Dental Amalgam and the Environment

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An Examination of Three Different Global Dental Profiles

It is universally appreciated that the dental needs of the world are constantly changing. Currently, there are three distinct populations on the planet, who, because of their unique dental situations, each have a profound effect on the global use of amalgam. That being said, understanding these three profiles is essential in assessing future needs for dental restoration, as well as quantifying the impact the use of dental mercury has on the world’s environment.

1) Global Profile #1: Populations in Developed Countries

20% of the over 7 billion people on this planet are considered to live in developed countries,¹ and it has been reported that this group has the highest need for tooth restorations.²

Because residents of developed countries visit the dentist more often, many mercury fillings are already in the mouths of citizens who live in areas with adequate and available medical care. It should be recognized that these are the same people who could need additional medical care due to health issues caused by mercury.

Additionally, according to the United States Environmental Protection Agency (EPA), there is currently over 1,000 tons of mercury in the mouths of Americans, which is more than half of all the mercury being used in the U.S. today.³ Thus, patients who have amalgam fillings carry a “societal load” of mercury in their mouths.

A significant trend is that the demand for mercury fillings in this “developed countries” group is decreasing slightly, and the amount of mercury being removed from this group is slightly higher than that which is being placed.⁴

2) Global Profile #2: Populations in Underdeveloped Countries

Another 20% of the over 7 billion people on this planet are considered to live in underdeveloped countries. There is difficulty in tracking the need for restorations and dental decay in the
underdeveloped population of the world because of a lack of data. Yet, possibly due to a lesser access to fermentable sugars, the reportable decay rate for this group is very low. However, an accurate, statistically-demonstrated need for restorations in underdeveloped countries does not exist until the country moves into a “developing” status.\textsuperscript{5}

\textit{3) Global Profile #3: Populations in Developing Countries}

The population of the developing nations, which comprises the remaining 60\% of the over 7 billion global population,\textsuperscript{6} presently has a decayed, missing, and filled (DMF) tooth status in 12-year olds more than 2.5 times higher than other populations.\textsuperscript{7}

As populations in developing countries gain more wealth, they also have greater access to sugar, and as this consumption increases, the probability is that this population’s DMF will likewise rise.

Regardless of the cause, if the developing population required just one additional amalgam filling per person, the amount of mercury required to meet this demand would be over 2000 tons of mercury [\(0.5 \text{ gm/filling} \times 60\% \text{ (the developing population)} \times 7.2 \text{ billion (the world population)} = 2,160,000,000 \text{ gm or 2160 tons.}\) This would be added to the current 350 tons that is presently used globally on an annual basis. There is therefore, a profound greater risk of increased planetary exposure to mercury by the use of dental amalgam in countries that are developing.

Furthermore, the pattern of decay in developed countries has followed a very distinct pattern over the last 40 years, which is very relevant for developing countries to take into account.

Previous reports show that as countries were developing, decay rates in the general population rose to a peak of four to eight DMF (in the 1960’s) and then showed a dramatic decrease (today’s levels), as the following chart shows:
It has been hypothesized that increased access to preventative services and more awareness of the detrimental effects of sugar are responsible for the visible decrease of tooth decay in the chart above. However, it should be noted that this trend occurred with and without the systemic application of fluoridated water, so it would appear that factors other than fluoride caused this change.

In Denmark and Sweden, the decrease in DMF shown in the chart above was concurrent with a decrease in the use of mercury for dentistry. In these two countries, the peak use of amalgam occurred in the mid 1970’s, but it continued to decline simultaneously with the growing practice of using alternatives to mercury.

This is significant because newly developing countries may experience a similar pattern in which decay, and therefore restoration requirements increase substantially before leveling out to developed country levels. In fact, there is evidence of this happening in the world right now. Currently, Latin America has DMF scores over ten in 35-44 year olds. If this trend continues, the use of amalgam would then cause a proportional increase in the risk of mercury exposure to our environment.

The potential increase in dental mercury use is especially concerning in developing countries because these countries usually do not have the resources, infrastructure, or capital to activate proper best practice management (BPM) or to adequately protect the environment, patient, and dental professionals from the mercury in dental amalgam.

Another significant implication in the pattern of developed nations using more dental mercury for fillings is that previously, this trend occurred when environmental issues of amalgam were not known or being considered. Today, we know better, ans aside from the easily retrieved
mercury waste collected for recycling, the majority of mercury used in dentistry is released to the environment.

**Dispersive Model of Anthropogenic Release of Mercury from Dental Amalgam**

Because the U.S. has some of the most available and up-to-date research on dental health, and because most developed countries have shown similar patterns in dental restoration use,\(^9\) we can conservatively extrapolate the known U.S. data and apply it to other developed nations by multiplying the data by four. (This figure is based on developed populations accounting for 20% of the population and the fact that the U.S. population accounts for one-fifth to one-quarter of the developed countries’ population).

Evaluation of the accessible data shows that dental amalgam creates one of the most dispersive sources of mercury exposure to the environment. Dental use of mercury has globally increased from an estimated 270 tons to 350 tons per year over an eight-year period, which means that dentistry and small-scale gold mining are two of the few industries where mercury usage is on the rise.\(^{10}\)

One way to assess the environmental impact of dental amalgam fillings is to employ a basic accounting principle for determining the fate of the mercury-containing tooth restorations. Applying estimates of global and domestic mercury usage, using a routine process of
accounting, and analyzing available literature, allows one to determine the annual global impact of amalgam on the various subsets of the environment (air, water, soil, and living creatures).

This system helps to identify inadequacies in the use of dental mercury, which assists in gauging BPM (best practice management) in need of improvement in developed countries. This is particularly valuable for countries that are underdeveloped or developing, where decay rates and dental restorations could just beginning to increase.\(^{11}\)

Thoughtful consideration must be made as to infrastructure and BPM, which are required to justify the continued use of amalgam in an environmentally-responsible and conscientious manner. Developing countries, if they choose to use dental amalgam, will require consultation and capital to build BPM, while avoiding the same mistakes environmental mercury exposure has caused to developed countries over the past 140 years.

As such, below is a flowchart developed by the Government of Denmark on the dispersion of mercury from dental amalgam.\(^{12}\) This chart is especially enlightening when remembering the fact that mercury is vaporized from dental amalgam:

The chart above represents a “year’s snapshot” from 2001, and it would be reasonable to extrapolate these numbers to most developed countries using amalgam fillings, as this model was constructed before Denmark rejected the use of amalgam. However, the ratios of dispersion cannot necessarily be extrapolated to all countries since one must take into account the three distinct global population categories of populations outlined above.

In order to fully account for all of possible global dispersions of mercury from dental amalgam, the Danish model can be expanded, as in the chart below, which clarifies other integral areas of consideration:
The Issue of Dental Mercury that Does Not Reach Dental Facilities

Manufacturing Accidents and Small-scale Mining

The annual global use of mercury for dentistry is approximately 350 tons/year. Considering there is some pre-installation spillage at the manufacturing level, and some of this material is diverted for other uses such as small-scale mining, the actual amount used for dentistry is difficult to confirm.

Because there are no accurate tracking methods on a global scale for the ultimate use of mercury or for amalgam manufacturing spillage of mercury, this becomes the first inadequacy in the management of the material. This statistical issue further identifies the need for a global initiative to design a better BPM tracking model.
Although the percentage of spillage is quite likely much less than 1%, it is still significant, as it is a notable source of occupational mercury vapor exposure for those who work in the amalgam manufacturing sector.

It is also understood that virtually all of the dental mercury diverted for small-scale gold mining (SSGM) ends up in the atmosphere as a result of burning gold amalgam or in the rivers that are associated with the mining. During 2005 in Brazil, most of the mercury used in SSGM was labeled for use in dentistry,14 and the most recent estimates have global anthropogenic release of mercury into the air by SSGM at 1000 tons annually.15

**Environmental Dispersion of Mercury after It Reaches Dental Facilities**

Mercury from dental restorations enters the environment after it reaches the dental office in two ways: dental mercury is released to the environment from amalgam waste (i.e. amalgam that is not placed in patients’ teeth) and dental mercury is released to the environment from amalgam that is placed patients’ teeth.

Placing mercury fillings, cleaning them, and/or removing them results in dangerous levels of exposure, as the table below shows:

<table>
<thead>
<tr>
<th>OSHA maximum allowable level of mercury in the workplace during a single exposure</th>
<th>100 micrograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing with a triturator</td>
<td>400-600 micrograms</td>
</tr>
<tr>
<td>Opening autoclave with mercury-contaminated instruments</td>
<td>10-50 micrograms</td>
</tr>
<tr>
<td>Opening trap on the back of a dental chair filled with amalgam scrap</td>
<td>300-600 micrograms</td>
</tr>
<tr>
<td>Removing amalgam with water</td>
<td>100-200 micrograms</td>
</tr>
<tr>
<td>Removing amalgam with drill if water is accidentally turned off</td>
<td>1200-2500 micrograms</td>
</tr>
</tbody>
</table>

1) Dental mercury released into the environment from amalgam waste (i.e. amalgam that is not placed in patients’ teeth).

Knowledge of the basic dental process of placing an amalgam filling is necessary to explain the various components of mercury-containing waste created by this routine procedure. Much of this is outlined in the following chart created by Environment Canada; however, there are breaches in the accountability of the mercury’s fate because of a lack of monitoring that likewise need to be addressed.
a) Mercury waste from capsules

The first form of mercury waste created by dental amalgam placement is from the capsules (both used and unused) that contain or have contained the mercury and base metal elements. Each capsule contains 400 to 1200 mg of mercury, and there are plastic containers used to mix in the mercury and base metal components of amalgam.

Although some countries only allow encapsulated dental amalgam, there are still countries that allow the use and importation of bulk mercury for dental purposes. It is difficult to calculate the
actual number of mercury-filled capsules that must be stored indefinitely, yet there have been no
initiatives until the last decade to control where these capsules end up.

Currently, there is also no international body overseeing the safe disposal of this toxic waste, and
as a result, many of the mercury capsules end up in landfills. These unused capsules pose a
greater risk to the environment than used capsules because the mercury content in an unused
capsule is of greater quantity than the mercury remnants in a used capsule. Therefore, unused
capsules have the potential to leak out more mercury over a longer period of time.

The Environment Canada flow chart above suggests that the empty capsules may be thrown in
the garbage, as local bylaws allow. This practice means that the incineration of the amalgam
waste can result in the production of mercury vapor from the remnants of mercury on the
capsules, which would add up to a significant amount when considering the number of amalgam
fillings placed in Canada each year.

The only environmentally-safe fate the used or unused capsules have is in indefinite, long-term
storage, but interestingly enough, this type of facility has not been developed nationally or
globally. In Canada, where only encapsulated dental amalgam is allowed for importation, the
approximately 5000 kg of mercury brought in for dental use would yield close to 10 million
capsules that require safe disposal annually.

b) Mercury waste from sundries
The second form of mercury waste from placing an amalgam filling is tainted sundries. Rubber
dams, gowns, bibs, barriers, masks, gloves, cotton rolls, suction tips, suction screens, and wipes
all have the potential to carry amalgam particles. There are no programs in place to collect and
store this waste, and as a result, most of it is either sent to the landfill and/or incinerated as waste
or bio-hazardous waste, which obviously emits notable amounts of toxic mercury vapor to the
environment.

Additionally, a thorough cleaning of amalgam debris is required for reusable instruments, such
as mirrors, pluggers, carriers, rubber dam clamps and frames, carvers, and burs. Generally, this
waste is rinsed down the drain. For any instrument that is not properly rinsed, subsequent
sterilization can produce occupationally hazardous mercury vapor. This second category of
mercury waste may account for up to 1% of the total mercury used for dentistry or 3.5 tons
annually on a global basis.

Unfortunately, because the mercury is associated with sundries, the opportunity for recycling this
mercury is unlikely. Again, the only other option for BPM for this waste is indefinite storage
facilities. Without this type of facility, the waste will continue to be dispensed into the land fill
or down the sewers where it is leached into the environment.

c) Mercury waste from large-sized amalgam particles
The third form of waste from placing mercury fillings are large “chunks” of amalgam measuring more than 1 mm³. These are either unused particles or the amalgam scrapings that are produced when the filling is carved into its final shape. The chunks are supposed to be collected by hand and forceps, screens on suction lines, and amalgam traps.

Then, the amalgam particles are supposed to put in a sealed containers and eventually taken for long-term storage/recycling. There are no tracking instruments or long-term storage facilities in place in Canada or anywhere else in the world to ensure this safe practice occurs.

Furthermore, the recommended cleaning of the contents in “amalgam traps” provides another opportunity of vaporization and occupational exposure. This waste is not commonly caught in the “amalgam separators,” but rather the 1mm screens that fit inline on the suction hoses.

Theoretically, the “large chunk” waste of the process would account for most of the unused portion of the mercury in the installation of dental amalgam, or 54% of the amalgam not placed into patients’ teeth. This adds up 175 tons of mercury annually.

Yet, there is no reliable way to measure the amount that is recovered from this quantity, and the dental profession and related organizations that collect this waste also cannot account for this very large amount of material. Commonly these “chunks” are either “spit” down the drain and into the sewage system, swallowed by the patient (estimates of 17.5 tons of 10%17), thrown in the garbage where they enter the landfill, or disposed of as a biohazard which is incinerated, thus creating mercury vapor released to the air.

The author, a dentist himself, tried to establish some tracking method for how much of this type of waste is collected on an annual basis in Canada; however, there was no manageable way to calculate this to date.

d) Mercury waste from medium-sized amalgam particles
The fourth form of waste from amalgam placement is the particles larger than 1 cubic micron but smaller than 1 cubic mm. This size of particle is not as common in the initial placement of amalgam fillings as it is when amalgam fillings are being replaced.

These smaller scraps are not captured by the inline suction screens and normally make their way into the sewer, although recent recommendations on the use of amalgam separators are geared to prevent this size of particle from entering the environment.

e) Mercury waste from small-sized amalgam particles and vapor
The fifth form of waste from the insertion of amalgam fillings is sub-micron particles and mercury vapor. Mercury vapor from the actions of trituration, condensation (packing), and polishing commonly exceed maximum allowable occupational levels.18 19 20
As a result, safety measures must be taken to avoid this contact. Sub-micron particles are more commonly released when amalgam fillings are removed, as discussed in the next section.

2) Dental mercury released into the environment from amalgam that is placed in patients’ teeth:

46% of the mercury used for dental amalgam is placed in the mouth, which adds to the existing societal stock. According to WHO’s estimates on global use of mercury in dentistry, this amount could reach as much as 184 tons a year (400 tons x .46).

The mercury presently stored in the mouths of U.S. population has been estimated at 1000 tons, although this estimate is from 2004 and may be declining since more Americans are choosing non-mercury fillings and since the use of mercury in dentistry has been declining over the last decade.

Applying the 2004 U.S. rate to the population of Canada would provide for an estimated additional 100 tons of mercury stored in the mouths of dental patients. Applying this rate to the population of the developed countries, especially because the populations of the developed countries account for majority of the current societal load, would result in a conservative estimate that the global stock of mercury in the mouths of humans is presently at approximately 4000 tons.

Here it should be noted that there is a lack of clarity as to whether the amalgam fillings present in teeth (societal load) are considered to be part of the environment:

If the definition of the environment is only the land, water, and soil, then one can consider the mercury placed in the mouth of a human as being “out of the environment.”

If, on the other hand, the definition of environment is taken from the 1988 edition of the Canadian Webster’s Dictionary, then the environment is also the “surrounding, especially the material and spiritual influences which affect the growth, development and existence of a living being.” This definition means that the womb of a mother is one of the most important environments there is, and therefore females that are (or potentially will be), mothers should be considered an essential part of the environment.

This definition also means that if all men, women, and children are recognized as “living beings,” then every person is part of the environment, which would mean that any and all dental mercury placed in any human tooth is “in the environment.”

Regardless of what definition of environment is used, all of the mercury placed in the tooth that is not removed by careful protocol and BPM is doomed to end up in the outside environment from excretion via feces, exhalation, urine, sweat, burial, or cremation.
While developing countries are generally exhibiting a gradual decrease in the use of mercury in dentistry, trends show that developing countries are in a position to create a much higher need for tooth restoration. If these teeth are restored with amalgam, there will be a concurrent increase in the use of mercury for dentistry. 24

The societal store of mercury in amalgams has several secondary opportunities to be released into the environment, and these are discussed in the section below.

**Secondary Environmental Mercury Exposure from the Societal Load**

*Exhalation of mercury from placed dental amalgam as a source of air exposure*

The continuous vaporization of mercury from fillings in the mouths of humans creates much more of a dramatic impact on the environment than one might first consider.

First, the average filling has .5 gm of mercury,25 and the global societal store of mercury is estimated at 4000 tons (comprised of up to 8 billion fillings in peoples’ mouths worldwide).

Next, as indicated in the introduction, the amount of mercury vapor that comes off amalgam fillings in the mouth is dependent on many factors.

Thus, quantifying the mercury emissions from fillings in patients’ mouths has been attempted by many researchers. A conservative estimate of mercury vapor given off an average filling is from 0.6 - 2.5 ug/filling/day.26 Using 1.5ug/filling/day as an average to calculate the amount of mercury vapor entering our air from existing fillings, the annual global amount released would be approximately 12 billion ug/day x 360 days/year or 4320 billion ug (4.32 tons).

Of this vapor, approximately 80% is absorbed into the body by inhalation. Therefore, the total mercury vapor exhaled from the societal load is 20% of the unabsorbed mercury on inhalation.27 Based on these estimates, 2.6 tons of mercury vapor is exhaled into the atmosphere annually from amalgam fillings, and about 1.7 tons are absorbed into the human body via the lung.

Recent studies by Mark Richardson used EPA standards to calculate that 67 million Americans exceed the reference exposure level for mercury established by the EPA.28

*Mercury exposure from amalgam removal in societal load*

There are many reasons why amalgams are removed. In addition to hypersensitivity, metallic taste, restoration failure, and patient desire for superior esthetics, removal also occurs due to concerns about various medical conditions possibly associated with mercury exposure.29 30 31 32 Additionally, the average amalgam filling has a lifetime of 10 to 15 years, after which replacement is required.
Removal of old or unwanted fillings creates its own set of considerations with respect to the dispersion of mercury into the environment. This is largely because the routine technique of amalgam replacement requires removing the old filling with a high-speed dental drill. The action of the bur (bit) on the amalgam creates micron and sub-micron particles, as well as mercury vapor due to the heat of the drilling. It is well-known that heated mercury vaporizes at a higher rate and poses a greater threat to the people and the environment.

Thus, the overall procedure of taking out amalgam fillings produces mercury debris that is very difficult to account for because bits and shards are commonly projected several feet from the operating site. These can end up in the patient’s and operator’s mouth, eyes, clothing, hair, or on the floor. It is estimated that 10% of this amalgam is swallowed by the patient, and the remained, the majority of the waste, ends up in the sewage system through the eventual washing of hair, clothing, and floors, or via excretion.

Although the amount of mercury that is vaporized in this process is small percentage-wise, it can lead to levels ranging from .1 to 25 mg/m3 in the breathing space of both operators and patients. These levels exceed ceiling rates that are considered safe and lead to a significant increase in body burden of mercury in unprotected people working in the dental profession as well as their patients.

Alberta Occupational Standards (Alberta, Canada) allow no more than a 0.025 mg/m3 continuous exposure in an eight-hour working day and consider 0.125 mg/m3 mercury vapor to be the ceiling rate that is never to be exceeded for any duration. In addition, Alberta Occupational Standards consider mercury vapor to be a toxic substance readily absorbed through the skin, so protection for bare skin exposure at these levels is as important as avoidance of inhalation.

Furthermore, during the process of removal, high volume suction is recommended to prevent occupational exposure, but many of these suction units are vented to the outside. The amount of mercury vapor that comes out of suction venting in American Dental Clinics may be as high as 1 ton annually. Any vapor that is not evacuated by the suction has the opportunity to increase societal load by being up taken by dental workers and patients.

There have been attempts to monitor dental clinic air for mercury vapor; however, because the exposures are localized and concentrated, the standard occupational room monitors for mercury vapor do not fully reflect the actual amount of mercury vapor or the occupational risk that exists in a dental clinic setting.

Dental professionals have demonstrated higher levels of mercury in their urine when compared to the general population. The culprit of this phenomenon is unknown, but it could be from mercury vapor releases, intake of micron and sub-micron particles, or both. At any extent, the
production of particles of amalgam during removal creates an environment that can create a very significant occupational exposure to mercury, as well as patient exposure.

Studies have shown that the amount of amalgam particulate in the breathing space of patient and worker can equate to an inhalation rate of 19 mg per filling removed. Amalgam particulate is known to embed in the alveoli of the lungs where it is conducive to mercury disassociation. The mercury absorbed by this method is more likely to be elucidated in fecal samples rather than the urine.

The reason for this large volume of inhalation exposure is that regular operative masks commonly used for dentistry are designed for the resistance of micro biota. Masks do not afford any protection from mercury vapor and also allow mercury particles as large as 3 microns to pass through them. It has been estimated that 68% of the particles that are created by drilling on an amalgam filling are .7 um or less, which means these small fragments containing mercury are inhaled by dental personnel.

Another hypothetical issue of the masks commonly used in dentistry today is that the amalgam particles that are caught in the mask are immediately exposed to warming by the exhalation of the operator. This rise in temperature increases the disassociation of mercury in the amalgam particles, and thus exposes the operator to more mercury vapor.

The particulate produced by dental drilling that is not absorbed by inhalation of the dental staff and/or patient and that does not end up in the operator masks, ends up trapped in the suction, and hopefully in an amalgam separator, or it is dispersed throughout the dental operating room.

This means that mercury particles are taken into the bare skin of any individual within the sub-micron plume, protective layers covering the patient, the dental equipment, the hair and clothing of the workers and their patients, and/or the floor of the clinic.

Because of all of these hazards, extra precaution must be taken to protect the patient and the dental staff. This includes the utilization of the nitrile rubber dam (latex is not impervious to mercury), mercury rated masks, alternative air sources for the patient, drapes on all bare skin, horizontal mercury suction units, high volume suction, copious amounts of water, and nitrile gloves.

The techniques involved in removing amalgam from teeth causes the same mercury-contaminated sundry burden as what was outlined earlier in the section entitled “Dental mercury released to the environment from amalgam waste (i.e. amalgam that is not in a patient’s tooth).”

The difference between the placement and the removal of amalgam fillings is that the removal causes a much larger ratio of smaller particles that are not captured in conventional suction screens. In North America, it appears that there are slightly more mercury amalgam fillings
coming out of the mouth than going in, as the shift to non-mercury fillings in these jurisdictions occurs.

The decreasing placement of amalgam in developed countries\textsuperscript{33} causes a gradual decrease in the developed populations’ contribution to the amalgam societal load; however, this change creates a larger burden on the environment due to the removal of these mercury-based fillings. Extrapolating the numbers in Canada and applying them to other developed countries suggests that there could be as much as 200 tons of mercury drilled out of teeth each year.

Removal techniques have a profound effect on the environmental impact of this mercury. Dentists can reduce the burden on the environment, themselves, their staff, and their patients by using the drill bit to cross-hatch the old amalgam and “chunk” out the amalgam to retrieve these chunks by suction or by forceps. These larger chunks can then be placed into proper storage and disposed of in an environmentally-conscientious manner. The “chunking” also minimizes drilling and therefore reduces the production of micro and sub-micron particles and vapor. Using a generous water spray while drilling keeps the old amalgam filling cool and reduces the vaporization of mercury from the friction of the drilling. There are also special suction tips designed to increase the capture of mercury-laden aerosol produced by the dental drilling.

\textit{\textbf{-----The use of amalgam separators in preventing dental mercury releases-----}}

Amalgam separators are likewise essential in reducing mercury releases to the environment, as they can reduce up to 99\% of the small-sized particles that normally make their way to the sewer.

As such, after 14 years of an ineffective “voluntary” program to install amalgam separators, Canada has instituted a mandatory program for amalgam separators. However, these separators create an added expense to using amalgam, and the separators are only effective if they are maintained properly.

Amalgam separator maintenance creates another situation where human exposure to mercury can occur, and there are risks of spillage during maintenance of the separators and transportation of the waste collected in them. There are very few effective amalgam separator programs where both installation and maintenance are monitored, such as in the province of Ontario. Presently, there are very few jurisdictions in the U.S. where amalgam separators are mandatory, but efforts are underway to enforce their use. Several other developed countries including many European countries have embraced the use of separators.

Thus, although the maintenance of amalgam separators needs consideration and attention, at least their effectiveness in collecting some types of amalgam particulate has been well-established. Specifically, amalgam separators remove a significant amount of “fine” amalgam particles that would otherwise escape into the sewage system, which is known to be burdened by mercury discharge from dental offices. Yet, if the waste from the separators is not handled
properly, the particles that were collected could end up being released to the environment anyway.

Studies acknowledging the amount of dental waste emitted into sewage demonstrate the necessity for enforcement of amalgam separators and maintenance regulations, especially because much of the mercury amalgam in sewage sludge ends up being incinerated or spread on the soil as fertilizer, which again adds to the environmental burden.\textsuperscript{84}

The impact of waste from amalgam into sewage treatment facilities is prolifically shown by evidence of the quantity of mercury releases to the water supply caused by dental offices. For example, the New York Academy of Sciences estimated that 40-60\% of the mercury in the NY/NJ harbor was a result of dental office waste,\textsuperscript{85} and the Metropolitan Council Environmental Services for Minneapolis-St. Paul estimated the following breakdown of sources of mercury that their sewage system handled:\textsuperscript{86}

1) Industrial 5-10\%
2) Residential 15-20\%
3) \textbf{Dental Sources 76-80}\%

While it is clear that the use of amalgam separators is essential for protecting the environment, the separators simply do not prevent all of the mercury releases into the environment by dental amalgam.

A study involving analysis of mercury containment in Ontario wastewater in 2002 calculated that roughly half of the amalgam removed from the societal load makes its way down the suction to the amalgam separator.\textsuperscript{87} So, what happens to the other half?

Based on statistics collected, about 1350 kgs of particulate are targeted for amalgam separator recovery while the additional portion finds its way into the sewer annually.

The remaining 1350 kgs of waste from amalgam removal, along with the other 2614 kg waste created by new fillings being placed (4665 kg - 2051 kg), must be accounted for. Although 1081 kgs of amalgam particulate are collected in the 1 mm screens during this study, 2883 kgs of amalgam are still missing from the equation.

This missing mercury likely consists of large chunks of amalgam that are collected, jarred, swallowed, or thrown in the waste. The unaccounted mercury may also be comprised of miniscule particles that are either inhaled, embedded in clothing, hair, and dental sundries, or trapped in the operatory, where cleaning procedures are likely to carry this waste into the sewer. Lastly, this unaccounted waste could be in the form of mercury vapor that is inhaled via the lungs or absorbed through the skin by dental staff and/or patients, or mercury that is heated and emitted as vapor to the atmosphere.
The point is that 2883 kgs of Canada’s mercury is left unaccounted for, even if amalgam separators are used. This is a significant amount which poses a serious hazard to the Canadian environment and the people in it, and this same practice is happening in other countries.

*Secondary exposure of mercury from the amalgam societal load via extracted teeth*

Many times when dentists remove teeth, the extracted tooth contains amalgam filling material. The fate of this mercury is not well-tracked, and there is inconsistency from jurisdiction to jurisdiction regarding the handling of an extracted tooth with an amalgam filling.

For an example, the most recent recommendations from Alberta Health Services advise that extracted teeth be placed in bio-hazardous containers. There is difficulty in classifying this biohazardous waste because extracted teeth contain a wide variety of micro biota, which has resulted in a recommendation to incinerate the waste. Yet, incineration is contraindicated for a material that contains mercury because it causes heat and thus more rapid mercury vapor releases to the environment.

There is still debate on how to best handle these situations; however, there appears to be only two solutions: 1) The tooth with mercury is placed in a landfill, risking mercury and micro-biotic leaching, or 2) The amalgam is removed and placed in the “large chunk” sealed container that ultimately is taken to a recycling/storage facility, and the rest of the material is handled with consideration for micro-biotic leaching. The first scenario results in endangerment to the environment and landfill operators, and the second scenario endangers the person removing the amalgam. Both scenarios add an additional cost to the delivery of the amalgam filling service.

There is no data from any country that specifically tracks extracted teeth, let alone extracted teeth with amalgam fillings. It has been estimated that there could be up to 10 million extractions a year in the U.S. that are not for orthodontic purposes or wisdom teeth (unlikely to contain amalgam).

Considering that numerous teeth are removed because of pathology, and many times as many teeth are removed because of a “deep filling” that has abscessed, there are likely a substantial number of extracted teeth containing amalgam. Conservatively, if merely one-quarter of these teeth have amalgams, and each filling averages .5 gm, then a reasonable amount of mercury in extracted teeth would be in the hundreds of kilograms in America. Globally, this burden could be four times the American amount.

At any extent, there are no established protocols to protect the environment from mercury-containing extracted teeth, even though the releases are clearly substantial.

*Secondary mercury exposure from the societal load via human excretion*

Although mercury can be excreted both via the feces or the urine, the majority is fecally
eliminated. Research has shown that the average person with amalgam excretes approximately 0.1 mg of mercury per day in his/her feces. In the United States, this amounts to over eight tons of mercury per year eventually being flushed out to sewers, streams, and lakes. Applying this rate to the developed population, the amount of mercury entering our sewers from this route possibly reaches 32 tons.

**Mercury from amalgam in the saliva**

Mercury releases from the saliva of people with amalgam fillings would seem to be a small amount, but the analysis of these concentrations raises some essential considerations:

- First, the amount of mercury in saliva is directly related to number of fillings.
- Furthermore, the output of mercury vapor continuously emitted from amalgam fillings is dependent upon other activities associated with the human mouth, such as chewing (such as food and gum), teeth-grinding, and the consumption of hot liquids.
- Next, the production and the swallowing of saliva account for up to .5 to 1.5 litres per person, per day. The concentration of mercury in saliva in people with amalgam fillings commonly reaches more than 4.14 ugm/l, which is more than four times Health Canada’s allowable limit of 1 ug/l mercury concentration in water.
- Finally, the recommended consumption of water per person is 2-3 litres a day, but if the saliva of a person with mercury fillings was assessed for consumption, it would be declared unfit for drinking because of unacceptably high levels of mercury!

**Secondary mercury exposure from the societal load via cremation**

The amount of mercury that enters the environment from crematoriums is directly related to the amount of mercury contained in amalgam fillings, and the demographics of the population likewise correspond with this pollution. In the developed populations, as more elderly are keeping their teeth, there is a higher prevalence of mercury in the cremated body. Similarly, as the developed populations begin to reject amalgam and choose non-mercury containing filling material, the risk of mercury vapor being produced by cremation will be reduced.

Estimates of mercury releases during cremation have been offered by several researchers. Mills in the UK estimated an average of 3 grams/cremation, and this estimate has been judged reasonable by Swiss and Swedish and Finnish researchers.

Another major factor is that many citizens in the developing populations are choosing cremation over burial. The Cremation Association of North America estimates that over 40% of deaths will be handled via cremation in 2010 in the U.S., and a U.S. estimate of mercury emissions from crematoriums prepared for EPA Region V by Barr Engineering and updated by EPA staff concurred. In the January 2006 version of this document, the estimate was that in 2005, there
were 2,961 kilograms of dental mercury in the corpses cremated, and 75% (2,221 kg) of that mercury was released as air emissions, while 25% (740 kg) was released to the land. The primary source of the land emissions is mercury attached to settled particulates from the crematoria.

Overall, global amounts of mercury entering the environment via cremation can be conservatively estimated at 12 tons annually. Obviously, this amount of anthropogenic exposure requires attention, and it is not surprising that localities around the world have even begun fighting crematoriums in their neighborhoods due to fears of mercury releases.

Mercury release by cremation merits consideration of mandatory “extraction” of mercury-containing teeth prior to cremation and/or scrubbers in the stack to help protect the environment. This once again attaches an additional financial burden to the placement of amalgam fillings. Although these management practices can help reduce mercury exposure, one has to consider that scrubbers on stacks are not known to be 100% efficient. They are also extremely expensive. The practice of removing the mercury-containing teeth from the deceased not only increases the financial burden, but it also creates an increased need for storage, recycling, and/or handling, as well as an additional risk of exposure to the people that remove the teeth and/or amalgam.

Secondary mercury exposure from the societal load via burial

There are no studies on whether mercury from the fillings of the deceased who are buried leach out into the surrounding soil over time. Yet, a variety of burial methods would seem to cause environmental exposure.

Whether an individual is buried in a sealed casket, a cement vault, a tomb, or a shroud, inevitably bugs, worms, water, bacteria, and soil find their way into the area. A so-called “natural burial” (commonly promoted as a “green” resting place) actually seems to have higher potential for mercury exposure into the soil and water table since the body is not at all encased in this circumstance.

Any type of burial that promotes the oxidation of the body and the casket (if used) presents a greater risk of causing mercury contamination. If “green burials” gain popularity, then there is an urgent necessity for an established protocol to remove the mercury from the mouths of these bodies before they are placed in the earth.

One thing is clear: any mercury amalgam buried with a person impacts the soil, water, and animals in the vicinity.

Motherhood as another secondary exposure of the societal load
If environment is, as defined by the 1988 Canadian Webster’s dictionary as “the surrounding, especially the material and spiritual influences which affect the growth, development and existence of a living being”, then the mother or potential mother most certainly plays a major role in the “environment.”

Indeed, scientific studies have already proven the devastating impact of mercury on pregnant women and children, which is why pregnant women and children are advised not to eat certain types of seafood that might contain methyl mercury.\textsuperscript{109 110 111}

The dangers of fetal and infant exposure to mercury via maternal dental amalgam have likewise been scientifically established, and specific concerns have been raised about neurological issues, developmental delays, and cleft palate development.\textsuperscript{112 113 114 115 116 117 118 119 120 121 122}

Furthermore, the most up-to-date science continues to expose the havoc that the mercury in dental amalgam fillings wreaks upon pregnant women and children. A study published in the April 2011 edition of \textit{Environmental Monitoring and Assessment} notes, “As we showed, the number of amalgam filled teeth in breast-feeding mothers strongly influences the mercury level in their milk. Take it into consideration that maternal milk is the only source of nutrition during the first few months after birth.”\textsuperscript{123}

Another recent study published in \textit{Science of the Total Environment} cautions, “Changes in dental practices involving amalgam, especially for children, are highly recommended in order to avoid unnecessary exposure to Hg.”\textsuperscript{124}

Perhaps the best summation of using mercury in products for children was made at the 2010 United States Food and Drug Administration’s Dental Product Panel hearings by Dr. Suresh Kotagal, a pediatric neurologist at the Mayo Clinic, when he announced, “There is really no place for mercury in children.”\textsuperscript{125}

Meanwhile, mercury has suspected as a factor in autism,\textsuperscript{126 127 128 129 130 131 132 133 134 135} and as such, maternal dental amalgam fillings have been linked to autism as well.\textsuperscript{136 137 138 139 140}

\textbf{Closing Statements}

A peak of mercury use in 70’s has been recognized,\textsuperscript{141} and since dental amalgam use began in the mid 1800’s, there has been very little attention given to the environmental impact of this material until the last 15-20 years.

Because dental amalgams require replacement every 15 years or so, it can be argued that the majority of mercury used in dentistry from its initial use up until 1995 is functionally “in the environment.” The only mercury that was recaptured during this time would be the large chunks of amalgam waste that dentists might have collected. The rest of the mercury is inevitably
released in the soil, air, water, and patients. There is not enough data to calculate this burden, but an educated guess would put the number in the thousands of tons.

This mercury released from dental amalgam exists in all facets of the environment, and it exists in many forms. It may exist as an amalgam particle continually vaporizing mercury, it may exist as inorganic mercury, or it may have been converted into methyl mercury by a number of organisms that have this potential.

Considering this, it may be a moot point to separate the methyl mercury from the consumption of fish and the inorganic mercury that is produced by mercury vapor. There is a real possibility that because of the magnitude of mercury pollution created by dental amalgams, the mercury in fish might have originated from dental amalgam filling material.

It is concerning that although the developed countries are beginning to understand and act upon the environmental mercury hazard created by amalgams, there is a population three times the size of the developed population that is just beginning to enter a phase requiring extensive dental restoration.

It is also clear that a true global phase down of dental amalgam would assist in a smoother, safer, and more economical transition to a healthier world without so many mercury releases to the environment. The filling alternatives are already in place, and there are organizations such as The International Academy of Oral Medicine and Toxicology and countries such as Norway, Sweden, and Denmark that are willing to assist in this changeover.


5 Ibid.

6 Ibid.

7 Ibid.


9 Ibid.

10 Ibid.

11 Ibid.


15 Ibid.


21 Ibid.


Ibid.


Ibid.


Ibid.


Ibid.

Ibid.

Ibid.

Ibid.

Ibid.

Ibid.


Numerous examples of this exist, as you can see simply by internet searching for news stories about communities fighting crematoriums and crematoriums being required to reduce mercury emissions. Here are several:
- http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2006/07/07/BAG7OJQPDC1.DTL&ao=all
- http://www.dudleynews.co.uk/news/9613140.Dated_crem_facilities_to_get___1m_overhaul/


United Nations Environmental Programme. [UNEP (DTIE)/Hg/INC.4/3 -] “Revised draft text for a comprehensive and suitable approach to a global legally binding instrument on mercury” Draft text accessed online 13 April 2012 at http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/INC4/4_3_drafttext_advance.doc