EVALUATION OF MERCURY VAPOR EXPOSURE WHILE PREPARING DENTAL FILLINGS WITH PRE-ENCAPSULATED AMALGAMS

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ABSTRACT

The purpose of this project was to investigate occupational exposure to mercury vapor using modern dental techniques for preparing amalgams. First recognized approximately fifteen years ago, exposure to mercury vapor in dental clinics problem to dental health professionals. Mercury, which vaporizes at room temperature, is used in the preparation of amalgam. Past amalgam preparation techniques enabled elemental mercury to be spilled easily on counters, floors, equipment, and in wastebaskets. Occupational exposures to spilled mercury prompted a change in the dental technique to prepare amalgam using disposable pre-encapsulated amalgam capsules. Preliminary findings presented in published scientific literature suggests that the use of the pre-encapsulated amalgam capsule does decrease the amount of mercury vapor exposure received by dental health professionals, but may not offer protection to acceptable levels of exposure.
This study investigates exposure to mercury vapor in a dental clinic during preparation of amalgam using modern techniques. Occupational exposures to mercury vapors were evaluated by conducting personal airborne samples taken in the breathing zone of an employee manipulating the amalgam in the amalgam well. In addition to full work shift and 25-45 minute dental restoration process, real time airborne samples were taken in various locations in the room evaluating the zone of contamination from the amalgam well to the employee's breathing zone. Exposure concentrations were compared to OSHA PELs and ACGIH TLVs.

INTRODUCTION

Mercury, best known for its use as a measurement medium in thermometers, has over 3,000 industrial uses. Battery manufacturing and chloride-alkali production are the main industrial uses of mercury (Michigan State University, 1996). Mercury compounds have also been used in heat transfer processes, pigments, refining processes, lubricating oils, catalysts, and preservatives for paint in storage (ACGIH, 2002). Desirable properties such as the ability to alloy with most

metals, liquidity at room temperature, ease of vaporizing and freezing, and electrical conductivity make mercury an important industrial metal.

Mercury occurs naturally in the environment as mercury sulfide, also known as cinnabar. Cinnabar, the primary ore of mercury, has been refined for its mercury content since the 15th or 16th century B.C. (Michigan State University, 1996). Mercury is present in many chemical forms, and may change from one form to another. One form, elemental mercury is toxic and cannot be broken down into less hazardous compounds. The human toxicity of elemental mercury depends on the absorbed dose. The amount of elemental mercury absorbed by the body is a function of the exposure pathway. Elemental mercury absorbed from the gastrointestinal tract and skin contributes only a small portion of the exposure (Michigan State University, 1996). In contrast, inhalation of elemental mercury vapor is more efficient in terms of contributing a toxic dose upon exposure, with only about 25% of an inhaled dose being exhaled during respiration (Michigan State University, 1996).

Scientific studies investigating the acute effects of inhaled elemental mercury vapor have shown headaches, cough, chest pains, chest tightness, breathing difficulties and chemical pneumanitis (DHHS, 1974). These studies have also shown that acute exposure to elemental mercury can also cause soreness of the mouth, loss of teeth, nausea, diarrhea, and skin irritation. Repeated or prolonged exposure to elemental mercury liquid or vapor can also cause chronic adverse health effects including fine shaking of the hands, eyelids, tongue, or jaw (DHHS, 1974). Other recognized effects are allergic skin rash, headache, sores in the mouth, sore and swollen gums, loose teeth, insomnia, excess salivation, personality change, irritability, indecision, loss of memory, and intellectual deterioration (DHHS, 1974).

Human contact with mercury often occurs through occupational exposure. One source of occupational exposures are dental clinics involved with the mixing of amalgams. Recognized as silver fillings, dental amalgam is a mixture of elemental mercury and an alloy of silver, tin, and copper. Elemental mercury makes up approximately 40-50% of the amalgam compound. Elemental mercury is used to bind the alloy metals together, which provides a strong, hard, durable filling (Academy of General Dentistry. 1982). Historically, mercury has been found to be the best binding agent due to the formation of an amalgam that is easily manipulated into a tooth cavity. It is estimated that over a billion amalgam restorations (fillings) are placed in human teeth annually (Academy of General Dentistry. 1982).

Traditional preparation of dental amalgam involves the open-air mixing of mercury and alloy powder. To obtain the proper consistency, the mixed amalgam is mulled by hand thus removing excess mercury. Studies have shown that handling amalgam in this manner increases the potential for occupational exposure to elemental mercury vapor (NIOSH, 1982). A new technique to mix amalgam involves the use of a capsule instead of directly mixing mercury with an alloy powder. The capsule, consisting of two chambers, contains a predetermined amount of mercury and alloy powder. This capsule is placed on an amalgamator/triturator, which agitates the capsule in such manner that the mercury and alloy powder are mixed to form paste. The paste is then emptied into an amalgam well and is ready for application. The use of the pre-enclosed capsule minimizes liquid mercury contact and the release of elemental mercury vapor into ambient air. Some studies have shown that new generation dental amalgam capsules release

lower mercury vapors; however, there are always exceptions, which is why periodic checks are recommended to protect the dentist and his/her team from avoidable exposure to elemental mercury vapors (Wirz, J., et al., 1993).

One intuitive perception among dental health care workers is that the potential for mercury vapor in the ambient atmosphere increases with the number of capsules utilized in the restoration process. The number of capsules used for each patient is dependent on the size of the cavity and the number of teeth needing repair. Typically, three capsules may be used for every two teeth undergoing a restoration. Little published data are available documenting elemental mercury vapor concentration with an increase in the number of amalgam capsules in use.

Occupational exposure to elemental mercury vapor is regulated by different agencies. The Occupational Safety and Health Administration (OSHA) has established a Permissible Exposure Ceiling Limit ($PEL_{ceiling}$) of 0.1 mg/m^3 for the inhalation of elemental mercury vapor (OSHA, 2003). A ceiling limit is defined as the concentration of mercury vapor in air that should not be exceeded during any part of the working exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) has established an 8-hr time-weighted average (TWA) Threshold Limit Value (TLV) of 0.025 mg/m^3 for the inhalation of elemental mercury (ACGIH, 2003). A TWA is the average exposure concentration over an 8-hour workday and is based on a 40-hour workweek. The National Institute for Occupational Safety and Health (NIOSH) has established a Recommended Exposure Level (REL) of 0.05 mg/m^3 for the inhalation of mercury vapor (NIOSH, 2003). This REL is based on an 8-hr TWA exposure. In addition, the Environmental Protection Agency (EPA) has established a 7-day per week lifetime Reference Concentration for the Chronic Inhalation Exposure (Rfc) of 0.009 mg/m^3 lowest-observed-adverse-effect-level (LOAEL) for the inhalation of mercury vapors (EPA, 2003).

The purpose of this study is to evaluate occupational exposure to mercury vapor while preparing amalgams using the pre-encapsulated technique. Evaluation of occupational exposure to mercury vapor was accomplished through the collection of time-integrated samples in an employee's breathing zone and the collection of grab samples taken at various locations through the dental clinic. Results acquired from this study show that the use of capsules containing mixed amalgam lower the potential for adverse exposure to elemental mercury vapor concentration in a dental clinic.

MATERIALS AND METHODS

Sampling of elemental mercury vapors were conducted at an active dental clinic consisting of four examining rooms, a waiting area, a dark room, a laboratory, sterilization room, and a lounge. Each examination room is configured to provide care for one dental patient at a time except for one, which is configured to provide simultaneous care for two dental patients. The primary activities performed in the dental clinic are tooth restorations (composites and amalgams), exams, and oral surgery. The clinic has eleven employees consisting of two clinic managers, four dental assistants, four dental residents and one attendee. This study was conducted for ten days over a four-week period.

Integrtated Sampling Methodology

Twenty-four elemental mercury vapor samples were collected over the four-week sampling campaign (thirteen 8-hr TWA samples evaluating full shift exposures and eleven short-term TWA samples evaluating exposures during the dental restoration process). All TWA samples were collected in an employee's breathing zone according to OSHA Analytical Method ID-140.[10] For each sample, the mercury vapor was using SKC Hydrar^R sorbent tubes attached to the employee's shirt lapel. Negative air pressure to facilitate contaminant collection was provided by an SKC Airchek® 2000 sampling pump attached to an employee's waist. The negative pressure pump was calibrated using a BIOS Drycal DC-Lite Primary Flow Meter to a flow rate of 0.20 liters per minute. Each sorbent tube was attached to the negative air pressure pump using tygon tubing. After the completion of each sampling event, each SKC Hydrar^R sorbent tube was sent to a Proficiency Analytical Testing (PAT)-certified laboratory for analytical analysis of captured elemental mercury. Quantification of elemental mercury was accomplished through the use of cold vapor-atomic absorption spectrophotometry.

Direct Reading Sampling Methodology

Grab samples of workplace air assessing the presence of elemental mercury vapor was conducted using a Model 431-X Jerome Mercury Vapor Analyzer. The Jerome 431-X instantaneously measures the concentration of mercury vapor in mg/m^3. When a sample cycle is activated, the internal pump draws a precise volume of air over a gold film sensor. Mercury in the sample is adsorbed and integrated by the sensor, registering it as a proportional change in electrical resistance. The sensitivity of the instrument is 0.003 mg/m^3 Hg with a range of 0.003 to 0.999 mg/m^3. Data acquisition to record monitoring information was accomplished using the Jerome Data Logger Data Acquisition System, which was attached to the Jerome 431-X. Direct Reading monitoring was conducted to establish a "zone of contamination" from the amalgam holding well to the employee's breathing zone. In addition, waste baskets inside the dental clinic where monitored for potential for mercury contamination.

RESULTS

Integrated Sampling

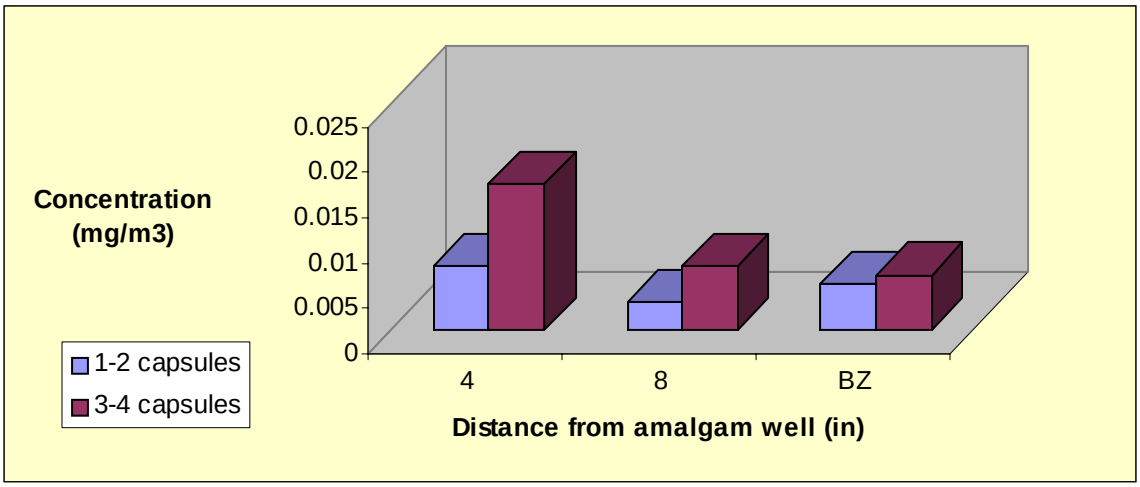
Elemental mercury concentrations acquired from the 8-hr TWA breathing zone samples ranged from non-detectable to 0.0006 mg/m^3. Elemental mercury concentrations acquired from the TWA breathing zone samples collected during the 20-45 minute dental restoration process ranged from non-detectable to 0.0034 mg/m^3.

Direct Reading Sampling

The "zone of contamination" was measured at four inches and eight inches from the amalgam well and in an employee's breathing zone. Each average concentration is displayed according to the number of capsules used for a specific restoration procedure. Average concentrations using 1-2 capsules are 0.007 mg/m^3, 0.003 mg/m^3, and 0.005 mg/m^3 respectively. Average

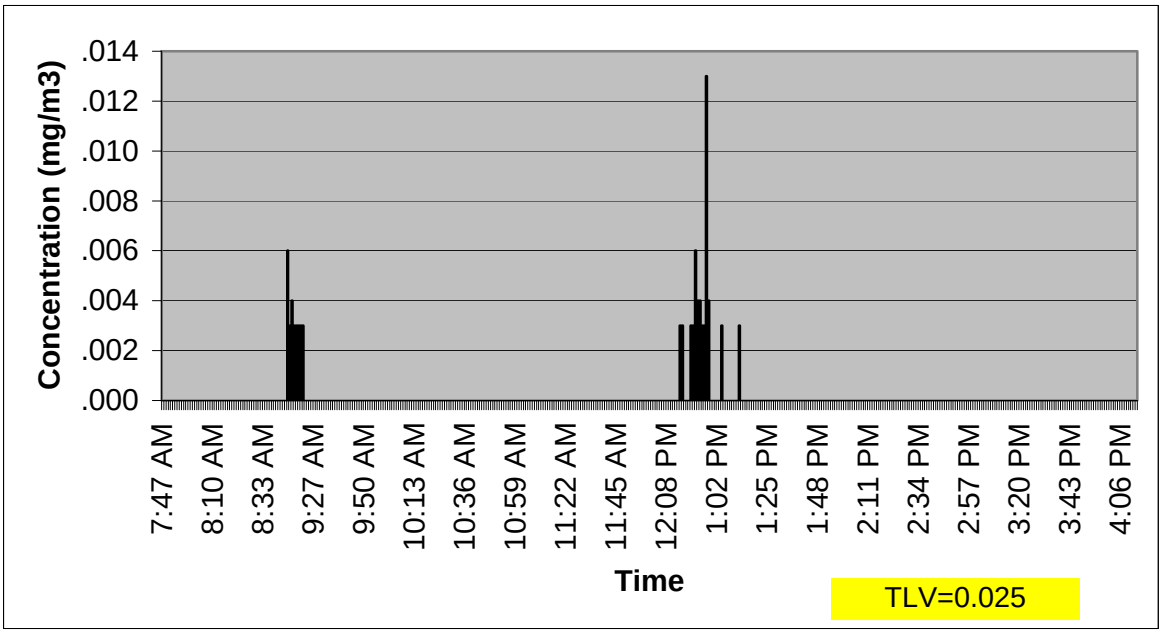
concentrations using 3-4 capsules are 0.016 mg/m^3, 0.007 mg/m^3, and 0.006 mg/m^3 respectively. An illustration of both categories is depicted in Figure 1 below. The highest mercury

Figure 1: Average Megury Concentration using 1-2 & 3-4 Capsules



concentration detected was 0.199 mg/m^3 at the amalgam well. This concentration exceeded OSHA $PEL_{ceiling}$. The highest mercury concentration acquired from the breathing zone of a clinic employee was 0.017 mg/m^3 and was sampling from the breathing zone of a dental assistant during a tooth restoration process. The Jerome 431-X data logging results are depicted in Figure 2 below. The results provide a representation of varying mercury vapor concentrations

Figure 2: Jerome 431-X Data Logging Results



in an examining room throughout an entire workday. The Jerome 431-X was placed approximately 6 feet from the amalgam mixing area. The highest observed concentration was 0.013 mg/m^3 at 12:57 PM. The peaks in the graph illustrate mercury vapor generation during an amalgam preparation process. All wastebaskets in each examining room were monitored for mercury contamination and each result showed non-detectable levels of mercury vapor except for a wastebasket in the sterilizing room, which registered a concentration of 0.004 mg/m^3.

DISCUSSION

The dental assistant job category is identified as the "worst case" scenario for elemental mercury exposure due to the increase potential for mercury vapor generation during the amalgam preparation process. Field observations of clinic activities show that there are differences in the work practices (i.e. discarding of excess amalgam, housekeeping) among the dental assistants that may lead to unnecessary mercury vapor exposure. For example, if waste amalgam is not properly disposed of after its use, this may lead to excess mercury vapor generation. The use of pre-enclosed dental amalgam is an approach to mercury control that is specific to the dental industry. The handling of mercury is minimized because the mixing of the alloy and mercury is enclosed.

All sampling results depicted mercury vapor exposure during worst case and typical case scenarios. A limitation of this sampling campaign included placing the Jerome 431-X, with the data logger attached, closer to the amalgam mixing area. The Jerome 431-X was placed at a distance that would not hinder the dental health care workers performance.

CONCLUSIONS

All sampling methods, (direct reading to establish a zone of contamination, data logging direct reading results throughout an entire workday, 8-hr TWA breathing zone samples, and TWA breathing zone samples during dental restoration processes) showed no mercury vapor exposure that will exceed occupational standards for mercury. Results show an increase in mercury vapor generation as the number of capsules used increases. It is believed that dental health professionals are at a low risk for being exposed to occupational mercury vapor that will cause adverse health effects.

The following recommendations should be considered to minimize mercury vapor exposure in dental clinics:

- Annual Hazard Communication in dealing with elemental mercury;
- Maximize the distance between an employee's breathing zone and the amalgam well while preparing amalgam. The breathing zone should be at least 12 inches from the amalgam well;
- Follow manufacturer's instructions on further manipulation after trituration, and;

- Technique for handling waste amalgam should be standardized to minimize unnecessary exposure to mercury vapor and should include the following:

    1. Change amalgam traps at least once a week or more frequently as needed;
    2. Use disposable amalgam traps instead of reusable traps;
    3. Never place used or excess amalgam down the drain;
    4. Secondary filters in vacuum pump systems should be changed once a month or more frequently if needed or according to manufacturer's specification, and;
    5. All materials that have the potential to contain amalgam particles such as gauze, paper towels or empty amalgam capsules should be disposed of through the methods of solid waste.

Concentrations attained during the study demonstrate that the capsules succeed in maintaining low, acceptable levels of mercury vapor in the dental clinic. The pre-encapsulated amalgams eliminate mercury-handling operations, thus reducing the potential for mercury vapor generation.

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