A Comparison of Availability, Affordability, Effectiveness, Risks and Benefits of Dental Materials

Report of the Chief Dental Officer

World Alliance for Mercury Free Dentistry

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1. Report #1 - A Comparison of Dental Materials

Dental Filling Materials A Comparison of Availability, Affordability and Effectiveness Risks & Benefits

1.1.Introduction

This report provides information on the availability, technical and economic feasibility as well as the environmental and health risks and benefits of non-mercury alternatives to dental amalgam.
A direct comparison between the non-mercury dental materials and mercury dental amalgam is given to illustrate the information.

From its first introduction over 150 years ago, dental amalgam from its onset has always been a controversial material [1] [2]. Reports of pathology associated with dental amalgam appeared very quickly along with the damage caused to teeth by the physical characteristics of the early amalgams. However, at that time there was no alternative to dental amalgam available other than gold to restore teeth. Amalgam fillings soon became the mainstay of dental incomes.

The early poor handling characteristics were reduced but not eliminated over time and dental amalgam became an accepted dental restorative material of choice for posterior teeth.

Dentists are trained on the practical and functional aspects of restoring teeth, they are not trained toxicologists. The pathology and environmental effects associated with mercury from amalgam can have a delayed onset and it was assumed that dental amalgam was a safe material to restore teeth. Dentists did not see any problems with mercury dental amalgam but they never looked for any problems nor are they qualified to do so.

The non-mercury alternatives are composite, compomers and glas-ionomer materials.
Composite is the material most used as a replacement to dental amalgam in adults while compomer, a cross between composite and glas-ionomer, and glas-ionomers tend to be used more in first or deciduous teeth in children. These materials were introduced in the 1960's and have since become commonplace. There has been significant progress made in the development of all these materials and at the Stockholm meeting of the Minamata Convention in the Swedish Chemical Agency stated the alternatives to dental amalgam are available, affordable and effective.

Composite is a resin filled with ceramic particles, glas-ionomer is a silica and polyacrylic acid combination and compomer is a mixture of both.

Dental amalgam is a mixture of 50% mercury and 50% silver, tin, copper and other metals. The term amalgam means mercury mixed with metal. The mercury is held in place physically with no chemical bonds and can be released by heat, abrasion or chemical reaction between dissimilar metals.

Dental amalgam consists of a mixture of metals including liquid mercury (Hg) and a powdered alloy composed of silver, tin, and copper.
Approximately 50% of dental amalgam (by weight) is elemental mercury. This mercury can pollute the environment and high levels of mercury vapour exposure may cause potential toxic effects endangering patients and dental professionals as well.

Exposure to dental amalgam will result in increased mercury levels, often in correlation with the number of personal or placed/removed dental amalgam fillings [3]

When considering the health aspects of all dental materials the effects to be assessed are twofold.

- Allergy or immunological.
- Toxic or poisonous.

An allergic response is not dose dependant and even traces of the allergen can cause symptoms.
A toxic or poisonous event is dose dependant, the more of the toxin present, the greater the effect observed.
Mercury can be both toxic and allergenic at the same time hence the confusion that can arise.

Mercury released from dental amalgam is converted in vivo into highly toxic methyl mercury [4].
The Wingspread Consensus statement of 1998 states [5]:

"The Precautionary Principle calls for preventive actions when an activity is believed to threaten human health or the environment, even if there is no scientifically established evidence"

This "*Precautionary Principle*" must apply to all dental materials especially as dental amalgam is the source of the greatest body burden of mercury in humans [6].

1.2.Availability

The Swedish Chemical Agency stated at INC1 in 2010 that the alternatives to dental amalgam are "*Available, Affordable and Effective*".

In the intervening ten years since that statement the alternatives to dental amalgam, composite, compomer, glas-ionomer, have become significantly more *"Available, Affordable and Effective"* for both developed and developing nations.

1.2.1. Composite, compomer and glas-ionomer

All these materials are now available as a liquid/powder to be mixed together by hand prior to use. The material is placed into the prepared cavity and self hardens quickly.

This method is suitable for ART, (Atraumatic Restorative Technique) as well as more traditional techniques.

ART can be performed by personnel with limited training and without electricity using hand instruments only. It is especially suitable for situations where trained dental personnel, equipment and electricity are not available.

The use of these materials allows access to dental care to populations where traditional dental care facilities are limited.

The materials are also available in a light hardening form and premixed in tubes or capsules.

A variety of shades are available when aesthetics is a consideration. The use of the light hardening materials does require an equipped dental clinic and access to electricity.

Surplus material and waste products present no environmental hazard.

1.2.2. Mercury Dental Amalgam

Dental amalgam fillings require trained dentists, an equipped dental clinic and access to electricity all of which can limit access to dental care in certain populations.

Excess dental amalgam and the waste products including used capsules do present an environmental hazard due to the mercury release in both vapour and particulate form.

It is noteworthy that Zambia, a developing country with limited financial resources has been amalgam free for children since the beginning of this century illustrating both the availability and economic viability of the alternatives to dental amalgam.

Conclusion: Mercury-free alternatives to dental amalgam are freely available and offer advantages in methods of treatment in challenging situations.

1.3.Technical and Economic Considerations

1.3.1. Direct one on one costs

As a direct result of the Minamata Convention one European materials manufacturer has developed a composite filling material that has the handling characteristics of glas-ionomer and is equal in cost to amalgam. The composite is called Cention N [7] and the cost is USD 0.50 / filling.

Compomer and glas-ionomer materials are generally the same cost or less than USD 0.50 / filling. The cost varies from brand to brand as with all types of dental materials.

Dental amalgam again varies in cost according to the manufacturer but the lowest price is around USD 0.50 / filling. The cost of amalgam has increased significantly since the ratification of the Minamata Convention due to the increase in cost of mercury.

Dental amalgam is 50% mercury and 50% silver, tin, copper and other metals. The cost of amalgam varies also according to the prices of these metals, all of which have increased in the last few years.

Conclusion: There is no difference in price between dental amalgam and the mercury-free alternatives. Current trends in the increasing price of mercury since the ratification of the Minamata Convention means that dental amalgam will become more expensive per filling than the mercury-free alternatives on a like for like basis.

This does not include any additional environmental and health costs related to mercury release.

1.3.2. New composites, bulk fill, no light, pad mixing

The latest development in composites means that some are self hardening without curing lights and some require curing lights. Only the early composites showed shrinkage when setting, which has been virtually eliminated now. To overcome the shrinkage composites required a layering technique in placement but the new bulk-fill composites have done away with this, allowing the whole filling to be placed at once. This significantly reduces the time needed to fill the tooth and makes bulk-fill composites slightly quicker to place into a cavity than dental amalgam.

Dental students who train with composite take a longer time when placing amalgam so amalgam is not necessarily easier or quicker to use.

Composites always used to require a separate bonding agent to be applied to the tooth to “stick” the composite into the tooth and the bonding agents need a light to cure them. Some composites can now be used without bonding agents but this does mean that the tooth has to be prepared as for a dental amalgam filling with mechanical undercuts for retention.

Composites, compomers and glas-ionomer materials come as a liquid/powder to be hand mixed or in tubes or small tubs already premixed and require no additional equipment.

Dental amalgam capsules require specialise equipment to mix the amalgam in the capsule.

Conclusion: Composite use requires different techniques than dental amalgam but also can be quicker to place and can require no special equipment. Composites are suitable for use in dental clinics and along with glas-ionomer and compomer, can be suitable for ART in more challenging situations allowing dental care to become more universally available.

1.3.3. Reduced tooth destruction

Glas-ionomers are sticky by nature and generally require no healthy tooth tissue removal in order to place them into teeth.

Composites used with a bonding agent also require no removal of healthy tooth tissue as they adhere strongly to the tooth. The strength of a bonded composite filling is up to 80% of that of a healthy tooth which is higher by far than any other filling material [8] [9].

Mechanical retention requiring substantial removal of healthy tooth tissue to create undercuts is a requirement for dental amalgam.

Conclusion: The mercury-free alternatives to dental amalgam require less healthy tooth tissue removal than dental amalgam and in the case of composite produce a stronger filled tooth.

1.3.4. Life of filling (life of tooth)

The WHO report “The Future Use of Materials for Dental Restoration” 2011 states that the life of the tooth is the most important factor when considering what filling material to use. It goes on to state that dental amalgam is not the first choice for deciduous or “baby” teeth. The reason for this is that the use of composite or glas-ionomer fillings retains more of the healthy tooth structure and has adhesive properties that dental amalgam lacks. As the useful life of “baby” teeth is quite limited then glas-ionomer material is the material of choice for “baby” teeth although the material may not be as structurally strong as other materials and is more soluble over a period of years.

Glas-ionomer is the material of choice for ART and the work by Frencken [10]has shown that in fact glas-ionomer is effective and practical as well as economical for restoring “baby” teeth and in some cases adult teeth too.

Composites are durable, the author has seen composite fillings he did over 30 years ago that are still viable. The older composites were more technique sensitive to place than dental amalgam but the latest developments in composite have reduced the skill necessary for the placement of a satisfactory composite filling to the level required of that of dental amalgam.

The length of life of a composite filling is at least as long as that of dental amalgam and many reports show a longer life for composite fillings than for mercury amalgam fillings [11] [12] [13] [14] [15] [16] [17].

All materials need to be placed into a dry cavity in order to obtain marginal integrity. Fillings of any material placed into a cavity that is wet or contaminated with saliva are likely to experience secondary caries (decay) in a short period of time. The exception to this is glas-ionomer which can

remain viable if the cavity is not too wet. This is another reason for the success of glas-ionomer in treating “baby” or deciduous teeth.

Dental amalgam expands as it sets and this expansion can crack the remaining tooth. If the dental amalgam is placed in a “wet” cavity, the expansion is even greater and quicker. Even a correctly placed dental amalgam will expand as it releases mercury into the body. This expansion can result in the failure of the tooth structure requiring an expensive laboratory made restoration such as a crown or inlay or onlay in order to save the tooth.

In many cases the crack is so extensive that the tooth cannot be saved.

It is extremely unlikely that the teeth illustrated in Figure 1 will survive for any great length of time as the crack continues down the tooth into the root structure.

Figure 1 Teeth cracked by amalgam

Repair: All dental filling materials can fail. However, because composite strengthens the tooth as opposed to dental amalgam which weakens a tooth, usually it is the composite filling rather than the tooth that can become damaged. In many cases where composite has fractured it is possible to satisfactorily repair the filling. This capability of being able to repair composite is a considerable benefit to the patient in terms of time, discomfort and money when compared to dental amalgam which is seldom repairable [18] [19]

Conclusion: Glas-ionomer and composite have more favourable handling characteristics than dental amalgam which results in less healthy tooth substance being removed. Composites and glas-ionomers have a greater dimensional stability that dental amalgam that leads to less damage to the filled tooth. Composite fillings exhibit a greater longevity than dental amalgam. Composites can be repaired easily to restore a tooth to function unlike dental amalgam fillings which, cannot be so easily repaired and made functional.

1.3.5. Facilities needed.

Dental amalgam and the traditional composites require trained personnel, such as dentists or dental therapists, in a full dental clinic setting. This involves considerable financial investment and length of time to establish. In addition to this the facilities are fixed and need reliable supply of electricity. Mobile clinics are rare and most often used by the military.

Dental amalgam in capsule form requires special equipment to mix the amalgam material in the capsules. Composites and the other materials do not need any specialised equipment except curing lights in some circumstances.

The need for fixed facilities limits access to restorative dental care for large numbers of people especially in developing nations.

However, glas-ionomers and newer composites can be placed using ART which can be done by quickly trained non-dentist personnel, no electricity and be effective in restoring teeth even in the most challenging of situations. No fixed facilities are needed for ART making the restoring of decayed teeth available to many who would otherwise be denied it.

Conclusion: The alternatives to dental amalgam require substantially less fixed facilities than dental amalgam.

1.3.6. Personnel training.

Dental amalgam requires the services of fully trained dental personnel in removing old dental amalgam fillings, placing new ones and safely disposing the mercury waste produced.

All dental staff should be trained in the safe handling of dental amalgam when placing a new filling to protect themselves from the mercury vapour released when mixing and placing dental amalgam fillings.

Light cured composites also require trained personnel and require different cavity preparation techniques and placement procedures which some dentists used to placing dental amalgam can find challenging. The younger generation of dentists are trained on composites and the handling characteristics of the newer composites are greatly superior to the first composites on the market.

Personnel can be trained for ART within a matter of days. The type of restoration performed by such personnel will be reasonably simple and the more complex restorations will need to be done by trained dentists. This makes ART especially suitable for treatment of children and juveniles in a less threatening environment that that of a fixed clinic with a gowned and masked staff.

Conclusion: Dental amalgam and light cured composites require a fully equipped dental clinic with trained staff. The newer self cured composites and glas-ionomers can be used with a bare minimum of personnel training and clinical facilities.

1.3.7. Economic Considerations:

There are three aspects to the economic considerations between the various dental materials. Micro-economics, Clinical Time and Macro-economics.

1.3.7.1. Micro-economics

This is the direct comparison for each material to fill any tooth. Composites and dental amalgam can be considered equal when considering the cost of a filling but today's composite fillings have been shown to last longer than dental amalgam.

In the future as the costs of mercury rise due to the Minamata Convention limiting availability and the historic violent fluctuations in the price of silver, composites should cost less per filling than dental amalgam. Composite fillings can be repaired and strengthen teeth unlike dental amalgam which gives composite a distinct economic advantage over dental amalgam.

Glas-ionomer per filling is less than either dental amalgam or light cured composites but cannot be used in all situations and will not last as long.

1.3.7.2. Clinical Time

Placing the alternative materials requires one visit only. Amalgam requires two visits, the first to place the filling and the next one at least 24 hours later to polish the filling.

The extra personnel costs of the extra visit should be considered in the economic viability of the non-mercury versus the mercury containing fillings.

1.3.7.3. Macro-economics

This is the cost of each material to the environment, personal health of the patient and the economic considerations to any country using dental amalgam. The Concorde [20] report "*The Real Cost of Dental Mercury*" written in 2012 rigorously looks at the overall cost of mercury from dental amalgam into all these aspects. The report therefore concludes:

"*from a full cost perspective, that dental amalgam should be phased out.*" [20]

There is a cost to the environment of at least $60 per filling which will at some future date have to be paid most likely from the public purse in addition to the adverse health impact mercury from dental fillings has on direct medical costs and loss of productivity of the affected individuals.

Mercury exposure does have the effect of reducing intelligence [21] which at an individual level may not seem so severe but taken over the whole population the consequences can be dramatic.

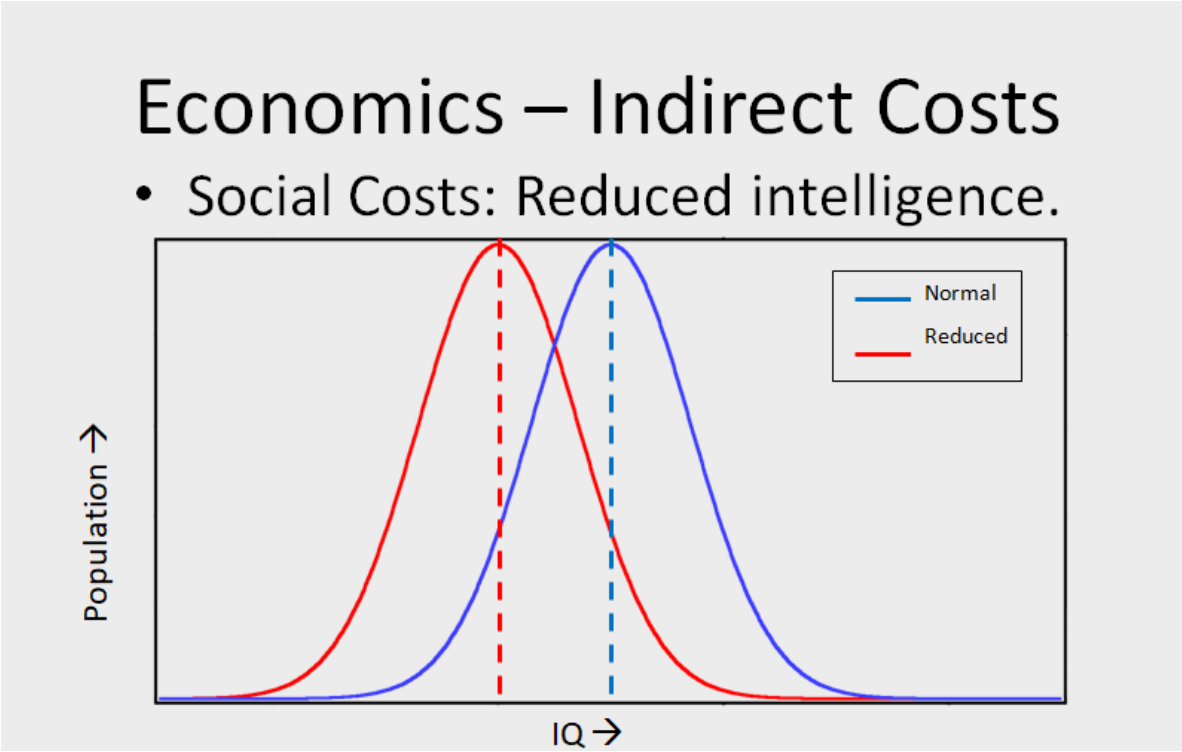

Figure 2 Reduced intelligence due to mercury

A normal intelligence quotient of a population is a Bell shaped curve. Reducing the overall intelligence by just a few points moves the whole curve to the left. At the top end of the curve there would not be much noticeable difference between the two normal and mercury exposed (reduced) groups. However, looking at the curve at the extreme right it becomes apparent that there is a significant reduction in the individuals of very high intelligence in the mercury exposed group compared to the normal group.

These high end individuals are among the economic drivers of a society and where many of the political class and academics achievers come from. The overall cost to a society from the reduction in numbers of this group is obviously difficult to quantify.

The Real Cost of Dental Mercury report states on pg44 "*One important observation more or less hidden in the recent research results of increased risk to cognitive development in exposed*

populations is that such effects are likely to occur in a much larger fraction of the population than previously thought. In effect, it may be argued that reducing mercury exposure for the population as a whole – even by a few percent – can have a disproportionately large benefit at the margin". [20]

Conclusion: This is a clear case on health and economic grounds to immediately stop the use of dental amalgam on children and pregnant ant nursing mothers followed by an overall ban on amalgams.

1.4.Environmental

1.4.1. Exposure: Vapour/Particulate. Filling and Removing. Routes of release.

Composite, compomer and glas-ionomer are stable materials and do not release any toxic vapour unlike dental amalgam which releases mercury vapour throughout the life of the filling. As wear occurs on these filling materials particles can enter the GI tract and the environment but there are no reports of any health or other problems associated with such small amounts. Drilling these materials out of a tooth will result in particles the size of that of the bur, these are not micro particles and again there are no reports of any health or other problems associated with this.

Mercury from dental amalgam is entirely a different matter.

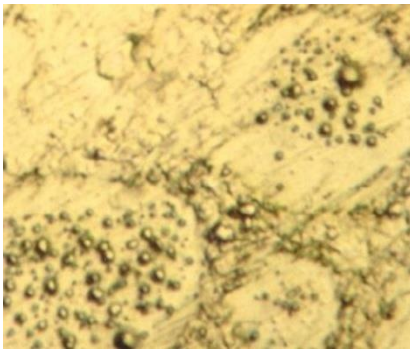

Figure 3 Droplets of mercury on an amalgam filling - Courtesy of Dr. Jaro Pleva

Figure 4 Mercury vapour released from a 22year old amalgam filling - Courtesy of IAOMT.org

Mercury is always being released from dental amalgam throughout the life of the filling. It is released as vapour and as particles from abrasion, chewing and brushing. Hot drinks will release increased amounts of mercury vapour as will dissimilar metals in the mouth such as restorations made from other metals [22] [23] [24] [25] [26].
Mercury vapour is hydrophilic, easily absorbed and accumulates in the major organs of the body. [27] [28] [29]

The body has evolved ways of dealing with toxins from food or water but has no defence mechanisms against inhaled vapour which makes this method of mercury exposure so potentially dangerous. Twenty seconds after inhalation, mercury attaches to –SH groups within the brain for example.

The half-life of mercury in the body is measured in years so the effect of mercury from amalgam which constantly releases mercury is both profound and long lasting.
Mercury from amalgam is released into the environment via faeces, sweat and, at the end of life, by cremation or burial.

According to Health Canada 2007 10% of amalgam's mercury is swallowed directly on placement, 34% gets captured in separators and as waste (provided the separators are available, well maintained, regularly serviced and cleaned) and 28% is unaccounted for [30]. This unaccounted for mercury will be the mercury vapour released during mixing and placing the filling and particulate

mercury adhering to the clinical equipment and clothing of the patient and clinical personnel. So even with all best practice measures in place for dental amalgam, at least 38% of the mercury content of every mix of amalgam walks out of the door.

Eventually all the mercury used in dental amalgam will end up in the environment bar the 34% captured by separators. The used dental amalgam capsules are contaminated with mercury and will require special disposal procedures in order not to release this mercury into the environment as will the gloves and other disposable materials used in the removal or placement of amalgam fillings.

Conclusion: Mercury is released from dental amalgam throughout the life of the filling and is a threat to the environment and human health.
Composite and the other alternative materials create no threat to the environment.

1.4.2. Limits

The reference limits for non-occupational exposure to mercury are:

California EPA	0.005mg/kg/day
Richardson	0.01mg/kg/day
US ATSDR	0.32mg/kg/day

Vimy and Lorscheider [31] estimate an average of 10 mcg/day of mercury is absorbed from amalgam. WHO 118 estimated the daily dose of mercury from amalgam between 4 and 21 mcg [6].

To put this in perspective for infants and children the number of amalgam fillings allowed before exceeding the reference dose is 1.For adults the number of amalgam fillings before an adverse health event may occur is 4 using the outdated US ATSDR levels [32] [33]

Lettmeier et al has calculated that the Richardson exposure limit is the one that is scientifically valid which would mean one amalgam filling per child only and 2 for an adult [34].

Conclusion: More than one amalgam filling in a child will result in exposure to elemental mercury levels that exceed current recommended limits and increase the possibility of an adverse health event due to mercury. For adults, 4 amalgam fillings will mean an adverse health event due to mercury exposure from the fillings is possible.

1.4.3. Environmental Costs. The Real Cost Of Dental Amalgam report.

The costs to the environment and to society at large were estimated in the published Concorde report of 2012, “The Real Cost of Dental Amalgam” [20].

This report examined the release of mercury from dental amalgam from all aspects such as:

- human health
- socioeconomics
- environmental effects
- benefits to children
- cost of alternative materials
- cleaning up released mercury

The real cost of using amalgam was estimated at between $60 and $80 per filling when these factors were considered.

Professor Lars Hylander, Uppsala University, has also estimated the cost of released mercury into the environment: "*Remediation costs in the presented case studies range between 2500 and 1.1million US$ kg−1 Hg isolated from the biosphere depending on local circumstances such as quantities to secure, nature of pollution, media, geography, technology chosen etc. In general, remediation costs are lower the sooner remediation takes place after the pollution has occurred. To prevent pollution, regulations on discontinued use of mercury in all forms is cost effective*". [35]

Prof. Hylander was awarded the Stoten Prize for the quality of this report.

It should be noted that the costly and dangerous diversion of dental mercury to ASGM would cease if dental amalgam were no longer in use as a restorative material. [36]

Conclusion: The real cost of dental amalgam is not borne by the user or recipient but by society as a whole and is and will be substantial.
"*The polluter pays*" principle has not been applied to dental amalgam. If it was, then the average price of a dental amalgam filling would be at least twice the price of an average composite filling.

1.4.4. Separators:

As mentioned previously, Health Canada states that best practice use of amalgam separators to capture waste amalgam only accounts for 34% of the mercury. 66% of the mercury walks out of the door or is scattered into the environment.

Separators are costly to buy and require regular maintenance and cleaning. In addition to this the waste dental amalgam from separators must be collected safely and disposed of in an environmentally sound manner in specialised facilities.

There must be safe collection methods and secure disposal points for the waste amalgam all of which involve considerable investment in time planning and financial resources to build and properly maintain.

In the author's own practice, the waste dental amalgam was collected in a specially adapted secure vehicle by personnel in complete hazmat clothing.

The claim of the various separator manufacturers to capture 99% of the dental amalgam waste was examined by Prof Hylander in [37] [38] whose conclusion was:

- "*The presently used amalgam separators cannot reduce the Hg content to levels needed for combating pollution in a society based on criteria of sustainability*".
- "*Hg emissions due to abrasion from everyday chewing (one third of total Hg emissions in Sweden) cannot be recovered by any amalgam separator*".
- 60% efficiency was a more realistic capture figure for the separators.
- Water leaving a separator is still contaminated with so much mercury that its release is not sustainable to the environment.

Conclusion: Separators are not a solution to mercury release from dental amalgam despite the initial expense and ongoing costs due to the poor results obtained from their use. Only in a country that has a long history of amalgam use along, has already moved to phase out its amalgam use, and has the necessary financial capability for maintenance of separators, creation of specialised mercury waste handling facilities, and enforcement of separator use are amalgam separators good idea.

The best way to stop mercury from dental amalgam being released into the environment is to stop the use of dental amalgam completely.

1.4.5. BIS-GMA: Acrylics

There have been no reports of any damage to the environment from the use of composite, compomer or glas-ionomers.

The BIS-GMA (Bisphenol-A Glycylmethacrylate) component is released by composites and has estrogenic properties. However, even if all restorations were composite the estrogenic effect is 65 times lower than risk levels. Composite can degrade to formaldehyde and methacrylic acid. The amount of formaldehyde released is 10,000 times lower than risk levels and 1,600,000 times lower for methacrylic acid [39].

Conclusion: There is no harm to the environment from the alternatives to dental amalgam.

1.5.Health Risks and Benefits

1.5.1. Alternatives: Composite/Glas-ionomer: Risk Assessments

Richardson's Composite Safety report states: [39]

"*BIS-GMA exposure estimates presented indicate that composite material should not present a serious risk for estrogenic effects even if all amalgam fillings were replaced with composite resin*".

Degradation products of composites other than BIS-GMA are also well below any risk levels and there is no oestrogenic effect observable [40].

Even more than 200 composite fillings, were such a thing possible, would present no problems to human health [41].

Conclusion: Composites and the other alternative materials present no risk to human health.

1.5.2. Mercury Amalgam: Risk Assessments

It is an entirely different picture for mercury dental amalgam. From Maths Berlin 2002 report for the Swedish Government [42], Mutter, 2005 [43], Richardson 1996 [44] and 2010 [45] the conclusion is the same:
"*Mercury release from dental amalgam is a danger to the foetus, children and the medically compromised and that the precautionary principle must be invoked*".

Maths Berlin

> "*Mercury is thus a multipotent cytotoxin that intervenes in the primary processes of the cell. This creates scope for a broad spectrum of possible side-effects. The analysis performed in 1997 identified the following health risks from mercury in dental fillings:*
>
> • *Risk of impairment in the functions of the central nervous system.*
>
> • *Risk of impairment in kidney function.*
>
> • *Risk of impairment in the immune system.*
>
> • *Risk of impairment in foetal development, especially development of the nervous system.*"

Dr. Mutter

> "*Recent publications point to the risk that kidney damage, neuro-psychological impairment, induction of auto-immune diseases or sensitization, heightened oxidative stress, autism, skin*

and connective tissue diseases and non-specific complaints are caused by amalgam exposure. Both Alzheimer's disease and the development of MS are also thought to be connected to it.

Taking all available data into account, amalgam can neither in medicinally, nor in the field of occupational medicine, nor ecologically be considered a safe tooth filling material." [43]

G.M. Richardson:

The report showed that an adverse health event is possible due to the mercury released from one or more dental amalgam filling in an infant or child. For adults, an adverse health effect is possible from three or more dental amalgam fillings.
Other dental metals were also shown to be a risk factor [41].

Richardson discusses the direct link between the number of amalgam fillings of the mother to the umbilical cord blood and foetal blood levels.

Dental material	Component	Safe no. of filled surfaces (N)	Safe no. of filled teeth (N)
Gold alloys	Au	4	2
	Ag	4	2
	Pd	8	3
	Pt	6	2
Ceramic	Li	13	5
Amalgam	Hg	7	3
Composite resin	All	No limit	No limit

Table 1 Comparison of materials and safety (adults only) [41]

The greater the number of fillings of the mother, the higher the mercury level for the foetus and child. It is known that mercury from maternal amalgam fillings reaches the placenta and the foetus [46] [47] [48].

This carries over to breast milk as a delivery route of maternal dental mercury to the suckling child. The greater the number of amalgam fillings of the mother, the greater the mercury load for the infant [47] [49] [50] [51].

It is known from autopsy-studies that the mercury content in the organs and brains of infants and children correlates with the number of amalgam fillings in the mother. The number of amalgam fillings as well as the removal and placing of amalgam fillings during pregnancy increased the mercury concentration in the hair of newborns [52].

A German prospective study of 3,946 pregnant women was carried out. The women were interviewed regarding mercury exposure at the workplace. The mothers-to-be exposed to mercury

or mercury compounds showed a significantly elevated risk of giving birth to babies who were small for their gestational age [53].

The absorption of mercury in the foetus from the mother is greater than its excretion from the foetus. This means that during the gestation of the foetus, the concentration of mercury continues to increase or bio-accumulate in foetal tissues as the mercury is unable to migrate out of foetal tissues; effectively creating a one-way migration of mercury from the mother to the foetus, leading to accumulation in the foetus throughout gestation.

In a manner similar to the blood-brain barrier, the placenta does not allow mercury to return to the mother's blood from the foetus once it is oxidized (and loses its lipid solubility) and is bound to sulfhydryl groups (such as GSH). Therefore, the mercury that is not metabolized in the placenta reaches the foetus where it becomes bound and is retained in the foetus [54].

Dr Lisa De Roo of the National Institute of Environmental Health Sciences reported in July 2010 at the Society for Pediatric and Perinatal Epidemiolic Research, in case controlled study of 1336 Norwegian infants over a 7 year period found that the incidence of cleft palate quadrupled if amalgams were placed in the first two months of pregnancy. If multiple procedures were carried out in the first trimester, the risk of cleft palate increased even further.

A study into perinatal deaths in Norway over a 9 year period involving over 72000 births came to the conclusion: "*The current findings suggest that the risk of perinatal death could increase in a dose-dependent way based on the mother's number of teeth filled with dental amalgam*." To put in simply, the more amalgam fillings a mother had, the greater was the chance of still birth after 22 weeks or death within 7 days of birth [55]. It was estimated that among mothers with more than 12 teeth filled with amalgam, 57% of the cases of perinatal death were attributable to amalgam

Conclusion: The risk assessments show that mercury from dental amalgams is a threat to health. This is especially true in mercury from mother's amalgam fillings is deposited and accumulates in the foetus. The greater the number of amalgam fillings the greater the infant burden of mercury and the greater chance of death for the infant.
The Precautionary Principle would indicate that dental amalgam should not be used at the very least especially for pregnant and nursing women and their infants.

1.5.3. Allergies:

All materials have a potential to cause allergies. In the case of the mercury free alternative materials it is the photo-initiators and BIS-GMA components of the fillings that have allergic potential. There are new composites on the market that have significantly reduced this potential problem.
The degradation products of composite break down to water and carbon dioxide in the liver. A Swedish study showed that only 1 in 1623 patients who attended a department of dermatology had an allergic response to these materials. This corresponds with the author's experience [56] and non-mercury alternatives have always been found to successfully treat these patients.
In a general population who do not show such extreme sensitivity the numbers will be significantly lower than this.

These alternative materials cause no adverse cellular response. [57]

Mercury dental amalgam is a proven allergen. Amongst these are Eczematous Dermatitis [58] [59], Contact Dermatitis [60], Atrophic Dermatitis [61], Generalised Allergic Reactions [62]and many others including Lichen Planus [63] [64]. Lichen Planus is a proven cancer risk [65] [66].
The risk of an allergic response increases with the number of fillings and with their age [67].
Between 5-30% of amalgam wearers show allergic responses [68].

Researchers from Harvard School of Medicine [69] state: "*Dermal hypersensitivity to metal is common and can affect up to 15% of the population. The contact with metal has been linked to hypersensitivity reactions, generally type IV delayed- type hypersensitivity (DTH) reactions, which can manifest as cutaneous eczematous eruptions, and as a range of adverse reactions, including chronic inflammation, pain...*".

However, one issue with calculating the number of patients with adverse reactions to a metallic material is that the onset of symptoms can be delayed and therefore might not be associated with the implant or device. For example, researchers writing about dental amalgam fillings warned: "*Sensitization appears most frequently after the amalgam has been present in the mouth for more than 5 years.*" [68] Another issue is that there may not be any local reaction to help the patient and doctor identify the metal as the culprit in ill health [70] and even if hypersensitivity reactions are noticed, they can be misdiagnosed as infection [71]

Conclusion: Allergy to the mercury free materials is less than 1 in 1000. Allergy to mercury is 1 in 7. The symptoms of mercury allergy can be delayed for several years after the placement of the filling and are frequently misdiagnosed.

1.5.4. Direct mercury pathology

The published scientific data on the toxic effect of mercury is extremely large and goes back to nearly 100 years to the experiments of Dr Stock at the Kaiser-Wilhelm Institute in Germany in the 1920s and 30s to the present day. This is a brief overview of some of the pathology associated with mercury; it is not complete but does show how dangerous mercury from dental amalgam can be to human health.

According to the paper from WHO 118 1992 on mercury, dental amalgam is the largest source of mercury to the human population, there is a constant release of mercury from dental amalgam and it is accumulative in the human body. WHO Mercury Health Care (policy paper) August 2005 states: "*Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental defects during foetal development, and attention deficit and developmental delays during childhood. Recent studies suggest that mercury may have no threshold below which some adverse effects do not occur*".

The level of mercury in the foetus is directly proportional to the amount of dental amalgam fillings present in the mother and mercury is toxic to all cells.

Mercury causes two medical conditions. Lichen Planus and Mercurialism:

Lichen Planus is a pre-cancerous allergic response to contact with mercury. Lichen Planus is resolved when the mercury filling in contact with the lesion is removed.

Mercurialism, according to Dreisbach Handbook of Poisoning 2001 published by Taylor & Francis can exhibit extremely varied symptoms but predominantly consist of headache, depression, anxiety, irritability, amnesia (short term memory loss), intellectual mental deterioration, insomnia, nephritis (kidney disease).
Mercury's mode of action is by suppressing enzyme groups by attaching to –SH groups within the cells.
Mercury is toxic to all cells.
Neuromuscular toxicity is <0.1mcg/ml blood and this level should never be exceeded.
Mercury vapour concentration varies according to the temperature; at 20°C it is 15mg/m3 but at 40°C it is 68mg/M3. [23]This explains the high mercury vapour readings found in the mouth from dental amalgam fillings.
Removal of amalgam fillings significantly improves health, see Figure 5.

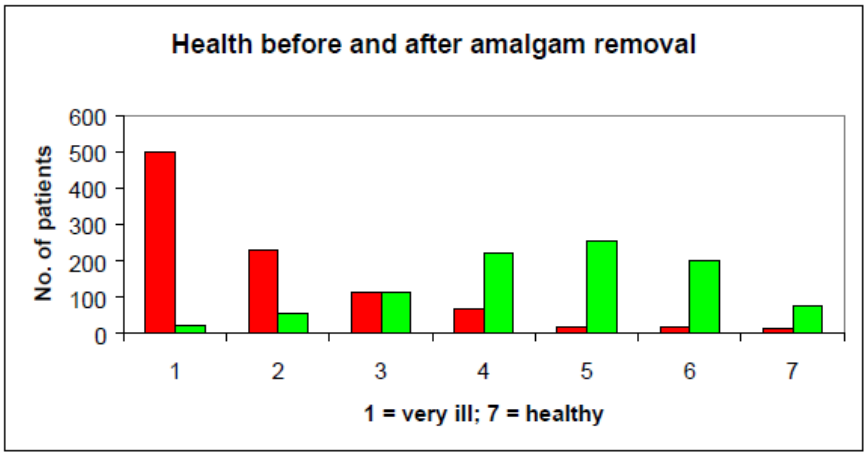

Figure 5 Health before and after amalgam removal [72]

1.5.4.1. Antibiotic Resistance

Mercury is toxic to all cells including bacteria. However, bacteria have the capacity to become resistant to mercury and can even transfer this resistance between different species of bacteria. The reason this is of importance is that the mercury resistant bacteria also become resistant to antibiotics. The genetic information that allows them to survive exposure to mercury also gives them resistance to antibiotics [73] [74] [75].

Antibiotic resistance among bacteria is becoming increasingly prevalent worldwide and infections that were once easily dealt with can become life threatening. However, once the mercury has been removed, within a few months the bacteria lose their mercury resistance and revert to their original state and the antibiotic resistance is gone too.

If dental amalgam is no longer used, then within a generation a possible source of antibiotic resistance will have been removed.

1.5.4.2. Heart Diseases

Mercury has been shown to cause the following heart conditions

- Arterial Damage – Myocardial infarct to Aneurism
- Low Blood Pressure to High Blood Pressure
- Muscle Damage.
- Electrical Conduction Disturbance
- Arrhythmias and valve abnormalities
- Triglycerides abnormalities
- Mercury affects the heart by:
- Vagal nerve inhibition
- Hg blocked acetylcholine receptors
- Hg caused functional changes in muscles, valves, centres of cardiac regulation
- Damage to Aorta
- Muscle damage in coronary arteries
- Arterial constriction
- EKG changes
- Reduced kidney function leading to HBP
- Increased blood clot formation
- Increased Triglyceride levels
- Displaces Calcium from cells in heart

The damage mercury causes to heart muscle is as a result of displacing Calcium from the normal sites. It reduces heart muscle function, in time this damage becomes permanent. Inflammation and fatty degeneration are seen [76].

Mercury also causes thickening of the arteries and clot formation in the blood vessels [77]. Blood coagulation or "stickiness" increases [78]. This has a direct correlation with heart attacks.

Mercury is absorbed preferentially into the pituitary gland in the brain [79]. It alters the production of Pituitrin from the gland, which constricts the coronary arteries.
Mercury constricts the coronary arteries [80] [81]

Mercury impairs cardiac electrical function. This causes an interruption of the cardiac electrical pattern [82] [83]

A comparison between patients with and without amalgam fillings showed that patients with amalgam had significantly higher blood pressure, lower heart rate, lower haemoglobin levels, lower number of red blood cells [76] [84] [85]

Cholesterol – Triglycerides Myth

"*Elevated levels of Cholesterol /Triglycerides are a defence reaction to exposure to toxins, including mercury. Subjects with amalgam fillings have elevated levels of Cholesterol – Triglycerides.*" [86]

This was the author's experience too. Removing amalgam fillings would reduce cholesterol levels without resorting to drugs.

Conclusion: Mercury causes and is associated with many human health conditions.
Mercury is a major contributor to heart disease. This is incontrovertible and cardiac disease is the second leading cause of death. Removing the largest source of mercury exposure, which is dental amalgam, will be of great benefit in preventing and treating existing heart conditions.
Stopping the use of dental amalgam will have significant health and socio-economic benefits.

1.5.5. Personnel safety considerations

The most at risk groups of exposure to dental amalgam are dental personnel involved in the removal and placement of dental amalgam fillings. The mechanical mixing of encapsulated amalgam spreads mercury vapour as does the drilling out of old amalgam and the placing of new amalgam fillings. There have been numerous studies on the adverse effect mercury has on dental personnel.

Dentists using amalgam have neuropsychological and motor control deficits along with neurobehavioral changes such as impairment of attention, motor and perceptual skills and increased irritability [87]. Depression and mood alteration have been found too. [88]

Fertility amongst female dental assistants using mercury was 37% lower than those not exposed to mercury [89]. There have been a number of studies that support these findings. [90] [91]

A 1998 study by the prestigious Battelle Centers for Public Health Research found that mercury levels commonly seen among dental professionals with very low levels of mercury vapour exposure, demonstrated alterations in mood, motor function and cognition (thinking). These, they emphasized, were symptoms that can be subtle and missed by conventional neuropsychological testing [92]. These results have been confirmed by a number of other independent laboratories and reported in peer-reviewed journals. Even at very low levels, mercury had a significant impact on the dental professionals who removed and placed dental amalgam fillings. [93] [94] [95] [96] [97]

Dentists are exposed to mercury during the removal of amalgam fillings, which fail just like any other filling. Recent research [98] on dentists and other occupational groups report neurological impairment at Hg exposure levels below the current occupational limit of 25 µg/m^3. This respirable particulate matter represents the vast majority of daily mercury exposure in practicing dentists. What indirect data does exist demonstrates that absorption from the lung occurs but that faecal excretion may predominate. As a result, urine analysis for mercury may be ineffective as a means of occupational monitoring.

Conclusion: The health of dentists and their staff who are exposed to chronic low levels of mercury from dental amalgam can be severely adversely. This includes memory deficit, anxiety, depression, reduced motor skills and fertility. These symptoms are often missed or misdiagnosed.

1.6.Report Conclusion

The mercury free alternative dental materials, composite, compomer, glas-ionomer are available, affordable and effective. They have little impact on the environment or on human health. They can require less equipment and be used in challenging situations without electricity using quickly trained personnel. They last as long as mercury fillings and save more tooth substance than dental amalgam in preparing the filling. They have no adverse effect on the foetus or suckling child and can be used in any trimester of pregnancy.

Dental amalgam on the other hand does require fully trained personnel and a fully equipped dental clinic. It also needs two clinic visits per filling as opposed to one visit for the alternative mercury free materials. Mercury is released from the filling throughout the life of the filling and accumulates in the body and the foetus and suckling child. The number of fillings a child can have before being at risk from an adverse health effect is one and for an adult it is three.

There is no way of stopping most of the dental mercury entering the environment even if best practice management techniques are in place.

Dental personnel are at risk when handling this material and the symptoms are often difficult to diagnose correctly.

Mercury at the levels released by amalgam fillings and mercury from amalgam fillings in the environment can have a significant impact on various aspects of human health for the patient and the dentist is ill equipped to diagnose theses impacts or treat them.

There is no economic or practical reason to continue to use dental amalgam. Many countries around the world from Scandinavia to Indonesia are abandoning the use of dental amalgam.
Dental amalgam should no longer be placed in children or pregnant or nursing mothers and should be rapidly abandoned for all peoples and consigned to the history books.

2. Report #2 – Mercury Neurotoxicity and Dental Amalgam

Avoiding Neurotoxicity: An Important Benefit of Non-Mercury Alternatives to Dental Amalgam

2.1. Introduction

The term neurotoxicity refers to damage to the brain or peripheral nervous system caused by exposure to natural or man-made toxic substances.
Due to their high metabolic rate, neurons are at the greatest risk of damage caused by neurotoxins.

There are many substances that are associated with neurotoxicity; this report is concerned only with one, mercury. The "Mad Hatters" of the 18th century exhibited the gross symptoms of neurotoxicity due mercury exposure but the symptoms can be more subtle and are often misdiagnosed.

In 2002 the UNEP Chemicals Global Mercury Assessment stated:
"*The main route of exposure for elemental mercury is by inhalation of the vapours. About 80 percent of inhaled vapours are absorbed by the lung tissues. This vapour also easily penetrates the blood-brain barrier and is a well-documented neurotoxicant. Elemental mercury can be oxidized in body tissues to the inorganic divalent form. Neurological and behavioural disorders in humans have been observed following inhalation of elemental mercury vapour. Specific symptoms include tremors, emotional lability, insomnia, memory loss, neuromuscular changes, and headaches.*

In addition, there are effects on the kidney and thyroid. High exposures have also resulted in death.

Mercury releases from dental practices may be reduced by substituting other materials for mercury amalgams". [99]

This report outlines in brief the peer reviewed published science about the neurotoxicity of mercury. Mercury is associated with developmental neurological impairment and many of the neurological degenerative conditions that are increasing in society. Mercury has been associated with neurological developmental defects in children from autism to reduced intellect. Neurological conditions in adults such as Parkinson's disease, Alzheimer's disease, Multiple Sclerosis, Amyotrophic Lateral Sclerosis (ALS) and mental illnesses have all been associated chronic low dose mercury exposure. Dental amalgam fillings are a source of chronic low dose exposure of mercury.

This report is an overview of mercury neurotoxicity from dental amalgam because mercury is so neurotoxic. The report outlines the effects on the vulnerable groups using the scientific published data and finishing with recommendations. The damaging effect of mercury neurotoxicity on individuals and society can be profound and long lasting. Some of the data goes back many years but now mercury dental amalgam can be eliminated as a major source of human exposure to mercury as the alternative non mercury filling materials are available, affordable and effective. [100]

The Precautionary Principle [101] should be invoked which calls for preventive action when an activity threaten human health or the environment even if there is no scientifically established evidence. However, there is ample evidence against mercury use on the ground of human health and dental amalgam should no longer be permitted to exert its malign influence on future generations. Non-mercury alternatives to amalgam offer the benefit of avoiding these harms of dental amalgam.

2.2.Definition

"*Neurotoxicity occurs when the exposure to natural or manmade toxic substances (neurotoxicants) alters the normal activity of the nervous system. This can eventually disrupt or even kill neurons, key cells that transmit and process signals in the brain and other parts of the nervous system. Neurotoxicity can result from exposure to substances used in chemotherapy, radiation treatment, drug therapies, and organ transplants, as well as exposure to heavy metals such as lead and* ***mercury****, certain foods and food additives, pesticides, industrial and/or cleaning solvents, cosmetics, and some naturally occurring substances. Symptoms may appear immediately after exposure or be delayed. They may include limb weakness or numbness; loss of memory, vision, and/or intellect; headache; cognitive and behavioural problems; and sexual dysfunction. Individuals with certain disorders may be especially vulnerable to neurotoxicants*". [102]

2.3.Sources of Mercury

2.3.1. Dental Amalgam

The World Health Organisation found that dental amalgam is the greatest source of mercury in humans. [103]

Dental amalgam consists of 50% mercury, 25% silver and 25% other metals. The mercury is not stable and constantly released by the dental amalgam filling. The mercury is emitted as vapour to be inhaled, with droplets and particulate to be swallowed. Mercury vapour is the fastest way to absorb mercury and is the most bioavalable form. Within 20 seconds of inhalation, mercury is found in the brain due to its affinity to lipid (fat) and SH groups. In the gut mercury can be changed to methylmercury which is one of the most dangerous forms of mercury when considering health issues.

The dose of mercury an individual is exposed to from dental amalgam will vary according to the number of amalgam restorations and whether dissimilar metals are present in the mouth. Mercury exposure from dental amalgam is constant, 24 hours daily, the levels rising during chewing, consuming hot drinks and tooth brushing. Establishing an "average" exposure is, therefore, difficult. Various studies have been done with the WHO estimating a daily dose of 20mcg mercury from dental amalgam. [103]

Conclusion: Since dental amalgam is the largest source of mercury humans are exposed to, eliminating the use of dental amalgam mercury should significantly enhance human neurological health.

2.3.2. Other

Even if special measures are taken such as separators and specialised waste handling of dental amalgam, most dental mercury will end up in the environment. [104] Once released into the environment mercury can enter the ground water and marine ecosystems. Mercury levels increase in the fish food chain with the top marine predators having a high body burden of mercury which is in the form of methylmercury which is biologically very active and very toxic. Humans are at the apex of the food chain and are the recipient of this methylmercury which has permanent adverse effects on neurological health. [105] [106] Dental mercury is one of the sources of illicit mercury for ASGM

as described at the various INC meetings. Mercury used in ASGM will have an adverse impact on the environment and human health as no effort is made to capture or contain it.

Conclusion: Stopping the use of dental amalgam will have a significant impact on reducing mercury levels and the toxic consequences of mercury in the environment.

2.4.Vulnerable Groups

2.4.1. Pregnant Women & Children

The foetal and infant brains are exquisitely sensitive to mercury damage during their development.

The foetus and young infant are vulnerable or "sensitive" receptors with respect to exposure and risks to neurotoxic substances such as Hg0. An immature blood-brain barrier, and the continuing development and maturation of the brain in utero and well beyond birth are the primary reasons for this vulnerability. [107]

Women with amalgam fillings expose their foetus to mercury; the more amalgam fillings the expectant mother has, the greater is the mercury exposure of the foetus. [104]. Mercury exposure, nutritional deficiencies and metabolic disruption affect learning in children. [108] [109] Changes in the brain caused by mercury poisoning result in significant clinical deficit in motor skills, coordination, and general activity rate of cognitive and psychological disorders. [110] Studies also demonstrate that mercury has the ability to reduce the number of neurons and alter the actual brain structure in individuals with prenatal exposure to mercury. [111] [112]

Mercury levels of up to 20 ng Hg/g were found in German infant brain tissues which were caused by dental amalgam fillings of their mothers. [113] Mercury levels of 0,02 ng Hg/g leads to degeneration of neurons. [114]. Umbilical cord blood mercury increases according to the number of dental amalgam fillings in the mother. The level of mercury in cord blood per maternal amalgam fillings is between 0.76 and 1.4 ug Hg/L per amalgam filled tooth. One amalgam filling in the mother will potentially expose the foetus to levels of mercury shown to cause abnormal brain development. [107]

Conclusion: Mothers with even one amalgam filling will expose their unborn child to levels of mercury that can cause permanent and irreversible damage to the infant brain.

2.4.2. Occupational Exposure

Dental personnel are one of the most likely groups to suffer from the adverse effects of mercury exposure from dental amalgam [115]. They are exposed to mercury vapour and particulate in the mixing, placing and removing dental amalgam fillings. Mercury vapour can penetrate clothing and surgical gloves and can be especially high when mixing and opening capsulated amalgam.

In personnel occupationally exposed to mercury, anxiety, memory problems, depression, excessive anger, sleep disturbances and confusion have been reported. [116] [117] [118] [119] When dental personnel have presented with symptoms to physicians or other healthcare workers, it can be misdiagnosed as other more common or diffuse health problems. Depression and anxiety have been associated with Hg from dental amalgam as well. [120] [121] Dentists using amalgam have neuropsychological deficits and neurobehavioral changes such as impairment of attention, motor and perceptual skills and increased irritability. [122] [123] Compared to controls, dentists with high urinary mercury levels had significant reduced memory function. [124] [125]

An increased rate of suicide has also been reported among dentists and other dental personnel. [126] Studies relating mood disorders and suicide to occupation have revealed a high suicide rate for dentists compared to other professions and compared to the general population. [127] [128] [129] It is the dentists who place and remove dental amalgam fillings that are most at risk.

Among dental assistants it is peripheral neuropathy with sensory impairments that is the main feature of chronic mercury exposure. Other complaints were impaired colour vision, impaired taste and smell as well as hearing, along with memory loss and blurred vision. Dental assistants exposed to mercury can also have increased anxiety, reduced cognitive function, psychoticism, short term non-verbal recall and generally increased distress. [130] [131] [132] [133]

Various studies have shown that some dental personnel have a genetic susceptibility to mercury or to put it another way, have a polymorphism of an environmental gene that can play a role in the health outcomes when the personnel are exposed to mercury. In these unfortunate individuals the neurotoxic effects of mercury are significantly increased. [134] [135] [136] [137]

Conclusion: Occupational exposure to mercury, especially in dental personnel, can have serious and permanent adverse effects on neurological health. These include increased suicide risk and mental illness. To reduce these risks, the further use of dental amalgam must be stopped and effective protective measures put in place in the removal of failed amalgam fillings.
This will minimise mercury exposure to dental personnel and reduce the possibility of damage to their health whilst patients still have existing dental amalgam fillings.

2.4.3. Elderly

The ever increasing elderly proportion of the population exhibit a high propensity for neurological damage due to dental mercury. They are likely to have been exposed to mercury released from dental fillings for many years; this exposure is increased if other metallic restorations are present. They will have been exposed to many other toxicants too, such as lead, which has a synergistic effect increasing the toxicity of mercury. The nutritional status of the elderly is likely to be poor and they take on average 3 or more prescription drugs (figures for the 70-74 year olds in England). [138]Their immune and the detoxification systems are likely to be sub optimal and their metabolic rate is slowed, all of which leaves them vulnerable to the neurotoxic effects of mercury. This is seen in the increasing incidence of Parkinson's disease (PD) and Alzheimer's disease (AD) which are associated with mercury exposure and are predominantly a disease of the elderly.

Conclusion: The elderly are particularly susceptible to mercury neurotoxicity due to years of exposure to a variety of neurotoxicants. The personal and financial cost for the elderly and to society at large of mercury neurotoxicity can, therefore, be high.

2.5.Mechanisms of Action

2.5.1. General Biochemistry

The neurotoxic effects of mercury on any individual will depend on the dose of mercury, genetic susceptibility, [139] and presence of synergistic toxins such as lead. Also, the efficiency of detoxification pathways, nutritional state, immune system and any medical problems are factors to be considered.

Recommendations of acceptable levels of exposure on a medical basis must be based on the most sensitive individuals. A small part of the population may be particularly sensitive to mercury. There are no dose-response data for vulnerable segments of populations.
Therefore, no zero-effect level can be established where Hg-related symptoms cannot occur. [115]
Dental mercury is metallic or inorganic mercury. 22% of the population are susceptible to metallic mercury [140] [141] therefore a substantial segment of the population may be sensitive to mercury. Mercury in its various forms has different pathways of metabolism and toxicity. In general, the critical organ is defined as the organ in which changes are first developed. For inorganic Hg salts, the kidneys and the central nervous system (CNS) are the critical organs.
For organic Hg compounds and metallic Hg, the CNS is the critical organ. [103]

Mercury vapour, Hg0, is readily absorbed through the lungs; it is highly diffusible and can pass through cell membranes as well as the blood-brain and placental barriers to reach target organs. Once there it changes to Hg++ and becomes lipid soluble attaching to SH groups in the brain. It can displace essential minerals such as zinc and interfere with enzymatic processes. [142]. In this form it can kill neurons [143] generate high levels of ROS (Reactive Oxygen Species) and oxidative stress, depletes glutathione which leads to greater damage from ROS. [144] Mercury can change metallprotein compounds that have structural and catalytic effects on gene expression including cellular respiration, enzymatic processes, autoimmune reactions and metabolism. [145] [146] [147]

Conclusion: The neurotoxic actions of mercury and many and complex. Many aspects of body functions can be affected by the neurotoxicity of mercury which is why so many medical conditions have been associated with it. There is no zero-effect level for mercury and a substantial proportion of the population may be adversely affected by mercury.

2.6.Symptoms of Neurotoxicity

2.6.1. Central Nervous System

The CNS is regarded by WHO as a critical organ for mercury toxicity. Mercury can damage the blood-brain-barrier allowing access to larger and potentially harmful substances. Mercury attaches to the lipids of the brain and can replace essential minerals such as zinc in enzymatic processes. It can damage neurons and axons and block neurotransmitters. [148]
A large epidemiological study, NHANES III, by the National Institutes of Health (NIH) found significant correlation between chronic neurological conditions and the number of amalgam fillings. These included multiple sclerosis, epilepsy, mental disorders, diseases of the nervous system and peripheral neuropathy. [149] Oxidative stress within neural tissues can be caused by mercury and has been implicated as a major factor in many neurological conditions including stroke, Alzheimer's and Parkinson's. [144]

Conclusion: Mercury may only be one part of a multifactorial neurological disease process but there is a large number of studies and show that exposure to mercury is a highly significant factor in the aetiology of many severe neurological conditions. The major source of mercury in humans is from dental amalgam; therefore, with the affinity for brain tissue and the known neurotoxic effects of mercury, it is necessary to stop the use of dental amalgam.

2.6.1.1.Developmental

The severity of the effect of mercury neurotoxicity on any individual is dependent on the dose, nutritional state, the presence of other neurotoxins such as lead and genetic makeup or genotype. Those born with the *Apoe* epsilon 4 which is associated with poor neural repair function and is a risk factor associated with Alzheimer disease showed that adverse effects on neurodevelopment were consistently associated with prenatal mercury exposure. [150]
Mercury can disrupt metabolic processes and alter neuronal plasticity. Neurons lacking in plasticity are a factor in neurodevelopmental disorders such as autism and mental retardation. [109] [151]. Even at very low concentrations there is strong evidence that exposure to mercury is associated with the onset of neurological and heart disorders in children. [108]
Maternal amalgam fillings increase the mercury exposure in the foetus and infant, [152] [153] and using national blood mercury prevalence data from the CDC that around 500,000 children each year in the USA have cord blood mercury levels >5.8 µg/L, a level associated with loss of IQ. The resulting loss of intelligence causes diminished economic productivity that persists over the entire lifetime of these children. [154]. One maternal amalgam filling gives a blood level of 0.76-1.40 µg/L so the magnitude of the problem can easily be grasped.
The association between very low levels of mercury and abnormal neurodevelopment was confirmed in another later study from Saudi Arabia. [155]

Whereas reduced intelligence or cognitive skills may not be immediately apparent, autism certainly is and casts a dark shadow over all continents. Autism like Alzheimer's was unknown 100 years ago and both conditions have seen a dramatic rise over the last 50 years. Autistic children have poor mercury detoxification ability and mercury has been associated scientifically with autism for a number of years. [156] [157] [158] [159] [160] [161] These are just a few of many references. An absolute causal link is still debated but with the strong associations between mercury and autism exists.

Conclusion: A child has only one chance to develop their brain. Exposure to mercury can have a serious impact on many aspects of neurodevelopment in children and every measure must be taken to reduce maternal and infant exposure to mercury.

2.6.1.2. Mental - Anxiety, depression, memory loss, irritation, anger

Exposure to mercury from dental amalgams and mental health conditions such as anxiety, depression, memory loss and even suicide have long been reported. [162] [163] [164] [165]. Depression has been called an epidemic sweeping the world. According to the WHO [166] depression is a mental disorder affecting 322 million people of which half live in the Western Pacific and Asian regions. The report goes on to state that depression is a leading cause of disability worldwide.

The rate of depression across the world has increased by 18.4% from 2005 to 2015. [167] In the UK 20% of adults showed symptoms of anxiety or depression in 2014 an increase of 1.5% over one year. [168]The fact that dental mercury is a cause of depression is incontrovertible [169] [162] [119] along with schizophrenia. [170]

Conclusion: Exposure to mercury and dental mercury in particular has been linked to the incidence of depression and other mental illnesses. The incidence of these conditions is increasing worldwide and is a leading cause of disability. Reducing the largest source of human exposure to mercury, dental amalgam, can be a significant step in reducing the increase worldwide of depression and other mental illnesses.

2.6.1.3. Physical - ALS, MS, Alzheimer's, Parkinson's

The conditions, Alzheimer's, (AD) Parkinson's, (PD) Multiple Sclerosis, (MS) and Amyotrophic Lateral Sclerosis, ALS, have a firm association with mercury exposure. There are reports in the literature of remission of ALS and MS after dental amalgam removal. [171] [172]. All these conditions were unknown before dental amalgam came into use.

There has been a dramatic increase in Alzheimer's disease, Parkinson's disease and Amyotrophic Lateral Sclerosis over the last 40 years. A 300% increase for Alzheimer's disease [173] and a 50% increase in Parkinson's disease. [174] The cost of Alzheimer's in 2018 is estimate to be 1.09% of worldwide GDP or in excess of US$1 trillion. [175]

A study in 2016 showed that amalgam wearers were nearly 1.6 times more likely to get PD than the control group. [176] Studies have shown the connection between mercury exposure and PD. [177] [178] [179] [180] [181]

Alzheimer's was first described in 1908 and has a firm connection to low dose mercury exposure. [182] [183] [184] [185] [186] [187] [188] [189]

Conclusion: The treatment for these conditions is essentially palliative and the individual suffering and the overall cost to society of degenerative neurological diseases is huge. The link to mercury exposure in these degenerative neurological conditions is firmly established. Reducing overall mercury exposure by stopping the use of dental amalgam should have a significant benefit to society as well as the quality of life of the individual.

2.7.Discussion

2.7.1. Financial and Social consequences

Mercury neurotoxicity has severe financial and social consequences both on an individual level and for society at large. It can reduce the net economic contribution of individuals to society by its effect on the intellectual development as well as putting large financial burdens on society in the treatment of degenerative neurological conditions. [190] A study on mercury release in the United States [154] estimated that due to the mental retardation effects of mercury on the developing brain the loss of economic performance would be US$8.7 billion annually of which US$1.3 billion was due to mercury released from power stations. As the greatest human exposure to mercury is from dental amalgam the loss annually to the US economy should be in excess of this figure.

2.7.2. Recommendations

Dental amalgam is the greatest source of mercury in humans and mercury is a potent neurotoxin.
A large body of published scientific literature firmly establishes the connection of low dose chronic mercury exposure with a number of neurological and developmental conditions.
Dental amalgam is an outdated material from the last century that belongs in the history books, its use supported only by a small minority of elderly dentists unable and unwilling to embrace change.
The alternatives to dental amalgam are available, affordable and effective. Use of these non-mercury alternatives offer the distinct benefit of avoiding these harms that stem from dental amalgam's mercury.
The case for an immediate cessation of use of dental amalgam as a filling material on health and economic grounds is overwhelming.

Help and advice to transition away from dental amalgam to the satisfactory alternatives is available for interested parties from the World Alliance for Mercury Free Dentistry.

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