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A pilot study to determine mercury exposure through vapor and bound to PM$_{10}$ in a dental school environment

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Mercury (Hg) is widely used in the dental working environment, exposing dental practitioners and assistants to potentially toxic Hg vapors. Concentrations of Hg in vapor and in particulate matter (PM$_{10}$) were measured in the Dental Simulation Laboratory (DSL) and in the Dental Clinic (DC) at the School of Dentistry, University of Puerto Rico. PM$_{10}$ samples were collected over a 36-hr period and Hg vapor was collected for eight-hour periods. PM$_{10}$ mass was determined gravimetrically and Hg (bound to PM$_{10}$ and vapor) was extracted and analyzed by atomic absorption. Indoor levels of PM$_{10}$ in the DSL ranged from 9.2 to 41.6 µg/m$^3$ and 35.0 to 68.2 µg/m$^3$ in the DC. Levels of particle-bound Hg ranged from 0.1 to 1.2 µg/m$^3$ and in vapor 1.1 to 3.3 mg/m$^3$ at the DSL; the DC levels ranged from <0.01 to 0.2 µg/m$^3$ for particle bound Hg and 13.6 to 102.7 µg/m$^3$ in vapor. PM$_{10}$ concentrations were below Indoor Air Quality suggested limits for total dust (100 µg/m$^3$). Levels of mercury bound to PM$_{10}$ were low; however, mercury vapor was several times higher than the suggested OSHA (permissible exposure limit – 100 µg/m$^3$) in the DSL.

**Key words:** amalgam fillings; dental clinics; health effects; mercury vapor; passive sampler; PM$_{10}$

**Introduction**

Methyl mercury (Hg) is a toxic environmental pollutant that is among the most highly bioconcentrated trace metals. Exposure to organic Hg levels is associated with many health problems, such as birth defects and neurological disorders. Inorganic Hg however has not been associated with toxicity but recent literature has attracted the attention of many researchers and is redirecting and cautioning thinking along these lines. It has been reported that inorganic Hg induces degeneration of neurons *in vitro* (Leong *et al.*, 2000).

Hg has been widely used in dental practices, with an estimated 300 metric tons used annually in dental amalgam (Arenholt-Bindslev and Larsen, 1996). Many common dental procedures (condensing, polishing, grinding and mixing amalgam) are known to release Hg vapor, which results in high exposure through inhalation (Nixon, 1971). Past studies of dental activities, were conducted in previous decades when good hygiene practice were not in place. Brune and Beltesbrekk (1978) evaluated a dental laboratory using a Bacherach Hg vapor sniffer in inhalation position and detected high levels of Hg associated with coarse and fine grinding (up to 380 µg/m$^3$) and mulling of amalgam (up to 130 µg/m$^3$). Richards and Warren (1985) detected relatively high levels of Hg during removal of amalgam in the breathing zone of the dentists (110 µg/m$^3$). Haikel *et al.* (1990) measured Hg vapor levels in intraoral air during removing, setting and polishing amalgam and found that average
levels ranged from 85 to 326 \( \mu g/m^3 \). Hg levels were positively associated with the restoration size.

Previous research has demonstrated that Hg from amalgam put into sheep teeth would concentrate in kidneys (Vimy et al., 1990) up to 5–10 \( \mu g/g \) tissue. Hahn et al. (1989) used radioactive \( ^{203} \text{Hg} \) mixed with dental amalgam and put it in teeth of adult sheep. The isotope appeared in various organs and tissues. After absorption, high concentrations of Hg from dental amalgam were localized in kidneys and liver. It was then further demonstrated that dental Hg impaired kidney function (Boyd et al., 1991). Nylander et al. (1987) reported total Hg levels in the kidney cortex from seven subjects with amalgams and five subjects without amalgams. In this study, the mean Hg level among subjects with 11 to 33 amalgams was 433 ng Hg/g wet weight compared with 49 ng Hg/g wet weight for subjects without dental amalgams. Kidney and lung were the most affected organs when pregnant and nonpregnant rats were exposed to 4mg/m^3 Hg during 2h/day for 10 days (Morgan et al., 2002). Significantly higher concentrations of Hg were found in the kidneys and brain of exposed rats as compared with the control, being eight times higher in rats with amalgam fillings and twofold higher in rats exposed to amalgam-supplemented diet (Galic et al., 1999). It is interesting to state here an association between Hg exposure and reports of dentists and dental assistants with higher potential risk of kidney function disturbances as compared with the general industry worker (Sikorski et al., 1987).

Currently, good dental practices and increased knowledge and awareness of Hg toxicity have reduced the Hg vapor levels in dental clinics (Brune and Beltesbreke, 1978; Nilsson and Nilsson, 1986; Langan et al., 1987; Powell et al., 1994); while proper handling and storage of amalgam, as well as a good ventilation system, can ensure that the recommended ACGIH threshold limit (50 \( \mu g/m^3 \) – TWA 8h day/40h week) is not exceeded. Some countries have taken immediate steps to protect their population from any possible effects of Hg, for example, Sweden and Denmark, have banned the use of amalgam altogether. Many European countries have followed but the United States still practices the use of amalgam throughout the population.

Few studies have reported particulate matter (PM\(_{10}\)) levels in indoor environments and even fewer in dental clinics. PM\(_{10}\) is produced during carving, burnishing and polishing of amalgam. PM\(_{10}\) has a direct effect on health through respiration (Dockery and Pope, 1994; Pope et al., 1995). Metal concentrations are generally determined in coarse (PM\(_{10}\)) and fine (PM\(_{2.5}\)) particles because these particles can reach the lower respiratory tract and induce damage to the organs. Speciation of atmospheric particles collected in urban area in Seville, Spain, showed that Hg was distributed in fine and coarse fraction between 0.6 to 4.9 \( \mu m \) in size, where Hg in fine mode corresponds to 40.4% (Alvarez et al., 2004). Atmospheric PM\(_{10}\) samples in that area presented low concentration of Hg, 0.07 ng/m^3 (Alvarez et al., 2004). As high levels of Hg vapor has been reported in the dentistry working environment and as small particles enter the respiratory tract, we evaluated the amount of Hg in PM\(_{10}\) in two working environments.

**Methodology**

Hg and PM\(_{10}\) levels at the University of Puerto Rico School of Dentistry were evaluated in two environments: at the Dental Simulation Laboratory (DSL; where second-year students develop dental amalgam restoration skills using mannequins), and at the Dental Clinic (DC; where third-year students perform amalgam restorations in patients). PM\(_{10}\) samples were collected in Teflon filters for a 36-h period and Hg vapor was collected using passive samplers (SKC) over an 8-h period. Hg content (vapor and bound to PM\(_{10}\)) was extracted with acid digestion and analysed by atomic absorption. PM\(_{10}\) was determined by gravimetry.

**Sampling sites**

**Dental Simulation Laboratory**

The 496.7-m^3 DSL has 10 air-conditioner vents; no windows or exhaust system; and five long benches each containing 10 mannequins for student use (Figure 1). A five-day (7h each) dental restoration class with 39 second-year students, assisted by five professors, was monitored (Table 1).

**Dental Clinic**

The 2240-m^3 DC operates daily for five days in a week for eight hours. A one-day class for 35 students performing amalgam restorations on patients, assisted by five professors and utilizing a 992-m^2 area, was monitored (Figure 2). The practical exam was divided
Dental Simulation Laboratory (BB48B)

Figure 1. Diagram of the Dental Simulation Laboratory. The location of particulate matter (PM$_{10}$) Andersen RAAS2.5-200 air sampler (rectangle) and SKC mobile samplers placed on students working at specific benches (circles) are indicated.

Table 1. Concentrations of particulate matter (PM$_{10}$) and mercury (Hg) bound to PM$_{10}$ and amalgam capsules by date at the Dental Simulation Laboratory (DSL), UPR, School of Dentistry ($n = 1$)

<table>
<thead>
<tr>
<th>Date</th>
<th>Class description</th>
<th>PM$_{10}$ ($\mu$g/m$^3$)</th>
<th>Hg bound to PM$_{10}$ ($\mu$g/m$^3$)</th>
<th>Amalgam capsules used per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 11</td>
<td>Day 1 – no class exercise</td>
<td>9.2</td>
<td>ND</td>
<td>0</td>
</tr>
<tr>
<td>August 12</td>
<td>Day 2 – preparing laboratory, mannequins and drilling of ivory teeth</td>
<td>39.8</td>
<td>ND</td>
<td>1</td>
</tr>
<tr>
<td>August 19</td>
<td>Day 3 – Amalgam restorations</td>
<td>12.2</td>
<td>0.2</td>
<td>87</td>
</tr>
<tr>
<td>August 26</td>
<td>Day 4 – Amalgam restorations</td>
<td>16.2</td>
<td>0.1</td>
<td>85</td>
</tr>
<tr>
<td>September 2</td>
<td>Day 5 – Removing fillings and restoring amalgam – exam</td>
<td>12.4</td>
<td>1.1</td>
<td>104</td>
</tr>
<tr>
<td>September 9</td>
<td>Day 6 – Removing and repeating previous amalgam restorations; cleaning and organizing the lab – exam</td>
<td>41.6</td>
<td>0.9</td>
<td>81</td>
</tr>
</tbody>
</table>

ND, below detection limit in solution: 5.5 ng/L.
into two three-hour sections. Air monitoring was scheduled during these periods.

**Particulate matter**

The sampling procedures are based on the Quality Assurance Guidance Document 2.12 (EPA, 1998). The sampling instrument was the Particulate Chemical Speciation Air Sampler (Andersen Instruments Inc. RAAS2.5-200; Franklin, MA, USA). The flow meter (FM) intakes air at 17 L/min while monitoring and recording the ambient manifold and enclosure temperatures, barometric and vacuum pump pressures, humidity, flow rates and volumes.

At the DSL and DC, the air sampler was placed at the middle of the room or working area (Figures 1 and 2). PM$_{10}$ samples were collected over 36-h periods previous to the lab exercise and during the class (Tables 1 and 3).

All PM$_{10}$ samples were collected on Teflon filters. Immediately following the sampling time, filters were placed in a stainless steel protective container, sealed, transported to the toxicology lab, weighed using a balance model M-220D (Denver Instrument, Denver, CO, USA), preconditioned in petri slides and kept in a drykeeper (Samplatec Corp., Osaka, Japan) at a temperature of 20–23 ± 2°C with a relative humidity of 40–45 ± 5% (EPA, 1998) and analysed. Filters were

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**Figure 2.** Diagram of the Dental Clinic working area. The location of the particulate matter (PM$_{10}$) Andersen RAAS2.5-200 air sampler (rectangle), the stationary SKC samplers (rectangle), the mobile SKC samplers of teachers (asterisk) and students (circles) are indicated. The numbers indicate the location of chairs used by students in the exercise.
weighed each day until three consecutive measurements yield a standard deviation of 0.00002 g; filters were then stored at −20°C for further analyses. PM$_{10}$ mass was determined by gravimetry; the concentration was obtained by dividing the mass by air volume.

Filters were extracted using concentrated nitric acid (5 mL) and sulfuric acid 5 M (15 mL), a 5% potassium permanganate solution added to dissolve the sample matrix and a hydroxylamine hydrochloride solution (20%) to reduce excess potassium permanganate (OSHA, 1989). Six filters and six field blanks were collected from the DSL, three filters and three field blanks from the DC.

The acidified aqueous samples were then analysed by spectroscopy using atomic absorption (FIMS 100 model – Perkin Elmer, Norwalk, CT, USA) following the manufacturer’s recommendations (Perkin Elmer, 1994).

**Hg vapor collected in passive sampler**

Passive sampler devices (SKC Inc., Eighty Four, PA, USA) are a plastic and reusable holder containing an Hg vapor sorbent which has been approved by OSHA and is worn in the breathing zone of individuals for a recommended time period.

Five students at the DSL were selected (from each working bench) (SKC mobile # 1, 2, 3, 4 and 5) to wear a passive sampler, attached to the lab coat as close to the breathing zone as possible. The selection was performed to achieve a uniform Hg exposure distribution within the lab. Each student wore the passive sampler during two four-hour occasions and used between 4 and 10 amalgam capsules. Total amalgam capsules used during this training ranged from 81 to 104 (Table 1).

At DC, students occupy a numbered (40) dental chair (Figure 2). Eighteen students took the exam in the morning and 17 in the afternoon. Twelve passive samplers were worn by 23 students during the exam and five by the professors. Each sampler was worn by two students (i.e., one in the morning and another during the afternoon); one sampler was worn by only one student (mobile # 15). This experimental design was established in order to follow an exposure period compared with that suggested by the sampler manufacturer. An average of 1.5 amalgam capsules was used by each student during the exam period (a total of 51 amalgam capsules). To evaluate the Hg vapor dispersion and extent of distribution throughout the environment, five samplers were also placed throughout the general dental clinic environment (stationary samplers identified as numbers according to the nearest dental chair: 22, 25, 28, 67, 74) (Figure 2). A sampler was also placed in an office (stationary sampler # 13) on the same floor (out of the immediate air space of the dental clinic in order to evaluate Hg distribution throughout the floor). In addition, a reference station sampler was placed outside the building (stationary sampler # 5) (Figure 2).

The SKC cartridge sorbents were acidified for 40 min as recommended by the manufacturer (SKC, 2004; OSHA, 1991). A total of six passive samplers (five samples plus a blank) were analysed from the DSL and 26 (12 mobile, 7 stationary and 2 blanks) from the DC. All samples were analysed by spectroscopy, as described previously.

**Quality control**

Unused clean filter blanks were used to determine possible background contamination. Blanks were processed simultaneously and handled in an identical manner as the samples. The average Hg value was subtracted from the samples. A SKC passive sample blank was prepared by dissolving a fresh, unexposed sorbent content capsule (from the same lot) and processed. The value, representing the background Hg level, was subtracted from all readings.

The accuracy was evaluated using spike blanks of known Hg concentration and digestion of a standard reference material (Indoor Dust SRM 2583, National Institute of Standards and Technology, Gaithersburg, MD, USA). Recovery efficiency was calculated from the SRM. The recovery of spikes and SRM were good, ranging from 90 to 100%. Instrument performance was checked using a QCI701B ultrachck Hg; recovery ranged from 90 to 100%. The detection limit was calculated based on the injection of 10 blanks and the standard deviation multiplied by 3. The detection limit for each sample ranged from 5 to 7 ng/L in solution.

All acids (HCl, HNO$_3$ and H$_2$SO$_4$) were trace metal grade (Fisher Scientific, Pittsburg, PA, USA). NH$_3$OH·HCl suitable for Hg analysis (Spectrum, New Brunswick, NJ, USA), Mercury AA standard solution, 1 mg/mL in 10% HNO$_3$ (Acros Organic, NJ, USA), KMnO$_4$ and SnCl$_2$ (Fisher Scientific, Pittsburg, PA, USA), QCI 701B Ultrachck Metals Samples (Ultra Scientific, North Kingston, RI, USA) were employed. All solutions were prepared fresh daily.
Statistical analysis

The statistical software ‘GraphPad Prism’ version 4.0a was used for statistical analysis. Two-tail paired t-test’s assessed differences between the means of PM$_{10}$ and Hg concentrations (95% confidence interval). Linear regressions analysed the relationship between Hg concentration and number of amalgams used during the exercises.

Results

The results obtained for PM$_{10}$ and Hg bound to PM$_{10}$ from the DSL are summarized in Table 1 and illustrated in Figure 3. Levels of PM$_{10}$ in the DSL ranged from 9.2 to 41.6 μg/m$^3$ while particle-bound Hg increased from 0.1 to 1.2 μg/m$^3$ progressively. Both parameters (PM$_{10}$ and Hg in PM$_{10}$) were related to indoor activity and movement. All Hg vapor concentrations obtained during the DSL class are summarized in Table 2. The Hg vapor concentrations ranged from 1.1 to 3.3 mg/m$^3$ and are directly related to the number of amalgam capsules used per student (Figure 4).

PM$_{10}$ concentrations and Hg bound to PM$_{10}$ at the DC, as well as the Hg vapor levels in air are shown in Tables 3 and 4. Concentrations ranged from 35.0 to 68.2 μg/m$^3$ for PM$_{10}$, <0.01 to 0.2 μg/m$^3$ for Hg bound to PM$_{10}$ and 13.6 to 102.7 μg/m$^3$ of Hg vapor. These values were around 5- to 30-folds lower than those obtained at the DSL exercise.

A linear relationship between Hg concentration in air and number of amalgam capsules performed per student was found ($r^2 = 0.9$) at the DSL as well as ($r^2 = 0.6$) at the DC (Figure 4). No correlations were obtained for time of exposure and Hg levels from passive samplers.

Discussion

Particulate matter

The concentrations of PM$_{10}$ found in the DSL ranged from 12.2 to 41.6 μg/m$^3$ (average 24.5 μg/m$^3$). Baseline reference value (9.2 μg/m$^3$) was obtained for background levels (Table 1). The indoor PM$_{10}$ concentration is dependent on human activity, which creates air movements resuspending PM$_{10}$ throughout the room. The highest PM$_{10}$ concentrations were found

![Figure 3](http://tih.sagepub.com)  
**Figure 3.** Concentrations of particulate matter (PM$_{10}$) and mercury bound to PM$_{10}$ (μg/m$^3$) over the course of a dental exam period at the Dental Simulation Laboratory (August/September 2004), UPR School of Dentistry. Each mercury concentration corresponds to the value obtained from its corresponding filter illustrated above or below it ($n = 1$).
Figure 4. Linear correlation between mercury vapor levels from SKC passive sampler and the number of amalgams used per student during restoration exercise at the Dental Simulation Laboratory (a) and Dental Clinic (b). The red line represents the suggested exposure concentration by OSHA (100 μg/m³).

Table 3. Concentrations of particulate matter (PM₁₀) and (Hg) bound to PM₁₀ at the Dental Clinic, UPR School of Dentistry

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>PM₁₀ (μg/m³)</th>
<th>Hg bound to PM₁₀ (μg/m³)</th>
<th>No. of amalgam capsules per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 1, 2004</td>
<td>Two days before exam</td>
<td>35.6</td>
<td>0.02</td>
<td>20</td>
</tr>
<tr>
<td>December 3, 2004</td>
<td>Exam day</td>
<td>68.2</td>
<td>0.2</td>
<td>51</td>
</tr>
<tr>
<td>December 6, 2004</td>
<td>Three days after exam</td>
<td>35.0</td>
<td>&lt;0.01</td>
<td>Not determined</td>
</tr>
</tbody>
</table>

Table 4. Average sampling period and mercury (Hg) vapor concentrations at the Dental Clinic, UPR School of Dentistry

<table>
<thead>
<tr>
<th>Description</th>
<th>Sampling period (min) (SE)</th>
<th>Hg vapor (μg/m³) (SE)</th>
<th>Number of amalgam capsules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile students with SKC samplers (n = 12)</td>
<td>251.7 ± 13.3</td>
<td>50.6 ± 9.7</td>
<td>51</td>
</tr>
<tr>
<td>Mobile professors with SKC samplers (n = 5)</td>
<td>304.8 ± 13.3</td>
<td>39.7 ± 6.4</td>
<td>–</td>
</tr>
<tr>
<td>Outdoor stationary sampler (n = 1)</td>
<td>349</td>
<td>10.9</td>
<td>–</td>
</tr>
<tr>
<td>Indoor stationary samplers (n = 6)</td>
<td>390.2 ± 8.9</td>
<td>24.2 ± 3.1</td>
<td>–</td>
</tr>
</tbody>
</table>

SE, standard error.
during days 2 and 6 (the first and last days of the class). In the first day of class activity students prepared and drilled cavities in ivory teeth to prepare the amalgam restorations. These activities generated great quantities of dust which corresponds to high levels of particles (39.8 µg/m³) collected during the day. On day 6, students cleaned up and resuspended dust particles that remained in the mannequins and in their working areas also generating high levels of particulate matter (41.6 µg/m³). During these days, PM₁₀ increased fourfold (39.8 and 41.6 µg/m³) from that encountered during background levels (9.2 µg/m³). On days 3 and 4, students mainly performed fillings, which accounted for low air particles (12.2–16.2 µg/m³; Figure 3). To this date, there are no recommended PM₁₀ indoor air quality standards; however, total dust should not exceed 100 µg/m³ (Indoor Air Quality Guideline, 2003) in any moment. The National Ambient Air Quality Standards (1997) recommend a 24-h PM₁₀ level of 150 µg/m³ for an outdoor environment, not to exceed more than once in a year. Indoor suggested dust concentrations are more stringent than the outdoor Air Quality Standards.

The average PM₁₀ concentration at the DC was 46.3 µg/m³ (35–68 µg/m³), greater than the DSL average, 24.5 µg/m³. This is probably because of the high number of students and personnel working in this common area; thus, more activity and more resuspended dust. Normal PM₁₀ levels at the DC were estimated to be 35.5 µg/m³, using values from before and after the exercise. This increase in PM₁₀ was because of the increased human activity; concentrations rose to 68 µg/m³, about twice the normal levels.

**Hg bound to PM₁₀ particles**

The average concentration of Hg bound to PM₁₀ in the DSL was 0.6 µg/m³ (0.1–1.2 µg/m³). The highest Hg concentrations occurred during the day of the exam (day 5) when most of the amalgam capsules (104) were used. Hg levels were also high on day 6, although the number of capsules used was similar (81). The Hg concentration increase is associated with reperforming restorations of unacceptable work (removal of existing fillings/amalgams), increasing the total Hg used.

The average concentration of Hg bound to PM₁₀ at DC was 0.1 µg/m³ (<0.01–0.2 µg/m³), much smaller (ninefold less) than in DSL because of fewer amalgam capsules used in the DC (51 versus 358 in DSL), the DC room space is also 4.5 bigger (2240 m³ versus 496.7 m³ in DSL), and only one-third (996 m³) of the general clinic area was used by the students in this procedure. The averages did not exceed the limit for neither PM₁₀ (150 µg/m³ 24-h) nor Hg vapor (100 µg/m³) at the DC.

**Hg vapor**

Hg exposure was measured in the breathing zone of students using the mobile passive sampler at both sites (DSL and DC). The average concentration of Hg vapor found in the mobile passive samplers used by students at the DSL was 2.2 mg/m³ and ranged from 1.1 to 3.3 mg/m³, indicating that some students were exposed to Hg concentrations 30 times above the OSHA's recommended level (PEL = 100 µg/m³).

The average Hg vapor exposure per student at the DC was 50.6 µg/m³ over 4.2 h. This is 4.3 times lower than the exposure at DSL. This is considerably lower because of the shorter sampling period and the reduced number of amalgam capsules employed during the exercise. In addition, third-year students (DC) are more experienced in handling and task performing than second-year students and the type of exercises are obviously different. Students spent less time on amalgam restorations as these are much smaller compared with those performed during training (Mesial Oclusal Dental – MOD) at the DSL. In the DC, the average time spent in restoration is approximately about 5–10 min while in the DSL students spend several hours working with amalgam restorations. The average Hg vapor exposure to students at the DC was significantly higher (50 µg/m³) than for professors 39.7 µg/m³. This is expected as professors are by standers while students have direct contact with amalgams. The average values obtained at the DC were lower than the suggested by OSHA standard (100 µg/m³). Tezel *et al.* (2001) analysed blood Hg levels in dental students and staff of a School of Dentistry in Turkey, and reported significantly higher levels in the second-year students compared with higher year students. Similar to DSL (r² = 0.9), a relatively good correlation (r² = 0.6) was obtained between the number of amalgams used and Hg vapor concentrations at DC. However, the slopes are different and the concentrations of exposure are significantly greater during the DSL exercise (Figure 4a,b). Levels as high as 3 mg Hg/m³ were obtained at the DSL. These differences in Hg vapor exposure between students is mainly because...
of the type of the exercise (use of mannequins, student density, skills, size of cavities, amount of amalgam used and so on) and the indoor environment conditions (size of rooms, ventilation, temperature, human activity, air circulation and so on) as previously discussed.

As expected, indoor stationary samplers distributed within the dental clinic show varying Hg levels. Higher Hg levels (average 29 μg/m³) were found in the exam area (samplers # 22, 25 and 28 – Figure 2) than in other areas of the general clinic (average 17 μg/m³; samplers # 67, 74), which were more distant to the source and hence had more time for the dispersion of Hg throughout the room. This is evident with Hg vapor reaching the peripheral sample sites (# 67 and 74). The overall average of Hg concentration in stationary samples was 24.2 μg/m³ similar to the suggested industrial threshold by WHO (25 μg/m3). It is also similar to those reported by Tezel et al. (2001), where Hg levels in a Dentistry School from Turkey clinic registered an annual average ranging from 8 to 48 μg Hg/m³.

Hg was also detected in the indoor reference site (stationary sampler # 13 with 16 μg/m³) indicating that Hg vapor is spread throughout the floor, either by the air-conditioning system or through upper ceiling connections between rooms that link the clinic to offices. Other factors such as human movement throughout the premises also play a role in Hg distribution. At the outdoor site (stationary sampler # 5), Hg vapor was also detected (average 10.9 μg/m³). Previous study in Puerto Rico showed that the Hg concentration outdoors ranged from 0.012 to 0.019 ng/m³ (Gioda et al., 2006), that is, much lower than that measured outside the clinic. This suggests that Hg vapor can travel from indoor to outdoor, influenced by body movement and through entrance and exit pathways.

Toxicological effects

Studies using animals during and even prior to the gestation for all chemical forms of Hg has resulted in reproductive problems (WHO, 1991). Rats exposed to Hg vapor at 1000 μg/m³ during gestation caused congenital malformation (Schuurs, 1999). Much of the research on effects of Hg in humans have been performed at the occupational scenario and have correlated symptoms and effects with urine and blood levels (Roels et al., 1985). Another study performed by Roels in 1987 correlates air Hg to blood and urinary Hg. Based on these studies, the investigators suggest that some Hg-induced effects occurs when urine levels exceed 50 μg/g of creatinine and that this values corresponds to TWA of about 40 μg/m³. As this study did not look at blood or urine levels of Hg it is impossible to compare with other occupational studies. However, results from our study show that students could be exposed to concentrations three times higher than that reported by Schuurs (1999) and 50 times higher than the TWA determined by Roelz et al. (1987). Although the exposure to Hg vapor during the DSL exercise were not in consecutive days, the exposure per day did exceed that of the OSHA PEL of 100 μg/m³ and is therefore important to be aware and design preventive measures. Symptoms such as tremor, ataxia, personality change, loss of memory and weight, depression, insomnia have all been associated with long-term occupational exposure to inorganic Hg levels greater than 50 μg/m³ (WHO, 1991).

We believe that a class on handling of amalgams and good practice techniques in conjunction with general knowledge of Hg exposure should be given to students before this exercise. In addition, practices for the immediate removal of any extra amalgam in the working area of mannequins should be given. Pregnant students particularly in the early stages of gestation should postpone the exercise for a latter date. It is also important to include a continuing education course that explains and deals with Hg exposure during dental practices in order to provide public awareness of recent findings.

Conclusion

The present study shows that the differences in PM₁₀ concentrations obtained during dental training are probably because of the type of classroom activities associated with the educational training. The high levels of Hg vapor adsorbed onto personal samplers are directly related to the amount of amalgam capsules used during the exercise. The levels exceeded up to 30 times the standard limits of 100 μg/m³ suggested by OSHA at the DSL; however, the levels at the DC were within regulated levels. A number of factors are responsible for the differences in Hg concentrations at both sites. These include: student skills, the physical area or working space, the dental work force, hygiene practices, kind and nature of work and the number of amalgam capsules used at either
of the exercises. The results indicate that students are exposed to higher Hg vapors than professors. The proximity of a person to the Hg source (amalgam) will increase exposure and possibly absorption.

Acknowledgements

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