

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG



EVALUATION OF MERCURY VAPOUR LEVELS ASSOCIATED WITH AMALGAM USAGE AT THE WITS ORAL HEALTH CENTRE (WOHC)

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the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for
the degree of Master of Science in Dentistry*

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DECLARATION

I, **Makhado Masakona**, declare that this research report is my own, unaided work. It is being submitted for the Master of Science in Dentistry (Restorative Dentistry) the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

September 2024 in Parktown

DEDICATION

I dedicate this project to my Mother, Thabo Rebecca Makhado.

ACKNOWLEDGEMENTS

To the Head of School, Prof S. Nmutandani, Thank you for granting the opportunity to conduct the study at WOHC.

To the Head of Oral Biological Sciences Department, Prof J. Molepo, for a great support structure.

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ABSTRACT

Background: Dental alloys contain 50% or more mercury by weight, raising concerns about their toxicity. Mercury is a hazardous heavy metal; in particular, its gaseous and organic forms contain nephrotoxic and neurotoxic chemicals. The danger of mercury poisoning may rise with prolonged exposure to mercury vapor. Understanding the safety precautions for amalgam can help prevent mercury poisoning in both the patient and the dentist.

Aim: The purpose of this study was to evaluate the levels of mercury vapour released in the atmosphere during the use and disposal of dental amalgam at the Wits Oral Health Centre (WOHC). In addition, the perceptions and opinions of dental professionals towards mercury toxicity were evaluated with the use of a survey.

Methods: A laboratory analysis was carried out to measure the mercury vapour levels released into the atmosphere from dental amalgam restorations. A questionnaire was administered to 117 dental professionals comprised of dental students, dental assistants and dentists to evaluate their perception and awareness towards mercury toxicity regulations.

Results: The laboratory experiments conducted showed that mercury levels at WOHC were below the detection limit of the assay. The average number of amalgam capsules used by dental students per day for a single tooth cavity restoration was two capsules. About 115 dental professional participants completed the questionnaire resulting in a 98.3% response rate. The majority (84.3%) of participants were aware of mercury toxicity issues associated with amalgam use. However, about 70% of the participants suggested that stricter measures regarding the safe use and disposal of dental amalgam should be implemented, to prevent exposure to mercury vapor released from dental amalgam. Furthermore, more than 68 % of the participants were in support that dental amalgam restorations should be removed based on the patient's request. In addition, about 70% of the participants suggested that mercury levels in the blood of health care professionals should be evaluated periodically.

Conclusions: Mercury vapour levels released into the atmosphere at WOHC were below the recommended threshold described by the World Health Organisation (WHO), despite the average number of amalgam capsule usage per tooth restoration. Dental health care professionals at WOHC were aware of dental amalgam safety regulations. However, a larger number of dental students suggested that stricter safety

guidelines should be implemented. In addition, dental students also suggested that monitoring of mercury vapour levels in the atmosphere and evaluation of mercury levels in the blood of dental professionals handling amalgam restorations at WOHC should be done frequently. The dental students' heightened awareness was due to their recent undergraduate education, serving as the major source of information on the safety concerns of using dental amalgam restorations.

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LIST OF ABBREVIATIONS

ADA	American Dental Association
ACGIH	American Conference of Governmental Industrial Hygienists
FDI	Federation Dentaire International
FDA	Food and Drug Administration
Hg	Mercury
ISO	International Standards Organisation
MCM	The Minamata Convention on Mercury
MSTL	Multi Skill Technique Laboratory
PC1	Polyclinic 1
PC2	Polyclinic 2
PC3	Polyclinic 3
PC4	Polyclinic 4
RNA	Ribonucleic Acid
SADA	The South African Dental Association
Sta	Station
TLV	Threshold Limit Value
WOHC	Wits Oral Health Centre
WHO	World Health Organization
UNEP	United Nations Environmental Programme
γ	Gamma
γ_1	Gamma-1
γ_2	Gamma-2
ϵ	Epsilon
η'	Eta

1. LITERATURE REVIEW

1.1. Introduction

Dental amalgam is a mercury (Hg) alloy that has been used to restore dental cavities caused by tooth decay or trauma for more than 150 years worldwide [1]. Despite better motivation for maintaining good oral hygiene, dental caries remains a global public health challenge in many countries [2]. Dental amalgam is the most cost-effective dental material and has a relatively long service life of up to 10 years [3, 4]. When aesthetics is not a concern, dental amalgam is commonly used for direct, permanent restorations in stress-bearing areas and posterior restorations [5].

The use of dental amalgam alloy is less of a concern with countries like Norway and Sweden since they have banned the use of mercury in dental fillings due to environmental health issues [6]. Over the past decade, research on alternative restorative materials and their use has increased significantly in high-income countries, but dental amalgam remains preferred in low, middle-income and disadvantaged communities in high-income countries [7].

Mercury, a widely available metal in the environment, poses a significant concern for human beings. Exposure to this toxic substance can occur through various channels, including the air we breathe, the water we drink, and the food we consume [8]. Mercury is absorbed in the body through the respiratory system, digestive system, and contact through the skin [9]. The respiratory tract absorbs about 80% of the inhaled metallic mercury vapour where, as it passes through the alveolar cell barrier it oxidizes to inorganic mercury [10]. Mercury is then distributed by the blood circulation system to several key organs such as the liver, heart muscle, oral tissues, and the brain [11]. Unfortunately, prolonged mercury exposure may lead to various conditions such as autoimmune system disorders, renal dysfunction, infertility, negative effect on the foetus, neuro-behavioural problems and cardiac dysfunction [12].

Dental healthcare professionals are at risk of mercury vapour exposure from the dental amalgam by two routes, namely through amalgam restorations placed in their mouths and by handling the materials during treatment of patients [13]. Mercury vapour is

released from dental amalgam restorations during all procedures such as trituration, condensation, setting, polishing, removal and any spills that may occur in dental practice [14]. Recent studies have shown that dental health workers present with low concentrations of urinary mercury in contrast to those published a decade ago [15]. A decrease in the number of dental health workers with high urinary mercury concentrations is related to an increased awareness of mercury toxicity and improved compliance with dental amalgam safety protocols [13].

University dental students use dental amalgam during their pre-clinical training in the technical laboratories using visaco teeth mounted on dummies as well as during clinical training in patients [16]. All dental schools in South Africa make extensive use of dental amalgam restoration as a prerequisite for completing their clinical quota [17]. The amount of mercury vapour expelled from dental amalgam during training may have adverse health effects for students.

In this study, the levels of mercury vapour released from dental amalgam in the atmosphere will be investigated as well as the awareness towards mercury toxicity and the adherence of dental professionals at Wits Oral Health Centre (WOHC) to safe handling procedures. There is currently no reported study in South Africa on the assessment of mercury vapour released from dental amalgam at all dental schools.

The results of the study will indicate whether there is a need to assess mercury vapour levels at the clinics in South African dental schools as well as make awareness of mercury toxicity apparent and, encourage compliance to dental amalgam safety regulations.

1.2 Dental amalgam and its composition

By composition, dental amalgam is a mixture of metals in the form of a powdered alloy comprised of silver, tin, zinc, copper and liquid elemental mercury (Hg) [15]. Approximately 50% of dental amalgam is elemental mercury by weight [11]. Anusavice et al., (2012) described the microstructure of amalgam as constituted by several different phases such as gamma (γ), gamma-1 (γ_1), gamma-2 (γ_2), epsilon (ϵ) and eta (η') phases [5]. There are two copper-based amalgam alloys where the low copper

alloy (Cu 2-6%, also known as conventional) has been widely used in the past and has been replaced by high copper alloy (Cu 6-30%) [18].

High copper alloys, as compared to low copper amalgams, have several advantageous properties. They exhibit high strength, reduced corrosion and tarnish, and minimal creep. These characteristics contribute to desirable long-term clinical benefits [18]. Additionally, high copper alloys have lower incidences of marginal failure when compared to low copper amalgams [5].

The composition of low copper amalgam typically includes mercury (50%), silver (22-32%), tin (14%), zinc (8%), and copper (12-13%) [19]. On the other hand, high copper amalgam contains a sufficient amount of silver (40%-60%), tin (27-30%), copper (13-30%), and mercury mixed with zinc (1%). Depending on the alloy composition and particle size, insignificant quantities of indium and palladium may also be included [19].

During trituration in low copper alloy, the unreacted alloy particles of silver and tin are regarded as the gamma phase [20, 21]. These particles of the gamma phase amalgamate with mercury and form a matrix consisting of gamma-1(Ag_2Hg_3) and gamma-2 phases (Sn_{7-8}Hg) [21]. The gamma-2 phase is the weakest and most likely to cause early fracture and marginal failure of the restoration; therefore, copper is added to eliminate the gamma-2 phase by substituting the tin-mercury phase with copper-tin phase (Cu_5Sn_5) in high copper alloy, providing a drastic improvement in physical properties [5, 21].

Silver enables setting expansion and causes an increase in strength and resistance to corrosion, while Tin causes setting contraction and copper improves strength, minimizes corrosion and tarnish, reduces creep and marginal leakage [5]. Zinc prevents the oxidation of other alloys in the metal by acting as a scavenger of oxygen [19]. It has been shown that zinc-containing amalgams have a longer life when compared to non-zinc amalgams [5]. Indium also reduces creep and increases strength whereas palladium reduces corrosion and tarnish [22].

1.3 Mercury release from dental amalgam restorations

The population can be exposed to mercury from diet, drinking water, air and dental amalgam restorations [1]. Mercury vapour as monoatomic gas is emitted from dental amalgam largely in the form of elemental mercury [1]. Studies suggest that mercury from dental amalgam is continuously released from the oral cavity [23]. An output of mercury vapour is intensified by the number and size of restorations, composition, chewing habits, food texture, grinding, brushing of teeth and many more physiological factors [21].

The quantities of mercury vapour released from dental amalgam restorations are small and do not result in verifiable adverse effects on individuals [24]. Okabe et al., (1994) reported that mercury blood levels captured in one study illustrated that the average level of mercury in patients that presented with amalgam restorations was 0.7ng/ml compared with a value of 0.3ng/ml for subjects without amalgam restorations [9]. Low levels of mercury released from dental amalgam in the form of vapour may be inhaled and absorbed in the lungs [15]. Reported values of mercury release from the amalgam are controversial; one worst-case predicted mercury release of 2µg/day [25], suggesting that losses are very small and that they contribute to a lower amount of the overall body burden of mercury content while another article reported a lesser amount [25]. A study by Guzzi et al., (2006) reported that the lowest dose of mercury that can cause a toxic reaction is 3-7µg/kg body weight. The same study also reported that 500µg Hg/kg of body weight causes paresthesia; an abnormal sensation typically presenting with tingling as a result of damage to peripheral nerves. On the other hand, they indicated that 1000µg Hg/kg of body weight causes ataxia which is a neurological condition characterized by lack of voluntary coordination of muscles such as gait abnormality and speech problems [26].

Many retrospective studies on the safety of amalgam have indicated that dental amalgam is a safe restorative material, but components of amalgam and other dental restorative materials may cause local side effects or allergic reactions in rare cases [27]. According to the affirmation conducted in 1995 by WHO and Federation Dentaire International (FDI), dental amalgam has not been shown to cause adverse health effects, however, it emphasized that mercury is of environmental concern within the

dental practice and waste management [28]. Dental practitioners are advised to take safety precautions when working with mercury to avoid inhalation of mercury vapour which may produce symptoms of mercury toxicity over time.

1.4 Controversies on the use of dental amalgam as a restoration material

Throughout the 150 years of dental amalgam existence, there have been debates on amalgam association with mercury poisoning [14, 21]. Even though some studies have shown a correlation between amalgam restorations and increased levels of mercury in human blood and urine, there is insufficient clinical evidence linking dental amalgam with neurological, immunological or renal dysfunction [24]. Results from different studies on the association between dental amalgam and mercury levels in humans are inconclusive and contradictory [29]. Nonetheless, the insufficiency of information does not eliminate the possible health risks which could result from mercury exposure released from dental amalgam [24].

Many European countries have reduced the use of dental amalgam to less than 5%, with restricted use on children under the age of five as well as pregnant or breastfeeding women [30]. The American Dental Association and the US Food and Drug Administration have, however, opposed and questioned the banning of mercury-containing dental materials including dental amalgam [31]. Thus, extensive research is necessary to obtain clinical evidence for the direct correlation of mercury vapour released from dental amalgam restorations to the mercury toxicity observed in both patients and dental personnel.

Despite the ongoing debates on the safety of dental amalgam, amalgam is still a popular dental material and widely used in other developed countries [32]. Dental amalgam continues to be preferred because of its advantages over other available dental material. Other dental materials may not be as durable as amalgam or they may be technique sensitive during placement [1]. Furthermore, dental amalgam is affordable because of its low cost. However, it is not tooth-coloured while alternative dental materials that are tooth coloured are relatively expensive and unaffordable to patients in low and middle-income countries [32]. The replacement of amalgam

restorations with alternative dental materials for patients presenting special cases such as hypersensitive reactions may prove necessary [33]

1.5 Sources of mercury

There has been a significant controversy perpetuated by the health impact of mercury in humans, particularly with the use of dental amalgam restorations. Mercury exists in several forms including inorganic, organic and metallic or elemental mercury [1]. The pattern with regards to ecosystem circulation, accumulation, exposure to the human body, biological effects, and toxicity depends on the characteristics of the different mercury forms [10]. Inorganic mercury is highly toxic; it can cause renal failure and loss of the gastrointestinal tract lining [34]. Methyl mercury is a form of organic mercury. Almost all of the human ingestion of methyl mercury is from contaminated fish, and wildlife [34–36]. Mercury has also been shown to have health effects on kidneys and the central nervous system [26]. The half-life of mercury in the body is estimated to be around 70-90 days [10]. The pathway of mercury exposure is determined by factors such as ingestion of food, inhalation or absorption of mercury vapour at worksites [14]. In 2012, the Korea food and drug administration reported that the major medium of mercury exposure is food, which contributed to 98.85% - 99.98%, as compared to inhalation from the air (0.47 - 0.83%) and drinking water (0.01-0.02%) [10].

1.6 Regulations on the use of dental amalgam in dentistry

In 2018, the governing council of the United Nations Environmental Programme (UNEP) developed a global legally binding agreement on mercury [37]. The agreement was called The Minamata convention. This convention was named after Minamata Bay, in Kumamoto city in Japan, where many people died due to the effects caused by mercury pollution [38]. This convention aimed to protect humans and the environment from the lethal effects of mercury and to provide regulations across a range of processes, products and industries where mercury is used or released [38]. Reports from the Minamata convention indicated that dental amalgam is a key restorative material used to fight against a global problem, dental caries. According to reports at the convention, dental amalgam is the only mercury-containing dental product that is subject to a phase-down approach, meaning that its use in dentistry should be limited

rather than phased out [38]. To phase down the use of dental amalgam in dentistry, nine measures shown in **Table 1.1** were put in place at this convention.

Table 1.1: Nine measures to Phase down the use of dental amalgam [38]

Number of Measures	Details of Measure
1	Setting national objectives aiming at dental caries prevention and health promotion, thereby minimizing the need for dental restoration.
2	Setting national objectives aiming at minimizing its use.
3	Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration.
4	Promoting research and development of quality mercury-free materials for dental restoration.
5	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.
6	Discouraging insurance policies and programs that favour dental amalgam use over mercury-free dental restoration.
7	Encouraging insurance policies and programs that favour the use of quality alternatives to dental amalgam for dental restoration.
8	Restricting the use of dental amalgam to its encapsulated form.
9	Promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

The world dental body, Fédération Dentaire Internationale played a role in establishing guidelines for dental use and promotion of extensive research into mercury amalgam exposure [39]. Because of the set guidelines and research conducted, countries such as Norway, Sweden, and Denmark have banned the use of dental amalgam [39].

According to the South African Dental Association (SADA) and WHO, low levels of mercury released from amalgam restorations are not linked to any adverse health effects. Few individuals with sensitivity to mercury have presented with localized contact reactions including amalgam tattoos, oral lichenoid reactions, erythematous

lesions of the mucosa and the tongue which are caused by abrasion to the rough surfaces of amalgam restoration [40]. The aforementioned localized health effects may be encountered when the amalgam restoration is not properly placed, finished, polished and removed [21].

Another study on the effects of dental amalgam toxicity on health and nutritional status conducted by Labban [8] reported that a certain percentage of lichenoid lesions are caused by amalgam restorations, leading to the conclusion that constant exposure to mercury in amalgam predisposes patients to oral lichenoid lesions [8, 41]. Hence, corrosive amalgam restoration or the presence of biofilm on the amalgam restoration may contribute to the development of hypersensitivity reactions in patients rather than the material itself. Dunsche [42] reported that 97.1% of patients presenting with hypersensitivity reactions benefited from the removal of amalgam restorations [42]. Nevertheless, in the dental amalgam position statement advocated by SADA in conjunction with the food and drug administration (FDA), dental amalgam is considered safe for adults and children over the age of six years [43].

Adherence to the UN treaty on environmental mercury protection at the Minamata Convention (2013) was fostered by the establishment of a two-phase protocol which promotes the significance of public awareness of oral health care and ensuring that dental workers limit mercury exposure to themselves and patients [38]. SADA agrees with the recommendation for a phased reduction in the use of dental amalgam as a restorative material [40]. Moreover, it also encourages the need for further research on alternative restorative materials that present with a lower risk of chemical exposure.

1.7 Alternative restorative materials to dental amalgam

In recent years, dental materials such as composites, glass ionomer cement and a variety of hybrid structures have been in use due to increased demand for aesthetic restorations [21]. Composite restorations have been shown to serve better than amalgam when conservative cavity preparations are recommended like small occlusal restorations, to which amalgam would require removal of a more sound tooth structure [44]. Research conducted by anti-amalgamists has suggested that no studies have proved that amalgam is a safe restorative material with any kind of finality; therefore,

the same speculations can also be alleged against composites and other dental materials [45]. Composites have shown to be cytotoxically eliciting a chronic inflammatory response to the dental pulp [21]. Despite the characterization of composites as 'non-toxic' restorative materials, composites have been suggested to be more toxic than amalgams [45]. The peroxides used to generate free radicals in the polymerization of dental composites are known as skin tumour promoters that encourage the development of skin cancer [21].

Glass ionomer cements are also cytotoxic materials and they inhibit Ribonucleic acid (RNA) synthesis. Studies have shown that glass ionomers cements are also not safe restorative materials since they are found to contain aluminium that causes Alzheimer's disease [25]. Soncini [46] reported that amalgam restorations possess greater longevity than composites, and their tolerance to moisture is better in contrast with composite resins that are more technique sensitive and require a greater number of steps during placement [46]. Recurrent marginal decay is a clinical indication for replacement of both composites and amalgam restoration, where studies have shown that compomers and composites were seven times likely to require replacement than amalgam [46].

1.8 Mercury exposure and health concerns of dental health care workers

Dental health care professionals are at risk of exposure to inorganic mercury through the handling of dental amalgam [15]. Various studies reported that dental workers on the average present with a higher systemic level of mercury in their tissues and organs [1]. In many countries such as Canada, dental students in university remove dental amalgams with drills during their academic training [16]. These procedures are first performed on plastic teeth in the laboratory setting without any strict protective measures implemented to limit mercury exposure such as the use of high volume suction or water sprays during drilling [16]. The significance of using water sprays and suction is usually emphasized in the clinical settings to avoid damage to the dental pulp and the nerves from heat generated by high-speed drilling [43]. The two most common dental procedures in which dental amalgam restoration may be removed without concern to preserve the dental pulp are the root canal treatment and dental extractions [16].

Most governments liable for workers' safety have established the recommended thresholds of mercury exposure, although this does not indicate that being exposed to low thresholds guarantees the workers safety [32]. According to the WHO, "mercury does not have a low threshold below which adverse effects do not occur" [47]. In contrast, the Canadian regulatory bodies responsible for worker's safety protocols have established safety levels that might not be suitable for the dental profession [48]. The threshold was set based on the data involving male Chloralkaline workers [16], and the method used is very different from the incidents surrounding mercury exposure in dental working environments. The presence of chlorine in Chloralkali working environments protects workers against mercury exposure. However, it was noted that females and other population groups appeared to be intolerant to mercury exposure, and this aspect makes it challenging to set up a standardized threshold that ensures workers' safety [16]. The Canada labour code and all provincial codes adopted the occupational exposure limits of mercury exposure defined as a threshold limit value (TLV) from the American conference of governmental industrial hygienists (ACGIH) [7]. The limit is prescribed at an average TLV of 25.0mg/m³ over 8 hours [16]. The ACGIH, Alberta Occupational Health and Safety and other provinces also set up a maximum ceiling limit of 5 times the TLV (125mg/m³) which should not be exceeded [16].

The National Health and Medical Research Council of Australia advocates for reduced use of dental amalgam in special populations including pregnant women, children and in individuals with chronic kidney diseases. Requirements established included that only capsulated dental amalgam complying with ISO24234:2015 should be used in dental clinics and that dental clinics should practice mercury hygiene and dispose of dental amalgam waste correctly [7]. Finally, the American Dental Association(ADA) concluded that based on available scientific information, amalgam continues to be a safe and effective restorative material; there is no justification for dental amalgam use to be discontinued [49].

1.9 The rationale for the study

Dental amalgam restoration remains a cause for toxicity concerns due to a mercury content of 50% by weight. The need for research on improved alternative restorative materials with less or no toxicity is necessary. Dental schools ought to ensure that all

precautionary measures regarding the safe use and limiting mercury exposure from the dental amalgam are emphasized in both non-clinical and clinical settings. Dental health care professionals handling amalgam should undergo routine evaluations of mercury exposure levels to prevent future adverse health effects such as kidney dysfunction or Alzheimer's disease. Protocols regarding patients indicated and contraindicated for placement of amalgam restorations ought to be set up by all oral health care organizations and enforced on dental health professionals.

This study seeks to evaluate the levels of mercury vapour released at the WOHC and to ensure that precautionary measures regarding the safe use and disposal of dental amalgam are in place. Results from this study will encourage routine monitoring of mercury vapour levels in dental clinics and evaluation of body mercury levels on dental health care workers if possible. According to the United States Occupational Safety and Health Administration (OSHA), the maximum amount of mercury vapour allowed in the workplace also referred to as the Threshold Limit Value (TLV), is set as 0.05 mg/m³ [46].

The most important factors which affect the body mercury levels in dentists include mechanical ventilation, the method of amalgam mixing, the type of amalgam used, number of amalgam restorations done per day, working hours per week, work experience, and the dental professional's age [16]. Since dental practitioners perform dental procedures involving the use of amalgam daily, it is imperative that the possible quantities of mercury emitted during their workday(s) be measured or estimated. Following this, proper measures ought to be put in place to foster regulation of the emitted mercury vapour in dental clinics for safety precautions. There is no documented study on the measurement of mercury vapour levels at the WOHC.

1.10 Aim

The purpose of the study is to evaluate the levels of mercury vapour released into the atmosphere during the use and disposal of dental amalgam and the adherence of staff to mercury hygiene protocols at WOHC.

1.11 Objectives

The objectives of the study were:

1. To evaluate and compare the level of atmospheric elemental mercury vapour in three dental clinics and the technique's laboratory at WOHC.
2. To investigate the association between the atmospheric levels of mercury and the number of amalgam capsules used daily in dental clinics.
3. To assess the clinical staff knowledge and adherence to mercury hygiene principles through the use of a questionnaire.
4. To analyse the responses obtained from the questionnaire.

2. MATERIALS AND METHODS

2.1 Study location

The research was conducted at the Wits Oral Health Centre (WOHC), which falls under the School of Oral Health Sciences at the University of the Witwatersrand. This exceptional institution is a dental academic institution that offers a wide range of dental services such as prosthodontics, restorative, periodontology and oral medicine, oral and maxillofacial surgery, amongst others. Additionally, this institution undertakes teaching and training of both undergraduate and postgraduate registered students. Training is done through the use of four polyclinics: Polyclinic (PC) 1 (PC1), 2 (PC2), 3 (PC3) and 4 (PC4), as well as through two multi-skilled techniques laboratories (Paediatrics and Restorative dentistry, and the Prosthodontics laboratory). During the data collection period, the polyclinics and laboratories that were used included PC2, PC3, the Department of Paediatrics and Restorative Dentistry laboratory unit, and the Prosthodontics laboratory. Locations within the polyclinics were selected based on approved areas for aerosol generated dental procedures at WOHC as a result of Covid-19 regulations. The Prosthodontics laboratory was used for non-aerosol generated dental procedures unrelated to restorative dentistry and therefore used for control purposes in the study. Three working stations with slides were set up within the selected areas, for data collection to improve the likelihood of detecting different mercury vapour concentrations.

2.2 Study design

The study design included an experimental laboratory section as well as an online survey section in the form of a questionnaire.

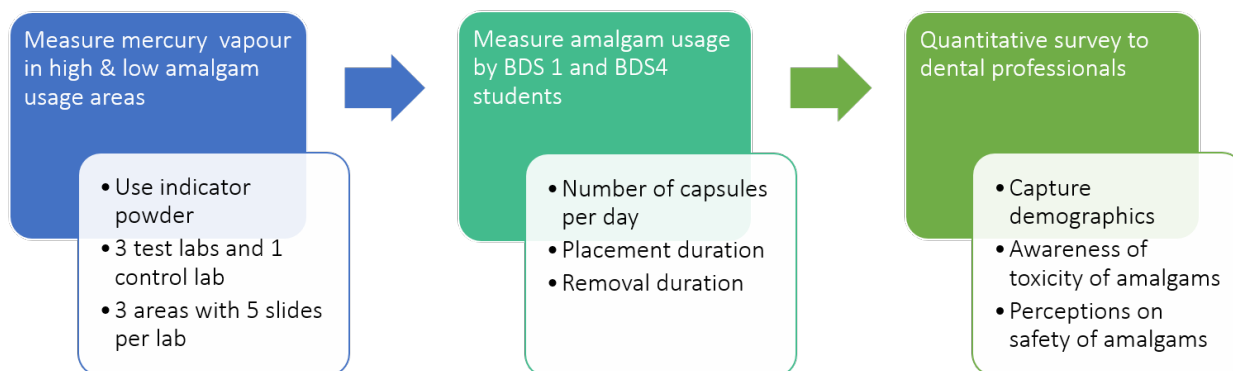


Figure 2.1: An overview of the study design showing the measurement of mercury vapour levels, amalgam usage as well as a survey.

2.3 Experimental methodology

2.4 Laboratory methods

2.4.1. Measurements of the level of atmospheric elemental mercury vapour

Elemental mercury vapour levels were measured in the aerosol generated areas at PC2, PC3, Paediatrics and Restorative dentistry laboratory and the non-aerosol generated prosthodontics control laboratory. The levels of mercury vapour were monitored by using a revised method described by Hawks et al. [50]. A mercury indicator powder was used for the determination of the concentrations of mercury vapour levels released from dental amalgam in closed cabinets. However, in our study, mercury vapour was determined in ambient air. The powder was constituted of a mixture of cuprous iodide, sulfur, amorphous silica, and starch in proprietary proportions. The indicator powder was produced to highlight areas of surface contamination, as a result, colour changes are not precise, thus, the powder is now sold as a cheap and quick method to confirm mercury contamination. The instruction sheet states that the indicator powder colour changes from light yellow to dark orange in the presence of mercury vapour (Table 2.1) and it also darkens to a dark grey or black colour on exposure to the surface over a predetermined time. For the preparation of slides, the powder was mixed with distilled water and applied to the labelled glass

microscope slides as a strategy to hold the paste into place and to create a mixture that would fit along the marked demarcations on each slide. Microscope slides were carefully cleaned with distilled water and then with 95-99% of ethanol then wiped dry with clean cotton wipes. Labelling of slides was done with the use of a pencil at the top of each slide for tracking purposes.

The adopted study indicated that the powder rapidly changes colour on exposure to mercury vapour. Therefore, a thin slurry of the paste was used instead of a thick consistency, this was the strategic plan to detect the colour changes on a thin scale than on a thick dispersion. However, the slides did not change colour at the same rate. For preparation of slides, 2.5 g of the powder was mixed with 5.5 ml of the distilled water with the use of a clean nylon bristle brush. The mixture was used to produce a thin slurry consistency. Subsequently, the slurry was evenly applied in a circular motion onto the circles (i.e. 20. mm diameter and 1.8 mm thickness) that were drawn on the slides. The slides were left open for 4-6 minutes to dry the slurry paste sufficiently for them to be moved without loss of the dispensed paste. Five slides were placed in three different stations in all four areas to obtain the concentrations of mercury vapour at different stations. Two experiment slides were left open to encourage mercury exposure from the atmosphere while three control slides were sealed in a petri dish with the use of the parafilm. The first control slide was a negative control that comprised of the paste only, while the second control slide was the first positive control that consisted of the paste and the triturated amalgam restoration, the third control slide was the second positive control made up of the paste and the mercury content that was expelled from the amalgam capsule.

The total number of microscopy slides that were used for the study were 180 in counting. Colour changes in the positive experiment slides were assessed every 24-h interval. However, Mercury vapour levels were evaluated three times a day, in the morning, during the day and in the afternoon for seven consecutive days for any possible colour change during the 24-h interval. Evaluations of colour changes were monitored three times a day to rule out any possibility of the mercury vapour attaching and detaching from the sulfur indicator powder and the evaluations were recorded daily. The data collection was carried out for seven consecutive days for three weeks to increase the likelihood of obtaining accurate results. Differences between the

measurements were determined using the Generalized Estimating Equations (GEE) test. The GEE test can be used for multinomial outcomes measured at two or more time points. The colour change in the experimental indicator was compared to the unexposed negative control slides using the Fisher's exact/Chi-square test. Moreover, the mercury levels in the control lab were compared to each of the aerosol lab using Fisher's exact/Chi-square test. The mercury vapour levels were to be determined as indicated in the (Table 2.1.1) below according to the manufacturer's instructions [48]

Table 2.1: Estimation of the levels of mercury vapour based on the colour change of the indicator

Color	Mercury range
Yellow	<1 µg/m ³
Light orange	1-30µg/m ³
Orange with grey	30-300µg/m ³
Dark grey	>300µg/m ³

A pilot study was conducted before the data collection process to determine the reliability and validity of the study.

2.4.2. Investigating the association between atmospheric levels of mercury vapour and the number of amalgam capsules used daily in dental clinics

The placement of amalgam restorations involved several key steps: first, the removal of carious lesions; then, the application of a matrix band to support the restoration walls and a rubber dam to prevent aspiration or swallowing of excess amalgam. After condensing the restoration, patients were instructed to return for a follow-up appointment after 24 hours for polishing and finishing, during which dental suction was used. Any defective restorations were removed using high-volume suction, and the areas where amalgam was placed were kept carpet-free to facilitate easy cleaning of dental remnants.

The number of dental amalgam capsules used was ascertained by monitoring the restorative procedures performed in PC2, PC3 and Paediatrics and Restorative dentistry laboratory during the data collection period. The daily number of dental amalgam capsules used per procedure was recorded. All dental practitioners handling dental

amalgam were provided with an amalgam recording sheet to note the number of amalgam capsules that they each used and the duration of time of amalgam restoration placement and removal. Also, empty amalgam waste containers were placed at each rosette every morning and collected for counting at the end of each day. This strategy was adopted to compare the information obtained from the recording sheets with the total number of capsules collected per day. This process was followed for seven consecutive days for three weeks. The normal distribution of the measurements was determined using the Shapiro Wilk test ($p > 0.05$). The measurements were reported as either mean \pm SD or median (IQR).

2.4.3 Questionnaire data collection

2.4.3.1. Research approach

A descriptive, quantitative survey was used to analyse the perception of dental professionals towards mercury toxicity at WOHC. The cross-sectional study was conducted between September 2020 and October 2020.

2.4.3.2. Research methods

The data collection process involved the use of a structured questionnaire that was adapted from a previous study conducted by Udoye and Aguwa [58]. The questionnaire was designed in English using Google Forms software and distributed online through WhatsApp groups and emails. The questionnaire was divided into three sections, with the first section focusing on obtaining informed consent from dental professionals who participated in the study. This approach ensured that the participants were aware of the purpose and nature of the study before providing their responses. The second section captured demographical information and factors contributing to awareness of dental professionals towards mercury toxicity in dental amalgam, while the third section included 21 questions to collect data on the perception of dental professionals towards mercury toxicity relating to the release of mercury vapour from dental amalgam.

2.4.3.3 Sampling and data collection

A total number of 117 dental professionals at WOHC were recruited to participate in the study. The questionnaire was circulated to dental professionals including: dental students, dentists and dental assistants. However, other dental professionals such as dental technicians involved in prosthodontic related procedures were excluded from participation on the survey. All the participants included in the study were between the ages 18 to 65 years. The criteria for inclusion and exclusion of participants were based on dental professionals that handle dental amalgam restorations and those that do not carry out any restorative dentistry related procedures. The purpose of the questionnaire was to assess the dental professional's knowledge and adherence to mercury hygiene principles. Convenience sampling was used to sample participants for data collection.

2.4.3.4 Data Presentation and analysis

The questionnaire responses thus received were compiled and tabulated in Microsoft Excel software followed by statistical analysis using SPSS software. Categorical variables were compared using the Chi-square test. The alpha level was adjusted using the Bonferroni correction, based on the number of Chi-square tests performed. The chi-square test is a statistical test commonly employed to compare observed data with expected data. In this case, the test was utilized to determine the relationship between two categorical variables derived from both the experimental and questionnaire studies. By analyzing the data using the chi-square test, the aim was to assess whether there was a significant association or connection between the variables under investigation. This statistical analysis provides insights into the relationship between the variables and contributes to the overall findings of the study. The formula for the chi-square is as follows:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where:

c = Degrees of freedom

O = Observed Value

E = Expected Value

2.5 Limitations and feasibility, reliability, validity and dependability.

Table 2.2: Limitations and feasibility, Reliability, validity and Dependability

	Experimental data	Questionnaire Data
Limitations and feasibility	<p>The experimental data collection was easy to conduct. This study required the use of the mercury indicator powder to set up slides at the dental clinic followed by monitoring of slides for color change on a daily basis over a period of seven consecutive days for three weeks.</p> <p>The mercury indicator powder was cheap. However, delivery of the material took longer than expected because it was purchased internationally.</p> <p>In addition, the exact concentration of mercury vapour could not be detected in the atmosphere because the mercury indicator powder was not sensitive enough to indicate with accuracy the mercury concentration present in the atmosphere.</p>	<p>The use of an online survey saved time and required minimal effort to access participants.</p> <p>Accessibility from any device was an advantage as all participants could access the questionnaire with ease and flexibility, to fill the survey forms.</p> <p>The web-based survey was easy to set up using google forms format, making it easy to factor in a combination of long, short, complex and easy questions.</p>

<p>Reliability, validity and dependability</p>	<p>Repetition was used to test the reliability of the study. The experimental slides were set up in triplicates to create more chances to compare the color change of the experimental and control slides. The slides were set up in areas with and without mercury exposure to confirm reliability of the mercury indicating powder.</p> <p>Construct validity was used to assess how well the results of the study correspond to the theoretical claims of other studies. The quantities of mercury vapour in the atmosphere could not be picked up by the indicator powder because the adopted study was designed to measure mercury levels in closed cabinets and not in ambient air.</p> <p>Due to lack of an electronic device, it was not possible to get an accurate measurement of mercury vapour levels in the selected locations.</p>	<p>Data collection and in- depth analysis was easy as it was convenient to view the results and get access to valuable insights such as how many participants responded to the survey, the total number of responses received daily, weekly and monthly.</p> <p>Reliability is the consistency, stability and precision of the survey. Internal consistency reliability was used to assess the participants personal views on the use of dental amalgam in terms of their beliefs, behavior and emotional state.</p> <p>The accuracy and relevance of the measurements were tested when conducting the online survey. Content validity was used to evaluate the extent in which the questions covered the main topic of the study which is mercury toxicity concern. Dental participants' response rate indicated that participants were aware of all the important aspects to be considered when using dental amalgam.</p>
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2.6 Ethics

Prior to the commencement of the study, the necessary ethical clearance was obtained from the University of the Witwatersrand Human Research Ethics Committee (HREC, Ethics No: M190261) and the CEO of WOHC. The ethics clearance certificate for the current study is illustrated in Appendix 7.1. To ensure participant confidentiality, the personal details of the participants were anonymized, and their responses were treated as confidential. Participants were provided with an information document containing instructions and an informed consent form before completing the questionnaire. These measures were taken to uphold ethical standards and protect the privacy of the participants involved in the study.

2.7 Budget

The total cost of the study was R4290.83, as shown in Table 2.3.

Table 2.3: The estimated budget for the study

Materials	Amount
Mercury Indicator Powder, Vapour Indicator	R 3400.00
100 glass microscope slides (1 PACK)	R22.00
Plastic petri dishes	R72.00
Cotton wipes	R22.00
Nylon bristle brush	R40.00
Tweezer	R228.10
Mixing Spatula	R271.73
Ethanol	R235.00
Total cost of materials	R4290.83

2.8 Funding

An amount of R6000.00 was awarded by the University of the Witwatersrand Faculty of Health Sciences Research Committee (FRC) individual Grant in 2019. The funds contributed towards the purchase of all the materials utilised in the experimental setup of the study.

3. RESULTS

3.1. Laboratory evaluation of mercury vapour levels

In an experimental setup, atmospheric mercury vapour concentrations emanating from dental amalgam capsules used for restorations at PC3 and the Restorative and Paediatrics dentistry laboratory were evaluated using a sulphur indicator powder for a period of three consecutive weeks. The experimental tests indicated no colour change throughout the three weeks, since the sulphur remained in its original yellow shade (Table 3.1). The positive controls, which were analysed in covered petri dishes, indicated colour changes (Figure 3.1). One of the controls indicated the presence of mercurous sulfide (Hg_2S , a black compound, Figure 3.1).

Table 3.1: Determination of Mercury vapour based on sulphur colour change on the experimental slides.

Week 1-Week 3	PC 2	PC 3	Lab 1	Lab 2
Day 1	Yellow	Yellow	Yellow	Yellow
Day 2	Yellow	Yellow	Yellow	Yellow
Day 3	Yellow	Yellow	Yellow	Yellow
Day 4	Yellow	Yellow	Yellow	Yellow
Day 5	Yellow	Yellow	Yellow	Yellow
Day 6	Yellow	Yellow	Yellow	Yellow
Day 7	Yellow	Yellow	Yellow	Yellow

*Yellow ($<1 \mu\text{g}/\text{m}^3$), Light orange ($1-30 \mu\text{g}/\text{m}^3$), Orange with grey ($30-300 \mu\text{g}/\text{m}^3$), Dark grey ($>300 \mu\text{g}/\text{m}^3$)

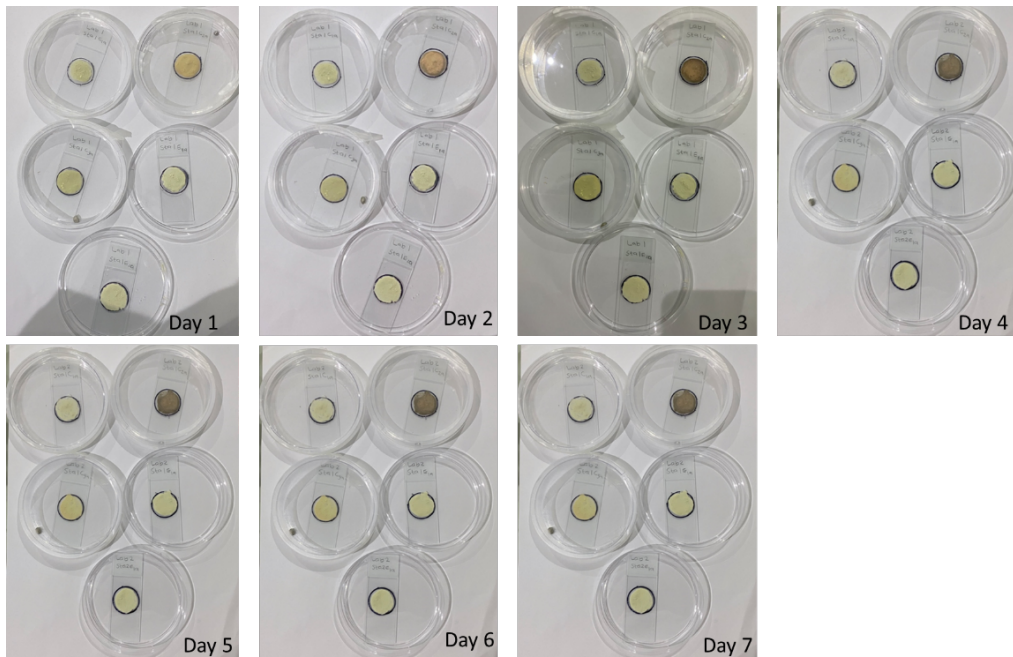


Figure 3.1: Daily pictures taken for mercury vapour detection using the sulphur indicator powder for experimental and control microscope slides over a 7 day period.

3.2. Amalgam capsules used per restoration

The study focused on assessing the average number of amalgam capsules used during restoration placement by BDS1 and BDS4 students. It is important to note that the study was conducted during the Covid-19 era, and these students were included because they were present in the dental clinic to complete their required clinical quota while other students were attending the classes virtually.

During clinical operations at the restorative laboratory, BDS1 students used approximately 3 amalgam capsules per restoration, with an average of less than 2 overall amalgam restorations placed per day. The estimated time for placement of each restoration was 14 minutes. On the other hand, BDS4 dental students used an average of 1.5 capsules per restoration, with an estimated time of 2.5 minutes for restoration placement. These findings provide insights into the usage patterns and time requirements for amalgam restorations among the respective student groups.

Table 3.2: A summary of the number of amalgam capsules used by students per restoration

Student group	Number of Amalgam Capsules Used Median (IQR)	Number of Amalgam restorations Placed Median (IQR)	Estimated time of placement/Min/hr Median (IQR)
BDS 1 (n=47)	2 (2)	1 (1)	3 (8)
BDS 4 (n=2)	1,5 (1)	1 (0)	2.5 (1)

3.3 Results on the questionnaire

3.3.1. Demographics of the study participants

The study invited 117 participants from Wits Oral Health Centre (WOHC) to complete the questionnaire. However, only 115 (98%) of the 117 participants completed the questionnaire in its entirety. Among the 115 participants, 26% (n=30) were males, while 74% (n=85) were females (Table 3.3). The participant's field of practice included undergraduate and postgraduate dental students (57%, n=65), dental assistants (9%, n=10) and dentists (35%, n=40) rendering services at WOHC. The participants indicated that undergraduate education was a major (85%, n=98) contributor to their awareness of mercury toxicity in dental amalgam restorations, while continuing dental education contributed to about (12%, n=13), followed by (3%, n=4) that indicated that disseminated protocols from departments further enhanced their level of awareness (Figure 3.2).

Table 3.3: A summary of the recorded demographics of the study participants

Demographics (N=115)		
Gender	n	%
Male	30	26.1
Female	85	73.9
Field of practice		
Dentist	40	34.8
Dental assistant	10	8.7
Dental student	65	57.0

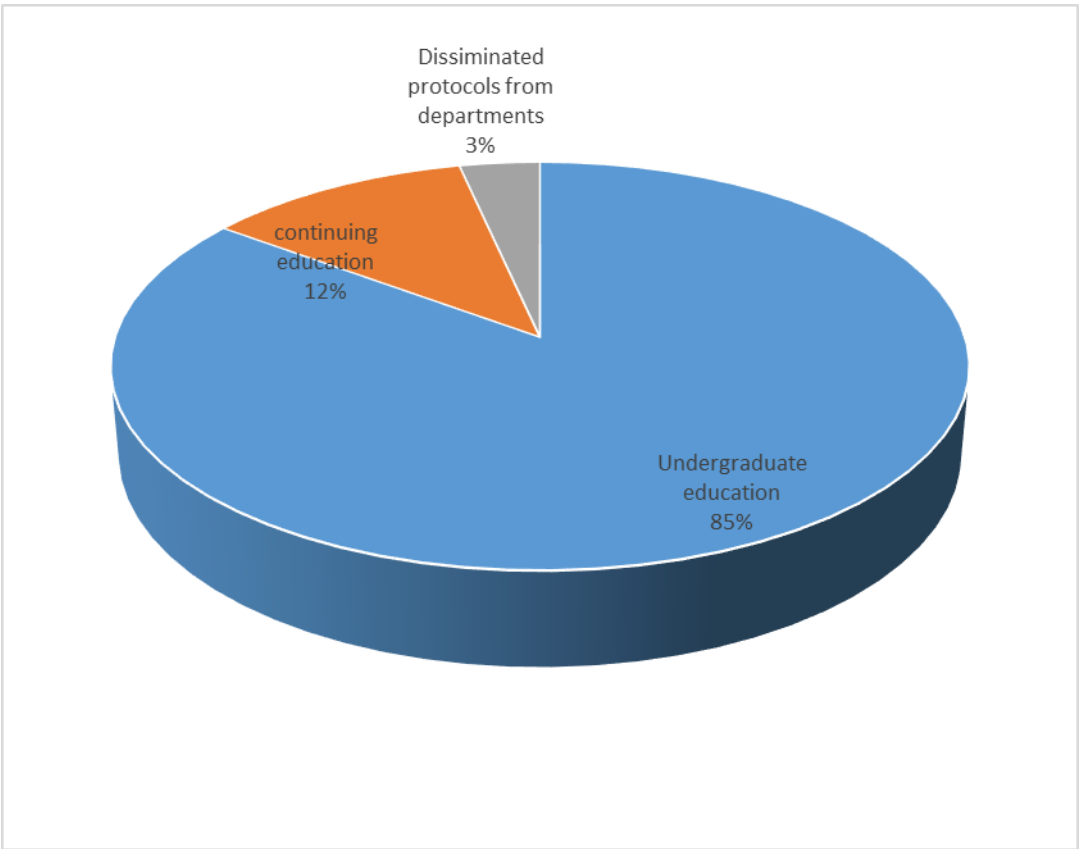


Figure 3.2: A breakdown of factors that contributed towards awareness of mercury toxicity in dental amalgam restorations by health professionals at WOHC.

Table 3.4: A summary of the responses given by dental professionals regarding mercury toxicity in amalgam restorations

Awareness	No, n (%)	Yes, n (%)	Uncertain (%)	
Q1; Are you aware of mercury toxicity issues associated with dental amalgam use?	2(1.7)	97(84.3)	16(13.9)	
Q2; Are guidelines regarding the safe use and disposal of dental amalgam necessary?	2(1.7)	111(96.5)	2(1.7)	
Q3; Do you follow guidelines regarding the safe use and disposal of dental amalgam?	16(13.9)	79(68.7)	19(16.5)	
Q4; Should stricter guidelines regarding the safe use and disposal of dental amalgam be implemented?	9(7.8)	83(72.2)	23(20.0)	
Q5; Should less strict guidelines regarding the safe use and disposal of dental amalgam be implemented?	95(82.6)	6(5.2)	14(12.2)	
Q6; Is the placement of dental amalgam restoration safe for the operator?	15(13.0)	77(67.0)	23(20.0)	
Q7; Is the placement of dental amalgam restoration safe for patients?	20(17.4)	70(60.9)	25(21.7)	
Q8; Is the mercury vapor released from dental amalgam absorbed into the body tissues?	17(14.8)	56(48.7)	41(35.7)	
Q9; Does long-term exposure to mercury from dental amalgam pose any adverse health effects such as Alzheimer's disease?	18(15.7)	30(26.1)	67(58.3)	
Q10; Does direct oral contact with dental amalgam causes allergic reactions to patients?	28(24.3)	65(56.5)	22(19.1)	
Q11; Should the use of dental amalgam restoration be banned?	74(64.3)	21(18.3)	20(17.4)	
Q12; Is there sufficient scientific evidence to suggest that dental amalgam should be banned?	64(55.7)	11(9.6)	40(34.8)	

Q13; Should the use of dental amalgam restorations to children under the age of 6 years as well as pregnant women be restricted?	14(12.2)	83(72.2)	18(15.7)	
Q14; Is there a need for extensive research on alternative materials that present low risk of chemical exposure?	10(8.7)	102(88.7)	3(2.6)	
Q15; Are you aware of alternative restorations? e.g., Resin composites, glass ionomer		115(100.0)		
Q16; Should dental amalgam restorations be removed, based on patients request?	26(22.6)	79(68.7)	10(8.7)	
Q17; Do you advocate for the removal of dental amalgam restorations from patients and their replacement with alternative restorations?	45(39.1)	59(51.3)	11(9.6)	
Q18; Are you concerned about the environmental issues brought about by dental amalgam use in the dental clinic?	27(23.5)	79(68.7)	9(7.8)	
Q19; Should mercury vapor exposure levels in the dental clinic be monitored?	9(7.8)	97(84.3)	9(7.8)	
Q21; Should mercury blood levels of dental professionals be monitored?	14(12.2)	88(76.5)	13(11.3)	
	Quarterly,n(%)	Semesterly,n(%)	Yearly,n(%)	Uncertain,n(%)
Q22; How often should the monitoring of mercury vapor levels in the dental clinic be done	71(61.7)	15(13.0)	12(10.4)	17(14.8)
Q23; How often should mercury blood levels of dental professionals be monitored	36(31.3)	23(20.0)	35(30.4)	21(18.3)

3.3.2 Questionnaire tool

3.3.2.1. Awareness of mercury toxicity in amalgam restorations

The majority of the participants (84%) were aware of the mercury toxicity issues associated with amalgam use (Table 3.4). Most participants (96%) were in agreement that guidelines for using and disposing of amalgam were necessary and that they followed them (68%) (Table 3.4). However, more than 70% of the dental professionals (inclusive of dentists, dental assistants and students) suggested that stricter measures regarding safe use and disposal of dental amalgam should be implemented, to prevent exposure of dental professionals and patients to mercury vapor released from dental amalgam at the WOHC. The correspondents who were in support of stricter guidelines included dental students (44%), dentists (31%) and dental assistants (8%), and the difference was statistically significant ($p=0.045$). However, just 6% of dentists and 3% of dental students believed that tight regulations should not be put into place, while 18% of dental students, 2% of dental assistants, and 3% of dentists expressed uncertainty (Table 3.5).

3.3.2.2. Perceptions on the safety of amalgam restorations

The majority of participants as shown in Table 3.4 suggested that the placement of dental amalgam restoration was safe both for the operator (67%) as well as the patient (61%). However, almost half of the participants felt that mercury vapour is absorbed into the body tissues (49%), while the rest were either unsure (36%) or felt that it was not absorbed by the body (15%). They were also unsure (58%) of the effects that long term exposure to mercury vapour had on the development of adverse health conditions such as Alzheimer's disease. More than half (57%) of the participants were aware that exposure to direct amalgam can cause allergic reactions to patients, while 19% were unsure.

3.3.2.3. Opinion on the banning of amalgam and existence of alternative materials

According to Table 3.4 of the study, more than sixty-two percent (62%) of the participants did not support the idea of banning dental amalgam restorations, 55%

believed that there was sufficient scientific evidence to support the continued use of dental amalgam, while 35% were unsure and the remaining participants had no opinion on the matter. However, a significant majority (72%) believed that the use of dental amalgam should be restricted and not used in children under the age of 6 years and pregnant women. All participants in the study were aware of alternative materials that could be used for dental restorations. Furthermore, the majority of dental professionals (88%) expressed the need for extensive research on alternative materials that pose a lower risk of chemical exposure. This suggests a recognition among dental professionals of the importance of exploring and developing alternative materials for dental restorations.

3.3.2.4. Removal of amalgam restorations based on patient's safety concerns

The majority (69 %) of participants were of the view that dental amalgam restorations should be removed, based on the patient's request. The perception scores between the dental professional groups were significantly different ($\chi^2= 15.89$, $p=0.003$; Table 3.5). Those who were in support included dental students (50%), dentists (21%) and dental assistants (8%). A lower percentage of dental students (7%), dental assistants (2%) and dentists (17%) were of the view that the restorations should be left intact. In addition, 8% of the dental students were uncertain on whether the dental amalgam restorations should be removed as compared to dental assistants (0%) and dentists (2%). Furthermore, more than half of the participants (51%) advocated for the removal of dental amalgam restorations from patients and their replacement with alternative restorations. They were also concerned about environmental issues brought about by dental amalgam use in the dental clinic (69%). The majority felt that mercury vapour levels should be routinely monitored at the dental clinic (84%) and in the blood of dental professionals (76%).

Table 3.5: Determining statistical differences in the responses given by dental professionals using a chi-square test.

Awareness	Student	Dental Assistant	Dentist	X²	p-value [§]
Are you aware of mercury toxicity issues associated with dental amalgam use	1:55:9	1:8:1	0:34:6	4.8	0.308
Are guidelines regarding the safe use and disposal of dental amalgam necessary	1:62:2	0:10:0	1:39:0	1.89	0.75
Do you follow guidelines regarding the safe use and disposal of dental amalgam	7:47:11	1:9:0	1:39:0	6.98	0.323
Should stricter guidelines regarding the safe use and disposal of dental amalgam be implemented	3:44:18	0:8:2	6:31:3	9.74	0.045
Should less strict guidelines regarding the safe use and disposal of dental amalgam be implemented	55:1:9	7:2:1	33:2:4	6.84	0.144
Is the placement of dental amalgam restoration safe for the operator	8:41:16	3:7:0	4:29:7	5.67	0.225
Is the placement of dental amalgam restoration safe for patients	9:40:16	4:6:1	8:24:8	2.49	0.647
Is the mercury vapor released from dental amalgam absorbed into the body tissues	11:27:26	3:4:3	3:25:12	7.17	0.305
Does long term exposure to mercury from dental amalgam pose any adverse health effects such as Alzheimer's disease?	9:13:43	4:3:3	5:14:21	867	0.075
Does direct oral contact with dental amalgam causes allergic reactions to patients	15:37:13	3:5:2	10:23:7	0.35	0.986
Should the use of dental amalgam restoration be banned	45:11:9	4:3:3	25:7:8	3.555	0.47
Is there sufficient scientific evidence to suggest that dental amalgam should be banned	32:4:29	8:1:1	24:6:10	8.384	0.078
Should the use of dental amalgam restorations to children under the age of 6 years as well as pregnant women be restricted	6:49:10	3:7:0	5:27:8	5.348	0.253
Is there a need for extensive research on alternative materials that present low risk of chemical exposure	8:55:2	0:10:0	2:37:1	3.122	0.538
Are you aware of alternative restorations? e.g., Resin composites, glass ionomer	0:65:0	0:10:0	0:40:0	-	-
Should dental amalgam restorations be removed, based on patients request	7:50:8	2:8:0	17:21:2	15.89	0.003

Do you advocate for the removal of dental amalgam restorations from patients and their replacement with alternative restorations	25:32:8	2:8:0	18:19:0	4.71	0.318
Are you concerned about the environmental issues brought about by dental amalgam use in the dental clinic	21:39:5	0:10:0	6:30:4	9.13	0.058
Should mercury vapor exposure levels in the dental clinic be monitored	4:57:4	0:9:1	5:31:4	3.012	0.556
Should mercury blood levels of dental professionals be monitored	7:53:5	0:10:0	7:25:8	8.77	0.067
How often should the monitoring of mercury vapor levels in the dental clinic be done	45; 6:7:7	7:1:1: 1:1	19:5:9:7	5.68	0.46
How often should mercury blood levels of dental professionals be monitored	26:13:12:14	5:3:0:2	5:19:9:7	15.78	0.015

*Ratio of Yes: No: Uncertain (n), §Adjusted p-value based on Bonferroni correction is 0.0023

3.3.2.5. Effect of field of practice on the awareness of monitoring frequency

Participants were assessed on their perception of mercury vapour monitoring at WOHC. Almost half (45%) of the dental student participants indicated that monitoring of mercury vapour levels should be quarterly, compared to 7% and 19% of dental assistants and dentists, respectively (p=0.46) who opined that monitoring should be undertaken semesterly or yearly respectively. The participants were also assessed on their awareness of the frequency of blood toxicity monitoring. About 26% of dental students, 5% of dental assistants and 5% of dentists suggested that the mercury blood levels of dental professionals exposed to mercury vapor released from dental amalgam should be monitored quarterly (p=0.015) (Table 3.6). On the other hand, 13% of dental students, 3% of dental assistants and a greater percentage of dentists (19%) proposed that mercury blood levels should be monitored yearly. In the same vein, about 14% of dental students, and 9% of dentists suggested that the mercury blood levels should be assessed semesterly. However, 12% of dental students, and 7% of dentists were uncertain on whether it is necessary to monitor mercury blood levels of dental professionals handling dental amalgam.

Table 3.6: Association between field of practice and awareness of monitoring frequency

Awareness	Student (%)	Dental assistant (%)	Dentist (%)	χ ²	p-value [§]
How often should the monitoring of mercury vapor levels in the dental clinic be done				5.68	0.46
Quarterly	45	7	19		
yearly	6	1	5		
Uncertain	7	1	9		
semesterly	7	1	7		
How often should mercury blood levels of dental professionals be monitored				15.78	0.015*
Quarterly	26	5	5		
yearly	13	3	19		
Uncertain	12	0	9		
Semester	14	2	7		

[§] Adjusted alpha level based on Bonferroni correction, 0.025

4. DISCUSSION

4.1 Laboratory evaluation of mercury vapour levels

The study sought to assess the presence of mercury vapour released at WOHC dental laboratory and clinics where dental amalgam restorations were undertaken. The level of mercury vapour was evaluated using an indicator powder in triplicate for a period of three consecutive weeks, rather than doing the study for one week, to maximize the chances of obtaining consistent and reliable data. No color changes were observed on the experimental test slides which were placed in open petri dishes (Table 3.1, Figure 3.1). This indicated that there was a low concentration of mercury, at levels less than 1 ug/m^3 in the atmosphere. Consequently, the indicator powder could not detect atmospheric mercury as it was below the detection limit [50].

The microgram levels released in dental amalgams were also observed by a study carried out by Berglund and coworkers [51] who measured the intraoral vapour levels in patients from at least nine amalgam restorations. These authors showed that the average daily dose of inhaled mercury vapour was $1.7 \text{ }\mu\text{g}$ (ranging from 0.4 to $4.4 \text{ }\mu\text{g}$), and below the WHO threshold limit of $300 \text{ }\mu\text{g/day}$. In addition, a study by Sahani et al., (2016) investigated exposure to mercury by analysing the urine of 1871 dental health care workers [52]. The study's goal was to compare the risk of mercury exposure among dental health care employees to that of non-dental health care workers and to identify potential risk factors for mercury exposure such as sea food and cosmetic products. Urine mercury levels were $2.75 \text{ }\mu\text{g/L}$ on average for dental health care professionals and $266 \text{ }\mu\text{g/L}$ for non-dental health care workers, respectively. Therefore, the mean urinary mercury levels of health care workers were considered to be low because it was found to be lower than $10 \text{ }\mu\text{g/L}$. In general, the normal mercury concentration in urine samples is less than $20 \text{ }\mu\text{g/L}$. In addition, the exposure to dental amalgam was not associated with high mercury exposure. However, usage of mercury containing cosmetic products and high seafood consumption led to increased exposure to mercury.

The experiment involved using covered petri dishes containing slides with indicator powder as controls. These closed slides showed color changes, indicating that the dental amalgams released detectable concentrations of mercury vapor in an enclosed

environment. The reaction between mercury and powdered sulfur forms mercuric sulfide, which is the most stable compound formed between mercury and sulfur. However, simply placing elemental mercury in a bed of sulfur does not result in the desired mercuric sulfide reaction. Sufficient heat is required to overcome the energy of activation for the reaction to occur. Therefore, the presence of mercuric sulfide, as indicated by the color change, suggests that the dental amalgams did release mercury vapor, and the closed petri dishes allowed for the observation of color changes due to the heat produced and conserved within the enclosed environment.

In a specific study mentioned by Vimy and Lorscheider (1985), the release of mercury vapor from dental amalgam was measured using a Jerome Hg detector in intra-oral air [54]. The study found that subjects with dental amalgam restorations had unstimulated mercury vapor concentrations that were nine times higher than the basal levels observed in control subjects without amalgam restorations. Furthermore, chewing stimulation in subjects with amalgams resulted in a six-fold increase in mercury vapor concentration compared to unstimulated levels, or a 54-fold increase compared to control subjects. The study performed by Vimy and Lorscheider (1985) highlighted the significance of the measurement site when assessing mercury vapor levels. On the other hand, our current study detected low levels of mercury vapor in the atmosphere. As such, measuring mercury released in the oral environment may produce higher concentrations. This increases the likelihood of the mercury being absorbed into brain tissue [26]. Devastatingly, this may result in unintended clinical manifestations of the central nervous system such as headaches, tremors, hallucinations, hearing and cognitive loss.

4.2 Amalgam capsules used per restoration

The number of capsules used by students per amalgam restoration was determined to range between 0 and 3. The first year dentistry program students used a higher number of capsules and took a longer time to place them. It was thus evident that placement skills acquired through training and practice were subject to improvement in the first year cohort of students. Another deduction from the observation made was that first year students are at higher risk of mercury vapour exposure since they took a longer time for placement of the dental amalgam restoration. However, the number

of capsules used per restoration (less than 3), has been previously shown by Guzzi et al., (2006) to cause less mercury absorption in the tissues of dental workers [26].

4.3 Results on the questionnaire

4.3.1 Demographics of the study participants

A large proportion of the participants were comprised of females (Table 3.3). This is in line with the recent sharp increase in females within the South African oral health profession observed by Bhayat and Chikte (2018) [55]. The increase of female professionals in the oral health discipline could be attributed to the government's corrective action measures aimed at improving female children education [56]. The majority of the participants were aware of the mercury toxicity issues associated with amalgam use, as well as the guidelines related to safety. This is consistent with the findings of Pooja and Antony's study on dentists' awareness of mercury poisoning in amalgam fillings [57].

The study conducted by Pooja and Antora (2019) involved 132 dentists, including both general practitioners and specialists working in clinics. The study utilized a questionnaire consisting of 15 questions related to amalgam restoration and safety precautions. The results of the questionnaire indicated that 52% of general practitioners and 90% of specialists were aware of the safety measures associated with amalgam restoration. Furthermore, our study found that undergraduate education played a significant role in the participants' awareness of mercury toxicity from dental amalgam. This finding aligns with the results of a previous cross-sectional survey conducted on Nigerian dentists in 2008 [58], which also identified undergraduate education as a major contributing factor to dentists' awareness of mercury toxicity associated with dental amalgams. These findings highlight the importance of comprehensive education during undergraduate dental training to ensure dentists are well-informed about the potential risks and safety measures associated with dental amalgam restorations.

4.3.2 Effect of the field of practice on the awareness of monitoring frequency

Amalgam restorations are considered safe, irrespective of the inclusion of mercury within them which may lead to possible health side effects [21, 28]. The small amount of mercury vapour released from dental amalgam during its use has not caused any other adverse health effects [28]. A potential health risk to oral health personnel from mercury exposure exists if working conditions do not follow safety guidelines [13]. Adhering to mercury handling protocols together with a monitoring of mercury vapours will reduce mercury exposure [13, 28]. The majority of dental students felt that the monitoring of mercury vapour and the blood of dental professionals should be done every quarter, compared to the other dental professionals suggesting that it should be done on a yearly basis.

The expectation of a higher frequency within the dental students is an indication of the level of fear regarding the chronic exposure of dental professionals to mercury in the workplace. This fear was probably fuelled by their recent undergraduate education, in which they would have been introduced to the amalgam restoration controversy [21, 58]. It is likely that dental assistants and dentists no longer fear mercury toxicity from dental amalgams due to the length of time since training.

4.3.3 Awareness of mercury toxicity in amalgam restorations

The majority of the dental professionals were aware of the mercury toxicity issues associated with amalgam use and were in agreement that guidelines for using and disposing of amalgam were necessary and that they followed them. However, they also suggested that stricter measures ought to be implemented to prevent exposure to mercury vapor. There was a statistically significant difference to the perception scores for each group of dental professionals to this question (Q1, Table 3.4). A large number of dental professionals including dental students (52%) and dentists (72%) were in support of stricter guidelines, compared to those who were not in favor and unsure (20%). This observation once again highlights the heightened awareness of students fueled by their more recent exposure to the debates on dental amalgams and related information. In the same manner, more than a quarter (27%) of the dental professionals are not aware of mercury toxicity issues associated with amalgam use. This may also be fueled by lower levels of continuous professional development

(Figure 3.2).

4.3.4 Perceptions on the safety of amalgam restorations

The high percentage of the dental professionals felt that the placement of dental amalgam restoration was safe both for the operator (67%) and the patient (61%). This may be due to the excellent attributes of amalgam which include cost-effectiveness and durability [58]. In addition, the WHO endorsed dental amalgam use due to minimal exposure to mercury [7, 28]. However, the dental professionals in this study were concerned of mercury absorption into body tissues. Their concern was seemingly unfounded since Guzzi et al., (2006) has shown that mercury is absorbed in body tissues if more than 12 amalgam restorations are used [26].

The participants were unsure of the effects that long term exposure to mercury vapour had on the development of adverse health conditions such as Alzheimer's disease. In contrast, more than half were aware that exposure to direct amalgam can cause allergic reactions to patients. This suggests that, when teaching students about the hazardous effects of mercury in dental amalgams the focus should be on both the short-term impacts and the long-term consequences of mercury exposure. This implies that greater educational marketing is needed to raise awareness of the symptoms produced by chronic mercury exposure.

4.3.5 Opinion on the banning of amalgam and existence of alternative materials

In this study, the toxicity concerns tied to mercury did not affect the use of amalgam fillings. Despite the participant's knowledge regarding the safety concerns of mercury, the participants were not aware of the long-term effects of mercury on patients' health. This may be due to lack of convincing evidence on the adverse health effects of dental amalgam restorations [21]. As a result, the majority of the participants (56%) did not think that the use of dental amalgam restoration should be banned, because they held the view that there was insufficient scientific evidence to suggest that dental amalgam should be banned.

All the participants were aware of alternative materials that may be used in tooth restoration. According to the study conducted by Pooja and Antora [57] a significant

percentage of participants were knowledgeable about the safety measures associated with amalgam restorations. Additionally, they were also aware of alternative materials that are available in the market as alternatives to amalgam. The study suggests that there is awareness among participants regarding both safety measures and alternative options for dental restorations [57]. In addition to the lack of evidence on adverse effects of amalgam use, the cost of the alternative restorative materials may have also supported the hesitance towards the banning of amalgam restorations in the clinic [19, 59].

4.3.6 Removal of amalgam restorations based on patient's safety concerns

More than two thirds of the participants felt that dental amalgam restorations should be removed, based upon the patients' request. However, the various groups' perception on this question was statistically different (Table 3.5). In comparison to qualified dentists and dental assistants, there were more undergraduate students who supported the removal of amalgam restorations based on patient requests. Again, the larger proportion of undergraduate students highlighted their recent exposure to the dental amalgam debates [58]. In addition, more than half of the participants advocated for the removal of dental amalgam restorations from patients and their replacement with safer alternative restorations. This may be due to their knowledge of the existence of safer alternative restorative materials [19].

4.3.7 Conclusion on the questionnaire

Based on the obtained questionnaire results, it appears that undergraduate dental students at Wits Oral Health Centre are more concerned about the toxicity of mercury released from dental amalgam restorations compared to qualified healthcare professionals, including dentists and dental assistants. This discrepancy may be attributed to the experience of older healthcare professionals who have encountered a few reported cases of dental amalgam toxicity. While dentists and dental assistants recommend annual monitoring of mercury vapor at the dental clinic, undergraduate students suggest it should be measured quarterly. However, all healthcare professionals acknowledge the toxicity of mercury and agree that stricter guidelines should be implemented regarding the use of amalgam restorations. Dental amalgam is considered an affordable and durable material and based on the low number of

reported long-term effects, most dental professionals argue against its complete ban. Furthermore, dentists and dental assistants advise against the removal of dental amalgams based solely on patient concerns. Conversely, undergraduate students advocate for their removal due to their knowledge of new, safer dental materials being introduced in the market.

5. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

5.1. Conclusions

The laboratory part of the study suggested that undetectable levels of mercury vapour were released into the atmosphere at WOHC. These mercury vapour concentrations were far below the WHO's threshold limit. Based on the provided context, the study found that students used an average of less than three capsules per amalgam restoration. It was also observed that this usage did not result in a noticeable rise in atmospheric mercury levels. The survey of the dental professionals revealed that the majority of the participants were aware of the safety concerns regarding amalgam use as well as the guidelines regulating its handling and disposal in a safe manner.

In addition to the findings regarding capsule usage and atmospheric mercury levels, a significant number of dental students expressed the opinion that stricter guidelines should be established for handling dental amalgam. They also believed that more frequent monitoring of mercury vapor concentration toxicity in dental clinics and the blood of dental professions should be conducted. The dental students' heightened awareness and sensitivity was due to their recent undergraduate education, which was the major source of information on the safety concerns of using dental amalgam restorative material.

5.2. Limitations

The laboratory part of the study was limited by the sensitivity and limit of detection of the assay as well as the colorimetric detection of mercury levels (from the mercury

vapor indicator), which may be subjective. The survey aspect of the study was limited by the low number of participants in some of the dental professionals' groups. A larger sample size, per group, may be required to further analyze the various dental professionals' perceptions.

5.3 Recommendations

Below are recommendations resulting from this study's findings:

- All dental institutions handling dental amalgam restorations should analyze mercury vapour levels at a set periodic interval by using more sensitive mercury vapour analyzers such as the Jerome J405, for accurate quantification of the daily release of mercury vapour levels in the atmosphere.
- The promotion of awareness and education of patients regarding the adverse effects related to dental amalgam restorations such as localized contact reactions including amalgam tattoos, oral lichenoid reactions, erythematous lesions of the mucosa and the tongue which are caused by abrasion to the rough surfaces of amalgam restoration should be well communicated to the patients before placement of the restoration.
- Dental health care professionals who handle amalgam restorations should have their mercury exposure levels checked on a regular basis to avoid long- term health problems including kidney dysfunction or Alzheimer's disease.
- The WOHC should establish rules and guidelines concerning the use of dental amalgam restorations on children younger than 10 years and pregnant women, and these should be clearly indicated on the Restorative and Paediatric dentistry study guide
- Protocols on the removal of a sound dental amalgam restoration, based on patients' requests, should be implemented at WOHC.
- Safety guidelines regarding handling of mercury containing products in dental clinics such as the use of high-volume suction to remove the amalgam restoration to reduce the mercury content released in the atmosphere and storage of amalgam remnants in an amber-coloured glass container (targeting dentists and dental assistants) should be implemented.
- Research committees in dental institutions should encourage the need for more

research on improved alternative restorative materials containing less mercury toxicity to limit mercury release from the dental amalgam alloy.

- It is recommended that stricter guidelines for handling dental amalgam should be thoroughly documented and implemented across all departments where amalgam restorations are performed. This documentation will ensure that all dental professionals have access to clear and comprehensive guidelines for the safe handling of amalgam materials.

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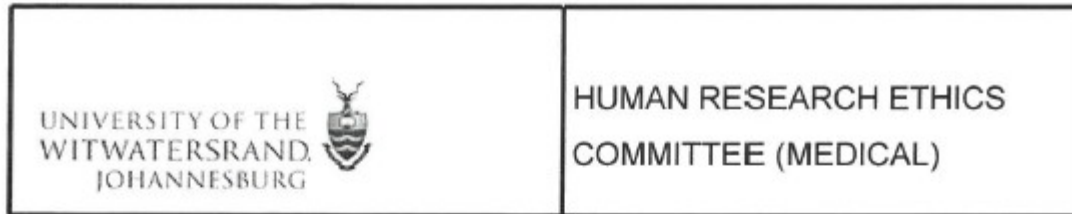
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7. APPENDICES

Appendix 7.1. Human Research Ethics Clearance Certificate



Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Dr M Makhado
School of Oral Health Sciences
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E-mail: Masakona.Makhado@wits.ac.za

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FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2019/06/20

REF: R14/49

PROTOCOL NO: **M190261** (*This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study*)

PROJECT TITLE: *Evaluation of Mercury vapour levels associated with amalgam usage at Wits Oral Health Centre*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.



MSWorks2000/Iain0007/Clearscan.wps

R14/49 Dr M Makhado

**HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M190261**

NAME: Dr M Makhado
(Principal Investigator)
DEPARTMENT: School of Oral Health Sciences
Department of Oral Biological Sciences
Dental School
University


PROJECT TITLE: Evaluation of Mercury vapour levels associated with
amalgam usage at Wits Oral Health Centre

DATE CONSIDERED: 2019/02/22

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Drs J Molepo & S Moeno; Prof S Nmutandani

APPROVED BY: 
Dr CB Penny, Chairperson, HREC (Medical)

DATE OF APPROVAL: 2019/06/20

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. I **agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **February** and will therefore reports and re-certification will be due early in the month of **February** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date

PLEASE QUOTE THE CLEARANCE CERTIFICATE NUMBER IN ALL ENQUIRIES

Appendix 7.2. The BDS1 amalgam capsule usage of the year 2020

A compilation of the BDS 1 Amalgam capsule usage from 21/09/2020- 05/10/2020

Number of Amalgam Capsules Used	Number of Amalgam restorations placed	Estimated time of placement/Min	Estimated time of placement/Min
12	3	3	3/min
4	3	4	4/min
3	2	7	7/min
2	1	6	6/min
6	2	30	30/min
2	1	1	1/min
14	1	120	120/min
3	3	5	5/min
4	3	3	3/min
1	1	1	1/min
1	1	1	1/min
1	1	5	5/min
1	1	10	10/min
4	1	60	60/min
2	2	3	3/min
2	1	4	4/min
3	2	2	2/min
2	1	3	3/min
4	2	2	2/min
2	1	5	5/min
2	2	3	3/min
2	1	1	1/min
1	1	3	3/min
3	2	3	3/min
1	1	3	3/min
3	3	3	3/min
5	1	45	45/min
2	2	60	60/min
2	1	10	10/min
2	2	10	10/min
2	1	3	3/min
4	2	40	40/min
2	1	6	6/min
1	1	1	1min
1	1	5	5/min
2	1	120	120/min

2	2	3	3/min
5	3	2	2/min
3	3	2	2/min
2	2	10	10/min
1	1	2	2/min
1	1	5	5/min
1	1	5	5/min
5	1	40	40/min
2	1	3	3/min
1	1	1	1/min
3	1	3	3/min

Appendix 7.3. The BDS4 amalgam capsule usage during the year 2020

A compilation of the BDS 4 amalgam capsule usage during the period 22/09/2020-30/09/2020

Number of Amalgam Capsules Used	Number of Amalgam restorations placed	Estimated time of placement/Min/hr
2	1	3
1	1	2
1,5	1	2,5

Appendix 7.4. Clinical details of the dental amalgam recording sheet

Dental Amalgam Recording

Sheet Date: _____

Field of Practice: Dentist
Student

Dental Assistant

Venue: Poly 1: Poly 2: Poly 3:

Techniques Lab: **Number**

of Amalgams capsules used: _____

Estimated time of placement: _____

Number of Amalgam restorations placed: _____

Appendix 7.5. The Participants Consent Form

AMALGAM QUESTIONNAIRE

CONSENT FORM

INFORMATION DOCUMENT TO STAFF/STUDENTS PARTICIPATING IN DENTAL AMALGAM QUESTIONNAIRE.

Good Day Dental Professionals.

I am Dr Masakona Makhado from the Department of Oral Biological Sciences in the Faculty of Health Sciences at Wits Oral Health Centre (WOHC), I will be conducting research on the "Evaluation of mercury vapor levels associated with dental amalgam usage at WOHC.

Introduction

For many years, dental amalgam has been utilized for dental restoration. However, there are toxicity concerns due to high mercury (Hg) content which can range from 40-55%. Mercury vapor is released from dental amalgam during all procedural steps such as trituration, condensation, setting, polishing, and removal. Dental amalgam restoration can become a health concern to both dental practitioners and patients due to mercury vapor emission.

The aim of the study is to evaluate the levels of mercury vapor released in the atmosphere during the use and disposal of dental amalgam and the adherence of staff to mercury hygiene protocols at WOHC.

The objectives of the study are:

1. To measure and compare the levels of atmospheric elemental mercury vapor at WOHC.
2. To investigate the association between the atmospheric levels of mercury and the number of amalgam capsules used daily at WOHC.
3. To assess the clinical staff knowledge and adherence to mercury hygiene protocols through the use of a questionnaire.
4. To engage in statistical analysis of data obtained from the survey.

What is involved in the study?

The study will require you to complete an online based questionnaire. It will take approximately ten to Fifteen minutes to complete the questionnaire.

Benefits of participating in the study:

The results of the study will indicate whether levels of mercury detected at WOHC is within the recommended values. By participating in this study, we will gain an understanding of your views and awareness of mercury vapor toxicity from dental amalgam.

Participation in the study is voluntary:

The study consist of a confidential, anonymous questionnaire. If you are not willing to participate in the study, you will not be penalized or lose out on any benefit that is entitled to you in any way. You may also withdraw from the study at any time.

Reimbursements:

There will be no compensation for participating in the study.

Confidentiality:

You may not disclose any of your personal information in the questionnaire and confidentiality will be maintained

for all information gathered during the study. All information recorded will be kept strictly confidential.

Contact details of researcher:

If you have any enquiries about the study please contact Dr Masakona Makhado from Oral Biological Sciences Department at the University of the Witwatersrand on telephone number 011 7172215 or email address; masakona.makhado@wits.ac.za.

For reporting of any complaints:

Please contact the Chairperson of the Wits Human Research Ethics Committee (HREC), Dr Clement Penny through the secretary Ms Zanele Ndlovu on telephone number 011 717 2700/1234 or e-mail address; Zanele.Ndlovu@wits.ac.za

By proceeding with this survey you are providing consent to participate.

Thank you

Dr Molepo.J, Dr Moeno.S, Prof Nmutandani.S and Dr Makhado.M

Appendix 7.6. The composition of the dental amalgam questionnaire

DENTAL AMALGAM QUESTIONNAIRE

Tick on the correct answer

Sex: Male Female

Field of Practice: Dentist Dental Assistant Dental Student

What contributed to your awareness towards mercury toxicity in dental amalgam?

Undergraduate education

Continuing dental education

Disseminated Protocols from Departments

Other(specify) _____

1. Are you aware of mercury toxicity issues associated with dental amalgam use?

Yes No Uncertain

2. Are guidelines regarding the safe use and disposal of dental amalgam necessary?

Yes No Uncertain

3. Do you follow guidelines regarding the safe use and disposal of dental amalgam?

Yes No Uncertain

4. Should stricter guidelines regarding the safe use and disposal of dental amalgam be implemented?

Yes No Uncertain

5. Should less strict guidelines regarding the safe use and disposal of dental amalgam be implemented?

Yes No Uncertain

6. Is the placement of dental amalgam restoration safe for the operator?

Yes No Uncertain

7. Is the placement of dental amalgam restoration safe for patients?

Yes No Uncertain

8. Is the mercury vapor released from dental amalgam absorbed into the body tissues?

Yes No Uncertain

9. Does long term exposure to mercury from dental amalgam pose any adverse health effects such as Alzheimer's disease?
 Yes No Uncertain
10. Does direct oral contact with dental amalgam causes allergic reactions to patients?
 Yes No Uncertain
11. Should the use of dental amalgam restoration be banned?
 Yes No Uncertain
12. Is there sufficient scientific evidence to suggest that dental amalgam should be banned?
 Yes No Uncertain
13. Should the use of dental amalgam restorations to children under the age of 6 years as well as pregnant women be restricted?
 Yes No Uncertain
14. Is there a need for extensive research on alternative materials that present low risk of chemical exposure?
 Yes No Uncertain
15. Are you aware of alternative restorations? e.g. Resin composites, glass ionomer.
 Yes No Uncertain
16. Should dental amalgam restorations be removed, based on patients request?
 Remove Don't Remove Uncertain
17. Do you advocate for the removal of dental amalgam restorations from patients and their replacement with alternative restorations?
 Yes No Uncertain
18. Are you concerned about the environmental issues brought about by dental amalgam use in the dental clinic?
 Yes No Uncertain
19. Should mercury vapor exposure levels in the dental clinic be monitored?
 Yes No Uncertain
20. How often should the monitoring of mercury vapor levels in the dental clinic be done?
 Quarterly Semesterly Yearly
21. Should mercury blood levels of dental professionals be monitored?

Yes

No

Uncertain

22. How often should mercury blood levels of dental professionals be monitored?

Quarterly Semesterly Yearly