Reprinted from *Advances in Dental Research,* September 1992

DENTAL AMALGAM-ENVIRONMENTAL ASPECTS

D. ARENHOLT - BINDSLEY
Royal Dental College
Aarhus, Denmark

Adv Dent Res 6:125-130. September, 1992

Abstract- Increasing knowledge about the risk of toxic effects caused by anthropogenic mercury accumulation in ecosystems has resulted in a growing pressure forreduction of the discharge of mercury waste. Consequently, the mercury waste problems of dental clinics have been given increased attention. and restrictions on handling and discharge of contaminated waste have been established in several countries.

Major amalgam particles from trituration surplus of those produced during the carving and burnishing of new amalgam restorations are generally collected in coarse filters and sold for refinement. Minor amalgam particles released by production of new fillings or by removal of old restorations partly sediment in tubes and drains. The remaining particles are carried with the waste water stream to the local purifying plant. In Scandinaviathe industrial discharge of mercury-contaminated waste water has been reduced to a minimum. According to recent investigations, dental clinics appear to be responsible for the major amount of mercury collected in the sludge generated in purifying plants. If threshold values for heavy metal content, including mercury, are exceeded, the sludge is not allowed to be recycled as fertilizer. Installation of an approved amalgam-separating apparatus in dental clinics is now mandatory in several countries- for example, Switzerland, Germany, Sweden, and Denmark. Approval of amalgam separators is based on national testing programs, including clinical or laboratory tests demanding 95-99% separating efficiency.

This manuscript is published as part of the proceedings of the NIH Technology Assessment Conference on Effects and Side-effects of Dental Restorative Materials, August 26-28, 1991, National Institute of Health. Bethesda, Maryland, and did not undergo the customary journal peer-review process.

Natural deposits of mercury were formed when hydrothermal solutions from hot springs or volcanic activity penetrated unstable geological formations to replace porous sandstone or limestone formations with mineral solution containing mercury. Major deposits are therefore found in areas of previously high volcanic activity. Mercury commonly occurs in nature as sulfides and in a number of minerals. From natural deposits, mercury is circulated naturally in the biosphere, primarily by degassing from the earth's crust and oceans.

Globally. around 10,000 tons of mercury are produced yearly for anthropogenic use. It has been estimated that 3-4% is used in dentistry. Between 20,000 and 30,000 tons of mercury are discharged annually into the environment as a result of human activities, such as processing of minerals and ores, and combustion of fossil fuels. Natural emission of mercury amounts to around 150.000 tons per year (Kaiser and Tölg, 1980).

The possible toxic effects of mercury are strongly dependent upon the chemical form in which the mercury is available. Furthermore, the toxicokinetics of mercury compounds varies considerably in different species, Due to the basic chemical properties of mercury, several basic biological mechanisms are affected in living organisms in general. A major factor underlying the biochemical properties of mercury and mercury compounds is the fact that mercury possesses a strong affinity for sulfur and sulfhydryl groups. and thereby may interfere with important basal biological functions in living organisms. i.e.. membrane and enzyme functions (Berlin. 1986).

Mercury is accumulated in food chains, thus. to a high degree. in the aquatic environment. with the highest levels occurring in predators. A biological magnification of up to 100,000 times from the algae level to predators has been reported. In areas with polluted water, levels of methylmercury in living organisms, such as fish, will increase, with a tendency toward increasing levels with increasing size and age of the fish. Mercury accumulation is seen in terrestrial food chains as well, but not to the same extent of enrichment as in the aquatic food web (Kaiser and Tölg, 1980).

CONSUMPTION

Increasing knowledge of the risk of toxic effects to humans from mercury pollution in ecosystems has resulted in growing pressure for the reduction of the discharge of mercury waste. The industrial discharge of mercury has been reduced markedly in several countries. Subsequently. increased attention has been focused on the uncontrolled discharge of mercury waste from dental clinics. In a few countries, including Denmark. the government is considering banning the use of mercury in dentistry for environmental reasons. National surveys show that mercury consumption in dentistry has declined markedly in recent years. Figs. 1a and 1b illustrate the dental mercury

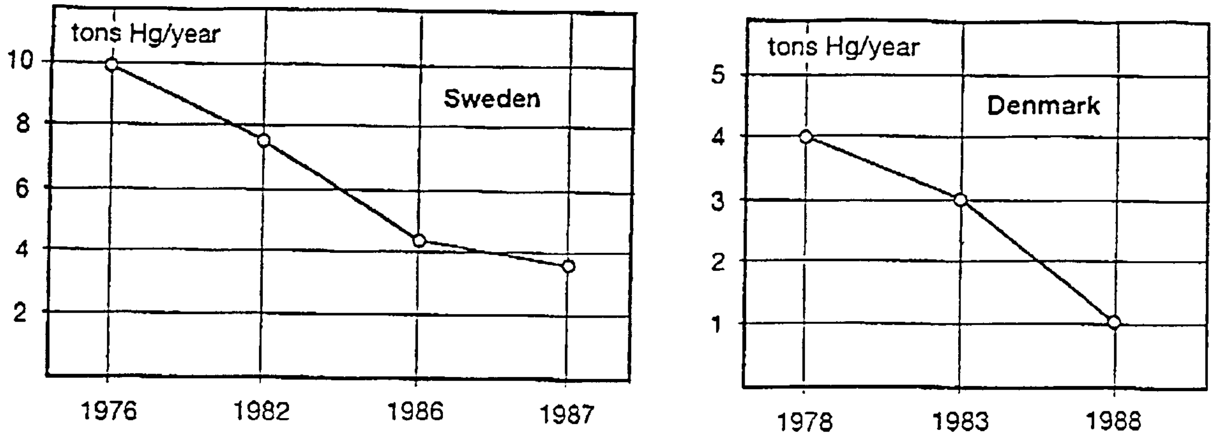

Fig. 1 - Mercury consumption in dentistry. (a) Sweden. 1976-87 (Hogland et al., 1990). (b) Denmark. 1978-88 (Arenholt-Bindslev and Larsen. 1990).

consumption in Sweden and Denmark during the last decade. A reduction of between 50 and 75% is seen. This reduction is also reflected in the statistics on the numbers of amalgam fillings produced per year (Fig. 2).

WASTE CATEGORIES

Fig. 3 summarizes the mercury cycle in dentistry (Hörsted-Bindslev *et al.*, 1991). According to a recent German report, around 46% of the freshly triturated amalgam will be inserted as new amalgam fillings (Rahimy. 1988). *Major amalgam particles* (around 15%), surplus in trituration capsules and carved surplus, are expected to be collected for recycling. *Minor amalgam particles* produced during carving. burnishing, and polishing procedures will be sucked up and transported by the vacuum system. A pan of it will sediment in tubes and drains in the clinic. Depending on the presence or absence of an amalgam separating unit in the clinic, a part of the generated amalgam-contaminated sludge will be discharged with the sewage. *Lost or extracted teeth* with amalgam fillings and amalgam-contaminated waste as trituration capsules and cotton

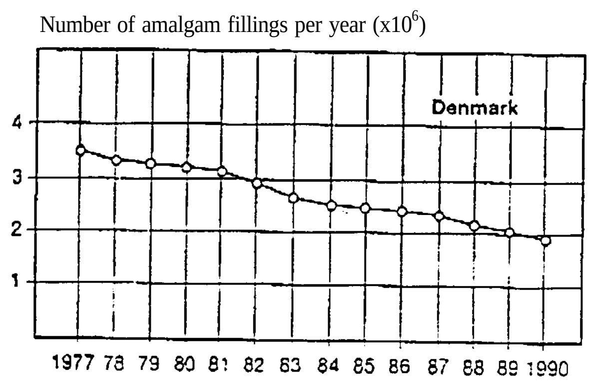

Fig. 2- Number of amalgam fillings produced per year in Denmark. 1977-90 (Arenholt-Bindslev and Larsen. 1990).

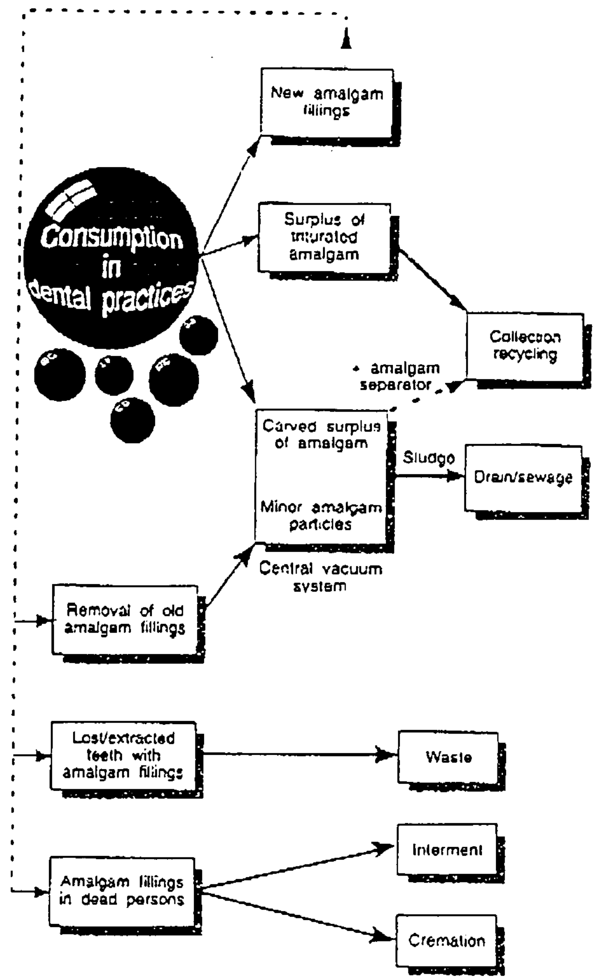

Fig. 3- Mercury cycle in dentistry (from Hörsted-Bindslev et al.. *1991).*

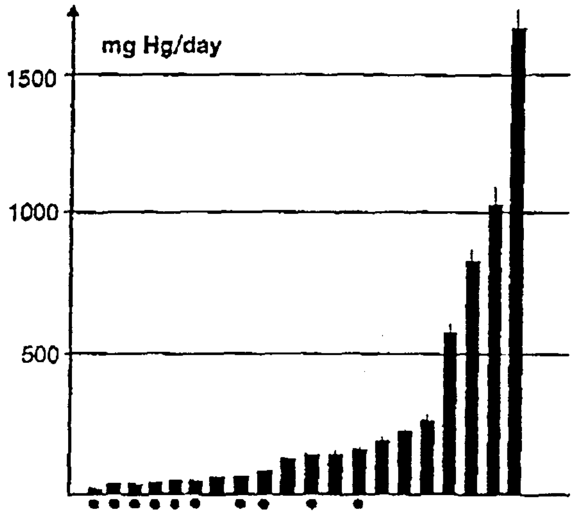

Fig. 4- Mercury burden in waste waxer samples collected during one working day in 20 Danish dental clinics. ● indicates clinics equipped with a Swedish-approved amalgam-separating device (Arenholt-Bindslev and Larsen, 1990).

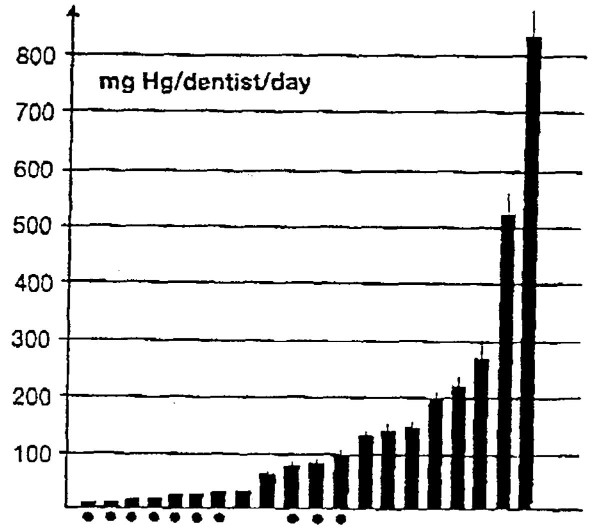

Fig. 5- Mercury burden in waste water collected during one working day in 20 Danish dental clinics (Arenholt-Bindslev and Larsen, 1990). ● indicates clinics equipped with a Swedish-approved amalgam-separating &vice (Arenholt-Bindslev and Larsen, 1990).

rolls will be discharged with the solid waste and in most instances, will be subjected to combustion. Corpses with or without amalgam fillings are cremated or buried.

PRIMARY AMALGAM PARTICLES

No exact data exist on the extent to which primary amalgam particles are collected and recycled. However, because of its value, dental scrap amalgam is, in general. carefully collected and sold for refinement. A thorough review of the status of amalgam scraps as environmental health hazards or toxic substances has demonstrated that there is no evidence that dental amalgam in the form of scrap, when properly stored and handled, should be considered as a health hazard (Rogers. 1989). To ensure proper handling and recycling, dental personnel should take care that amalgam scrap is handled only by companies that adhere to government regulations.

SEWAGE

The discussion of mercury consumption and mercury waste handling in dentistry has been dominated by rough estimates and assumptions. Few investigations have presented data on which mare reliable and realistic estimates can be generated. Primarily, national reports or documents worked out by local and national environmental authorities are available. The major parts of the following data were obtained from several European reports of this kind, some of which are available only as national publications in German or Scandinavian languages.

In a recent Danish investigation. sewage was collected during one working day from 20 general dental practices (Arenholt-Bindslev and Larsen, 1990). Ten clinics were equipped with an amalgam separating unit, approved by Swedish authorities. All clinical procedures performed during waste water sampling were recorded. Waste water samples were subjected CO routine authorized analysis. with data given on the total amount of mercury in each sample. but not on the chemical form in which the mercury was present. Fig. 4 shows the data on the amount of mercury discharged with the sewage from each clinic during one working day. There is a wide variation (from 24- 1700mg/day). Lower values were observed in clinics equipped with an amalgam separator. Fig. 5 shows the data correlated with the number of full-time dentists

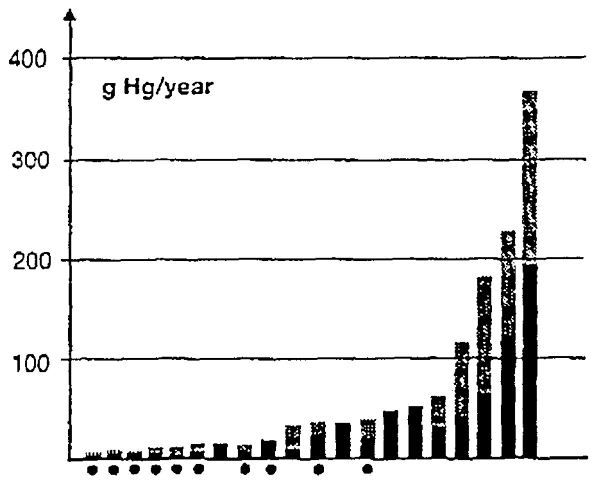

Fig. 6- Estimates of the amount of mercury discharged per year with the waste water from 20 Danish dental clinics (Arenholt-Bindslev and Larsen. 1990). ● indicates clinics equipped with a Swedish-approved amalgam-separating device. Dotted bars indicate estimated values per clinic. Solid bars indicate estimated values per dentist per clinic.

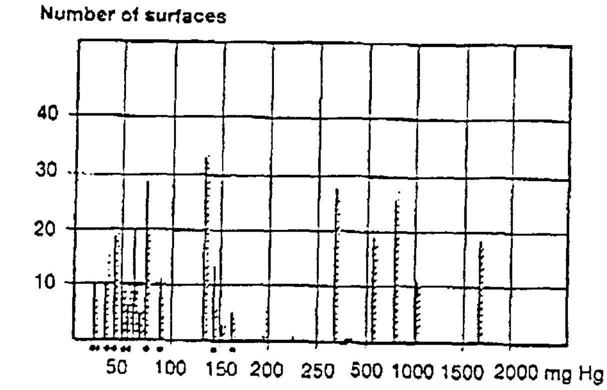

Fig. 7- Mercury burden in waste water collected during one working day in 20 Danish dental clinics (x-axis) correlated with the numbers of amalgam procedures performed during waste water sampling. Pairs of solid and hatched bars represent the number of new (solid bars) and old (hatched bars) amalgam surfaces produced or removed in each individual clinic during waste water sampling) (Arenholt-Bindslev and Larsen, 1990).

practicing in each clinic. The highest value obtained was 800 mg *per* dentist *per* day; lower values were found in clinics equipped with amalgam separators. From the same study. Fig. 6 shows an estimate of the possible yearly amount of mercury discharged with the waste water. Calculated values up to 100-200 g mercury per dentist per year were seen. Data from clinics without amalgam separators in the recent Danish study correspond rather well with previous German studies (Gräf *et al.*. 1988; Töpper, 1956) and Swiss estimations (Fischer and Borer. 1989). all based on data from fewer clinics. In the study by Töpper (1986), major amalgam particles retained in coarse filters in the spittoons were added to the water samples. resulting in relative higher values in that study.

Data from studies investigating sewage from dental clinics equipped with amalgam separators (Arenholt-Bindslev and Larsen. 1990: Hogland *et al.*. 1990; Gräf *et al.*. 1988) demonstrated that the mean mercury level in waste water is about 10% of the values obtained in studies including clinics without separators. Two studies have concluded that there is no correlation between the amount of amalgam work performed during waste water sampling and the actual amount of mercury found by waste water analysis (Fig. 7) (Arenholt-Bindslev and Larsen, 1990: Hogland *et al.*, 1990). These findings indicate that amalgam particles are sedimented in tubes and drains within the clinic and continuously released by the water stream.

MERCURY IN SLUDGE

Based on results from Danish and Swedish studies (Arenholt-Bindslev and Larsen. 1990; Hogland *et al.*, 1990). 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 located in each area (Fig, 8). According to these estimates. the major amount of mercury concentrated in the sludge may theoretically derive from the dental clinics. Some of the amalgam particles released from

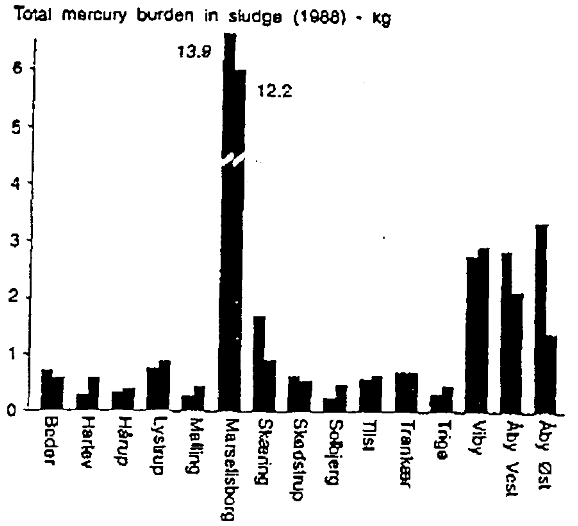

Fig. 8- Total mercury burden per year in the sludge produced by 15 purifying plants in Aarhus, Denmark (appr. 250,000 inhabitants) (solid bars). and estimated values of the mercury burden delivered to each individual plant from the dental clinics in each drainage area (hatched bars) (from Hörsted-Bindslev et al., 1991).

dental clinics will sediment in the drainage system, and no available data indicate how much actually can be expected to reach the purifying plant.

BIOAVAILABILITY

It is uncertain to what extent mercury bound in released amalgam particles becomes bioavailable. Investigations on the solubility of amalgam suggest that, in pure water as well as in sewage, only minute amounts of mercury (< 0.004%) are released from set amalgam (Heintze *et al.,* 1983; Beckert, 1988). However. Ekroth (1975) investigated fish living in waterwith set γ_2 -amalgam particles and reported accumulation of mercury in the fish. She suggested that corrosion of amalgam and methylation of inorganic mercury compounds had taken place. Whether a methylation of mercury released by corrosion of dental amalgam actually takes place in sediment or sludge is an open question. Both methylating and demethylating organisms are known to exist (Walsh *et al.,* 1988).

A key question is to what extent mercury is released by corrosion of amalgam particles in sewage and sludge. If the mercury bound in amalgam particles does not become bioavailable. it may be a minor environmental risk

AMALGAM SEPARATORS

In several countries. the threshold limits for heavy metals content in sludge are currently being lowered. National reports have described how local areas. such as Zürich in Switzerland. expend tremendous amounts of money on depositing sludge as chemical waste instead of being able to recycle the sludge as fertilizer (Fischer and Borer, 1989). Consequently. amalgam separators are now mandatory in several European countries. National test programs have been developed for approval of

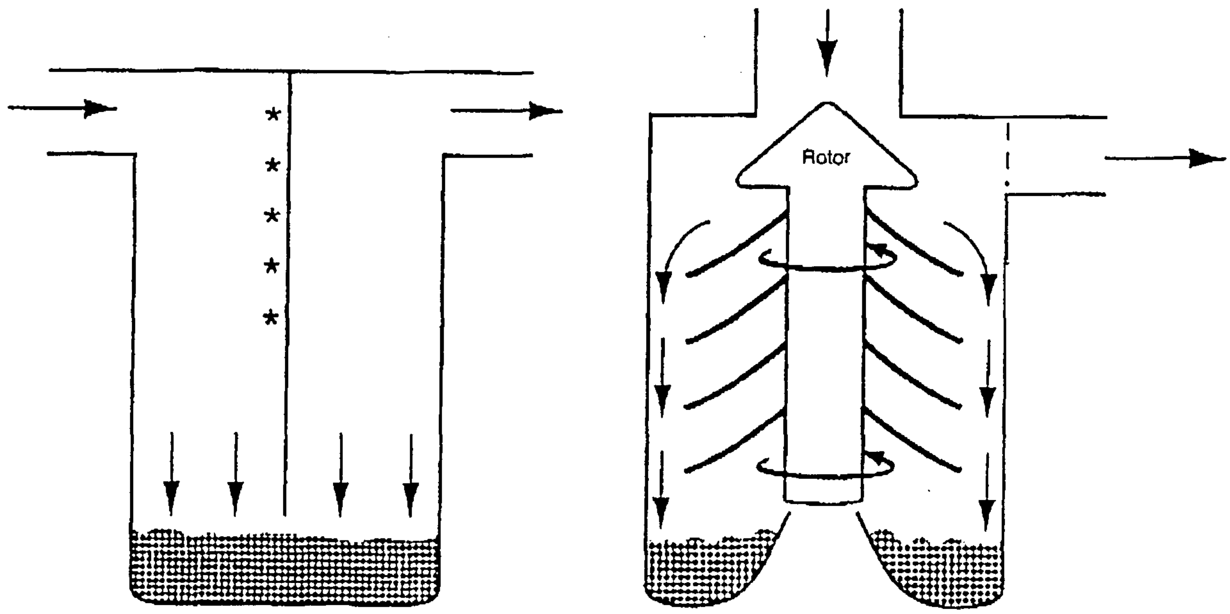

*Fig. 9- Main principles of amalgam separation. (a) Sedimentation: * indicates individual constructions (i.e., filters, slats, granular material) facilitating sedimentation. (b) Centrifugation: container or central rotor rotates to separate amalgam particles from the water stream, (from Hörsted-Bindslev* et al., *1991).*

separating devices. No international standard has yet been elaborated. The Swedish and German test programs demand 95% efficiency in individual short-term laboratory set-ups, while the Danish program demands 99% efficiency in a standardized clinical long-term set-up. The Swedish test procedure has been criticized for being unrealistic, since the standard amalgam particles used for testing differconsiderably from "naturally" derived amalgam sludge (Töpper, 1986). The Swedish test procedure is presently under revision.

Several different amalgam separating devices are commercially available. Two main principles for separation have been introduced: sedimentation, where sedimentation of amalgam particles is facilitated by filters, slats, or granular material: and centrifugation, where the water stream parses a rotating unit before outlet (Figs. 9a-b).

SOLID WASTE

During combustion of amalgam-contaminated solid waste, such as extracted teeth with amalgam fillings, trituration capsules, and cotton rolls, mercury will be released as bioavailable mercury vapor. Trituration capsules and extracted teeth with amalgam fillings should therefore be collected for delivery to authorized handling facilities, similar to the procedure adopted for the handling of mercury-containing batteries.

CREMATION/INTERMENT

The possible environmental effects of burying and cremating dead persons with amalgam fillings have been debated, especially in Sweden. Since few data are available. discussions have been very emotional. Concerning interment. no data are available. According to preliminary results from an ongoing Danish research project investigating samples of soil and drainage water from cemetery areas, no traces of mercury were found in drainage water (Eiskjœr. personal communication).

During cremation. mercury bound in amalgam fillings will be released as bioavailable mercury vapor. The cremation frequency is increasing in most Western countries, and it has been claimed that cremation is a major source of mercury vapor emission. The amount of available data is sparse and based primarily on rough estimates.

Estimates of the mean amount of mercury emitted during cremation have ranged between 3.8 g and 1.8 g mercury per cremation (Mörner and Nilsson. 1986; Rivola *et al.,* 1990). A few national reports have presented slightly elevated mercury values in soil and plants close to crematories. whereas others have failed to demonstrate elevated values (Mörner and Nilsson. 1986). Further research is needed.

A recent Swedish study (Hogland and Wendt, 1990) represents the first reported data on *measurements* of mercury release during cremation. Mercury emission was recorded during 17 cremations. The individuals' dental status were not given. No values exceeding 2.1 g mercury per cremation were recorded (mean, 0.6 g mercury *per* cremation). The study indicated that simultaneous combustion of selenium ampoules may reduce the emission ofmercury vapor. Further studies are required for this suggestion to be elucidated.

SUMMARY

Amalgam - contaminated water is released from dental clinics, with a possible risk of adding significantly to the mercury burden in sludge, thus preventing recycling. This problem can be solved relatively easily by installation of efficient amalgam-separating devices.

By proper collection of mercury-contaminated solid waste, primarily extracted teeth with amalgam fillings. release of mercury vapor during combustion of mercury-contaminated solid waste should be prevented.

Mercury vapor emission during cremation appears to be 2-3 g mercury vapor per cremation. Mercury emission filters are available. but expensive, and may give rise to other environmental problems. Simultaneous combustion of selenium ampoules may be relevant, but further research is needed for the efficacy of this to be assessed.

Interment of corpses seems to be negligible as an environmental mercury problem.

In any country or local area the relatively few environmental mercury problems related to dentistry become important and relevant only when environmental mercury problems in the society in general have been reduced to a minimum. In a large number of countries, the dental problem may therefore be negligible in comparison with industrial pollution and combustion of fossil fuels.

By the practicing of simple guidelines for mercury waste handling, the environmental consequences of amalgam waste handling in dentistry can be reduced to an insignificant level.

REFERENCES

Arenholt-Bindslev D, Larsen A (1990). Kviksølv i spildevand fra tandklinikker. *Tandlægehladet* 94:410-415.

Beckert J (1988). Amalgamabfälle aus zahnarztpraxen. *Zahnärztl Mitteil* 78:2525-2526.

Berlin M (1986). Mercury. In: Friberg L, Nordberg GF, Vouk V, editors. Handbook on the toxicology of metals. Amsterdam (The Netherlands): Elsevier Science Publishers, 387-445.

Eiskjær M (1991). Personal communication.

Ekroth G (1978). Anrikning i fisk af kvicksilver fràn tandamalgam. Rapport SNV PM 1072. Stockholm (Sweden): Statens Naturvårdsverk.

Fischer W, Borer G (1989). Amalgamentsorgung im bereich abwasser. *Schweiz Monatschr Zuhnmed* 99:61-68.

Gräf W, Sühs K, Pfarrer R (1988). Die umweltbelastnung durch quecksilber, silber, entwikler und fixierer aus zahnärtzlicher praxis. *Zahnärztl Mitreil* 78:214-218.

Heintze U, Edwardsson S, Dérand T. Birkhed D (1983). Methylation of mercury from dental amalgam and mercury chloride by oral streprococci *in vitro. Scand J Dent Res* 91:150-152.

Hogland W. Jensson B, Petersson P (1990). Kvicksilverutsläpp från tandvårdsverksamheten i Lund. Internrapport 3132. Malmö (Sweden): University of Lung.

Hogland, W. Wendt W (1990). Mäminger av kvicksilverutsläpp från krematoriet på Norrakyrkogården i Lund. Internrapport 3142. Malmö (Sweden): University of Lund.

Hörsted-Bindslev P. Magos L. Holmstrup P, Arenholt-Bindslev D (199 1). Dental amalgam-a health hazard? Copenhagen (Denmark): Munksgaard. 99-108.

Kaiser G, Tölg G (1980). Mercury. In: Hutzinger O. editor. The handbook of environmental chemistry. Vol. 3. Part A. Berlin (Germany): Springer Verlag, l-58

Mörner S, NilssonT(1986). Kvicksilverutläpp från Göteborgs krematorier. Göteborg (Sweden): Rapport Göteborgs Kommun.

Rahimy SI (1988). Abfallproblem und möglichkeiten des recyclings beim silberamalgam. Wilhelmshaven (Germany): Fachbereich Feinwerktechnich. Diplomarbeit bei der Fachhochschule Wilhelmshaven.

Rivola J, Krejci J. Imfeld T, Lutz F (1990). Feuerbestattung und quecksilberumweltlast. *Schweiz Monatschr Zahnmed* 100:1299-1303.

Rogers KD(1989). Status of scrap (recyclable) dental amalgams as environmental health hazards or toxic substances. *J Am Dent Assoc* 119: 159- 166.

Töpper H (1986). Rückhaltung von amalgamabfällen aus zahnarztpraxen. In: Umweltplanung und umweltschutz. Schriftenreihe der Hessischen landesanstadt für umwelt. Nr. 44. Wiesbaden (Germany): Hessischen Landesanstadt für Umwelt, l-88.

Walsh CT, DiStefano MD, Moore MJ, Shewchuk LW, Verdine GL (1988). Molecular basis of bacterial resistance to organomercurial and inorganic mercuric salts. *Fed Amer Soc Exp Biol J* 2:124-l30.