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Improper Waste Disposal of Silver-Mercury Amalgam

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Abstract The objective of this work was to estimate the quantity of mercury residue present in dental amalgam that is generated and discarded in the city of Manaus (Amazon-Brazil). For this purpose, the locations of amalgam usage (10 public and 31 private dental clinics), the method by which the residue is discarded (14 clinics improper disposal), and the analysis of total mercury in the sediment of the controlled landfill (2.68–3 μgHg/g), were described. It was concluded that: there are dental clinics in the city that discard mercury residue into the common waste disposal system, which contravenes health safety standards.

Keywords Silver amalgam · Mercury · Landfill

The use of amalgam, initially composed of a simple mixture of silver and mercury, for dental restorations, was first described by Taveu around (1826). This discovery was excellent for its time, but chemists had already noted the toxic effects of mercury. Later, some authors described its toxic effects, stating that the fact that mercury vapor remains in the environment is harmful to the dental surgeon and to others nearby, such as the dental assistant and the patient (Echeverria et al. 1998; Bittner et al. 1998). Inside the clinic, the principal sources of mercury exposure for the dental team and patients, including children (Maserejian et al. 2008), are related to routine activities, including accidental spillage of mercury, use of mechanical amalgamators, and dry removal of old restorations with high-speed drills (Marek 1990). Although manipulation of the amalgam generates toxicity, it is still widely used, due to its low cost, high resistance, and durability; amalgam can last for approximately 30 years while resin lasts for only 7–10 years.

In developing countries in particular, silver amalgam has a major impact on urban solid residues, not only in terms of the quantity generated, but also due to the potential risk that it represents to public health and the environment (Stone et al. 2009). Some of the main obstacles to preventing and controlling environmental problems caused by the lack of residue management are political disinterest, inadequate legislation, and a lack of human, financial, and information resources. Another factor that contributes to the impact of mercury on the environment is its ability to accumulate in various organisms throughout the food chain, increasing the number of contaminated species. Despite the many forms in which mercury can accumulate, methylmercury accumulates to a much greater extent than other chemical forms of the metal. Inorganic mercury becomes a soluble lipid upon alkylation, and can, therefore, be transported across cell membranes and deposited in the tissue, a process known as bioaccumulation. The inorganic species of the metal (excluding elemental mercury) and methylmercury are capable of reacting with intracellular ligands, which may explain the high degree of accumulation of these compounds. Organic Hg in fish constitutes an important contaminant that causes human neuromotor disturbances and neuropathies under special circumstances. Episodes of Niigata Minamata disease represent the most dramatic form of methylmercury

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poisoning through contaminated fish caught in industrially polluted areas of Japan (Clarkson 1998). The objective of this study was to estimate the quantity of mercury residue present in dental amalgams that are generated and discarded in the city of Manaus (Amazon, Brazil).

Materials and Methods

The study was performed in Manaus, the capital of the state of Amazonas, Brazil. The sample collection sites included dental clinics that were registered with the Amazonas Regional Board of Dentistry during the period July 4, 2007 to September 27, 2007. A total of 54 dental clinics, 44 private (82%) and 10 public (18%), were randomly chosen from 118 clinics in the area, for analysis. Sampling was distributed in urban zones: (1) North—5.55%; (2) Central-West—3.70%; (3) West—7.41%; (4) Central-South—74.07%; (5) South—1.85% and (6) East—7.42%. The research activities began after obtaining approval from the Research Ethics Committee (Process 007/07-MFP/CEP) and took place during september 2007. In the first stage of the study, a written questionnaire was used to obtain a description of the work performed by the dental professionals (Table 1).

All discarded residue samples that contained silver amalgam were collected at the end of one working day, at each clinic. The residues collected were placed in amber glass containers filled with a sufficient volume of distilled water to completely submerge the samples.

To determine the quantity of mercury present in the controlled landfill in Manaus, three samples were taken: two soil samples were collected from the waste deposit area, and one sample was collected from river sediment that was impacted by leachate (liquid produced from the decomposition of solid residues in the landfill). A stainless steel cylindrical soil sampler was used to collect the sediment sample in each collection, and the quantity of sample collected at each site corresponded to a sediment column with a height of 10 cm and diameter of 1.0 cm, respectively. The samples were transported to the toxicology laboratory of the Centro Universitário Nilton Lins, and the sample materials were screened, properly stored in labeled glass containers, protected from light, for subsequent analysis at the Center of Mineral Technology (CETEM) and the Laboratory of Environmental Mercury Specification (LEMA-RJ).

The amalgam and sediment residue samples were prepared at the CETEM-LEMA. Five grams of each sample was dried at 40°C for 24 h. The material was then transferred to a porcelain mortar and homogenized at room temperature, to obtain grains of a homogeneous size. The homogenized sample was then sieved through nylon screens with a particle size of 200-mesh. One gram of the sieved sample was dissolved in 2 mL of deionized water, and the material in suspension was transferred to a round-bottom volumetric flask connected to a reflux condenser. Ten milliliters of concentrated nitric acid were added to the volumetric flask, and this mixture was maintained in a water bath at 60°C for 30 min. The addition of nitric acid was repeated two more times, with incubations of 30 min and 60 min, respectively. Afterwards, 3 mL of an aqueous solution of 5% (w/v) potassium permanganate was added.

After cooling, the samples were transferred to a volumetric flask, adjusting the volume to 100 mL with deionized water. For the analysis of total mercury, 50 mL of the sample was transferred to a hydride generation system. Next, a solution of 10% (w/v) tin chloride and 10% (v/v) sulfuric acid was added, in order to reduce the mercury ions. An atomic absorption spectrophotometer with a mercury hollow cathode lamp (*Perkin Elmer model* 373) coupled to a MHS-10 model hydride generator with an open quartz cell and optical path of 12 cm (Lumex Mercury Analyzer RA-915 +) was used for the analysis. The mercury detection limit was 0.5 μg/kg. The highest absorption reading registered in a 40 s period was used in

Table 1 Estimated disposal of mercury waste in the city of Manaus-AM

	Private clinics (N = 31)				Public clinics (N = 10)	
		Mercury in silver amalgam residues				Mercury in silver amalgam residues
Number of restorations performed per day	n	Inappropriate disposal (45%) (g/day) (mean ± SD)	n	Appropriate disposal (55%) (g/day) (mean ± SD)	n	Appropriate disposal (g/day) (mean ± SD)
01–05	1	1.28	6	1.01 ± 0.29	–	–
06–10	4	1.21 ± 0.47	1	1.59	–	–
11–15	2	3.28 ± 0.7	4	2.73 ± 1.28	–	–
16–20	–	–	5	3.25 ± 0.45	–	–
21–25	4	3.35 ± 0.24	1	3.90	–	–
26–30	3	4.40 ± 0.77	–	–	10	3.83 ± 0.55
Total	14	2.80	17	2.28	10	3.83

the conversion calculation. The analysis of each sample was performed in duplicate, and the results are expressed in terms of the dry weight of the sample.

The remaining samples were properly reprocessed with recovery of the mercury and silver.

Results and Discussion

The data set obtained from the questionnaire enabled the characterization of the following scenario. Of the private clinics visited, 70% (31 units) use amalgam and 30% (13 units) do not. Of the public clinics visited, 100% (10 units) use amalgam. Among the clinics that routinely use amalgam, it was verified that the average number of restorations performed per day in public clinics ranges from 26 to 30; however, in private clinics, the variation in number of restorations per day was more homogeneous among the units studied (Fig. 1).

The estimated quantity of mercury that was released into the environment due to inappropriate disposal of residue is described in Table 1. Among the private clinics analyzed, 55% claimed that they perform appropriate disposal, obeying the biosafety criteria, while 45% reported that they dispose of the residues inappropriately. Of this latter group (14), the average amount disposed of was found to be approximately 2.8 g of Hg/day. Clinics that disposed of residues appropriately (17) released an average of 2.28 g of Hg/day. All of the public clinics (10) claimed to dispose of amalgam residues properly, and on average, discarded a total of 3.83 g of Hg/day. It is important to emphasize that the condition noted as "clinic with appropriate disposal" does not necessarily mean the residue is disposed of properly. This description was used when the clinic conformed to the disposal norms within the clinic, but the collection and final destination of the residue were not defined.

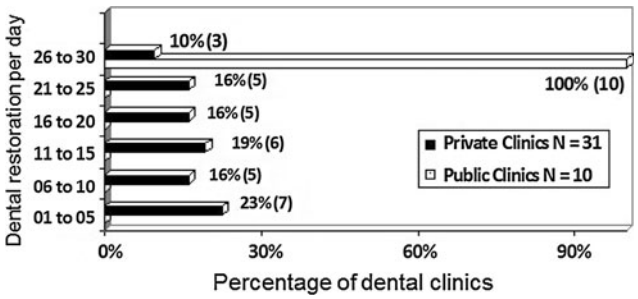

Fig. 1 Average daily restorations performed with silver and mercury amalgam in private and public dental clinics

Table 2 Quantity of mercury analyzed in the sediment samples collected at the Manaus landfill

	Contamination by total (μg/g)	
Sample category	Collection site	Values
Sediment I	Sediment in bottoms of the impacted river	0.118
Sediment II	Sediment at the landfill	0.079
Sediment III	Sediment at the landfill that contained hospital residues	2.683

The sediment samples collected in the Manaus controlled landfill were categorized as sediment from the bottom of the impacted river, sediment from the landfill, and sediment from the landfill that contained hospital waste. The quantity of mercury in each sample is described in Table 2. The reference values were taken from CONAMA (National Environment Council) resolution 344/2004, and consider two values (in units of dry weight): Level 1, the lower threshold of 0.17 μg/g, below which a low probability of adverse effects to the biota is indicated, and Level 2, the upper threshold of 0.486 μg/g, above which probable adverse effects to biota are indicated. The analyses of sediments that contained hospital waste detected a concentration of mercury that was 5.5 times higher than the concentration predicted to cause adverse damage to the biota, a figure that is similar to the concentrations found in many mineral mines (Qiu et al. 2005).

The increasing replacement of amalgam restorations containing mercury with photopolymerizable resin restorations in the posterior teeth has been a relevant factor in reducing levels of mercury residues; however, there are no references to this fact in the specialized literature. While this replacement promotes a reduction in the use of mercury in dentistry, it could also theoretically increase environmental mercury contamination, due to the higher number of patients requesting replacement of their old amalgam fillings with photopolymerizable resin ones, resulting in greater disposal of residues containing mercury. In this case, especially in developing countries, the majority of amalgam residues are irregularly transported to controlled city landfills, where they can contaminate the soil, rivers and ground water.

All the public clinics evaluated in this work used silver and mercury amalgam as a restorative material, and performed more than 25 restorations per day, on average. Only 10% of the private clinics evaluated performed more than 25 restorations per day using silver and mercury amalgam (Table 1). This data characterizes a social scenario, with the public clinics, using low-cost techniques and treating mostly low-income patients, in contrast to the practices and clienteles of the private clinics.

In Brazil, the ANVISA (National Health Surveillance Agency) (2004) classifies mercury within Group B. The characteristics of risks from Group B substances are

outlined in the material safety data sheet (MSDS, known in Brazil as the FISPQ), according to NBR 14725 of the ABNT (Brazilian Technical Standards Association) and Decree/PR 2657/98. Item 11.15 of the ANVISA document states that the disposal of batteries and accumulators containing lead (Pb), cadmium (Cd) and mercury (Hg) and their components must be performed according to CONAMA Resolution 257/1999. Item 11.17 of the ANVISA document states that residues containing Hg must be packed in sealed underwater containers and sent for recovery. However, in many cases, there is no effective inspection agency to ensure that these safety practices are carried out. According to some authors (Marek 1990; Özdabak et al. 2008), mercury evaporation occurs during treatment carried out on teeth with restorations containing silver and mercury amalgam. Used capsules that contained amalgam cannot be discarded into the environment because they are contaminated with mercury. According to the present legislation, these capsules should be stored with amalgam mercury residues and sent to a chemical waste recovery laboratory.

The participation of health agencies is essential for the establishment of educational biosafety programs for dental clinics. The information collected in this study regarding biosafety in dental clinics is similar to the data reported by Nash (1992), who found that biosafety is a regular practice among only 43.25% of professionals. Although the majority of clinics are aware of the standard procedures for appropriate disposal of residues, roughly 45% of private clinics still do so inappropriately. Inadequate storage of amalgam residues in dental clinics is also widely recognized in the literature as an important source of contamination by mercury vapors (Rupp and Paffenbarger 1971). Recycling methods in dental clinics are still economically impractical, since special environments are required for processing this metal. Therefore, storage in hermetically sealed containers with a proposed fixative solution (CONAMA 257/1999), although not considered an ideal solution, is still the most appropriate technique.

In general, the quantity of residue produced during the preparation of amalgam for restorations can be as high as 30% of the amalgam. This residue results from excessive manipulation and production of waste by sculpting the amalgam. On average, 2 g of amalgam is prepared for each restoration, of which 0.6 g ends up being discarded. According to this theory, and supposing that a dental clinic performs 30 amalgam restorations per month, that clinic will produce 18 g of residue/month and 216 g of residue/year. Considering that mercury comprises 50% of the amalgam (Zolfaghari 2007), this corresponds to a total disposal of 108 g of mercury/year. For a city with one thousand dental surgeons, the calculations of environmental contamination are alarming: 216 g of discarded residue $\times 1{,}000 = 216$ kg of discarded residue/year, or 108 kg of discarded mercury/year; over a 10-year period, the contamination would be in the order of 1,080 kg of residue discarded into the environment. The estimated inappropriate disposal of silver and mercury amalgam residues produced in 1 day at dental clinics in the city of Manaus was 5.62 g of residue/day.

We can conclude that although most public clinics perform appropriate disposal practices, according to the present standards, they are still potential sources of environmental mercury contamination. This potential for contamination is due to the lack of an appropriate site for the collection and treatment of mercury residue in Manaus. The concentration of mercury analyzed in controlled landfill sediments that contained hospital waste (2.683 μg/g) was approximately 5.5 times greater than the "upper level threshold above which a probable adverse effect on the biota system" (min = 0.17; max = 0.486 μg/g) (CONAMA 344/2004), indicating that residues containing mercury are discarded in the regular landfills.

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