Dental amalgam: is this the end?

Précis
The use of dental amalgam in dentistry and its health and environmental impacts have been a global matter of interest and controversy for the last decade.

Abstract
Dental amalgam is a reliable and effective restorative material with a well-established role in modern dentistry. Throughout the years its mercury content and the risks posed to human health were main topics of interest for many scientists. This paper offers a review of the scientific literature on the health and environmental impact of mercury in dentistry published over the last decade. A variety of peer-reviewed, epidemiological and large-scale clinical studies on dental amalgam, as well as published reports of professional and governmental bodies, were organised thematically and analysed. The most relevant findings of the aforementioned literature are reported. No reliance has been placed on unpublished work or publicly available opinions that are not scientifically based. In order to offer an appropriate view on the topic the toxicology, health impacts and possible environmental threats are briefly presented in relation to the relevant literature published in the last ten years.

It is almost unanimously accepted that dental amalgam is a safe material, with little or insignificant adverse effect on general health. However, current and mostly unfounded environmental concerns may result in the implementation of new across the board legislation that could lead to a global dental amalgam ‘phase out’.


Introduction
Dental amalgam was introduced in clinical dentistry over 150 years ago and has provided a valuable and relatively inexpensive service for patients ever since. While the role of dental amalgam in disease causation with a focus on its mercury content has constituted a matter of controversy for many years now, its environmental impact started to raise some concerns in the last decade, becoming a matter of political interest at international level.

Composition, toxicity, exposure
The key elements of dental amalgam are liquid mercury and a metal alloy. Conventional dental amalgam was predominant in silver (67-74%) and tin (16-28%), also known as the $\gamma$(Ag$_3$Sn) phase, and contained very little copper (6%). In order to increase the strength of the amalgam alloys the copper content was subsequently increased to 13% in the dispersion type alloys, or to 30% in the high-copper content alloys. The most commonly used dispensing
format for dental amalgam is sealed capsules with two compartments, one containing amalgam alloy particles – either spherical or irregular – and the other containing liquid mercury at a 1:1 weight ratio. The amalgamation reactions for high-copper content amalgam alloys are briefly presented below:1

\[ \text{Ag}_3\text{Sn} + \text{Hg} \rightarrow \text{Ag}_9\text{Sn} + \text{Ag}_3\text{Hg}_2 + \text{Sn}_7\text{Hg} \]

\[ \gamma + \text{Hg} \rightarrow + \gamma_1 + \gamma_2 \]

Followed by:

\[ \text{Sn}_7\text{Hg} + \text{AgCu} \rightarrow \text{Cu}_6\text{Sn}_5 + \text{Ag}_3\text{Hg}_2 \]

\[ \gamma_2 + \text{AgCu} \rightarrow \text{Cu}_2\text{Sn}_3 + \gamma_1 \]

Set amalgam contains 50% mercury. The majority of this mercury is contained in the \( \gamma_1 \) phase and a minor percentage in the \( \gamma_2 \) phase. As is well known, set amalgam restorations are subject to tarnish and corrosion. The latter is mainly caused by the higher electronegativity of the \( \gamma_2 \) phase, which leads to galvanic corrosion with the release of tin and mercury. The tarnish process, however, due to the passivating effect of the deposited layer, gives the amalgam alloy a greater protection from corrosion. It is also believed that the corrosion potential of the set amalgam decreases due to surface ennoblement.2,3

When assessing the toxicology of dental amalgam it is widely agreed that the element of concern is its mercury content. The analytical instruments for the determination of mercury concentrations in biological samples are well developed and sufficiently sensitive; however, a number of problems with sampling, the determination of mercury speciation, and the interpretation of results are evident.4 Human exposure to mercury from dental amalgams may occur by inhalation of the mercury vapours, by ingestion of released elemental mercury, or by swallowing small pieces of amalgam. The absorption of ingested elemental mercury is very limited, typically lower then 0.01% of the dose ingested.5 However, approximately 80% of inhaled elemental mercury is absorbed in the lungs, with a small part of this (7-14%) being eliminated by exhalation within a week of exposure.6 Another small part is delivered to the central nervous system, while the rest is slowly oxidised in the blood to \( \text{Hg}^{2+} \) and distributed to all body tissues. The principal mode of action for its toxicity is by tightly binding to proteins. The elimination of elemental mercury or \( \text{Hg}^{2+} \) takes place by excretion via urine or faeces. While some studies state that the elemental mercury's half-life varies within the range of 20-90 days,7 others assume it to be up to one to 18 years in the brain and bones.8 Following elemental mercury and \( \text{Hg}^{2+} \) exposure, the highest concentration is contained in the kidney.5,6

In order to quantify the exposure from dental amalgams, measurements of mercury concentration in urine, blood, saliva, hair, nails and faeces have been proposed and used. However, it is now accepted that urine levels tend to reflect inorganic mercury exposure. Total mercury levels in whole blood are more indicative for methyl mercury exposure, while measurements of saliva, hair, nails and faeces are controversial and not always relevant.9,10,11

The World Health Organisation (WHO) estimates the average daily mercury intake derived from amalgam restorations to be 10 g (range 3-17 μg). Low concentrations of mercury, usually below 5 μg/litre of whole blood, are inevitably detectable in individuals with or without amalgam fillings. No adverse effects were detected at the concentrations mentioned above.4 The respiratory, blood and urinary mercury levels of individuals with amalgam fillings are up to 30 times lower than considered safe for occupational exposure. The estimated mercury levels are presented in Table 1.

A study carried out by Zimmer et al., which examined the mercury concentration in blood, urine and saliva samples from 40 female subjects who claimed to suffer from serious health damage due to amalgam fillings (“amalgam-sensitive subjects”) and 43 female control subjects, concluded that mercury levels in the blood (2.35-3 μg/litre) and urine (1.5-1.8 μg/litre) of the examined subjects were within the range of background levels in the general population. The median mercury blood levels were slightly lower (2.35 μg/litre) in the amalgam-sensitive group, but the differences were not significant.11 Halbach et al. (2000, 2007) remarked that the plasma levels of mercury are slightly higher than the mercury in erythrocytes, and also noted that a daily intake of 7.4 μg of mercury, associated with a high dental amalgam load, was well below the tolerated dose of 30 μg agreed by the WHO.12,13

When measuring urinary concentration of mercury in children, a study carried out in Germany revealed mean levels of 0.25 g/litre, indicating some correlation with the number and integrity of amalgam restorations,9 while another study reported a high correlation with the number of amalgam fillings and time of placement, and outlined a slight difference in urinary levels of mercury between boys and girls.14

Occupational exposure in dental personnel was the topic of interest of a variety of studies carried out in the last two decades. It is widely agreed that due to appropriate dental mercury hygiene and increased interest in the use of non mercury-containing restorative

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<th>Medium</th>
<th>Individual with typical number of fillings</th>
<th>Occupational limit</th>
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<tr>
<td>Respiratory air concentration</td>
<td>3-17 μg Hg/day</td>
<td>346 μg Hg/day</td>
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<tr>
<td>Urinary concentration of mercury</td>
<td>3.5 μg Hg/L</td>
<td>100 μg Hg/L</td>
</tr>
<tr>
<td>Blood concentration</td>
<td>3-5 μg Hg/L</td>
<td>25 μg Hg/L</td>
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Table 1: Respiratory air concentrations, blood levels and urinary excretion of mercury in individuals with amalgam fillings compared to levels of mercury considered safe for occupational exposures.1

(Source: SCENIHR, The safety of dental amalgam and alternative dental restoration materials for patients and users.)
Adverse effects

During the last decade, a variety of studies have focused on analysing the relationship between mercury sensitivity and localised mucosal reactions, such as lichen planus and burning mouth syndrome. These studies concluded that in mercury patch-test positive patients, the removal of the amalgam fillings should lead to improvement or complete remission of the symptoms.

From a systemic point of view older epidemiological studies investigated the negative effects of mercury released by dental amalgam fillings on the nervous and renal system, and also on the immune, respiratory, cardiovascular, gastro-intestinal, haematological and reproductive systems. However, the existing information does not provide sufficient evidence of a correlation between the mercury released by dental amalgam fillings and chronic disease incidence and mortality.

Environmental and political aspects

Concerns over the persistence and effects of mercury in the environment, particularly in wastewater, have increased significantly over the past decade. It is believed that the mercury, being chemically bound in a metal alloy, produces a very stable compound and may only be released in a very small proportion over time as corrosion takes place. Dental mercury contamination is considered to represent only a small proportion of terrestrial mercury contamination, with values ranging from 3-4%. However, the extended impact of dental amalgam components on the environment is not fully known, so source reducing and elimination stands as the best defence against environmental mercury contamination.

In 2007, The Scientific Committee on Health and Environment Risks (SCHER) was requested to investigate environmental risks and indirect health effects connected to the use of dental amalgam. The

<table>
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<th>Organ system</th>
<th>Epidemiological outcomes</th>
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<td>Urinary system</td>
<td>Urinary mercury mean levels are higher in dentists, but there is no evidence of higher morbidity and kidney dysfunctions. When comparing children with and without amalgam fillings, no statistically significant differences were found in the renal glomerular function.</td>
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<td>Neurological system</td>
<td>The available data does not support the existence of an association between amalgam and Alzheimer’s disease. Anti-amalgam militants, however, maintain that inorganic mercury might play a role as a co-factor in the development of Alzheimer’s disease. There is no conclusive evidence of an association between exposure to dental amalgam and multiple sclerosis. However, future studies that take into consideration the size of restoration and the duration of exposure are considered to be needed by some scientists. No link could be established between neuropathy and amalgam exposure. Exposure to mercury from dental amalgam does not adversely affect neurological status. Low-level mercury exposure does not interfere with sensory nerve function.</td>
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<tr>
<td>Immune system</td>
<td>Mercury exposure does not cause autoimmune disease directly, but it might interact with triggering events, either genetic or acquired. Mercury has the potency to induce localised mucosal reactions as a manifestation to mercury allergy.</td>
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<tr>
<td>Reproductive system</td>
<td>A study carried out on a population of dental nurses showed that the group that worked with silver and copper amalgam fillings without protective gloves or ventilation was more prone to reproductive health problems, especially early hysterectomy. The possibility of a weak association between exposure to mercury and some other routinely used substances and the risk of miscarriage among dental workers cannot be excluded.</td>
</tr>
<tr>
<td>Psychological conditions</td>
<td>While many individuals attribute their neuropsychological conditions to mercury exposure from dental amalgam, there is no credible supportive data in the literature to the present date. A study carried out in Norway on a group of self-assessed patients complaining of fatigue, muscle and joint pain, dizziness, headache, burning or dry mouth, and altered taste due to mercury in amalgam fillings revealed a slight decrease in the intensity of the general symptoms after the removal of the fillings. However, the intra-oral symptoms decreased significantly.</td>
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Table 2: Brief presentation of studies into effects of amalgam by organ system.
The conclusion of this investigation was that due to lack of detailed quantitative information on the use and release patterns in all EU-27 countries, a comprehensive risk assessment could not be performed. SCHER had attempted to perform a screening level risk assessment outlining that the main concern related to the emission of inorganic mercury into the environment is its potential for bioaccumulation and biomagnification through the food chain. The conclusions of this screening were that the added risk for aquatic and soil organisms through inorganic mercury contributions from dental clinics should be considered low, and that it is essential to assess the methylation rates of inorganic mercury in order to conduct a correct evaluation.

The report advised that the atmospheric emissions and further deposition of mercury from crematoria should be considered as an additional contribution of mercury from dental amalgam. However, the BIO Intelligence Services (BIOIS) study entitled 'Study on the potential for reducing mercury pollution from dental amalgam and batteries', published in July 2012, reported a stabilisation in mercury emissions from crematoria since 2005. The number of crematoria equipped with mercury abatement devices in European countries is increasing progressively.

The dental profession worldwide has shown an ethical and responsible attitude to the often-perceived problem with dental amalgam. Various representative organisations for the dental profession expressed their interest and concern in the environmental issue, and developed guidelines and recommendations for handling dental amalgam waste. In November 2010, The Council of European Dentists (CED) encouraged national dental associations to support their members in compliance with EU waste management laws, and in November 2011 it adopted a statement on responsible practice regarding dental amalgam.

At national level, some countries have adopted their own protocols and legislation in relation to the use of mercury alloys in dentistry. In an attempt to phase out the use of dental amalgam the federal governments of Norway, Finland, Denmark and Sweden had enacted legislation requiring that dental patients receive informed consent information about the dental restorative material that will be used, and that other materials than amalgam are to be considered as first choice. Later in 2008 and 2009, Norway, Sweden and Denmark prohibited the use of dental amalgam in tooth restorations unless the patient presents special medical circumstances (allergies to alternative filling materials or treatment under general anesthetic). Through UN negotiations, Norway is actively pursuing a legally binding global agreement on the reduction of the use and release of mercury with the final aim of implementing a global ban on the use of products containing mercury. Some scientists, however, vehemently express their disapproval of the banning of dental amalgam, voicing their concern about the impact that this could have on dental health. It is considered that this is a political issue, which will have an insignificant impact on total worldwide mercury pollution, and which could be very well managed by adopting an adequate mercury hygiene regimen, including ISO-approved amalgam separators. DW Jones estimated that the environmental impact of mercury from 800,000 dental offices worldwide would represent between 0.04 and 0.2% of the total worldwide environmental mercury pollution from all sources, and this could be significantly reduced by using amalgam traps.

At international level, in Maine, California, Connecticut, and Vermont the state governments have enacted informed consent legislation for dental patients receiving amalgam dental restorations. In 2009, the US Food and Drug Administration issued final regulations that classified dental amalgam into class II (moderate risk) and released a guidance document that contains the special control measures imposed. A report released in 2010 states that after the Geneva meeting in 2009, the WHO encourages a global phasing down of the use of dental amalgam, and considers that an immediate ban is not appropriate, suggesting a multi-pronged approach with short-, medium- and long-term strategies. It also outlined that there is a need for more research into the performance, possible adverse effects and viability of alternative dental materials, and that strengthening of disease prevention and health promotion policies is highly important in reducing the need for restorative dental care.

The European Commission (DG Environment) adopted the mercury strategy in 2005 with the aim to reduce mercury levels in the environment. The BIOIS study, carried out for DG Environment and made public in July 2012, estimated that in 2010 the EU demand for mercury in dentistry was an average of 75 t Hg/year. The same study estimated that the dental amalgam contribution to overall EU mercury emissions to the air and surface water are as high as 21-32% and 9-13%, respectively. Mercury pollution from dental amalgam is considered to arise from both historical use of amalgam fillings (i.e., dental amalgam). The report advised that a dental amalgam ban would eliminate the environmental impact in the longer term, and the cessation of mercury usage would only be significant after about 15 years; therefore, both policies need to be employed to reduce mercury release in the short term as well. The study suggested that if such a ban was to be implemented in 2013, dental amalgam would be phased out by 2018.

The conclusion of the BIOIS study was that the combination of policies should not create implementation difficulties from a political point of view, and that the associated costs would be reasonable for the various stakeholders and would be outweighed by the environmental benefits. The study admitted that due to a lack of accurate quantitative information and uniformity of national protocols, rough estimations and approximations had to be considered in order to assess the environmental burden of dental amalgam.

The CED strongly criticised the methods used in conducting this study. The lack of established evidence and the significant number of
rough estimations and assumptions is rigorously outlined in the CED response to the BIOIS final report. It is rightly considered that a strong emphasis should have been placed on the 2009 WHO consensus expert report on ‘future use of materials for dental restoration’ developed by experts in material science and dental teaching and practice; however, the BIOIS draft report made insignificant reference to this study. While acknowledging the need for improvement in the enforcement of waste legislation regarding dental amalgam, the CED fully agrees with the conclusion of the WHO report, which advises on a “phasing down” rather than a “phasing out” approach of dental amalgam at the current time. The CED response highlighted the complexity of the problem, strongly advising the implementation of well-funded prevention programmes as a medium- and long-term alternative to reduce environmental pollution from dental practices. The CED considered it important that more research was done in order to establish the toxicology and the environmental impact of waste products generated by the use of alternative materials.64

A news release posted on the British Dental Association website at the end of 2012 voiced newly emerged concerns that the United Nations Environmental Programme (UNEP) Intergovernmental Negotiating Committee (INC) seemed to be favouring the implementation of an outright dental amalgam ban rather than the phasing down approach proposed by the WHO65 and the CED.44 However, the outcome of the fifth and final INC meeting on January 13 in Geneva appears to be a positive one. The committee decided to take a balanced approach that recognises the benefits brought by dental amalgam to oral health. It is now believed that the multilateral environmental agreement on mercury, due to be released during this year, will reinforce the need for a gradual reduction in the use of dental amalgam, committing to a global phase down approach.56

Conclusions
Dental amalgam is an effective restorative material, its popularity arising from its ease of use, good long-term performance and low cost. A variety of scientific studies carried out during the last decade show that the material is safe to use. While dental amalgam might be associated with very low rates of local adverse effects, there is no conclusive evidence suggesting risk of adverse systemic effects. Mercury exposure from dental amalgam has decreased significantly in recent years due to responsible professional conduct and proper mercury hygiene protocols. Due to lack of detailed information on the country-specific use and release patterns for dental amalgam, it is very difficult to quantify the environmental burden of mercury in dentistry. The evidence brought by studies assessing the environmental risks is based on estimations and assumptions; therefore, no concrete conclusions can be drawn. Against the valid hypothesis proposed by some scientists that the environmental impact of dental amalgam is almost insignificant, there are vehement voices at both European and international level demanding the introduction of new polices that would restrict the use of dental amalgam, therefore reducing its environmental impact. Dental amalgam ‘phase down’ would most certainly have its implications on national dental health, affecting and possibly reducing treatment alternatives. However, this approach would have a milder impact on dental professionals and dental health than the introduction of an outright dental amalgam ban. A transitional period would allow time for increased concentration on preventive care and implementation of possible changes to national health insurance schemes.

Despite the fact that dental amalgam has a well-established position in modern dentistry and that the vast majority of dental professionals have adopted responsible practice protocols, it appears that the days of dental amalgam use in dentistry might be coming to an end. It seems that 2013 could prove to be quite a decisive year for the future of this low-cost, highly effective direct restoration material.

References


