

# The environmental effects of dental amalgam

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## Abstract

Dental amalgam is one of the most commonly used materials in restorative dentistry. However, one of its major components, mercury, is of particular concern due to its potential adverse effects on humans and the environment. In this review, the environmental impact of dental amalgam will be discussed, with particular reference to the effects attributed to its mercury component. Mercury commonly occurs in nature as sulfides and in a number of minerals. Globally, between 20,000-30,000 tons of mercury are discharged into the environment each year as a result of human activities. According to a recent German report, approximately 46 per cent of the freshly triturated amalgam is inserted as new amalgam restorations and the rest is waste. Depending on the presence of an amalgam separating unit, some of the generated amalgam-contaminated sludge is discharged into the sewage system. Lost or extracted teeth with amalgam fillings and amalgam-contaminated waste, such as trituration capsules and cotton rolls are discharged with the solid waste and, in most instances, are incinerated. Use of disinfectants containing oxidizing substances in dental aspirator kits may contribute to remobilization of mercury and its subsequent release into the environment. Nevertheless, dental mercury contamination is only a small proportion of terrestrial mercury (3-4 per cent), which is quite insignificant compared with industrial pollution and combustion of fossil fuels by vehicles. The environmental impact of dental mercury is mainly due to the poor management of dental amalgam waste. Proper collection of mercury-contaminated solid waste prevents the release of mercury vapour during combustion. In addition, the use of amalgam separating devices reduces the amount of amalgam-contaminated water released from dental clinics.

**Key words:** Dental amalgam, environment, mercury.

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## Introduction

Dental amalgam is one of the most commonly used materials in restorative dentistry. Its physical and mechanical properties, stability, ease of use and relatively low cost have made amalgam the preferred choice in many clinical situations when compared with other direct restorative materials such as composites and glass ionomers. However, one of its major components, mercury, is of particular concern due to its potential adverse effects on humans and the environment. There are four possible harmful effects of dental amalgam – oral galvanism, toxicity, allergenicity and ecological grievances.<sup>1</sup> In this review, the environmental impact of dental amalgam will be discussed, with particular reference to the effects attributed to its mercury content.

## Mercury and the environment

Mercury commonly occurs in nature as sulfides and in a number of minerals. From these deposits, mercury is circulated naturally in the biosphere, primarily by degassing from the earth's crust and oceans. Natural emission of mercury amounts to around 150,000 tons a year. Globally, approximately 10,000 tons of mercury are mined each year, with an estimated 3-4 per cent used in dentistry. Between 20,000-30,000 tons of mercury are discharged into the environment each year as a result of human activities, including processing of minerals and ores and fossil fuel combustion.<sup>2</sup>

The possible toxic effects of mercury are strongly dependent on its chemical form. In dentistry, only the metallic form is used, while inorganic and organic compounds are also present in the environment. The metallic form is mainly absorbed in the human body through skin, while mercury vapour absorption is through the lungs. The absorbed mercury passes into the circulation and is disseminated throughout the body. After cellular absorption, metallic mercury is converted into mercuric ions which can produce toxic effects.<sup>3</sup>

The toxicokinetics of mercury compounds vary considerably in different species; however, in

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general, several basic biological mechanisms are affected in living organisms. Mercury compounds possess a strong affinity for sulfur and sulfhydryl groups and thereby affect cell metabolism by interfering with membrane and enzyme functions of individual cells.<sup>1,2</sup> The severity of any toxic effect usually follows a dose-response pattern; however, the form of mercury is also important. For example, methylmercury is significantly more toxic than other mercury compounds. Most important among the target organs for mercury toxicity are the brain, liver and kidneys.<sup>1</sup> Excretion of mercury occurs mainly through urinary and fecal routes. The body burden of mercury in humans has a half-life of approximately two months.<sup>4</sup>

Mercury is accumulated in both aquatic and terrestrial food chains, with higher levels occurring in predators.<sup>5</sup> A biological magnification of up to 100,000 times from algae to predators at the top of the food chain has been reported.<sup>2</sup> In polluted waters, levels of methylmercury in living organisms such as fish will increase, with a tendency toward higher levels with increasing size and age of fish. Mercury accumulation is also seen in terrestrial food chains. When total mercury content was measured in the feathers of 95 wild birds collected on the shores of Japan's Shiranui Sea,<sup>5</sup> relatively high mercury levels, and a strong correlation between feeding habits and mercury content were observed.<sup>5</sup> The five groups, in order of diminishing mercury content, were fish-eating sea birds, omnivorous water fowl, predatory birds, omnivorous terrestrial birds and herbivorous water fowl, indicating the importance of the aquatic environment underlying the mercury problem.<sup>6</sup>

Elementary mercury entering the waterways is converted to methylmercury, mediated by methylcobalamin or by sediment micro-organisms, including bacteria and fungi.<sup>6</sup> The subsequent uptake of methylmercury occurs via two mechanisms – either directly from the water or through the food chain. Direct extraction of mercury from water occurs as a result of mercury's high affinity for sulfur and sulfhydryl groups. The food chain facilitates the biomagnification of mercury levels when organisms higher in the food chain ingest other organisms contaminated with ethylmercury. Plankton and algae that take up methylmercury are consumed by small fish that are in turn consumed by larger fish and other predators, thus allowing the accumulation of mercury through the food chain.<sup>7</sup>

As a result, the prime concern for the environmental impact of dental amalgam lies with its disposal in the aquatic environment. With increasing knowledge of the risk of toxic effects from mercury pollution in ecosystems, there is growing pressure for the reduction of the discharge of mercury waste.

Industrial discharge has been markedly reduced; subsequently, increased attention has been focused on the uncontrolled discharge of mercury waste from dental clinics.

### **The mercury cycle in dentistry**

According to a recent German report, approximately 46 per cent of the freshly triturated amalgam is inserted as new amalgam restorations.<sup>8</sup> Major amalgam particles (15 per cent), surplus trituration capsules and carved surplus should be collected for recycling. Minor amalgam particles produced during carving, burnishing and polishing procedures are removed by the vacuum system. Some of these minor particles become sediment in tubes and drains of clinics. If an amalgam separating unit is not used, some of the generated amalgam-contaminated sludge is discharged into the sewage system. Lost or extracted teeth with amalgam fillings and amalgam-contaminated waste such as trituration capsules and cotton rolls are discharged with the solid waste and in most instances are incinerated. In addition, use of disinfectants containing oxidizing substances in dental aspirator kits may contribute to remobilization of mercury and its subsequent release into the environment.<sup>8</sup>

### **Primary amalgam particles**

Few data exist on the extent to which waste amalgam particles are collected and recycled. However, because of its value, dental scrap amalgam is usually carefully collected and sold for refinement. A thorough review of the environmental status of amalgam waste has demonstrated no evidence that scrap amalgam, when properly stored and handled, should be considered a health hazard.<sup>9</sup>

In order for scrap amalgam to be listed as a health hazard, there must be statistically significant evidence that acute or chronic health effects may occur in exposed employees.<sup>10</sup> The only component of scrap amalgam likely to be hazardous is mercury in the form of dust or particulate, mercury vapour, mercury leached by liquids or methylmercury.

There are no data to suggest that exposure to mercury dust and particulate generated from grinding old restorations or during storage, collection and sale of scrap amalgam resulted in adverse health effects. A study on the effects of inhaling high concentrations of amalgam dust generated from high-speed drilling revealed toxic levels were detected in rats.<sup>11</sup> However, the authors noted these findings could not be extrapolated to humans since the concentration and duration of mercury exposure would be less during removal of old restorations.

In a study of mercury vapour emitted from scrap amalgam,<sup>12</sup> the air next to open amalgam waste receptacles was sampled. The levels of mercury vapour detected ranged from 18-70µg/Hg/m<sup>3</sup>, with those above 50µg/Hg/m<sup>3</sup> exceeding Maximum Allowable Concentration (MAC). However, scrap amalgam stored under liquid in an airtight container would result in near-complete suppression of mercury vapour emissions.<sup>13</sup> Furthermore, the MAC is based on the assumption there is continual exposure during a 40-hour working week. None of the reports indicated dental personnel were continually exposed to high levels of mercury vapours.

As an alloy, scrap amalgam is physically and chemically stable and does not break down easily into its components. Thus, it is unlikely to leach into the solution in which it is stored. *In vitro* studies on the solubility of dental amalgam in various liquids have shown that the dissolution rate of set amalgam is low, that of all the components of amalgam, mercury has the least tendency to dissolve, and that the dissolution rate of mercury decreases dramatically over time.<sup>14</sup> Therefore, the evidence indicates set amalgam, and hence scrap amalgam, has low solubility in liquids and is unlikely to break down into its component elements. A variety of liquids have been tested as storage solutions for scrap amalgam. Although water is excellent at reducing vapour, radiographic fixer has been found to be more effective.<sup>12</sup>

Scrap amalgam cannot be converted into methylmercury while stored by dentists and other suppliers. Methylmercury can be produced in ecosystems by the activities of living organisms. However, in the event that scrap amalgam should enter an ecosystem, the low solubility of mercury from set dental amalgam would limit the generation of methylmercury to insignificant levels.

### **Mercury in sewage**

Waste material from dental surgeries may enter the aquatic and terrestrial environments via the sewage system. The most important polluting materials are the heavy metals, in particular mercury,<sup>5</sup> while most other chemically active and infected materials are almost harmless.<sup>2</sup> A Swedish study<sup>13</sup> estimated the yearly human waste emission of 100kg of mercury into the environment originating from a population load of amalgam fillings containing 90,000kg mercury.

In a recent Danish investigation,<sup>15</sup> sewage was collected during one working day from 20 general dental practices. Ten clinics were equipped with an amalgam separating unit. Wastewater samples were analyzed for total mercury content but not for the chemical form in which the mercury was present.

There was a wide variation (24-1,700mg/day). Lower values were observed in clinics with an amalgam separator, while the highest value was 800mg/dentist/day. Data obtained from dental clinics equipped with amalgam separators demonstrated a lower mean mercury level, about 10 per cent of the levels found in waste water from clinics without separators.<sup>15-17</sup> Once deposited in the sewage system, removal of amalgam from the sludge requires a specific apparatus.<sup>2</sup>

Based on results from Danish and Swedish studies,<sup>15,16</sup> the local environmental authorities in a major Danish city have estimated the possible amounts of mercury delivered to the purifying plants from the dental clinics in each area. According to these estimates, the majority of mercury concentrated in sewage may be from dental clinics. However, some of the amalgam particles released from dental clinics will sediment in the drainage system and the data do not indicate how much can be expected to reach the purifying plant.

### **Amalgam separators**

In several countries, threshold limits for heavy metals in sludge are currently being lowered. Reports have described how local areas, such as Zurich in Switzerland, expend large amounts of money depositing sludge as chemical waste instead of recycling it as fertilizer.<sup>18</sup> Consequently, amalgam separators are now mandatory in several European countries.

Sedimentation or centrifugal separators are used. Sedimentation of amalgam particles is facilitated by filters, slats or granular material; in the centrifugal method, the water stream passes through a rotating unit before outlet. The centrifuge method is more efficient than the sedimentation method, even though centrifuge units are less environmentally friendly and more expensive to operate than sedimentation units.

### **Cremation**

The cremation of cadavers is another way metallic mercury vapour is emitted into the atmosphere even though crematoria operating temperatures are usually above 80°C, sufficient to vaporize the mercury from amalgam fillings.<sup>19</sup> In addition, crematoria are usually located in densely populated areas, some having inadequate chimneys. The presence of the resultant mercury vapour so close to the ground facilitates more rapid conversion to soluble forms which are then deposited into the soil and water and eventually enter the food chain.

From 50,000 cremations,<sup>19</sup> it has been estimated approximately 170-180kg of metallic mercury is emitted into the atmosphere. Mercury vapour

remains in the atmosphere for up to three years (soluble forms of mercury have a three-week atmospheric lifespan) and the presence of such an amount of mercury vapour in the atmosphere may be deemed inappropriate. Most modern crematoria have selenium chimney filters that significantly diminish the amount of mercury vapour released into the atmosphere. However, the environmental effect of cremating amalgam-filling-bearing cadavers cannot be estimated until a global study on this mercury release is undertaken.

## Conclusion

There is some evidence that mercury particle release from dental amalgam has harmful effects on the environment but dental mercury contamination, at 3-4 per cent, is only a small proportion of terrestrial mercury, quite insignificant compared with industrial pollution and vehicle fossil fuel combustion. The environmental impact of dental mercury is mainly due to the poor management of dental amalgam waste. A regulated collection system for mercury-contaminated solid waste, especially extracted teeth with amalgam fillings, will ensure mercury vapour is not released during the combustion of mercury-contaminated solid waste. In addition, the use of amalgam separating devices can reduce the amount of amalgam-contaminated water released from dental clinics. During cremation, 2-3g mercury vapour is released into the atmosphere but this has minimal effect on the environment compared with the total amount of mercury discharged from other human activities.

The problem of environmental mercury contamination will not be solved by banning dental amalgam. As medical professionals, we should consider the various possibilities that can satisfy both the application of dental amalgam as a restorative material as well as minimizing the environmental effects. Tackling this problem by the application of simple guidelines for mercury waste handling will reduce the environmental concerns of dental waste to an insignificant level without compromising dental amalgam's important role in dentistry.

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