

**MERCURY EMISSIONS FROM DENTAL CHAIRS BY DISINFECTION****Kümmerer, K.<sup>1\*</sup>, Wallenhorst, T.<sup>2</sup> and Kielbassa, A. M.<sup>3</sup>**

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**ABSTRACT**

Dental aspirator kits are equipped with amalgam separators, which eliminate the particulate matter from the effluent. When the aspirator kits are disinfected, the disinfectant solution is in contact with the separated amalgams over night and over the weekend. Oxidizing components of the disinfectants dissolve mercury from the separated amalgam. The dissolved mercury is released into the environment along with the effluent on the beginning of the following workday. The degree of mercury remobilization depends on the amount and oxidizing power of the disinfectant components. The mercury concentrations measured in the effluent of the aspirator kits after the application of seven different disinfectants were 18.4 µg/l - 1396 µg/l. The emission of mercury by dental aspirator kits is lowered substantially by using disinfectants which contain no oxidizing substances. Disinfecting of dental aspirator kits for hygienic reasons is not necessary. Therefore we propose only cleaning rather than disinfecting dental aspirator kits. © 1997 Elsevier Science Ltd

**INTRODUCTION**

For a long time amalgam has been used as dental material (Mackert 1991), and from the beginning was considered hazardous to patients' health. In particular, the dissolution of mercury from dental fillings and its effect on human health was a main issue (Bergman 1990).

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Recently, possible health effects of the dental staff due to mercury vapors resulting from handling of the amalgam were investigated (Pleva 1994). Even earlier, the environmental impact of mercury coming from dental services has been studied (Bergman 1990, Arenholt-Bindslev 1992). It was found that micro-organisms are able to form alkylated mercury compounds from mercury dissolved in water like methylmercury in vitro (Heintze et al. 1983) or in the environment (Wade et al. 1993) e.g. in sediments of rivers. Mercury and alkylated mercury compounds enter the human food chain (Monteiro et al. 1995, Falter and Schöler 1994) and thus can have human health effects. Alkylated mercury compounds are more toxic to humans and the environment than mercury itself (Wade et al. 1993). One source of mercury in the environment are amalgam dental fillings. Current trends indicate that the number of amalgam fillings will decrease in the future because alternative filling materials will be used and the reduced need for dental fillings as caries prevention is improved (Bergman 1990). However, many amalgam fillings will still need to be removed in the future.

Removing amalgam fillings results in the formation of amalgam particles. These particles are released into the environment with the effluents from dental aspirator kits. The environmental impact of dental mercury is well documented and therefore since 1990 German law requires 95 % of the amalgam to be removed from the effluents (Anonymous 1989). The separated amalgam particles are collected during several weeks in the amalgam separator. The dental aspirator kits and the amalgam separators are disinfected routinely at the end of every workday and before the weekend. The disinfectant solution remains in the amalgam separator and stays in contact with the collected amalgam. Oxidizing components of the disinfectants may dissolve some of the mercury. The dissolved mercury is no longer removable by the amalgam separator and enters into the aquatic environment. In an earlier study we investigated mercury remobilization by a disinfectant containing an active chlorine forming component versus a cleansing agent. The cleansing agent caused very little mercury dissolution in contrast to the disinfectant containing an active chlorine forming agent (Kümmerer et al. 1996).

Therefore, we investigated the dependence of mercury remobilization from the redox potential of the seven most important disinfectants and cleansing agents available for dental aspirator kits. Furthermore, the amounts of mercury remobilized by different disinfectants and cleansing agents were roughly estimated and possible steps to minimize the mercury input into the environment by dental aspirator kits are discussed.

## EXPERIMENTAL

Eight used dental chairs equipped with dental aspirator kits (Systematica 1062 T, by *KaVo*, Biberach, Germany) and amalgam separators (Multisystem Typ 1, by *Metasys*, Innsbruck, Austria) were rinsed with 20 l of tap water. After the mechanical purification of the filter elements and the removable parts of the separator, the units were rinsed again with 20 l of tap water. Eight series of experiments were conducted: one series with rinsing water („blank“: tap water containing 0.03 %  $H_2O_2$  supplied by the dental chair and chlorine from drinking water disinfecting < 0,001%), one cleansing agent solution and six disinfectant solutions (Table 1).

Table 1. Tested disinfectants and dissolved mercury (total amalgam 17,8 g ≈ 8,9 g Hg)

Product	Manufacturer	concentration of the solution / active component	concentration of mercury (µg/l)	renobilized mercury (%)
Tiutol®	<i>Braun, Melsungen</i> Germany	3 % Chloramine T (HOCl, Cl <sub>2</sub> )	1395.7 (± 526.4)	0.17
Aseptoclean 2®	<i>KaVo, Biberach</i> , Germany	solid Chloramine T (HOCl, Cl <sub>2</sub> )	447.6 (± 396.2)	0.05
Orotol Ultra®	<i>orochemie, Kornwestheim</i> , Germany	1 % sodium perborate (H <sub>2</sub> O <sub>2</sub> )	213.7 (± 59.7)	0.02
Water supplied by the dental chair system	---	0,03 % hydrogen peroxide	41.0 (± 17.0)	0.004
Alprojet DD®	<i>Alpro Dental, Villingen</i> , Germany	5 % sodium hydroxide	40.9 (± 17.0)	0.004
Alprojet D®	<i>Alpro Dental, Villingen</i> , Germany	2 % sodium hydroxide	35,3 (± 7.3)	0.004
S&M matic®	<i>Schülke &amp; Mayer, Norderstedt</i> , Germany	ammonium chloride	22.1 (± 6.1)	0.003
Green & Clean M®	<i>Recyco Dent/Metasys, Innsbruck</i> , Austria	pyridine compound	18.4 (± 6.2)	0.002

In each series all eight solutions were used in each of the eight dental chairs as a reference to the contamination with amalgam due to prior use of the dental chairs. Two samples were taken from each chair, of the first rinsing (tap water) before the beginning of the experiment and of the second rinsing (water containing 0.03 % H<sub>2</sub>O<sub>2</sub> as supplied by the dental chair system) 18 hours after applying the amalgam and the disinfectant or cleansing agent solutions. For every experiment 17,8 g freshly triturated amalgam (10 capsules Amalcap Plus No. 3, *Vivadent*, Ellwangen, Germany) were used. The amalgam was condensed manually and stored in isotonic sodium chloride solution at 37 °C in tight closing glass bottles for 12 days. After aging the amalgam was machined with water cooling within a box (Technikerschleifbox, *Renfert*, Hitzingen, Germany). The box was connected to the aspiration kit. The box and the aspiration kit were then rinsed with tap water, until the effluent from the amalgam separator reached 2 l and then rinsed with a solution of the disinfectant or the cleansing agent under investigation. The solutions were prepared and applied according to the manufacturers' instructions. The solutions remained in the aspiration kit and the amalgam separator for 18 hours. 112 samples resulted from the described experimental procedure. The samples were taken into glass bottles, acidified with nitric acid to pH 1 (reduced mercury content, No. 441, *Merck*, Darmstadt, Germany) to prevent adsorption and microbial activity, and stored until analysis at room temperature. For the mercury analysis a flameless atomic absorption spectrophotometer equipped with a cold vapor system (AAS 100 with MHS 10, *Perkin Elmer*, Überlingen, Germany) and NaBH<sub>4</sub> was used. For statistical purpose (analysis of variance) software SAS<sup>®</sup>, release 6.09, was used. The analysis of significance was conducted according Closed Test Procedure, based on Kruskal-Wallis, the level of significance was  $p \leq 0.05$ .

## RESULTS AND DISCUSSION

The experimental procedure simulated the dissolution of mercury from dental amalgams by different disinfectants under realistic conditions. The dissolved mercury was detected as the amalgam particles are retained in the amalgam separator, only the (re)dissolved part was washed out. The results are summarized in Table 1. The disinfectants containing highly oxidizing components (sodium perborate: hydrogen peroxide; chloramine T: hypochlorite and chlorine, respectively) remobilized significantly ( $p \leq 0.05$ ) more mercury than agents containing no such compounds. The standard potentials of the oxidizing components are summarized in Table 2. All the strongly oxidizing components have a markedly higher oxidizing potential than elemental mercury and will therefore dissolve mercury from dental amalgams. Four main groups of products were identified: Tiutol<sup>®</sup> dissolves most mercury from dental amalgam ( $p \leq 0.05$ ). The measured mercury concentrations for Tiutol<sup>®</sup>, Aseptoclean<sup>®</sup> and Orotol Ultra<sup>®</sup> were partly above the limit set by legislation of the state Baden-Württemberg for industry (500 µg/l). Significantly less mercury than by Tiutol<sup>®</sup> is remobilized by the two disinfectants Aseptoclean2<sup>®</sup> and Orotol Ultra<sup>®</sup> ( $p \leq 0.05$ ). The difference between Tiutol and Aseptoclean 2<sup>®</sup> is probably caused by the higher amount of chloramine T, its and the amalgams pH-dependent oxidation power (Hahn et al. 1994, Soh et al. 1991) and by the fact that Aseptoclean 2<sup>®</sup> is a powder and therefore part of the amount used may be retained in the hose system of the aspirator kit.

Table 2. Standard reduction potentials of disinfectant components (in volts) and elemental mercury\*  
(Weast and Astle 1983)

compoundt	active substance/ reaction	standard potential (V)
chloramine T	$\text{Cl}_{2(g)} + 2 e^- \rightleftharpoons 2 \text{Cl}^-$	+ 1.36
	$\text{HClO} + \text{H}^+ + e^- \rightleftharpoons 1/2 \text{Cl}_2 + \text{H}_2\text{O}$	
	$\text{HClO} + \text{H}^+ + 2 e^- \rightleftharpoons \text{Cl}^- + \text{H}_2\text{O}$	+ 1.63
		+ 1.49
sodium perborate	$\text{H}_2\text{O}_2 \rightleftharpoons \text{HO}_2 + \text{H}^+ + e^-$	+ 1.50
	$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2 e^- \rightleftharpoons 2 \text{H}_2\text{O}$	+ 1.76
mercury	$\text{Hg}^{2+} + 2 e^- \rightleftharpoons 2 \text{Hg}$	+ 0.85

\* the standard redox potential of Hg in dental amalgams is a little bit different; but  
in dental amalgams, mercury is the noblest component

The two products Alprojet D® and Alprojet DD® remobilized mercury in the same concentration as water containing 0.03 percent of hydrogen peroxide ( $p \leq 0.01$ ). The results for Aseptoclean 2® and the cleansing agent Alprojet D® are in agreement with results reported earlier (Kümmerer et al. 1996). S&M matic® and Green and Clean® dissolved less mercury than the other disinfectants ( $p \leq 0.05$ ) compared to water and Aseptoclean D® and Aseptoclean DD®,  $p \leq 0.01$  compared to the disinfectants containing highly oxidizing agents. The low concentrations measured for these disinfectants may be due to the low oxidation and thus remobilization power. An influence of other constituents like quaternary ammonium compounds or ammonium chloride and pyridine compounds seems unlikely. No significant differences were found between the samples taken before the beginning of every experimental series (data not shown). In these samples (tap water only) between 17.3 and 31.7 µg/l Hg were detected. This result confirms that no cross contamination by the different chairs used occurred. In the samples taken before the experiments, tap water was used for rinsing with only little oxidizing potential (chlorine from drinking water disinfecting), whereas the water used in the experiments for rinsing contained 0.03% hydrogen peroxide. This water is routinely supplied by the aspiration kit of dental chairs to disinfect the rinsing

water. The results show that the remobilization of mercury from dental amalgam corresponds clearly to the oxidizing power of the disinfectant used. In a separate study the remobilization of mercury from freshly prepared dental amalgam was investigated as well. No significant differences between different disinfectants could be detected due to the easy oxidation of fresh amalgam (Kümmerer et al. 1996).

The main reduction of mercury emissions by dental chairs is accomplished by using amalgam separators. On basis of the above results an average input of mercury into the aquatic environment for Germany can be calculated. Approximately 32,500 dental chairs are used in Germany with a daily effluent of 5 l rinsing water. From a mercury concentration of 1.4 mg/l of the effluent an amount of about 50 kg/year Hg is emitted by dental chairs, whereas on basis of the lowest measured concentration (18.4 µg/l) only 0.6 kg/year are emitted. This are 0.5 % and 0.006 % of the annual German dental amalgam consumption, respectively. This amount seems to be quite low, but is about 1.5% of the separated amount of mercury in dental aspirator kits. According to the International Commission for the Protection of the River Rhine the mercury concentrations are still 2-4 times the acceptable amount. 44% of the annual German Hg input results from communal sewage, which the dental chair effluents are part of (International Commission for the Protection of the River Rhine 1994). Up to six percent on the basis of the highest concentration measured in our study may result from the remobilized mercury in dental amalgam separators. A realistic approximation would be an amount of 30 kg/year, i.e. 3.6 %.

## CONCLUSIONS

The use of disinfectants which contain highly oxidizing components, cause mercury dissolution from the separated amalgam. Although this is only a minor part of the mercury content of the separated amalgams, a further reduction of mercury emissions from dental chairs and dental hospitals is easily achievable by using disinfectants with a low redox potential. Further improvements for the aquatic environment are the prevention of absorbable organic halogen compounds e.g. by chloramine T or other chlorinating compounds or the emission of boron (see Table 1). The removal of amalgam fillings under the formation of mainly bigger amalgam particles by using a proper working technique seems to be possible and will further reduce mercury emissions if the amalgam separator works on the principle of centrifugal forces or filtering (Kümmerer et al. 1996). Omitting disinfectants with oxidizing compounds is a low cost but very effective possibility for further reduction of mercury emissions caused by dental chairs. For hygienic reasons routinely disinfecting of dental aspirator kits and amalgam separators seems to be unnecessary. Therefore the use of cleaning agents is sufficient. Disinfecting components like quaternary ammonium compounds are not required. Hg remobilization is one environmental impact of disinfecting dental chairs with an amalgam separator. Others are the remobilization of zinc, copper and silver which are important components of dental amalgams too. Some of them contain only poorly biodegradable compounds as organic quaternary ammonium compounds like benzalkonium chloride. If disinfectants for dental chairs are used their total environmental impact has to be evaluated thoroughly, regarding the remobilization of mercury is one important step of this procedure.

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