cited above. Brunthaler et al. noted that "favourable results for composite mate-

Table 1

Studies Cited by Hickel and Manhart 2001 Review[22]

Material	# studies	# short-term studies (ffi5 years)	# long-term studies (ffl10 years)	# small studies (ffi 100 restorations)	# large studies (> 1000 restorations)
Amalgam	34	5 (14 percent)	20 (59 percent)	4 (12 percent)	9 (26 percent)
Resin composite	24	14 (58 percent)	6 (25 percent)	7 (29 percent)	1 (4 percent)
Glass ionomer	16	12 (75 percent)	2 (12.5)	7 (44 percent)	0 (0 percent)
Cast gold	14	1 (7 percent)	9 (64 percent)	4 (29 percent)	5 (36 percent)
Ceramic or composite inlays	47	38 (81 percent)	2 (4 percent)	32 (68 percent)	1 (2 percent)

rials are frequently based on short-term results."[24] The annual failure rate ranges for glass ionomer and resin composite were less favorable than those for amalgam and cast gold. Since the resin composite and glass ionomer studies were generally much smaller and shorter-term than the amalgam and cast gold studies, the discrepancy would have been much more pronounced, however, were it not for these inherent weaknesses with annual failure rate reporting (**Table 1**).

Ceramic and Composite Inlays and Onlays

Of the studies published on ceramic and composite inlays and onlays, most have been relatively small, with less than 200 restorations.[22] As one would expect for any relatively new technology, we could find only a few long-term studies on the longevity of ceramic and composite inlays and onlays and no large, long-term retrospective studies of replaced ceramic and composite inlays. In 1998, Fuzzi and Rappelli published the results of a 10-year longitudinal study on 183 Class 1 and 2 ceramic inlays and found a survival rate of 97 percent.[25] In 2000, Reiss and Walther published a 12-year study of more than 1,000 computer-generated Class 1 and 2 ceramic inlays and found an 85 percent survival, with inlay fracture or cusp fracture the most common causes of failure.[26] In 1999, Donly et al. reported a 75 percent survival rate of 36 composite inlays and onlays after seven years, with the main reasons for failure secondary caries and fracture.[27] A similar 1998 study of 232 ceramic inlays showed a 98 percent probability of survival after seven years.

Gold Restorations

Although limited, the data available shows that gold restorations can yield excellent longevity, even more so than amalgam. Mjör and Medina reported a median age of 18.5 years for 111 failed cast and compacted gold restorations and median ages of at least 15 and 17 years for 1,689 gold castings and 875 compacted gold restorations in situ.[28] The most common causes of failure were enamel fracture and recurrent caries. In 1999, Stoll et al. studied 1,839 cast gold inlays placed over a 30-year period and found a 10-year survival rate of 76 percent for occlusal inlays and 83 percent to 88 percent for Class 2 inlays.[29] The most common causes of failure were recurrent caries and lack of retention. A similar study in 2001 of 2,071 cast gold inlays were placed over a 30-year period, showing a 10-year survival rate of 97 percent and a 73 percent 25-year survival rate.[30]

Clinical Issues

Proximal Contacts

One challenge with posterior composites as compared to amalgam has been the operator's ability to achieve acceptable proximal contacts in Class 2 cavity preparations. As an answer to this problem, packable composites were introduced to handle like amalgam. These composites can be "packed" into the cavity preparation, but they have not been shown to yield better proximal contacts than conventional composites.[31] However, there are devices such as the Contact Pro, BiTine rings, and ceramic inserts that have been effective aids in achieving acceptable proximal contacts.[32] After reviewing 24 prospective studies on posterior resin composite performance published between 1996 and 2002, Brunthaler et al. found that isolation method (rubber dam or cotton rolls) and packability of the composite material had no effect on restoration success.[24]

Wear

In the past, posterior composite materials were plagued by much lower wear resistance than amalgam,[33] but improvements in posterior composite materials have led to clinically acceptable wear resistance.[34-36] Even with the newest composite materials, however, greater wear than amalgam is apparent after two years.[37]

Postoperative Sensitivity

Postoperative sensitivity in Class 1, 2, and 5 resin composite restorations has been a problem and a cause of restoration failure. Christensen described several methods to prevent such sensitivity, including perfect use of the total-etch technique, tooth desensitizing solutions, flowable resins, high-viscosity bonding agents, resin-reinforced glass ionomer liners, and using multiple layers of bonding agent.[38] He stated that the introduction of self-etching primers, which do not remove the smear layer, has virtually eliminated the problem of postoperative sensitivity.[38] Two recent clinical studies that examined whether self-etching adhesives result in less postoperative sensitivity than total-etch adhesives were not able to demonstrate a difference between the two methodologies.[39,40] Both studies found virtually no postoperative sensitivity with either technique, so if postoperative sensitivity is observed more often clinically with total-etch adhesives, it may be attributable to their greater technique sensitivity.[40]

Secondary Caries

Secondary caries has been the leading cause of resin composite restoration replacement in several studies.[16,41,42] A five-year comparative prospective study showed a higher incidence of secondary caries in Class 2 composite restorations than in Class 2 amalgam restorations,[43] possibly because composite resin components may contribute to plaque formation[44] and the levels of cariogenic bacteria at the margins of composite restorations have been shown to be higher than at those of amalgam restorations.[45]

Although glass ionomer cements offer greater ease of placement than composites and have been advocated in caries-prone patients because of their fluoride-release, they have not been considered to possess adequate mechanical properties to function as long-term definitive restorations.[22] Paradoxically, in spite of the fluoride release which occurs from glass ionomer restorations, studies have shown that the leading cause of failure of glass-ionomer restorations has been secondary caries. The most frequent reason for replacement of 278 glass ionomer restorations studied in 1997 was secondary caries.[46] The median age of 309 failed glass ionomer restorations studied in 2001 was slightly more than four years, with secondary caries the leading cause of restoration failure.[14] In a 2000 study of the replacement of 662 glass ionomer restorations in Norway, secondary caries was the most common reason for glass ionomer restoration replacement.[47] The authors observed, "the anticariogenic effect of glass ionomer is limited and may be insignificant." A systematic review of 28 papers on the putative secondary caries treatment effect of glass-ionomer restoratives did not reach any conclusion about the validity of such an effect.[48] Despite the observation that glass ionomer appears to exert an anticariogenic effect in laboratory studies, Papagiannoulis et al. found that "no preventive effect was exerted in vivo from the glass-ionomer to protect the adjacent enamel wall from secondary caries attack."[49] The median age of 409 replaced glass ionomer restorations was only three years and two years for 156 replaced resin-modified glass ionomer restorations.[15] The median age of 262 failed glass ionomer restorations in a 1999 study was three years, with secondary caries being the leading cause of failure.[16] In all these studies where restoration longevity was analyzed, the median age of failed resin composite exceeded that of failed glass ionomer. Therefore, there is little or no advantage in sacrificing the esthetics of resin composite for the fluoride release of glass ionomer, even in caries-prone patients. Manhart et al. stated, "Glass ionomers can be considered only as long-term provisional restorations in stress-bearing posterior cavities."[34]

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Cost-effectiveness

Smales et al.[50] calculated that amalgam fillings are 3.8 times more cost-effective than gold crowns, and Mjör[51] has stated that amalgam is the most cost-effective dental restoration material. The authors of a systematic review of restoration longevity performed an economic evaluation and concluded that "amalgam clearly dominates composite and inlays across all time periods considered because it is cheaper and has better survival."[5] They estimated that composite "was between 1.7 and 3.5 times more expensive than amalgam to generate one tooth year."[5]

Biological risks

Patient Risks

Estrogenicity Issue

The "estrogenicity issue" for resin composites and sealants was first raised in 1996 in work performed by Olea et al. at the University of Granada and Tufts University.[52] The purpose of their work was to determine whether compounds derived from restorative resins or sealants based upon bis-GMA (bisphenol-A diglycidylether methacrylate, "Bowen's resin") could exhibit estrogenic activity — i.e., whether chemicals or breakdown products derived from these resins could mimic the activity of endogenous steroidal estrogens. Chemical compounds that mimic the activity of endogenous steroidal estrogens are called xenoestrogens. Xenoestrogens form the largest subset of the 48 endocrine-disrupting chemicals (EDCs) — compounds that can mimic or antagonize the actions of hormones — recognized by the Centers for Disease Control and Prevention.[53,54] It is well established that EDCs can cause alterations in development, growth, and reproduction in wildlife that are exposed to them.[55-57] Olea et al. suggested that xenoestrogens "are also being implicated in human infertility, genital tract malformations, and increased cancer rates in estrogen target tissues," and concluded their paper by stating, "In view of the documented exposure to bis-GMA-based composites and sealants used in dental treatments for adults and children, the use of these xenoestrogens should be reevaluated."[52]

The publication of the Olea et al. paper[52] generated considerable concern. The original focus of concern was on the compound bisphenol-A (BPA), and debate initially centered on whether BPA did or did not leach from dental resins.[52,58-63] Bisphenol-A is an aromatic compound that is widely used in the plastics industry and that has been known for decades to be a xenoestrogen. It is present in some dental resins as an impurity residue from the manufacture of bis-GMA[64] or as a breakdown product of other compounds.[65] As this issue has been further investigated, other compounds besides bisphenol-A that leach from dental resins have also been found to be estrogenic.[66-68] Even bis-GMA itself has been shown to exhibit modest estrogenic activity in a mouse animal model,[69] although this observation may have resulted from impurities in the bis-GMA.[64] Currently, there are no standard methods to determine whether a chemical is estrogenic or not,[70] and Wada et al. have discussed factors that can lead to false positives and false negatives in estrogenicity screening tests.[68] Wada et al. used a sensitive and specific test (reporter gene assay) to examine the estrogenicity of 24 resin composites, and they found that six products were estrogenic.[68] They also found that three of 18 different resin composite constituents exhibited estrogenicity.[68]

Currently, there are no standard methods to determine whether a chemical is estrogenic or not.

The Olea et al. report raised questions as to the persistence of the estrogenic effects of dental resins, particularly in light of their comments that data from one subject had to be excluded from analysis because bisphenol-A and bisphenol-A dimethacrylate were measured in her saliva prior to placement of sealants in their study.[52] They noted that this subject had had sealants placed two years earlier.[52] The implication was that "bisphenol A may be continually released after the initial dental work,"[71] although others have reasoned that this would be unlikely.[59,72] The persistence of leaching of BPA from dental resins has been examined in two clinical studies, which found that BPA release declined to levels below detection limits in a short period (one to three hours).[61,62] However, both of these studies used HPLC-UV (high-pressure liquid chromatography with UV detection) to analyze the substances leached from the dental resins, a technique that "may not be sensitive enough to detect biologically relevant release from these materials."[73] The persistence of leaching of other estrogenic compounds from dental resins has not yet been investigated, but it is likely "that the estrogenic effect that might be induced from a newly placed restoration or sealant will decrease over time."[64] On the other hand, "such a conclusion cannot exclude some additive or synergistic effect with other xenoestrogens present in the mouth."[64] Such an additive effect was found by Rajapakse et al., who demonstrated that combining xenoestrogens below their individual no-observed-effect concentrations led to a dramatic enhancement of the action of the natural steroid hormone 17β-estradiol.[74]

The debate on estrogenicity of dental resins is ongoing, and additional research is needed to resolve this issue.

Cytotoxicity and Other Effects

It has been known for some time that dental resin composites release substances which are toxic to cells and which alter cell function. Leaching from composites occurs as a result of two overlapping processes, 1) the short-term release of unpolymerized material from the composite after curing and 2) the long-term release of breakdown products of set polymer.[75] Salivary enzymes (esterases) are thought to play a major role in the breakdown of the set polymer.[76] Synergistic action of esterases has been shown to increase the biodegradation of dental resin composites beyond a simple additive effect.[77] Many organic compounds can be extracted from set dental composites in water and/or methanol, even without the use of esterases.[78,79]

Composites and compomers have been shown to exhibit severe cytotoxicity even after aging in artificial saliva (aging times studied were 0, 7, and 14 days).[73] As noted above, of particular note in this study was the discovery that cytotoxicity continues even when HPLC-UV shows no significant mass release versus Teflon controls.[73] A study of flowable composites and core materials used a longer aging time in artificial saliva (aging times studied were 0, 1, 2, and 4 weeks), but all materials were found to be "severely cytotoxic" in cell culture at all aging times.[80]

The cytotoxicity of five glass ionomer cements and resin-modified glass ionomer cements has been studied recently by de Souza Costa et al.[81] They found that all of the materials were cytotoxic in cell culture, but that the conventional GICs were less so. They remarked that the RMGICs "caused intense cytopathic effects on the cultured cells decreasing significantly the cell metabolism as well as causing remarkable cell death."[81]

Ceramics have been generally regarded among the most inert — and therefore biocompatible — dental biomaterials. However, the potential for adverse effects from dental ceramics has been recognized for some time, and the possibility of silica granulomas of dental biomaterial origin has been discussed in particular.[82] Recently, a case of granulomatosis in renal and hepatic tissue was reported in the literature, and the authors presented compelling evidence that it was traceable to wear debris from two porcelain fixed partial dentures.[83,84] Messer et al. evaluated the cytotoxicity of five dental ceramics and noted that most ceramics "caused only mild in vitro suppression of cell function to levels that would be acceptable on the basis of standards used to evaluate alloys and composites."[85] However, one of the ceramics, a lithium-disilicate material, "exhibited cytotoxicity that would not be deemed biologically acceptable on the basis of prevailing empirical standards for dental alloys and composites."[85]

Many organic compounds can be extracted from set dental composites in water and/or methanol, even without the use of esterases.

Allergenicity

Several cases of allergic reaction to components of resin composites have been reported in the literature. One clinical report presented an unusual response of acute gingivostomatitis caused by contact sensitivity to the methacrylate compounds present in a dental restorative material.[86] Another report described an intra-oral lichenoid lesion closely approximating anterior restorations.[87] In a study of patients who had positive reactions to the standard Bis-A epoxy resin, 20 percent of these patients exhibited cross reactivity with other epoxy acrylates.[88] The most common reaction was to Bis-GMA.[88]

A recent report of an adverse reaction unit for dental biomaterials in Norway examined the frequency of positive patch test results among 296 patients referred for clinical evaluation because of reaction to or concern about dental biomaterials.[89] A surprising finding was that gold contact allergy was the second most frequent at 23 percent (after nickel at 28 percent). Interestingly, patients were slightly more likely to be allergic to one or more resin composite ingredients (8 percent), than to mercury (6 percent).

Blue Light

The adverse biological effects of UV light are well recognized, but the use of blue light has been regarded among dental personnel as having few effects on tissues other than the retina.[90] However, Wataha et al. demonstrated that exposure of cells to blue light disrupted cell mitochondrial function (as assessed by succinic dehydrogenase activity), an effect that persisted for the entire 72-hour post-exposure observation period.[90] They concluded that their results indicated "that dental photocuring lights pose at least some risk to oral cells" and that further study was warranted.[90]

Occupational Risks

Allergenicity

In a Swedish study of dental personnel who were referred to the Department of Occupational and Environmental Dermatology in Stockholm, allergies to acrylates were the most common as determined by patch testing.[91] Reactions to HEMA (2-hydroxyethyl methacrylate), EGDMA (ethyleneglycol dimethacrylate) and MMA (methyl methacrylate) were most frequent. Hand eczema was the main manifestation of allergy,[91] but one case of allergy to HEMA and other methacrylates produced asthma and rhinoconjunctivitis that were sufficiently severe to force a cessation of work with methacrylates.[92] Unfortunately, dental exam gloves do not tend to form an effective barrier against many of the allergens encountered in dental practice. One study measured the resistance of five types of dental gloves (latex, powder-free latex, coated latex, polychloroprene, and polyvinyl chloride) to permeation by six different dental monomers (methyl methacrylate [MMA], 2-hydroxyethyl methacrylate [HEMA], triethyleneglycol methacrylate [TEGDMA], ethyleneglycol dimethacrylate [EGDMA], urethane dimethacrylate [UDMA], and Bis-glycidyl methacrylate [Bis-GMA]).[93] Four of the monomers tested (MMA, HEMA, TEGDMA, and EGDMA) permeated all the gloves tested.[93] Another study found that the "protection of the poorest glove [against HEMA] was comparable to that of the positive control (no glove)."[94] Andreasson et al. evaluated the permeability of various types of gloves to methyl methacrylate (MMA), 2-hydroxyethyl methacrylate (HEMA) and triethyleneglycol dimethacrylate (TEGDMA) and made recommendations regarding glove selection.[95]

Respirable Dust

A study of the dust generated during finishing of composite restorations found that between 14 percent and 22 percent of the dust generated was respirable.[96] Although some dental masks appear to be capable of filtering out a high percentage of respirable particles,[97,98] the average is in the range of 40 percent to 50 percent.[96,98] Concern has been expressed about the use of intra-oral air abrasion technology and its accompanying potential exposure to respirable particulates.[99] However, two studies have demonstrated that the quantity of respirable dust generated is insufficient to pose a health hazard.[99,100] The aggregate effect of all sources of particulates may be a concern in the dental office, however. A recent study of dental clinics found that respirable particulate matter exceeded ambient standards by a factor of 2 to 6.[101] Of particular note was the observation of these elevated levels throughout the building, not merely in dental operatories.[101] Thus, dental office personnel without masks would be exposed to respirable particles.

It has been argued for more than 20 years that when the variety of possible and actual systemic effects are considered along with local reactions at the implant site, no fully biocompatible material can be said to exist.

Silicosis has been recognized as an occupational hazard of dental laboratory technicians.[102,103]

Blue Light

Most clinicians are aware of the need for eye protection during photocuring with blue light, and use protective orange-tinted eyewear or shields during photocuring. The sensitivity of the retina to light damage is dependent on the wavelength of the light, and blue light is many times more efficient at causing retinal damage than longer wavelengths.[104]

Summary and Conclusions

It has been argued for more than 20 years that when the variety of possible and actual systemic effects are considered along with local reactions at the implant site, no fully biocompatible material can be said to exist.[105] Even gold alloys and ceramic materials — long considered the most biocompatible — have been shown to have significant biological liabilities in certain individuals. Over the past 20 years or so, various anti-mercury groups have fought to effect a ban on the use of dental amalgam. As no fully biocompatible material exists, this would appear to be a short-sighted objective. Not only would a ban on dental amalgam limit choices for the dentist and dental patient, but it would eliminate the only material that certain patients — those with allergies to components of resin composites and/or to gold alloys — may be able to tolerate.

For the vast majority of patients, amalgam still appears to be the most cost-effective and longest-lasting restorative material for posterior teeth. For those desiring a more esthetic alternative to amalgam, resin composites appear the best choice, although biocompatibility issues remain to be resolved. Glass ionomer cements offer greater ease of placement than composites and have been advocated in caries-prone patients because of their fluoride-release, yet they have not been considered to possess adequate mechanical properties to function as long-term definitive restorations. Because of the lack of definitive evidence for an anticariogenic effect of fluoride release from glass ionomer materials in vivo, there would appear to be no advantage in sacrificing the superior esthetics and greater durability of resin composite for the fluoride release of glass ionomer, even in caries-prone patients. Ceramic and gold restorations have their place as amalgam alternatives under certain circumstances, particularly where the restoration is large, but both of these treatment modalities are considerably more expensive that a similarly sized amalgam. CDA

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Robert E. Horseman, DDS

The Wonder Years

I'm in my mid-80s now. I've been in classier places, but considering I've got 45 percent of my original hair, all my teeth except my third molars and I'm still ambulatory, it's not a bad place to be. I don't have to golf, surf, dance or go to the gym three times a week to prove anything. I don't have to wear a tie. I can enjoy the benefits of selective hearing. In my 80s, I can be as eccentric as I want. People expect it. "Isn't your father a little ... uh, strange? I mean, he just called me 'Sparky' and his socks don't match."

"He's, you know, 84, dear, and at that age ..." The eyes roll.

Anybody in his 80s who doesn't take advantage of this period of absolution misses the whole point of being 80. Say anything, do anything short of mayhem and you're home free.

> Mostly, the trouble with old age is that it comes when we are too old to enjoy it.

Of course, there's a downside. There's a downside to being 15, 40, 50. It is said that man alone is born crying, lives complaining and dies disappointed. Oscar Wilde mused, "The tragedy of old age is not that one is old, but that one is not young." Mostly, the trouble with old age is that it comes when we are too old to enjoy it. So, if you are to get your fair share of the Golden Years, your vitals should include besides your blood pressure and ability to instantly identify the songs of 1940, an active curiosity, a robust, if quirky, sense of humor and a continual feeling of wonderment. A dollop of skepticism wouldn't hurt.

If you can still be dumbfounded that anything was ever invented, that pictures and sound can be sent through the air, that the sun comes up every morning and an adult woman could ever remotely consider a permanent union with Ashton Kutcher, it can almost overcome the shock of seeing your children becoming depressingly middle aged.

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This startling announcement runs contrary to the general public's belief that all worms were drunk and never drew a sober breath.

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In that regard, we have scientists to thank on a daily basis. Here's Fred McGehan. He's the spokesman for the National Institute for Science and Technology in Boulder, Colo. The scientists there are in a tizzy because the Earth is right on schedule in its orbit for the fifth straight year! Right on schedule — how weird is that? Well, in 1972, because the Earth was slowing down in its travels through space, it was necessary to add an extra "leap second" on the last day of the year. This can be a big deal affecting everything from communication, navigation, air traffic control systems and the precise distribution of your medications. But — and here is the part that will keep you too amazed to nap — this slowing suddenly came to a halt in 1999 and the Earth resumed its normal speed. What's up with that? Fred said it could be the tides, weather and changes in the Earth's core. He's guessing. It could as easily be the demise of English in an English-speaking country.

No less exciting is this headline from San Francisco: "SF Researchers Find Drunken Worms Move Slowly." After six years of work on the project, Dr. Steven McIntire concludes that drunken worms move more slowly and more awkwardly than sober ones. This startling announcement runs contrary to the general public's belief that all worms were drunk and never drew a sober breath.

The science journal *Cell* delineates the whole sordid spectacle, but the gist is this: Thousands of tiny worms were dosed with enough alcohol to render them unfit to drive in any state of the union. Instead of propulsing themselves in neat little S-shaped configurations like any self-respecting worm would do, the drunk worms bodies were straighter and they tended to lollygag along the way. A couple wanted to challenge a robin to a fight and one was weaving about with a little lampshade on its head.

But here's the thing that makes you glad you're old enough to have the free time to devote to the wonder of it all: some of the worms didn't get sloshed. Those sober worms were found to have a mutated gene that appears to make them immune to alcohol's intoxicating effects. You see where this is going? These particular worms could carouse all night and still qualify for designated driver. Isolate this special bomb-proof gene, figure out how to get it into the human gene system and there goes the market for "a guy goes into a bar ..." type jokes.

If only it were that simple. They main purpose of the gene (called slo-1) is to help slow brain transmissions. If the gene is disabled like in the mutant worms, the brain never gets the signal to slow down, the liver eventually turns to the density of Girl Scout cookies and the drinker runs up a tab that gets him tossed out on his ear.

Neurobiology professor Steven Treistman at the University of Massachusetts Medical School gives the worm thing considerable thought, finally concluding, "Humans are a lot more complicated than the worm." Some are not, but that's beside the point. In the fight against alcoholism, he agrees, you've got to start somewhere. Slurred speech and loss of inhibition in the average worm are difficult qualities to measure, so the research goes on.

The point is, between bouts at the bingo table and awaiting that 3rd-of-the-month Social Security check, we old people have lots of quality time to wonder what's coming next.

And that, not Metamucil, is what keeps us young. **CDA**