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IAOMT SMART CERTIFICATION--

Checklist for Completing Module 1:

Mercury 101 and 102

SMART PRE-REQUISITE

- ☐ **Make sure that you print out the DISCLAIMER on page 4 of this PDF, read it, sign it, scan it, and submit it to the IAOMT office.**
Click here to go to disclaimer on page 4.

INTRODUCTION TO MODULE: MERCURY 101/102

- ☐ Take the Module 1 Pre-test. Click here to go to page 5.
- ☐ Read “The Dangerousness of Mercury Vapor” by Alfred Stock in 1926 [Translated by Birgit Calhoun]. Click here to go to pages 6-14.
- ☐ Peruse the Quick Reference Module 1 test questions.
Click here to go to pages 15-19.

REQUIRED (MANDATORY) CONTENT MODULE 1: MERCURY 101/102

- ☐ Read the “Mercury” fact sheet by the Agency for Toxic Substances and Disease Registry (ATSDR). Click here to go to pages 20-21.
- ☐ View the IAOMT online learning module “Mercury 101” at <https://iaomt.org/mercury-101-video-activity/>.
Click here to go to page 22.
- ☐ Read the “Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT. Click here to go to pages 23-56.
- ☐ View the IAOMT online learning module “Mercury 102” at <https://iaomt.org/mercury-102-video-activity/>.
Click here to go to page 57.

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- ☐ Read the “Fact Sheet: Effluent Limitations Guidelines and Standards for Dental Offices” from the United States Environmental Protection Agency about new guidelines from the EPA. The guidelines were released in December 2016 and went into effect in July 2017. Click here to go to pages 58-59.
- ☐ View the IAOMT online learning module “Dental Amalgam and the Environment” at <https://iaomt.org/mercury-environment-video-activity/>. Click here to go to page 60.

TEST FOR MODULE 1: MERCURY 101/102

- ☐ Take the Post-Test for Module 1 at <https://www.cvent.com/d/lvq3k2>
Click here to go to pages 61.

NEXT STEPS TO ACHIEVE SMART

- ☐ Continue to Module 2.
Click here to go to pages 62-183. *You still need to complete Module 2 and the post-course requirements to achieve SMART certification.*

Record of Module 1 Updates---

1/2020: IAOMT Fact Sheets (removed from Introduction since information is included in Comprehensive Review); Comprehensive Review (updated to 2019 version); Online Learning Videos for Mercury 101 and 102 (revised for new formatting); Stock 1926 (moved to Introduction); Koral Risk Assessment and Selected Abstracts (moved to Optional); Mercury Vapor Scientific Review (moved to Optional); Online Learning Video for Dental Amalgam Mercury and the Environment (moved from Unit 6 to this Unit); EPA Fact Sheet (moved from Unit 6 to this unit); Module 1 Test (revised all test questions to incorporate new materials)

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The IAOMT offers training and provides guidance and procedures for dentists and physicians to accomplish the safest possible replacement of amalgam dental fillings. Methods and techniques discussed in this program, in the opinion of this organization's leadership, enhance the safety of the health care practitioner, and his/her patients and staffs. However, it is up to the licensed practitioners to exercise their own judgment concerning the specific treatment options that should be utilized in their healthcare practices.

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PRE-TEST* FOR MODULE 1 TO BE TAKEN BEFORE STUDYING MERCURY 101 AND MERCURY 102

****This is a pre-test, and the results are for your records only.***

You are not expected to know the answers since you have not studied this material yet.

The pre-test is simply designed to assist you in recognizing some of the important information that will be presented in this unit. There is no time limit for this test.

Choose the option that BEST answers each question. Answers are provided below.

1. Dental amalgam was first introduced for common use around the year _____.
 - A. 70 BC
 - B. 1000 AD
 - C. 1820
 - D. 1990

2. Human exposure to elemental mercury is known to _____.
 - A. have 80% uptake in the lungs
 - B. cross the BBB (blood brain barrier)
 - C. have moderate uptake in the intestines
 - D. all of the above

3. Mercury exposure from fish mostly takes the form of _____.
 - A. inorganic mercury
 - B. acetyl mercury
 - C. mercury vapor
 - D. methyl mercury

4. The United Nations Environment Programme's Minamata Convention on Mercury includes a _____ on dental amalgam use.
 - A. voluntary phase down
 - B. voluntary phase out
 - C. mandatory phase out
 - D. mandatory phase down
 - E. none of the above

5. In December of 2016, the US Environmental Protection Agency (EPA) released technology-based pretreatment standards under the _____ to reduce discharges of mercury and other metals from dental offices into municipal sewage treatment plants known as publicly owned treatment works (POTWs).
 - A. Dental Pollution Act
 - B. Clean Water Act
 - C. Atomic Energy Act
 - D. none of the above

Answers: 1. C; 2. D; 3. D; 4. A; 5. B

The Dangerousness of Mercury Vapor

By Alfred Stock, Berlin-Dahlem

Kaiser-Wilhelm-Institut fuer Chemie

(Eingeg. Febr. 9, 1926)

Translated by Birgit Calhoun

When I am making the decision to report without hesitation to a wider circle about my personal problems, which ordinarily wouldn't concern others and would not be worthy of publication, I am driven by the intense desire to warn emphatically all those who have to deal with metallic mercury about the dangers of this unstable metal, and to save them from the horrible experiences which have spoiled a great part of my life. Today I can speak about them freely because luckily they have been concluded, and they are behind me with sufficient distance.

The insidious horror of mercury is not nearly sufficiently well known and is being taken note of too little in those places where one is particularly threatened by it, in chemical and physical laboratories.

For nearly 25 years I have suffered from ailments, which, in the beginning, arose only occasionally, then gradually got worse and worse and finally increased to unbearable proportions so that I disparingly doubted my ability to continue to work scientifically. The cause was understood neither by me nor many outstanding physicians. They thought that it was possible that it could be found in the especially narrow built of the nasal passages and an unusual irritability of the nasal mucosa. Because of this, I underwent decades of treatments of the nose with cauterizations, burnings, massages, electrification, and bloody operations. Without success. Two years ago--a few of my colleagues fell ill with similar symptoms--it was accidentally discovered that it had to do with an insidious poisoning by mercury vapor. In my chemical work, which involves testing of volatile substances by the "vacuum method," which uses mercury-tubs, -pumps, -manometers, and -valves¹⁾, I had been in constant contact with mercury for 25 years.

Today there is no doubt about the diagnosis any more because all my symptoms, although not gone completely, have more or less been diminished²⁾, after having avoided inhaling mercury vapors for the last two years without the use of any other healing methods.

First I am describing the difficulties as they developed in me over time. They are identical to an insidious mercury poisoning in every detail. I was able to convince myself of this through my colleagues and other peers, who suffered and still suffer from mercury vapor poisoning. Some of them, it is noted, were not cognizant of the origin of their difficulties. Many pertinent symptoms have, up to now, been insufficiently described. At any rate, insidious mercury vapor poisoning has not received the attention it deserves.

With me the situation began with slight intermittent headaches and mild drowsiness, which increased gradually, over the years, to constant nervous restlessness and "jitteriness." Head-

pressure impaired the ability to think. It worsened and finally became an almost uninterrupted vexing headache (sits mostly over the eyes). I had strong vertigo, which was occasionally connected with visual disturbances (unclear and double vision). Soon the upper air passages were involved as well. This started with a slight transient nose cold. This was followed by a constant "stuffy nose," which later turned into severe nose, throat and sinus infections. They were followed, one by one, almost without interruption, by pussy, often bloody, mucosal discharge and scabbing, frequent sore throats and ear aches connected to auditory loss and loss of smell (some sense of smell remained; e.g. cyanic acid). There was a distaste for tobacco smoke. During the last years prior to recognition of the poisoning, there were added signs: a strong flow of saliva, a sour, insipid taste in the mouth, infections of the eyes and oral mucosa. There were little blisters, sensitive and sore areas on the tongue, the palate, the gums and the insides of the lips and cheeks. There was reddening of the gums and slight bleeding while brushing the teeth. There were toothaches, receding of the gums and formation of "pockets" and temporary loosening of individual teeth. The mouth and tooth signs revealed themselves only (in part they only reached their peak months after recognition of the poisoning) because, since my youth, I have been taking good care of my teeth (among other things nightly long rinses with 1 and 1/2% hydrogen peroxyde solution and sodium bicarbonate). If this hadn't been the case, I might possibly have become aware of the cause of my problems through mouth infections.

Other signs were: Mental weariness and exhaustion, lack of inclination and inability to perform any, particularly mental, work, and increased need for sleep. There were tremors of the spread-out fingers and also sometimes the eyelids. There was pain in various locations of the body, tearing in the back and limbs, and pressure in the liver area. At times, there were disturbances of stomach and intestinal activity, loss of appetite, sudden bladder pressure, isolated bouts of diarrhea, which occurred without other possible causes. There were sudden blistering rashes, e.g. on the insides of the arms and thighs.

The most depressing accompanying sign relating to mental work was the diminishment of memory. My memory, which had previously been excellent, left more and more to be desired and became worse and worse until, two years ago, I suffered from nearly complete memory loss.

Only with the help of extensive notes and great effort was I able to put together a scientific paper or deliver a lecture. I forgot the telephone number on the way from the telephone book to the telephone. I forgot everything that I had once learned by heart. I forgot the content of the book or theater play I had just read or seen as well as my own work, which had been published. It was impossible for me to remember numbers and names. Often even the names of good acquaintances were lost. Specifically, I lost the ability for arithmetic and mathematical figuring. Also my chess playing ability suffered. The impairment of memory, particularly that of people memory and the worsening ability to do arithmetic, seem to be signs peculiar to insidious mercury vapor poisoning. This showed itself in blatant form in my co-workers and other people whom I got to know who had been under the influence of mercury for a longer period of time. Soon after all of us in the laboratory had found out what was wrong with us, we sat down together to put down on paper a completed piece of work where we had to do a lot of mathematics. None of us was able to add up columns of ten to twenty multi-digit numbers without making mistakes.

While my physical ability, e.g. mountain climbing, did not seem to have been weakened, the ability to work mentally suffered a little, although not in as devastating a fashion as had been the case with memory. Added to that were depression, and a vexing inner restlessness, which later also caused restless sleep. By nature companionable and loving life, I withdrew moodily into myself, shied away from the public, stayed away from people and social activity, and unlearned the joy in art and nature. Humor became rusty. Obstacles, which formerly I would have overlooked smilingly (and am overlooking again today), seemed insurmountable. Scientific work caused great effort. I forced myself to go to the laboratory without being able to get anything useful accomplished in spite of all efforts. Thought came laboriously and pedantically. I had to deny myself working on solutions to questions beyond the nearest tasks at hand. The lecture that used to be a pleasure became a torture. The preparations for a lecture, the writing of a dissertation, or merely a simple letter caused unending effort in styling the material and wrestling with the language. Not seldom did it happen that I misspelled words or left out letters. It was not nice to be aware of these shortcomings, not to know their cause, not to know a way to their elimination, and to have to fear further deterioration.

All attempts to improve the situation went awry. Staying in the mountains for many weeks did not help. I felt hardly less ill than in Berlin. The nose treatments and operations sometimes brought short-lived, yet never lasting relief. It was peculiar that all mental difficulties disappeared for hours when the physician treated certain areas of the mucosa of the upper nose with cocaine. When the right spot was hit, headache and vertigo disappeared sometimes in a few minutes; memory, inclination to work, and good mood reappeared, but, sadly, only as fleeting guests. Sometimes I made use of this possibility to call them up before a lecture, an important meeting etc.

As already indicated, my colleagues in the laboratory, my assistants, doctorants [PhD Candidates], and female lab workers had already suffered for some time from all kinds of problems: Fatigue without recognizable cause, worsened memory, mild headaches and drowsiness, occasional digestive disturbances, limb aches, slight mouth inflammation, nose colds [runny nose], sinusitis etc. The difficulties expressed themselves differently from person to person, whereby they came to light foremost in the areas of lowest resistance. All of them showed fatigue and diminished ability to perform mental tasks [work]. But nobody had the idea that the cause of it could be the same for all of us. Only the convergence of several lucky/unlucky circumstances finally opened our eyes.

In 1921, out of frugality, we had switched off the much more expensive power consuming electrical ventilation system of the Kaiser-Wilhelm-Institute for Chemistry. Since the middle of 1923, two of my colleagues, an assistant and a Spanish guest, were working on gas density measurements, which required maintaining a constant temperature, and for this reason kept the windows and doors closed if possible. The work had to be done by the spring of 1924 because my assistant wanted to go into industry, and the Spanish colleague wanted to return home. The work was performed hastily so that our ordinarily scrupulous cleanliness suffered in every room. Spilled mercury remained unattended, and much of it lay under tripods, in cracks and slits between the floor boards and on tables. Thus the conditions presented themselves that, instead of the slow insidious mercury poisoning, the more easily recognizable acute mercury poisoning became apparent. The assistant fell ill more seriously, not only with headaches, mental fatigue

etc., but also with stronger bodily deterioration; with tooth abscesses and such. His brother, a physician, suspected that the symptom complex pointed to mercury poisoning. The experienced poison researcher L. Lewin [Louis Lewin, 1850-1929] whom we consulted checked out all laboratory personnel and declared that, based on his experience, he was certain that all of us were suffering from mercury poisoning. Indeed the test showed (according to the procedure described in the following memorandum) mercury in the air of the workrooms as well as in the urine of all involved. The mercury content of the air in the individual rooms was quite varied: Depending on the results of the specimens it showed thousandth or hundredth of mg, i.e. only a small fraction of what the air under saturation with mercury vapor can accommodate. At room temperature, taking .001 mm mercury saturation pressure as its base value, this figures to be about 12 mg per cubic meter. Since man breathes in about 1/2 cubic meter air per hour, and the inhaled mercury apparently³⁾ is retained for the most part in the lungs, it would require a very extended period of time in mercury saturated air to suffer from acute mercury poisoning. However it takes a long time after inhaling mercury containing air before the poisoning becomes obvious. For one or more years the signs may be limited to fatigue and slow diminution of mental performance and memory. Thus the already mentioned Spanish colleague, for example, showed outward signs of inflammation of the oral cavity only at the very end of the year he stayed in our laboratory. The symptoms reached their climax months after he had left us, and after he was removed from the influence of mercury. He had noticed the mental effects much earlier without being able to explain the cause. "For me, it was," he said, "as if I was getting dumber and dumber in Germany." And I had to make similar observations with my remaining co-workers. Thus all my PhD candidates had difficulty withstanding the rigors of the doctor's exams. The PhD candidates and assistants recovered after a few years, once they had left the laboratory without being aware of the mercury poisoning. As for me, the effects of the minute amounts of mercury increased over the course of decades as described in the following narrative.

Particularly significant for insidious mercury poisoning is a noticeable coming and going of symptoms. Following a few days or weeks of improved well-being comes, sometimes setting in suddenly, a time of increased ill health. This also happens in the form of frequent relapses during the recovery period. As soon as my illness had reached its pinnacle, there were, as a rule, one or two tolerable days. Then the saliva flow, runny nose, and sinusitis, starting from the nose down to the throat and sliding down to the bronchi, increased again. There were tooth inflammations, highest fatigability and drowsiness, vexing headache, often also tearing and diarrhea. Headache, drowsiness and memory loss are connected to the irritation of the nerves leading to the upper part of the nose seen in the already mentioned effect of cocaine application on the nasal mucosa.

Apparently there are many similarities between insidious mercury poisoning and the better known lead poisoning. The [latter] is more thoroughly researched because it happens more often in industry. It, too, concerns mainly the nervous system and shows the same waxing and waning of the symptom complex⁴⁾. "After a period of health the poison can suddenly, without cause, display its effects again by evoking an attack of lead colic or other symptoms. This phenomenon can only be explained by the poison having been encapsulated for a long time in a place in the body to which, suddenly, the circulation has access again..."⁵⁾. According to F. Schuetz and H. Bernhardt⁶⁾ lead deposits itself preferably in the spleen, gall bladder, and brain, and is primarily excreted with the bile, possibly also through the colon wall. The kidneys, in this case, are less involved in the acute and chronic course of poisoning. Mercury seems to act similarly. After one

year of excluding mercury as the cause of mercury poisoning, it could not be detected in my urine, in spite of the fact that there were still very strong signs of illness. The saliva, however, still contained mercury⁷⁾.

After we had recognized the source of our illness, our first worry was how to protect ourselves from mercury in the future. The first thing, of course, was to remove carefully everything on tables, in drawers, slits, cracks and joints, and under damaged areas of the linoleum flooring, whereby a modified "vacuum cleaner" (consisting of suction connection, suction bottle with a long rubber hose in front of which was attached a cut-burner type widened glass nozzle) served us well. We had the linoleum repaired. All cracks in the work tables were eliminated. The dangerous corners between floors and the so-called scrub molding were rounded off (putty, painted with oil paint) so that they were more easily accessible for cleaning. Wherever tripods stood for a longer period of time, the joints between tripod and table tops were also closed off with putty. All open mercury surfaces on tubs, manometer holders etc. were covered as completely as possible with fit-cut cello plates. We avoided eating in the work rooms or saving food and took especially good care cleaning our hands (particularly brushing our finger nails) after handling mercury. We also paid good attention so that no mercury fell into pockets and folds of the work coats. Moreover we gave full attention to the airing out of the work rooms by testing the success with air analyses (Compare the following memorandum). It was soon apparent that the reinstallation of the strong house ventilation system (very strong ventilators in the attic suck the air out through hoods; fresh air enters from channels through flaps above the doors) was not nearly sufficient enough to make the air mercury free. The situation in our laboratory is inopportune in that we are working with particularly many mercury apparatuses whereby open mercury surfaces and occasional sprinkling of mercury is not altogether avoidable. An added factor is that the work rooms in the very modern and well-built and furnished Kaiser-Wilhelm-Institut for Chemistry are so large (several hundred cubic meters air space) that the air does not get renewed fast enough by the ventilation system. In this regard smaller rooms may be advantageous because, naturally, the same ventilation works better and causes faster replacement of the air⁸⁾. Sufficiently airing ventilation, in this case, as it turned out, is obtainable only through constantly opening windows and creating a draft (regulated by temperature, windspeed, and - direction). At the same time the ventilation system is at work. Because it rests at night, the laboratory is being supplied with fresh air through opening the windows wide. This measure is repeated at noon. Thus we have succeeded in keeping the laboratory air so clean that traces are detectable only in small quantities, and we can continue working with our mercury apparatuses without having to fear new health problems.

Whenever one deals with mercury one should devote great care to the testing and cleanliness of the air. One should check the airstream situation in the work space⁹⁾ and provide for as much fresh air as possible. It goes without saying that all work with mercury, if at all possible, should be performed under hoods¹⁰⁾. That is the only way that protects from damage with certainty. These precautions are necessary even if one has to choose the path through the Scylla of mercury poisoning and the Charybdis of a cold. A chemical removal of mercury cannot be obtained according to our experiences. It had been suggested to distribute sulfur powder or zinc dust in the work place. We also tried large foil flags that were hung in long rows from the ceiling. Although tin foil amalgamates quickly if you put it into a closed container next to mercury, it failed in this case: The mercury content in the air did not lessen noticeably; one tin flag (33 X 100cm area;

weighing 57g), which had hung for 11 months over a mercury apparatus, was weighed afterwards. It contained only .005 mg mercury.

The recovery from insidious mercury poisoning, after the removal of the poison source, takes place very slowly. Professor Lewin predicted this, and the development of our wellbeing confirmed this. The time period is visibly connected to the duration of the poisoning, and possibly also to how old you are. My co-workers who had left the laboratory were, thankfully, rid of their problems in the course of 1 - 2 years and have fully recovered the freshness of their thinking ability and memory. Nevertheless, even they had to suffer for a long time from relapses not only of mental but also of physical nature (particularly mouth inflammation). Some assistants and female lab workers continued to work here where they, unfortunately, cannot operate without mercury. Even today, after two years, they are still suffering from clearly visible, but steadily diminishing, after-effects of the poisoning. As for me, who was exposed to the damaging influences for over 20 years, the recovery apparently is taking the longest. All in all, I recovered the ability to work. I had only occasional relapses (headaches, drowsiness and mild mouth inflammation). Considering the course of the recovery up to now, I do not doubt, however, that my last co-workers and I will lose our symptoms completely. It seems that you have to count on it to take years to excrete the mercury again that took years to build up in the body. In this regard the following case has been educational to me recently, which at the same time proves that it is irrelevant for the course of insidious mercury poisoning whether the poison gets into the body via the lungs or through the skin¹¹⁾

A medical assistant who had applied mercury salve therapy on his patients fell ill in 1905 with those symptoms (moodiness, headache, vertigo), which gradually got worse (fatigue, unbearable headache, oral inflammation, loosening and loss of teeth, constant runny nose, sinusitis, sore throat, ringing in the ears, hearing and vision disturbances). Only in 1911 was the situation recognized as mercury poisoning. The man stopped applying the salve therapy, but still needed many years before he lost his symptoms. After 1914, when he went to war he suffered from headaches and drowsiness. Today as a fifty-five-year-old he is again the picture of health and quite youthful.

It seems that an existing mercury intoxication preconditions a special sensitivity vis-a-vis renewed exposure from mercury vapor. Some of us who, at our work, and also during occasional mistakes with ventilation, had come in contact again with more mercury, noticed this soon because of the stronger symptomatology after the relapses. That is not surprising because, as the long development period of the insidious illness shows, a certain borderline value has to be reached before noticeable symptoms appear. The borderline value is certainly exceeded for a long time, even during recovery, so that each added amount of mercury worsens your wellbeing at once.

On doctor's orders we tried to hasten the recovery in various ways through use of diuretics and emetics, through hot baths and prolonged use of small amounts of sodium iodide. I do not get the impression that healing was particularly accelerated. The iodide has the reputation of bringing the metal into soluble form from insoluble organic mercury compounds. This is the form in which the mercury is probably anchored in the body. As far as I am concerned, there was no proof that significantly more mercury was excreted after addition of iodide. No progress was to

be expected from diuretics, as already mentioned, since the mercury excretion in the urine had stopped relatively soon altogether. The healing arts are sadly lacking in medicines that detoxify mercury in the body ¹²⁾.

Exercise in fresh air is still best suited to make the subjective symptoms less noticeable. With milder headaches and vertigo Novalgin has been proven worthwhile as a palliative. All in all, it has to be left to time to become master over this destroyer of peace. For me even a four-week long stay in the high mountains and an ocean voyage to southerly latitudes brought hardly any progress, (which normally occurs with unaffected people), although, naturally, the mental relaxation helped the nerves.

Why were our illnesses not recognized sooner as being mercury poisoning? I have often asked myself this question, not without self-accusations. The first signs, those that preceded the oral signs of slow mercury poisoning, are hardly known by the medical profession.¹³⁾ They consist only of fatigue, lowering of thinking and memory skills, slight headaches and drowsiness and rare occasional diarrhea. In the same way, it was little known until now that the nose and remaining breathing passages are being compromised in the form of a runny nose and sinusitis. But exactly these symptoms brought me and the physicians who treated me on the wrong track, and have been misleading in other cases that I have come to know about. Thus one of my assistants was treated for a long time for a sinus infection before the true cause came to light. By the way, balanced judgment of the bad situation becomes impaired in those who are affected exactly because of the existing drowsiness: "Quem Mercurius perdere vult, dementat prius!" [Whom Mercury wants to destroy, he first robs of his mind!]

At this time I would like to warn about a little known source of insidious mercury poisoning: It is amalgam tooth fillings. Professor Lewin suggested to me at once, when he noticed mercury poisoning in me, to replace all amalgam fillings--of which I had a considerable number in my mouth since early youth--with other fillings. Telling me this, he recalled a case of a university colleague who was at the edge of mental and physical collapse when the cause was found just in time. It was found in the numerous amalgam fillings stemming from the time when he was young. After their removal slow recovery followed.¹⁴⁾

Dentists used to prefer copper and cadmium amalgams and now often use the so-called silver amalgams for tooth fillings because these amalgams are easy to work with and fill out the cavities well. Silver amalgam is superior to the earlier named amalgams, which corrode and rot over time. However it, too, releases mercury at room temperature as the following assays¹⁵⁾ proved to us:

We enclosed silver amalgam samples in an evacuated glass tube, which was bent [in the middle] at a ninety-degree angle with the ends melted shut. The horizontal tube shank with the amalgam piece was kept warm at 30-35 degrees C; the other shank serving as a receptacle, was cooled with ice or liquid air. We then measured the mercury that had sublimated in the receptacle in all cases.

I. Amalgam piece carefully made for this purpose by dentist in the state-of-the-art method from metal powder and mercury: .801 g. Enclosed by melting into glass tube 24 hours after manufacture. Warmed [30-35 degrees] for 23 days. Receptacle in ice. Distilled mercury = 11.2 mg

II. Same as above: .810 g. Kept for three weeks to make hardening as complete as possible. Only after that period of time was it enclosed by melting into glass tube. Warmed [30-35 degrees] for 12 days. Receptacle in liquid air. Distilled mercury = 15.3 mg

III. Amalgam piece made by taking care using as little mercury as possible: 1.000 g. As in II was kept in the open for three weeks. Warmed [30-35 degrees] for 9 days. Receptacle in ice. Distilled mercury = 8.2 mg

IV. Amalgam filling, which had been in a tooth for years and had fallen out: .894 g. Warmed [30-35 degrees] for 14 days. Receptacle in liquid air. Distilled mercury = 29.4 mg

Without doubt, the fillings that were used here in the laboratory would have allowed mercury to evaporate from the mouth as well and supplied the inhaled air with a small amount of mercury, which, in the long run, has to be harmful. The old copper and cadmium amalgams are likely to be even more harmful.

For some time, one of my faculty colleagues had been suffering from occasional headaches and drowsiness the cause of which he couldn't explain. After he had an old amalgam filling removed, which had caused a slight infection near the tooth in question, his symptoms disappeared gradually. After its removal the filling showed itself as crumbly and laced with mercury droplets, throughout.

Dental medicine should do without the application of amalgam as means for filling teeth altogether or, at least, wherever at all possible. There is no doubt that many complaints such as fatigue, memory weakness, oral inflammation, diarrhea, lack of appetite, chronic runny nose and sinusitis are sometimes caused by mercury that has been directed to the body from amalgam fillings, maybe only in small quantities, but constantly. The physicians should give this fact the most serious attention. Then it will probably become apparent that the frivolous introduction of amalgams as tooth filling device was a nasty sin against humanity.

Insidious mercury poisonings are certainly much more common than ordinarily thought. This is true particularly for chemists and physicists who so often have to work with it. The great danger here is being noted much too little, and the true cause of symptoms and illness is often not recognized. In literature you find almost nothing about this.¹⁶⁾ Since the discovery of our misfortune I have found out about a dozen certain cases of insidious mercury poisoning, just in the circle of my acquaintances. They almost always have the same symptoms. Often the correct cause was missed and therefore the correct treatment was missed as well. An important example is that of a foreign colleague who had been working with mercury apparatus' for a long time. When he visited me and I asked him whether he had ever felt any mercury poisoning, he decidedly said that he had not. Upon further questioning about his health he then admitted: "I am in bad shape. For years I have been suffering from neurasthenia and had to stay away from the

laboratory from time to time." The doctors had tried all kinds of things with him. They had treated him for stomach, intestinal, and ribcage disease with a special diet etc. In reality what he had been dealing with was full-blown mercury poisoning without doubt.

One unknowing victim of mercury poisoning has probably been Faraday. In the last two to three decades of his life, which came to an end in his late seventies, he was bothered increasingly by health problems, which made his scientific work more and more difficult, and which played a significant role in his letters and descriptions of his life. They were diagnosed by physicians as neurasthenia and early onset arteriosclerosis. They consisted of, at times, strong mental and physical fatigue, "irritable weakness," headaches, vertigo, "rheumatism" and, more than anything else, constant increasing memory loss.¹⁷⁾

Faraday, being spared serious "bodily" illnesses, was even in old age a strong hiker and swimmer. But he avoided people for the last third of his life. Scientific work, including his lectures, were continued with long interruptions into the last decade of his life. It is heart rending to read in the great researcher's letters that he went to see his physician friend so often to complain to him about vertigo and headache, that he couldn't remember names, that he was losing the connections with his colleagues, that he was forgetting his own work and notes, that he was forgetting his letter writing, and that he didn't know any more how to write words. "The affected organ is my head. The result is loss of memory and clarity and vertigo." All these symptoms make it most likely that Faraday suffered from an insidious mercury poisoning from the vapors used in the laboratory. It makes you shudder to think how, in all likelihood, this rich intellect could have been freed from this suffering, and what gifts he could have given to science if the cause of his illness could have been recognized and remedied.

Maybe--Professor Jaensch (Marburg) brings this to my attention--the mysterious sickness the mathematician, physicist, and philosopher, Blaise Pascal (1623-1661), succumbed to when he was still young was mercury poisoning. Pascal worked with mercury in his well-known barometer research. His suffering from sustained headaches, vertigo, toothache, loss of appetite, and lasting bad colic complete the picture of advanced slow mercury poisoning.

No doubt mercury, the use of which sadly cannot be done away with in research, has done heavy damage to science in the past as it still does today in the way it curtailed the output of many a researcher. May this present-day warning help us pay better attention and avoid the dangers of this insidious metal.

Please view the bibliography in the original article at
<http://www.amalgam-informationen.de/stock2.html>

**TEST QUESTIONS FOR
QUICK REFERENCE
SMART MODULE 1:
MERCURY 101 and 102**

*THIS IS A PRINTABLE TEST FOR QUICK REFERENCE, AS SOME CANDIDATES
PREFER TO PREFER TO PREPARE ANSWERS WHILE THEY COMPLETE EACH
COMPONENT OF THE MODULE. TO ACHIEVE CREDIT FOR THIS TEST,
IT MUST BE TAKEN AFTER YOU HAVE COMPLETED MODULE 1 AT
<https://www.cvent.com/d/lvq3k2>*

“Mercury Fact Sheet” by the Agency for Toxic Substances and Disease Registry:

1. According to the ATSDR document, there is not enough evidence to state that mercury can cause cancer in humans.
- A. True
 - B. False

“Mercury 101” Online Learning Module:

2. In the 1850's dentists were divided over the use of mercury. The amalgam technique continued to be used despite its known dangers because_____.
- A. it was cheaper.
 - B. it caused less sensitivity.
 - C. it looked better.
 - D. the color silver was a status symbol at the time.

“Mercury 101” Online Learning Module:

3. In the 1920's, an accidental spill in his lab led chemist Alfred Stock to define which condition/s?
- A. renal insufficiency
 - B. erythemanodosum
 - C. micromercurialism
 - D. none of the above

“Mercury 101” Online Learning Module:

4. Mercury is the only metal that is_____at room temperature.
- A. metamorphic
 - B. pleomorphic
 - C. endomorphic
 - D. liquid

“Mercury 101” Online Learning Module:

5. Mercury binds most tightly to which element, so critical for enzyme function?
- A. manganese
 - B. fluoride
 - C. silver
 - D. sulfur

“Mercury 101” Online Learning Module:

6. What level of mercury exposure is accepted as safe for human health?

- A. 100 mg per kg
- B. 10 mg per kg
- C. 1.0 mg per kg
- D. 0.1 mg per kg
- E. no known safe level

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

7. Research has shown that amalgam fillings contribute to notable mercury levels in saliva, urine, and feces, and patients with dental amalgam excrete more than ten times more mercury in their feces than those without mercury fillings.

- A. True
- B. False

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

8. The output of mercury vapor from dental amalgam can be intensified by_____.

- A. the number of fillings
- B. chewing
- C. teeth-grinding
- D. the consumption of hot liquids
- E. all of the above

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

9. In addition to genetic predisposition and metal allergies,_____can play a role in each person’s unique response to mercury.

- A. gender
- B. dental plaque
- C. exposure to lead
- D. consumption of milk or alcohol
- E. all of the above

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

10. According to a scientific researcher interviewed in a 2016 news article by McClatchy’s Greg Gordon, as many as_____people have genetic variants associated with adverse neurobehavioral effects from dental mercury.

- A. 1-5%
- B. 10-20%
- C. 25-50%
- D. 80-90%

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

11. Metal-induced inflammation has been linked to autoimmune diseases including chronic fatigue syndrome and multiple sclerosis.

- A. True
- B. False

“Comprehensive Review of the Toxic Effects of Mercury in Dental Amalgam Fillings on the Environment and Human Health” by the IAOMT:

12. A series of recent studies continues to prove that although composite resin fillings are considered less of a risk for chemical exposures, they are not as durable as amalgam fillings.

- A. True
- B. False

“Mercury 102” Online Learning Module:

13. Three classic papers from the 1970s and 1980s document how much more mercury vapor is found in the mouths of people with amalgam fillings as compared to people without fillings.

- A. True
- B. False

“Mercury 102” Online Learning Module:

14. In 1991 the World Health Organization published a graph, which shows that when mercury amalgam was the predominant dental filling material, people were being exposed to mercury far more by _____ than any other source.

- A. fluorescent light bulbs
- B. dental fillings
- C. tuna
- D. coal-fired power plants

“Mercury 102” Online Learning Module:

15. _____ were published in the *Journal of the American Medical Association* in 2006 and extensively publicized throughout the dental world. Initially, these two studies were used as proof that mercury amalgams were safe; however, researchers have since refuted this claim with new perspectives.

- A. A series of studies by the Geiers
- B. Extensive papers by Alfred Stock
- C. The Children’s Amalgam Trials
- D. A sheep study and a monkey study

“Mercury 102” Online Learning Module:

16. CPOX-4 is an example of _____ reported upon in the scientific literature.
- A. a novel approach to heavy metal chelation
 - B. a common genetic variant that reduces absorption of mercury
 - C. a common genetic variant that increases susceptibility to mercury toxicity
 - D. an immunofluorescent test for mercury in the blood

“Mercury 102” Online Learning Module:

17. Research is also demonstrating that _____, which has long been associated with an increased risk of early onset Alzheimer's disease, has a clear connection to the neurotoxic effects of mercury.
- A. Melanocortin 1 Receptor
 - B. GABRA1 gene
 - C. AZt6 variant
 - D. Apolipoprotein E4
 - E. None of the above

“Fact Sheet: Effluent Limitations Guidelines and Standards for Dental Offices” by EPA:

18. According the EPA, dental offices which discharge mercury and other metals present in amalgam used for fillings are the main source of mercury discharges to POTWs.
- A. True
 - B. False

“Fact Sheet: Effluent Limitations Guidelines and Standards for Dental Offices” by EPA:

19. The EPA expects compliance with its final rule for effluent limitations for dental offices will reduce the discharge of metals to publicly owned treatment works by at least _____ tons per year, about half of which is mercury.
- A. 1.2
 - B. 10.2
 - C. 100
 - D. 1000

“Fact Sheet: Effluent Limitations Guidelines and Standards for Dental Offices” by EPA:

20. In the EPA’s rule, dental offices that place or remove amalgam must _____.
- A. operate and maintain an amalgam separator
 - B. must not discharge scrap amalgam or use certain kinds of line cleaners
 - C. must also submit a One-Time Compliance Report
 - D. A & B only
 - E. all of the above

“Dental Amalgam and the Environment” Online Learning Module:

21. _____ was the site of a mass mercury poisoning incident in the 1950s, and the United Nations Environment Programme named its treaty to reduce global mercury emissions after the locale.

- A. Tokyo
- B. Minamata
- C. Iran
- D. None of the above

“Dental Amalgam and the Environment” Online Learning Module:

22. The US Environmental Protection Agency has taken major steps to reduce mercury releases from ____.

- A. crematoria and antique dealers
- B. battery operated tools and power cords
- C. dental offices and artisanal gold mining
- D. B & C
- E. none of the above

“Dental Amalgam and the Environment” Online Learning Module:

23. Mercury concentrations in the world’s oceans are expected to rise even if anthropogenic mercury emissions are stopped due to a lag time that varies from decades to centuries.

- A. True
- B. False

“Dental Amalgam and the Environment” Online Learning Module:

24. Mercury in seafood has led to the FDA and EPA issuing advisories not to eat certain types of fish.

- A. True
- B. False

“Dental Amalgam and the Environment” Online Learning Module:

25. When choosing an amalgam separator, it is important for a dentist to consider _____.

- A. the size of the practice, and how many chairs will be removing amalgam at a time
- B. how often will the separator will need to be changed, and what the exposure risk will be when it needs to be changed
- C. research on the efficiency of amalgam separators
- D. all of the above

TO ACHIEVE CREDIT FOR THIS TEST, IT MUST BE TAKEN AFTER YOU HAVE COMPLETED MODULE 1 AT <https://www.cvent.com/d/lvq3k2>

This fact sheet answers the most frequently asked health questions (FAQs) about mercury. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Exposure to mercury occurs from breathing contaminated air, ingesting contaminated water and food, and having dental and medical treatments. Mercury, at high levels, may damage the brain, kidneys, and developing fetus. This chemical has been found in at least 714 of 1,467 National Priorities List sites identified by the Environmental Protection Agency.

What is mercury?

(Pronounced mŭr'kyə-rē)

Mercury is a naturally occurring metal which has several forms. The metallic mercury is a shiny, silver-white, odorless liquid. If heated, it is a colorless, odorless gas.

Mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or "salts," which are usually white powders or crystals. Mercury also combines with carbon to make organic mercury compounds. The most common one, methylmercury, is produced mainly by microscopic organisms in the water and soil. More mercury in the environment can increase the amounts of methylmercury that these small organisms make.

Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings, and batteries. Mercury salts are sometimes used in skin lightening creams and as antiseptic creams and ointments.

What happens to mercury when it enters the environment?

- ☐ Inorganic mercury (metallic mercury and inorganic mercury compounds) enters the air from mining ore deposits, burning coal and waste, and from manufacturing plants.
- ☐ It enters the water or soil from natural deposits, disposal of wastes, and volcanic activity.

- ☐ Methylmercury may be formed in water and soil by small organisms called bacteria.
- ☐ Methylmercury builds up in the tissues of fish. Larger and older fish tend to have the highest levels of mercury.

How might I be exposed to mercury?

- ☐ Eating fish or shellfish contaminated with methylmercury.
- ☐ Breathing vapors in air from spills, incinerators, and industries that burn mercury-containing fuels.
- ☐ Release of mercury from dental work and medical treatments.
- ☐ Breathing contaminated workplace air or skin contact during use in the workplace (dental, health services, chemical, and other industries that use mercury).
- ☐ Practicing rituals that include mercury.

How can mercury affect my health?

The nervous system is very sensitive to all forms of mercury. Methylmercury and metallic mercury vapors are more harmful than other forms, because more mercury in these forms reaches the brain. Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems.

Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea,

ToxFAQs Internet address via WWW is <http://www.atsdr.cdc.gov/toxfaq.html>

vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.

How likely is mercury to cause cancer?

There are inadequate human cancer data available for all forms of mercury. Mercuric chloride has caused increases in several types of tumors in rats and mice, and methylmercury has caused kidney tumors in male mice. The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens.

How can mercury affect children?

Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there. It can also can pass to a nursing infant through breast milk. However, the benefits of breast feeding may be greater than the possible adverse effects of mercury in breast milk.

Mercury's harmful effects that may be passed from the mother to the fetus include brain damage, mental retardation, incoordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage.

How can families reduce the risk of exposure to mercury?

Carefully handle and dispose of products that contain mercury, such as thermometers or fluorescent light bulbs. Do not vacuum up spilled mercury, because it will vaporize and increase exposure. If a large amount of mercury has been spilled, contact your health department. Teach children not to play with shiny, silver liquids.

Properly dispose of older medicines that contain mercury. Keep all mercury-containing medicines away from children.

Pregnant women and children should keep away from

rooms where liquid mercury has been used.

Learn about wildlife and fish advisories in your area from your public health or natural resources department.

Is there a medical test to show whether I've been exposed to mercury?

Tests are available to measure mercury levels in the body. Blood or urine samples are used to test for exposure to metallic mercury and to inorganic forms of mercury. Mercury in whole blood or in scalp hair is measured to determine exposure to methylmercury. Your doctor can take samples and send them to a testing laboratory.

Has the federal government made recommendations to protect human health?

The EPA has set a limit of 2 parts of mercury per billion parts of drinking water (2 ppb).

The Food and Drug Administration (FDA) has set a maximum permissible level of 1 part of methylmercury in a million parts of seafood (1 ppm).

The Occupational Safety and Health Administration (OSHA) has set limits of 0.1 milligram of organic mercury per cubic meter of workplace air (0.1 mg/m³) and 0.05 mg/m³ of metallic mercury vapor for 8-hour shifts and 40-hour work weeks.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is <http://www.atsdr.cdc.gov/toxfaq.html> ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.



YOU NOW NEED TO ACCESS THE IAOMT'S
"MERCURY 101" VIDEO ACTIVITY AT
<https://iaomt.org/mercury-101-video-activity/>

Be sure to complete the pre-activity survey, read the references and selected literature, and take the post-activity survey.

UPON COMPLETION OF THE "MERCURY 101"
VIDEO ACTIVITY, YOU WILL NEED TO
CONTINUE WITH THE ADDITIONAL
REQUIREMENTS FOR MODULE 1.

A COMPREHENSIVE REVIEW OF THE TOXIC EFFECTS OF MERCURY IN DENTAL AMALGAM FILLINGS ON THE ENVIRONMENT AND HUMAN HEALTH

The International Academy of Oral Medicine and Toxicology

October 2019 Update



About the IAOMT:

Representing a network of over 1,000 dentists, physicians, and other health professionals in more than 30 countries, the International Academy of Oral Medicine and Toxicology (IAOMT) has been researching the risks of dental mercury since our non-profit organization was founded in 1984. Our members have been expert witnesses for government bodies and health agencies around the world. We are an accredited member of the United Nations Environment Programme (UNEP)'s Global Mercury Partnership and were involved in the negotiations leading to UNEP's Minamata Convention on Mercury.

Brief Overview of Mercury Used in Dentistry:

Millions of dentists around the world routinely use dental amalgam as a filling material in decayed teeth. Often referred to as “silver fillings,” all dental amalgams actually consist of 45-55% metallic mercury.¹ Mercury is a neurotoxin that can cause harm to humans, especially children, pregnant women, and fetuses. Furthermore, the use of dental amalgam results in substantial quantities of toxic mercury released annually into the environment. Once in the environment, mercury pollution damages animals, plants, and the entire ecosystem, while creating “hotspots that last for centuries.”²

According to the United States Environmental Protection Agency (EPA), there are currently over 1,000 tons of mercury in the mouths of Americans, which is more than half of all the mercury being used in the U.S. today.³ While amalgams are currently used for 45% of all direct dental restorations worldwide,⁴ articles published in the *Journal of the American Dental Association* have established that these mercury fillings are used on 51.0% of White/Caucasian Americans, on 53.4% of Black/African Americans, on 72.9% of American Indians/Alaska Natives/Asians/Pacific Islanders,⁵ and on more than 75% of posterior restorations for new recruits to the U.S. Navy and Marines.⁶



Many people do not realize that all silver-colored dental fillings contain approximately 50% mercury.

Controversy has surrounded the use of mercury in dentistry since the 1800's, when the hazardous material was first widely introduced as a filling component. The American Society of Dental Surgeons, the predecessor to the American Dental Association (ADA), made its members pledge not to use mercury because of its known toxicity,⁷ and in more recent years, government officials, scientists, dentists, consumers, and many others have raised serious concerns about the threats dental mercury poses to humans and to the environment at large.

In 2013, the United Nations Environment Programme (UNEP)'s Intercessional Negotiating Committee formalized a global, legally-binding mercury treaty, which has now been signed by over 100 countries, including the U.S. Part of UNEP's “Minamata Convention on Mercury” text includes initiatives with regards to dental mercury amalgam such as setting national objectives aimed at minimizing its use, promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration, discouraging insurance policies that favor dental amalgam use over mercury-free dental restoration, and promoting the use of best environmental practices in dental facilities to reduce releases of mercury and its compounds to water and land.⁸

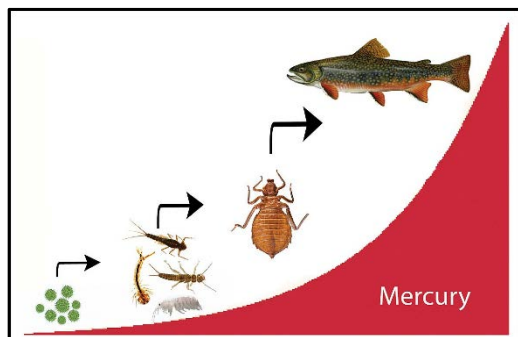
A number of countries have taken action against the use of dental mercury amalgam fillings. In Norway and Sweden, dental amalgam is no longer in use.⁹ Bangladesh, the Czech Republic, Finland, Ireland, Nepal, and Slovakia are phasing it out.^{10 11 12} Denmark uses dental amalgam for only 5% of restorations, and Germany for about 10%.¹³ The government of Canada has recommended that dentists not use amalgam for children, pregnant women, and persons with kidney disorders.¹⁴

As part of the Minamata Convention on Mercury, the European Parliament voted in March 2017 to reduce dental mercury use. In addition to reporting “on the feasibility of a phase out of the use of dental amalgam in the long term, and preferably by 2030,”¹⁵ the new European Union regulation qualifies that dental amalgam not be used for children under 15 years and pregnant or breastfeeding women.

In spite of this international action, the U.S. Food and Drug Administration (FDA) “considers dental amalgam fillings safe for adults and children ages 6 and above.”¹⁶ However, details in the FDA’s public statements about dental amalgam on its website have changed over the years, including information about amalgam’s potentially harmful impact on pregnant women, fetuses, and children under the age of six. Due in part to concerns about this lack of protection, the IAOMT filed a lawsuit in 2014 against the FDA over its classification of dental mercury amalgam.¹⁷ As part of the case, the IAOMT secured an internal FDA document proposing to restrict dental mercury amalgam use in pregnant and nursing women and children under the age of six, as well as individuals with mercury allergies and pre-existing kidney or neurological disease.¹⁸ Yet, allegedly for administrative reasons, the FDA communication (dated January 2012) was never released to the public.

Meanwhile, scientific studies continue to demonstrate that the mercury used in dentistry poses serious risks to the environment and public health.

Dental Amalgam Pollutes the Environment in a Variety of Ways:



This graphic from the National Park Service shows how mercury levels increase exponentially up the food web as larger species eat smaller ones and “bioaccumulate” the mercury. Most fish advisories, which warn people to limit or avoid eating certain types of fish, are due to dangerous mercury levels.

Some 340 tonnes of mercury is used per year in dentistry, of which about 70-100 tonnes (i.e. 20- 30%) likely enters the solid waste stream.¹⁹
*--United Nations Environment Programme (UNEP),
Global Mercury Assessment, 2013*

1) Wastewater from Dental Offices

After mercury is released into the environment, it can contaminate the food web and harm wildlife in the area for multiple generations. According to the United States Geological Survey, in 2010, dental amalgam was the leading end-use sector of mercury in the U.S.²⁰ The use of mercury for dental amalgam in the U.S. has been estimated at 35.2 tons/year,²¹ and the discharge per dentist is an average of 250 milligrams/day (for an equivalent of 12 tons collectively released to the environment each year).²² For example, a 2002 New York Academy of Sciences report found over 40% of the mercury entering the New York/New Jersey harbor through wastewater was the result of discharges from dental offices.²³

Additionally, in a 2014 document, the EPA recognized that “dental offices are the largest source of mercury discharges to POTWs [publicly-owned treatment works], contributing about half of the mercury received by POTWs.”²⁴ This is dangerous because wastewater treatment facilities are designed to process human waste, not heavy metals. Thus, the mercury from dental discharges is separated out into sludge or biosolids.²⁵ The sludge is usually incinerated, which releases mercury pollution into the atmosphere,²⁶ and the biosolids are often used as fertilizer, which contaminates soil with mercury.²⁷

“Human waste is second only to direct release from dental offices as a contributor of dental mercury to wastewater plants (AMSA 2001).”²⁸

*--Cited in Letter to the Editor by Larose & Basciano (IAOMT),
Journal of Dental Research, 2008*

2) Human Waste

Research has shown that amalgam fillings contribute to notable mercury levels in saliva, urine, and feces, and patients with dental amalgam excrete more than ten times more mercury in their feces than those without mercury fillings.²⁹ Based on figures provided in scientific studies, the IAOMT has estimated that in the U.S., this amounts to over eight tons of mercury being flushed out to sewers, streams, and lakes per year.³⁰ The same types of calculations were derived in Sweden in 1994, when researchers suggested that 100 kilograms (over 220 pounds) of mercury was being released to their country’s environment annually as a result of dental mercury excretion in feces and urine.³¹

Considering that dental mercury is released in feces and urine,³² and methylmercury (such as that taken in from fish consumption), is also released in feces and urine,³³ the impact of human waste containing various forms of mercury is a pertinent factor in water pollution.



Human waste from people with dental amalgam mercury fillings is another route of mercury pollution, especially because treatment works cannot remove all of the mercury.

“Amalgam fillings not replaced before death will cause emissions to air, soil, and water upon cremation or burial.”³⁴

--Hylander & Goodsite, Science of the Total Environment, 2006

3) Cremation and Burial



Rates of cremations are expected to rise over the next several decades, which means that the levels of mercury released into the atmosphere from corpses with dental amalgam fillings will also continue to increase.

A 2013 assessment on mercury from UNEP reported: “Global emissions from use of mercury in dental amalgam resulting from cremation of human remains are estimated at 3.6 (0.9 – 11.9) tonnes in 2010.”³⁵ With this consequential amount of mercury being released, it is apparent that cremation of bodies with amalgam fillings adds to air emissions and deposition onto land and into waterways. To illustrate this point, in 1992, the IAOMT applied scientific data to calculate that the cremation of 320,372 bodies in the U.S. during the preceding year added an estimated 2,800 pounds of mercury emissions into the atmosphere.³⁶

Austria, Belgium, Germany, the Netherlands, Norway, Sweden, and Switzerland have applied measures to reduce mercury pollution from cremations.³⁷ Although legislation has yet to be passed in the U.S.,³⁸ Colorado, Maine, Minnesota, and Vermont have attempted to achieve regulations that would make removing amalgam fillings before cremation mandatory.³⁹ Meanwhile, citizens in the U.S. have fought crematoriums in their neighborhoods by filing lawsuits⁴⁰ and initiating protests.⁴¹

A variety of trends suggest that mercury releases from amalgam fillings in crematoriums will continue to increase.^{42 43} However, one alternative to cremation is a traditional burial, but burying an individual with amalgam fillings means that the mercury is deposited directly into the soil. This means that whether a person is cremated or buried, the mercury is released back to the environment.⁴⁴

“Hg [mercury] vapor release to the atmosphere from dental vacuums can be substantial and can exceed human exposure limits.”⁴⁵

--Stone, Cohen, & Debban, Naval Institute for Dental and Biomedical Research, 2007

4) Mercury Vapor

In offices with air/water separator tanks as part of the central vacuum system, mercury vapor has been found in air vented to the *outside* of the dental office.^{46 47} Dr. Paul G. Rubin of IAOMT has explained: “This mercury-containing material is discharged into waste streams via the dental office vacuum-pump system. This system also discharges large quantities of air, either into the atmosphere exterior to the office building or into the sewer system, depending on the type of equipment used.”⁴⁸

Indoor air can also be dangerously polluted as a result of dental mercury. A study published in 2014 comparing air measurements at 42 dental sites in 17 countries found that mercury levels at most of the clinics were above safe limits. Their comparison included ten sites in the U.S., eight of which reportedly had levels higher than the EPA reference concentration in air. The authors noted that one of the two sites in the U.S. with mercury levels *below* the EPA reference level was from an office that had not placed mercury fillings in 20 years.

Amalgam Separators Can Reduce Dental Mercury Releases to the Environment:

Amalgam separators can successfully reduce the amount of mercury discharge in wastewater from dental offices^{49 50 51 52 53 54 55 56 57 58 59 60 61} with reported capture efficiency rates ranging between 95-99%.⁶² Recently, the U.S. Environmental Protection Agency (EPA) utilized measures in the Clean Water Act to develop standards for dental offices/clinics to use amalgam separators so that dental mercury is not flushed down the drain and into the environment.⁶³ EPA estimates about 103,000 dental offices use or remove amalgam in the U.S. and that almost all of these send their wastewater to POTWs [publicly owned treatment works].⁶⁴ The new guidelines went into effect in July 2017, and the EPA has estimated that these new measures could reduce dental discharges of mercury by 5.1 tons annually.⁶⁵

However, even with required standards, there should be enforced maintenance requirements for amalgam separators, as the Royal College of Dental Surgeons has done in Ontario, Canada.⁶⁶ It must also be remembered that amalgam separators only contribute to solving the problem of dental mercury in wastewater and not the additional burdens placed by amalgam fillings on the environment and human health.

Human Health Risks of Dental Amalgam Mercury:

Mercury particulate can be discharged from dental amalgam fillings, and mercury vapor is continuously emitted from dental mercury amalgam fillings,^{67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92}

which means that people are directly exposed to mercury as a result of their dental mercury amalgam fillings. The output of mercury is intensified by the number of amalgam fillings in the mouth^{93 94 95 96 97 98 99 100 101} and/or the number of amalgam surfaces in the mouth,^{102 103 104 105 106 107 108 109 110 111 112 113} the type of the amalgam filling (i.e. specific content of metals),^{114 115} and other factors such as chewing, teeth-grinding, brushing, dental treatments and procedures, and the consumption of hot liquids.^{116 117 118 119 120}

^{121 122 123 124 125 126 127 128 129 130 131 132 133 134 135} Mercury is also known to be released during the placement, replacement, and removal of dental mercury amalgam fillings.^{136 137 138 139 140 141 142 143 144 145 146 147 148 149 150}

NOTICE TO PATIENTS

PROPOSITION 65 WARNING: Dental Amalgam, used in many dental fillings, causes exposure to mercury, a chemical known to the state of California to cause birth defects or other reproductive harm.

Root canal treatments and restorations, including fillings, crowns and bridges, use chemicals known to the State of California to cause cancer.

The U.S. Food and Drug Administration has studied the situation and approved for use all dental restorative materials. Consult your dentist to determine which materials are appropriate for your treatment.

Warning proposed by settlement in *As You Sow v. Roger Feldman, DDS and California Dental Association* (CGC-01-402974). Sign designed by OEHHA.

*“And I think that there really is perhaps
no place for mercury in children.”¹⁵¹*

*--Dr. Suresh Kotagal, pediatric neurologist at the Mayo Clinic;
FDA Dental Products Panel, 2010*

1) Pregnant Women and Children

Authorities have issued distinct warnings about mercury's use in children and pregnant women. For example, a 2005 World Health Organization (WHO) report identified harmful effects of mercury exposure, including areas of risk specifically linked to mercury in fetuses and children: “Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental deficits during fetal development, and attention deficit and developmental delays during childhood.”¹⁵²



*A number of countries have banned
dental amalgam fillings for children and
pregnant women, although this use of
dental mercury is still allowed in the U.S.*

Moreover, as stated at the top of page 2 in this document, international legislation has warned of the clear and present danger that the mercury in dental amalgam fillings poses to pregnant women and children. Also, 19 members of the U.S. Congress wrote a letter to the FDA in 2009 to express their concern about mercury used in amalgam fillings, with a focus on potential dangers to pregnant women and children,¹⁵³ and when Representative Diane Watson of California proposed a *Mercury Filling Disclosure and Prohibition Act* (H.R. 2101 {not enacted}), she explained: “It is, in fact, children who are at greatest risk from these fillings.”¹⁵⁴



*Pregnant women, lactating women, and
women of childbearing age should be aware
that mercury from their dental amalgam
fillings can pose a risk to fetuses and children.*

Fetal and infant exposure to mercury is known to have potentially serious health consequences, and the number of maternal amalgam fillings has been associated with mercury levels in cord blood;^{155 156 157} in the placenta;¹⁵⁸ in the kidneys^{159 160} and liver¹⁶¹ of fetuses; in fetal hair;^{162 163} and in the brain¹⁶⁴ and kidneys¹⁶⁵ of infants. Additionally, mercury is excreted in breast milk of mothers with dental mercury amalgam fillings, and the mercury concentration in breast milk increases as the number of amalgam fillings in the mother increases.^{166 167 168 169} Significantly, a study published in 2018 by researchers in Norway involved over 72,000 pregnant women with data on the number of teeth containing dental amalgam fillings. The researchers discovered a “statistically significant association between the number of teeth filled with dental amalgam and the risk of perinatal death.”¹⁷⁰

Although two studies^{171 172} (commonly referred to as the “New England Children’s Amalgam Trial” and the “Casa Pia Children’s Amalgam Trial”) have repeatedly been used to defend the use of amalgam in children, other researchers have since demonstrated that factors such as long term effects, genetic predisposition, and measurement errors must be taken into account.^{173 174 175 176 177 178} Furthermore, researchers studying the same cohort (of the Children’s Amalgam Trials) have provided data that has identified potential risks to these subjects from mercury exposure based on gender,^{179 180 181} genetic predisposition,^{182 183 184} and even gum-chewing.¹⁸⁵ Risk assessments have also explored designating safe levels for children, who are smaller and still developing,¹⁸⁶ especially since many dose levels are based on a one-size-fits-all scale for children and adults.

In the meantime, scientific research continues to show that children are, in fact, at-risk for health impairments potentially caused by dental amalgam mercury fillings.^{187 188 189 190 191 192 193 194 195 196} In summary, authors of a study from 2011 cautioned: “Changes in dental practices involving amalgam, especially for children, are highly recommended in order to avoid unnecessary exposure to Hg [mercury].”¹⁹⁷

2) Dentists and Dental Personnel

Dentists, dental staff, and dental students are exposed to mercury at a greater rate than their patients. Severe exposures from past practices include hand-squeezing of fresh amalgam, where drops of liquid mercury could run over the dentist's hands and contaminate the entire office.¹⁹⁸ Dangerous levels of mercury are still generated in the dental workplace, and research has clearly identified that exposure to these mercury levels can cause ill-health to dental workers,^{199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234} and dental students.^{235 236 237} Another area that has received attention is the possibility of reproductive hazards to female dental personnel, including menstrual cycle disorders, fertility issues, and pregnancy risks.^{238 239 240 241 242 243 244 245}

Dental workers require protection from mercury exposures when working with mercury amalgam, and a variety of studies have specifically called for protective measures to be taken in the dental office as a means of limiting mercury releases.^{246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264}

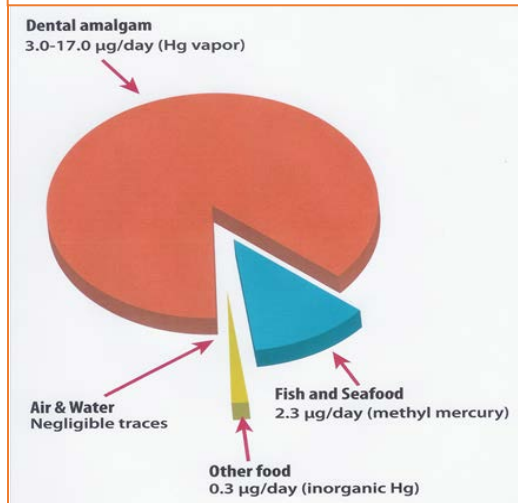
^{265 266} Significantly, research published in 2019 in the peer-reviewed *Journal of Occupational Medicine and Toxicology (JOMT)* showed that the safety thresholds for mercury exposure can be exceeded during dental procedures involving drilling on amalgam fillings if special precautions are not in place.²⁶⁷ The researchers emphasized that specific safety measures can mitigate these mercury levels and provide more rigorous protection for patients and dental workers. More on the importance of safety measures is provided in the “Safe Removal of Existing Amalgam Fillings” section on page 10 of this document, which outlines the [IAOMT's Safe Mercury Amalgam Removal Technique \(SMART\)](#).



A growing body of scientific research has recognized risks of mercury exposure for dentists, dental professionals, and dental students who routinely clean, polish, place, remove, and replace amalgam fillings. Also, based on efforts by dental nurses who had been harmed by mercury, the Norwegian Labour and Welfare Service officially recognized mercury injury as an occupational disease in 2012.

3) The General Population

*Sources of Human Mercury Exposure;
World Health Organization [WHO],
1991*



Dental amalgam constitutes a main source of mercury exposure to people with these fillings in their mouths, as the chart to the left shows. 80% of the mercury vapor emitted from dental amalgam is absorbed by the lungs and passed to the rest of the body.²⁶⁸ In research published in 2011, Dr. G. Mark Richardson reported that more than 67 million Americans aged two years and older exceed the intake of mercury vapor considered “safe” by the U.S. EPA due to the presence of dental mercury amalgam fillings, whereas over 122 million Americans exceed the intake of mercury vapor considered “safe” by the California EPA.²⁶⁹

Properly diagnosing “adverse health effects” related to dental mercury amalgam fillings is impeded by the intricate list of potential responses to the elemental form of the substance, which include over 250 specific symptoms.²⁷⁰ One reason for the wide-range of symptoms is that mercury taken into the body can accumulate in virtually any organ.

Another reason for the wide-range of symptoms is that an array of co-existing factors influence each person's reaction to dental mercury, including the presence of other health conditions, the number of amalgam fillings in the mouth, gender, genetic predisposition, dental plaque, selenium levels, exposure to lead, consumption of milk or alcohol, methylmercury levels from fish consumption, and the potential for mercury from dental amalgam fillings to be transformed into methylmercury within the human body.²⁷¹

This is an abbreviated table of common symptoms of elemental mercury vapor inhalation^{272 273 274 275 276 277 278 279 280 281} to be considered by practitioners when evaluating the possible side effects of dental mercury amalgam:

Acrodynia or similar symptoms such as emotional instability, loss of appetite, general weakness, and skin changes (<i>Magos and Clarkson, 2006</i>)	Anorexia (<i>Bernhoft, 2011</i>)	Cardiovascular problems/ labile pulse [frequent changes in heart rate]/tachycardia [abnormally rapid heartbeat] (<i>Klassen, 2008</i>)
Cognitive/neurological impairments/memory loss/decrease in mental function/difficulties with verbal and visual processing (<i>Echeverria et al., 1998; Clarkson and Magos, 2006; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016</i>)	Delusions/delirium/hallucination (<i>Bernhoft, 2011; Syversen and Kaur, 2012</i>)	Dermatological conditions/ dermographism [skin condition characterized by raised red marks]/dermatitis (<i>Bernhoft, 2011; Klassen, 2008</i>)
Endocrine disruption/enlargement of thyroid (<i>Bernhoft, 2011; Klassen, 2008</i>)	Erethism [symptoms such as irritability, abnormal responses to stimulation, and emotional instability] (<i>Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Magos and Clarkson, 2006</i>)	Fatigue (<i>Bernhoft, 2011; Echeverria et al., 1998</i>)
Headaches (<i>USEPA, 2016</i>)	Hearing loss (<i>Rothwell and Boyd, 2008</i>)	Immune system impairments (<i>Bernhoft, 2011; Clarkson and Magos, 2006</i>)
Insomnia (<i>USEPA, 2016</i>)	Nerve response changes/peripheral neuropathy/decreased coordination/ decreased motor function/ polyneuropathy/ neuromuscular changes such as weakness, muscle atrophy, and twitching (<i>Bernhoft, 2012; Clarkson et al., 2003; Clarkson and Magos, 2006; Echeverria et al., 1998; USEPA, 2016</i>)	Oral manifestations/ gingivitis/metallic taste/oral lichenoid lesions/stomatitis/salivation (<i>Bernhoft, 2011; Camisa et al., 1999; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; Magos and Clarkson, 2006</i>)
Psychological issues/mood changes related to anger, depression, excitability, irritability, mood swings, and nervousness (<i>Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; USEPA, 2016</i>)	Renal [kidney] problems/ proteinuria/nephrotic syndrome (<i>Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012</i>)	Respiratory problems/ bronchial irritation/bronchitis/cough/ dyspnea [breathing difficulties]/ pneumonitis/respiratory failure (<i>Bernhoft, 2011; Clarkson et al., 2003; Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016</i>)
Shyness [excessive shyness]/social withdrawal (<i>Magos and Clarkson, 2006; USEPA, 2016</i>)	Tremors/mercurial tremors/ intention tremors (<i>Bernhoft, 2011; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012</i>)	Weight loss (<i>Bernhoft, 2011</i>)

While the symptoms of mercury exposure are individualized and have the potential to change over time, specific health conditions related to dental mercury exposure are also aptly documented in scientific literature, as the table below demonstrates.

Dental mercury amalgam fillings can potentially exacerbate and/or contribute to the conditions included below, as well as a myriad of other health outcomes:

Allergies ^{282 283 284}	Alzheimer's disease ^{285 286 287 288 289}	Amyotrophic lateral sclerosis (Lou Gehrig's disease) ²⁹⁰	Antibiotic resistance ^{291 292 293 294}	Autism spectrum disorders ^{295 296 297 298}	Autoimmune disorders/immunodeficiency ^{299 300 301 302 303 304 305 306 307}
Cardiovascular problems ^{308 309 310}	Chronic fatigue, fatigue, and/or myalgic encephalomyelitis /chronic fatigue syndrome ^{311 312 313 314 315 316 317 318}	Dermatitis ^{319 320}	Fibromyalgia ^{321 322 323 324}	Gastrointestinal issues and/or irritable bowel syndrome ^{325 326 327}	Hearing loss ³²⁸
Kidney disease ^{329 330 331 332 333 334 335 336}	Multiple sclerosis ^{337 338 339 340}	Oral lichenoid reaction ^{341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357} and oral lichen planus ^{358 359 360 361 362}	Orofacial granulomatosis ^{363 364}	Parkinson's disease ^{365 366 367 368 369 370 371}	Periodontal disease ^{372 373}
Psychological issues such as depression and anxiety ^{374 375 376 377 378 379 380}	Reproductive dysfunction ^{381 382}	Suicidal ideations ^{383 384}	Symptoms of chronic mercury poisoning ³⁸⁵	Systemic lupus erythematosus ³⁸⁶	Thyroiditis ^{387 388 389 390 391}

4) Genetic Predisposition

The association of genetic predisposition with specific, adverse effects from mercury exposure has been examined in several studies. It has been found that mercury exposure from dental mercury amalgam particularly threatens individuals with genetic variants that can impact their response to mercury exposures such as those with CPOX4,^{392 393 394} APOE(3,4),^{395 396 397 398} and BDNF (brain-derived neurotropic factor) polymorphisms.^{399 400 401} For example, the researchers of a study published in 2006 linked the polymorphism CPOX4 (coproporphyrinogen oxidase, exon 4) to decreased visuomotor speed and indicators of depression in dental professionals.⁴⁰² Furthermore, the CPOX4 genetic variation was identified as a factor for neurobehavioral issues in a study of children with dental amalgams. The researchers noted, "...among boys, numerous significant interaction effects between CPOX4 and Hg [mercury] were observed spanning all 5 domains of neurobehavioral performance...These findings are the first to demonstrate genetic susceptibility to the adverse neurobehavioral effects of Hg [mercury] exposure in children."⁴⁰³

The ability of specific genetic variants to negatively impact the body's reaction to dental mercury exposure has even achieved attention in the mainstream media. A [January 2016 article by Greg Gordon of McClatchy News](#) included interviews with some of the researchers of the studies mentioned in this document.

Markedly, **Dr. James Woods stated:**

“Twenty-five percent to 50 percent of people have these (genetic variants).”

In the same article, **Dr. Diana Echeverria discussed**

“a lifetime risk” of neurological damage

related to this population, and she elaborated:

“We’re not talking about a small risk.”

Another area of genetic susceptibility in relation to dental mercury risk that has merited attention is the APOE4 (apo-lipoprotein E4) genetic variation. A 2006 study found a correlation between individuals with APOE4 and chronic mercury toxicity.⁴⁰⁴ The same study found that removal of dental amalgam fillings resulted in “significant symptom reduction,” and one of the symptoms listed was memory loss. The symptom of memory loss is quite interesting, as APOE4 has also been associated with a higher risk for Alzheimer’s disease.^{405 406 407} Importantly, the authors of a study which found a connection between number of mercury fillings and neurotoxic effects for those with APOE genotype explained: “APO-E genotyping warrants investigation as a clinically useful biomarker for those at increased risk of neuropathology, including AD [Alzheimer’s disease], when subjected to long-term mercury exposures...An opportunity could now exist for primary health practitioners to help identify those at greater risk and possibly forestall subsequent neurological deterioration.”⁴⁰⁸

Research has also shown that dental mercury fillings can play a role in immune system problems for genetically predisposed patients. Whereas research on animals has established a connection between dental mercury and autoimmunity,^{409 410} research involving human subjects has confirmed that genetic susceptibility to reactions from dental mercury is potentially related to chronic fatigue syndrome,⁴¹¹ as well as amyotrophic lateral sclerosis, multiple sclerosis, and rheumatoid arthritis.⁴¹² In addition, scientific data has linked mercury and genetic traits to autism,^{413 414} chemical sensitivities,⁴¹⁵ and Kawasaki’s disease,⁴¹⁶ and research has also suggested that genetic transporters could be involved in the toxicokinetics of mercury.⁴¹⁷

Other than CPOX4, APOE, and BDNF polymorphisms, genetic traits that have been examined for association with health impairments caused by mercury exposure include metallothionein (MT) polymorphisms,^{418 419} catechol-O-methyltransferase (COMT) variants,⁴²⁰ PON1 variants,^{421 422} MTHFR mutations and other genetic aspects.^{423 424 425} The authors of one of these studies concluded: “It is possible that elemental mercury may follow the history of lead, eventually being considered a neurotoxin at extremely low levels.”⁴²⁶

5) Mercury and Metal Allergies

In some genetically susceptible individuals, metals can also induce allergies.⁴²⁷ A study published in 2018 in the journal *Dermatitis* was conducted on 686 adults who were patch tested for allergies. The results demonstrated that “38.9% of patients had 1 or more positive patch-test reactions to a metal allergen, most commonly nickel (17.4%), mercury (12.3%), and palladium (9.2%)...Among patients with positive reactions to nickel, 34.5%, 15.1%, and 5.0% had positive reactions to 1, 2, or 3 additional metals, respectively.”⁴²⁸ That study involved individuals with suspected allergies; however, the statistics are relevant, as studies involving the general population and the prevalence of metal allergies are rare.⁴²⁹ However, a 1993 study reported that 3.9% of healthy subjects tested positive for metal reactions in general.⁴³⁰ If this figure is applied to the current U.S. population, this would mean that dental metal allergies potentially impact as many as 12.5 million Americans.

The number of affected individuals is likely much higher, though, because recent studies and reports tend to agree that metal allergies are on the rise.^{431 432} Part of this could be caused by increased exposure to metals, including ear/body piercings, because exposure to metals has been cited as a potential trigger for the development of allergies to them.⁴³³ Additionally, it has been hypothesized that contact with metals during an infection could increase chances of developing a metal allergy later in life.⁴³⁴

An issue is the wide-range of symptoms patients allergic to dental metals can exhibit. In a 2014 publication, Dr. Vera Stejskal wrote: “Metal-induced inflammation may be involved in the pathology of various autoimmune and allergic diseases, where abnormal fatigue, joint and muscle pain, cognitive impairment and other non-specific symptoms are often present.”⁴³⁵ Additionally, a gamut of health conditions has been linked to dental metal allergies, including autoimmunity,^{436 437} chronic fatigue syndrome,^{438 439 440} fibromyalgia,^{441 442} metallic pigmentation,⁴⁴³ multiple chemical sensitivities,^{444 445} multiple sclerosis,⁴⁴⁶ myalgic encephalitis,⁴⁴⁷ oral lichenoid lesions,^{448 449 450 451 452} orofacial granulomatosis,⁴⁵³ and even infertility in both women and men.⁴⁵⁴

Another issue with calculating the number of patients with adverse reactions to a metallic material is that the onset of symptoms can be delayed and therefore might not be associated with the implant or device. For example, researchers writing about dental amalgam fillings warned: “Sensitization appears most frequently after the amalgam has been present in the mouth for more than 5 years.”⁴⁵⁵ Furthermore, there may not be any local reaction to help the patient and doctor identify the metal as the culprit in ill health,⁴⁵⁶ and even if hypersensitivity reactions are noticed, they can be misdiagnosed as infection.⁴⁵⁷

Clinical screening for metal allergy has been recommended,⁴⁵⁸ and the importance of patients reporting reactions to metals to their doctors has also been emphasized in the scientific literature.^{459 460 461 462 463 464} In addition to reporting any rashes from jewelry, watches, or other metal exposures, it is essential for each patient to recognize the gamut of symptoms that can be related to the presence of a metal implant or device in their body. **It is also vital for patients to remember that sensitization to metal can develop years after an implant or device has been placed and that adverse effects can occur *with or without* the sign of a rash or eruption on the skin or in the mouth.**



Many patients are not aware that reactions they have to jewelry and other metal accessories are a warning sign that they could have allergic reactions to dental amalgam fillings and/or metal implants in their bodies.

Unfortunately, in some reported cases, the only way to fully establish that a metal implant or device was causing health problems was to have it removed and then document the results. Researchers from Harvard School of Medicine wrote in 2016: “Paradoxically, a patient can sometimes only be diagnosed with metal allergy when the symptoms resolve upon replacement with an immunologically inert implant.”⁴⁶⁵

A few examples of conditions reportedly improved and/or cured as a result of removing dental metal allergens include amyotrophic lateral sclerosis,⁴⁶⁶ chronic fatigue syndrome,⁴⁶⁷ dermatitis,⁴⁶⁸ fibromyalgia,⁴⁶⁹ multiple sclerosis,⁴⁷⁰ oral lichen planus,^{471 472 473} oral lichenoid lesion,^{474 475 476} orofacial granulomatosis,⁴⁷⁷ and other symptoms.⁴⁷⁸ In a 2011 report, Hosoki and Nishigawa suggested: “In principle, all restorations with allergy-positive metal elements need to be removed.”⁴⁷⁹

Safety Measures for Removal of Dental Amalgam Mercury Fillings:



Although individual response varies, in addition to the recovery situations listed above, research has documented the reduction of other health issues after the removal of amalgam fillings.^{480 481 482 483 484 485 486 487 488 489 490} However, it is important to note that removal of any dental material requires a number of precautions. This is because an unsafe removal process can cause serious injury to the patient, including the possibility of increased metal exposure. For example, if dental amalgam fillings are removed unsafely, patients can be exposed to increased levels of mercury.

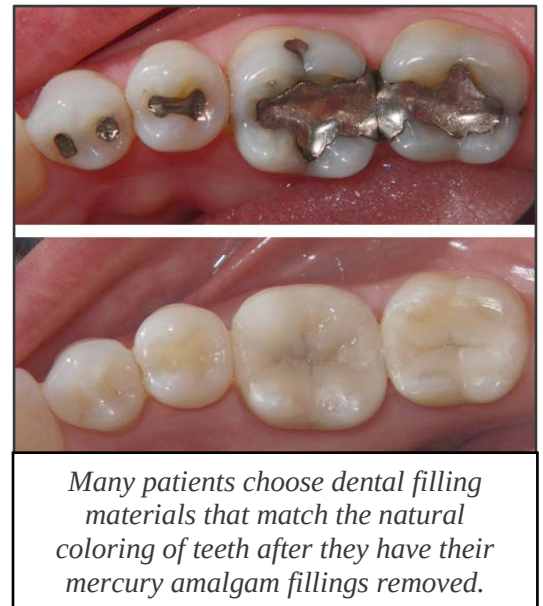
To assist in mitigating the potential negative outcomes of mercury exposure to dental professionals, students, staff members, patients, and others, the IAOMT has developed safety recommendations for removal of existing dental mercury amalgam fillings.⁴⁹¹ IAOMT's Safe Mercury Amalgam Removal Technique (SMART) is located online at <https://iaomt.org/safe-removal-amalgam-fillings/>.⁴⁹² The innovative recommendations build upon traditional safe amalgam removal techniques such as the use of masks, water irrigation, and high volume suction by supplementing these conventional strategies with a number of additional protective measures, the need for which have only recently been identified in scientific research. In addition to the dozens of studies that support each separate step of the recommendations, the overall technique has been supported by two studies published in peer-reviewed journals in 2019.^{493 494} IAOMT recommends that patients familiarize themselves with the recommendations to ensure protective strategies will be applied during amalgam removal.

Alternatives to Amalgams as a Filling Material:

Obviously, once amalgams have been removed, they must be replaced with a different dental filling material. Alternatives to amalgam include composite resin, glass ionomer, porcelain, and gold, among other options. When given the choice, most consumers opt for direct composite fillings because the white coloring matches the tooth better and the cost is considered moderate.

In the past, a common argument against composite fillings was that they were not as durable as amalgam. However, recent studies have debunked this claim. Researchers of a study which was published in 2016 and conducted on over 76,000 patients for over ten years found that posterior amalgam fillings had a *higher* annual failure rate than composites.⁴⁹⁵ Two separate studies published in 2013 found that composite fillings performed as well as amalgam when comparing failure rates⁴⁹⁶ and replacement filling rates.⁴⁹⁷ Other research offers similar findings in support of composite filling durability.^{498 499 500}

501



Many patients choose dental filling materials that match the natural coloring of teeth after they have their mercury amalgam fillings removed.

Research has further confirmed that composite resins present a lower risk for chemical exposures. In a 2016 publication co-authored by risk assessment specialist Dr. G. Mark Richardson, it was reported: "Relative risks of chemical exposures from dental materials decrease in the following order: Amalgam>Au (Gold) alloys>ceramics>composite resins."⁵⁰²

Yet, composite fillings have been criticized because some of them contain fluoride and/or bisphenol-A (BPA). Dentists have a variety of opinions about the safety of fluoride, BPA, and other types of bisphenol, such as Bis-GMA and Bis-DMA. Patients who are concerned about the specific components of their fillings often choose to speak with their dentists about using a material that does not contain certain ingredients. For example, a product named Admira Fusion⁵⁰³/Admira Fusion X-tra⁵⁰⁴ released in January 2016 by the dental company VOCO is being touted as “the first purely ceramic-based restorative material”⁵⁰⁵ and does not contain Bis-GMA or BPA before or after it has been cured. No matter which replacement material is selected, whether it be ceramics, composites, gold, or other materials, it should be assessed for safety and biocompatibility with special consideration for all populations and all known risk factors.⁵⁰⁶

Allergy testing can be used to assist in identifying some of the individuals susceptible to adverse reactions to metals. Patch testing is generally regarded as the “gold standard” in allergy testing; however, patch testing has also been criticized because it involves directly applying the allergen to the skin, it can exacerbate symptoms in patients, it can result in sensitization, and the results can be affected by other conditions.⁵⁰⁷ Two relatively new alternatives to skin patch testing are a modified version of the Lymphocyte Transformation Test (LTT) known as MELISA⁵⁰⁸ and the Lymphocyte Response Assay (LRA) by ELISA/ACT.⁵⁰⁹

Another option for testing has been created specifically for dental materials. If this biological testing is used, a patient’s blood sample is sent to a laboratory where the serum is evaluated for the presence of IgG and IgM antibodies to the chemical ingredients used in dental products.⁵¹⁰ The patient is then provided with a detailed list of which name-brand dental materials are safe for their use and which ones could result in a reaction. Two labs that currently offer this service are Biocomp Laboratories⁵¹¹ and Clifford Consulting and Research.⁵¹²

It is important to note that many factors can influence whether or not a patient improves after the removal of dental amalgam fillings. While many patients improve or even recover, there are some who do not. One obvious reason for this is if the patient is still being exposed to the metal or a different sensitizer through another implant, device, or other source. Dr. Vera Stejskal has also noted that in order to get well, some patients further require the eradication of *Helicobacter pylori*,⁵¹³ the cessation of smoking,^{514 515} and/or the adoption of a low nickel diet.^{516 517} Some medical professionals and researchers have also suggested the need for detoxification and supplements to assist the body in recovering from metal exposure. Additional impediments in achieving improved health can include the presence of another illness and/or allergy, exposure to certain pesticides, solvents, molds, and foods, hormonal imbalances, stress, a sedentary lifestyle, and countless other factors.

For all these reasons and more, it is imperative for patients to work with their doctors and other healthcare professionals so that toxins and allergens are kept out of their bodies and healthier, safer options are put in to replace them.

Additional Resources:

The IAOMT has also developed free, online dental education resources detailing implementation strategies for mercury-free and mercury-safe practices, including information for dentists, physicians, health care professionals, patients, and the general public. These resources include the following:

- Dental Mercury Facts: <https://iaomt.org/resources/dental-mercury-facts/>
- Dental Mercury Education Videos: <https://iaomt.org/free-online-learning/>
- Position Statement against Dental Mercury Amalgam Fillings: <https://iaomt.org/iaomt-position-paper-dental-mercury-amalgam/>
- Safe Mercury Amalgam Removal Technique (SMART): <https://iaomt.org/resources/safe-removal-amalgam-fillings/>
- More resources available at www.iaomt.org

PHOTO CREDITS:

Middle of page 1: Mercury Amalgam Fillings; IAOMT File Photo

Bottom of page 2: Mercury (Hg) Biomagnification Graphic; National Park Service;

<https://npgallery.nps.gov/AssetDetail/ba40f463-9f49-4a28-bcd9-a1e65a0d1dee>; Accessed October 2019

Top of page 3: Picture of a Honolulu city sign warning of sewage contamination, with Waikiki hotels and Diamond Head in background; Released under CC-BY-SA 2.5; Keith H.;

https://commons.wikimedia.org/wiki/File:20060402_waikiki_sewage.jpg; Accessed October 2019 and cropped to fit page. (For more about mercury contamination in sewage, see <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4764622/>.)

Bottom of page 3: Chimney Crematorium Peak Smoke Top, Stock Photo purchased by IAOMT from 123rf;

[https://www.123rf.com/photo_9682193_chimney-crematorium-peak-smoke-](https://www.123rf.com/photo_9682193_chimney-crematorium-peak-smoke-top.html?term=crematorium%2Bblack%2Bsmoke&vti=lsapn7cqoj9yci0ytl-1-11)

[top.html?term=crematorium%2Bblack%2Bsmoke&vti=lsapn7cqoj9yci0ytl-1-11](https://www.123rf.com/photo_9682193_chimney-crematorium-peak-smoke-top.html?term=crematorium%2Bblack%2Bsmoke&vti=lsapn7cqoj9yci0ytl-1-11); Purchased March 2018

Bottom of page 4: Dental Office Warnings, Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency; [https://oehha.ca.gov/media/downloads/proposition-](https://oehha.ca.gov/media/downloads/proposition-65/presentation/dentalofficewarnings041514.pdf)

[65/presentation/dentalofficewarnings041514.pdf](https://oehha.ca.gov/media/downloads/proposition-65/presentation/dentalofficewarnings041514.pdf); Accessed October 2019

Top of page 5: Sri Lankan Woman and Child; Steve Evans;

https://commons.wikimedia.org/wiki/File:Sri_Lankan_woman_and_child.jpg; Accessed October 2019 and slightly cropped to fit page; Originally posted at <https://www.flickr.com/photos/64749744@N00/549738320/>; Shared in compliance with <https://creativecommons.org/licenses/by-nc/2.0/>.

Bottom of page 5: Patient with Dentist in Alaska; Official Website of the United States Navy; 090309-F-3646G-199;

https://www.navy.mil/view_image.asp?id=69543; Accessed October 2019

Top of page 6: Protective Equipment during Amalgam Removal; Courtesy of Dr. Jack Kall

Bottom of page 6: Sources of Human Mercury Exposure based on 1991 World Health Organization [WHO] Report; Chart Made by the IAOMT from Statistics in <http://www.inchem.org/documents/ehc/ehc/ehc118.htm>

Top of page 8: Quotes on Genetic Variants from: Gordon G. Dental group defends mercury fillings amid mounting evidence of risks. McClatchy News Service. January 5, 2016. Available from:

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Middle of page 9: Pile of Old Jewelry; Retrieved from Pixabay; <https://pixabay.com/photos/jewelry-junk-fake-gem-jewel-314473/>; Accessed October 2019

Top of page 10: Before and After Photos of Teeth from Amalgam Removal; Courtesy of Dr. Michael Rehme from

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YOU NOW NEED TO ACCESS THE IAOMT'S
"MERCURY 102" VIDEO ACTIVITY AT
<https://iaomt.org/mercury-102-video-activity/>

Be sure to complete the pre-activity survey, read the references and selected literature, and take the post-activity survey.

UPON COMPLETION OF THE "MERCURY 102"
VIDEO ACTIVITY, YOU WILL NEED TO
CONTINUE WITH THE ADDITIONAL
REQUIREMENTS FOR MODULE 1.

Fact Sheet: Effluent Limitations Guidelines and Standards for Dental Offices

Summary

EPA finalized technology-based pretreatment standards under the Clean Water Act to reduce discharges of mercury and other metals from dental offices into municipal sewage treatment plants known as publically owned treatment works (POTWs). Dental offices, which discharge mercury and other metals present in amalgam used for fillings, are the main source of mercury discharges to POTWs; these metals are subsequently released to the environment. The rule requires dental offices to comply with requirements based on practices recommended by the American Dental Association, including the use of amalgam separators. Once captured by the separator, dental amalgam can be recycled. Removing mercury when it is concentrated and easy to manage, such as through low-cost amalgam separators at dental offices (average annual cost per dental office is about \$800), is a common sense solution to managing mercury that would otherwise be released to air, land, and water.

In addition, this rule minimizes dental office reporting requirements and the administrative burden to federal, state, and local regulatory authorities responsible for oversight of the new requirements.

EPA expects compliance with this final rule will reduce the discharge of metals to POTWs by at least 10.2 tons per year, about half of which is mercury.

EPA projects the total annual cost of the final rule will be \$59 - \$61 million.

Background

Why are standards needed for the dental industry?

When dentists remove old amalgam fillings from cavities, or when dentists place a new filling, mercury in the form of dental amalgam enters the wastewater of the dental office. Mercury from waste amalgam can make its way into the environment from the POTW through the incineration, landfilling, or land application of sludge or through surface water discharge. Mercury is a potent neurotoxin that can have a wide range of health effects, and mercury pollution is a global concern. Once released into the aquatic environment, certain bacteria can change mercury into methylmercury, a highly toxic form of mercury that bioaccumulates in fish and shellfish. Eating fish and shellfish is the main source of people's exposure to methylmercury in the U.S.

Who is affected by this regulation?

This rule applies to offices, including large institutions such as dental schools and clinics, where dentistry is practiced that discharge to a POTW. It does not apply to mobile units or offices where the practice of dentistry consists only of the following dental specialties: oral pathology, oral and maxillofacial radiology, oral and maxillofacial surgery, orthodontics, periodontics, or prosthodontics.

Control Authorities (which are often the state or POTW) are responsible for oversight associated with this rule.

What does this rule require of dental offices?

Dental offices that discharge to POTWs that do not place or remove amalgam need only submit a one-time certification.

Dental offices that place or remove amalgam must operate and maintain an amalgam separator and must not discharge scrap amalgam or use certain kinds of line cleaners. They must also submit a One-Time Compliance Report.

Where can I find more information?

You can access the Federal Register notice on EPA's Effluent Guidelines website at: www.epa.gov/eg/dental-effluent-guidelines. In addition, the final rule will be available at regulations.gov under Docket ID: EPA-HQ-OW-2014-0693.

You may also email Karen Milam at milam.karen@epa.gov.

YOU NOW NEED TO ACCESS IAOMT'S
"DENTAL AMALGAM MERCURY AND THE
ENVIRONMENT" VIDEO ACTIVITY AT
<https://iaomt.org/mercury-environment-video-activity/>

Be sure to complete the pre-activity survey, read the references and selected literature, achieve an 80% on the test, and take the post-activity survey.

UPON COMPLETION OF THE "DENTAL
AMALGAM MERCURY AND THE
ENVIRONMENT" VIDEO ACTIVITY, YOU WILL
NEED TO CONTINUE WITH THE ADDITIONAL
REQUIREMENTS FOR MODULE 1.

YOU NOW NEED TO TAKE THE MODULE 1
TEST AT

<https://www.cvent.com/d/lvq3k2>

IT IS AN OPEN BOOK TEST AND CONSISTS OF
25 QUESTIONS. YOUR SCORE WILL BE
AUTOMATICALLY CALCULATED AND SENT
TO YOU VIA EMAIL.

UPON COMPLETION OF THE MODULE 1 TEST,
YOU WILL NEED TO CONTINUE WITH
MODULE 2 AND THE POST-COURSE
REQUIREMENTS TO OBTAIN YOUR SMART
CERTIFICATION. MODULE 2 BEGINS ON THE
NEXT PAGE...

IAOMT SMART CERTIFICATION--

Checklist for Completing Module 2:

Safe Removal of Amalgam Fillings

INTRODUCTION TO MODULE 2

- ☐ Take the Unit Module 2 pre-test. Click here to go to page 64.
- ☐ Read the “Mercury Vapour Exposure during Dental Student Training in Amalgam Removal” study by Warwick, O’Connor, and Lamey. Click here to go to pages 65-71.
- ☐ Peruse the Quick Reference Module 2 test questions. Click here to go to pages 72-76.

REQUIRED (MANDATORY) CONTENT FOR MODULE 2

- ☐ View the IAOMT online learning module “Safe Removal of Amalgam Fillings” at <https://iaomt.org/amalgam-removal-video-activity/>. Click here to go to page 77.
- ☐ Read the “IAOMT Position Paper against Dental Mercury Amalgam Fillings.” Click here to go to pages 78-168.
- ☐ Read the “Mercury Vapor Volatilization from Particulate Generated from Dental Amalgam Removal with a High-Speed Dental Drill—A Significant Source of Exposure” study by Warwick, Young, Palmer, and Ermel. Click here to go to pages 169-180.
- ☐ Read the “Tips for the Mercury-Free Dentist” Article from the IAOMT. Click here to go to pages 181-182.

Continued on next page...

TEST FOR MODULE 2

- ☐ Take the Post-Test for Module 2 at <https://www.cvent.com/d/fvqcm>.
Click here to go to page 183.
- ☐ If you are interested in learning more about any of the topics in this unit, explore the readings in the OPTIONAL PDF file. *Note that these are not required materials.*
- ☐ **Read the SMART requirements, which begin at page 184 of this document. Click here to go to page 184.**
- ☐ **Send in your SMART forms so that you are officially SMART Certified!**
- ☐ Congratulations!

Record of Module 2 Updates---

2/2020: *Dentist's Health* article (removed from Introduction); Warwick, O'Connor and Lamey 2013 study (moved from Main Content to Introductory); Online Learning Video for Safe Removal (revised to incorporate SMART and new formatting); IAOMT Position Paper (updated to 2019 version); Ziff excerpt (removed from materials as information is now covered in Position Paper); Warwick, Young, Palmer, and Ermel 2019 study (added to Main Content); Module 2 Test (revised all test questions to accommodate updated materials); SMART requirements (updated with current versions of all forms and documents)

PRE-TEST FOR MODULE 2 TO BE TAKEN BEFORE STUDYING SAFE REMOVAL OF AMALGAM FILLINGS

****This is a pre-test, and the results are for your records only.***

You are not expected to know the answers since you have not studied this material yet.

The pre-test is simply designed to assist you in recognizing some of the important information that will be presented in this unit. There is no time limit for this test.

Choose the option that BEST answers each question.

1. Early dental research reported that using a rubber dam during amalgam removal can reduce mercury exposure.
 - A. True
 - B. False
2. Data has shown that when old amalgams are drilled out, the people at risk for exposure to mercury vapor and fully inhalable particulates are _____.
 - A. the patient
 - B. the dental assistant
 - C. the dentist
 - D. everyone else in the office
 - E. all of the above
3. A 2015 publication by Anglen et al. in the *Journal of the American Dental Association* shows a positive association between dentists, mercury exposure, and _____.
 - A. tremor
 - B. hair loss
 - C. athletic performance
 - D. the number of returning patients
4. A peer-reviewed study by Warwick et al. published in 2019 found that there is a significant source of mercury exposure from _____ during amalgam removal.
 - A. lack of chairside assistance
 - B. drilling with a high-speed drill
 - C. left-handed dentistry being practiced
 - D. none of the above
5. Scientific literature promotes utilizing a full head/face/neck barrier under/around the dam to protect patients from mercury exposure.
 - A. True
 - B. False

Answers: 1. A; 2. E; 3. A; 4. B; 5. A

RESEARCH

Open Access

Mercury vapour exposure during dental student training in amalgam removal

Robin Warwick^{1*}, Andrea O'Connor² and Brianne Lamey³

Abstract

Background: Amalgam that is used for dental fillings contains approximately 50% elemental mercury. During dental student training, amalgam is often removed by drilling without the use of water spray and suction, which are protective measures in preventing mercury aerosol. In this study we measured mercury vapor levels in ambient air during amalgam removal as is typically performed in dental training.

Methods: Mercury vapor levels in ambient air were measured in a dental school laboratory during removal of amalgam fillings from artificial teeth set into a dental jaw simulator. Mercury vapor was measured under three conditions (25 measurements each): with the simultaneous use of water spray and suction, with the use of suction only, and with the use of neither suction nor water spray. These three conditions are all used during dental student training. Results were compared to Alberta occupational exposure limits for mercury vapor in order to assess potential occupational risk to students. Analysis of variance testing was used to compare data obtained under the three conditions.

Results: When water spray and suction were used, mercury vapor levels ranged from 4.0 to 19.0 $\mu\text{g}/\text{m}^3$ (arithmetic mean = 8.0 $\mu\text{g}/\text{m}^3$); when suction only was used, mercury vapor levels ranged from 14.0 to 999.0 (999.0 $\mu\text{g}/\text{m}^3$ represents the high limit detection of the Jerome analyzer) (arithmetic mean = 141.0 $\mu\text{g}/\text{m}^3$); when neither suction nor water was used, the vapor levels ranged from 34.0 to 796.0 $\mu\text{g}/\text{m}^3$ (arithmetic mean = 214.0 $\mu\text{g}/\text{m}^3$).

Conclusions: The Alberta Occupational Health and Safety threshold limit value for mercury vapor over an eight-hour time-weighted period is 25.0 $\mu\text{g}/\text{m}^3$. The absolute ceiling for mercury vapor, not to be exceeded at any time, is 125.0 $\mu\text{g}/\text{m}^3$. When both water spray and suction were used, mercury vapor levels were consistently below this threshold. When suction without water spray was used, mercury vapor levels exceeded the safety threshold 8% of the time. When neither water spray nor suction was used, 36% of the mercury vapor readings exceeded the absolute ceiling value. To maximize safety, dental schools should train students to remove amalgam only while using water spray and high volume suction. Alternatively, students should use appropriate occupational hygiene personal protective equipment during amalgam removals.

Keywords: Mercury, Mercury vapor, Dental amalgam, Occupational exposure to mercury, Amalgam removal

Background

Elemental mercury is a large component (approximately 50%) of dental amalgam. Manipulation of in situ amalgam (as is done during polishing, scaling, and removal with a drill results in vaporization of mercury), results in short-term exposure of mercury vapor to dentists and other dental workers that may exceed occupational safety limits. Dentists are known to have occupational

exposure to mercury vapor during these procedures [1]. Many studies have shown that dental workers on average have higher systemic levels of mercury in their tissues and organs than do members of control groups [2-7].

Dental students in Canada and many other countries remove amalgam fillings with dental drills during their training. These procedures are first commonly performed without any measures to reduce or limit mercury exposure; such protective measures include the concomitant use of water spray and/or high-volume suction during drilling. Water spray and suction are generally

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used in the clinical setting to prevent damage to dental pulp and nerve from heat generated by high-speed drilling. Two common dental procedures in which amalgam may be removed without the protection of water spray and/or high-volume suction are root canal surgery and tooth removal. In these two circumstances, water spray is unnecessary to preserve the pulp because in both cases the pulp is being removed. In other non-clinical settings in which enhanced visibility is needed, dental students are trained to drill on mercury amalgam fillings without protective measures.

Although most government agencies that are responsible for worker safety generally have established thresholds of allowable mercury exposure, it does not ensure that being exposed to levels below these thresholds is safe. The WHO has stated "*studies suggest that mercury may have no threshold below which some adverse effects do not occur*" [8]. Canadian Regulatory bodies involved in worker safety have established safety levels that may not be appropriate for the dental profession [9]. Present thresholds are set predominantly from data involving male chloralkali workers, which is a much different model than the circumstances surrounding mercury exposure in dental clinics. The presence of chlorine in Chloralkali work places protects the worker against mercury exposure. In addition, females and other specific subsets of the population have been identified to have less tolerance to mercury exposure. These factors make it difficult to set a threshold that ensures safety.

The Canada Labour Code and all Provincial Codes have either adopted or specifically referenced the occupational exposure limits for mercury vapor defined as a threshold limit value (TLV) by the American Conference of Governmental Industrial Hygienists (ACGIH) [10-12]. The average TLV for mercury vapor, as prescribed by the ACGIH, is $25.0 \mu\text{g}/\text{m}^3$ over an 8-hour period. The ACGIH, Alberta Occupational Health and Safety, and most other provinces also prescribe a maximum ceiling limit of 5 times the TLV ($125 \mu\text{g}/\text{m}^3$), which is not to be exceeded at any time. Because the study was undertaken in the Province of Alberta, and Alberta Occupational Health and Safety levels are established and enforceable, the data was compared against these limits.

The purpose of this study was to duplicate the conditions of mercury exposure commonly experienced by dental students in Canada performing amalgam removals, to quantify the levels of mercury vapor exposure, and to compare those levels to occupational exposure limits for mercury prescribed in occupational health and safety regulations in Alberta and Canada. We found significantly high levels of mercury vapor in ambient air that exceeded these occupational limits unless both water spray and suction were used.

Methods

All three authors were dental students at the University of Alberta at the time of the study, which was conducted in a laboratory setting at the dental school. Three researchers (the authors) worked together to collect the data. One researcher performed the amalgam removals, while the second researcher assisted with high-volume suction for water and particulate removal (when required); meanwhile, the third researcher operated a Jerome model 431-X mercury vapor analyzer (Arizona Instrument, LLC, Tempe, AZ) to collect mercury vapor measurements in the ambient air surrounding the dental student performing the removals. This technology was chosen for a number of reasons; the new machine was readily available to the researchers, the Jerome is still relied on in the field by occupational officials to assess conditions where mercury vapor may be an issue, and the Jerome is capable of accurately reading levels in and around the concerned levels set by Alberta Occupational Health and Safety.

All researchers were equipped with Ansell Micro-touch® Powder Free Latex gloves and a disposable ear-loop mask (3 M™ ESPE™ Ear Loop Face Mask, 2000 F). These protective measures are routinely used by students in this laboratory setting. See Figure 1 for a drawing of the experimental setup.

Amalgam removals were performed from upper or lower posterior (molar) teeth on a bench top using amalgam-filled plastic teeth set into a dental jaw simulator. The experimental set-up replicated that of a dental school laboratory. Amalgam removal procedures followed the standard methods prescribed during dental student training at the University of Alberta, which follow accepted standards of dental training in Canada. The removals were performed using a standard high-speed hand piece equipped with a #556 bur. Each filling was prepared as a standard 2-surface molar restoration, involving the occlusal and proximal surfaces, prepared using Dispersalloy® amalgam (50% Mercury, 34.65% Silver, 8.95% Tin, 5.9% Copper, and 0.5% Zinc). These fillings contained an estimated 200 mg to 600 mg of mercury. The amalgam fillings were installed in the teeth of the dental jaw simulator, following accepted techniques, at least one year prior to this study.

A newly purchased, manufacturer-calibrated Jerome 431-X mercury vapor analyzer was used to record air-borne mercury vapor concentrations during the amalgam removal procedures. Regeneration and zeroing of the Jerome analyzer was carried out following the manufacturer's recommendations [13] throughout the data collection process. The minimum limit of quantification of the Jerome 431-X is $3 \mu\text{g}/\text{m}^3$. Care was taken to ensure that no solid or wet materials were drawn into the analyzer during data collection. To mimic the protective equipment worn by a dental student, a disposable



Figure 1 Experimental setup.

ear-loop mask (3 M™ ESPE™ Ear Loop Face Mask, 2000 F) was placed over the intake nozzle of the Jerome analyzer. The mask was replaced after every two mercury vapor concentration recordings. As recommended in the instruction manual, the Jerome analyzer was regenerated on the morning of each data collection day, at the end of each day, and when the Jerome display indicated that regeneration was necessary during the data collection process. Thirty minutes after regeneration, the analyzer was calibrated and then used to collect data. Mercury vapor readings were taken at an average distance of 38 cm from the dental jaw simulator implanted with the amalgam-filled plastic teeth, with the nozzle of the Jerome analyzer pointed directly towards the working area from a superior position, thereby mimicking the position of a dental student's face during amalgam removal. The distance of 38 cm was determined to be the average distance from the face of the drill operator to the operative site.

When readings were taken with suction alone, and with suction and water spray, one researcher held the suction tube to the left of the researcher performing the removals, with its source coming from the superior position at a 45-degree angle. The tip of the suction device was placed as close to the contact point of the dental bur on the amalgam as was possible.

Amalgam removals were conducted until a total of 75 mercury vapor readings were performed. Twenty-five measurements were conducted under each of these three conditions: with water spray and high-volume suction, with suction only (no water spray), and with neither water spray nor suction. A University of Alberta

statistician determined that 25 measurements under each of the three conditions would be sufficient for satisfactory statistical analysis. The time between each vapor measurement varied depending on a number of factors including recalibration and maintenance requirements of the Jerome analyzer, time required to replace amalgam-filled plastic teeth in the dental jaw simulator, and work area clean up.

Non-parametric Mann-Whitney tests were performed on the raw data, and parametric analysis of variance (ANOVA) was performed on the log-transformed mercury concentration data. A University of Alberta statistician performed all of the data analyses.

Results and discussion

The mean, median, and range of mercury vapor concentrations in ambient air were measured during the removal of dental amalgam fillings with and without water spray and suction (Table 1). The greatest average concentration of mercury vapor was recorded when no suction or water spray was used during amalgam removal. Adding suction lowered average mercury vapor levels; however, the lowest levels of mercury vapor were measured when suction and water spray were both used. In all cases of measurement, mercury vapor concentrations were greater than the limit of detection ($> 3 \mu\text{g}/\text{m}^3$) of the Jerome analyzer.

Table 1 Sample size = 25 for each of the three experimental conditions. During removal of dental amalgams from model teeth in the dental jaw simulator using a dental drill, mercury vapor in ambient air was measured at a distance of 38 cm from the amalgam site.

Table 1 Measured mercury vapor concentrations ($\mu\text{g}/\text{m}^3$) in ambient air during dental amalgam removal

	Suction and water spray	Suction only (no water spray)	No suction and no water spray
Arithmetic mean and standard deviation ($\mu\text{g}/\text{m}^3$)	8.0 ± 3.7	142.0 ± 234.6	214 ± 226.4
Median ($\mu\text{g}/\text{m}^3$)	8.0	68.0 ¹	117.0 ²
Range ($\mu\text{g}/\text{m}^3$)	4.0–19.0	14.0–999.0	34.0–796.0

¹ Statistically significantly greater ($p < 0.001$) from Suction & Water.

² Statistically significantly greater ($p = 0.031$) from Suction & Water.

The results of this study demonstrate that the use of suction and water spray during dental amalgam removal procedures significantly reduces the concentration of mercury vapor in ambient air. When suction and water were used, 100% of measured mercury vapor levels were below both the Alberta occupational ceiling limit (AOCL) of $125.0 \mu\text{g}/\text{m}^3$ and the Alberta Occupational Threshold Limit Value (AOTLV) of $25.0 \mu\text{g}/\text{m}^3$ over an eight-hour time-weighted period for mercury vapor exposure. When suction only (no water spray) was used, the AOCL was breached 8% of the time, with another 16% of the readings close to this limit. In addition, 84% of these readings exceeded the AOTLV. In the absence of both water spray and suction, 100% of the readings exceeded the eight-hour AOTLV of $25.0 \mu\text{g}/\text{m}^3$, and 44% of the readings breached the AOCL of $125.0 \mu\text{g}/\text{m}^3$. Figure 2 displays the measured mercury vapor concentrations in relation to occupational exposure limits published by Alberta Occupational Health and Safety (AOHS).

With suction and no water as a level of protection, the value range was dramatic ($14 - > 999 \mu\text{g}/\text{m}^3$). The authors hypothesize a number of reasons why this may have occurred. First, the nature of mercury vapor created from a single source (the operative field) in ambient air behaves in a chaotic way, so by chance and by the currents of the ambient air in the room, these mercury plumes may have in some instances concentrated towards the nozzle of the Jerome, and in other times, may have not been proximate to the intake. As well, there could have been some influence of random, volatilizing particulate that landed near the intake of the Jerome, which provided an extra source of mercury vapor during the removal when suction but no water was used. Further studies on the footprint and behavior of mercury contaminated particulate during removal is necessary to fully understand the impact of this source of mercury vapor.

Occupational safety levels for mercury vapor are set by provincial jurisdictions in Canada and may not represent an absolute level of safety. For example, the current time-weighted AOTLV level of $25.0 \mu\text{g}/\text{m}^3$ is only $1.0 \mu\text{g}/\text{m}^3$ less than the average level shown to

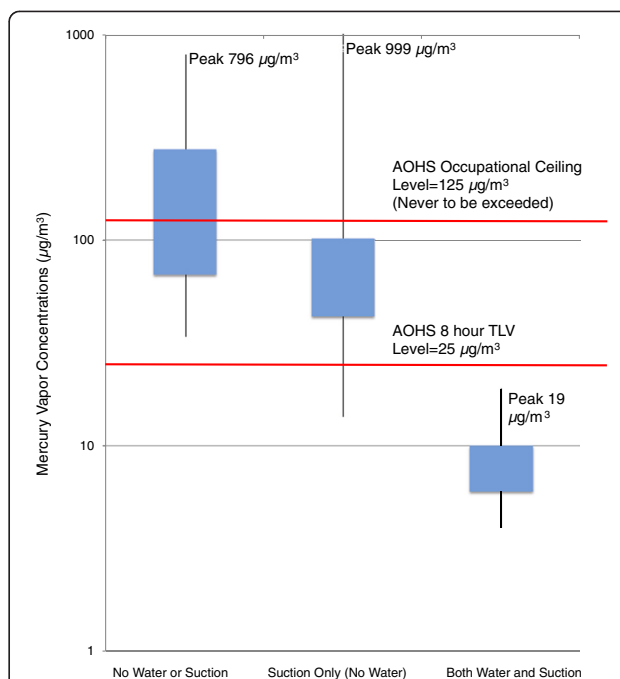


Figure 2 Mercury vapor concentrations in ambient air during amalgam removal relative to AOHS permissible exposure limits.

Sample size = 25 for each of the three experimental conditions. During removal of dental amalgams from model teeth in the dental jaw simulator using a dental drill, mercury vapor in ambient air was measured at a distance of 38 cm from the amalgam site. The range of measurements and highest measurement obtained under each of the three experimental conditions is portrayed. The thick band indicates the range between the first and fourth quartiles. Alberta Occupational Health and Safety (AOHS) permissible exposure limits for mercury vapor are indicated.

cause mild tremors in workers chronically exposed to mercury vapor ($26.0 \mu\text{g}/\text{m}^3$) [14].

This study suggests that dental students training in amalgam removal without the use of water spray and suction are frequently exposed to mercury vapor levels that exceed established safety standards. In order to prevent exposure to unsafe levels of mercury vapor, suction and water spray should be used during all amalgam removal procedures conducted by dental students (as well as by dental practitioners). Dental students in university laboratories often remove amalgams from plastic teeth without the use of protective measures such as water spray or suction in order to enhance visibility of the amalgam and drill. In clinical cases in which the vitality of a tooth is a not a concern, dental students may be advised to drill on mercury amalgam without using water spray. Although mercury vapor exposure occurs predominantly by inhalation, Alberta Occupational Health and Safety, the ACGIH and all Canadian occupational health and safety regulations make specific reference to the risk of skin exposure and penetration by

mercury vapor. In the course of conducting this study, we noted significant accumulation of amalgam particles on clothing and exposed skin. The authors have observed that fellow dental students routinely expose their arms (roll up their sleeves or remove long sleeve outerwear) when working in the dental school laboratories. In situations where exposures exceed occupational limits, such as those reported here during amalgam removals without water or suction, adequate occupational hygiene protective equipment should be considered for student use. Latex gloves commonly worn by dental students are known to be less protective of mercury exposure than non-latex nitrile gloves [15]. Training in proper mercury hygiene is important because dentists and dental workers are at risk of exposure to mercury, the absorption of which has been confirmed by studies that have demonstrated higher systemic levels of this toxin in this population compared to controls. The long-term effects of chronic mercury exposure among dental workers have been established. In an extensive review of the literature Mutter described adverse health issues related to mercury exposure in dental workers that handle dental amalgams [16]. Neurological symptoms were found to be significantly more prevalent among dental assistants compared to non-exposed assistant nurses. These symptoms include psychosomatic symptoms, problems with memory and concentration, fatigue, and sleep disturbance [17]. Female dental assistants working with amalgams have a lower fecundability (ability to conceive) than controls [18]. Among dentists intoxicated with occupational mercury there were significant increases in the prevalence of skin hyper-pigmentation, respiratory disorders, irregular pulse, hand tremor, spasm of upper extremities, neuropsychological symptoms, tachycardia, painful chewing, thyroid enlargement, vague fears and difficulty in writing [19]. Swedish dental workers exhibited increased central nervous symptoms [20]. Ritchie, et. al. reported increased self-reported kidney disorders and memory disturbances among dentists [21]. Female dental workers who work with mercury show an increased risk of miscarriage [22]. It has recently been demonstrated that dentists use medications for ailments that are consistent with chronic mercury poisoning at rates up to 7.5 times that of the non-dental population [23]. The issue of mercury exposure in the dental setting is not isolated to Canada or North America. Díaz Arrázola and María Armida of Columbia concluded that *"there is a total ignorance of the danger to occupational and environmental level in the use of dental amalgam and the dental professionals, education or training on the subject"* [24] (Author's English translation of a conclusion written in Spanish). Ritchie et al. found that a

significant number of dental clinics in Scotland had levels of mercury in the office air and at the inhalation point of dental staff that exceeded Occupational Exposure Standards and recommended that "greater emphasis should be made relating to safe handling of amalgam in the training and continuing professional development of dentists" [21].

The results we obtained in this study agree with some other studies of similar design, however we could find no study that simulated laboratory work of a dental student or used the exact controls that were used in this study. Pohl and Bergman found that when controls were used (water and suction and saliva evacuators) during amalgam removal, the levels at the breathing zone of the dental worker were in the range of 1-2 $\mu\text{g}/\text{m}^3$, however when high volume suction was removed, these researchers obtained "highly fluctuating" mercury levels of mercury vapor ranging from 60 to 450 $\mu\text{g}/\text{m}^3$ [25]. Brune et al. measured both particulate and mercury vapor at the level of the breathing zone and found when water spray was removed, *"short time threshold limit values for exposure to mercury and silver were exceeded about 10 times. With water spray the mercury content was reduced to a level considerably lower than the threshold limit value, whereas the silver concentration slightly exceeded the corresponding limit"* [26]. Nimmo et al. assessed particulate levels at the inhalation area of the dentist and the patient during amalgam removal under three conditions; no water or suction (control), water and suction, and water, suction and the use of a rubber dam. The researchers found that the use of water and suction significantly reduced the respirable particulate when compared to the control and that the addition of the rubber dam reduced the particulate further, however they concluded that even with suction, water and rubber dam, the dentist was still exposed to sufficient particulate to warrant the use of a face shield during amalgam removal [27].

In our study, we assessed only dental students' exposure to mercury vapor when amalgam is removed with a high-speed drill. The aerosol generated from drilling on amalgams also includes particulate material that is a far greater source of mercury exposure when inhaled than is mercury vapor [28]. In addition, our study did not consider the exposure to mercury via the skin, which is another known route of entry of this toxin. Other sources of mercury vapor when working with amalgam may come from amalgam placement (FDI) of the material, as well as polishing and scaling (cleaning) the surfaces of mercury amalgam fillings [29]. Future studies should be undertaken to quantify the dermal exposure to mercury of dental students as a result of exposure to both mercury vapor and mercury-containing amalgam

particles. Other studies could be designed to assess the value of personal protective equipment such as mercury-resistant clothing and certified respirators [30,31] designed to reduce or prevent mercury exposure. Assessments of exposure of dental hygienists exposure to mercury vapor when polishing and scaling amalgam fillings is also highly recommended.

As the occupational risks of using amalgam continue to grow, and the availability of more effective [32-34], economical [35] and safer [36] materials such as composites exists, it appears logical that the use of amalgam be discontinued.

Conclusions

It is paramount that dental schools consider how dental students are trained in the subject of mercury hygiene when removing dental amalgam as well as other procedures where mercury exposure may occur. They must also train dental students in the effective use of personal protective equipment in order to prevent occupational exposure to mercury while in dental school and in clinical practice. Some dental associations and government agencies have developed educational health and safety information identifying occupational hazards and control measures for dental workers. In the "Handbook of Occupational Hazards and Controls for Dental Workers" [30], Alberta Occupational Health and Safety (AOHS) summarizes the need for engineering controls and personal protective equipment when removing amalgams. In this handbook, AOHS recommends the "Elimination of mercury containing amalgams. Substitution with less harmful product(s)" as part of the major engineering control strategies to reduce the risk to dental workers. In some instances, dental schools are not presently teaching mercury hygiene to the standards set by agencies responsible for occupational safety. Dental students require mercury hygiene training so that they may integrate this knowledge into their clinical practices, thus enhancing the safety of dental staff and patients.

Abbreviations

AOCL: Alberta occupational ceiling limit; AOTLV: Alberta occupational threshold limit value; TLV: Threshold limit value; ACGIH: American Conference of Governmental Industrial Hygienists; AOHS: Alberta Occupational Health and Safety.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

BL, AO, and RW participated in the design of the study, carried out the simulations, and collected and recorded data. RW drafted the manuscript. All authors read and approved the final manuscript.

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**TEST QUESTIONS FOR
QUICK REFERENCE
SMART MODULE 2:
SAFE REMOVAL OF
AMALGAM FILLINGS**

*THIS IS A PRINTABLE TEST FOR QUICK REFERENCE, AS SOME CANDIDATES
PREFER TO PREFER TO PREPARE ANSWERS WHILE THEY COMPLETE EACH
COMPONENT OF THE MODULE. TO ACHIEVE CREDIT FOR THIS TEST,
IT MUST BE TAKEN AFTER YOU HAVE COMPLETED MODULE 2 AT
<https://www.cvent.com/d/fvqcmm>*

“Safe Removal of Dental Amalgam Fillings” Online Learning Module:

1. Scientific literature has demonstrated that mercury exposure created by removing old amalgams is a hazard for _____.
- A. dental patients
 - B. dentists and dental staff
 - C. the environment
 - D. all of the above

“Safe Removal of Dental Amalgam Fillings” Online Learning Module:

2. Research shows that the potential for the greatest mercury exposure when drilling out old fillings comes from _____.
- A. skin transmission
 - B. mercury vapor
 - C. fully inhalable amalgam micro-particles
 - D. gray sludge

“Safe Removal of Dental Amalgam Fillings” Online Learning Module:

3. The methods used to mitigate hazardous exposure are technically referred to as _____.
- A. engineering controls
 - B. biomimetics
 - C. on-site mitigation
 - D. separation

“Safe Removal of Dental Amalgam Fillings” Online Learning Module:

4. Evidence from the dental literature demonstrates that a patient's blood mercury goes up after removing amalgam fillings and the effect is greatly reduced by using a rubber dam.
- A. True
 - B. False

“Safe Removal of Dental Amalgam Fillings” Online Learning Module:

5. Beyond the rubber dam, methods that are recommended in scientific literature for protecting patients from breathing, swallowing, and skin exposure to mercury when removing old fillings are _____.
- A. draping and a saliva ejector
 - B. water spray and high speed suction
 - C. room air filtering
 - D. all of the above

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

6. Employee exposure to mercury is regulated in the United States by the 1970 Occupational Health and Safety Act and Workers’ Rights Handbooks which require employers to train employees to avoid or minimize exposures.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

7. Even though dentists, dental professionals, dental staff, and dental students are occupationally and chronically exposed to mercury released from dental mercury amalgam, researchers and clinicians have not raised any concerns whatsoever about the safety of dental personnel who work with dental mercury amalgam.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

8. By minimizing mercury exposure from dental mercury amalgam fillings or completely avoiding the use of dental mercury amalgam fillings, an individual’s total body burden of mercury can be reduced.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

9. According to the IAOMT position statement, minimizing or eliminating mercury exposure can potentially result in improvement and/or decreased risk of disease/illness/health impairments for _____.

- A. dental workers, children, patients with Alzheimer’s disease
- B. pregnant women, patients with multiple sclerosis, patients who are detoxing
- C. dental workers, patients with reproductive dysfunction, breast-fed children
- D. A & B
- E. all of the above

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

10. The room where mercury removal is to take place needs to have adequate air filtration, which requires _____.

- A. a small fan
- B. closing and locking the doors
- C. a high volume, air filtration system
- D. all of the above

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

11. Copious amounts of water to reduce heat and a conventional high speed evacuation device to capture mercury discharges are required to reduce ambient mercury levels during removal.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

12. During removal, the amalgam should be sectioned into chunks and removed in as large of pieces as possible, using a small diameter carbide drill.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

13. The dentist and the assistant should wear _____ during amalgam removal.

- A. face shields
- B. hair coverings
- C. a properly-sealed, respiratory grade mask rated to capture mercury OR a positive pressure, properly-sealed mask providing air or oxygen
- D. A & C only
- E. all of the above and more

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

14. The patient should be provided with _____ for amalgam removal.

- A. barriers to protect skin and clothing
- B. an adsorbent drink before amalgam removal (unless contraindicated)
- C. external air or oxygen via a nasal mask or a nasal cannula completely covered with an impermeable barrier
- D. A & C only
- E. all of the above and more

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

15. A study published in 2016 and conducted on over 76,000 patients for over ten years found that posterior amalgam fillings had a higher annual failure rate than composites.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

16. Sensitization to metal develops in the form of a rash immediately after an implant or device has been placed.

- A. True
- B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

17. Genetic variants scientifically known to impact response to mercury exposures include _____.

- A. KITLG gene on chromosome 12 and variants near the OCA2 gene
- B. BRCA1 and BRCA2
- C. CPOX4; APOE3,4; BDNF (brain-derived neurotropic factor) polymorphisms
- D. None; no specific variants have been documented in the literature

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

18. The number of maternal amalgam fillings has been associated with _____
- A. mercury levels in cord blood
 - B. mercury levels in the placenta, in the kidneys, and liver of fetuses
 - C. mercury levels in fetal hair, and in the brain and kidneys of infants
 - D. the risk of perinatal death
 - E. All of the above

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

19. The use of dental mercury worldwide finally dropped below 25% among dentists worldwide in 2020.
- A. True
 - B. False

“Position Statement against Dental Mercury Amalgam Fillings for Medical and Dental Practitioners, Dental Students, and Patients” by the IAOMT:

20. Some studies advocating the safety of dental mercury amalgam have failed to take into account _____.
- A. genetic factors
 - B. susceptible populations
 - C. metal allergies
 - D. none of the above
 - E. all of the above and more

Mercury Vapor Volatilization from Particulate Generated from Dental Amalgam Removal with a High-Speed Dental Drill—A Significant Source of Exposure:

21. The researchers showed that drilling dental amalgam generates particulate that volatilizes significant amounts of mercury vapor generally for more than an hour after removal.
- A. True
 - B. False

Mercury Vapor Volatilization from Particulate Generated from Dental Amalgam Removal with a High-Speed Dental Drill—A Significant Source of Exposure:

22. The researchers also found that the levels of mercury vapor created by amalgam filling removal with a high-speed dental drill frequently _____ the safety thresholds of several jurisdictions and agencies.
- A. remain well below
 - B. are the exact same as
 - C. exceed
 - D. none of the above

Mercury Vapor Volatilization from Particulate Generated from Dental Amalgam Removal with a High-Speed Dental Drill—A Significant Source of Exposure:

23. The underrecognized source of localized exposure to mercury vapor identified in this study was _____.

- A. related to fish from the diet of dentists, dental hygienists, staff, and patients
- B. amalgam that is flushed into the environment through the water supply
- C. vapor that is constantly given off of amalgam fillings
- D. microgram levels of particulate generated from dental amalgam removal with a high-speed dental drill

Recommendations for the Mercury-Free, Mercury-Safe Dental Office:

24. Some states have regulations that specifically address the removal of mercury fillings from patients for reasons other than the clinical performance of the filling.

- A. True
- B. False

Recommendations for the Mercury-Free, Mercury-Safe Dental Office:

25. The IAOMT recommends to:

- A. never "diagnose" mercury poisoning or claim mercury poisoning from amalgam mercury exposure
- B. never promise patients health improvement from the removal of amalgam fillings. Similarly, do not suggest causation of any type of adverse health effect as a result of mercury.
- C. never worry about using specific terms/language, disclaimers, and informed consent
- D. A & B
- E. all of the above

TO ACHIEVE CREDIT FOR THIS TEST, IT MUST BE TAKEN AFTER YOU HAVE COMPLETED MODULE 2 AT <https://www.cvent.com/d/fvqcmml>

YOU NOW NEED TO ACCESS THE IAOMT'S
“SAFE AMALGAM REMOVAL” VIDEO
ACTIVITY AT [https://iaomt.org/amalgam-removal-
video-activity/](https://iaomt.org/amalgam-removal-video-activity/)

Be sure to complete the pre-activity survey, read the references and selected literature, and take the post-activity survey.

UPON COMPLETION OF THE “SAFE AMALGAM
REMOVAL” VIDEO ACTIVITY, YOU WILL NEED
TO CONTINUE WITH THE ADDITIONAL
REQUIREMENTS FOR MODULE 2.



**International Academy of Oral Medicine and Toxicology
(IAOMT)**
**Position Paper against Dental Mercury Amalgam Fillings
for Medical and Dental Practitioners, Dental Students,
Dental Patients, and Policy Makers**

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INTRODUCTION

Position Paper Objectives:¹

- 1) To end the use of dental mercury amalgam fillings. Many other mercurial medical devices and mercury-containing substances have been removed from use, including mercurial wound disinfectants, mercurial diuretics, mercury thermometers, and mercurial veterinary substances. In this era when the public is advised to be concerned about mercury exposure through fish consumption, dental mercury amalgam fillings should also be eliminated, especially because they are the predominant source of non-industrial mercury exposure in the general population.
- 2) To assist medical professionals and patients as a whole in understanding the scope of mercury hazards from dental mercury amalgam fillings. The risk of illness or injury associated with the use of dental mercury presents an unreasonable, direct, and substantial danger to the health of dental patients, dental personnel, and the fetuses and children of dental patients and dental personnel.
- 3) To establish the health benefits of mercury-free, mercury-safe, and biological dentistry.
- 4) To educate dental and medical professionals, dental students, patients, and policy makers about safe removal of dental mercury amalgam fillings, while raising the standards of scientific biocompatibility in dental practice.

Regulations Overview:

According to the [United States Food and Drug Administration](#) (FDA), “Dental amalgam is a mixture of metals, consisting of liquid (elemental) mercury and a powdered alloy composed of silver, tin, and copper. Approximately 50% of dental amalgam is elemental mercury by weight. The chemical properties of elemental mercury allow it to react with and bind together the silver/copper/tin alloy particles to form an amalgam. Dental amalgam fillings are also known as ‘silver fillings’ because of their silver-like appearance. Despite the name, ‘silver fillings’ do contain elemental mercury.”²

Millions of dentists around the world routinely use dental mercury amalgam to repair decayed teeth, but controversy has surrounded the use of mercury in dentistry since the 1800’s, when the neurotoxin was first widely introduced as a filling material. The American Society of Dental Surgeons, the predecessor to the American Dental Association, [made its members pledge not to use mercury because of its known toxicity](#),³ and in more recent years, government officials, scientists, dentists, consumers, and many others have raised serious concerns about the risks dental mercury poses to humans and to the environment at large.

International Regulations:

The United Nations Environment Programme’s Intergovernmental Negotiating Committee agreed upon the text of a global, legally-binding mercury treaty in 2013, and over 100 nations have since signed the “[Minamata Convention on Mercury](#).” The United States was the first country to give its support for ratification of the international agreement, which entered into force in 2017. Annex A, Part II, includes the following initiatives with regards to dental mercury amalgam:⁴

- (i) Setting national objectives aiming at dental caries prevention and health promotion, thereby minimizing the need for dental restoration;
- (ii) Setting national objectives aiming at minimizing its use;
- (iii) Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration;
- (iv) Promoting research and development of quality mercury-free materials for dental restoration;
- (v) Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices;
- (vi) Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration;
- (vii) Encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration;
- (viii) Restricting the use of dental amalgam to its encapsulated form;
- (ix) Promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.⁵

As part of the Minamata Convention on Mercury, the European Parliament voted in March 2017 to reduce dental mercury use. In addition to reporting “on the feasibility of a phase out of the use of dental amalgam in the long term, and preferably by 2030,”⁶ [the new European Union regulation](#) includes the following measures:

1. From 1 January 2019, dental amalgam shall only be used in pre-dosed encapsulated form. The use of mercury in bulk form by dental practitioners shall be prohibited.
2. From 1 July 2018, dental amalgam shall not be used for dental treatment of deciduous teeth, of children under 15 years and of pregnant or breastfeeding women, except when deemed strictly necessary by the dental practitioner based on the specific medical needs of the patient.
3. By 1 July 2019, each Member State shall set out a national plan concerning the measures it intends to implement to phase down the use of dental amalgam.⁷

A number of countries have likewise taken action against the use of dental mercury amalgam fillings. A [2017 report from the United Nations Environment Programme](#) establishes that the following measures have been taken around the globe:

In Norway and Sweden, dental amalgam is no longer in use.
 In Japan, Finland and the Netherlands, dental amalgam is being phased out.
 In Mauritius and the European Union, dental amalgam is banned from use on children.
 Denmark uses dental amalgam for only 5 per cent of restorations, and Germany for about 10 per cent.
 In Bangladesh, dental amalgam is to be phased out in 2018.
 In India, dental schools are required to eliminate amalgam in favor of mercury-free alternatives.
 In Nigeria, the government has printed and distributed consumer information brochures promoting mercury-free alternatives to amalgam.
 The government of Canada has recommended that dentists not use amalgam for children, pregnant women and persons with kidney disorders.⁸

U.S. Regulations--States:

In the United States, brochures have been created to educate patients about their choices for dental fillings in [California](#),⁹ [Connecticut](#),¹⁰ [Maine](#),¹¹ and [Vermont](#).¹² The brochures, some of which are legally required to be presented to dental patients, contain information about the release of mercury vapor from dental mercury amalgam fillings and concerns related to dental mercury amalgam usage.

U.S. Regulations--Environmental Protection Agency (EPA):

Recently, the U.S. Environmental Protection Agency (EPA) utilized measures in the Clean Water Act to develop standards for dental offices/clinics to use amalgam separators so that dental mercury is not flushed down the drain and into the environment.¹³ EPA estimates about 103,000 dental offices use or remove amalgam in the U.S. and that almost all of these send their wastewater to POTWs [publicly owned treatment works].¹⁴ [The new guidelines](#) went into effect in July 2017, and the EPA has estimated that it could reduce the discharge of mercury by 5.1 tons annually.¹⁵

U.S. Regulations--Occupational Safety and Health Administration (OSHA):

Employee exposure to mercury is regulated in the United States by the [1970 Occupational Safety and Health Act](#)¹⁶ and [Workers' Rights Handbooks](#)¹⁷ from the United States Department of Labor's Occupational Safety and Health Administration (OSHA), which establish that all employees have the right to know about the chemicals in their work environment. OSHA's Hazard Communication Standard (HCS) states: "All employers with hazardous chemicals in their workplaces must have labels and safety data sheets [SDS] for their exposed workers, and train them to handle the chemicals appropriately. The training for employees must also include information on the hazards of the chemicals in their work area and the measures to be used to protect themselves."¹⁸

The purpose of the safety data sheets (SDS, formerly known as material safety data sheets, or MSDS) required by OSHA is to protect workers by supplying them with the most crucial facts about the hazardous materials at their jobsite, such as the physical properties of the material, proper storage and handling techniques, known health risks and essential emergency procedures. Thus, manufacturers of amalgam fillings must create these information sheets, and excerpts from just a few of the SDSs for dental amalgam includes compelling evidence about the known dangers of using mercury in fillings:

- [SDI; Permite; Lojic +; GS-80, GS-80 Spherical; F400; Ultracaps +; Ultracaps S; SDI Admix; SDI Spherical and New Ultrafine.- Capsules](#); Australia, Brazil, Ireland, and the USA; 2015:¹⁹
 - Hazard Identification/California Prop 65 Warning: "This product contains mercury, a chemical known to the State of California to cause birth defects or other reproductive harm."
 - First Aid Measures: "May cause respiratory disorders including inflammation and fluid retention. Inhalation of mercury vapours at high concentration can cause dyspnea, coughing, fever, severe nausea, vomiting, excess salivation, kidney damage with renal shutdown."

- o Toxicological Information/Chronic Health Effects: “Inhalation of mercury vapours, dusts or organic vapours, or skin absorption or mercury over long periods can cause mercurialism. Symptoms include tremors, inflammation of mouth and gums, excessive salivation, stomatitis, blue lines on gums, pain and numbness in extremities, weight loss, mental depression, and nervousness. Exposure may aggravate kidney disorders, chronic respiratory disease and nervous system disorders. May cause damage to blood, kidneys, liver, brain, peripheral nervous system, central nervous system.”
- [Kerr Corporation; Tytin FC™](#); USA; 2014:²⁰
 - o First Aid Measures/Inhalation: “Adverse symptoms may include the following: reduced fetal weight, increase in fetal deaths, skeletal malformations, salivation, metallic taste, eye irritation, respiratory tract irritation, coughing, pulmonary edema, wheezing and breathing difficulties, headache, fever, nausea or vomiting, diarrhea, abdominal cramps and pain, muscle weakness / pain, mental confusion or disorientation.”
 - o First Aid Measures/Skin Contact: “Adverse symptoms may include the following: reduced fetal weight, increase in fetal deaths, skeletal malformations.”
 - o First Aid Measures/Ingestion: “Adverse symptoms may include the following: reduced fetal weight, increase in fetal deaths, skeletal malformations.”
- [Henry Schein; SDS acc. to OSHA HCS/GHS; Stratosphere, Ionosphere, Troposphere](#); USA; 2016:²¹
 - o Risk phrases: “May cause harm to the unborn child. Also very toxic by inhalation. Also toxic: danger of serious damage to health by prolonged exposure through Inhalation.”
 - o Additional toxicological information: “Avoid exposure of mercury to pregnant person.”

U.S. Regulations--U.S. Food and Drug Administration (FDA):

In [September of 2006](#), a joint panel of FDA scientific experts rejected an FDA White Paper’s assurances of the safety of dental mercury amalgam.²²

On July 28, 2008, the IAOMT submitted [a public comment to FDA](#)²³ demanding dental mercury amalgam be classified in conformance with the mandate of the [Medical Device Amendments of 1976](#).²⁴ Nearly a year later, the IAOMT also filed a Citizen’s Petition to further influence FDA policy-making on amalgam. A few days after that, on July 28, 2009, [FDA announced](#) it was classifying dental mercury amalgam for the first time in Class II without requiring any significant special controls.²⁵

FDA’s [Final Rule](#) on this issue was published on August 4, 2009,²⁶ and an FDA [warning](#) for dental mercury amalgam use in developing children and pregnant women (fetuses)²⁷ was soon removed from the FDA website.

FDA also published an [Addendum](#) in support of its Final Rule,²⁸ which attempted to address the recommendations of the joint panels that convened in [September of 2006](#) when they rejected the

proclamations of dental mercury amalgam safety set forth in the FDA's White Paper on amalgam fillings.²⁹

Following the issuance of the FDA's Final Rule, the IAOMT sponsored a [Petition for Reconsideration](#) in 2009 which identified over 25 errors committed by FDA in its discussion of risk assessment principles.³⁰

Based on the IAOMT petition, the FDA scheduled a meeting of the Dental Products Panel of the Medical Devices Advisory Committee in December 2010. At the meeting, Dr. Suresh Kotagal, a pediatric neurologist at the Mayo Clinic announced: "...I think that there is really no place for mercury in children."³¹ The [2010 Dental Products Panel](#) encouraged the FDA to consider limiting dental mercury amalgam use in pregnant women and children and to consider labeling that would warn consumers about the risks of this mercury-containing product.³²

In spite of this meeting and international legislative actions, the [U.S. Food and Drug Administration \(FDA\) currently](#) "considers dental amalgam fillings safe for adults and children ages 6 and above."³³ However, details in the FDA's public statements about dental mercury amalgam on its website have changed over the years, including information about its potentially harmful impact on pregnant women, fetuses, and children under the age of six. Importantly, there are no enforced FDA regulations for this susceptible population or any other population.

Due in part to concerns about this lack of protection, the IAOMT filed a lawsuit in 2014 against the FDA over its classification of dental mercury amalgam.³⁴ As part of the case, the IAOMT secured an [internal document from the FDA](#) that had proposed restricting dental mercury amalgam use in pregnant and nursing women and children under the age of six, as well as individuals with mercury allergies and pre-existing kidney or neurological disease.³⁵ Yet, allegedly for administrative reasons, the FDA communication (dated January 2012) was never released to the public.

IAOMT's Position on Regulations:

Founded in 1984, [the International Academy of Oral Medicine and Toxicology \(IAOMT\)](#) is a worldwide organization of dentists, physicians, and research professionals devoted to the examination, compilation, and dissemination of scientific information about the biocompatibility of oral/dental materials. The fundamental mission of the IAOMT is to promote the health of the public. In this regard, the IAOMT continually reviews, composes, and shares analytical research and educational materials related to the biocompatibility of oral/dental materials.

Thus, this position paper was formulated by conducting a PubMed literature search, hand-searching an IAOMT collection of published literature, analyzing the available scientific data, reviewing personal experiences of IAOMT members in clinical settings, synthesizing expert opinions, funding relevant research to explore various aspects of dental mercury amalgam and non-amalgam alternate dental materials, and evaluating information about the issue provided by governmental authorities, health organizations, and environmental groups from around the world.

Additionally, this position paper clearly outlines significant quantities of reputable research and challenges the safety of dental mercury amalgam fillings by applying two cornerstones of public health policy: 1) risk assessment and 2) the precautionary principle.

1) “[Risk assessment](#)” has been defined by the FDA as follows: “Risk assessment consists of identifying and characterizing the nature, frequency, and severity of the risks associated with the use of a product. Risk assessment occurs throughout a product’s lifecycle, from the early identification of a potential product, through the premarketing development process, and after approval during marketing. Premarketing risk assessment represents the first step in this process prior to marketing.”³⁶

Risk assessment expert Dr. G. Mark Richardson was invited by the FDA to present the results of a major risk assessment analysis of dental mercury amalgam fillings at the [2010 FDA Dental Products Panel meeting](#).³⁷ Dr. Richardson’s work, which established that millions of Americans exceed the intake of mercury vapor considered “safe” by the U.S. Environmental Protection Agency (EPA) due to the presence of dental mercury amalgam fillings, was published shortly thereafter.³⁸ [FDA’s report about the 2010 meeting](#) noted: “The Panel deliberated on the exposure to mercury from dental amalgam, reference exposure levels, human clinical studies and the strength and weaknesses of the available evidence.”³⁹

Additionally, a conscientious and ethical deliberation of the data and analysis should include a second cornerstone of public health policy known as the precautionary principle.

2) In June 1992, the United Nations Environment Programme ratified the [Rio Declaration on Environment and Development](#) which, among other principles, established the precautionary approach among UNEP member states. In particular, Principle 15 states: “In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”⁴⁰

Further to the Rio Declaration, in January 1998, at an international conference involving scientists, lawyers, policy makers, and environmentalists from the United States, Canada and Europe, a formalized statement was signed and became known as the “[Wingspread Statement on the Precautionary Principle](#).”⁴¹

In it, the following advice is given: “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof.”⁴²

Based on scientific evidence, concepts of risk assessment, and the precautionary principle, it is our position that dental mercury amalgam fillings should not be used in dentistry. It should also be noted here that the IAOMT is concerned that dental mercury amalgam fillings are following the same delayed route to safety regulations as occurred with cigarettes and lead-based paint.

SUGGESTED ACTION BY MEDICAL AND DENTAL PRACTITIONERS AND PATIENTS:

INTERVENTIONS

Summary of Interventions:

- 1) The main ingredient for mercury amalgam fillings is mercury, approximately 50% by weight. Therefore, the appropriate terminology is “dental mercury amalgam fillings.”
- 2) Dental mercury amalgam fillings should not be used in dentistry.
- 3) The detrimental impact of mercury on fetuses, pregnant women, women of childbearing age, children, patients experiencing health issues, and dental workers mandate that special protection be provided to these populations with regards to dental mercury amalgam fillings.
- 4) Removal of existing dental mercury amalgam fillings requires safety measures for dentists, dental staff, dental students, and patients.

Detail of Interventions:

1) The main ingredient for mercury amalgam fillings is mercury, approximately 50% by weight. Therefore, the appropriate terminology is “dental mercury amalgam fillings.”

All dental amalgam restorations contain approximately 50% mercury,⁴³ and reports and research are consistent that these fillings emit mercury vapors.^{44 45 46 47 48 49 50 51 52 53 54 55 56 57 58}

Thus, while these restorations are commonly referred to as “silver fillings,” “dental amalgam,” and/or “amalgam fillings,” the public is often unaware that amalgam refers to the combination of other metals with mercury.⁵⁹ A 2014 Zogby poll established that 57% of Americans did not know that mercury is the main ingredient in amalgam fillings and that 63% thought the commonplace practice of referring to mercury amalgams as “silver fillings” was misleading.⁶⁰ It would be more appropriate therefore to recognize them as “dental mercury amalgam fillings,” “mercury silver fillings,” or “mercury fillings.” Terminology recognizing the main ingredient of mercury is needed so that medical and dental practitioners, dental students, patients, and policy makers are aware that mercury is the main ingredient in this medical device.^{61 62 63} As such, this document refers to these tooth restorations as “dental mercury amalgam fillings.”

Additionally, an understanding of the terminology associated with dentists that aim to end the use of dental mercury amalgam fillings is helpful to medical professionals and patients. These terms are commonly used, and dentists often choose one or several of these terms to describe their practice:

- “Mercury-free” is a term with a wide-range of implications, but it typically refers to dental practices that do not place dental mercury amalgam fillings.
- “Mercury-safe” typically refers to dental practices that use safety measures to limit or prevent mercury exposure, such as in the case of removing previously existing dental mercury amalgam fillings and replacing them with non-mercury alternatives.
- “Biological” or “Biocompatible” dentistry typically refers to dental practices that utilize mercury-free and mercury-safe dentistry while also considering the impact of dental conditions, devices, and treatments on oral and systemic health, including the biocompatibility of dental materials and techniques.

2) Dental mercury amalgam fillings should not be used in dentistry.

Exposure to mercury, even in minute amounts, is known to be toxic and poses significant risks to human health. A 2005 [World Health Organization report](#) warned of mercury: “It may cause harmful effects to the nervous, digestive, respiratory, immune systems and to the kidneys, besides causing lung damage. Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental deficits during fetal development, and attention deficit and developmental delays during childhood. Recent studies suggest that mercury may have no threshold below which some adverse effects do not occur.”⁶⁴

Scientific research demonstrates that dental mercury amalgam exposes dental professionals, dental staff, dental patients, and fetuses to releases of mercury vapor, mercury-containing particulate, and/or other forms of mercury contamination.^{65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109} Dental mercury amalgam is therefore not a suitable material for dental restorations.

Furthermore, mercury vapor is known to be released from dental mercury amalgam fillings at higher rates during brushing, cleaning, clenching of teeth, chewing, etc.,^{110 111 112 113 114 115 116 117 118 119 120 121 122 123} and mercury is also known to be released during the placement, replacement, and removal of dental mercury amalgam fillings.^{124 125 126 127 128 129 130 131 132 133 134 135 136 137 138}

A series of studies demonstrate that urinary mercury concentrations consistently increase as the number of amalgam fillings increases.^{139 140 141 142 143 144} In these studies, the average urine mercury content is consistently greater in groups with amalgam fillings than in those without, and urine mercury content consistently increases as the number of dental mercury amalgam fillings increases.

Numerous studies have also demonstrated that the mercury exposure or concentration increases in the following tissues and situations

- Due to chewing, brushing, and/or bruxism^{145 146 147 148 149 150 151 152 153 154 155}
- In exhaled or intra-oral air of persons with amalgam fillings^{156 157 158 159}
- In saliva of persons with amalgam fillings^{160 161 162 163 164 165}
- In blood of persons with amalgam fillings^{166 167 168 169 170 171 172 173 174 175 176 177 178}
- In various organs and tissues of amalgam bearers, including the kidney, liver, pituitary gland, thyroid, and brain or parts thereof^{179 180 181 182 183}
- In feces of amalgam bearers^{184 185 186}
- In amniotic fluid, cord blood, placenta, and various fetal tissues including liver, kidney, brain, and hair in association with maternal amalgam load^{187 188 189 190 191 192 193 194 195}
- In colostrum and breast milk in association with maternal amalgam load^{196 197 198}

Scientific evidence confirms that in most individuals with dental mercury amalgam fillings, [mercury exposure exceeds the Reference Exposure Level \(REL\)](#).¹⁹⁹ [REL is a term used to denote the exposure level defined by national and international regulatory agencies at which there is an expectation of *no negative health outcomes* within the population.]

Also, [reports from the World Health Organization \(WHO\)](#) and [Canada's federal department of health \(Health Canada\)](#) conclude that mercury vapor from dental amalgam is the greatest source of human exposure to mercury in non-industrial settings.^{200 201}

Additionally, [in research published in 2011](#), Dr. G. Mark Richardson reported that more than 67 million Americans aged two years and older exceed the intake of mercury vapor considered “safe” by the U.S. EPA due to the presence of dental mercury amalgam fillings, whereas over 122 million Americans exceed the intake of mercury vapor considered “safe” by the California EPA due to their dental mercury amalgam fillings.²⁰²

3) The detrimental impact of mercury on fetuses, pregnant women, women of childbearing age, children, patients experiencing health issues, and dental workers mandate that special protection be given to these populations with regards to dental mercury amalgam fillings.

Mercury's damaging influence on the developing brain and neurological system makes dental mercury amalgam fillings an inappropriate material for use in children, pregnant women, and women of childbearing age. In fact, research has repeatedly shown the potential for significant impacts to pregnant women, fetuses, and children as a result of dental mercury.^{203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242}

Additionally, physicians and dentists should, where patients are suffering from pathological states and/or disease of unclear causation, consider in their differential diagnosis whether exposure to mercury released from dental mercury amalgam fillings might be a contributing or exacerbating factor in such adverse health conditions. This is because dental mercury amalgam has been associated with a wide-range of adverse health conditions.^{243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339} It should also be remembered that reactions to mercury exposures vary from person to person, including exposures to dental mercury.^{340 341}

Finally, dentists, dental staff, and dental students are exposed to mercury at a greater rate than their patients. Severe exposures from past practices include hand-squeezing of fresh amalgam, where drops of liquid mercury could run over the dentist's hands and contaminate the entire office.³⁴² Dangerous levels of mercury are still generated in the dental workplace, and research has clearly identified that exposure to these mercury levels can cause ill-health to dental workers,^{343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378} and dental students.^{379 380 381} Another area that has received attention is the possibility of reproductive hazards to female dental personnel, including menstrual cycle disorders, fertility issues, and pregnancy risks.^{382 383 384 385 386 387 388 389}

Dental workers require protection from mercury exposures when working with dental mercury amalgam, and a variety of studies have specifically called for protective measures to be taken in the dental office as a means of limiting mercury releases.^{390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410}

4) *Removing dental mercury amalgam fillings requires safety measures for dentists, dental staff, and patients.*

Chronic (low dose, long-term) exposure to mercury for dentists, dental staff, dental students, and dental patients does not exist when alternative materials are used for dental fillings. However, there is a high risk of acute (high dose, short-term) mercury exposure to dentists, dental staff, dental students, and dental patients when dental mercury amalgam fillings are drilled out. Essentially, an unsafe amalgam removal process releases mercury vapor and particles that can be harmful to the patient, the dentist, the dental staff, and the environment.^{411 412 413 414 415 416 417 418}
^{419 420} Obviously, the danger to the patient is increased since mercury is being released directly into the mouth and lungs.

There are levels of increasing protection for limiting exposure during mercury-related dental procedures. Depending on the level of protection, health risks will vary. The challenge is training dentists from around the globe to use effective engineering controls and personal protective equipment as they remove the thousands of tons of mercury currently stored in the mouths of patients with dental mercury amalgam fillings. An additional challenge is training U.S. dentists to properly comply with both the current OSHA standards⁴²¹ and the EPA standards.⁴²²

Utilizing the most up-to-date science and research, the IAOMT has developed extensive safety recommendations for removal of existing dental mercury amalgam fillings, including detailed protective measures that are to be utilized for the procedure.⁴²³ The IAOMT's innovative recommendations build upon traditional safe amalgam removal techniques such as the use of masks, water irrigation, and high volume suction by supplementing these conventional strategies with a number of additional protective measures, the need for which have only recently been identified in scientific research. The IAOMT's Safe Mercury Amalgam Removal Technique (SMART) is described in more detail on pages 14-16 below.

OUTCOMES CONSIDERED

Individual Response:

First, it should be noted that mercury influences each individual differently based on a wide-range of co-existing factors.⁴²⁴ For example, other health conditions (specified throughout this document), the number of amalgam fillings in the mouth,^{425 426 427 428 429 430 431 432 433} and/or the number of amalgam surfaces in the mouth,^{434 435 436 437 438 439 440 441 442 443 444 445} the type of the amalgam filling (i.e. specific content of metals);^{446 447} gender;^{448 449 450 451 452 453 454} genetic predisposition;^{455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474} dental plaque;⁴⁷⁵ exposure to electromagnetic fields (EMF) from magnetic resonance imaging (MRI),^{476 477 478 479} mobile/cellular phones,⁴⁸⁰ and Wi-Fi;^{481 482 483} exposure to aluminum,^{484 485} fluoride,^{486 487} lead,^{488 489 490 491 492} and other environmental toxicants;⁴⁹³ selenium levels;^{494 495} consumption of milk^{496 497} or alcohol;⁴⁹⁸ methylmercury levels from fish consumption;^{499 500 501} the potential for mercury from dental amalgam fillings to be transformed into methylmercury within the human body;^{502 503 504 505 506 507} and other circumstances^{508 509} can play a role in each person's unique response to mercury. Table 1 below shows a number of factors related to mercury responses.

TABLE 1: Abbreviated list of variables potentially influencing individual reactions to dental mercury exposure

Factors related to mercury vapor release from dental amalgam filling
Age of amalgam filling
Cleaning, polishing, and other dental procedures
Contents of other materials mixed with the mercury, such as tin, copper, silver, etc.
Dental plaque
Deterioration of amalgam filling
Habits such as brushing, bruxism, chewing (including gum chewing, especially nicotine gum), consumption of hot liquids, diet (especially acidic foods), smoking, etc.
Infections in the mouth
Number of amalgam fillings
Other metals in the mouth, such as gold fillings or titanium implants
Root canals and other dental work
Saliva content
Size of amalgam filling
Surface area of amalgam filling
Techniques and safety measures applied when removing amalgam filling
Techniques used when placing amalgam filling
Exposure to electromagnetic fields (EMF) from magnetic resonance imaging (MRI), mobile/cellular phones, and Wi-Fi
Personal traits and conditions related to mercury exposure response
Alcohol consumption
Allergy or hypersensitivity to mercury
Bacteria, including mercury resistant and antibiotic resistant
Burdens in organs and tissues such as the kidney, pituitary gland, liver, and brain
Diet and levels of nutrients such as selenium
Drug use (prescription, recreational, and addiction)
Exercise
Exposure to other forms of mercury (i.e., fish consumption), aluminum, fluoride, lead, pollution, and any toxic substances (presently or previously)
Fetal or breast milk exposure to mercury, lead, and any toxic substances
Gender
Genetic traits and variants
Infections
Microbes in the gastrointestinal tract
Milk consumption
Nutrient levels, especially copper, zinc, and selenium
Occupational exposures to toxic substances
Overall health
Parasites and helminths
Stress/trauma
Yeast

SOURCE: This has been adapted from Table 7.3 in Kall J, Just A, Aschner M. What is the risk? Dental amalgam, mercury exposure, and human health risks throughout the lifespan. *Epigenetics, the Environment, and Children's Health across Lifespans*. David J. Hollar, ed. Springer. 2016. pp. 159-206 (Chapter 7). Abstract available from: http://link.springer.com/chapter/10.1007/978-3-319-25325-1_7. Accessed March 19, 2019.

In the same way that individual response influences reactions to mercury exposures, individual response also varies from patient to patient upon amalgam removal. Research supports the fact that many patients benefit from having their amalgams removed and replaced with an alternative material. A few examples of conditions reportedly improved and/or cured as a result of removing dental metal allergens include amyotrophic lateral sclerosis,^{510 511} autoimmune thyroiditis,^{512 513 514 515 516} myalgic encephalomyelitis/chronic fatigue syndrome,^{517 518 519 520 521 522} dermatitis,^{523 524 525 526} fibromyalgia,^{527 528 529} multiple sclerosis,^{530 531 532} oral lichen planus,^{533 534 535 536 537 538 539} oral lichenoid lesion,^{540 541 542 543 544 545 546 547 548 549 550 551 552} orofacial granulomatosis,^{553 554} and other symptoms.^{555 556 557 558 559} In addition to the recovery situations mentioned above, which are specifically related to dental allergies, research has likewise documented the reduction of other health issues after the removal of mercury amalgam fillings.^{560 561 562 563 564 565 566 567 568 569 570 571 572 573 574} Table 2 is brief overview of some of the research articles showing improvement in autoimmune illnesses after amalgam removal.

TABLE 2: Condensed List of Research Documenting Improvement in Autoimmune Conditions upon Metal Implant/Device Removal, including Dental Mercury Amalgam Fillings

Health Condition/s Improved or Recovered	Implant/Device Removed
Autoimmune Thyroiditis/ Fatigue	Dental mercury amalgam fillings ^{575 576 577 578}
Chronic Fatigue Syndrome (Myalgic Encephalomyelitis/Chronic Fatigue Syndrome)	Dental mercury amalgam fillings and other metallic dental restorations ^{579 580 581 582 583}
Chronic Fatigue Syndrome (Myalgic Encephalomyelitis/Chronic Fatigue Syndrome)	Nickel clips from tubal ligation, dental mercury amalgam fillings and other metallic dental restorations ⁵⁸⁴
Crohn's Disease	Dental mercury amalgam fillings and other metallic dental restorations ⁵⁸⁵
Dermatitis	Cobalt-chromium prosthesis and dental mercury amalgam fillings ⁵⁸⁶
Fibromyalgia	Dental mercury amalgam fillings and other metallic dental restorations ^{587 588 589}
Multiple Sclerosis	Dental mercury amalgam fillings and other metallic dental restorations ^{590 591}
Multiple symptoms including fatigue, pain, depression, and headache	Dental mercury amalgam fillings and other metallic dental restorations ⁵⁹²
Oral lichen planus	Dental mercury amalgam fillings and other metallic dental restorations ^{593 594}
Sjögren's Syndrome	Dental mercury amalgam fillings and other metallic dental restorations ^{595 596}
Systemic Lupus Erythematosus	Dental mercury amalgam fillings ⁵⁹⁷

Amalgam Removal:

However, an outcome of dental mercury amalgam removal is acute exposure to mercury vapor and particulate for dentists, dental staff, dental students, and dental patients,^{598 599 600 601 602 603 604 605 606 607 608 609} especially endangering pregnant women, lactating women, women of childbearing age, fetuses, children, and other sensitive populations.

Other than primary exposures during dental mercury amalgam removal, secondary exposures in less obvious areas of the dental office are emerging as additional sources of chronic mercury exposures. Some of these peripheral exposures include the following:

- mercury exposure to staff, patients, and visitors in other parts of the office not directly involved in the removal process
- environmental mercury exposure caused by the waste from removal and storage of amalgam, especially because the ADA's "[Best Management Practices for Amalgam Waste](#)"⁶¹⁰ is voluntary
- storage and disposal of workplace protective clothing and instruments used during procedures involving dental mercury amalgam
- mercury vapor exposure from sterilization of instruments used on dental mercury amalgam fillings
- mercury vapor and particulate on the carpeting/flooring, walls, ceilings, drapes, HVAC ducts, etc.
- mercury particulate that is carried home in hair, on shoes, clothing, and other items from the dental office

To assist in mitigating the potential negative outcomes of both primary and secondary mercury exposure during amalgam removal, the IAOMT has developed new safety recommendations for removal of existing dental mercury amalgam fillings to protect dental professionals, students, staff members, patients, and others from mercury exposure.⁶¹¹

More specifically, the IAOMT's [Safe Mercury Amalgam Removal Technique \(SMART\)](#) includes the following practices, which are cited here with scientific research supporting each step of the technique:

An amalgam separator must be properly installed, utilized, and maintained to collect mercury amalgam waste so that it is not released into the effluent from the dental office.^{612 613 614 615 616 617 618 619 620 621 622 623 624 625}

Each room where mercury fillings are removed must have adequate filtration in place,^{626 627 628 629} which requires a high-volume air filtration system (such as an at source oral aerosol vacuum) capable of removing mercury vapor and amalgam particles generated during the removal of one or more mercury fillings.^{630 631}

If possible, windows should be opened to reduce the mercury concentration in the air.^{632 633 634 635}

The patient will be given a slurry of charcoal, chlorella, or similar adsorbent to rinse and swallow before the procedure (unless the patient declines or there are other contraindications making this clinically inappropriate).^{636 637 638}

Protective gowns and covers for the dentist,^{639 640} dental personnel,^{641 642} and the patient⁶⁴³ must be in place. All present in the room must be protected because substantial quantities of particles generated during the procedure will elude collection by suction devices.^{644 645} It has been demonstrated that these particles can be spread from the patient's mouth to the hands, arms, face, chest and other parts of the dental worker's and patient's anatomy.⁶⁴⁶

Non-latex nitrile gloves must be utilized by the dentist and all dental personnel in the room.^{647 648 649 650 651}

Face shields and hair/head coverings are to be utilized by the dentist and all dental personnel in the room.^{652 653 654}

Either a properly-sealed, respiratory grade mask rated to capture mercury or a positive pressure, properly-sealed mask providing air or oxygen must be worn by the dentist and all dental personnel in the room.^{655 656 657 658}

In order to protect the patient's skin and clothing, a full body, impermeable barrier, as well as a full head/face/neck barrier under/around the dam, need to be utilized.^{659 660 661}

External air or oxygen delivered via a nasal mask for the patient also needs to be utilized to assure the patient does not inhale any mercury vapor or amalgam particulate during the procedure.^{662 663 664} A nasal cannula is an acceptable alternative for this purpose as long as the patient's nose is completely covered with an impermeable barrier.

A dental dam^{665 666 667 668 669 670 671} that is made with non-latex nitrile material^{672 673 674} must be placed and properly sealed in the patient's mouth.

A saliva ejector must be placed under the dental dam to reduce mercury exposure to the patient.^{675 676}

During amalgam filling removal, the dentist must utilize an at source oral aerosol vacuum in close proximity to the operating field (i.e., two to four inches from the patient's mouth) to mitigate mercury exposure.^{677 678}

High speed evacuation produces better capture when fitted with a Clean Up device,^{679 680} which is not mandatory but is preferred.

Copious amounts of water to reduce heat^{681 682 683 684 685 686 687 688} and a conventional high speed evacuation device to capture mercury discharges^{689 690 691 692 693 694 695 696 697 698} are required to reduce ambient mercury levels.⁶⁹⁹

The amalgam needs to be sectioned into chunks and removed in as large of pieces as possible,^{700 701 702 703} using a small diameter carbide drill.^{704 705}

Once the removal process is complete, the patient's mouth should be thoroughly flushed with water^{706 707} and then rinsed out with a slurry of charcoal, chlorella or similar adsorbent.⁷⁰⁸

Dentists must comply with federal, state, and local regulations addressing the proper handling, cleaning, and/or disposal of mercury-contaminated components, clothing, equipment, surfaces of the room, and flooring in the dental office.

During the opening and maintenance of suction traps in operatories or on the main suction unit, dental staff should utilize the appropriate personal protection equipment described above.

In addition to the research cited above supporting each step of the IAOMT's SMART protocol, SMART has also been recommended by [researchers of a study published in 2019 in the peer-reviewed *Journal of Pharmacy and Bioallied Sciences*.](#)⁷⁰⁹

Alternatives to Amalgams:

Obviously, once amalgams have been removed, they must be replaced with a different dental filling material. Alternatives to amalgam include composite resin, glass ionomer, porcelain, and gold, among other options. When given the choice, most consumers opt for direct composite fillings because the white coloring matches the tooth better and the cost is considered moderate.

In the past, a common argument against composite fillings was that they were not as durable as amalgam. However, recent studies have debunked this claim. Researchers of a study which was published in 2016 and conducted on over 76,000 patients for over ten years found that posterior amalgam fillings had a *higher* annual failure rate than composites.⁷¹⁰ Two separate studies published in 2013 found that composite fillings performed as well as amalgam when comparing failure rates⁷¹¹ and replacement filling rates.⁷¹² Other research has offered similar findings:

- a study about the longevity of composite fillings published in 2017 and authored by researchers at the University of Pittsburgh School of Dental Medicine concluded that composites can replace amalgam restorations;⁷¹³
- a study published in 2015 documented "good clinical performance" of composite resins over a 30-year evaluation;⁷¹⁴
- a meta-analysis published in 2014 noted "good survival" of posterior resin composite restorations;⁷¹⁵
- and a study published in 2011 found "good clinical performance" of composites over a 22-year period.⁷¹⁶

Research has further confirmed that composite resins present a lower risk for chemical exposures. In a 2016 publication co-authored by risk assessment specialist Dr. G. Mark Richardson, it was reported: "Relative risks of chemical exposures from dental materials decrease in the following order: Amalgam>Au alloys>ceramics>composite resins."⁷¹⁷

Yet, composite fillings have been criticized because some of them contain fluoride and/or bisphenol-A (BPA). Dentists have a variety of opinions about the safety of fluoride, BPA, and other types of bisphenol, such as Bis-GMA and Bis-DMA. Patients who are concerned about the specific components of their fillings often choose to speak with their dentists about using a material that does not contain certain ingredients. For example, a product named Admira Fusion⁷¹⁸/Admira Fusion X-tra⁷¹⁹ released in January 2016 by the dental company VOCO is being touted as “the first purely ceramic-based restorative material”⁷²⁰ and does not contain Bis-GMA or BPA before or after it has been cured.

Any replacement materials, including ceramics, composites, gold, and other types of metal, should be assessed for safety and biocompatibility with special consideration for all populations and all known risk factors.⁷²¹ In particular, clinical screening for patients’ metal allergies has been recommended,⁷²² and the importance of patients reporting reactions to metals to their doctors has been emphasized in the scientific literature.^{723 724 725 726 727 728} In addition to reporting any rashes from jewelry, watches, or other metal exposures, it is essential for each patient to recognize the gamut of symptoms that can be related to the presence of a metal implant or device in their body. It is also vital for patients to remember that sensitization to metal can develop years after an implant or device has been placed and that adverse effects can occur *with or without* the sign of a rash or eruption on the skin or in the mouth.

Allergy testing can be used to assist in identifying some of the individuals susceptible to adverse reactions to metals. Patch testing is generally regarded as the “gold standard” in allergy testing; however, patch testing has also been criticized because it involves directly applying the allergen to the skin, it can exacerbate symptoms in patients, it can result in sensitization, and the results can be affected by other conditions.⁷²⁹ Two relatively new alternatives to skin patch testing are a modified version of the Lymphocyte Transformation Test (LTT) known as [MELISA](#)⁷³⁰ and the Lymphocyte Response Assay (LRA) by [ELISA/ACT](#).⁷³¹

Another option for testing has been created specifically for dental materials. If this biological testing is used, a patient’s blood sample is sent to a laboratory where the serum is evaluated for the presence of IgG and IgM antibodies to the chemical ingredients used in dental products.⁷³² The patient is then provided with a detailed list of which name-brand dental materials are safe for their use and which ones could result in a reaction. Two labs that currently offer this service are [Biocomp Laboratories](#)⁷³³ and [Clifford Consulting and Research](#).⁷³⁴

It is important to note that many factors can influence whether or not a patient improves after the removal of a metal implant or device. While many patients improve or even recover, there are some who do not. One obvious reason for this is if the patient is still being exposed to the metal or a different sensitizer through another implant, device, or other source. In a most unfortunate circumstance, patients can even have a reaction to the new implant or device. This is why it is crucial to select a biocompatible replacement.

Susceptible Populations:

In conclusion, the following populations could substantially reduce the risk of harm from mercury exposure by taking the suggested measures:

- 1) Minimization of exposure to dental mercury, vapor, and particulate for
 - All dental professionals, dental staff (including hygienists), and dental students who work with dental mercury amalgam
 - All patients with existing dental mercury amalgam fillings
 - All patients requiring the cleaning and/or removal of dental mercury amalgam fillings
- 2) Avoidance of dental mercury amalgam fillings for
 - All patients requiring new dental fillings
 - Pregnant or lactating women
 - Women of childbearing age
 - Fetuses
 - Children
 - Patients genetically predisposed to mercury toxicity
 - Patients with
 - Allergies, especially allergy to mercury
 - Alzheimer's disease
 - Amyotrophic lateral sclerosis (Lou Gehrig's disease)
 - Antibiotic resistance
 - Autism spectrum disorders
 - Autoimmune disorders/immunodeficiency
 - Cardiovascular problems
 - Chronic fatigue, fatigue, and/or myalgic encephalomyelitis/chronic fatigue syndrome
 - Complaints of unclear causation
 - Dermatitis
 - Fibromyalgia
 - Gastrointestinal issues and/or irritable bowel syndrome
 - Hearing loss
 - Kidney disease
 - Micromercurialism
 - Multiple sclerosis
 - Oral lichenoid reaction and oral lichen planus
 - Orofacial granulomatosis
 - Parkinson's disease
 - Periodontal disease
 - Psychological issues such as depression and anxiety
 - Reproductive dysfunction
 - Suicidal ideations
 - Symptoms of chronic mercury poisoning
 - Systemic lupus erythematosus
 - Thyroiditis
 - Patients undergoing chelation treatment or other detoxification treatments

MAJOR RECOMMENDATIONS

Recommendations:

- 1) Dental mercury amalgam fillings should not be used in dentistry.
- 2) Furthermore, safety precautions should be taken when working with and/or removing previously existing dental mercury amalgam fillings so as not to expose dentists, dental staff, dental students, dental patients, and their fetuses and breast-feeding children to mercury.
- 3) Moreover, based on scientific evidence, the practice of mercury-free dentistry [dentistry that does not place any new mercury amalgam fillings] and mercury-safe dentistry [dentistry that utilizes protective measures when removing existing mercury amalgam fillings] as a means of improving public health should especially be considered for the following reasons:

O WORKPLACE EXPOSURE:

- Dentists, dental professionals, dental staff, and dental students are occupationally and chronically exposed to mercury released from dental mercury amalgam, and researchers and clinicians have raised concerns about the safety of dental personnel and students who work with dental mercury amalgam.^{735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787}
- This includes mercury released during hygiene, cleaning, and polishing procedures.
- This includes mercury released during removal of old mercury amalgam fillings and replacement with new ones.
- Scientific data indicates that female dental personnel are uniquely impacted by occupational exposure to mercury.^{788 789 790 791 792 793 794}

O PATIENT EXPOSURE:

- Mercury vapor is continuously emitted from dental mercury amalgam fillings, and particulate can also be discharged from dental mercury amalgam fillings,^{795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820} which means that people are directly exposed to mercury as a result of their dental mercury amalgam fillings.
- The output of mercury is intensified by the number of amalgam fillings in the mouth^{821 822 823 824 825 826 827 828 829} and/or the number of amalgam surfaces in the mouth,^{830 831 832 833 834 835 836 837 838 839 840 841} the type of the amalgam filling (i.e. specific content of metals),^{842 843} and other factors such as chewing, teeth-grinding, brushing, dental treatments and procedures, and the consumption of hot liquids.^{844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863}
- This includes mercury released during hygiene, cleaning, and polishing procedures.
- This includes mercury released during placement of new restorations and removal of old ones.
- Ergo, men, women, and children patients are all at risk from the hazards of mercury released from dental mercury amalgam fillings.

o GENETIC PREDISPOSITION:

- Mercury exposure from dental mercury amalgam particularly threatens individuals with genetic variants that can impact their response to mercury exposures such as those with CPOX4,^{864 865 866} APOE(3,4),^{867 868 869 870} and BDNF (brain-derived neurotropic factor) polymorphisms.^{871 872 873}
- Recent research has identified a genetic predisposition to neurological impacts by mercury exposure from dental amalgam in male children with the polymorphism CPOX4.^{874 875}
- Other than CPOX4, APOE, and BDNF polymorphisms, genetic traits that have been examined for association with health impairments caused by mercury exposure include metallothionein (MT) polymorphisms,^{876 877} catechol-O-methyltransferase (COMT) variants,⁸⁷⁸ PON1 variants,^{879 880} MTHFR mutations and other genetic aspects.^{881 882 883}

o WOMEN AND CHILDREN:

- Fetal and infant exposure to mercury is known to have potentially serious health consequences, and the number of maternal amalgam fillings has been associated with mercury levels in cord blood,^{884 885 886} in the placenta,⁸⁸⁷ in the kidneys^{888 889} and liver⁸⁹⁰ of fetuses; in fetal hair;^{891 892} and in the brain⁸⁹³ and kidneys⁸⁹⁴ of infants; as well as the risk of perinatal death.⁸⁹⁵
- Mercury is excreted in breast milk of mothers with dental mercury amalgam fillings, and the mercury concentration in breast milk increases as the number of amalgam fillings in the mother increases.^{896 897 898 899}
- Additional research has likewise examined the potential dangers that dental amalgam mercury poses to pregnant women, their fetuses, and infants.^{900 901 902 903 904 905 906 907 908 909 910 911 912}
- Children are also at-risk for health impairments linked to dental amalgam mercury fillings.^{913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930}

o ALLERGY TO MERCURY:

- This is a completely separate health issue from toxicity.
- Based on statistics from the North American Contact Dermatitis Group,⁹³¹ it is estimated that approximately 21 million Americans are allergic to mercury. However, this figure could be even higher because recent studies and reports tend to agree that metal allergies are on the rise.^{932 933}
- Most patients are not tested for dental metal allergies, but, according to statistics in scientific research,^{934 935} millions of patients are allergic or sensitive to the dental mercury amalgam fillings in their mouths because of the mercury or the other components. In addition to research that demonstrates this is a pertinent issue,^{936 937 938 939 940 941 942} a number of patients with health conditions linked to dental metal allergies have improved or recovered from their ailments after removal of their fillings.^{943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976}
- Studies also establish that exposure to dental mercury amalgam fillings correlates with higher prevalence of mercury allergies.^{977 978}

o ADDITIONAL AT-RISK POPULATIONS:

- Dental mercury amalgam fillings can potentially exacerbate and/or contribute to the conditions stated below, as well as a myriad of other health outcomes:

o Patients with

- Allergies^{979 980 981}
- Alzheimer's disease^{982 983 984 985 986}
- Amyotrophic lateral sclerosis (Lou Gehrig's disease)⁹⁸⁷
- Antibiotic resistance^{988 989 990 991}
- Autism spectrum disorders^{992 993 994 995}
- Autoimmune disorders/immunodeficiency^{996 997 998 999 1000 1001 1002 1003 1004}
- Cardiovascular problems^{1005 1006 1007}
- Chronic fatigue, fatigue, and/or myalgic encephalomyelitis/chronic fatigue syndrome^{1008 1009 1010 1011 1012 1013 1014 1015}
- Complaints of unclear causation^{1016 1017 1018 1019 1020 1021 1022}
- Dermatitis^{1023 1024}
- Fibromyalgia^{1025 1026 1027 1028}
- Gastrointestinal issues and/or irritable bowel syndrome^{1029 1030 1031}
- Hearing loss¹⁰³²
- Kidney disease^{1033 1034 1035 1036 1037 1038 1039 1040}
- Micromercurialism¹⁰⁴¹
- Multiple sclerosis^{1042 1043 1044 1045}
- Oral lichenoid reaction^{1046 1047 1048 1049 1050 1051 1052 1053 1054 1055 1056 1057 1058 1059 1060 1061 1062} and oral lichen planus^{1063 1064 1065 1066 1067}
- Orofacial granulomatosis^{1068 1069}
- Parkinson's disease^{1070 1071 1072 1073 1074 1075 1076}
- Periodontal disease^{1077 1078}
- Psychological issues such as depression and anxiety^{1079 1080 1081 1082 1083 1084 1085}
- Reproductive dysfunction^{1086 1087}
- Suicidal ideations^{1088 1089}
- Symptoms of chronic mercury poisoning¹⁰⁹⁰
- Systemic lupus erythematosus¹⁰⁹¹
- Thyroiditis^{1092 1093 1094 1095 1096}

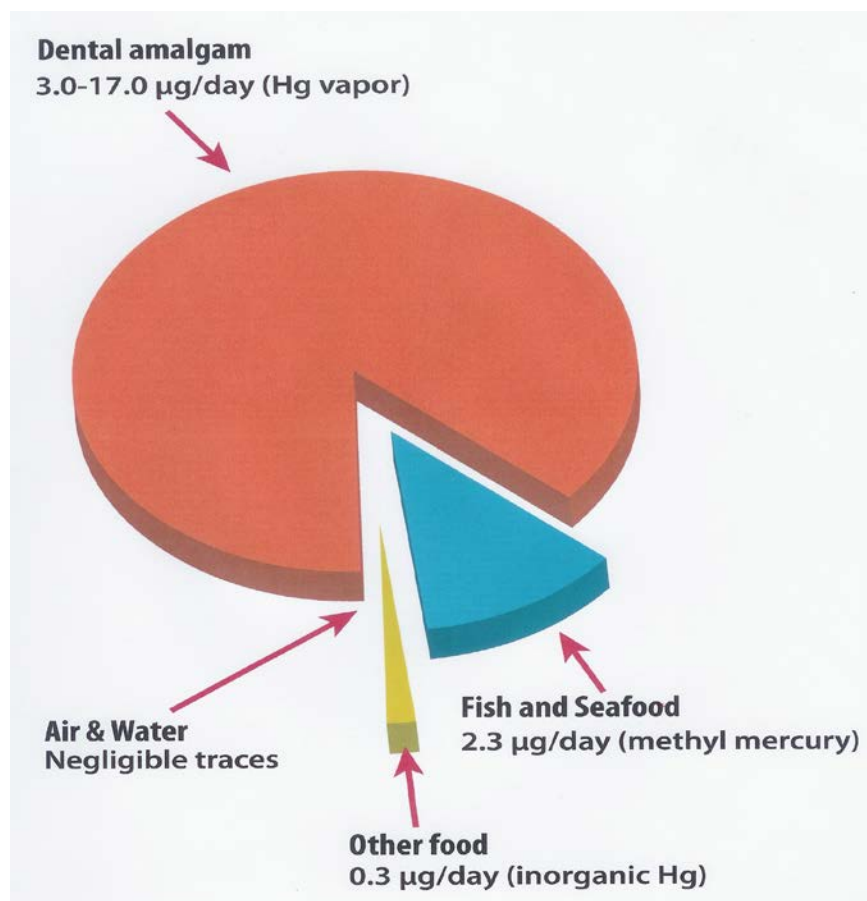
o Patients undergoing chelation treatment or other detoxification treatments

Additional Data Supporting Recommendations:

The data on the following pages provide additional information about the hazards of dental mercury amalgam fillings and mercury exposure presented in these recommendations:

CHART 1: This chart shows that dental mercury amalgam is the major route of mercury exposure for the general public.

Sources of Human Mercury Exposure (World Health Organization [WHO], 1991)*



*Note: In 1991, the [WHO Environmental Health Criteria 118](#) concluded that “[e]stimated average daily intake and retention” from dental amalgam was **3.8-21 (3-17) ug/day**.¹⁰⁹⁷ In the [2003 Executive Summary](#) of this document, WHO stated: “Dental amalgam constitutes a potentially significant source of exposure to elemental mercury, with estimates of daily intake from amalgam restorations ranging from **1 to 27 ug/day**.”¹⁰⁹⁸ [Emphasis added]

TABLE 3: This is a list of common symptoms of elemental mercury vapor inhalation^{1099 1100 1101}
^{1102 1103 1104 1105 1106 1107 1108} to be considered by practitioners when evaluating the possible side effects of dental mercury amalgam:

Acrodynia or similar symptoms such as emotional instability, loss of appetite, general weakness, and skin changes (<i>Magos and Clarkson, 2006</i>)	Anorexia (<i>Bernhoft, 2011</i>)	Cardiovascular problems/ labile pulse [frequent changes in heart rate]/tachycardia [abnormally rapid heartbeat] (<i>Klassen, 2008</i>)
Cognitive/neurological impairments /memory loss/decrease in mental function/difficulties with verbal and visual processing (<i>Echeverria et al., 1998; Clarkson and Magos, 2006; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016</i>)	Delusions/delirium/hallucination (<i>Bernhoft, 2011; Syversen and Kaur, 2012</i>)	Dermatological conditions/ dermographism [skin condition characterized by raised red marks]/dermatitis (<i>Bernhoft, 2011; Klassen, 2008</i>)
Endocrine disruption /enlargement of thyroid (<i>Bernhoft, 2011; Klassen, 2008</i>)	Erethism [symptoms such as irritability, abnormal responses to stimulation, and emotional instability] (<i>Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Magos and Clarkson, 2006</i>)	Fatigue (<i>Bernhoft, 2011; Echeverria et al., 1998</i>)
Headaches (<i>USEPA, 2016</i>)	Hearing loss (<i>Rothwell and Boyd, 2008</i>)	Immune system impairments (<i>Bernhoft, 2011; Clarkson and Magos, 2006</i>)
Insomnia (<i>USEPA, 2016</i>)	Nerve response changes /peripheral neuropathy/decreased coordination/ decreased motor function/ polyneuropathy/neuromuscular changes such as weakness, muscle atrophy, and twitching (<i>Bernhoft, 2012; Clarkson et al., 2003; Clarkson and Magos, 2006; Echeverria et al., 1998; USEPA, 2016</i>)	Oral manifestations/ gingivitis/metallic taste/oral lichenoid lesions/stomatitis/salivation (<i>Bernhoft, 2011; Camisa et al., 1999; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; Magos and Clarkson, 2006</i>)
Psychological issues /mood changes related to anger, depression, excitability, irritability, mood swings, and nervousness (<i>Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; USEPA, 2016</i>)	Renal [kidney] problems/ proteinuria/nephrotic syndrome (<i>Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012</i>)	Respiratory problems/ bronchial irritation/bronchitis/cough/ dyspnea [breathing difficulties]/ pneumonitis/respiratory failure (<i>Bernhoft, 2011; Clarkson et al., 2003; Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016</i>)
Shyness [excessive shyness]/social withdrawal (<i>Magos and Clarkson, 2006; USEPA, 2016</i>)	Tremors /mercurial tremors/ intention tremors (<i>Bernhoft, 2011; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012</i>)	Weight loss (<i>Bernhoft, 2011</i>)

EVALUATION OF SUGGESTED ACTION:

POTENTIAL BENEFITS

By minimizing mercury exposure from dental mercury amalgam fillings or completely avoiding the use of dental mercury amalgam fillings, an individual's total body burden of mercury is beneficially reduced. Minimizing or eliminating mercury exposure can potentially result in improvement and/or decreased risk of disease/illness/health impairments for

All dental professionals, dental staff (including hygienists), and dental students who work with dental mercury amalgam

All patients with existing dental mercury amalgam fillings

All patients requiring the cleaning and/or replacement of dental mercury amalgam fillings

All patients requiring new dental fillings

Pregnant or lactating women

Women of childbearing age

Fetuses

Children

Patients genetically predisposed to mercury toxicity

Patients with

- o Allergies, especially allergy to mercury
- o Alzheimer's disease
- o Amyotrophic lateral sclerosis (Lou Gehrig's disease)
- o Antibiotic resistance
- o Autism spectrum disorders
- o Autoimmune disorders/immunodeficiency
- o Cardiovascular problems
- o Chronic fatigue, fatigue, and/or myalgic encephalomyelitis/chronic fatigue syndrome
- o Complaints of unclear causation
- o Dermatitis
- o Fibromyalgia
- o Gastrointestinal issues and/or irritable bowel syndrome
- o Hearing loss
- o Kidney disease
- o Micromercurialism
- o Multiple sclerosis
- o Oral lichenoid reaction and oral lichen planus
- o Orofacial granulomatosis
- o Parkinson's disease
- o Periodontal disease
- o Psychological issues such as depression and anxiety
- o Reproductive dysfunction
- o Suicidal ideations
- o Symptoms of chronic mercury poisoning
- o Systemic lupus erythematosus
- o Thyroiditis

Patients undergoing chelation treatment or other detoxification treatments

As far as considering the costs of implementing these recommendations, in a report entitled “The Economics of Dental Amalgam Regulation,” the authors noted that amalgam use is already declining and that restrictions on mercury are inevitable.¹¹⁰⁹ The authors concluded, “We can then make the case that the overall health care expenditures necessary to deal with diseases and conditions, known or unknown, arising from the continued installation of amalgam could far exceed the relatively manageable cost increases to the consumer for the alternatives...This is not to mention the cost to the U.S. economy of lost work time owing to concomitant illness and disability.”¹¹¹⁰

Additionally, the IAOMT co-released a [2012 report from Concorde](#) of Brussels, Belgium, which noted: “In order to obtain a useful perspective on the ‘external’ costs to society that are not included in the fees a dental patient pays the practitioner, we have examined 1) the costs of keeping dental mercury releases from being released into the environment, and 2) when dental mercury is no longer released into the environment, the various benefits accrued to human health and society. ...[W]hichever analytical approach one chooses, even when using conservative assumptions, and even allowing for the uncertainties inherent in much of the cost data, it is clear that the real cost of using amalgam far outweighs the cost of using mercury-free composite...”¹¹¹¹

Yet, from a consumer standpoint, some insurance companies only cover the cost of dental mercury amalgam fillings, which means that oftentimes patients have to pay additional fees for alternative materials and techniques.¹¹¹² However, the United Nations Environmental Programme (UNEP)’s 2013 “Minamata Convention on Mercury,” signed by over 100 nations including the U.S., specifically discourages insurance policies and programs favoring dental mercury amalgam use over mercury-free dental restoration.¹¹¹³

Since some countries have successfully eliminated dental mercury amalgam, ending the use of mercury in dentistry has already proven to be both feasible and economical. For example, Carsten Lassen and Jakob Maag, of the Nordic Council of Ministers, shared the following observation with a committee of the United Nations in 2010: “Dental treatment without mercury is becoming the norm.”¹¹¹⁴ Norwegian dental researchers confirmed this statement in 2016 when they wrote: “Norwegian dentists showed positive attitudes towards composite as a restorative material one year after amalgam was banned.”¹¹¹⁵

Additionally, scientific research about the measurements of mercury in dental offices has been instrumental in helping policy-makers and dentists around the world take steps to adopt workplace standards that reduce mercury releases in the dental office. Researchers from the USA, Africa, Asia and the United Nations explained in their 2018 scientific review published in the peer-reviewed journal *Ambio*:

For example, a civil society-initiated campaign to phase down the use of Hg amalgams in Asia and Africa faced initial resistance from policy-makers and dentists who did not believe that Hg posed a risk...On-the-spot measurements demonstrating high Hg levels proved to be a strong and salient method of risk communication with dentists across different cultural settings, and helped garner support for changing workplace practices to reduce Hg exposure.¹¹¹⁶

POTENTIAL HARMS

1) There is a risk of additional mercury exposure to dentists, dental staff, hygienists, dental students, and patients from current unsafe procedures involving mercury amalgam fillings, especially if treatment, hygiene routines, removal, and/or replacement of fillings are conducted without taking appropriate protective measures.

2) As such, special consideration of any dental work involving amalgam mercury fillings should be given to

All dental professionals, dental staff (including hygienists), and dental students who work with dental mercury amalgam

All patients with existing dental mercury amalgam fillings

All patients requiring the cleaning and/or removal of dental mercury amalgam fillings

All patients requiring new dental fillings

Pregnant or lactating women

Women of childbearing age

Fetuses

Children

Patients genetically predisposed to mercury toxicity

Patients with

- o Allergies, especially allergy to mercury
- o Alzheimer's disease
- o Amyotrophic lateral sclerosis (Lou Gehrig's disease)
- o Antibiotic resistance
- o Autism spectrum disorders
- o Autoimmune disorders/immunodeficiency
- o Cardiovascular problems
- o Chronic fatigue, fatigue, and/or myalgic encephalomyelitis/chronic fatigue syndrome
- o Complaints of unclear causation
- o Dermatitis
- o Fibromyalgia
- o Gastrointestinal issues and/or irritable bowel syndrome
- o Hearing loss
- o Kidney disease
- o Micromercurialism
- o Multiple sclerosis
- o Oral lichenoid reaction and oral lichen planus
- o Orofacial granulomatosis
- o Parkinson's disease
- o Periodontal disease
- o Psychological issues such as depression and anxiety
- o Reproductive dysfunction
- o Suicidal ideations
- o Symptoms of chronic mercury poisoning
- o Systemic lupus erythematosus
- o Thyroiditis

Patients undergoing chelation treatment or other detoxification treatments

3) Alternative dental restorative materials should likewise be assessed for safety and biocompatibility, especially on an individual basis.

4) Some insurance companies only cover the cost of dental mercury amalgam fillings which means that oftentimes consumers have to pay additional fees for alternative materials and techniques.¹¹¹⁷

Furthermore, whereas amalgams are used for 45% of all direct dental restorations worldwide,¹¹¹⁸ articles published in the *Journal of the American Dental Association* have established that these mercury fillings are used on 51.0% of White/Caucasian Americans, on 53.4% of Black/African Americans, on 72.9% of American Indians/Alaska Natives/Asians/Pacific Islanders,¹¹¹⁹ and on more than 75% of posterior restorations for new recruits to the U.S. Navy and Marines.¹¹²⁰

However, the United Nations Environmental Programme's 2013 "Minamata Convention on Mercury," signed by over 100 nations including the United States, specifically discourages insurance policies and programs favoring dental mercury amalgam use over mercury-free dental restoration.¹¹²¹

CONTRAINDICATIONS

1) Dentists, dental staff, and dental students working with mercury amalgam fillings during procedures such as cleaning, hygiene, and/or replacement are significantly exposed, along with their patients, fetuses, and breast-feeding children to mercury. Safety measures, when used, diminish but do not totally eliminate exposure.

2) Removal of dental mercury amalgam fillings without appropriate protection causes significant mercury exposure to dentists, dental staff, dental students, and patients, especially women of childbearing age, pregnant or lactating women, fetuses, children, and other sensitive populations.

3) Due to mercury releases, polishing, placement, removal, or any disruption of a dental mercury amalgam filling should not be done by dental personnel who are pregnant or lactating and should not be conducted upon patients who are pregnant or lactating.

4) Alternative dental restorative materials should likewise be assessed for safety and biocompatibility, especially on an individual basis.

QUALIFYING STATEMENTS

Although the use of dental mercury amalgam fillings has reportedly been decreasing in developing countries,¹¹²² the results of a survey published in 2017 in the *Journal of Public Health Dentistry* suggested that 62% of general dentists and 56% of pediatric dentists in the U.S. were still using dental mercury amalgam.¹¹²³ Additionally, billions of people have dental amalgam fillings in their mouths,¹¹²⁴ which means that even when the use of dental mercury ends, safe removal of amalgam fillings will continue to be a pertinent issue.

Whereas the American Dental Association (ADA), the United States Food and Drug Administration (FDA), and other groups have endorsed the use of dental mercury amalgam, numerous peer-reviewed, scientific studies report risks associated with dental mercury amalgam fillings. In fact, over 350 articles produced by a literature search on PubMed (collected by the U.S. National Library of Medicine National Institutes of Health) and a hand-search of IAOMT documents (collected by the International Academy of Oral Medicine and Toxicology) have been cited as evidence for this document.

The PubMed literature search was conducted online at the [PubMed database](#) from September 16, 2013 to March 6, 2014. The purpose of the research was to answer the following question: “Are there risks associated with dental mercury?” The PubMed search term used was “dental mercury risk,” and clinical trials and reviews were included in the search. The search was conducted from March 6, 2014 to as far back as PubMed provided results (1972), and the PubMed search resulted in 280 sources.

All PubMed sources were categorized into risk, no risk, or ambiguous categories. Articles were excluded from the final results of the search if they were not in English, they were not relevant (i.e. not significantly about dental mercury amalgam), they were an erratum, they were a comment on a different article, and/or if the abstract and study could not be found. Thus, 124 articles were excluded. Many of the articles that could not be located were not peer-reviewed and appeared in trade journals or journals of localized dental groups. Based on the 156 articles that were included, the PubMed search yielded 86 articles (55.1%) suggesting risk, 55 articles (35.3%) suggesting no risk, and 15 articles (9.6%) deemed as ambiguous.

An IAOMT hand-search of documents was conducted to supplement the PubMed search. The hand-search was originally conducted from September 16, 2013 to March 6, 2014, but it was first updated from December 1, 2015 to December 23, 2015, and then updated again from May 1, 2018 to March 20, 2019. Over 1,200 documents about this issue are currently on file in the IAOMT’s Library, which has documents dating from 1926 to present day. Of these hundreds of sources, those used for this article were limited to the scientific and regulatory documents most relevant to dental mercury amalgam health risks.

Even more specifically, sources for this paper were found by searching the IAOMT Library for scientific evidence of health risks from dental mercury exposures to the general population, pregnant women, fetuses, children, dental professionals, and those individuals who are genetically predisposed, who have an allergy to mercury, or who suffer from health conditions that have been potentially linked to mercury by scientific research. These health conditions include Alzheimer’s disease, amyotrophic lateral sclerosis (Lou Gehrig’s disease), antibiotic resistance, autism spectrum disorders, autoimmune disorders/immunodeficiency, cardiovascular problems, chronic fatigue syndrome, hearing loss, kidney disease, multiple sclerosis, oral lichenoid reaction and oral lichen planus, Parkinson’s disease, periodontal disease, and reproductive dysfunction.

The over 350 articles from the PubMed and IAOMT searches demonstrating risk have been used as sources for this document since they serve as evidence of the known hazards of dental mercury amalgam.

However, it should be noted that there were also a number of scientific studies suggesting dental amalgam does not pose a health risk, dental amalgam is safe, releases of mercury from dental amalgam are within acceptable exposure levels, and/or there is insignificant data to prove its hazards. For example, our PubMed literature search yielded 55 sources finding or suggesting “no risk.” Below is an abridged list of some of these sources, which suggested “no risk” for the following populations and scenarios:

- Children^{1125 1126 1127 1128}
- General health/general population and/or exposure levels^{1129 1130 1131 1132 1133 1134 1135 1136 1137 1138 1139 1140 1141 1142 1143 1144 1145 1146 1147 1148 1149 1150 1151}
- Pregnancy^{1152 1153 1154 1155 1156}
- Occupational^{1157 1158 1159 1160 1161 1162 1163 1164 1165 1166 1167}
- Other: Alzheimer’s disease,¹¹⁶⁸ antibiotic resistance,¹¹⁶⁹ autism,^{1170 1171 1172} fatigue,¹¹⁷³ immune system,^{1174 1175} kidney function,^{1176 1177 1178 1179} multiple sclerosis,^{1180 1181 1182} and Parkinson’s disease¹¹⁸³

It merits consideration that the technology of studying mercury’s impact on human health has evolved over the past several decades, and some studies advocating the safety of dental mercury amalgam failed to take into account genetic factors, susceptible populations, metal allergies, and other variables that are now known to impact each person’s response to mercury.¹¹⁸⁴

Another area of concern in relation to research about dental mercury amalgam is agreeing upon the definition of “risk.” To illustrate this point, a number of scientific articles claim that dental mercury amalgam is safe for the “general population.” Yet, given the current knowledge that sensitivities, biological predispositions, and a gamut of other conditions influence an individual’s reaction to mercury exposure,¹¹⁸⁵ the concept of accurately applying safety to the “general population” becomes highly subjective. This also applies to evaluating dental mercury amalgam risks for specific health conditions such as Alzheimer’s disease, autism, or multiple sclerosis.

Further issues with defining “risk” for dental mercury amalgam arise when considering the impact these restorations might have on an individual for a short amount of time versus long-term exposure, especially since many individuals have these fillings in their mouths for many years of their lives.¹¹⁸⁶

In particular, research has shown that an individual accumulates a chronic dose of mercury ranging from “0.2 to 0.4 µg/day per amalgam-filled tooth surface, or 0.5 to 1 µg/day/amalgam-filled tooth, depending on age and other factors.”¹¹⁸⁷ As detailed in other sections of this document, how each person processes mercury exposure is dependent on a wide-range of circumstances.

Practicing mercury-free dentistry [dentistry that does not place any new mercury amalgam fillings] and mercury-safe dentistry [dentistry that utilizes protective measures when removing existing mercury amalgam fillings] undoubtedly reduces the danger of chronic mercury exposure to dentists, their staff, dental students, and patients.

This is especially important considering that mercury exposures also occur from non-dental sources. For example, the issue of amalgam fillings contributing to human mercury exposures from fish consumption has been studied.^{1188 1189} The topic was discussed in 2013 by the European Food Safety Authority's Panel on Contaminants in the Food Chain (CONTAM). The EFSA Panel described the increased mercury danger from the combination of fish and dental amalgam: "The estimated exposure to inorganic mercury in Europe from the diet alone does not exceed the TWI [tolerable weekly intake]. Inhaled elemental mercury vapour from dental amalgam, which after absorption is converted to inorganic mercury, is an additional source that is likely to increase the internal inorganic mercury exposure; thus the TWI [tolerable weekly intake] might be exceeded."¹¹⁹⁰

Additionally, it is essential to acknowledge that there are various escalating levels of protection techniques for limiting mercury exposure during mercury-related dental procedures. Depending on the technique/s chosen, different results are reached in personal and patient protection levels from exposure. The more thorough the protection, the more complex and costly the technique, and as such, financial, cultural, and professional decisions are part of the process as to the level of protection ultimately used.

Overall, it is apparent that dental mercury amalgam and all dental restorative materials should be assessed for safety and biocompatibility with special consideration for all populations and all known risk factors.¹¹⁹¹

DESCRIPTION OF IMPLEMENTING SUGGESTED ACTION AND RESOURCES:

Research has suggested that resin composites or compomers are used for 55% of direct dental restorations worldwide.¹¹⁹² Thus, many dentists have already stopped using dental mercury amalgam; however, many of these dentists and others still require training in mercury-free dentistry [dentistry that does not place any new mercury amalgam fillings]. Since other countries have banned or strictly limited dental mercury amalgam, their dental schools and industry practices shed light upon how to make a complete transition away from dental mercury amalgam.

Yet, it must also be recognized again that since all dentists still must remove dental mercury amalgam fillings, dentists and dental students require training in mercury-safe dentistry [dentistry that utilizes protective measures when removing existing mercury amalgam fillings]. Essentially, properly applied protection techniques can minimize mercury exposure to dental workers, dental students, patients, fetuses, and other susceptible and sensitive populations.

The IAOMT has developed free dental education resources detailing implementation strategies for mercury-free dentistry [dentistry that does not place any new mercury amalgam fillings] and mercury-safe dentistry [dentistry that utilizes protective measures when removing existing mercury amalgam fillings], including information for dentists, physicians, health professionals, patients, and the general public. These resources include the following:

- [IAOMT's online learning videos, including dental education about mercury](#)
- [The IAOMT's Safe Mercury Amalgam Removal Technique \(SMART\)](#)
- [IAOMT's Dental Mercury Facts pages](#)
- More resources available at www.iaomt.org and www.theSMARTchoice.com

DISCLAIMER:

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RESEARCH

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Mercury vapor volatilization from particulate generated from dental amalgam removal with a high-speed dental drill – a significant source of exposure

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Abstract

Background: The ubiquitous use of dental amalgam for over 180 years has resulted in the exposure of millions of dental workers to mercury. Dental amalgam contains approximately 50% mercury. Dental workers, including dentists, dental assistants, and dental hygienists, have been shown to have increased levels of mercury and suffer more from health issues related to mercury exposure than the general public. Mercury is known to be absorbed via inhalation or through the skin. There are many routine dental procedures that require the removal of dental amalgam by using the dental high-speed drill, which we suspected generates an occupational mercury exposure that is not sufficiently recognized.

Results: We showed that drilling dental amalgam generates particulate that volatilizes significant amounts of mercury vapor generally for more than an hour after removal. The levels of mercury vapor created by this procedure frequently exceed the safety thresholds of several jurisdictions and agencies.

Conclusions: A significant, underrecognized source of localized exposure to mercury vapor was identified in this study. The vapor was created by microgram levels of particulate generated from dental amalgam removal with a high-speed dental drill, even when all feasible engineering controls were used to reduce mercury exposure. This exposure may explain why dental workers incur health effects when safety thresholds are not breached. The dispersion patterns for the particulate are not known, so the use of effective skin barriers and inhalation protection are required during amalgam removal to protect the dental worker from this form of occupational mercury exposure. Standard methodologies for occupational mercury exposure assessment appear to be inadequate when assessing mercury exposure during amalgam removal.

Keywords: Mercury, Mercury vapor, Dental amalgam, Occupational exposure to mercury, Amalgam removal

Background

We hypothesized that the action of drilling amalgam with a dental high-speed hand piece, even when using protocols and all feasible engineering controls to minimize mercury vapor, would still generate an aerosol of particles that would be heated sufficiently to produce increased mercury vapor. We designed the study to answer the following questions:

- What concentration of mercury vapor can be reached from particulate generated from the removal of dental amalgam restorations using a high-speed drill?
- How long can the particulate volatilize mercury vapor?
- Is the peak vapor generated associated with the mass of the mercury in the particulate?
- Does the amount of amalgam removed in each sample affect the peak Hg vapor?

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- Does the amount of amalgam removed in each sample affect the mass of mercury in particulate collected?

Amalgam fillings are a widely used dental restorative material and have been utilized since the nineteenth century. Use of the material is declining in the developed nations but is increasing in the developing countries. It has been estimated that global use of mercury for dental amalgam in 2015 was 226–322 tones [1]. The longevity of an amalgam filling has a very large range but is expected to provide service on average for 10 years. After the amalgam's service period has ended, removal is required which is generally achieved using a high-speed drill. There are other indications where dental amalgam removal is required and these are listed later in the background. Dental amalgam consists of approximately 50% mercury and 50% base metals. The toxicity of mercury is well established.

Dental workers, including dentists, dental assistants, dental hygienists, dental students, dental instructional staff, and dental laboratory and sterilization technicians are all at risk of mercury exposure if they work with dental amalgam [2–15]. Dental associations and dental schools have specific policies on the use of amalgam because of its mercury content. Additionally, Safety Data Sheets or SDS (formerly Material Safety Data Sheets or MSDS) from manufacturers of amalgam outline the risk of mercury exposure when using amalgam.

Dental workers have higher levels of mercury [3, 5, 10, 12, 16–18] as measured in blood, urine, stool, nails, hair and organs. Dental workers also have a higher prevalence of health issues consistent with chronic mercury exposure than controls. These health problems include adverse neurological conditions [2, 3, 6–9, 17, 19], while there are also some possible indications that exposure to elemental mercury may also affect reproduction [20–22].

Mercury levels either in the tissue of the dental worker or in the dental working environment have been found to be lower than established safety levels. It has, however, also been argued that adverse health effects can occur at such levels and after many years [23]. In a Swedish study conducted to assess mercury exposure and health effects in dental personnel, the researchers found that the mean mercury levels in the personal space of 44 dental workers were well below established safety thresholds. The urinary mercury levels of this group were not elevated when compared to a control group. Despite the unremarkable levels of mercury measured in air and urine, central nervous symptoms of the dental group were significantly higher than the controls [24]. This suggests that the current safety limits may be too lenient.

Although many jurisdictions have set biological exposure indexes, it was concluded within a review from 2012

that “it has not been possible to set a level for mercury in blood or urine below which mercury related symptoms will not occur [25].” Others claim that there is an unreliability in the current methods to measure various tissue samples to determine mercury exposure [17]. Further, WHO has stated: “Recent studies suggest that mercury may have no threshold below which some adverse effects do not occur.” [26]

It is certain that there are susceptible subsets of the population that are more likely to be affected by chronic mercury exposure. In a recent study of the effects of mercury in a cohort of children, genetic polymorphisms were identified that made the participants more susceptible to mercury [27], and additional research has explored this pertinent genetic component [28]. Specifically, the role of genetic profiles in dental workers' reactions to mercury has been examined [7–9].

The World Dental Federation (FDI) recommends avoiding direct skin contact with mercury or freshly mixed dental amalgam and avoidance of mercury vapour sources including during the removal of dental amalgam [29]

It has been claimed that the respirable particulate matter represents the largest share of daily Hg-exposure for the practicing dentist [14]. By use of standard exposure assessment methods it was found that a dentist who removes four amalgam fillings per day will inhale 38 mg of mercury derived from amalgam particulate, by far exceeding any level considered safe. When respirable amalgam particles are deposited in the lungs, they reach body temperature that enhances vaporization over days and thus, also subsequent absorption.

It is important to understand that although particulate is the exposure source, it is the vapor that comes off the particulate that is of interest because in this form, it is very easily taken into the body by the lungs and the skin. The amount of Hg vapor from amalgam increases with stimulus [15, 30, 31]. These stimuli generally cause an increase in temperature which increases the vapor pressure. The dental high-speed drill can spin up to speeds of 350,000 rpm [32], and therefore, can generate friction and increase the heat of the material being removed.

As long as installation of amalgam continues (and for years after it ends), there will be a need to remove amalgam from teeth. There are several circumstances that require the removal of dental amalgam from teeth using a high-speed dental drill. These include, but are not limited to, the following scenarios: sectioning of a tooth to facilitate dental extraction, failed seal of an existing amalgam restoration, recurrent decay under a filling, fracture of a tooth with an amalgam filling, adjustment of an incorrect bite, preparation for a fixed or removable prosthesis, root canal access opening, reshaping of an existing amalgam, removal of an amalgam that has an

open inter-proximal contact, removal to prevent galvanism with another intra-oral metal, removal for health reasons, removal to reduce exposure of mercury, treatment of periodontal disease, and removal due to mercury sensitivities.

The guidelines for assessing mercury presence in the work place is outlined by OSHA under Method Numbers ID-140 [33] for vapor and ID-145 [34] for particulate. The complete processes suggested in these documents are complicated and beyond the scope of this paper; however, there are some specific items in the methods that are pertinent to this study. The assessment of mercury in the workplace is accomplished by using three different techniques. The first is the use of a passive or active mercury vapor sampling device for atmospheric mercury vapor levels. The second is the use of a vacuum with a filter cassette to collect mercury containing particulate in the air, and the third method is the use of wipes to collect mercury containing particulate on surfaces.

There are several drawbacks to these methods with respect to assessing mercury exposure from amalgam particulate generated by drilling. Vapor samplers do not assess particulate or localized mercury vapor generated from particulate if the sensors are in a location that does not have access to the particulate. If particulate in air is assessed using the vacuum filter cassettes, according to procedure described in OSHA ID-145 section 5.4, the cassettes are to be sealed after taking the sample and sent to the lab to determine the mass of the mercury in the particulate. The cassette does not allow access to the filter in a way that assessment of mercury vapor from this particulate can be made. The standardized wiping technique for determining particulate on surfaces as outlined by OSHA ID-145 states that a wet gauze is used to wipe a 10 cm × 10 cm square. The most concerning surfaces that require assessing for particulate presence are the potential skin areas that may be exposed to the amalgam particulate. This is particularly true because skin is a known route of absorption for mercury. The shape of the hands, arms, face, chest and other parts of the dental worker's and dental patient's anatomy that may be exposed to amalgam particulate during dental operations do not lend themselves to classical surface wiping. When considering all of these drawbacks with respect to standard occupational assessment protocol for mercury exposure in dentistry, it is evident that these processes do not quantify the extent of mercury exposure.

There is very little information on the levels of mercury vapor that can be emitted from fresh amalgam particulate generated from the dental high-speed drill. There are two limitations that may have prevented this effort. The first is that the respirable particulate is

inhaled and not available for measurement of vapor because it is inaccessible to measuring devices. Second, as mentioned previously, current OSHA standards to collect particulate actually prevent the volatilization measurements because the concern of particulate assessment is to determine the mass of the mercury in the particulate, not the vapor emitting from the particulate.

There are others who have aimed to measure exposure by amalgam removal, but have failed to quantify mercury vapour from the particle matter generated [15, 35–38].

While these and other studies have examined the role of the dental drill in generating mercury releases [15, 35–40], it appears as though there have been no detailed attempts in the scientific literature to quantify the level of mercury that may vaporize from the surface of freshly ground dental amalgam particulate. By doing so, perhaps an under-estimated occupational mercury exposure in dentistry can be identified. This is the aim of this study.

Mercury vapor can be absorbed via inhalation and skin [41]. It is these two routes of absorption of mercury that prompted the design of this study. Assessing the concentration of localized mercury vapor that the skin or the lungs would endure after particulate exposure required measuring the vapor derived from particulate at as close a range as reasonably possible. In this methodology, we aim to illustrate the potential mercury vapour exposure from particulate that comes into contact with these two organ systems.

Method

There were no ethical implications of the methodology of this study as described in the “Declarations” section of this paper.

Amalgam particulate was collected in-vivo from 21 patients who were scheduled for amalgam removal in the dental offices of Dr. David Warwick and Dr. Matthew Young during a time period starting October 2016 and April 2018. The particulate was sampled from the head of the dental drill with a 5 cm × 5 cm (2 × 2) cotton wipe during a regularly scheduled clinical procedure. No procedure was performed on any patient that deviated from the standard of care. The following controls were in place to minimize drilling, particulate formation, and mercury vapor generation and exposure:

- copious amounts of water
- reduced drilling of the amalgam by cross hatching the material and removing bulk pieces.
- high volume suction with custom isolation tip (Clean Up brand)
- secondary air evacuation (additional venting to the dental suction providing approximately 9–20 cubic meters per minute laminar air flow evacuation

through a 8–12 cm hose from the operative site exhausted to the outside or through a set of mercury rated filters) eg. Dentair Vac.

- non-latex dental dam on the patient
- full facial and body barrier for patient
- patient saliva suction behind the rubber dam
- alternative air supply to patient.
- face shield, mercury rated gown and head protection, nitrile gloves, and mercury rated breathing protection for dentist and assistant

Immediately after the removal of the dental amalgam/s from patients' mouths, a sample of particulate was obtained by wiping the head of the dental drill with a 2×2 gauze. The head of the drill is a predictable area where particulate accumulates which makes it a convenient place to collect from. The 2×2 gauze containing the particulate was then placed 1 cm from the inlet hose of a recently calibrated Mercury Instruments Mercury Vapor Monitor 3000 (Model VM 3000) and 1 s increment readings of the localized mercury vapor concentration were recorded. The VM 3000 evaluates incoming gas for the presence of Hg using Atomic Absorption Spectroscopy (AAS) and is considered an industry standard in the field of mercury monitoring.

The authors also made note of the relative size of the amalgams being removed as large, medium, and small, and the number of amalgams removed in the session to generate a "Total Filling Size Score". The mercury vapor measurements were generally taken until the localized level fell below $10 \mu\text{g}/\text{m}^3$, although there were samples that did not drop to this level even after several hours of measurement.

After the vapor measurements were taken, the wipe containing the particulate was placed in a container using new gloves and shipped to AGAT labs in Canada. AGAT labs are an analytical lab certified to ISO 9001, ISO/IEC 17025 standards and is accredited with the following organizations; SCC, CALA and QMI-SAI Global. The mass of the mercury in each sample sent to AGAT was determined using ICP/MS analytical technique.

Two dentists (Warwick and Young) provided each 1 control and 16 and 5 patient samples respectively.

For each patient sample, we generated the following data:

- 1) the approximate size and number of the fillings that were removed depicted as a "Total Filling Size Score"
- 2) one second incremental readings by the VM 3000 which measured localized Hg vapor levels in $\mu\text{g}/\text{m}^3$ vaporizing from the amalgam particulate
- 3) peak Hg vapor
- 4) the mass of Hg contained in each sample

Additionally, one of the dentists provided measurements of the mercury vapor that evaporated from 400 mg of room temperature (20°C) elemental mercury (the mass of the elemental mercury was not measured but derived from the manufacturers data sheet on the Dispersalloy product) with an approximate surface area of 0.07 cm^2 from a Dispersalloy single spill dental amalgam capsule over a 33-min time period to compare with the readings from the particulate. This size of the elemental sample was used as it was readily available from a conventional unmixed amalgam capsule.

Only one elemental mercury sample was taken for this study as the results from this measurement fell within expected theoretical levels of mercury evaporation. In our sample, the average concentration for the first $\frac{1}{2}$ hour of the vapor expressing from the elemental mercury was $35 \mu\text{g}/\text{m}^3$. The VM 3000 has a flow rate of approximately 80 l/hour or $0.08 \text{ m}^3/\text{h}$. The mass of mercury that evaporated from the elemental mercury was $35 \mu\text{g}/\text{m}^3 \times \frac{1}{2} \times 0.08 \text{ m}^3/\text{h}$ or $1.4 \mu\text{g}/\text{h}$. The evaporation rate of elemental mercury at room temperature (20°C) is approximately $50 \mu\text{g}/\text{cm}^2/\text{h}$ (range of $40\text{--}60 \mu\text{g}/\text{cm}^2/\text{h}$) [42]. In the theoretical model, we would expect that the elemental mercury we measured, which had an estimated surface area of 0.07 cm^2 (radius of .15 cm), would evaporate $.07 \text{ cm}^2 \times \frac{1}{2} \text{ hour} \times 50 \mu\text{g}/\text{cm}^2/\text{h}$ or $1.75 \mu\text{g}/\text{h}$. It is most common to see experimental measures of mercury evaporation from elemental mercury to be lower than theoretical proposals. The most likely cause of this is oxidation of the surface of the mercury, which reduces the evaporation rate. The phenomenon of a decreasing volatilization of mercury from our sample over time is likely due to oxidation as well.

Results

None of the two control samples generated Hg vapor as monitored by the VM 3000 and had less than detectable μg of Hg mass as measured by AGAT labs. Each filling removed in the process was rated by the dentists (Warwick and Young) as small, medium or large and was given a score of 1, 2 or 3 respectively. A "Total Filling Size Score" for each session was then determined by summing the score of each filling removed in the session (Table 1).

Interestingly, the total mass of all the particulate collected in the 21 cases was $54,876 \mu\text{g}$, which represents only about 10% of the mercury in an average sized filling and only about 3–4% of the average mercury content of the amalgams removed in a single session.

Discussion

In order to understand the impact of the mercury sources identified in this study, an understanding of standardized safety levels or threshold limit values (TLV)

Table 1 Total Filling Size Score, volatilization readings and mass of mercury containing particulate ($n = 21$) and mass and volatilization readings of controls ($n = 2$) and an elemental mercury sample ($n = 1$)

Session Number	Total Filling Size Score	Mass Hg in particulate (μg)	Peak Hg Vap. ($\mu\text{g}/\text{m}^3$)	15 min avg($\mu\text{g}/\text{m}^3$)	30 min avg($\mu\text{g}/\text{m}^3$)	60 min avg($\mu\text{g}/\text{m}^3$)
1	6	380	93	60	56	45
2	6	238	46	31	27	22
3	6	734	57	42	43	6
4	4	1430	40	18	15	12
5	6	1920	74	30	33	25
6	8	1020	46	46	33	26
7	4	776	39	27	25	22
8	6	18395	44	15	12	10
9	7	810	69	40	31	22
10	5	2770	41	33	30	25
11	4	1190	150	89	73	54
12	6	3260	334	234	215	174
13	8	1750	43	15	11	8
14	6	525	80	56	48	38
15	6	779	129	34	22	16
16	8	34	127	103	98	83
17	8	3530	416	311	276	234
18	5	825	379	340	294	223
19	5	6190	899	800	728	601
20	6	2240	233	197	171	137
21	6	6080	759	662	599	499
Mean	6	2613	195	152	135	109
Standard Dev.	1	4005	241	217	196	163
Median	6	1190	80	46	43	26
Elem. Hg	N/A	400000	76	43	35	N/A
Control 1	N/A	<dl	<dl			
Control 2	N/A	<dl	<dl			

Details size rating of the fillings that were removed, the peak and 15-min, 30 min and 60-min average Hg vapor readings, and the mass of mercury in each sample. It also lists the peak and 15-min and 30-min average Hg vapor that was vaporized by the elemental mercury. The table further indicates the Hg mass and vapor results of the control wipes, which were below detectable limits (<dl)

is required. Occupational safety levels vary in different jurisdictions and in different administrations. In Table 2, reference levels from the Occupational Safety and Health Administration (OSHA)(U.S.), The National Institute for Occupational Safety and Health (NIOSH)(U.S.), Association Advancing Occupational and Environmental Health/American Conference of Governmental Industrial Hygienists (ACGIH), and Alberta (Canada) Occupational Health and Safety (AOHS) are listed. The Alberta

Code is included because the majority of samples were obtained in Alberta, Canada.

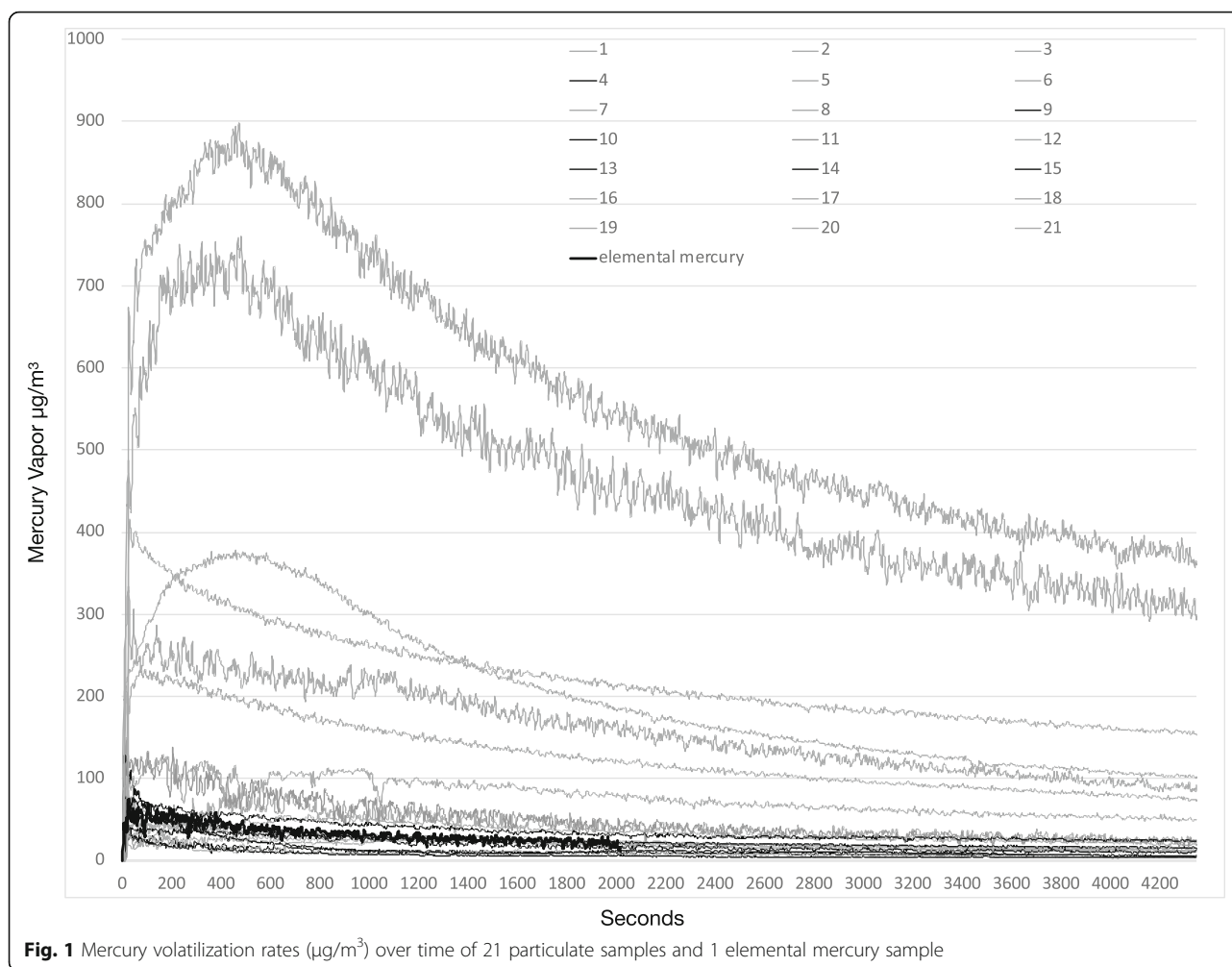
All of these groups acknowledge the ability of Hg vapor to be absorbed by the lungs and skin. Beyond this consistency, one can identify many differences these bodies have with regard to safety levels of occupational Hg exposure.

There are several observations from Figs. 1 and 2 that are pertinent to occupational safety.

Table 2 Occupational threshold levels from OSHA, NIOSH, ACGIH, and AOHS

OSHA	Mercury Inorganic Compounds
Ceiling (PEL)	100 µg/m ³
NIOSH	
8-Hour TWA	50 µg /m ³ , Skin
ST/Ceiling	100 µg/m ³ , (Ceiling) Skin
IDLH	10,000 µg/m ³
ACGIH	
8-Hour TWA	25 µg/m ³ , Skin
AOHS	
AOCL(ceiling)	125 µg/m ³ , Skin
AOTLV 30 min./24 hr.	75 µg/m ³ , Skin
AOTLV 8-Hour TWA	25 µg/m ³ , Skin

Various occupational threshold levels referenced from the OSHA Website (<https://www.osha.gov/SLTC/mercury/standards.html>) and GoAB (Government of Alberta) Occupational Health and Safety Act, Occupational Health and Safety Code. Edmonton, AB: Government of Alberta; 2009 illustrate the inconsistency of various responsible agencies.



Ceiling Thresholds

The first is the high levels of Hg vapor that are generated from amalgam particulate collected from the head of the drill by wiping with a 2×2 gauze. The arithmetic mean of the peaks of the 21 samples ($195.1 \mu\text{g}/\text{m}^3$) were substantially higher than OSHA's Permissible Exposure Limit (PEL) level and NIOSH's ceiling level of $100 \mu\text{g}/\text{m}^3$ and AOHS's ceiling of $125 \mu\text{g}/\text{m}^3$. Nine of the 21 peak levels breached both NIOSH's and AOHS's ceiling level. The median of the peak of the 21 readings was $80 \mu\text{g}/\text{m}^3$, which is under the ceiling levels described in this section.

Average Thresholds

Seven of the twenty-one 30-min averages breached the AOHS 30 min/24-h threshold, with another sample coming in just under the $75 \mu\text{g}/\text{m}^3$. In 4 of the 21 samples taken, the 60-min average was high enough that even if there was no other exposure for another 7 h, the time weighted 8-h average would still breach the $25 \mu\text{g}/\text{m}^3$.

In Figs. 1, 2 and 3, we observed an expected reduction of the mercury vapor levels over time due to anticipated cooling off of the particulate. It is also reasonable to assume that the surface may oxidize over time which also can reduce volatilization. It is clear that dental particulate generated from drilling amalgam fillings produces mercury vapor at levels of concern over a substantial period of time that can breach threshold levels and that this needs to be considered in occupational safety strategies.

It is also apparent that the peak and average vapor readings from room temperature elemental mercury were much lower than corresponding particulate readings. This was despite the fact that the mass of elemental mercury used was at least 100 times greater than any of the samples of particulate.

The surface area of mercury, being a factor in the rate of volatilization, is a calculation that we were unable to assess with respect to particulate since the surface area of the particulate is unknown. Because the levels of mercury vapor generated by particulate was up to 1 order of

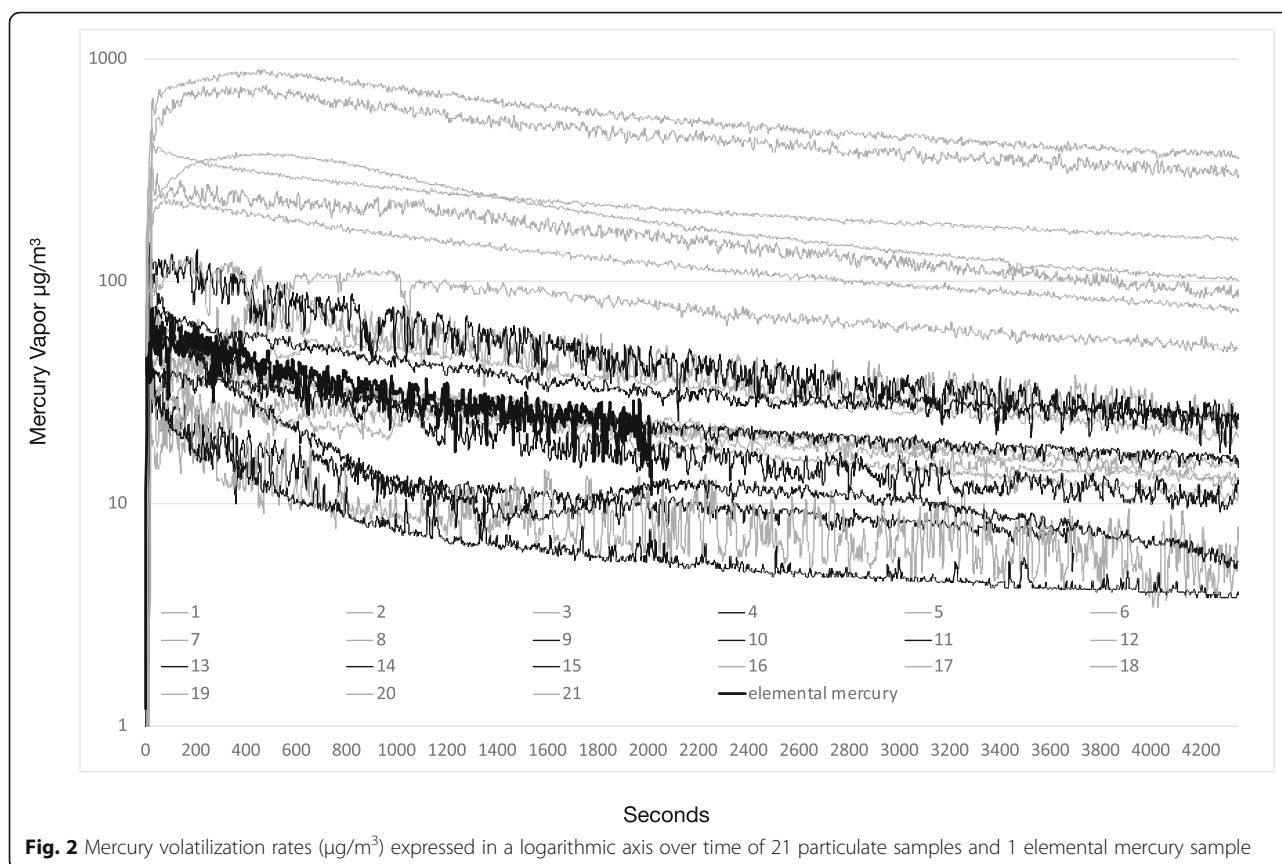


Fig. 2 Mercury volatilization rates ($\mu\text{g}/\text{m}^3$) expressed in a logarithmic axis over time of 21 particulate samples and 1 elemental mercury sample

magnitude higher than the levels generated by room temperature elemental mercury at masses 2 orders of magnitude less, particulate must be considered a dental waste that is more toxic than elemental mercury. Skin contact and inhalation must be avoided.

As well, several of the samples peak levels breached the stated ceiling thresholds by more than 7-fold. It must be understood that these thresholds are based on a general exposure, and the mercury sources from particulate that we have identified may not qualify for this protective limit, as these sources represent a localized source of acute mercury exposure.

Another observation from the data is the amount of time that the particulate emits Hg vapor, especially when one considers the very low mass. Although not shown in Figs. 1 or 2, some of the larger mass samples continued to off gas mercury vapor at levels above ceiling thresholds ($100\text{--}125\text{ }\mu\text{g}/\text{m}^3$) for over 4 h. The other implication of the extended time that the samples off-gas mercury vapor is that this exposure may increase the risk of time weighted exposure limits that have been established.

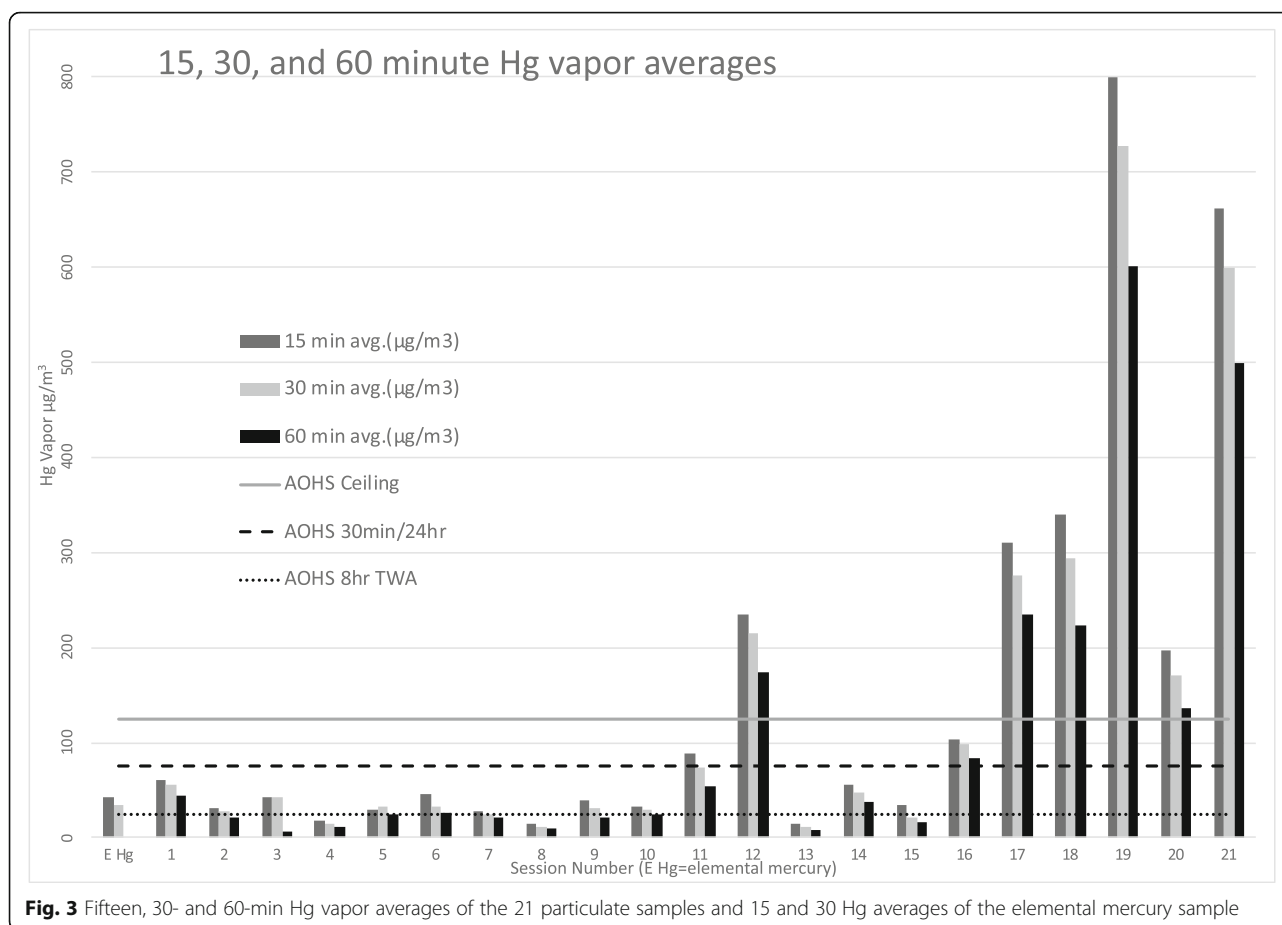
The greatest share of the amalgam particulate generated by high-speed dental drills is in the fully respirable range [14]. There are several models that suggest that the lungs provide an environment where the

volatilization of Hg vapor from particulate would be at least as favorable as particulate at room temperature, since the rate of volatilization is dependent on temperature [14]. Unfortunately, once these particles are inhaled, they are hidden by any occupational measuring technique. However, one could recognize the potential for an extended mercury exposure in the lungs that could last at least hours after the inhalation of amalgam particulate. The inhalation of particulate would then decrease the ability of occupational measurements to be made because the volatilization is occurring in the dental worker's body.

Particulate that lands on the skin can also provide a mercury source that may not be properly considered in occupational assessment. The Hg vapor from particulate is a very localized plume of Hg vapor that can absorb through the skin; however, if the skin as a surface is not measured locally, there may be an understated exposure level if, for example, ambient room air is assessed.

There is limited information regarding mercury absorption via the skin in the literature, and essentially no information specifically on volatilizing dental amalgam particulate.

Hursh et al. of the Environmental Health Sciences Center in Rochester, New York, measured human percutaneous absorption of mercury vapor at concentrations



of $0.88\text{--}2.14\text{ ng}/\text{cm}^3$ and estimated that the skin of the forearm will absorb approximately 2.2% that of the lungs at the same concentration of mercury vapor [43]. This testing showed that 216–844 ng of mercury was absorbed over a 27 to 43 min. Half of this was shed by desquamation, and the other half made it into the circulation and could be measured systemically. Given that the conversion of ng/cm^3 to $\mu\text{g}/\text{m}^3$ is 1:1000, the vapor generated by amalgam particulate is less than Hursh et al.'s source by a factor of 10. The median of Hursh et al.'s exposure level would be $1.51\text{ ng}/\text{cm}^3$ or $1510\text{ }\mu\text{g}/\text{m}^3$, as compared to the median peak levels of $80.1\text{ }\mu\text{g}/\text{m}^3$ in particulate group.

The particulate that was collected in this study was a small fraction of the potential amount of particulate generated, and a much larger amount has the potential to land on the skin proximal to the operative site such as the hands, wrists, forearms, face, neck and even lap and thighs of the dental worker. Multiple skin destinations of particulate could theoretically increase the potential exposure of mercury via this route. If a dental worker has bare skin or clothing that is permeable to Hg vapor, particulate on the skin or in the non-protective clothing can continue to provide a source of mercury vapor to the skin for hours.

There is a risk of skin absorption of mercury vapor from volatilizing particulate during and well after amalgam removal, and as a result, it would make sense for dental workers to wear skin barriers as the amalgam is being removed. It also makes sense, because of the extended time that the particulate emits mercury vapor, to remove the protective barriers and clothing once the amalgam removal is complete and conscientiously dispose of this contaminated gear outside the confines of the dental office.

It is important to understand that because the collection of samples was collected in vivo, the particulate was generated while using all the techniques known to minimize Hg vapor production. Warwick [15], Nimmo [35], and Brune [37] all confirmed a dramatic decrease in mercury vapor generation using the protocols described previously in this paper. Unfortunately, there are still instances where amalgam is drilled without some or all of these precautions. It would be anticipated that not using safety protocols would substantially increase the levels of mercury vapor generated from particulate and increase the risk of mercury absorption.

The average sized filling contains approximately 500 mg of mercury [44]. This filling would be comparable to

a 2 rated filling in the size scoring that was adopted in this paper. The amount of particulate generated is, of course, determined by not only the size of the filling but also the technique used to drill the tooth. Using a smaller sized, sharp bur (drill bit) and removing the filling by cross hatching and removing as many solid chunks of amalgam as possible can reduce the amount of amalgam that is drilled upon.

Nevertheless, the mass of mercury in the particulate that was measured accounts for much less than 1% of the total mercury in the filling. Considering the median size score was 6, it can be estimated that the fillings removed in this case would be made up of approximately 1500 mg of mercury. The median mass of particulate is 1190 μg or 1.19 mg, which accounts for 0.08% of the total mercury in the fillings.

It is difficult to account for all of the particulate because the ultimate destination of it is varied. It is favorable for the majority of it to be taken up by the high-volume suction and collected in an amalgam separator. Other destinations include the lungs, skin, clothing/uniforms of the patient and the dental worker, surfaces of the operator, the filters of an auxiliary evacuation, contamination of dental barriers, and contamination of dental instruments.

Answers to the research questions;

Using all engineering controls to reduce Hg vapor, the highest concentration of Hg vapor measured in this study was 899 $\mu\text{g}/\text{m}^3$.

There were samples that continued to emit mercury vapor levels above PEL (100 $\mu\text{g}/\text{m}^3$) for over 4 h. After 1 h, 17 of the 21 samples were still volatilizing Hg vapor that exceeded 10 $\mu\text{g}/\text{m}^3$.

Pearson coefficients and linear regressions were used to estimate correlations between three variables.

Correlations between mass and peak Hg (positive), mass Hg and size rating (negative), and peak Hg and size rating (negative) were all found to be statistically insignificant.

Conclusions

An unrealized, significant, localized mercury vapor source that may be present for hours after dental drilling on amalgam was identified in this study. We showed that micron amounts of amalgam particulate generated from dental high-speed drilling volatilized measurable amounts of mercury vapor that frequently breaches occupational safety thresholds. This occurred despite the fact that all feasible engineering controls were used to minimize mercury exposure. It can be reasonably assumed that not using the engineering controls used in this study will drastically increase this form of mercury

exposure to both the dental worker and the dental patient.

Current standard occupational practices of room monitoring for mercury vapor and swiping a specific 10 cm $\times$ 10 cm area for contamination may understate the risk of mercury exposure to dental workers and dental patients when amalgam particulate is generated. The mercury exposure defined in this paper may explain why dental workers seem to incur mercury related health effects even when safety thresholds are not breached.

Although there was an association with the mass of the particulate collected and the peak levels of mercury vapor measured, it was not statistically significant, and we noted a fairly broad variability in the amount of Hg vapor emitted from a given mass of particulate. There are many functions in the operation of amalgam removal that can have the potential to affect the temperature of the particulate. Factors such as drill pressure, drill rpm, sharpness of the bur (bit), type of bit (diamond vs carbide), accuracy of the positioning of the suction, water temperature, accuracy of the water spray, water flow, the type of amalgam, the age of the filling, and the size of the particulate all may play a role in the variability of volatilization that we experienced.

Recommendations

It is recommended that the engineering controls listed in this study be used at all times when amalgam is removed with a high-speed dental drill. In addition to these protocols, the authors have compiled a list of additional recommendations to reduce the risk of mercury exposure to dental workers and dental patients. These recommendations are available at Additional file 1.

Further study

Further studies are required to determine the dispersal pattern of particulate during amalgam removal.

Additional file

Additional file 1: Supplementary recommendations for dentists and dental schools to reduce mercury exposure from volatilizing amalgam particulate. (DOCX 20 kb)

Abbreviations

AAS: Atomic Absorption Spectroscopy; ACGIH: Association Advancing Occupational and Environmental Health/American Conference of Governmental Industrial Hygienists; AIHS: Alberta Innovates – Health Solutions; AOHS: Alberta (Canada) Occupational Health and Safety; ARECCI: A Project Ethics Community Consensus Initiative; FDI: World Dental Federation; Hg: Mercury; kPa: Kilopascal; MSDS: Manufacturers Safety Data Sheet; NIOSH: The National Institute for Occupational Safety and Health; OSHA: Occupational Safety and Health Administration; PEL: Permissible Exposure Limit; REL: Recommended Exposure Limit; SDS: Safety Data Sheet; TLV: Threshold limit values; TWL: Time Weighted Level; WHO: World Health Organization

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Authors' contributions

DW, MY, JP and RWE participated in the design of the study, DW and MY carried out the data collection. DW drafted the manuscript. All authors read and approved the final manuscript.

Authors' information

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Availability of data and materials

All data is available to the reviewers. The samples collected were destroyed in the analytical portion of the study.

Ethics approval and consent to participate

The ethical implication of the methodology of this study was assessed using A Project Ethics Community Consensus Initiative (ARECCI) ethics assessment tool. The tool was developed by Alberta Innovates – Health Solutions (AIHS) to allow researchers to assess ethical implications of a study. After completing the online tool, the results suggested that the methodology of this study was deemed to have minimal risk of ethical issues and could proceed without a formal ethics review. All dental patients involved were aware that the intention of the authors was to collect dental particulate waste after the regularly scheduled routine removal of dental amalgam and consented to both participate and to allow publication. The patients were also aware that their participation would remain anonymous.

Competing interests

The authors declare that they have no competing interests.

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RECOMMENDATIONS FOR THE MERCURY-FREE, MERCURY-SAFE DENTAL OFFICE



CLINICAL PRACTICE:

- * **NEVER** "diagnose" mercury poisoning or claim mercury poisoning from amalgam mercury exposure [because the dental boards consider this to be "practicing medicine without a license"].
- * **NEVER** promise patients health improvement from the removal of amalgam fillings. Similarly, do not suggest causation of any type of adverse health effect as a result of mercury.
- * **DO** utilize the IAOMT recommendations for amalgam removal. To read the IAOMT's Safe Mercury Amalgam Removal Technique (SMART), [click here](#).
- * **DO** carefully select the language you use in any information you share. For example, SMART reduces mercury exposures, but it does not completely eliminate them. Also, be careful of any suggestion that your practice is "better" than others.
- * **DO** provide patients with accurate information, based on valid documentation and inclusion of the opposing position. Cite only peer-reviewed sources. Do not cite publications intended for a lay readership.
- * **DO** use written informed consent for amalgam removal and other procedures, signed by the patient. Cite the scientific, medical, and/or dental references that support the statements made in your written informed consent. Include all statements made to the patient in your written informed consent. If you make statements concerning the potential adverse effects associated with mercury fillings, we highly recommend that you include a citation that supports this statement. We also highly recommend that you tailor your informed consent to the warnings contained in an amalgam safety data sheet. Remember that statements made about the toxicity of mercury in the safety data sheet has equal application to mixed dental amalgam unless the safety data sheet explicitly says otherwise {*Barnes v. Kerr Corp.*, 418 F.3d 583, 591 (2005)}. Some states (e.g., Pennsylvania) have regulations that specifically address the removal of mercury fillings from patients for reasons other than the clinical performance of the filling. Review those regulations, and if you have questions, contact one of the IAOMT's attorneys. In your informed consent, warn your patients about the potential complications that can occur during and after amalgam replacement. You should also advise your patients that you (and other dentists in your office) have chosen not to place mercury fillings (if that is, in fact, true.) Your informed consent should state the reasons why the amalgam fillings are being replaced. The reason may be because the fillings are not clinically serviceable, may be because the patient elected to replace them for cosmetic reasons, or may be because the patient believes they are toxic. If the latter reason is the best explanation, you should include a well-rounded statement in your informed consent that reflects a balanced discussion with the patient about the pros and cons of replacement. At a minimum, this should include a statement that the FDA believes that amalgams are safe.
- * **DO** keep accurate records, consistent with the current standard of care for the dental profession. Many states have specific regulations governing the specific information that must be kept in a patient's records. Understand the regulations that pertain to you and strictly follow them. An administrative law judge hearing a dental board case will strictly follow the regulations.
- * If your practice utilizes "alternative modalities" that are outside the scope of general dentistry's standard of care, obtain documentation supporting the procedure. For example, Dental Boards have indicated disapproval for utilization of the Amalgameter, EAV, muscle testing, electrodermal testing, Applied Kinesiology, Ozone Therapy, etc. for diagnostic and/or treatment purposes.

ADVERTISING (INCLUDING WEBSITE CONTENT/SOCIAL MEDIA):

- * Great progress has been made with the Dental Boards. In most states/provinces, advertising as "mercury-free" is acceptable. However, it is wise to play it safe, and check with the Dental Board in your state/province as to what they deem acceptable.
- * Several dentists have won board cases for advertising based on information that is supported by scientific documentation. However, they have been long, expensive battles in most cases. This appears to be changing, but it is still risky in some states.
- * Think about what you post on your website and social media accounts in the same way as advertising. Avoid making any claims that cannot be supported by science, and read all professional posts at least twice before publishing to make sure that you are sending the appropriate message.
- * Utilize a noticeable disclaimer on your website or other publications such as: "The information provided on this site is not intended as medical or dental advice and should not be interpreted as such. The intent is to provide as much scientific information as possible on different dental materials and aspects of dentistry where controversy exists and scientific clarification would be of benefit to patients, staff, dentists, physicians and scientists in making informed judgements. If you seek medical or dental advice, please consult with a health care professional. You must always exercise your own best judgement when using the services of any health care practitioner."

OFFICE:

- * Read the IAOMT's SMART Protocol Recommendations by [clicking here](#).
- * Read the IAOMT's SMART Equipment list for more information, by [clicking here](#).
- * Comply with federal, state, and local regulations addressing the proper handling, cleaning, and/or disposal of mercury-contaminated components, clothing, equipment, surfaces of the room, and flooring in the dental office. *Take the time to research this, as all of these items are contaminated, and your safety depends on how you handle all of these items, including your own clothing and shoes.* Check your local regulations at <http://earth911.com/>.
- * Consider completely decontaminating your office of mercury. For example, consider using non-carpet flooring and removing all old carpeting (probably loaded with mercury). Disposing of old carpet must be done properly, abiding by all applicable regulations. Know that if you keep carpeting, the heat generated by vacuuming will result in the release of mercury. For similar reasons, consider replacing drapes as well.
- * Likewise, consider taking advantage of renting a Mercury 3000 machine to measure and evaluate the mercury levels in areas of your office. For more information, email the IAOMT office at info@iaomt.org or by calling at (863) 420-6373.

ALWAYS REMEMBER THAT YOUR STATE/PROVINCE BOARD HAS ITS OWN SET OF RULES. IT IS ESSENTIAL TO COMPLY WITH THE EXPECTATIONS OF YOUR LOCAL BOARD, AND YOU SHOULD RESEARCH WHAT THESE RULES ARE AND HOW THEY DIRECTLY APPLY TO YOU.

YOU NOW NEED TO TAKE THE MODULE 2
TEST AT

<https://www.cvent.com/d/fvqcmm>

IT IS AN OPEN BOOK TEST AND CONSISTS OF
25 QUESTIONS. YOUR SCORE WILL BE
AUTOMATICALLY CALCULATED AND SENT
TO YOU VIA EMAIL.

UPON COMPLETION OF THE MODULE 2 TEST,
YOU WILL NEED TO CONTINUE WITH
THE POST-COURSE REQUIREMENTS TO
OBTAIN YOUR SMART CERTIFICATION. THE
POST-COURSE REQUIREMENTS BEGIN ON THE
NEXT PAGE...

IAOMT SMART-- Checklist for Completing SMART Requirements

- ☐ At a minimum, you will need to print out pages 185 and 191 of this document.
- ☐ **Make sure that you have completed Units 2 & 3 of Accreditation, including successfully passing all tests. You do not need to enroll in SMART because the initial SMART enrollment fee is waived for IAOMT members that are in the process of achieving Accreditation.**
- ☐ **Read, sign, and scan the SMART course disclaimer.** You will need to send the disclaimer to the IAOMT office with your application. Click here to go to the disclaimer on page 185.
- ☐ Read the IAOMT “[Safe Mercury Amalgam Removal Technique \(SMART\) Protocol Recommendations](#)” with scientific references. Click here to go to page 186.
- ☐ Read the “Essential Excerpts about Amalgam Removal” from the IAOMT Position Statement. Click here to go to pages 187-189.
- ☐ Read the “[SMART Equipment](#)” list (which provides resources for you to order the equipment mentioned in the SMART protocol recommendations). Click here to go to page 190.
- ☐ Read the “[SMART Checklist for Patients and Dentists](#)” (and print for your personal use, if you so desire). Click here to go to page 190.
- ☐ Visit the official SMART website at www.thesmartchoice.com and watch the videos and read the content. Click here to go page 190.
- ☐ Please check to see if you have a public directory listing at <https://iaomt.org/for-patients/search/>. If you don't have a listing, or need to update your listing, please follow this link: <https://iaomt.org/createupdate-public-search-listing/>.
- ☐ **Print, read, and sign your SMART application.** Click here to go to application on page 191.
- ☐ **Send your SMART disclaimer and application via email to info@iaomt.org. Use the subject line: SMART disclaimer and application.**
- ☐ Congratulations! You should now be officially SMART certified by the IAOMT!
- ☐ After you receive your SMART certification and are registered as SMART certified on the IAOMT Dentist Directory, **remember to annually renew your SMART certification.**
- ☐ Familiarize your office staff with the SMART program and your office's participation in it.
- ☐ Upon successful processing of your disclaimer and application, you will receive a link to SMART materials, including a logo for you to use on your website and print out for office display. Updates to SMART and other resources will also be provided to you in the future, so, be sure to read them!

SMART CERTIFICATION COURSE DISCLAIMER:

***By participating in IAOMT SMART certification,
you agree with the following--***



The fifty dollar fee for your SMART certification covers the period from your initial participation in the SMART Program through June 30th of the same or following year. To maintain SMART certification, each succeeding year of participation in the SMART Program will require the payment of an additional fee, the cost of which will be established from year to year by the IAOMT. The IAOMT may also require members participating in the SMART certification program to complete updated training.

The information provided in this course is not intended as dental or medical advice and should not be interpreted as such. In offering the SMART certification Program, the IAOMT's intention is to present as much scientific information as possible on different dental materials, treatments, patient and dental staff safety, and other aspects of dentistry where the health care practitioner can make their own informed judgments for the benefit of themselves and their patients and staffs. **Dentists must be also aware of and abide by the supervision laws for the particular region/state/country in which they hold a license.**

The IAOMT offers training and provides guidance and procedures for dentists and physicians to accomplish the safest possible replacement of amalgam dental fillings. Methods and techniques discussed in this program, in the opinion of this organization's leadership, enhance the safety of the health care practitioner, and his/her patients and staffs. However, it is up to the licensed practitioners to exercise their own judgment concerning the specific treatment options that should be utilized in their healthcare practices.

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SIGN HERE TO AGREE TO THE TERMS ABOVE:

X

PRINT NAME: _____ DATE: _____

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CHECK ONE:

☐ I am accredited by the IAOMT.

☐ I am NOT accredited by the IAOMT.

*After completing this page, please scan it and send it via email to info@iaomt.org.
If needed, you can also print and fax it to (863) 419-8136, or print and mail it to...*

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IAOMT SMART Disclaimer; Page 1

YOU NOW NEED TO READ
THE SMART PROTOCOL
RECOMMENDATIONS

by clicking on this link:



[https://iaomt.org/resources/safe-removal-
amalgam-fillings](https://iaomt.org/resources/safe-removal-amalgam-fillings)

**ESSENTIAL EXCERPTS ABOUT AMALGAM REMOVAL FROM
International Academy of Oral Medicine and Toxicology (IAOMT)
Position Statement against Dental Mercury Amalgam Fillings
for Medical and Dental Practitioners, Dental Students,
Dental Patients, and Policy Makers
*Highly Relevant to the Safe Mercury Amalgam Removal Technique (SMART)***

POTENTIAL HARMS

- 1) There is a risk of additional mercury exposure to dentists, dental staff, hygienists, dental students, and patients from current unsafe procedures involving mercury amalgam fillings, especially if treatment, hygiene routines, removal, and/or replacement of fillings are conducted without taking appropriate protective measures.
- 2) As such, special consideration of any dental work involving amalgam mercury fillings should be given to

All dental professionals, dental staff (including hygienists), and dental students who work with dental mercury amalgam

All patients with existing dental mercury amalgam fillings

All patients requiring the cleaning and/or removal of dental mercury amalgam fillings

All patients requiring new dental fillings

Pregnant or lactating women

Women of childbearing age

Fetuses

Children

Patients genetically predisposed to mercury toxicity

Patients with

- o Allergies, especially allergy to mercury
- o Alzheimer's disease
- o Amyotrophic lateral sclerosis (Lou Gehrig's disease)
- o Antibiotic resistance
- o Autism spectrum disorders
- o Autoimmune disorders/immunodeficiency
- o Cardiovascular problems
- o Chronic fatigue, fatigue, and/or myalgic encephalomyelitis/chronic fatigue syndrome
- o Complaints of unclear causation
- o Dermatitis
- o Fibromyalgia
- o Gastrointestinal issues and/or irritable bowel syndrome
- o Hearing loss
- o Kidney disease
- o Micromercurialism
- o Multiple sclerosis
- o Oral lichenoid reaction and oral lichen planus
- o Orofacial granulomatosis
- o Parkinson's disease
- o Periodontal disease

- o Psychological issues such as depression and anxiety
- o Reproductive dysfunction
- o Suicidal ideations
- o Symptoms of chronic mercury poisoning
- o Systemic lupus erythematosus
- o Thyroiditis

Patients undergoing chelation treatment or other detoxification treatments

3) Alternative dental restorative materials should likewise be assessed for safety and biocompatibility, especially on an individual basis.

4) Some insurance companies only cover the cost of dental mercury amalgam fillings which means that oftentimes consumers have to pay additional fees for alternative materials and techniques.¹

Furthermore, whereas amalgams are used for 45% of all direct dental restorations worldwide,² articles published in the *Journal of the American Dental Association* have established that these mercury fillings are used on 51.0% of White/Caucasian Americans, on 53.4% of Black/African Americans, on 72.9% of American Indians/Alaska Natives/Asians/Pacific Islanders,³ and on more than 75% of posterior restorations for new recruits to the U.S. Navy and Marines.⁴

However, the United Nations Environmental Programme's 2013 "Minamata Convention on Mercury," signed by over 100 nations including the United States, specifically discourages insurance policies and programs favoring dental mercury amalgam use over mercury-free dental restoration.⁵

CONTRAINDICATIONS

1) Dentists, dental staff, and dental students working with mercury amalgam fillings during procedures such as cleaning, hygiene, and/or replacement are significantly exposed, along with their patients, fetuses, and breast-feeding children to mercury. Safety measures, when used, diminish but do not totally eliminate exposure.

2) Removal of dental mercury amalgam fillings without appropriate protection causes significant mercury exposure to dentists, dental staff, dental students, and patients, especially women of childbearing age, pregnant or lactating women, fetuses, children, and other sensitive populations.

3) Due to mercury releases, polishing, placement, removal, or any disruption of a dental mercury amalgam filling should not be done by dental personnel who are pregnant or lactating and should not be conducted upon patients who are pregnant or lactating.

4) Alternative dental restorative materials should likewise be assessed for safety and biocompatibility, especially on an individual basis.

TO READ THIS DOCUMENT IN FULL, VISIT <https://iaomt.org/iaomt-position-paper-dental-mercury-amalgam/>

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- ¹ McCann D. "A Solution to our Country's Big Health Care Problem? *CFO*. October 30, 2012. http://www3.cfo.com/article/2012/10/health-benefits_parker-hannifin-washkewicz-complementary-alternative-medicine-cam-sherri-tenpenny-chelation-mercury-fillings-pelletier. Accessed March 2019.
- ² Heintze SD, Rousson V. Clinical effectiveness of direct Class II restorations—a meta-analysis. *J Adhes Dent*. 2012; 14(5):407-431. Abstract available from: <https://www.ncbi.nlm.nih.gov/pubmed/23082310>. Accessed March 2019.
- ³ Makhija SK, Gordan VV, Gilbert GH, Litaker MS, Rindal DB, Pihlstrom DJ, Qvist V. Practitioner, patient, and caries lesion characteristics associated with type of material used to restore carious teeth: findings from The Dental PBRN. *Journal of the American Dental Association* (1939). 2011 Jun;142(6):622. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3107519/>. Accessed March 2019.
- ⁴ Simecek JW, Diefenderfer KE, Cohen ME. An evaluation of replacement rates for posterior resin-based composite and amalgam restorations in U.S. Navy and Marine recruits. *J Am Dent Assoc*. 2009; 140 (2): 207. Abstract available from: <https://www.sciencedirect.com/science/article/abs/pii/S0002817714642835>. Accessed March 2019.
- ⁵ United Nations Environment Programme. *Minamata Convention on Mercury: Text and Annexes*. 2013: 48. Available from UNEP's Minamata Convention on Mercury Web site: http://www.mercuryconvention.org/Portals/11/documents/Booklets/Minamata%20Convention%20on%20Mercury_booklet_English.pdf. Accessed March 2019.

A FEW MORE ONLINE STEPS TO SMART-CERTIFICATION:

Read the “[SMART Equipment](https://iaomt.org/for-members/smart-equipment/)” list (which provides resources for you to order the equipment mentioned in the SMART protocol recommendations) at <https://iaomt.org/for-members/smart-equipment/>.

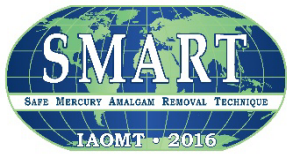
Read the “[SMART Checklist for Patients and Dentists](https://files.iaomt.org/wp-content/uploads/SMART-Patient-Dentist-Checklist.pdf)” (and print for your personal use, if you so desire) at <https://files.iaomt.org/wp-content/uploads/SMART-Patient-Dentist-Checklist.pdf>.

Visit the official SMART website at www.thesmartchoice.com and watch the videos and read the content.

Please check to see if you have a public directory listing at <https://iaomt.org/for-patients/search/>.

If you don't have a listing, or need to update your listing, please follow this link: <https://iaomt.org/createupdate-public-search-listing/>.





SAFE MERCURY AMALGAM REMOVAL TECHNIQUE (SMART) CERTIFICATION APPLICATION FROM THE IAOMT

Please complete this application and email to info@iaomt.org with the subject line "SMART Application."

You can also print and fax it to (863) 419-8136, or print and mail it to

*The International Academy of Oral Medicine and Toxicology
8297 ChampionsGate Blvd, #193; ChampionsGate, FL 33896.*

Name: _____ **Date:** _____

Email: _____ **Phone:** _____

Please check the boxes that pertain to your SMART certification training from the IAOMT:

1. ☐ I am an accredited member of the IAOMT applying for SMART certification.

OR

☐ I am a general member of the IAOMT who has completed Modules 1 and 2 of the SMART educational program (Units 2 and 3 of Accreditation), including successfully passing both tests.

2. ☐ I have read the [IAOMT's SMART Protocol Recommendations](#) with scientific references.

3. ☐ I have also read the [SMART Equipment List](#) and have the following items available for use: an amalgam separator; high-volume, at source, oral aerosol/air filtration vacuum system; air/oxygen equipment, and the additional equipment identified in the protocol recommendations.

4. ☐ I have also read the Essential Excerpts from the IAOMT Position Statement, the [SMART Checklist for Patients and Dentists](#), and all of the content, including watching the videos, on [the SMART Choice website](#).

5. ☐ I recognize that in order to maintain certification, I will need to renew it annually, which will require an additional fee and may require additional training.

Signature

