



April 2012

Occupational Exposure to Elemental Mercury in Odontology/ Dentistry

University of Massachusetts Lowell; Lowell, Massachusetts, USA

Institute for the Development of Production and the Work Environment (IFA); Quito, Ecuador

University of Sonora (UNISON); Hermosillo, State of Sonora, Mexico

Acknowledgements

This document was developed with input and guidance from the following individuals. We are grateful for their invaluable contributions.

Clara Rosalia Alvarez Chavez, University of Sonora, Hermosillo, Sonora, Mexico

Cathy Crumbley, Lowell Center for Sustainable Production,
University of Massachusetts Lowell, Lowell, MA, USA

Homero Harari, Department of Work Environment,
University of Massachusetts Lowell, Lowell, MA, USA

Raul Harari, Executive Director, Institute for the Development of Production
and the Work Environment (IFA), Quito, Ecuador

Primary Authors

Catherine Galligan, Lowell Center for Sustainable Production,
University of Massachusetts Lowell

Susan Sama, Lowell Center for Sustainable Production,
University of Massachusetts Lowell

Natalie Brouillette, Department of Work Environment,
University of Massachusetts Lowell

Support for this document was provided by:

Office of Pollution Prevention and Toxics of the
United States Environmental Protection Agency

The content of this report reflects the views of the authors and does not necessarily reflect the views or policies of the sponsors.



University of
Massachusetts
UMASS Lowell

The Lowell Center for Sustainable Production
www.sustainableproduction.org

For more information or to
comment on this topic, please
contact Catherine Galligan at
Catherine_Galligan@uml.edu.

About the Lowell Center

The Lowell Center for Sustainable Production is a research center of the University of Massachusetts Lowell working to build healthy work environments, thriving communities, and viable businesses that support a more sustainable world. We do this by working collaboratively with citizens' groups, workers, businesses, and government agencies.

Executive Summary

Mercury is recognized as harmful to human health and the environment. It is highly toxic to humans and may harm vital organ systems, including the nervous, digestive, respiratory, renal, and immune systems. As a result, international efforts are underway to eliminate the use of products with intentionally added mercury.

This report reviews the literature, describes the use of mercury in odontology, and raises issues of concern for human health. In odontology and dental clinics,¹ mercury may be found in dental amalgam and measuring devices such as thermometers and blood pressure cuffs (sphygmomanometers, tensiometers). Studies have shown elevated concentrations of mercury in the ambient air in dental settings. This mercury vapor may enter the body through inhalation and be transported to different organs throughout the body where it can accumulate.

This report recommends developing a program to minimize the use of mercury, lessen the potential for exposure, and control mercury waste. This will benefit dental workers by decreasing their exposure to this toxic material and will reduce environmental impacts from mercury in solid waste, in the air, and in wastewater.

Findings

Mercury exists in several forms:

Elemental mercury, used in dentistry, has no electrical charge (Hg^0)

Inorganic mercury has a positive charge of +1 or +2 (Hg^{1+} , Hg^{2+})

Organic mercury is a complex of mercury with carbon-containing compounds

Both the charge and the chemical form affect the absorption, transport, and impact of mercury in the body.

The silvery liquid elemental mercury, also called metallic mercury, is used in dental amalgams (Baelum and Pockel, 2007; WHO, 2003). Elemental mercury toxicity is usually a result of exposure to vaporized mercury that enters the body through inhalation. Brief exposures to a high concentration can result in toxicity to the lungs, including chest pain, bronchitis, and pneumonitis. Three signs of exposure to high concentrations are excitability (erethism), tremors, and gingivitis (MA DEP, 2011).

Poisoning from inhaled mercury can also result from chronic exposure at lower air concentrations. This is the exposure of most concern for health care workers in odontology. The nervous system is very sensitive to mercury and permanent damage can occur from chronic exposure to inhaled metallic mercury, which is transported in the blood and crosses into the brain where it can cause permanent damage. Health effects may include personality changes, tremors, vision changes, muscle incoordination, loss of sensation, difficulty with memory, and deafness (US DHHS, 1999; US DHHS ATSDR, 1999; WHO, 2003).

¹ Depending on geographic location, the term “dentistry” or “odontology” may be used to describe the branch of medicine dealing with the anatomy and development of diseases of the teeth. In this report the terms are used interchangeably.

Inhaled elemental mercury can accumulate in the kidneys and damage sensitive kidney tissue (US DHHS ATSDR, 1999). Long-term low-level exposures may result in damage to the lining of the mouth and lungs (MA DEP, 2011).

Exposure to elemental mercury is of particular concern to nursing or pregnant workers. Women who breathe contaminated air can pass elemental mercury into a developing baby via the placenta or breast feeding. These exposures have been associated with developmental delays and attention deficit disorders in childhood (WHO, 2005).

Studies show that clinics using mercury have elevated levels of mercury vapor in the work environment. This report shows that dental health care practitioners are routinely exposed and carry a higher body burden of mercury than the general population. Workers' body levels of mercury reflect their workplace practices including work tasks and frequency, types of equipment and processes, and workplace hygiene (Ritchie, 2004). Significant correlations have been found between body concentrations and work areas that have high mercury levels in the breathing zone, such as the amalgam preparation, autoclave, and amalgam storage areas. For dentists, the number of fillings placed or removed per week and the number of hours worked in the clinic was found to be related to their body level of mercury (Ritchie, 2004).

In many countries mercury exposures in odontology have been decreasing over the past decades. This is attributed to increased awareness and education, improved equipment and work controls, use of non-mercury restoration materials, and more rigorous occupational regulations (Ritchie, 2002). Increased patient awareness also plays a crucial role with patients asking that safer materials be used. Unfortunately, these improvements have not been incorporated universally and many dental health care workers are still exposed to mercury levels causing health risks (UNEP, 2002).

Recommendations

Minimizing, and ultimately eliminating, exposure to mercury in odontology is a precautionary approach that will reduce cumulative exposure to dental health care workers and prevent its transport to downstream ecosystems (Tickner, 2006).

1. Dental clinics should exercise precaution through the thoughtful choice of products and practices. Eliminating use of mercury where feasible, using engineering controls, improving systems of work, and use of personal protective equipment will all serve to reduce worker exposure to mercury. These are important first steps.

2. Governments and stakeholders (such as professional organizations, environmental groups, healthcare providers, and insurance companies) should act to make safe control and elimination of mercury economically, technically, and logistically feasible. Actions such as restrictions on the procurement, transportation, and use of mercury as well as fostering a means for safe mercury disposal, will provide a driving force for widespread improvements at the level of the dental clinics.

Reducing occupational exposure to elemental mercury in odontology and dentistry is a challenge, but solutions are within reach. No single step will be sufficient, but efforts at multiple levels—within clinics and at high levels of government and stakeholder organizations—will bring about the improvements that will protect the health of odontology workers and will reduce the impact of mercury in the environment.

Background

Mercury is highly toxic and may cause harmful effects to vital organ systems including the nervous, digestive, respiratory, renal, and immune systems. As a result, there is a large international effort by medical personnel, non-governmental agencies (e.g. WHO, UNEP), and governments to reduce both the use of and exposure to mercury in healthcare settings. In dentistry, the exposure of concern is elemental mercury (Hg^0), the very volatile silvery liquid used to make amalgam for filling cavities.

Approximately 80% of inhaled elemental mercury vapor is absorbed by the lungs and is circulated to organ systems (WHO, 2003). The effects of long-term chronic exposure may manifest in many ways including: tremors, impaired vision, impaired hearing, paralysis, difficulty sleeping, emotional instability, developmental deficits for fetuses, and developmental delays and attention deficit issues in childhood (WHO, 2005).

The purpose of this paper is two-fold:

1. Properly educate odontologists to reduce the use of and carefully control elemental mercury, including containment, clean up, and disposal practices.
2. Call for public health action by governments and stakeholder organizations that make elimination and control of mercury economical and technically and logistically feasible.



Health Effects of Mercury

This section describes the different forms of mercury and the health effects of elemental mercury exposure (the form used in dentistry). These effects highlight the need to reduce and eliminate the use of mercury whenever possible.

Mercury can exist in several forms.

Elemental or metallic mercury (often written as Hg^0) is used in amalgam, in measuring devices such as blood pressure cuffs (tensiometers) and thermometers, and in electrical devices. It readily vaporizes and has no electrical charge.

Inorganic mercury is positively charged at a level of either +1 or +2. It is found in salts that have been used in catalysts, paints, topical disinfectants, and preservatives in medical preparations.

Organic mercury is a complex of mercury with carbon-containing compounds. Although there are a number of sources of exposure, the primary source for most humans is consumption of methyl-mercury-contaminated fish (MA DEP, 2011).

Mercury in all three forms is highly toxic and accumulates in both body tissues and the environment, where it remains for long periods of time (MA DEP, 2011).

Route of entry, as well as the charge and chemical form of mercury affect how it is absorbed and transported in the human body. Uncharged mercury can move into cells readily. Mercury that has a charge is largely prevented from passing across barrier membranes such as the blood-brain barrier and the placenta, unless it is carried through as part of another molecule. The distribution and toxicity of mercury in the body are complex since each of the three chemical forms, under the right circumstances, can be changed to one of the other forms. In the body, conversion to the charged, inorganic form predominates but other transformations can also occur (MA DEP, 2011).

Transport and Toxicity of Elemental Mercury

Elemental mercury toxicity is usually a result of exposure to the vaporized form (WHO, 2003). Even a brief exposure to a high concentrations, can result in toxicity to the lung, including chest pain, bronchitis, and pneumonitis. Three signs of exposure to a high concentration of mercury in air are excitability (erethism), tremors, and gingivitis.

At lower air concentration there may be no early signs of toxic effects because the vaporized mercury is cleared from the lungs to the blood or by exhaling. Poisoning from inhaled metallic mercury can occur after chronic low-level exposure as the mercury is carried through the body and affects different organs and systems (MA DEP, 2011).

From the lungs, mercury moves through the body in the blood stream, in plasma and red blood cells. In plasma, mercury remains as Hg^0 and readily moves into the brain and placenta, where it is converted to Hg^{2+} and causes neurological damage. In red blood cells, mercury is oxidized to the Hg^{2+} form, which does not readily cross barrier membranes. Instead, it moves through to the kidneys where it collects (Timbrell, 1995).

Each of these forms of mercury is highly toxic. They accumulate in the body tissues and environment where they remain for long periods of time.

(MA DEP, 2011)



The **nervous system** is very sensitive to mercury and permanent damage to the brain can occur from exposure to sufficiently high levels of metallic mercury. After crossing into the brain, mercury may affect many different areas of the brain and their associated function, resulting in a variety of symptoms. These include personality changes (irritability, shyness, and nervousness), tremors, changes in vision, deafness, muscle incoordination, loss of sensation, and difficulties with memory (US DHHS, 1999; US DHHS ATSDR, 1999; WHO, 2003).

The **kidneys** are also sensitive to the effects of mercury. Mercury accumulates in the kidneys, causing continuous high exposures to these tissues and therefore more damage. All forms of mercury can cause kidney damage if large enough amounts enter the body (US DHHS ATSDR, 1999).

Skin contact with metallic mercury has been shown to cause an allergic reaction (skin rashes) in some people (US DHHS ATSDR, 1999).

Exposure to lower levels of mercury vapor over longer periods of time can result in damage to the lining of the **mouth and lungs** (US DHHS ATSDR, 1999).

Second-Hand Exposures

Metallic mercury can be carried home on a worker's contaminated clothing and shoes. Exposure to mercury has been reported in children of workers who are exposed to mercury at work, and increased levels of mercury were measured in places where work clothes were stored and in some washing machines. The children most likely to be exposed to risky levels of mercury are those whose parents work in facilities that use mercury, but where no protective uniforms or footwear are used. In some reported cases in which children were exposed in this way, protective clothing was used in the workplace, but contaminated items were taken home, thus exposing family members (US DHHS ATSDR, 1999).

The same harmful health effects seen in adults are also seen in children with similar mercury exposures (US DHHS ATSDR, 1999). Nursing or pregnant workers who breathe contaminated air can also pass elemental mercury into a developing baby. These exposures have been associated with developmental delays and attention deficit disorders in childhood (WHO, 2005).

The nervous system is very sensitive to mercury and permanent damage to the brain can occur from exposure to sufficiently high levels of metallic mercury.

(US DHHS ATSDR, 1999)

All forms of mercury can cause kidney damage if large enough amounts enter the body.

(US DHHS ATSDR, 1999)

Mercury Exposures in Dental Workers

Elemental mercury is a key ingredient in the dental amalgam used as a filling material for decayed or damaged teeth. Amalgam is an alloy comprising mercury (typically 45-55%), silver (approximately 30%), and other metals such as copper, tin, and zinc (WHO, 2005). Although other mercury-free options are now available, dental amalgams continue to be used worldwide because of familiarity, ease of use, durability, and favorable cost (CDC, 2009; UNEP, 2010).

Studies show that odontology and dental clinics that use mercury have elevated levels of mercury vapor in the work environment. Significant correlations have been found between dentists' body levels of mercury and workplace environmental mercury concentrations (Ritchie, 2004). Consequently, mercury in the ambient environment is of concern for dental practitioners.

Dentists, dental assistants, technicians, and other workers in the odontology or dental setting are exposed to mercury from a combination of amalgam-related tasks and workplace conditions, including:

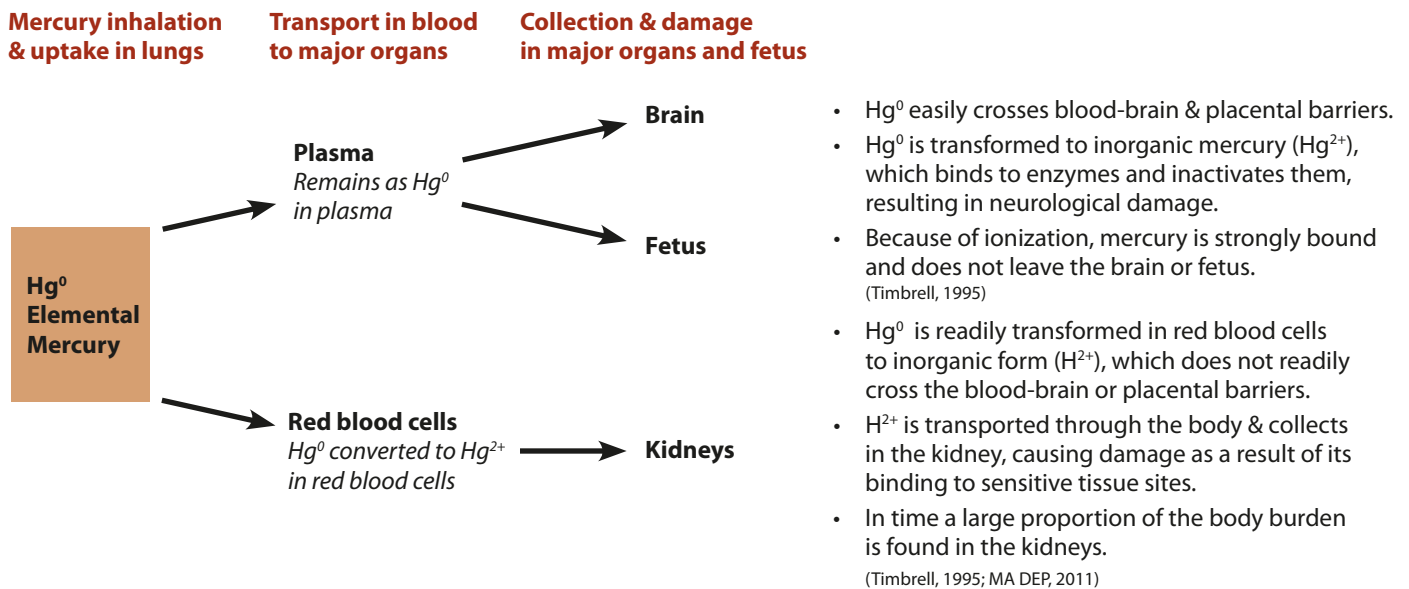
- Bulk storage, such as vials or jars of elemental mercury
- Spills during handling of bulk mercury
- Preparation of amalgam
- Use of amalgam in new dental fillings, including finishing and polishing the amalgam surface
- Restoration of old fillings, including removing old amalgam
- Clean up of work areas and tools, including cleaning waste amalgam residues from surfaces and autoclaving of tools
- Accumulated residue in the work areas
- Disposal and storage of waste amalgam and mercury (Canto-Pereira, 2005; Ritchie, 2004; US FDA, 2009)

Routes of Exposure

In odontology the three primary routes of exposure to mercury include: 1) inhalation of mercury vapor or amalgam dust, 2) ingestion, and 3) dermal exposure.

Inhalation

Inhalation of elemental mercury vapor is the most relevant and significant occupational exposure because it results in the greatest uptake of mercury into the body and has significant potential for neurological or kidney damage (Baelum and Pockel, 2007). Mercury vapor in the breathing zone (near the nose or mouth) is inhaled into the lungs, where an estimated 80 percent is absorbed by the lung tissues (UNEP, 2002). From the lungs, mercury vapor readily enters the blood stream through the alveolar capillary membrane and is distributed throughout the body via the blood stream. The locations in which mercury is concentrated lead to different types of toxicity, as shown in the following Figure 1 (Baelum and Pockel, 2007; MA DEP, 2011; Timbrell, 1995). There is also efficient transfer of inorganic mercury in the blood to breast milk, with an average concentration of approximately 55% of the corresponding concentration in blood (Baelum and Pockel, 2007).

Figure 1. Mercury Distribution Through the Blood Stream

Elemental mercury vapor can be inhaled into the lungs, where it moves into the bloodstream and is transported through the body. In plasma, mercury remains in its elemental form (Hg⁰) and can cross into the brain and into the fetus of a pregnant woman. In red blood cells, elemental mercury is readily metabolized to inorganic mercury (Hg²⁺), which tends to accumulate in the kidneys and damage sensitive tissues in that organ (MA DEP, 2011; Timbrell, 1995).

After absorption in the lungs, metallic mercury in the body is reduced by half every 1–2 months. Larger amounts of mercury in the body (body burdens) take longer to be removed than smaller amounts (MA DEP, 2011). Mercury is released from different organs at different rates. Brain and kidney have been found to retain mercury for a lifetime (MA DEP, 2011).

Dermal Exposure

Dermal uptake is possible if mercury or mercury vapor comes into contact with the skin. Limited data suggest that this is not a major route of exposure compared with inhalation (US DHHS, 1999; Baelum and Pockel, 2007). Even so, it can contribute to the body burden. An experimental study of exposure to radioactive-labeled mercury vapor showed a calculated uptake rate of 0.1–0.4 µg Hg per m² body area per minute for each µg/m³ Hg in the air. This would correspond to 2% of the respiratory uptake if the whole body surface were exposed (Baelum and Pockel, 2007).

Personal hygiene is a relevant factor in dermal absorption. A study of almost 300 dentists by Shapiro et al. used X-ray fluorescence to detect the presence of mercury on the wrist and temple (area of the head on either side of the forehead). Thirteen percent of dentists were found to have mercury concentrations greater than 40 µg/g of tissue at the temple (Shapiro, 1982). In other studies, a dentist with the highest mercury level in the study population, as judged by fingernail mercury levels, reported that he did not wear gloves (Ritchie, 2004) and a dentist who wore neither mask nor gloves had the second highest urinary mercury level among the group of exposed subjects (Baelum & Pockel, 2007). This suggests the importance of proper personal protective equipment and personal hygiene.

It is estimated that 80 percent of inhaled vapors are absorbed by the lung tissues.

(UNEP, 2002)

Ingestion

For ingested metallic mercury, less than 0.1% of elemental mercury is absorbed from the gastrointestinal tract, so it has little toxicity when ingested (Baelum and Pockel, 2007). Although ingestion is a less likely route for clinicians, it is possible; for example, fine powder particles of amalgam might be generated and introduced into oral mucosa during clinical operations (U.S. DHHS, 1999).

Exposure Levels of Elemental Mercury in Odontology Workplaces versus Recommended Limits

Vaporization of Elemental Mercury and Recommended Exposure Limits

The silvery liquid elemental mercury readily vaporizes at room temperature. Because saturated vapor at 24 °C contains about 18 mg/m³ of mercury there is a potential for high

Table 1. Occupational and Ambient Exposure Limits for Mercury

(Environment Canada, 2011; Scientific Committee on Occupational Exposure Limits, 2007; Secretaría del Trabajo y Previsión Social, 1999; US Department of Labor, 2011; US DHHS ATSDR, 1999)

Key Point: Ambient air can hold much more mercury vapor than would be deemed safe to breathe			
Mercury content of saturated vapor at 24 °C		18 mg/m ³	The maximum amount of mercury vapor that can be suspended in air before condensing.
Type of Standard	Regulating Agency	Exposure Level	Explanation
Permissible Exposure Limit (PEL)	Occupational Safety and Health Administration (OSHA)	0.1 mg/m ³	Worker's exposure to mercury vapor shall at no time exceed this level.
Ceiling Exposure Value (CEV)	Ontario, Canada occupational exposure limit	0.15 mg/m ³	Maximum airborne concentration for mercury to which a worker can be exposed at any time.
Recommended Exposure Limit (REL)	National Institute for Occupational Safety & Health (NIOSH)	0.05 mg/m ³	Time-weighted average (TWA) for up to a 10 hour workday and a 40-hour workweek.
Límite Máximo Permissible de Exposición Promedio Ponderado en el Tiempo (LMPE-PPT)	Secretaría del Trabajo y Previsión Social (STPS)	0.05 mg/m ³	Permissible exposure limit time weighted average.
Mercury Vapor Threshold Limit Value (TLV)	American Conference of Governmental Industrial Hygienists (ACGIH) and the Canada Labor Code	0.025 mg/m ³	Time-weighted average for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed without adverse effect.
Recommended 8-hour Time-Weighted Average	Scientific Committee on Occupational Exposure Limit Value (European Commission committee that advises on occupational exposure limits for chemicals in the workplace)	0.02 mg/m ³	Time-weighted average for a normal 8-hour workday.
Reference Concentration (RfC)	U.S. Environmental Protection Agency (EPA)	0.0003 mg/ m ³	Estimate of a daily inhalation exposure of the human population (including sensitive subgroups) likely to be without appreciable risk of deleterious effects during a lifetime.
Minimal Risk Level (MRL) for Chronic Exposure	Agency for Toxic Substances and Disease Registry (US DHHS ATSDR)	0.0002 mg/ m ³	Estimate of the daily human exposure to a hazardous substance likely to be without appreciable risk of non-cancer health effects over a specified duration of exposure.



environmental levels and uptake by inhalation (Baelum and Pockel, 2007). To put this in perspective, consider recommended occupational and ambient exposure limits for mercury shown in Table 1. What this shows is that ambient air can hold much more mercury vapor than would be deemed safe to breathe.

Mercury Exposure Level Correlates to Odontology Work Environment and Procedures

Multiple factors can contribute to the airborne mercury level in odontology, including work tasks, types of equipment, and hygiene (Ritchie, 2004). For example, mercury exposures are significantly greater in areas where amalgam is still mixed by hand (UNEP, 2010). Accidents involving mercury spillage are also common. Twenty-seven percent of dentists surveyed in a study indicated that they had experienced a spill when filling an amalgamator, or from a thermometer or sphygmomanometer (Ritchie, 2004).

Detailed measurements of mercury vapor in dental offices in Scotland revealed that elevated levels of mercury were common. (See Table 2.) Measurements taken with a personal dosimeter in the dentist's breathing zone showed that the United Kingdom's Occupational Exposure Standard (OES) for mercury was exceeded in 29% of the readings during routine working conditions (Ritchie, 2004).

Procedures for mixing amalgam have a considerable impact on the air levels in the direct vicinity of dental workers. Older procedures involving manual handling of pure mercury give rise to higher levels up to and exceeding $50 \mu\text{g}/\text{m}^3$. The use of a mechanical device (e.g., Dentomat or triturator) reduces exposure, but there is still exposure from handling the fillings and from mercury vapor in the air around the machine depending on its enclosure. Using prefabricated amalgam capsules can decrease the number of high concentrations even more (Baelum and Pockel, 2007).

Drilling of old fillings gave the highest exposure to mercury in the dentist's breathing zone.

(Baelum and Pockel, 2007)

Table 2. Average Environmental Readings in Dental Surgeries

(Ritchie, 2004)

Findings:

1. Elevated levels of mercury were common.

2. A personal dosimeter in the dentist’s breathing zone showed that the Occupational Exposure Standard (OES) was exceeded in 29% of the readings during routine working conditions.

Area	Environmental measurements of mercury in surgeries [odontology work areas]			
	# measurements	Mean	Median	# readings where OES* was exceeded (%)
		µg/m³, time-weighted average		
Personal dosimeter in worker’s breathing zone	53	29.2	15.0	45 (29%)
Chair base	180	28.9	16.3	68 (38%)
Skirting board below mercury storage area	180	38.9	21.2	80 (44%)
Beside mixing device (amalgamator or area around capsules and capsule mixer)	110	37.8	21.0	46 (42%)
Capsule storage and preparation	43	15.2	10.3	38 (5%)
Above waste amalgam storage area	163	10.7	8.3	10 (6%)
Above autoclave	66	11.7	8.7	4 (6%)
Above amalgam preparation area	179	10.4	8.0	7 (4%)
Workplace air	112	6.5	5.7	0 (0%)

* Occupational exposure standard (OES) = $25 \mu\text{g}/\text{m}^3$

Procedures for mixing amalgam have a considerable impact on the air levels in the direct vicinity of dental workers.

(Baelum and Pocket, 2007)

Mercury levels in the dentist's breathing zone can vary with task and type of equipment. A significant association has been shown between the number of fillings placed per week and levels of mercury in surgery air (Ritchie, 2004). Drilling old fillings gave the highest exposure to mercury in the dentist's breathing zone. Mercury vapor levels are considerably decreased with the use of a high-volume air evacuator or mirror evacuator, as shown in Table 3 (Baelum and Pockel, 2007; Pohl and Bergman 1995).

Hygienic Measures

Mercury exposure is also directly related to hygienic measures in the dental workplace, with good hygiene essential for minimizing exposure to mercury vapor (Baelum and Pockel, 2007). Areas where spilled or waste materials can collect are prone to higher mercury vapor levels. Mercury from spills or leaking of capsules during trituration (that is, mixing mercury, silver, and other metals to form the amalgam) can collect around the skirting board (base board) and debris from amalgam placement, removing old amalgam restorations, and polishing can collect around the base of the chair. Ease and effectiveness of cleaning these areas and the floor/wall interface will impact the mercury vapor level (Ritchie, 2004; Baelum and Pockel, 2007).

Table 3. Mercury Measured During Dental Procedures

(Baelum and Pockel, 2007; Pohl and Bergman, 1995)

	Mercury Vapor, Median Values
Cutting (drilling), with use of saliva extractor	168 µg/m ³
Cutting & filling, with saliva extractor	6.6 µg/m ³
Cutting & filling, with use of high-volume evacuator, mirror-evacuator and saliva extractor	1.5 µg/m ³
Polishing, with use of saliva extractor	1.1 µg/m ³
Polishing with use of high-volume evacuator, mirror-evacuator and saliva extractor	1 µg/m ³
Condensing (compacting amalgam) with use of saliva extractor	2.2 µg/m ³



Body Mercury Levels in Dental Health Care Workers and Correlations with Work Environment and Tasks

Dentists are considered to have higher occupational exposure to mercury than most health professionals.

(WHO, 1991)

Many studies have reported that dentists and dental professionals have higher levels of mercury in their bodies than found in the general population (Canto-Pereira 2005; Urban, 1999; Ritchie, 2004). Dentists are considered to have higher occupational exposure to mercury than most health professionals, according to the World Health Organization (WHO, 1991). This section highlights studies showing that exposures to mercury vapors in the workplace are associated with higher body levels of mercury in dental workers.

Several studies that measured environmental and body mercury levels of dentists compared with a control group of non-dentists showed that dentists had, on average, urinary mercury levels over 3 to 4 times that of control subjects, as shown in Table 4 (Ritchie, 2004; Baelum and Pockel, 2007). Urban et al (Urban, 1999) compared a group of 36 dentists and dental assistants who routinely handled amalgam and were exposed to mercury vapor to a control group comprising 46 people without known exposures to mercury. Urinary and air concentrations were used to compare the groups. Table 4 shows that these dental practitioners were exposed to higher average air concentrations and had higher average urine mercury concentrations than the control group (Urban, 1999).

Table 4. Mercury Levels of Dental Practitioners and Control Groups
(Ritchie, 2004; Baelum and Pockel, 2007; Karahalil, 2005; Urban, 1999)

Findings: Dental practitioners had higher average urine mercury concentrations and were exposed to higher average air concentrations than the control groups.			
Study	Measure of Mercury	Dentists	Controls
Ritchie, 2004 – Dentists	Sample size	n = 162	n = 163
	Mean urinary mercury, nmol Hg/mmol creatinine	2.58	0.67
	Median urinary mercury, nmol Hg/mmol creatinine	1.70	0.50
Baelum and Pockel, 2007; Karahalil, 2005	Sample Size	n = 20	n = 9
	Urinary mercury, nmol Hg/mmol creatinine	3.1 ± 1.75	0.99 ± 0.45
Study	Measure of Mercury	Dentists and Dental Assistants	Controls
Urban, 1999	Sample size	n = 36	n = 46
	Mercury concentration in air (µg/m³, mean)	20	0
	Mercury concentration in urine, spontaneously (µg Hg/24 hrs, mean)	13.2	0.8
	Mercury concentration in urine, after DMPS* (µg Hg/24 hrs, mean)	97.1	3.6

* DMPS (sodium salt of 2,3-dimercapto-1-propane sulfonic acid), used as an agent for detoxification or to approximate mercury body burden

Significant correlations have been found between body mercury and workplace locations that produce **high mercury levels in the breathing zone**, including the amalgam preparation area, autoclave, and amalgam storage (Ritchie, 2004; U.S. DHHS, 1999; U.S. FDA, 2009). In contrast, areas of greater mercury contamination at floor level (outside the breathing zone) appeared to have little biological impact. A correlation has also been shown to exist between the **number of fillings placed or removed per week** and dentists' body mercury levels. The **number of hours dentists worked in surgery**, and the **number of amalgam surfaces** they had in their own mouths also were related to their body level of mercury (Ritchie, 2004).

Table 5. Urinary Concentrations of Mercury in Dental Workers
(Baelum and Pockel, 2007)

Finding: Variations exist by occupational group within the dental office and may reflect different work duties and exposures					
Study	Measure, Median value	Dentists [sample size]	Dental Assistants [sample size]	Dental Techs [sample size]	Dental Hygienists [sample size]
Akesson, 1991 Sweden	nmol Hg/mmol creatinine	1.58 [n=83]	2.21 [n=153]		1.79 [n=8]
Lenvik, 2006 Norway	nmol Hg/mmol creatinine	2.2 [n=33]	2.1 [n=75]	0.6 [n=1]	1.0 [n=1]

There is some evidence that the **length of work experience** of dentists influences urinary mercury. Dentists working less than 10 years were found to have a mean urinary mercury level of 25.0 nmol/l compared to dentists with 10 or more years of work experience with urinary levels at 44.5 nmol/l (Baelum and Pockel, 2007; Karahalil, 2005).

Limited studies suggest that **work duties** may result in different exposures by specific occupation within dentistry. Measurements of mercury urine in dental offices in Sweden and Norway showed variations by occupational group within the dental office; see Table 5.

Workplaces with **wooden floor material** showed about a 30% higher level of urinary mercury in comparison with tiles or linoleum (Baelum and Pockel, 2007). The **number of reported spills** has also been correlated with urinary mercury. Although a causal relationship has not been documented, a direct effect is probable but spills may also indicate poor hygienic measures in general (Baelum and Pockel, 2007).

High mercury levels in the breathing zone are significantly correlated with body burden of mercury in dental workers.

(Ritchie, 2004; U.S. DHHS, 1999; U.S. FDA, 2009)

Conclusions and Recommendations for Reducing Mercury Exposure in Odontology

In many countries, mercury exposure among dental practitioners has been decreasing over the past decades. Successful reductions in mercury exposure have been accomplished by replacing manual amalgam mixing with automated mixing, conducting mercury screening programs, increasing awareness and education regarding the risks associated with mercury exposure, and improving occupational regulations for dental clinics (Ritchie, 2002). Unfortunately, this is not true universally, and many workers are still exposed to mercury levels causing risks (UNEP, 2002). Studies have clearly shown that dental health care workers carry a higher level of mercury in their bodies than does the general population, and that body levels of mercury increase with workplace factors and with years of dental practice.

Minimizing, and ultimately eliminating, exposure to mercury in odontology is a precautionary approach that will reduce cumulative exposures to dental health care workers and will prevent its transport to downstream ecosystems. This is consistent with the precautionary principle, as defined in the Wingspread Conference on the Precautionary Principle held in January of 1998:

When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically (SEHN, 1998).

There are steps that odontologists can take immediately to reduce worker exposure to mercury:

Eliminate use of mercury by using alternative filling materials where feasible.

Use engineering controls such as dental tools that minimize the escape of mercury, amalgam separators, and appropriate ventilation.

Improve systems of work. This could include using amalgam capsules and mercury-tight storage containers to reduce the potential for exposure.

Use personal protective equipment (e.g., gloves, goggles, gowns) to protect dental health care workers from liquid mercury or amalgam particles.

Examples of these controls (Table 6) and best management practices (Table 7) may be useful for guiding these first steps.

As dentists and dental clinics work to eliminate mercury, they encounter economic, technical, and logistical challenges. Support and international cooperation are needed, at the highest levels of governments and NGOs, to remove these barriers. This might include:

Promote widespread educational outreach on mercury.

Commit to high-level mercury reduction and control within countries, regions, or medical communities.

Provide financial and technical assistance for investments in non-mercury products.

Enact regulations for import, export, transportation and storage of mercury.

Create systems for safe collection and confinement of waste mercury.

Establish waste regulations that protect air, water, and land from mercury, such as bans on dumping of mercury.

Ensure cradle-to-grave responsibility (from creation to disposal of products) for producers of mercury-containing products.

This report shows that dental health care practitioners are routinely exposed and carry a higher body burden of mercury than the general population. Reducing occupational exposure to elemental mercury in dentistry is a challenge, but opportunities for solutions are within reach. Although no single step will be sufficient, efforts at multiple levels—within odontology, in government agencies and in professional stakeholder organizations—will bring about the improvements that will protect the health of odontology workers and reduce the impact of mercury in the environment.

Table 6. Workplace Controls to Prevent Exposure to Mercury

Type of Control	Actions
Eliminate the Hazard	<ul style="list-style-type: none"> • Use mercury-free dental materials when feasible. • Educate patients on improved oral hygiene to eliminate need for fillings. • Replace other mercury-containing devices, such as thermometers and tensiometers. (sphygmomanometers), with mercury-free alternatives.
Use Engineering Controls	<ul style="list-style-type: none"> • Provide ventilation of work and storage spaces (including waste storage areas). • Use dental tools that minimize escape of mercury vapor. • Install chair side amalgam separators to capture waste amalgam from waste water and prevent its going down the drain. • Install containment around storage & handling areas to prevent vapor from introduced to ambient air and to insure that mercury drips or spills are contained.
Improve Systems of Work	<ul style="list-style-type: none"> • Phase out bulk mercury and use single-use amalgam capsules to minimize amount of mercury in use or storage. • Use mercury-tight waste containers that prevent airborne mercury exposures . • Make sure that housekeeping practices are timely and effective for keeping mercury out of the drain and trash. • Clean up mercury spills quickly and properly using a spill kit and following safe spill clean-up procedures.
Use Personal Protective Equipment	<ul style="list-style-type: none"> • Use personal protective gloves, goggles, masks, gowns to protect health care workers from liquid mercury or amalgam particulates.

Table 7. Examples of Resources that Provide Best Management Practices for Mercury in Odontology

<p>FDI Policy Statement: Mercury Hygiene Guidance FDI World Dental Federation. 2007. Available Online: (English) http://www.fdiworldental.org/sites/default/files/statements/English/Mercury-hygiene-guidance-2007.pdf (Spanish) http://www.fdiworldental.org/sites/default/files/statements/Spanish/Mercury-Hygiene-Guidance-2007-Sp.pdf</p>
<p>Future Use of Materials for Dental Restoration: Report of the meeting convened at WHO HQ, Geneva, Switzerland November 2009. World Health Organization 2010. (See Section 6, “Best Management Practices”) Available Online: http://www.mercurypolicy.org/wp-content/uploads/2010/12/who_mtg_report_nov_20102.pdf</p>
<p>Guidance on the Cleanup, Temporary or Intermediate Storage, and Transport of Mercury Waste From Healthcare Facilities. United Nations Development Programme. GEF Global Healthcare Waste Project. July 2010. Available online by searching using a search engine and the title as the search term.</p>

References

- Akesson I, Schutz A, Attewell R, Skerfving S, Glantz PO. Status of mercury and selenium in dental personnel: impact of amalgam work and own fillings. *Arch Envir Health* 1991 Mar; 46(2): 102-9. As referenced in Baelum and Pockel, 2007.
- Baelum J and Pockel H. Reference document on exposure to metallic mercury and the development of symptoms with emphasis on neurological and neuropsychological diseases or complaints. Department of Occupational and Environmental Medicine, Odense University Hospital. November 2007.
- Canto-Pereira LHM, Lago M, Costa MF, Rodrigues AR, Saito CA, Silveira LCL, et al. Visual impairment on dentists related to occupational mercury exposure. *Environ. Toxicol. Pharmacol.* 2005 5;19(3):517-522.
- Centers for Disease Control and Prevention (CDC), Division of Oral Health. Dental Amalgam Use and Benefits. Page last modified: September 8, 2009. Available online: <http://www.cdc.gov/OralHealth/publications/factsheets/amalgam.htm> (accessed 2/7/11).
- Environment Canada, Ontario Region Environmental Protection Branch, Fact Sheet #21: Mercury-Containing Products. Available online: <http://www.on.ec.gc.ca/epb/fpd/fsheets/4021-e.html> (accessed 5/31/11).
- European Commission, Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). The safety of dental amalgam and alternative dental restoration materials for patients and users. 2008.http://ec.europa.eu/health/ph_risk/committees/04_scenihhr/docs/scenihhr_o_016.pdf.
- Karahalil B, Rahravi H, Ertas N. Examination of urinary mercury levels in dentists in Turkey. *Hum Exp Toxicol* 2005 Aut; 24(8):383-8. As referenced in Baelum and Pockel, 2007.
- Lenvik K, Woldbaek T, Halgard K. Kvikksoveksponering blant tannhelsepersonell. *Nor Tannlaegeforen Tid* 2006; 116:350-6. As referenced in Baelum and Pockel, 2007.
- Massachusetts Department of Environmental Protection. Toxics and Hazards, Appendix D. Mercury Toxicity: Technical Overview. Available online: <http://www.mass.gov/dep/toxics/stypes/appd.htm> (accessed 2/7/11).
- Pohl L, Bergman M. The dentist's exposure to elemental mercury vapor during clinical work with amalgam. *Acta Odontol Scand* 1995 Feb; 53(1):44. As referenced in Baelum and Pockel, 2007.
- Ritchie KA, Burke FJT, Gilmour WH, Macdonald EB, Dale LM, Hamilton RM, et al. Mercury vapour levels in dental practices and body mercury levels of dentists and controls. *British Dental Journal* 2004 11/27;197(10):625-632.
- Ritchie KA, Gilmour WH, Macdonald EB, Burke FJT, McGowan DA, Dale IM, et al. Health and neuropsychological functioning of dentists exposed to mercury. *Occup Environ Med* 2002 05/01;59(5):287-293.
- Science and Environmental Health Network (SEHN). The Wingspread Consensus Statement on the Precautionary Principle. Wingspread Conference on the Precautionary Principle. January 26, 1998. Online: <http://www.sehn.org/wing.html> (Accessed 2/15/11).
- Scientific Committee on Occupational Exposure Limits (SCOEL). Recommendation from the Scientific Committee on Occupational Exposure Limits for elemental mercury and inorganic divalent mercury compounds. May 2007.

Secretaría del Trabajo y Previsión Social (STPS). United Mexican States, Ministry of Labor and Social Security. NORMA Mexicana NOM-010-STPO-1999, Condiciones de seguridad e higiene en los centros de trabajo donde se manejen, transporten, procesen o almacenen sustancias químicas capaces de generar contaminación en medio ambiente laboral. (Health and safety conditions in the workplace where chemical substances capable of generating contamination in the labor environment are handled, transported, processed, or stored.)

Shapiro IM, Sumner A, Spitz LK, Cornblath DR, Uzzell B, Ship II, et al. Neurophysiological and Neuropsychological Function in Mercury-exposed Dentists. *Lancet* 1982;1:1147-1150.

Tickner J, Coffin M. What Does the Precautionary Principle Mean for Evidence-Based Dentistry? *J. Evid Base Dent Pract* 2006;6:6-15.

Timbrell JA. Introduction to Toxicology, 2nd Edition. Taylor and Francis Ltd, London. 1995.

United Nations Environment Programme (UNEP) Mercury Program. Global Mercury Assessment Report. December 2002. Available online: <http://www.chem.unep.ch/mercury/Report/final-report-download.htm>. (Accessed 2/14/11).

United Nations Environment Programme (UNEP). Mercury: A Priority for Action. Mercury Use in Healthcare Settings and Dentistry. 2010; Module 4. <http://new.unep.org/hazardoussubstances/LinkClick.aspx?fileticket=yDKY6ZBMVbk%3d&tabid=4022&language=en-US>.

U.S. Department of Health and Human Services (DHHS), Public Health Service. Agency for Toxic Substances and Disease Registry (ATSDR). Public Health Statement: Mercury. CAS# 7439-97-6. March 1999.

U.S. Department of Health and Human Services (DHHS), Subcommittee on Risk Management of the Committee to Coordinate Environmental Health and Related Programs. Dental Amalgam: A Scientific Review and Recommended Public Health Service Strategy for Research Education and Regulation. 1999; Department of Health and Human Services, CCE-HRP, HFZ-1: Available at: <http://web.health.gov/environment/amalgam1/ct.htm>.

U.S. Department of Labor, Occupational Safety and Health Administration. Occupational Safety and Health Guideline for Mercury Vapor. Available online: <http://www.osha.gov/SLTC/healthguidelines/mercuryvapor/recognition.html> (accessed 2/7/11).

U.S. FDA (Food and Drug Administration). FDA Issues Final Regulation on Dental Amalgam. 2009; Available at: <http://www.fda.gov/NewsEvents/Newsroom/Pressannouncements/ucm173992.htm>, Accessed 7/12/2010. Updated 01/04/10.

U.S. Public Health Service. Toxicological Profile for mercury update. U.S. Department of health and Human Services. Public Health Service. Atlanta: Agency for Toxic Substances and Disease Registry. 1993;25. TP92-10.

Urban P, Lukas E, Nerudova J, Cabelkova Z, Cikrt M. Neurological and electrophysiological examinations on three groups of workers with different levels of exposure to mercury vapors. *European Journal of Neurology* 1999, Vol 6 No. 5: 571-577.

World Health Organization (WHO). Concise International Chemical Document 50: Elemental Mercury and Inorganic Mercury Compounds: Human Health Aspects. 2003.

World Health Organization (WHO). Mercury in Health Care: Policy Paper. 2005. Available online: http://whqlibdoc.who.int/hq/2005/WHO_SDE_WSH_05.08.pdf (accessed 2/7/11).

Occupational Exposure to Elemental Mercury in Odontology/Dentistry

Mercury has long been recognized as harmful to human health and the environment. It is highly toxic to humans and may harm vital organs including the nervous, digestive, respiratory, renal, and immune systems. Because it is so toxic, international efforts are underway to eliminate the use of products with intentionally added mercury.

In odontology, mercury may be found in dental amalgam and measuring devices such as thermometers and blood pressure devices (sphygmomanometers, tensiometers). Dental professionals in these clinics may be routinely exposed to ambient air with elevated concentrations of mercury. This mercury vapor enters the body primarily through inhalation, is transported throughout the body and accumulates in different organs.



This report describes the use and impact of mercury on health care workers in odontology and dental settings. A review of the literature is used to elucidate: the health effects of the type of mercury used in odontology, mercury exposure, and body levels in dental workers, correlation of body levels with the work environment and work tasks, and recommendations for reducing exposures.

