

Alarming Findings on Mercury Dental Amalgam – Latest Research Using the National Health and Nutrition Examination Survey (NHANES) Database: A Mini-Review

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Received: 27 Jul 2022; **Accepted:** 12 Sep 2022; **Published:** 17 Sep 2022

Citation: Anita Vazquez Tibau, Blanche D Grube, et al. Alarming Findings on Mercury Dental Amalgam – Latest Research Using the National Health and Nutrition Examination Survey (NHANES) Database: A Mini-Review. Oral Health Dental Sci. 2022; 6(2); 1-6.

ABSTRACT

Mercury dental amalgam has been used as a dental restorative material for almost 200 years. Even though mercury is the most toxic non-radioactive material known to man, there has been an ongoing controversy about its safety since it was first introduced for use in dentistry. In 2013, a global treaty was adopted to address the dangers of mercury-containing products and processes called the Minamata Convention on Mercury Treaty, which went into force in 2017. This global mercury treaty listed mercury dental amalgam as a “phase-down” product. It is the only product in the treaty that is implanted in the human body and the only product listed simply as “phase-down”. While many evidence-based scientific papers have reported that mercury dental amalgam negatively affects human health, it is still the most commonly used dental restorative material in the world. Since the treaty has gone into force, many developed countries, countries with emerging economies, and developing countries have banned the use of mercury dental amalgam in the spirit of the treaty whose mantra is “Make Mercury History”. However, a date certain to ban mercury dental amalgam’s use globally has not yet been achieved. The latest significant findings on human exposure to mercury dental amalgam using the “Gold Standard” National Health and Nutrition Examination Survey (NHANES) database, may finally be the catalyst that will achieve the goal and “Make Mercury History” in the dental sector.

Keywords

Arthritis, Asthma, Infertility, Mercury Dental Amalgam, Minamata Convention on Mercury Treaty, National Health and Nutrition Examination Survey (NHANES).

Abbreviations

NHANES: National Health and Nutrition Examination Survey; WHO: World Health Organization; UNEP: United Nations Environmental Programme; ASGM: Artisanal and small-scale gold mining; FDI: World Dental Federation; ADA: American Dental Association; EPA: Environmental Protection Agency; FDA: Food and Drug Administration; GRAS: Generally Recognized as Safe; ART: Atraumatic Restorative Treatment; THg: Blood total

mercury; MeHg: Methylmercury; IHg: Inorganic mercury; UTHg: Urine creatinine corrected mercury; CDC: Center for Disease Control and Preventions.

Introduction

The World Health Organization (WHO) deemed the first route of mercury exposure to humans is from dental amalgam [1]. Mercury dental amalgam is approximately 50% mercury, and various amounts of silver, tin, copper, and zinc. According to the United Nations Environmental Programme (UNEP), as much as 20% of the annual total global mercury consumption is used for dental restorations. Mercury which has been allocated for dental use worldwide also finds its way into the black market for artisanal-

small-scale gold mining (ASGM). This is of particular concern because ASGM is the greatest user/polluter of mercury globally, and is a priority of the Minamata Convention on Mercury Treaty [2]. The two key non-governmental organizations (NGOs) who were also major industry stakeholders of the treaty, the World Dental Federation (FDI), and the American Dental Association (ADA) are still in favor of the continued use of mercury dental amalgam. These NGOs maintain that mercury “dental amalgam is a durable, safe, and effective cavity-filling option” [3,4].

The Environmental Protection Agency (EPA) defers to the Food and Drug Administration (FDA), on the safety of mercury dental amalgam, while acknowledging that placing, removing, and chewing can cause mercury dental amalgam fillings to off-gas mercury and those vapors can be absorbed by inhaling or ingesting them [5]. The FDA continues to mislead consumers about the safety of mercury dental amalgam stating, “Mercury is used to bind the alloy particles together into a strong, durable, and solid filling.” While also stating under Potential Risks of Dental Amalgam Releases that “Low levels of mercury in the form of vapor can be inhaled and absorbed by the lungs. Exposure to high levels of mercury vapor, which may occur in some occupational settings, has been associated with adverse effects on the brain and the kidney. Developing neurological systems in fetuses and young children may be more sensitive to the neurotoxic effects of mercury vapor [6].”

The FDA contends that there is very limited to no clinical data on long-term health outcomes of the use of mercury dental amalgam on women, developing fetuses, children under six, and breastfed infants, but then lists vulnerable populations that may be more susceptible to potential adverse effects from this exposure, i.e., pregnant women, women of childbearing age, nursing women, children, especially under six years old, individuals with pre-existing neurological disease, impaired kidney function, and sensitivity (allergy) to mercury or other components of mercury dental amalgam.

The FDA says mercury from dental amalgam can bioaccumulate in bodily fluids, tissues, kidneys, and the brain, but then states that “studies have not shown that increased mercury levels and bioaccumulation due to dental amalgam result in detectable damage to target organs”. This contradicts their previous statements, which can confuse the consumer who is trying to decipher if there are serious health risks, or not. For example, the FDA does not recommend removing mercury dental amalgam because of the destruction of the healthy tooth structure and a temporary increase in mercury vapor exposure. But doesn’t discuss the potential toxicity of this acute mercury exposure if extremely significant and rigorous engineering controls are not followed during the drilling process and the dangerous risks of this exposure not only to the patient but also to dental workers [6].

Dental workers including dental assistants, dental hygienists, and dentists are exposed to higher levels of mercury due to occupational exposure. As previously mentioned, mercury is

absorbed by inhalation or through the skin. Various common dental procedures involve mercury dental amalgam removal, which is often performed using a high-speed dental drill. Warwick et al. (2019) designed a study to answer numerous questions such as:

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

They noted that while there are diverse occupational safety levels depending on territories and governments, it is mutually agreed that mercury vapor can be absorbed by the lungs and skin.

There are engineering controls that have been established which are recommended to minimize mercury exposure that include:

- “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
- 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 the patient face shield, mercury-rated gown and head protection, nitrile gloves, mercury-rated breathing protection for dentist and assistant”

Warwick et al. found that mercury vapor volatilization from particulate generated from mercury dental amalgam removal with a high-speed dental drill was a significant source of mercury exposure, even when a variety of engineering controls were used. They concluded that it is imperative to use all engineering controls when removing mercury dental amalgam, to minimize the risk of mercury exposure [7].

It is significant to note that mercury dental amalgam was grandfathered in under Generally Recognized as Safe (GRAS) due to long-term usage in 1976. Therefore, it has never been clinically tested for safety and efficacy even though it is implanted in the human body [8].

In 2017, the WHO stated that “Exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child in utero and early in life. Mercury may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin, and eyes.” However, during the treaty process, the WHO (2009) only recommended a “phase down” for mercury dental amalgam as the proper approach, stating it would be problematic for public health and the dental sector to

ban its use [9]. The same stakeholders mentioned above, continue to discuss mercury dental amalgam's inexpensive cost, durability, ease of use, and the need for the development of mercury-free dental materials. However, a pilot project developed in Tanzania that was supported by the WHO over 30 years ago created what is called "Atraumatic Restorative Treatment" (ART), which uses glass ionomer cement, a non-mercury filling material. ART doesn't require the use of electricity or water and is used without anesthesia which is especially important for dental care in remote regions. Using the ART technique has the lowest cost, reduces destruction to the healthy tooth structure and tissue, is less painful, causes less sensitivity, and reduces dental patient anxiety. It is well documented that the success of ART and its survival rate shows it as being equal to or better than mercury dental amalgam [10,11].

Mercury Dental Amalgam

According to Sanchez-Alarcon et al. (2021) mercury dental amalgams "provide significant iatrogenic exposure to xenobiotic compounds". They noted that the number of mercury dental amalgams and exposure time can cause DNA damage, which can be dangerous for vulnerable subpopulations [12].

Andreoli and Sprovieri (2017) reported on over 250 symptoms related to mercury exposure in humans, involving the neurological, renal, respiratory, gastrointestinal, cardiovascular, hepatic, reproductive, and immune systems, with fetotoxicity and genotoxicity, noting methylmercury may possibly be carcinogenic. Because of the complexity and multitude of pathways that mercury affects humans, with either acute exposure or long-term low dose exposure, it is very difficult to diagnose mercury toxicity. Studies have now determined, however, that specific genes can assist in identifying an individual's risk of toxicity to mercury [13].

Siblerud and Mutter (2021) reviewed the literature to provide a snapshot of the toxic health effects produced by exposure to mercury dental amalgams. Some of their findings included:

Mental Health Disorders

- depression, anger, irritability
- schizophrenia and bipolar disorders

Cardiovascular Problems

- high blood pressure
- heart rate
- hemoglobin
- hematocrit
- red blood cells

Diseases Linked to Mercury Dental Amalgam

- Alzheimer's disease (AD)
- Multiple sclerosis
- Amyotrophic lateral sclerosis

They remarked that there is a preponderance of evidence that exposure to mercury from dental amalgam is a causative factor in many health maladies. The negative effects of exposure to

individuals are diverse. Health problems that are related to mercury dental amalgam are significant and numerous [14].

Latest Findings National Health and Nutrition Examination Survey (NHANES) Database and Mercury Dental Amalgam

The NHANES database is considered the "Gold Standard" for the health and nutritional status of the United States population [15]. The NHANES database is the only existing national survey that captures both environmental and clinical data and provides an invaluable database unmatched by any size or content. Starting in the 1960s it was designed to assess the health status of children and adults of all demographics, races, and ethnicities using personal interviews, physical exams, and lab testing [16].

Using the NHANES data from 1999-2000, Dye et al. investigated the link between urinary mercury concentrations and dental restorations in US women of reproductive age. They noted that this was the first study to assess the relationship between mercury dental amalgam restorations and mercury concentrations in a nationally represented US population sample. They found that the women who had higher levels of mercury in their urine also had a greater number of mercury dental amalgam surfaces. They also stated that they did not investigate the adverse health effects of low thresholds of mercury exposure, but their reference data would be a significant contribution to the ongoing scientific and public health policy debate on the use of mercury dental amalgam [17].

Richardson et al. (2011) examined mercury exposure and risks from dental amalgam in the US population, post – 2000, using the NHANES database. It was reported that between 2001 – 2004, 181.1 million Americans had a total of 1.46 billion dental restorations. This included children as young as 26 months and the majority of these dental restorations were mercury dental amalgam. By utilizing various scenarios, they calculated that about 67 million Americans would exceed the mercury reference dose determined by the EPA, and almost double that number of people would exceed the reference dose by California EPA standards. It is widely accepted that mercury dental amalgam constantly releases mercury. Regardless of how small the dose is, it can present a health risk if "the substance is sufficiently toxic and received in sufficient dose to exceed a reference level considered 'safe' [18]."

A study using the NHANES database from 2001-2010 was designed to investigate the relationship between socioeconomic status and environmental toxicant concentrations in adults. Exposure to environmental pollutants has been linked to various widespread chronic diseases. They found that mercury dental amalgams may explain increased levels of mercury levels in individuals of higher socioeconomic status because they visit their health care providers more often. This may include more mercury dental amalgams, which would allow for higher levels of mercury exposure [19].

For the first time ever, Estrich et al. (2021) was able to calculate the number of mercury dental amalgam fillings in the US population using the NHANES dataset from 2015-2016. They only included individuals 15 years and older. They found that non-Hispanic

Whites had the highest number of teeth that included a mercury dental amalgam restoration, while non-Hispanic Blacks had the lowest number of mercury dental amalgam restorations. They also stated that over half of the US population does have mercury dental amalgam restorations, however, that percentage may be significantly higher when counting the mercury dental amalgam restorations of individuals under the age of 15 years old [20].

Chewing, brushing teeth, drinking hot liquids, and simply breathing will release mercury vapor from mercury dental amalgams. Exposure to mercury vapor has been identified as a significant health risk. The objective of a recent study by David and Mark Geier was to investigate the mercury vapor safety limits from mercury dental amalgams using the NHANES database. Their results found that roughly 91 million adults had one or more mercury amalgam fillings, and approximately 67 million had no mercury amalgam fillings. There were differences noted for gender and racial groups. The daily mercury vapor dose from the exposure to mercury dental amalgams was in excess of approximately 86 million people when using the exposure safety limits of the California EPA, which are the most stringent in the US. When using the US EPA safety limits mercury vapor exposure was in excess for about 16 million adults. Like previous studies, the Geier's observed that higher amounts of urinary mercury correlated with a higher number of mercury dental amalgam fillings. This study showed that a significant portion of the US population is exposed to mercury vapor over the current safety limits which should be cause for alarm in the general population [21].

Infertility is a global problem affecting over 185 million people. While it has been found that there are causative factors such as endometriosis, autoimmune disease, fallopian damage, etc. it is still complicated and ambiguous. Zhu et al. (2020) examined elevated blood mercury levels and their association with infertility in American women using the NHANES data from 2013-2016. There have been multiple studies on animals that show that mercury exposure could cause reproductive harm but studies on infertility in women have yet to be conducted. What has been shown is there are elevated mercury levels found in infertile women. Using 1796 NHANES participants, they intended to establish the linear and non-linear relationship between mercury and infertility. Their study found a positive and non-linear relationship between mercury and infertility and noted that infertile women must consider mercury exposure sources as potentially harmful [22].

It is universally recognized that the two most common exposures to mercury in a non-occupational setting are mercury dental amalgams and seafood. Using the NHANES database Yin et al. investigated this hotly contested subject as to which exposure is a greater risk to humans. They noted that previous NHANES data from 2003-2004 and 2010-2012 recorded the number of dental surface restorations, but they did not state the type of restorative materials that were used. However, by counting the number of dental restorations they were able to significantly predict blood mercury in all demographics using the NHANES data.

Regarding fish/seafood consumption, both the FDA and EPA have been publishing advisories on the dangers of eating certain species that are of particular concern due to high levels of mercury contamination for vulnerable populations such as women and children. However, it is only recently that there are advisories to these same vulnerable populations about mercury dental amalgams. Studies have shown that the number of mercury dental amalgams has been linked to brain, blood, and urinary concentrations of mercury. By using the NHANES data from 2015-2018 they found that the higher number of mercury dental amalgam restorations significantly raised blood concentrations of blood total mercury (THg), methylmercury (MeHg), inorganic mercury (IHg), urine creatinine corrected mercury (UTHg). Their results indicated that individuals with more than five mercury dental amalgam fillings could be a significant source of mercury exposure. They found that children with mercury dental amalgam fillings had significantly elevated blood and urine mercury levels. Most significantly they reported that children under six years old with more than five mercury dental amalgam fillings had the highest blood IHg and urine UTHg amongst all age groups [6,23].

Again, using the NHANES database the Geier's looked at the connection between mercury dental amalgam exposure and reported asthma diagnoses using the age group of adults from 20 to 80 years old. There were a total of 97,861,577 persons with one or more dental amalgam surfaces (exposed group) and 31,716,558 persons with one or more non-mercury dental restorations (non-mercury control group). It had been previously suggested that most researchers are looking at the negative systemic effects of exposure to mercury in humans. The Geier's noted that the location of the respiratory system, its immediate contact with mercury vapor, and its critical importance in whole-body health necessitated their investigation and the consequences of this exposure. According to the Centers for Disease Control and Prevention (CDC) (2009), the rate of asthma in the US is growing each year, accounting for about one in twelve people or about 25 million who have been diagnosed with this disease. The cost of asthma is also rising for example from 2002 to 2007, there was a 6% increase from \$53 billion to \$56 billion. The Geier's calculations using their current data of asthma-related health costs to individuals with mercury dental amalgam would be about \$47,838,861, and the cost over 25 years for these individuals would be \$1,195,971,525. They concluded that the increase in exposure to mercury dental amalgam was related to an increased risk of reported asthma diagnoses, in the US adult population, and more studies are needed in this area [24].

The CDC has stated that arthritis is a leading cause of disability and causes pain, aching, stiffness, and swelling of the joints with accompanying physical and mental adverse effects.

Another investigation by the Geier's (2021) studied the relationship between mercury dental amalgam and arthritis diagnoses amongst adults ages 20 to 80 using the NHANES database. They theorized that while arthritis may have a genetic, or epigenetic vulnerability as a causative factor, they also submitted that environmental toxins like mercury could be a risk factor. Included in their

investigation were a total of 86,305,425 weighted -persons with lmercury dental amalgam and 32,201,088 weighted -persons with ≥ 1 non-mercury dental restoration (controls). They observed a significant increase in the arthritis exposed group compared to the controls noting that they also found a significant link between mercury dental amalgam and arthritis risk and a dose-dependent mercury dental amalgam associated immune-stimulation/immune-suppression with arthritis. Their cost analysis based on new-onset arthritis diagnosis between medical and lost wages was a total of \$281,633,494 annually. They advocated for dentists to inform their patients of the risk factors associated with mercury dental amalgam and arthritis [25].

Conclusions

The monumental yet meticulous data collection that creates the NHANES database is the “Gold Standard” in the world. Now that the NHANES database shows the actual number of mercury dental amalgam fillings in the US population, for the first time ever researchers are able to analyze that data and investigate the health risks associated with that exposure. Even though we have included some of the most recently published papers, we believe that this is just the tip of the iceberg as to what diseases will be investigated using the NHANES database and the link between mercury dental amalgam. There is no doubt that the continued use of mercury dental amalgams may not only cause harm to those individuals that have them but also the legacy pollution that results from its continued use, clearly shows mercury can never be captured or contained once it enters the environment. Therefore, the long-term environmental impact is incalculable.

In several of the papers in this mini-review, health care costs were calculated based on the NHANES data and showed the staggering financial implications of just two diseases. As more studies are conducted it is likely that they too will reveal astronomical costs for health care that are related to individuals who have mercury dental amalgams. Meanwhile, the ADA and FDI industry stakeholders, continue to lobby against an outright ban, even as recently as the 4th Conference of the Parties (COP 4), where the African Group’s proposal to ban mercury dental amalgam was rejected. This is the second time the collective African Group which represents 54 countries and is the largest regional group at the UN level, has tried unsuccessfully to get a ban on mercury dental amalgam.

The intentional continued push-back from banning the use of mercury dental amalgam in the dental industry continues. What their feeble arguments fail to address, is the continued use of mercury dental amalgam will prolong human exposure which has been linked to many health problems, and also the mercury waste problem that will continue indefinitely. The industry stakeholders do, however, continue to promote biased and deceptive messaging to the public at large regarding the safety of mercury dental amalgam when evidence-based science confirms that plainly, it is not safe. Additionally, the FDA provides consumers with mixed messages that are extremely confusing to the reader. The toxicity of mercury dental amalgam has been widely established around the world with evidence-based scientific research, while industry

stakeholders continue to say it is “safe”. Even though there have been many mercury-containing products such as blood pressure cuffs, lighting, switches, and thermometers that have been banned globally, the refusal to ban mercury dental amalgam continues.

Another question that needs to be asked is with all that is known about mercury dental amalgam being sold illegally for use in ASGM, which is the greatest polluter of mercury worldwide, why are the countries where ASGM is a monumental problem, are they not pushing for a ban on mercury dental amalgam? Many of the researchers who have been cited in this paper are sounding the alarm as to the devastating effects that can occur from exposure to mercury dental amalgam. Their findings are irrefutable and not only health care policymakers, but governments who have ratified the treaty must take action to finally “Make Mercury History”.

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