CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

AN ENVIRONMENTAL STUDY OF
MERCURY CONTAMINATION IN DENTAL OFFICES

A thesis submitted in partial satisfaction of the
requirements for the degree of Master of Science in

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by

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The thesis of Meier Schneider is approved:

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To my wife, Theresa,
my daughters, Leah and Diane,
and my son, Alan

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ABSTRACT

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An environmental health survey of 19 dental offices employing a total of 282 dental workers was conducted to determine sources of uncontrolled exposure of dental workers to mercury vapor. An additional objective of this study was to assess, on a job-function basis, those groups of workers at greatest risk with respect to handling mercury. Data obtained from analysis of collected wipe, air, and urine samples were used to evaluate the degree of risk with respect to absorption of mercury vapor for the cohorts studied. The group showing the greatest risk of exposure to mercury vapor is that comprised of dental assistants who prepare mercury amalgams for filling tooth cavities. No evidence of acute exposure to mercury vapor was found for any of the cohorts studied. Further studies appear to be warranted, in order to determine the effects on the health of those dental workers whose urinary mercury concentrations indicate absorption of abnormal amounts of mercury vapor.

Chapter 1

INTRODUCTION

Literature Review

Mercury in its elemental state is the only metal that exists in a liquid form over a wide range of room temperatures. Its use by man dates back to the earliest period of recorded time.

Some evidence exists that indicates this metal was known in the 15th or 16th Century B.C. and that Hippocrates may have used it as a drug in Greece about 400 B.C.¹

The use of mercury by the people in ancient times was extremely limited because these people lacked sufficient knowledge of the properties of this element. As man increased his technical knowledge of mercury's properties, he began to exploit the use of this element as an element and as a compound. With the advent of its use in medicine, early-day physicians, such as Hippocrates, Pliny, Galen and others observed the toxic effects of mercury. Initially, compounds of mercury were used in medicine for the treatment of such ailments as chronic skin diseases, especially by Arabian physicians in the time period of 1,000 A.D. When syphilis was definitely recognized in 1495, physicians of that time began intensive treatment of the disease with mercury and its compounds.¹

However, according to Goldwater,² a treatise by Ulrich

Ellenbog entitled "Von den gifftigen Besen Temmphffen von Reuchen der Metal," and written probably in the year 1473, described some of the toxic effects of mercury vapor as an industrial hazard. This monograph by Ellenbog was not published until 1524.

The consensus of modern-day toxicologists is that intoxication from absorbed mercury in vapor or compound form is due to the action of the mercuric ion. The absorbed mercury is biotransformed to the higher valence state partly in the blood and tissues, but mainly in the red blood cells, or erythrocytes.³ The exact mechanism of mercury intoxication is not completely understood. Hughes⁴ and Rodin⁵ have advanced the most commonly accepted explanations of this mechanism, which appears to involve the reaction of mercuric ion with thiol or sulfhydryl (S-H) groups on the surface of mitochondria. The latter are organelles found in the cytoplasm of all cells and contain some of the enzymes needed to carry on life processes.⁶ It has been suggested by Rodin⁵ that cell death occurs when mercury combines with the sulfhydryl groups on enzymes.

Berlin^{7,8,9} Nordberg,¹⁰ and Friberg¹¹ have on the basis of animal experimentation, concluded that long-term mercury vapor exposure results in an accumulation of mercury in nerve tissue, particularly in the brain. They also conclude that not only is elimination of mercury from brain tissue slow, but that the sensitivity of this organ to mercury is such that high mercury concentrations occur in localized regions of brain tissue; Friberg¹¹ also found that organic mercury compounds were more firmly bound to

brain substance than the inorganic compounds. He concluded that organic compounds of mercury penetrate the blood-brain barrier more easily than do the inorganic.

Mercury absorbed by humans exposed to its vapor is eliminated from the body to a great extent in the urine and the feces. A greater amount of mercury is excreted in the feces than in the urine.^{12,13} Mercury is also excreted in the bile, sweat, milk, saliva and intestinal secretions.^{3,14}

Acute poisoning of humans from industrial exposure to mercury vapor other than by accident is a rare occurrence today, but was quite common as recent as 1923.^{1,3,13}

The most common form of occupational exposure of man to mercury vapor is that of chronic exposure. Symptoms that are associated with chronic exposure to mercury vapor or vapor/dust combinations, include gingivitis and stomatitis (inflammation of the oral mucosa) in persons with poor general standards of oral hygiene. The latter symptoms are often accompanied by excessive salivation and/or metallic taste. A frequently observed symptom is a discoloration of the anterior surface of the lens of the eye which is known as mercurialentis. Since the onset of symptoms is insidious, the affected individual may either ignore the previously described symptoms, or attribute them to other causes, unless these symptoms are accompanied by tremor.

When felt hats were made with mercuric nitrate, workers in this industry frequently exhibited marked tremor. This came to

be known in England as "Hatter's Shakes" and "Danbury Shakes" in the United States. Lewis Carroll's "Alice in Wonderland" describes one of the characters as "The Mad Hatter" who exhibited the classical signs of tremor and psychological disturbance resulting from chronic mercury poisoning. Thus, the expression "as mad as a hatter" may have been coined from observation of the symptoms displayed by many workers in the felt hat industry.¹

Emotional instability, or erethism, resulting from chronic mercury poisoning is most difficult for the physician to assess if tremor is absent and the patient's occupation is unknown to the examining physician. Individuals exhibiting this symptom may be irritable, nervous, and blush easily. Often the best history on this symptom is obtained from the close friends or members of the family who may observe a change of temperament, unexplained temper outbursts and a tendency to avoid meeting friends. Unless the physician is provided with information regarding the patient's occupation, these manifestations are often passed off as an anxiety state.¹

Mercury finds wide use in the occupational environment. Pressure and temperature sensing instruments contain mercury. It is used in dental amalgams, batteries, paint, commercial laundries, and in chlor-alkali plants. A complete inventory of uses of mercury in the work environment, as well as sources that might contribute to environmental contamination, has yet to be made. The foregoing represents only a partial listing.¹⁵

One of the most widespread occupational uses of mercury is the preparation of dental amalgam for restoring teeth that have decayed. Dental amalgams are solid solutions consisting of a mixture of mercury, silver, copper, zinc, and tin. About 70% of the alloy mixture, prior to amalgamation with mercury, consists of silver; somewhat more than 25% of the alloy mixture is tin; less than 6% is copper; and less than 2% is zinc. The amalgamation process occurs when alloy is brought into frictional contact with mercury in a process known as trituration. During trituration, alloy surfaces are penetrated by mercury to form a solid solution of silver alloy and mercury. This produces a plastic mass that will harden or "set-up" within a relatively predictable time period, after which it no longer can be worked into the tooth cavity.¹⁶ Working time of these amalgams ranges from three to six minutes, depending upon the percent of mercury in the total mix. Various dental amalgam manufacturers market preproportioned, separated mixes. Mercury content of these mixes may range from a low of 48% to a high of about 62%. According to most authorities in the dental profession, the ideal mix is a 1:1 ratio by weight of alloy to mercury, with the mercury content of the mix at the 50% figure. Modern methods of triturating involve placing the mix in a plastic capsule and shaking it in a mechanical device. Some of these mechanical triturators include a device that subjects the triturated amalgam to an additional mixing or kneading procedure known as mulling. When excess mercury is used to prepare dental amalgams,

the resultant plastic mix is too fluid to condense or compact into the tooth cavity. The excess mercury must be squeezed off, usually by placing the amalgam in a squeeze cloth, twisting the cloth into a small knot to contain the amalgam, and then applying pressure to the amalgam with the fingers or a pair of pliers. The excess mercury squeezes through the cloth.

Exposure of dental office personnel to mercury vapor can occur during preparation, and handling of mercury-silver amalgams, and from stored waste amalgams. Concern over environmental pollution has focussed attention on the use of mercury in dentistry. Questions regarding the potential hazards to dental personnel, as well as patients, from mercury in dental offices continue to be raised, although a number of studies have been made of this subject. The literature on hazards from use of mercury in dental offices consists of popular-type articles, as well as those of a scientific nature. The conclusions of these authors have ranged from casual dismissal of the hazard of mercury to dental office patients and employees, to dire predictions of damage to health.¹⁸⁻²⁸ A recent publication¹⁷ reports a fatality involving a dental assistant with a twenty-year history of exposure to dental amalgams containing about 40% mercury. The dental assistant died from acute renal failure attributed to mercury intoxication. The patient apparently had no indication of chronic mercury poisoning until she became suddenly ill with vomiting, passing of dark urine, pain in the right lumbar region of the abdomen and edema of the face and legs. The manner

in which death occurred in this case is considered somewhat uncommon for those exposed to mercury vapors. Unfortunately, the description of this case omitted environmental data pertaining to the manner in which this individual came into contact with mercury.

In addition to the previously cited publications, Frykholm²⁹ has published a comprehensive review of the literature related to the hazards involved in the handling of mercury in dental offices and Noe³⁰ has a similar review of hazards to personnel in medical laboratories. The general conclusion from the relatively voluminous data published on mercury in dental offices is that no danger of systemic poisoning exists for patients who have their teeth filled with mercury amalgams. However, individuals in medical and dental practices who handle mercury can suffer either acute or chronic mercury intoxication due to inhalation of mercury vapor. The extent of exposure to mercury vapor depends upon a number of factors. These include the quantity of metal handled, ventilation, and the manner in which the mercury is handled.

Statement of the Problem

A thorough review of the literature on hazards of mercury in dental offices revealed a number of field studies conducted in the United States, as well as some foreign countries. Also, these studies, in most cases, provided very little environmental information relating to details of mercury handling in dental offices. It was believed that a more searching study with greater attention to the manner in which mercury and silver amalgams are

handled by dentists and their assistants would provide information for the control of mercury vapor exposures in dental offices. One such study was conducted in the Province of Alberta, Canada³¹ during the summer of 1968. Inasmuch as climatic conditions, and dental practices, especially the manner of preparing mercury amalgams, can vary considerably from country to country, as well as from one part of a country to another, it was decided to repeat the Alberta study in Southern California.

Null Hypotheses

Several null hypotheses were formulated for this study as follows:

1. H_0 : There is no association between urine-mercury levels of dentists and dental assistants and surface-mercury contamination levels in dental offices.
2. H_0 : There is no significant difference between mercury levels in urine of operator personnel in dental offices when compared against similar data for nonoperator personnel in dental offices.
3. H_0 : There is no significant difference between mercury levels in the urine of dentists who handle mercury when compared against similar data for dentists who do not handle mercury.
4. H_0 : There is no significant difference between mercury levels in the urine of dental assistants who handle mercury when compared against similar data

for dental assistants who do not handle mercury.

5. H_0 : There is no significant difference between mercury levels in the urine of dentists who handle mercury when compared against similar data for dental assistants who handle mercury.

These hypotheses were tested by application of the chi square statistical procedure at the .01 level of significance.

Chapter 2

MATERIALS AND METHODS

The groups studied consisted of 19 dental offices, employing a total of 102 dentists, 86 dental assistants, 12 dental hygienists, 20 dental laboratory technicians, 9 dental X-ray technicians, 6 maintenance men, and 47 receptionist/clerical personnel. The survey included small offices as well as large clinics.

Most offices were engaged in the practice of general dentistry, and a few restricted their practice to pedodontics (children's dentistry). The latter used significantly larger quantities of mercury amalgams than do most offices engaged in the practice of general dentistry.

Data were collected on contamination of:

1. Surfaces by taking wipe samples.
2. The atmosphere by using a direct-reading instrument, as well as scrubbing the dental office air through an absorbing solution which was subsequently analyzed for mercury in vapor and/or particulate form in the laboratory.
3. For excreted mercury by analyzing collected urine samples.

These data were analyzed to determine those environmental factors primarily responsible for absorption of mercury by dental professionals.

Wipe Tests

All dental offices were wipe sampled for surface contamination. Wipe sampling was done with a piece of 9 centimeter circular high-quality, analytical grade "S and S" filter paper. This paper was folded four times, and a template was used to wipe an area of 100 square centimeters. Table tops near amalgamators, floor tile, as well as seats of dental chairs were wipe tested. The folded filter paper was placed in a clean glassine envelope and returned to the laboratory for analysis. Analysis of wiped samples for mercury was by cold vapor atomic absorption^{32,36}

Air Sampling

Analyses of mercury vapor concentrations in air was by means of a "J-W (Johnson-Williams)/Lemaire, Model MV Mercury Sniffer." This is a direct-reading, battery-operated instrument calibrated against a known air concentration of mercury in vapor form only.

The instrument will read other substances in air, such as water vapor, aromatic hydrocarbons, ozone, etc. Care was taken while using this instrument to avoid known interferences. The instrument scale face can be read to a lower limit of detection of about 0.0125 milligrams of mercury vapor per cubic meter of air. It has an upper limit of detection of 1.0 milligrams of mercury vapor per cubic meter of air.

Additional air samples were collected, using a midget impinger (sampling bottle) containing potassium permanganate

acidified with sulfuric acid. This sampling procedure trapped mercury vapor as well as mercury particulates.³²

Urine Samples

The literature^{33, 34} dealing with excretion of mercury in urine of humans indicates there is no consistent correlation for individuals between excretion and duration of exposure. However, on a group basis, there is apparently a good correlation between mercury exposure levels and levels of urinary excretion. Moreover, it is common to find wide fluctuations in hourly, as well as daily, excretion of mercury in the urine of exposed persons. Some of these studied³⁴ indicate a rhythmic pattern to the excretion of mercury. This pattern appears more related to some physiological mechanism rather than a direct effect of immediate environmental exposure. A considerable time lag exists between increased exposure and a corresponding increase in urinary mercury excretion.³⁵

During the planning phase of this study, a decision was made to use urinary mercury values to identify those groups of individuals in dental offices exposed to mercury who exhibit levels of urinary mercury in excess of those of the normal average non-occupationally exposed population. For the most part, all urine voidings during a normal work day were collected from personnel in the dental offices surveyed. A few spot-voidings were collected in instances where it was impractical to obtain a full day's voidings. No preservative was added to the containers used to collect the

urine specimens, and the containers were acid washed and rinsed in deionized water prior to collecting the samples. Samples were taken to the analytical laboratory (Southern California Laboratory), and aliquots were taken for analysis for mercury. Laboratory scheduling precluded analyzing all samples immediately after receipt. Samples awaiting analysis were kept in a frozen condition. No provision was made for standardizing for variation in urinary volume or specific gravity.

Urine samples were digested with acidified potassium permanganate. The solubilized mercury compounds were reduced to metallic mercury with hydroxylamine hydrochloride and final analysis for mercury was by cold vapor atomic absorption.³⁶

Chapter 3

RESULTS

All subjects in this study were involved with some aspect of dental practice. These subjects were classified into cohorts, according to functions performed with respect to mercury handling in the dental practice.

Urinary mercury concentrations were separated into two classes: Those individuals whose urinary mercury concentrations were equal to or less than 30 micrograms per liter were placed in the average "normal" category; and those exceeding the upper limit of the normal range were considered to be abnormal in the sense that these elevated values were indicative of increased mercury absorption over previously established "normal" limits for non-occupationally exposed individuals.^{2,37} It should be noted that urinary mercury values can be useful for evaluating human exposure to mercury, provided that the individual does not experience abnormal kidney function.

Ambient Air Concentrations

During this study, air in the dental offices was analyzed directly as well as indirectly for mercury vapor. Inasmuch as most offices surveyed had ambient air concentrations less than the currently accepted Threshold Limit Value^{*38} of 0.05 milligrams of

*This is an 8-hour work day, 40-hour work week concentration that most workers can be exposed to without adverse effect.

mercury per cubic meter of air (0.05 mg Hg/M^3), it was decided that ambient air mercury concentrations would not be suitable for establishing levels of mercury contamination in these offices. Table I presents the ambient air concentration data obtained in this study.

Table 1
Ambient Air Mercury Concentrations

No. Dental Offices	Average Ambient Air Concentration mg Hg/M^3	Range mg Hg/M^3
17	0.03	0.0 - 0.16

Mercury droplets oxidize rapidly in air, with the result that the metal is coated with oxide or sulfide. This oxidation coating suppresses the vaporization of the underlying metal provided that the droplet is undisturbed. It was found that after rubbing various surfaces, such as bench tops, carpets, flooring tile, operatory units, etc., mercury vapor was detected with a mercury vapor meter, a few inches above the disturbed surface. The rubbing action not only broke the oxide coating, exposing bare metal, but resulted in raising the surface temperature slightly, due to frictional heating. The latter served to increase the vaporization of the mercury contaminating the surface. Wipe samples were taken from surfaces in the dental

office to obtain an indication of the degree of mercury contamination.

Table 2 contains a list of those offices surveyed where wipe samples were obtained. Approximately six wipes were obtained for each office, and the individual samples were averaged for each office thus surveyed.

The first null hypothesis of this study states that no relationship or association will be found between the frequency of occurrence of elevated levels of mercury in the urine of dentists and their assistants ($>30\mu\text{g Hg/liter}$) and the surface contamination by mercury in these offices. In order to test this hypothesis and determine whether observed results agreed with expected results, urine values for dentists and dental assistants were dichotomized. Mercury concentrations equal to or less than average normal mercury in urine values for nonoccupationally exposed people were placed in one group. All values above these average normals constituted the significantly exposed group. In order to dichotomize the wipe values obtained for surface contamination by mercury, it was determined arbitrarily to use 100 micrograms of mercury per 100 square centimeters surface wiped as the upper limit for a moderately contaminated office. Heavily contaminated offices were those exceeding this upper limit.

Statistical Treatment

The chi-square (X^2) test was applied to measure the discrepancy between observed and expected frequencies for this as

Table 2

Surface Contamination by Mercury

Office No.	Averaged Surface Contamination ($\mu\text{g Hg}/100 \text{ cm}^2$ surface)
1	24
2	557
3	2
4	171
3	13
4	93
5	6
6	247
7	41
8	37
9	2
10	8
11	2
12	21
13	43
14	8

Table 3

Urine Mercury Values for All Dentists and
Dental Assistants vs Surface Contamination by Mercury

Urine Mercury Values	Surface Contamination, Micrograms Mercury per 100 square centimeters of surface wiped ($\mu\text{g Hg}/100 \text{ cm}^2$)		
	≤ 100	> 100	
$\leq 30 \mu\text{g Hg/Liter}$	(34) observed	(54)	88
	32.75 expected	55.24	R_1
$> 30 \mu\text{g Hg/Liter}$	(17) observed	(32)	49
	18.24 expected	30.76	R_2
	C_1 51	C_2 86	137 N

$$\chi^2 \cong 0.0739$$

Table 4

Urine Mercury Values for Dental Operator Personnel
vs Dental Nonoperator Personnel

	Urine Mercury, $\mu\text{g Hg/Liter}$		
	≤ 30	> 30	
OPERATORY	(100) 117.12	(50) 85.89	150
NONOPERATORY	(103) 32.88	(7) 24.12	110
	203	57	260

$$\chi^2 = 25.404 > .01$$

Table 5

Urine Mercury Values for Dentists Who Handle Mercury
vs Dentists Who Do Not Handle Mercury

	Urine Mercury, $\mu\text{g Hg/Liter}$		
	≤ 30	> 30	
DENTIST WHO HANDLES MERCURY	(56) 56.63	(20) 19.37	76
DENTISTS WHO DO NOT HANDLE MERCURY	(20) 19.37	(6) 6.63	26
	76	26	102

$$\chi^2 = 0.0046$$

Table 6

Urine Mercury Values for Dental Assistants Who Handle Mercury
vs Dental Assistants Who Do Not Handle Mercury

	Urine Mercury, $\mu\text{g Hg/Liter}$		
	≤ 30	> 30	
DENTAL ASSISTANTS WHO HANDLE MERCURY	(44) 50.08	(30) 16.92	74
DENTAL ASSISTANTS WHO DO NOT HANDLE MERCURY	(23) 23.92	(2) 8.08	26
	67	32	99

$$\chi^2 = 14.5158 > .01$$

Table 7

Urine Mercury Values for Dentists Who Handle Mercury
vs Dental Assistants Who Handle Mercury

	Urine Mercury, $\mu\text{g Hg/Liter}$		
	≤ 30	> 30	
DENTISTS WHO HANDLE MERCURY	(56) 50.67	(20) 49.33	76
DENTAL ASSISTANTS WHO HANDLE MERCURY	(44) 25.33	(30) 24.67	74
	100	50	150

$$\chi^2 = 31.2891 > .01$$

as well as the other null hypotheses of this study. Contingency tables are shown in Tables 3-7 for the null hypotheses postulated for this environmental survey. Certain corrections for continuity can be made when results for continuous distributions are applied to discrete data.

Without the application of a continuity correction, the χ^2 statistic would be computed as follows:

$\chi^2 = \sum_j E_j(o_j - e_j)^2$, where o_j and e_j represent, respectively, the observed and expected frequencies of the j th cell in the contingency table.

Since the number of degrees of freedom in these 2×2 contingency tables is 1, and since some of the samples obtained in this survey are relatively small, a Yates' correction for continuity has been applied to the data as follows:

$$\chi^2 \text{ (corrected)} = \frac{(|o_1 - e_1| - .5)^2}{e_1} + \frac{(|o_2 - e_2| - .5)^2}{e_2} + \dots$$

The data in the cells of the 2×2 contingency tables are presented in frequencies or counts for each of two conditions. Calculated expected frequency values are shown below each observed value. Expected frequencies were calculated from the equation

$$E_i = \frac{C_i \cdot R_i}{N}$$

If the observed and theoretical frequencies agree exactly, $\chi^2 = 0$. When $\chi^2_{.99}$ (at a .01 level of significance), a discrepancy exists between observed and expected frequencies, and the value of

χ^2 is the measure of that discrepancy. The expected frequencies are computed on the basis of an hypothesis, H_0 . Computed values of χ^2 with respect to the stated hypothesis may be greater or smaller than some critical value, such as $\chi^2_{.99}$ which would be the critical value at the .01 level of significance. If the value of the $\chi^2_{.99}$ is greater than the critical value, it can be concluded that the observed frequencies differ significantly from expected frequencies and, hence, the H_0 would be rejected at the level of significance, i.e., .01. Thus, we determine that the overall differences between exposed groups of dental personnel are attributable to the differences within the groups themselves, and that these differences are significant beyond those attributable to random sampling errors, or by chance alone.

Since the value of the computed χ^2 shown for Table 3 is less than the critical value at the .01 level of significance, we accept the first H_0 and conclude that no association exists between urine mercury levels of dentists and dental assistants and surface mercury contamination levels found in the surveyed dental offices.

Since the computed χ^2 value for Table 4 is much greater than the critical value at greater than a .01 level of significance, it can be concluded that there is a significant difference in urine mercury levels between operator and nonoperator groups of personnel in dental offices. Hence, the second H_0 of this study must be rejected.

The third H_0 of this study must be accepted, because the

value of the computed X^2 at the .01 level of significance is less than the critical value. Thus, there is no significant difference in urine mercury values for groups of dentists who handle mercury compared with groups of dentists who don't handle mercury.

The fourth null hypothesis in this study must be rejected, because the computed X^2 value for Table 6 is much greater than the critical value at .01 level of significance. Hence, there is a significant difference in urine mercury levels of dental assistants who handle mercury when compared against those assistants who don't handle mercury.

The fifth null hypothesis of this study must be rejected, because the computed value for X^2 shown in Table 7 is greater than the critical value for X^2 at the .01 level of significance. These data reveal that dental assistants who handle mercury are at greater risk with respect to absorption of mercury vapor than are dentists who handle mercury.

Chapter 4

DISCUSSION

Every dental office surveyed during this study was found to be contaminated with mercury. The extent of contamination was governed by many variables, such as: (1) The number of amalgams prepared; (2) the number of operatories in the office; (3) the method of mixing the amalgams; (4) the care in handling mercury and mercury amalgams; (5) the type of floor covering in the dental office; (6) housekeeping procedures; and (7) the type of ventilation available. Inasmuch as finely divided mercury can form a covering of either oxide, sulphide, dust, grease, etc., as a result of contact with air, the presence of such longstanding contamination may not pose a health hazard to personnel in the dental office unless this residual contamination is disturbed. Breaking the protective coating surrounding the mercury globule exposes the fresh metal to the operatory air with subsequent release of mercury vapor. The amount of the latter depends upon the air temperature. If ambient temperatures are relatively high, the vapor pressure of the mercury can increase to such an extent that vapor can penetrate and escape through the coating of the mercury droplet. In the latter case, hazardous concentrations of mercury may result in closed spaces, with insufficient ventilation to dilute the mercury vapor to safe levels. Thus, it is not surprising to find a lack of association between elevated urine mercury levels and surface

contamination levels in the offices surveyed. Of all the offices surveyed, only one had an association between urine mercury levels and surface contamination. This office had a very heavy patient load, and was devoted to caring for the dental needs of union members associated with a prepaid dental plan. The building housing the various operatories of this large, high-volume dental practice was completely air conditioned. Approximately 80 percent of the air in this building is recirculated. Puddles of mercury were noted on a ceramic tile floor, and dental office personnel were observed stepping on the liquid mercury and tracking it throughout the building. Shoe soles of a few dental assistants were checked with the "Mercury Sniffer" for evidence of contamination. In all cases, the meter went off scale. This office was so badly contaminated that the waiting room air measured 0.07 mg Hg/M^3 , which is in excess of the current TLV of 0.05 mg Hg/M^3 . The major cause of the mercury contamination in this office was the misuse of amalgamators. Amalgamator machines used in this office for preparing mercury amalgams were designed by the manufacturer for the preparation of single batches only of amalgam. That is, one measure of alloy, plus one measure of mercury. However, dental assistants were instructed by the dentists to prepare triple-size batches of amalgam. Since this type of amalgamator is unable to accommodate such large amounts of alloy and mercury, excess mercury was discharged from the machine during the initial amalgamation procedure prior to the final mulling procedure. This excess mercury spilled on to bench tops, rolled off the bench to the tile floor.

The second null hypothesis of this study relates to activities of two groups of dental office personnel. Those whose functions involve the use of the dental operator are more likely to be exposed to mercury vapor than those whose primary duties are conducted outside of the dental operator. It is not surprising, therefore, that there is a very strong association between elevated mercury levels in urine of dental operator personnel when compared with the mercury levels in urine of nonoperator personnel.

During amalgam preparation, the mercury and alloy mixture is subjected to severe vibratory motion to allow maximum contact between the liquid mercury and metal alloy. This intense vibration occurs while the amalgam ingredients are enclosed in a small plastic capsule. Frictional heating occurs during this operation, and is largely responsible for increasing the vapor pressure of the mercury above that associated with normal ambient temperatures extant in the dental operator. Thus, when the dental assistant opens the triturating capsule and drops the plastic amalgam onto a squeeze cloth or into a glass cup, preparatory to handing it to the dentist, she encounters a relatively high, but short-time (in the order of seconds) exposure to mercury vapor. This phenomenon was noted by sampling the breathing zone of the dental assistant during all phases of amalgam preparation, including the act of transferring amalgam from the amalgamator area to the dental unit. Air sampling with the J-W "Mercury Sniffer" during amalgam preparation and handling revealed values ranging from about twice the current TLV for mercury vapor in the workroom

(0.05 mg Hg/M³) to readings that were so high that they went off the scale of the meter. The highest readings on the "Mercury Sniffer" were noted during the time the triturating capsule was opened, and just prior to the transfer of the amalgam to the dental unit. Moreover, dental assistants receive greater mercury vapor exposures because they work in the immediate vicinity of the amalgamator, whereas dentists normally do not. The greatest contamination of mercury occurs as a general rule within a foot radius of the bench area where the amalgamation of the silver alloy and mercury metal is conducted. Mercury vapor is released as a result of spills of mercury metal, and improper storage of waste amalgam and recovered mercury metal. The constant activity in this area of the dental operatory disturbs mercury globules and very finely divided mercury on various surfaces, thus exposing fresh metal surfaces that give off vapor. Many dentists prefer a more plashy amalgam, which necessitates using an excess of mercury during amalgamation rather than the recommended 1:1 weight ratio of alloy and mercury. Much of this excess mercury must be expressed by hand-squeezing in a squeeze cloth. During this procedure, the dental assistant twists the squeeze cloth into a small knot in which the amalgam rests. She expresses some of the excess mercury by squeezing the amalgam within the cloth by use of a flat-nose pair of pliers. The excess mercury is normally deposited in some type of container, such as a jar, flat dish or glass, paper, or plastic cup. The latter may or may not be tightly lidded after

receipt of the mercury. Most storage containers for excess mercury and waste amalgam were not secured with lids. During the squeezing operation, the dental assistant receives an additional vapor exposure. The squeezing is normally done in the immediate vicinity of the amalgamator.

With the exception of the fatality cited in Reference 17, the literature on mercurialism is lacking in these data, as they pertain to individuals in the field of dentistry. This study confirms the fact that of all the personnel involved in handling dental amalgams in the dental operatory, the dental assistant is at greatest risk with respect to absorption of the metal by the body. The lack of data relating to mercurialism among dental assistants might be explained by the fact that (1) many dental assistants are young women in their early twenties who tend to leave the profession after a few years as a result of marriage; and (2) that the vapor exposures are intermittent and of relatively short duration.

No data are available regarding the effects on human health as a result of these intermittent exposures to mercury vapor. Inasmuch as there is a danger to the fetus, pregnant women should not be exposed to mercury vapor for any prolonged period of time.

Chapter 5

CONCLUSIONS

Several conclusions can be drawn from this study. These are that:

1. Environmental contamination of dental offices by mercury does not appear to pose an acute health hazard to personnel in these offices.
2. Dental office operatory personnel are at greater risk with respect to exposure to mercury vapor than nonoperatory personnel, when this risk is measured by urinary mercury concentrations.
3. Dentists who handle mercury amalgams are not at greater risk with respect to mercury vapor absorption when compared against dentists who don't handle mercury amalgams.
4. Dental assistants who handle mercury amalgams are at greater risk with respect to mercury vapor absorption when compared against dental assistants whose duties do not include handling mercury amalgams.
5. Dental assistants who handle mercury are at greater risk with respect to mercury vapor absorption than are dentists who handle mercury amalgams.

6. A detailed health study of dental personnel appears to be warranted for those individuals exhibiting higher than average "normal" urinary mercury concentrations.

Chapter 6

RECOMMENDATIONS

The following are recommended precautions for the safe handling of mercury by dental personnel:

Education

All personnel involved in handling mercury and mercury amalgams should be made aware of the toxic nature of these substances, and should be instructed in safe-handling practices.

Storage

a. All mercury should be kept in tightly sealed containers of glass, plastic or glazed ceramic when not being used. Waste mercury and mercury amalgams should be stored in similar type containers that have tight-fitting covers. If a tightly covered container is not available for stored waste amalgams, this material should be covered with about one-quarter inch of water.

b. All mercury and waste mercury amalgams should be stored in a cool place.

c. All stored mercury and waste mercury amalgam should be labeled. The label should indicate the contents of the container, as well as its hazardous nature.

Disposal

a. Waste mercury and mercury amalgam should be accumulated in tightly sealed containers. These materials should not be flushed down the sink, dropped on the floor, thrown into wastebaskets, or allowed to accumulate in open trays, beakers or on bench tops.

b. Operatory units should be equipped with suitable traps to trap out waste amalgam expectorated into sinks by patients. It would be preferable for the dentist to use a rubber dam on the patient when filling a tooth with amalgam or removing old amalgam fillings. Waste amalgam accumulated on the rubber dam can be suctioned off by the dental assistant.

c. All articles, such as paper tissues, squeeze cloths, etc., that have become contaminated with mercury or mercury amalgam should be placed in plastic bags that are kept sealed until ready for disposal.

Operatory

a. All amalgam preparation should be conducted in a glove box type ventilated enclosure. The enclosure should be under slight negative pressure with respect to the ambient air, and air discharged from the glove box should be passed through iodized activated charcoal

to remove mercury vapor. The glove box should be constructed of smooth metal or plastic, with no blind corners where mercury can collect. This unit should be equipped with a removable tray to catch any spilled mercury or mercury amalgam. The unit should be cleaned each day of all free mercury and amalgam. The interior surfaces and removable tray should be washed with a water solution containing a mercury decontaminant. Mercury filters should be checked with a mercury meter at least once every six months to ensure that no breakthrough of mercury vapor has occurred.

b. During removal of old amalgams, dentists should wear a tight-fitting oral/nasal dust mask capable of filtering out particulates as small as 0.5 micrometers in diameter to prevent inhalation of finely divided mercury amalgam particulates. The use of a drill equipped with a cooling water spray will prevent frictional heating of the amalgam and subsequent release of mercury vapor during removal from the patient's mouth.

c. All surfaces where mercury and mercury amalgam is used should be free of cracks or corners where mercury can be trapped. Stainless steel or formica with coved corners and edges are suitable for surface coverings. Floors should be one-piece,

vinyl-type coating, with coved corners, and with coving abutting walls. Carpets should not be used in operatories, since it is almost impossible to decontaminate them after a mercury spill. Furthermore, vacuuming mercury-contaminated carpets can create a temporary severe inhalation hazard from mercury, since the latter passing through the heated exhaust of the vacuum cleaner is readily vaporized.

d. Operatory chairs should be covered with smooth vinyl-type upholstery material. Cloth coverings should be avoided.

e. Excess amalgam should not be permitted to fall from the patient's mouth onto his clothing. It should be suctioned into a receiving trap in the sink drain system. This excess amalgam is released from patient's clothing, and can cause contamination of operatory floors, dental chairs, corridors, and waiting-room chairs and floors.

f. Waste amalgam and mercury can be accumulated for eventual disposal to a metal reclaimer. If the latter procedure is not feasible, it should be placed into a container that can be sealed. The waste container should be labeled as to the nature of its contents, and then disposed of through a

waste chemical collection service for ultimate burial in a legal dump designated for hazardous chemicals.

g. In order to eliminate mercury contamination during handling of the metal, it is recommended that encapsulated preproportioned materials be used when preparing amalgams.

h. Manufacturers' recommendations with respect to maximum quantities of materials to be used in their respective amalgamators should be followed.

i. Mulling cups that contain old amalgam should never be heated to remove the amalgam unless this procedure is carried out in a chemical fume hood equipped with mechanical exhaust ventilation to carry the fumes outside of the building. All fumes vented to the outside should be passed through an iodized charcoal filter.

Spills

a. Spilled mercury should be cleaned up immediately by use of a suction device that can trap out the collected metal. Other mechanical mercury-gathering devices may be obtained from a chemical supply house. A vacuum cleaner should never be used to clean up mercury spills, unless it is specially designed for that purpose. It must have a mercury

filter on the discharge.

b. If mercury has spilled into places inaccessible to use of a clean-up device, vaporization of the mercury can be suppressed by covering the metal with a thin coat of flowers of sulfur.

c. A commercial-type, water-soluble mercury decontaminant can be used to wash down table tops and benches and equipment that is contaminated. Dental tools that are contaminated with mercury in the course of tooth restoration can be soaked in this decontaminant solution for an hour prior to the washing and sterilizing of these tools. If the commercial decontaminant is not available, technical grade photographic "hypo" (sodium thiosulfate) can be used as a ten percent by weight water solution. The Occupational Health Section of the state or local health department should be consulted for detailed information on mercury decontaminants. These materials do not destroy mercury. They merely change its character to prevent the vapor from contaminating the dental office air.

Personal Hygiene

a. Mercury will adhere to the skin. This poses the danger of inhaling vapor, since body temperature is sufficiently high to cause vaporization of some of the metal adhering to the skin. Moreover,

those who smoke can transfer mercury from the skin to cigarettes, with subsequent vaporization and inhalation of the metal. Many individuals bring their hands near their nose from time to time, and thus any metal vaporizing from the hands can be inhaled. Some absorption of mercury can take place through the skin. The rate of absorption of metallic mercury through the unbroken skin appears to be low when compared against that for organo mercury compounds. However, specific data are not available for this phenomenon.

b. Personnel handling mercury or mercury amalgams should scrub their hands thoroughly, using soap or detergent, as soon as is practicable after contact with the metal or its alloy.

c. Smoking should be prohibited in areas where mercury and amalgams are being handled. Individuals who handle these substances should not smoke until they have thoroughly scrubbed their hands.

Medical

a. Periodic urine testing should be done on individuals handling mercury and mercury amalgams to determine the adequacy of preventive measures for safeguarding employees' health. The periodicity of these tests can be established on the basis of the

degree of exposure. Advice regarding medical monitoring of personnel handling mercury and amalgams, as well as guidelines with respect to the exposure of pregnant employees to mercury vapor, can be obtained from the Occupational Health Section of the state or local health departments.

Chapter 7

SUMMARY

An environmental health survey of mercury contamination in dental offices in the Southern California area encompassed 19 such offices, employing a total of 102 dentists, 86 dental assistants, 12 dental hygienists, 20 dental laboratory technicians, 9 dental X-ray technicians, 6 maintenance personnel, and 47 receptionist/clerical personnel. Dental offices engaged in the general practice of dentistry, as well as those specializing in pedodontics (children's dentistry) comprised the total dental offices in this study.

The environmental study was conducted in order to determine sources of uncontrolled exposure of dental personnel to mercury vapor. Surface wipe samples, air samples, and urine samples, were collected to obtain data on the exposure of dental personnel to mercury; as well as to determine those job functional groups in the dental office who are at greatest risk with respect to absorption of mercury.

Although no acute situations with respect to mercury absorption were found in this study, a statistical analysis of the data revealed that:

1. No relationship existed between surface contamination by mercury and elevated urinary mercury levels in dental office

personnel.

2. The risk of acute exposure of dental personnel appears to be minimal.
3. Personnel whose job function involves the dental operatory (operating room) have higher urine mercury levels than nonoperatory personnel.
4. Dentists who handle mercury do not show greater absorption of mercury when compared against dentists who don't handle mercury.
5. Of all personnel in the dental office, dental assistants who prepare mercury amalgams are at greatest risk with respect to mercury absorption.

Additional study is warranted regarding the impact on the health of dental workers whose urine analyses indicate absorption of abnormal amounts of mercury.

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APPENDIX

FORMS AND STUDY
QUESTIONNAIRE

MEMORANDUM

TO: FILE

Study No.: _____

RE: PRELIMINARY REPORT OF DENTAL OFFICE SURVEY FOR MERCURY

Date of Survey: _____

Survey No.: _____

Employer: _____

Address: _____
(Number) / (Street) / (City)

Telephone No.: _____

Number of Employees: _____

Type of Samples Taken: Vapor ☐ Vapor/Particulate ☐
Urine ☐

Study Conducted By: _____

Remarks: _____

cc: BOH, Berk.

Form #6

DENTAL OFFICE MERCURY SURVEY

Survey No. _____

Date _____

Name _____

Address _____

Air Conditioned ☒ Yes ☐ No

Operator Dimensions

Type of Floor Covering _____

Amalgam Preparation Procedure

Number of Amalgams Per Week

LOCATION	mg/M ³ Hg.	Temp. °F.	REMARKS
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--	--	--	--

Amalgam trap in sink ☐ Yes ☐ No

How is amalgam retrieved from sink on dental unit? _____

OCCUPATIONAL HISTORY OF EXPOSURE TO MERCURY

Sample No. _____ Study No. _____

Name _____ Age _____

Address _____

Name of Employer _____

Address of Employer _____

Present duties _____

How long have you worked at this job? _____

How many amalgams do you handle per week? _____

Did you ever work with mercury before you were
employed at your present job? (Check one) ☐ Yes ☐ No

If yes, how long? _____

Do you handle mercury in any activity other than your job? ☐ Yes ☐ No

If yes, explain _____

Do you smoke on the job? ☐ Yes ☐ NoIf yes, do you wash your hands before smoking? ☐ Yes ☐ No

Who normally cleans in areas where mercury has been used? _____

What is the present state of your health? _____

Have you had any recent illness? ☐ Yes ☐ No

If yes, explain _____

Date _____ Interviewer _____

Sample # _____

CONSENT FORM

DATE COLLECTED: _____ 1971
(Day) (Month)NAME: _____ / _____ / _____
(Please (Last) (First) (Middle)
Print)HOME ADDRESS: _____ / _____
(Number) (Street)
_____ / _____ / _____
(City) (County) (Zip)

I hereby agree to provide urine samples in conjunction with the mercury study in which I am participating. I understand that these samples are to be forwarded to the California State Department of Public Health for analysis for mercury. My signature below indicates my willingness to participate in this phase of the study by providing the required urine samples.

The Bureau of Occupational Health and Environmental Epidemiology of the California State Department of Public Health is hereby authorized to release urine mercury information to my personal physician, whose name is listed below:

NAME OF PHYSICIAN: _____ / _____
(Last) (First)
_____ / _____
(Number) (Street)
_____ / _____ / _____
(City) (State) (Zip)YOUR SIGNATURE: _____ / _____ 1971
(Day) (Month)

BOH STUDY # _____

DEPARTMENT OF PUBLIC HEALTH

Bureau of Occupational Health
& Environmental Epidemiology
1449 Temple Street, Suite 106
Los Angeles, California 90026

INSTRUCTIONS FOR COLLECTION AND
IDENTIFICATION OF URINE SAMPLES

Urine samples for mercury can be easily contaminated. Therefore, these routine instructions must be followed in order to obtain a proper, uncontaminated sample:

1. Make sure the Sample No. is the same on the three items: The Consent Form, the Questionnaire, and your sample plastic jar.
2. Write your name on the label on the plastic jar (last name first).
3. Write on the label the date when urine was collected.
4. Wash your hands with soap and water before unscrewing the lid of the sample jar.
5. Do not wipe off the bottle, but immediately screw the lid onto it. (If necessary, the bottle can be wiped dry after the lid has been tightened.)
6. Collect all urine voided during eight office hours on collection day.
7. Samples will be picked up within a day or two after collection, and will be taken to the laboratory for analysis. If practical, please refrigerate samples after collection and prior to pick up.
8. When all analyses are completed, your urine sample test result will be reported directly to you. If the result is not within normal limits, it will also be forwarded to the physician you designated on the consent form.

Please contact me at the above address if you have any questions regarding these procedures.

We sincerely appreciate your interest and help in the conduct of this study.

Sincerely,

Meier Schneider

Meier Schneider
Assoc. Industrial Hygiene Engineer

DEPARTMENT OF PUBLIC HEALTH

Bureau of Occupational Health
& Environmental Epidemiology
P.O. Box 30327, Terminal Annex
Los Angeles, California 90030
Tel.: 620-4290

Study No.:

Dear

The laboratory analysis of the urine collected from you on
, 1971 has been completed by the Public Health
Laboratory Southern California. The result shows a concentra-
tion of micrograms of mercury per liter of urine.

You did not provide us with a name of a physician to whom we
can transmit this result. We recommend, therefore, that you
contact a private physician of your choice for interpretation
of this result, and for any medical follow-up which may be
indicated.

Thank you for your participation in this Southern California
study of mercury handling by members of the dental profession.

Cordially yours,

H. P. Blejer →

Héctor P. Blejer, M.D., D.I.H.
Head, Occupational Health
Southern California

HPB:cs

DEPARTMENT OF PUBLIC HEALTH

Bureau of Occupational Health
& Environmental Epidemiology
1449 Temple Street, Suite 106
Los Angeles, California 90026

Study # _____

The laboratory analysis of the urine sample collected from you on _____, 1971, has been completed by the Public Health Laboratory Southern California.

You may be pleased to know that the results were within normal limits.

We appreciate your participation in this Southern California study of mercury handling by members of the dental profession.

Cordially yours,

H. P. Blejer

Hector P. Blejer, M.D., D.I.H.
Head, Occupational Health
Southern California

MPB:cs

DEPARTMENT OF PUBLIC HEALTH

Bureau of Occupational Health
& Environmental Epidemiology
1449 Temple Street, Suite 106
Los Angeles, California 90026

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC HEALTH
P. O. BOX 30327 TERMINAL ANNEX
LOS ANGELES, CA 90030

Study # _____

The laboratory analysis of the urine sample collected from you on _____, 1971, has been completed by the Public Health Laboratory Southern California.

The results have been forwarded to your physician as authorized by you. We recommend that you contact him for interpretation of these results.

Thank you for your participation in this Southern California study of mercury handling by members of the dental profession.

Cordially yours,

H P Blejer

Héctor P. Blejer, M.D., D.I.H.
Head, Occupational Health
Southern California

HPB:cs

cc:

DEPARTMENT OF PUBLIC HEALTH

Bureau of Occupational Health
& Environmental Epidemiology
1449 Temple Street, Suite 106
Los Angeles, California 90026

Study No.:

Patient's Name:

Dear Dr.

The Bureau of Occupational Health and Environmental Epidemiology is conducting tests in Southern California to determine the extent and nature of the hazard to dental personnel from the handling of mercury in the preparation of dental amalgams. A portion of this test program involves the analysis of urine for presence and concentration of mercury.

Your patient, noted above, has given permission to forward the results of the urine analysis to you. This patient has been advised to contact you for interpretation of the test results.

You may wish to know the levels of test results that our Bureau considers to merit medical concern. These are shown in Table I as a tentative guideline of how urine mercury levels might be interpreted. It is subject to change as new information dictates.

TABLE I

GUIDE FOR GROUPS OF WORKERS EXPOSED TO INORGANIC MERCURY

	Level of Mercury in Urine Micrograms/Liter
Normal	below 30
Increased Absorption	above 50
Warning Level	above 100
Hazardous Exposure Level--remove from further exposure	above 200
Symptoms of Poisoning May Appear	above 300

-2-

In the individual, the mercury in the urine may not be consistently proportional to the inorganic (metallic) mercury exposure by inhalation, skin absorption, or both. However, for groups of workers, the average for the group is a reliable indicator of the occupational environmental hazard. Occupational group average levels above 50 micrograms of mercury per liter of urine should arouse suspicion, and levels above 100 micrograms/liter call for correction of the faulty work situation. An individual who shows over 200 micrograms per liter on two successive tests should be removed for exposure to mercury until the level has been reduced to below 50 micrograms of mercury per liter of urine. Clinical poisoning does not usually occur with levels below 300 micrograms per liter unless kidney function is impaired.

If you have any questions regarding the enclosed results, please contact us. We appreciate your cooperation in this study.

Sincerely,

H. P. Blejer

Héctor P. Blejer, M.D., D.I.H.
Head, Occupational Health
Southern California

HPB:cs