DENTAL AMALGAM PROCUREMENT PATTERNS AND MERCURY LEVELS IN WASTEWATER GRAB SAMPLES AT WITS ORAL HEALTH CENTRE (WOHC)

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Declaration

I, Stephen Mughanga Sudi, declare that this research report is my own, unaided work. It is being submitted for the Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

(Signature of candidate)

06th day of November 2019 in Parktown

Dedication

I dedicate this work to my late father, Dr Esau Ghamunga Sudi.

Abstract

Background

Dental amalgam is an affordable, commonly used, and essential restorative material in primary oral health care provision in South Africa. Dental amalgam is composed of 43-50% liquid mercury. Over the past 40 years, concerns over the environmental effects of waste produced during the placement and removal of amalgam, have grown in parallel with the advancing knowledge of mercury eco-toxicity. The release of waste and residues produced during amalgam use to the environment poses a significant risk of mercury contamination.

Aim

The study aimed to describe dental amalgam procurement patterns, determine mercury levels in wastewater, and describe the best management practices at the Wits Oral Health Centre (WOHC) of the School of Oral Health Sciences, University of the Witwatersrand.

Methods

The procurement records at WOHC were accessed, and amounts of amalgam procured analysed for procurement trends. The wastewater generated at WOHC was collected through diversion and collection of the wastewater flow. The samples of wastewater collected were analysed for mercury concentrations at a laboratory. A structured interview was used to investigate the application of best management practices for dental amalgam use.

Results

The study revealed the increasing trend in the use of dental amalgam, high levels of mercury generated from amalgam use in wastewater at the WOHC. The best management practices for dental amalgam use were not adequately applied.

Conclusions

There is an urgent need to institute best management practice at the WOHC. There is a need to update the regulations and guidelines for amalgam waste management in South Africa. The establishment of best management practices should go hand in hand with building infrastructural support in amalgam waste management processes.

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List of Abbreviations

MCM - The Minamata Convention on Mercury

SADA - The South African Dental Association

ISO - International Standards Organisation

ADA – American Dental Association

BMPs – Best Management Practices for Dental Amalgam Use.

WOHC - Wits Oral Health Centre

CMJAH - Charlotte Maxeke Johannesburg Academic Hospital

P1 – Polyclinic 1

P2 – Polyclinic 2

P3 – Polyclinic 3

P4 – Polyclinic 4

MSTL – Multi Skill Technique Laboratory

ml – millilitres

L – Litre

mg - milligrams

kg – Kilogram

mg/L – milligrams per litre

µg/L – micrograms per litre

gm – grams

r_s - Spearman’s correlation coefficient

CHAPTER ONE

INTRODUCTION

Mercury, a naturally occurring heavy metal, is one of the earliest elements known to humankind. The early humans discovered and utilised mercury due to its existence as easily extractable and purified compounds (Wisniak, 2008).

The use of mercury by humankind is synonymous with the historical development of alchemy and medicine. The early alchemists recognised the properties of elemental mercury, leading to the expectation of transmuting base metals into silver or gold (King, 1957). Inorganic mercury compounds such as corrosive sublimate ($HgCl_2$), calomel (Hg_2Cl_2) and mercury sulphide compounds (HgS) were common medications (Wujastyk, 2015). Dental amalgam - a mercury silver alloy was used as a tooth filling material in the 7th century China and by 1800s introduced in Europe and North America (Dodes, 2001). The organic mercury compounds were synthesised in the 19th century and were used as a fungicide in seed dressing, slimicides in the paper industry, anti-syphilitic agents, and vaccine preservatives (Grandjean, et al., 2010).

The Roman scholar, Pliny the Elder reported the toxicity of elemental mercury in the 1st century AD. Pliny described mercury poisoning among slaves working in the contaminated mines of Amalden, Spain (Forrai, 2007). In the 19th century, occupational poisoning by mercury was reported among metalworkers, miners, felt hat manufacturers, dyers and paint manufacturers (Langford & Ferner, 1999). The increased use of mercury and mercury compounds from the early 20th century in industrial processes and products led to inadvertent human exposure, environmental release and contamination. The most significant catastrophic mercury poisoning occurred in the Japanese city of Minamata. Organic mercury released from industrial processes concentrated in marine life, part of the staple diet of the population (Harada, 1995). The consumption of grains treated with organic mercury fungicides led to poisoning epidemics in Iraq, Pakistan, and Ghana (Tchounwou, et al., 2003). In South Africa, poisoning of workers and contamination of the environment occurred at mercury waste recycling plant in the 1980s (Leonard, 2009).

Mercury is currently a recognised global environmental pollutant with various adverse health effects on animal and human life (UNEP, 2013). Mercury releases to the environment originate from geologic reservoirs to air, soil, and water by human activities. Human activities have increased total atmospheric mercury concentration by about 450% above natural levels. The estimated emission to the atmosphere for the year 2015 increased by 20% compared to those of 2010 (UN Environment, 2019).

In the environment, mercury persistently circulates in the atmosphere, water, soil, plants and animals. In efforts to minimise the risk of the environmental mercury contamination; the mining, usage, and trade of mercury are subject to control under the Minamata Convention on Mercury (MCM). The MCM entered into force on the 16th of August 2017 (UNEP, 2017). The Republic of South Africa became a party to the convention on the 29th of April 2019 (UNEP, 2019).

The dental amalgam restorative material is composed of 43-50% liquid mercury, which forms an intermetallic alloy; with varying amounts of silver, tin, copper, zinc, and palladium (Sakaguchi & Powers, 2012). The use of dental amalgam discharges waste and residues, which pose a risk of mercury contamination in the environment (Jones, 2004). The dental amalgam discharges contribute to the mercury contamination of the environment through direct wastewater discharge, incineration of solid waste, landfilling and sewage sludge incineration (Jokstad & Fan, 2006).

In the MCM, dental amalgam is the only mercury-added product subject to a phase-down approach based on prevention, research for alternative materials, and waste management practices (UNEP, 2017).

Most middle and low-income countries rely heavily on affordable dental amalgam in offsetting unmet restorative needs in their population. The contribution of dental amalgam in environmental mercury contamination in these countries is recognised, but data on the extent is lacking (WHO, 2005).

Dental amalgam is an essential restorative material in primary oral health care provision in South Africa (Department of Health, 2005) and was reported to be widely used in the training of restorative dentistry in all the four dental schools in South Africa (Lombard, et al., 2009). The amount of dental amalgam procured and used by the dental schools, as well as the potential wastewater contamination has remained unreported.

The prevention of environmental contamination by mercury from dental amalgam is through the use of guidelines and containment systems specifically developed for dental clinics. The World Health Organization (WHO) has adopted Best Management Practices (BMPs) for Dental Amalgam use previously developed by the American Dental Association (WHO, 2009). The South African Dental Association (SADA) advocated the introduction of the (BMPs) for dental amalgam use to prevent environmental mercury contamination (SADA, 2014). The extent of application of the BMPs in the republic of South Africa is unknown.

The study aimed to investigate the dental amalgam procurement patterns, determine mercury levels in wastewater and ascertain the application of BMPs for dental amalgam use at the Wits Oral Health Centre (WOHC), School of Oral Health Science (SOHS) of The University of the Witwatersrand.

Such information will provide a glimpse into the amount of dental amalgam procured by the WOHC, inform the oral and environmental health practitioners of the potential wastewater contamination by mercury originating from dental amalgam, and describe the extent and adequacy of the application of the BMPs at the WOHC.

CHAPTER TWO

LITERATURE REVIEW

Dental caries is the world's most widespread chronic disease, with untreated caries in permanent teeth being the most prevalent condition in the 2016 Global burden of Disease Study (Vos, et al., 2017). In the African region, dental caries disease burden among both urban and rural populations is on the rise, with most tooth decay remaining untreated (WHO, 2016).

The attempts to restore dentition damaged by dental caries employed different types of materials throughout human history. The recent discovery in remains of an individual living in Italy 13,000 years ago, suggests evidence of earliest attempts at restoration of tooth structure. In the remains, the anterior maxillary dentition exhibited ante-mortem exposure of both upper first incisor pulp chambers, enlargement, with a mixture of bitumen, vegetal fibres and probable hair adherent to internal walls of the cavities (Oxilia, et al., 2017),

Amalgam, a silver-tin-mercury alloy, was first reported in "Materia medica" literature of the T'ang dynasty, written by Su Kung in the "fourth year of Hsien Ch'ing" about 659 A.D. The alloy was used by Chinese artisans for building decorative work, and the literature details methods of preparations, proportions, and as well as its use for repairing decaying teeth (Chu, 1958).

The modern invention of dental amalgam is credited to Louis Regnart, a Parisian physician devoted to dentistry in 1818. Regnart improved the "fusible metal" for filling of cavities invented in 1805 by W.H Pepys and Joseph Fox of England, by adding mercury, to overcome the objectionable need for melting (Hyson, 2006). Prior to the use of silver amalgam, copper-based amalgam dental filling was reported in

Germany in the year 1528 (Riethe, 1966). The use of dental amalgam was further reported in the 19th century Europe, with practitioners such as A. Traveau from France in 1826, and JJ Murphy of England in 1837, employing the new material (Charles, 1982).

The use of dental amalgam entered its most controversial phase with the introduction of dental amalgam in the United States by the Crawcour brothers in 1833. The Crawcour brothers used crude methods to prepare dental amalgam, placing restorations without removal of caries, in lavish dental “parlours” (Hyson, 2006). The expansion of restorations, caused tooth fractures, restoration failure and immense suffering. The American Society of Dental Surgeons, the first national dental society, issued a statement in 1941, “the use of amalgam constitutes a malpractice” sparking what was termed the “Amalgam war” (Sweet, 1956).

The “new departure” – an organised movement supporting the use of dental amalgam began in late 1870. The introduction of a balanced amalgam formula and mechanical principles of the sound cavity by Dr GV Black, in 1896, entrenched the restorative model in the management of dental caries. The establishment of dental education from apprenticeship training to formal, school-based education program was one other favourable outcome of the “amalgam war” (Osborne, et al., 2002). The balanced formula by Dr Black prevailed until 1963 when Dr William Youdelis, a Canadian metallurgist, developed high copper amalgam with enhanced long-term marginal integrity (Innes & Youdelis, 1963).

Dental amalgam is produced by mixing approximately 50% - liquid mercury, with solid particles of an “amalgam alloy.” The composition of dental amalgam is controlled by an International Standards Organisation (ISO) standard, ISO 20749 – precapsulated dental amalgam. In the standard, dental amalgam alloy composition limits are silver 40%, Tin 32%, Copper 30%, Indium 5%, Palladium 1%, Zinc 2%, and Mercury 3% and mercury of high purity with less than 0.02% non-volatile residues (ISO20749, 2017).

Mercury is a chemical element with a symbol (Hg), has an atomic number 80, the standard atomic weight of 200.5924, with a melting point of 38.8°C, a boiling point of 356.7°C, a density of 13.534 g/cm3, and a specific gravity of 13.55. The vapour pressure of mercury is 1.22 $x10^{-3}$ mmHg at 20°C (2.8 x 10^{-3} mmHg at 30°C), and aqueous solubility of 5.6 x 10^{-7} g/l at 25°C (Kozin & Hansen, 2013). Mercury fascinated the ancient worlds of Egypt, India, China Greeks, and Romans, finding use in commercial activities, medicinal therapies, and industrial processes (Wisniak, 2008).

Mercury is currently a recognised global environmental pollutant with various adverse health effects on animal and human life (UNEP, 2013). Environmental emissions of mercury originate from natural (geogenic) and human (anthropogenic) sources, both of which contribute to the global mercury pool. Mercury takes on three different chemical forms in its biogeochemical cycle with varying toxicity, namely; elemental, inorganic, and organic mercury (Kozin & Hansen, 2013). Human activities have increased total atmospheric mercury concentration by about 450% above natural levels. The estimated emission to the atmosphere for the year 2015 increased by 20% compared to those of 2010 (UN Environment, 2019).

Elemental mercury, which exists in liquid form at room temperature readily, evaporates into mercury vapour. Ambient air and dental restorations are the most common source of human exposure, with no significant health effects (Clarkson, 2002). Elemental mercury has commercial applications in chloralkali and paint industries, artisanal gold mining, and production of thermometers, electrical switches and dental amalgam (UNEP, 2013). Detrimental exposure to elemental mercury may lead to accumulation of inhaled mercury vapour in red blood cells and deposition to various tissues in the body where it may affect the nervous, cardiovascular, respiratory, renal, immune, and reproductive systems (Li & Tse, 2015).

Inorganic mercury occurs in surface water and soil as cationic salts of mercury and other compounds. The main routes of human exposure are through consumption of contaminated food and contact with contaminated soil (UNEP, 2013). Inorganic mercury is less soluble than elemental mercury hence less likely to cross blood barriers (Li & Tse, 2015). Large volumes of absorbed inorganic mercury may cause damage to the renal, gastrointestinal, and immune systems. Inorganic mercury is used in skin creams, homeopathic medicine, and batteries (UNEP, 2013).

Organic mercury, the most toxic form, occurs through contamination of surface water with elemental mercury, with subsequent biotic and abiotic transformation into organic mercury. Human exposure is through consumption of fish and rice (Li & Tse, 2015). Organic mercury bio-accumulate in marine life and represents about 80% of mercury found in fish, while the ratios in sediment and water are 1% and 30% respectively (Sanborn & Brodberg, 2006). This form of mercury is well absorbed in the gastrointestinal tract, subsequently affecting the nervous, reproductive, and immune systems (UNEP, 2013). In its most common form of methyl mercury, it can cause foetal abnormalities and neurotoxicity even among infants born to mothers with minimal symptoms. Minamata syndrome is a neurological syndrome caused by severed organic mercury poisoning from eating contaminated seafood. The syndrome was first identified in Minamata Bay in Japan, where mercury contamination of the sea from an industrial source, which in the 1950s (Harada, 1995). The similarity in biochemical pathways affected by mercury exposure and inflammatory immune reactions may increase susceptibility to mercury toxicity among individuals living in developing countries (Bjorklund, et al., 2019).

The Minamata Convention on Mercury, aptly named after the Minamata city, is an international treaty aiming, “to protect the human health and environment from anthropogenic emissions and releases of mercury and mercury compounds,” (UNEP, 2017). The Republic of South Africa became a party to the convention on the 29th of April 2019, and the provision of the treaty became binding on the 29th of July of the same year (UNEP, 2019).

The treaty contains several controls regarding mercury mining, import and export, storage, disposal and reducing mercury emissions. A global ban on the import and export of products containing mercury will commence in 2020. Dental amalgam is exempted from the ban affecting mercury-containing products, and the treaty calls on countries that sign and ratify the convention to phase-down use of dental amalgam taking into account domestic circumstances and relevant international guidance whilst committing to required two or more measures (UNEP, 2013).

The measures include.

i. Setting national objectives aiming at dental caries prevention and health promotion, thereby minimising the need for dental restorations
ii. Setting national objectives aiming at minimising its use
iii. Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restorations
iv. Promoting research and development of quality mercury-free materials for dental restoration.

v. Encouraging representative professional organisation and dental schools to educate and train dental professionals and student on the use of mercury-free dental restorations alternatives and on promoting best management practices

vi. Discouraging insurance policies and programs that favour dental amalgam use over mercury-free dental restorations.

vii. Encouraging insurance policies and programs that favour use of quality alternatives to dental amalgam for restorations

viii. Restricting the use of dental amalgam to its encapsulated form

ix. Promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

(UNEP, 2013)

Despite the concern on its mercury content, dental amalgam is the most frequently used restorative material. The dental amalgam market is expanding at 5%, and expected to reach 500 million US dollars between 2018 and 2023. The largest market is North America and Europe while Asia Pacific region is the fastest-growing market. The continent of Africa is the slowest growing market, despite the significant unmet restorative needs (Market Research Future, 2018).

Globally, Dentistry consumes an estimated 340 tons of mercury (UNEP, 2013). The placement, replacement, and removal of dental amalgam release mercury-containing waste. The waste is generated in an open system, which is challenging to monitor and ultimately end in the environment (Figure2.1). The pathways of mercury to

the environment are estimated to be, atmosphere 50-70 tons/year, Surface water 35-45 tons/year, Groundwater 20-25 tons/year, Soil 75-100 tons per year. An estimated 40-50 tons/year of dental amalgam are recycled and 40-50 tons/year are processed through sequestration and secure disposal of (UNEP, 2016).

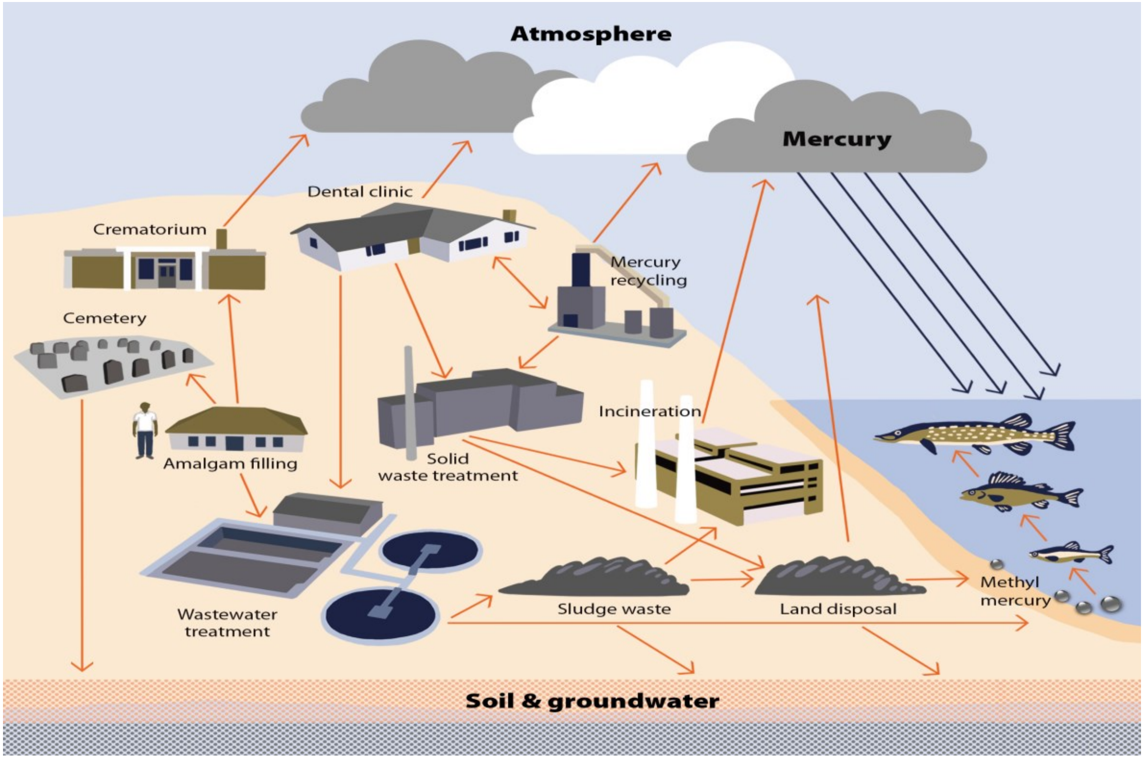

Figure 2.1. Mercury releases to the environment from dental care (UNEP, 2016)

Available estimates of dental amalgam usage in South Africa indicate that 70-100kg of dental amalgam was sold annually between 2009 and 2011, with a further 50kg of non-amalgamated mercury sold to dental practitioners (DEA, 2011).

In an investigation of the teaching approaches on direct restorative procedures in South African Dental Schools, all four schools devoted an equal number of sessions to pre-clinical teaching on amalgam and conventional composite resin. The clinical training of direct restorations includes requirements for dental amalgam and conventional composite resin restorations. (Lombard, et al., 2009). Amalgam waste produced in the dental clinic can be categorized as non-contact and contact amalgam waste. Used capsules and amalgam scraps form non-contact amalgam waste, while contact amalgam waste is composed of carved amalgam, amalgam captured in chairside traps, vacuum pumps filters and extracted teeth (Jokstad & Fan, 2006). In a restoration using a two spill dental amalgam capsule, an estimated

46.2% of amalgam is used in restoration, 43.1% produced as non-contact amalgam waste with 10.7%.is generated as contact amalgam waste. The ratio of non-contact to contact amalgam varies depending on the cavity size and ranges from 2.1 to 7.2% (Drummond, et al., 2003).

Dental amalgam, with a density of 9.50g/cm^3 (O'Brien, 1997) has average settling velocities of 16.56 to 65.7 cm/hour, leading to ninety per cent of amalgam particles settling in two hours (Calais, et al., 1994). The high settling velocity of dental amalgam induces deposition of amalgam in dental wastewater lines and continuous leaching of mercury into wastewater treatment plants (Stone, et al., 1999).

Conventional chair-side traps with a screen size of 0.70mm will trap 30% of amalgam waste by weight and with a further 35% of released amalgam waste captured by a vacuum pump filter with a screen size of 0.42mm. The remaining amalgam waste (35-40%) is released in dental wastewater (Adegbembo, et al., 2002. Ninety per cent (90%) of amalgam particles in dental wastewater are larger than 10 microns in size (Naleway & Ovsey, 1994). Average mercury load to the wastewater stream from dental clinics has been estimated to vary from 56 mg Hg/dentist/day to a maximum of 98 mg Hg/dentist/day (Walker Larry and Assoc, 2002). Oxidising disinfectants, when used as line cleaning agents, also cause a further release of mercury from amalgam particles deposited in the wastewater lines (Roberts, et al., 2005).

The amalgam separators are solid collecting devices, which utilise sedimentation, centrifugation, filtration, or a combination of the three mechanisms to capture amalgam before reaching the sewage wastewater lines. They can potentially remove 99.4% of solids in dental wastewater (Adegbembo, et al., 2002) with concomitant downstream reduction of mercury concentration in the sludge from wastewater treatment plants by 29–80% (Arenholt-Bindslev, 1998). The amalgam separators must conform to ISO 11143 standards, which stipulate the removal of 95% of dental amalgam in dental wastewater.

The evacuation of dental wastewater employs two basic types of vacuum pumps, a wet-ring, and dry vacuum pumps. A wet-ring pump uses water to maintain a vacuum seal. The separation of amalgam particles is convenient when seal water is not treated. It is for this reason; the installation of separation devices in a wet ring pump is usually before the pump. The dry vacuum pumps use an air-water separator tank. The separation of amalgam particles in a dry pump is by use of a modified separator tank or a separation device connected to the tank. (Tuominen, 2001)

Investigations of concentration of mercury in wastewater in clinics without amalgam separators tend to produce results with high deviation due to different clinical and procedural factors. In United Arab Emirates, mercury concentration ranges from minimum detected level of <1.0µg/l to 144 µg/l have been described (Al Kawas, et al., 2008) while in Iran, the concentration of mercury in dental wastewater of 21.030µg/l to 29.40µg was reported (Bahramian, et al., 2016) /l. In both countries, dental wastewater was a source of high and unacceptable levels of mercury in domestic wastewater sewers.

Production of organic methyl mercury in dental wastewater lines by sulfate-reducing bacteria with subsequent overloading into sewage treatment plants has been previously documented (Zhao, et al., 2008). Amalgam waste when released in dental lines, leads to sustained mercury load in the sewage treatment plant. In the sewage treatment plants, dental wastewater stream may cause from 14% to 70% of the mercury load (Arenholt-Bindslev & Larsen, 1996). The anaerobic digestion processes favour further transformation of elemental mercury into organic methyl mercury followed by downstream released into water bodies (Tchounwou, et al., 2003). Ultimately, mercury left trapped in sludge may be released in the environment during incineration or deposited in soils during farmland enrichment (Jones, 2004).

Wastewaters re-use is one of the viable methods aiming at easing the high water stress in South Africa (Adewumi, et al., 2010). During a recent water shortage, the city of Cape Town used treated wastewater to supply businesses with high water demand (CTGM, 2017). The town of Beaufort West obtains 20% of its supplies from reclaimed water since 2011 (Qukula, 2017). The release of wastewater contaminated by dental amalgam constituents to the sewerage systems may compromise efforts to reuse wastewater in South Africa. Dentists have a social responsibility to prevent mercury contamination of the wastewater flow.

Various Acts, Regulations, and By-laws regulate the use of water and sanitation services in South Africa. The City of Johannesburg Metropolitan Municipality – Water Services By-laws prohibit the release of wastewater with a concentration of mercury higher than 1,0mg/L into the sewer system. The release of wastewater with high mercury concentration is objectionable as it may prejudice sewage effluent re-use and affect water downstream to the treated sewage effluent discharge (COJMM, 2003).

The American Dental Association (ADA) published the Best Management Practices (BMPs) (Table 2.1) for dental amalgam use in 2002 (ADA, 2016). The World Health Organization (WHO) and the United Nations Environment Program (UNEP) adopted the BMPs in the year 2009 (WHO, 2009). The Basel Convention is a multilateral environmental agreement designed to reduce the movements of hazardous waste between nations. The Basel Convention developed guidelines on mercury waste.

The guidelines provide supplementary information on long-term storage and sequestration of mercury waste (Basel convention, 2011).

Table 2.1 The Best Management Practices for dental amalgam use (WHO, 2009)

DO	DON'T
Do use pre-capsulated alloys and stock a variety of capsule sizes	Don't use bulk mercury
Do recycle used disposable amalgam capsules	Don't put used disposable amalgam capsules in biohazard containers, infectious waste containers or regular garbage
Do salvage, store and recycle non-contact amalgam (scrap amalgam)	Don't put non-contact amalgam waste in biohazard containers, infectious waste containers or regular garbage
Do salvage (contact) amalgam pieces from restorations after removal and recycle the amalgam waste	Don't put contact amalgam waste in biohazard containers, infectious waste containers or regular garbage
Do use chair-side traps, vacuum pump filters and amalgam separators to retain amalgam and recycle their contents	Don't rinse devices containing amalgam over drains or sinks
Do recycle teeth that contain amalgam restoration. (Note: Ask your recycler whether or not extracted teeth with amalgam restorations require disinfection)	Don't dispose of extracted teeth that contain amalgam restorations in biohazard containers, infectious waste containers, sharps containers or regular garbage
Do manage amalgam waste through recycling as much as possible	Don't flush amalgam waste down the drain or toilet
Do use line cleaners that minimize dissolution of amalgam	Don't use bleach or chorine-containing cleaners to flush wastewater lines

A guide for the integration of BMPs (Table2.2) into the dental practice was also adopted by the WHO and the UNEP (WHO, 2009)

Table 2.2 Guide to integrating BMPs into the dental practice (WHO, 2009)

Non-contact (scrap) amalgam Place non-contact, scrap amalgam in a wide-mouthed container that is marked “Non-contact Amalgam Waste for Recycling”. Make sure the container lid is well sealed. When the container is full, send it to a recycler
Amalgam capsules Stock amalgam capsules in a variety of sizes. After mixing amalgam, place the empty capsules in a wide-mouthed, airtight container that is marked “Amalgam Capsules Waste for Recycling”. Capsules that cannot be emptied should likewise be placed in a wide-mouthed airtight container that is marked “Amalgam Capsules Waste for Recycling”. Make sure the container lid is well sealed. When the container is full, send it to a recycler.
Disposal chair-side traps Open the chair-side unit to expose the trap. Remove the trap and place it directly into a wide-mouthed, airtight container that is marked “Contact Amalgam Waste for Recycling”. Make sure the container lid is well sealed. When the container is full, send it to a recycler. Traps from dental units dedicated strictly to hygiene may be placed in with the regular garbage.
Reusable chair-side traps Open the chair-side unit to expose the trap. Remove the trap and empty the contents into a wide-mouthed, airtight container that is marked “Contact Amalgam Waste for Recycling”. Make sure the container lid is well sealed. When the container is full, send it to a recycler. Replace the trap into the chair-side unit (Do not rinse the trap under running water as this could introduce dental amalgam into the waste stream
Vacuum pump filters Change the filter according to the manufacturer’s recommended schedule. Note: The following instructions assume that your recycler will accept whole filters; some recyclers require different handling of this material, so check with your recycler first. Remove the filter. Put the lid on the filter and place the sealed container in the box in which it was originally shipped. When the box is full, the filters should be recycled
Amalgam separators Select an amalgam separator that complies with ISO 11143. Follow the manufacturer’s recommendations for maintenance and recycling producers.
Line cleaners Use non-bleach, non-chlorine-containing line cleaners, which will minimize amalgam dissolution

In a review of 15 studies involving 40,000 dentists and personnel, dental personnel had higher mercury exposure than the controls; nevertheless the exposure levels were below the limiting guideline of 35 μg/g creatinine for urine and 15 μg/L for blood as set by the American Conference of Governmental Industrial Hygienists (ACGIH) (Nagpal, et al., 2017). In Turkey (Karahalil, et al., 2005) and Iran (Kasraei, et al., 2010), the levels of mercury exposure in dentists and dental personnel were higher in practices with lower standards of management systems for dental amalgam use. The improvement in mercury hygiene practice led to a decrease in mercury exposure among oral health personnel in Norway. (Svendsen, et al., 2010). The inclusion of BMPs for dental amalgam use; improve not only the environmental impact of dental amalgam use but also the health of oral health personnel.

In South Africa, day-to-day implementation of the best management practices for amalgam falls under the scope of practice of dental assistants. Dental assistants, among other responsibilities, are required to prepare and manage the dental clinic environment, before, during and after patient care; including biological, medical, and bio-hazardous waste management within the dental environment, (Ministry of Health, 2012).

The need to limit mercury releases to the environment at local, regional, and global levels, led to the establishment of policies and regulations, which affect dental usage of amalgam (UNEP, 2013). A strong focus in developed countries is on collecting and recycling amalgam waste products. Technical challenges include concern for residual materials associated with the use, disposal of packaging, chair-side traps, vacuum pump filters, separators, plumbing, sewer systems, crematoriums, and cemeteries as well as other sites. Developing countries still face considerable challenges in waste management efforts, which add to the cost of treatment (Bayne, et al., 2013).

Concerns on the environmental effects of mercury lead to banning of dental amalgam in Sweden, Norway, and Denmark, and restriction of use in Germany, Finland, Bulgaria, Mongolia, Vietnam, Thailand, and Japan (UNEP, 2016).

In the year 2001, the Canadian Council of Ministers of the Environment (CCME) endorsed the Canada-wide Standard on Mercury for Dental Amalgam Waste. The standard established best management practices aimed to achieve a 95% national reduction in mercury releases from dental amalgam waste (CCME, 2001).

In the United States, the Environmental Protection Agency (EPA) implemented The Dental Office Point Source Category, a technology-based Pre-treatment Standards under the Clean Water Act to reduce discharges of mercury from dental offices. The ruling came into effect on July 14th, 2017 and it requires the use of ANSI/ADA Specification 108/ ISO 11143 compliant amalgam separator and implementation of two of the best management practices recommended by the American Dental Association (EPA, 2017).

The Australian Dental Association issued a policy statement 6.11 on dental waste management in April 2007. In its most recent amendment of April 2016, the policy statement addresses the issue of environmental contamination of mercury by dental amalgam by providing guidelines for amalgam waste management based on the American Dental Association's BMPs for dental amalgam use (ADA, 2016).

In the European Union, the European Parliament Council of 17 May 2017, promulgated regulation (EU) 2017/852) on mercury, with provisions for dental amalgam (EU, 2017).

Under the provisions

- Dental amalgam shall not be used for dental treatment of deciduous teeth of children under 15 years of age, and of pregnant or breastfeeding women from 1 July 2018.
- Dental amalgam shall only be used in pre-dosed encapsulated form. The use of mercury in bulk form by dental practitioners shall be prohibited from 1 January 2019,
- Member State shall set out a national plan concerning the measures it intends to implement to phase down the use of dental amalgam by 1 July 2019
- Operators of dental facilities in which dental amalgam is used or dental amalgam fillings or teeth containing such fillings are removed, shall ensure that their facilities are equipped with amalgam separators from 1 January 2019
- Dental practitioners shall ensure that their amalgam waste, including amalgam residues, particles and fillings, and teeth, or parts thereof, contaminated by dental amalgam, is handled and collected by an authorised waste management establishment or undertaking.
- Dental practitioners shall not release directly or indirectly such amalgam waste into the environment under any circumstances. (EU, 2017)

The East Africa Dental Amalgam Project (EADAP) was a joint program between UNEP, WHO and various international and national stakeholders. The project aimed at demonstrating the phase-down of amalgam in a low income setting countries. The first phase, in 2013, examined supply and trade patterns, raised awareness of preventive dental care, encouraged alternatives and promoted environmentally sound management practices for dental amalgam waste.

The survey found high awareness (80%), low adherence (40%) of amalgam best management practices among dentists in East Africa, with only 10% of dentists using an amalgam separator (UNEP and WHO, 2014). Among the greatest challenges in dental amalgam waste management, were lack of mercury recovery facilities and the high cost of imported amalgam separators. The quoted price of an amalgam separator used in a five chair dental clinic was US$1000 and for a separator used for up to fifteen chairs $3000. (UNEP, 2013).

The South African Dental Association recognised the importance of the prevention of environmental contamination by mercury and issued a position statement on the use of amalgam. The Association recommends the use of best practices when placing amalgam, including the use of pre-capsulated amalgam, chair-side traps, vacuum filters, and ISO 11143 certified amalgam separators in dental clinics (SADA, 2014). The regulations and guidelines on healthcare waste in South Africa are not up-to-date with the best current management practices for dental amalgam use.

The rationale for the study

The amount of dental amalgam procured, the levels of mercury in the dental wastewater flow, and adherence to best management practices for amalgam use at Wits Oral Health Centre (WOHC) are unknown.

Records of dental amalgam procurement will provide an insight on patterns of dental amalgam demands, while the levels of mercury in dental wastewater will inform on potential contamination emanating from dental amalgam use at WOHC.

The application of best management practices for amalgam use will serve to highlight the state of dental amalgam waste management practices at WOHC.

AIM

The study aimed to describe the procurement patterns of dental amalgam, determine mercury levels in wastewater and investigate the application of best management practices for dental amalgam use at the WOHC.

OBJECTIVES

The objectives of the study were to:

1. Determine the dental amalgam procurement patterns each year from the year 2009 to the year 2017.
2. Determine levels of mercury in dental wastewater grab samples from the polyclinics, and multi-skills techniques laboratory of the WOHC.
3. Correlate wastewater mercury levels with amalgam use at the WOHC.
4. Investigate the application of best management practices in the clinic and skills laboratory at the WOHC.

CHAPTER THREE

MATERIALS AND METHODS

3.1. STUDY SETTING

The Wits Oral Health Centre (WOHC), of the School of Oral Health Sciences, The University of the Witwatersrand, resides within the Charlotte Maxeke Johannesburg Academic Hospital (CMJAH).

The Wits Oral Health Centre (WOHC) provides clinical services and training through four polyclinics, a multi-skills technique laboratory, and various support sections. The layout in the polyclinics and the multi-skills techniques laboratory at the time of data collection was as follows; Polyclinic 1 (P1) with ten dental chairs in the main clinic area and thirteen chairs in eleven private treatment rooms, Polyclinic 2 (P2) and Polyclinic 3 (P3) were equipped with 25 dental chairs each, Polyclinic 4 (P4) was equipped with 16 dental chairs, and the Multi-Skills Techniques Laboratory (MSTL) had 40 working stations.

The polyclinics were used for the following treatment and training programs; P1 - oral and maxillofacial surgery, operative dentistry, paediatric dentistry and prosthodontics, orthodontics, and periodontology/implantology, P2 – assessment and emergency clinic, oral and maxillofacial surgery, operative dentistry and prosthodontics, P3 – oral medicine and periodontics, operative dentistry, orthodontics, paediatric dentistry and prosthodontics and P4 was used oral hygiene and occasionally operative dentistry. The operative dentistry pre-clinical program was conducted in the MSTL. The polyclinics and the MSTL were managed by controllers responsible for providing oversight and leadership in the day-to-day activities and ensuring adherence to standard operating procedures and guidelines.

In the centre, the central procurement section was responsible for all the procurement services of supplies and materials necessary for training and clinical operations.

The restorative procedures using dental amalgam were performed in the P1, P2, P3, occasionally in the P4 and in the MSTL. The flow of dental wastewater from WOHC polyclinics and the MSTL discharged to the main sewage line through four 50mm main vacuum lines located on the fourth inter-floor (maintenance level) of the CMJAH. Two vacuum pump stations each for P1, P2, P3, and MSTL evacuated wastewater generated during operations. In the P4, the vacuum supply scavenged from the main vacuum pipes serving P2 and P3. The model of vacuum pumps used at WOHC was the Midmark, Classic-Series® CV10 Wet-Ring twin. A technician, permanently stationed at the WOHC provided maintenance and repair services to the vacuum pumps. The P4 was excluded from the study due to the low number of dental amalgam restorative procedures and the unfavourable vacuum system layout.

3.2. STUDY DESIGN

The determination of dental amalgam procurement trends was through a retrospective study. The determination of the levels of mercury in wastewater samples and dental amalgam use at the WHOC was through a cross-sectional study. The determination of the application of best management practices for dental amalgam use was through a cross-sectional study using structured interview of the clinic controllers for P1, P2, P3, and clinic technician.

3.3. DENTAL AMALGAM PROCUREMENT TRENDS AT THE WOHC

Records of dental amalgam procured from April 2009 to March 2018 were accessed at the procurement office and central stores of the WOHC. Data collected from the records included the number of dental amalgam boxes procured and the number of dental amalgam boxes issued from the central procurement office to the WOHC polyclinics from April 2013 to March 2018.

The number of dental amalgam boxes issued, the number of capsules, i.e. the clinical utilisation unit, and the amount of dental amalgam calculated was entered into the data collection sheet for assessment of trends (Annexure A, & B).

3.4. DETERMINATION OF THE LEVEL OF MERCURY IN WASTEWATER AND CORRELATION WITH DENTAL AMALGAM USE

The study was planned for a six-day operational week at WOHC, with the three polyclinics and the MSTL in full use.

3.4.1. Determination of mercury level in wastewater grab samples

The wastewater collection was facilitated through the diversion of the flow using a collection apparatus made of sampling valve, vacuum hose with a lower ball valve and a 20L container (Figure 3.1).

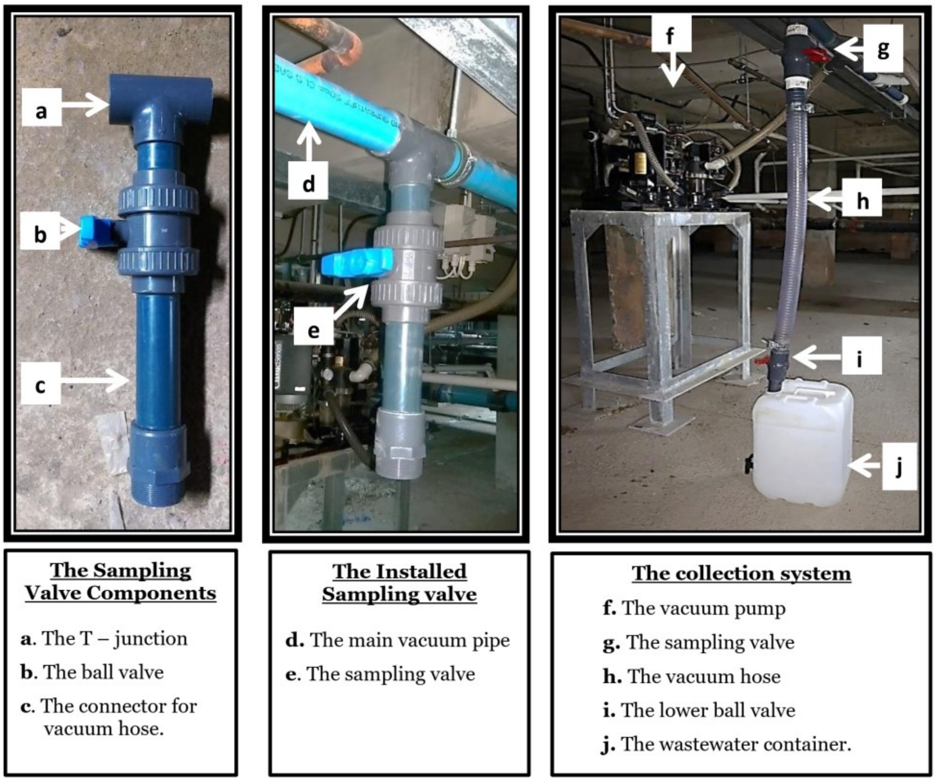

Figure 3.1 The wastewater collection system at WOHC

Eight sampling valves were installed on the four main vacuum lines at a location proximal to the suction pumps stations, two each for P1, P2, P3, and MSTL (Figure 3.2). Technicians from the Gauteng Department of Infrastructure Development installed the sampling valves.

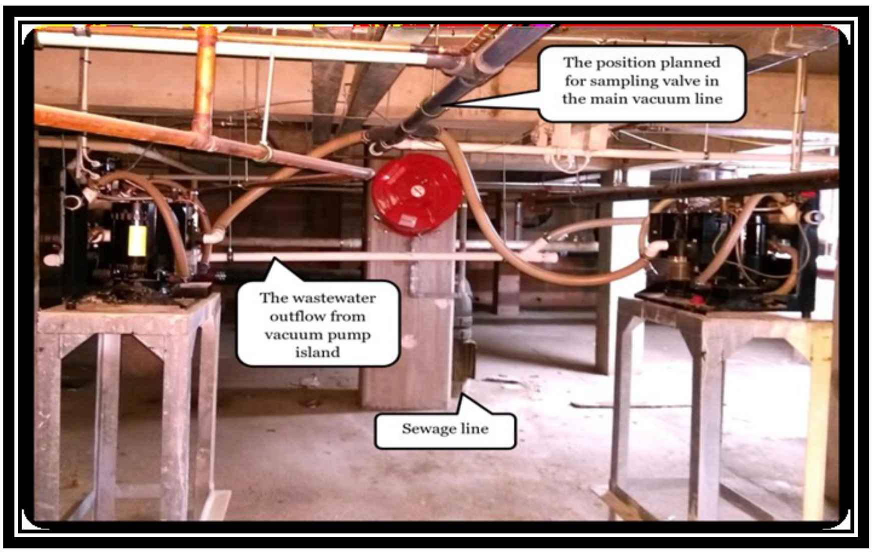

Figure 3.2 The location of the wastewater collection system

3.4.2. Pilot study

The wastewater collection system was tested and optimised for the layout and vacuum pressure characteristics at Wits Oral Health Centre. Three trials were conducted to determine the volume of wastewater produced in the polyclinics and the MSTL, compared the wastewater volume to the required sample volume, and established the collection efficiency of the system.

The collection of wastewater was achieved by turning off the lower vacuum hose valve and opening the sampling valve at 07:30 am. The system was checked every 60 minutes and the wastewater collected in the vacuum hose emptied into a 20L wastewater container, by closing the sampling valve and opening the lower vacuum hose valve. The 20L collection container was sealed between collections.

The first trials involved the collection of wastewater produced on the first day of the week (Monday) to determine the total volume produced, against the required sample volume of 500mls (Figure 3.2).

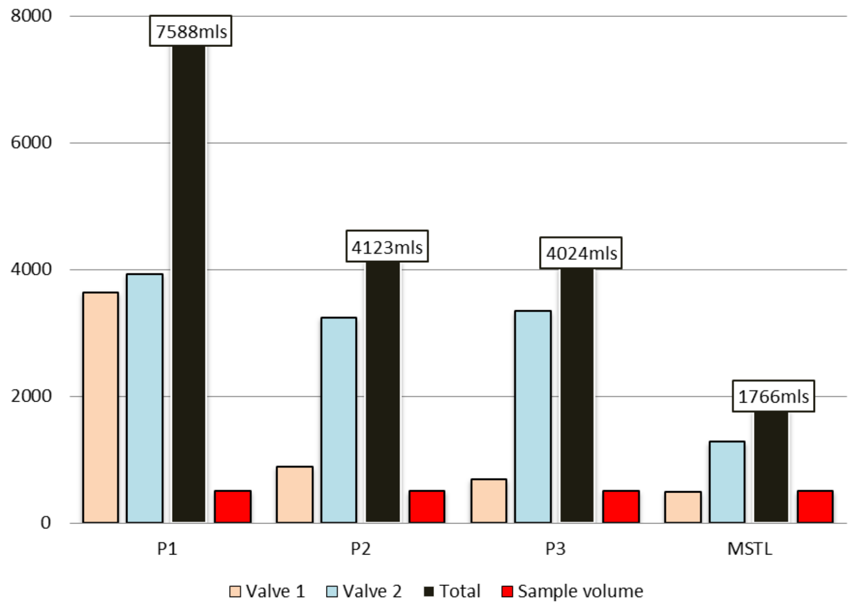

Figure 3.3 The wastewater collection in the first trial

The second trial was similar to the first trial. All the wastewater produced on the fourth day of the week (Thursday) was collected to determine the volume, compared with the required sample volume of 500mls. The wastewater collected from the MSTL was below the sample volume. On this particular week, the MSTL operated on the first day of the week (Monday).

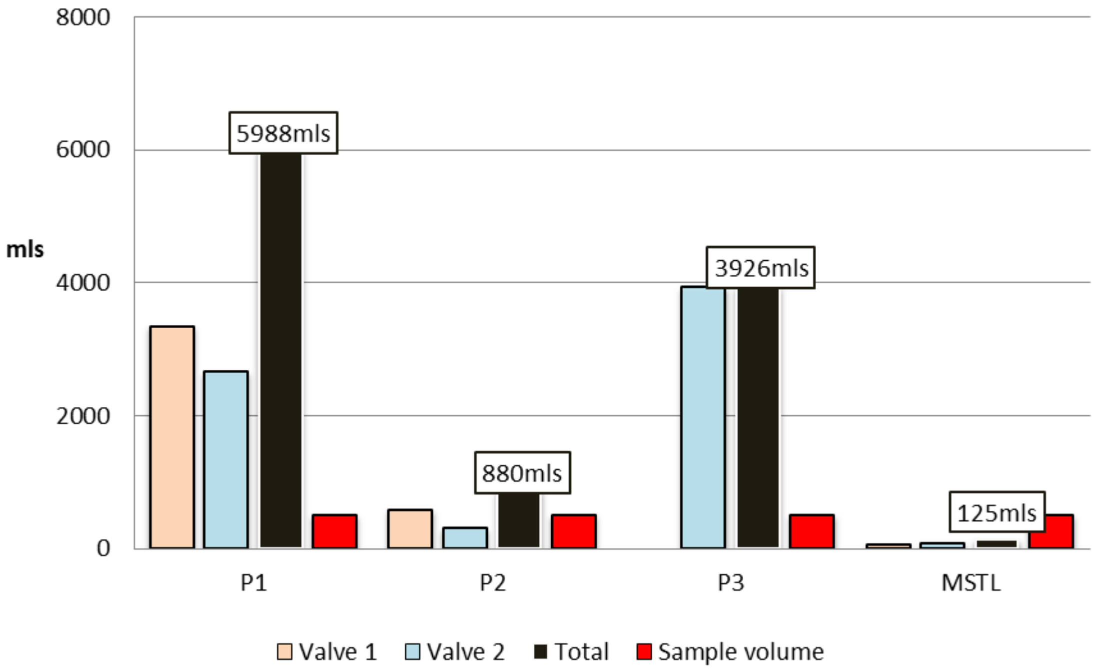

Figure 3.4 The wastewater collection in the second trial

The third trial involved testing the collection efficiency of the system at the MSTL. The lower vacuum hose valve was turned off, and the sampling valve opened at for collection. A test volume of 500mls was introduced into the vacuum system through the high volume evacuator tip of the first station on the first workbench (which was closest to the vacuum pumps), and the first station on the sixth workbench (which was furthest from the vacuum pumps).

.After two hours, the sampling valve was closed and lower vacuum hose valve opened and the amount of wastewater collected emptied into a measuring cylinder.

The amount of wastewater collected was measured and compared to the initial volume. System losses from the workbench furthest from the vacuum pump were slightly higher, due to the shorter time between the introduction and collection and longer distance to the vacuum pump.

Table 3.1 The wastewater collection efficiency

Workbench	1	6	1	6	1	6	1	6
Test volume	500mls	500mls	500mls	500mls	500mls	500mls	500mls	500mls
Collected volume	520mls	450mls	470mls	380mls	480mls	350mls	485mls	340mls
Capture Efficiency	104 %	90%	94%	76%	96%	70%	97%	68%

At the end of the trials, the collections system components were removed, cleaned with water and soap, and rinsed with de-ionised water.

The collection of wastewater during the study commenced by turning off the lower vacuum hose valve and opening the sampling valve at 07:30 am. The system was checked every 60 minutes and the wastewater collected in the vacuum hose emptied into a 20L wastewater container, by closing the sampling valve and opening the lower vacuum hose valve. The 20L collection container was sealed between collections.

At the end of each working day, the collected wastewater was poured into a plastic basin, manually agitated to obtain a uniform mixture. A test sample was obtained by grabbing the wastewater from the basin using a 500ml measuring jar. This was done for each polyclinic and MSTL. The collected 500ml sample was kept in polyethene

bottles previously rinsed with deionized water. The remaining wastewater was measured to determine the total amount of wastewater collected in each mainline per day. The collected wastewater was discharged to the main sewage line in the 4^{th} inter-floor. The information was entered into a data collection sheet (Annexure C).
The control samples were 500ml 'point-of-use water samples' obtained from the distillers installed at polyclinics 1, 2 and 3, and from the three-way air/water syringe in the MSTL. The total number of samples obtained was 24 test samples and 24 control samples. The obtained samples were preserved by the addition of 10mls of 32% hydrochloric acid, followed by storage in a refrigerator at 4°C. The measuring cylinders, funnels and 20L wastewater containers used for test sample collection were thoroughly washed with soap and water after each collection, rinsed with deionised water dried and stored ready for next day collection.

At the end of the study period, the collected wastewater samples were removed from the refrigerator, placed in a cooler box filled with ice, and transported to the Council for Scientific and Industrial Research (CSIR) - Water and Environment Laboratory in Pretoria, for analysis. The determination of mercury levels in wastewater was done using the USEPA method 245.7 - Cold Vapour Atomic Absorption Spectroscopy.

3.4.3. Dental amalgam use

The use of dental amalgam was determined by observation of restorative procedures performed in polyclinic 1, 2 and 3, and the MSTL during the study period. The information on the number of dental amalgam restorations removed or placed, the number of surfaces and the number and type of dental amalgam capsule used was recorded in a data collection sheet including the amount of dental amalgam calculated in milligrams (Annexure C).

3.5. BEST MANAGEMENT PRACTICES IN THE POLYCLINICS AND MULTI SKILLS TECHNIQUES LABORATORY

The application of best management practices for dental amalgam was determined through a structured interview with the clinic controllers for polyclinics 1, 2, 3 and the WOHC technician. The interview questionnaire was based on the practical guide to integrating best management practices (WHO, 2009) into the dental practice, with the main areas of focus including use of amalgam capsules, retention and storage of amalgam waste, equipment maintenance, prevention of releases, and disposal of dental amalgam waste. The interview was conducted on the sixth day of the study. (Annexure D)

3.6. STATISTICAL ANALYSES

The data was captured on a Microsoft Excel spreadsheet. The descriptive statistics of, median, interquartile ranges frequencies, percentages, and proportions were used to summarize the data. Trendline analysis was used to determine procurements trends. The Spearman correlation analysis through Stata 15 was used to determine the relationship between dental amalgam used and mercury levels in wastewater. The level of significance was set at $P<0.05$.

3.7. ETHICAL CONSIDERATIONS

Ethical clearance was obtained from the Human Research and Ethics Committee (HREC) of the University of the Witwatersrand with a clearance number: M170908 (Annexure F). Further approval to conduct the study was sought from The Hospital Research and Risk Committee (Wits Oral Health Centre) and was obtained before data collection.

CHAPTER FOUR

RESULTS

4.1. DENTAL AMALGAM PROCUREMENT AT WOHC.

The dental amalgam restorative material procured at WOHC was the Permite brand, manufactured by SDI Australia. The dental amalgam was packaged in predosed capsules of one/two spill sizes, with regular setting time and packed in a box of 50 capsules. The Permite dental amalgam alloy is a non-gamma 2 admix alloy with a composition of 56% Silver, 27.9% Tin, 15.4% Copper, 0.5% Indium, and 0.2% Zinc. In the predosed capsules, the Permite constitutes 52.1% alloy and the 47.9% mercury. The available setting speed options are fast, regular, slow, and extended carving time. The one spill size capsule contains 400mg alloy and 364mg mercury, while the two-spill capsule contains 600mg alloy and 552mg mercury (SDI Limited, 2016).

Over the nine years, the WOHC Procurement unit procured 454 boxes of permite dental amalgam, consisting of 219, one-spill capsule boxes and 235, two-spill capsule boxes. The procured boxes contained 22700 dental amalgam capsules, of which 51.8% were 2-spill capsules and 48.2% 1-spill capsules. For the duration of the study period, the number of one-spill capsules procured yearly ranged from zero in years 2013 and 2014 to 3000 in years 2012 and 2017, while for two-spill capsules, the number procured ranged from zero in the year 2014 to 3000 capsules in the year 2016.

The median number of capsules procured per year were 700 for one-spill capsules and 1500 for two-spill capsules for this period (Figure 4.1).

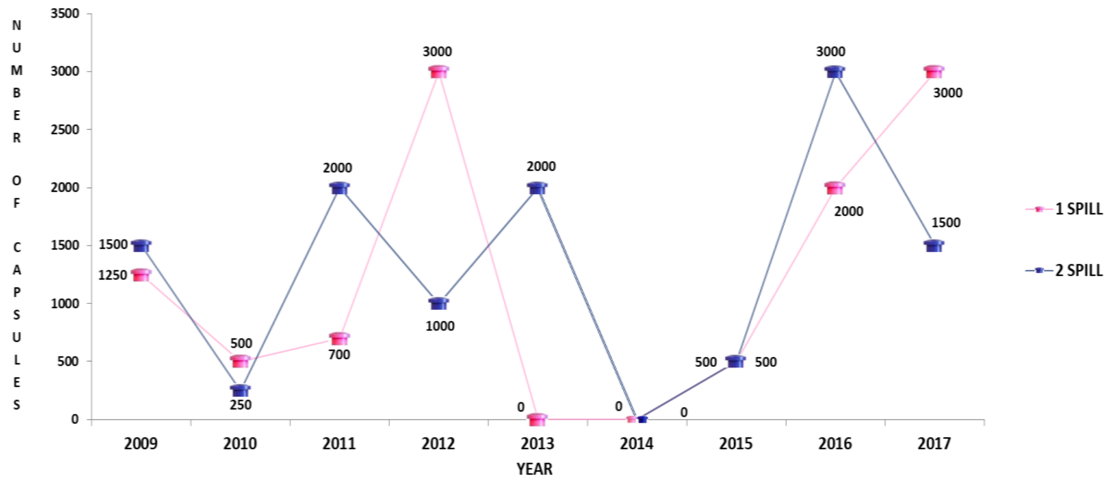

Figure 4.1 The number and type of dental amalgam capsules procured yearly at WOHC from 2009 to 2017

The predosed dental amalgam capsules procured for nine years, contained a total of 21.91 kilograms (kg) of Permite dental amalgam, consisting of 11.43 kg of alloy and 10.47 kg of mercury (Figure 4.2).

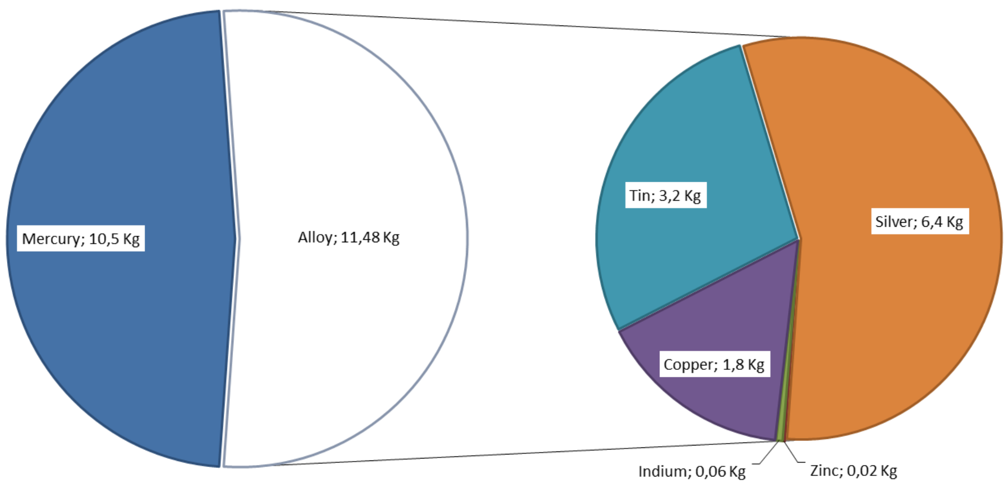

Figure 4.2 The compositional weight of dental amalgam procured at WOHC from 2009 to 2017.

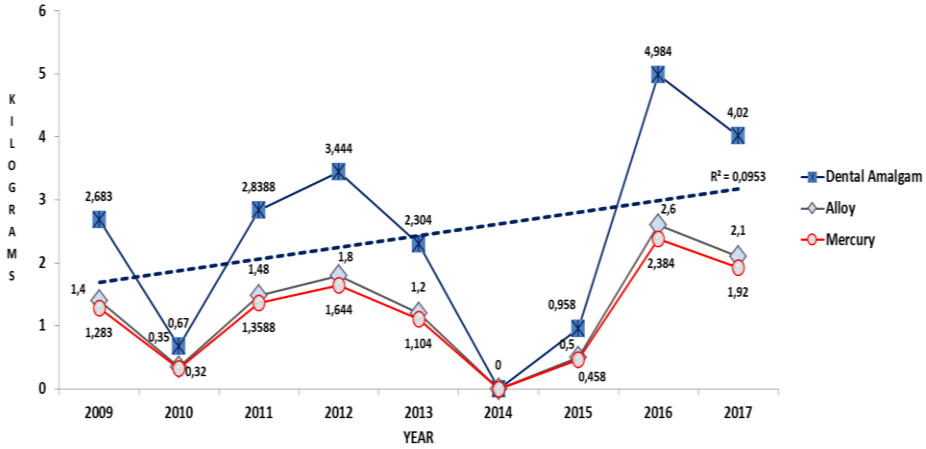

Figure 4.3 The amount in kilograms of dental amalgam and dental amalgam constituents procured yearly by WOHC 2009 to 2017.

The trendline analysis revealed a slight increase in dental amalgam procured by the WOHC from the year 2009 to 2017 (0.1847, R^2 0.0953) (Figure 4.3)

4.2. MERCURY LEVELS IN WASTEWATER AND DENTAL AMALGAM USE AT WOHC

The number of patients seen at P1, P2, and P3 during the seven days of the study was 820, of which 163 were restorative patients. The number of dental amalgam procedures recorded was 28, comprising removal of 9 amalgam restorations with 17 surfaces and the placement of 19 amalgam placements with 29 surfaces. The number and type of amalgam capsules used in P1, P2, and P3 were 41 one-spill and seven two-spill capsules. The fourth and fifth-year students performed the amalgam restorative procedures.

The MSTL was used on days 1, 3, 5 and 7 of the study. Fifty-seven restorations consisting of 69 surfaces were removed and 106 restorations with 146 surfaces placed. The number and type of amalgam capsules used were 67 one-spill capsules and 146 two-spill capsules (Figure 4.4).

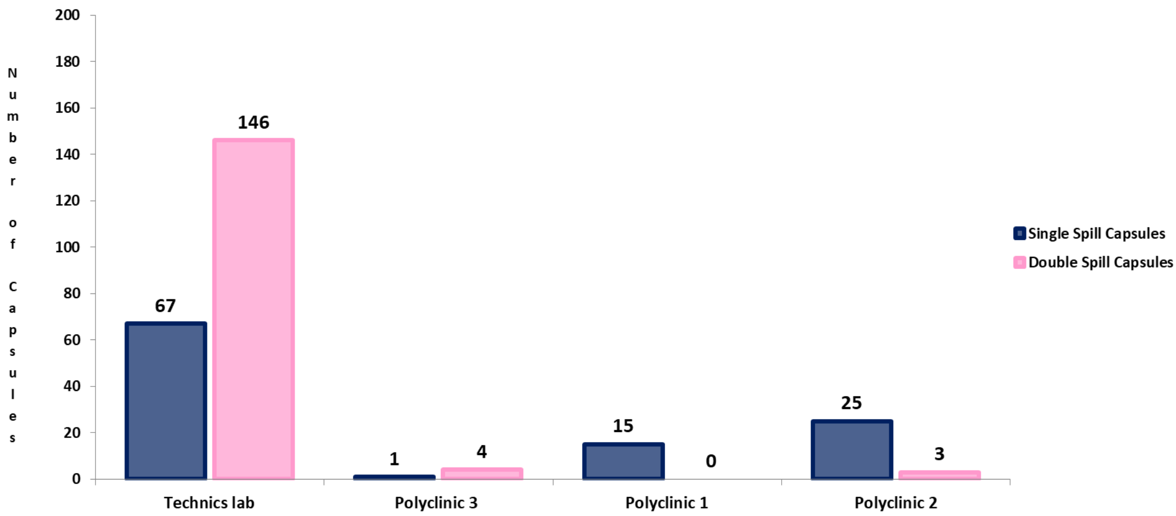

Figure 4.4 The number of dental amalgam capsules used in the polyclinics and the MSTL

The amount of dental amalgam used in grams in different sections of WOHC is described as MSTL 219.4gm (85%) and P1, P2 and P3 39.4gm (15%) as shown in Figure 4.5.

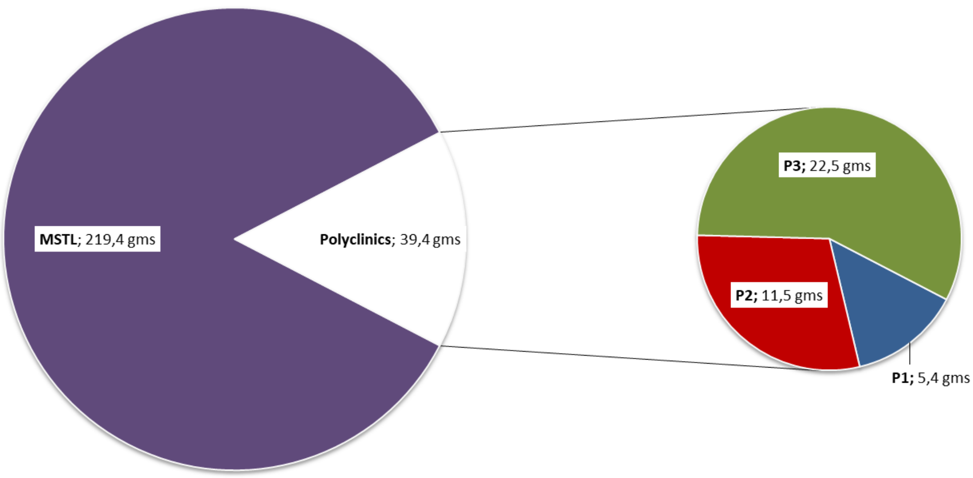

Figure 4.5 The amount of dental amalgam in grams used in the polyclinics and the MSTL

4.2.1 Polyclinic 1(P1)

The number of patients seen in P1 during the study period was 211, 21 patients received restorative treatment and the clinic generated 30.62 litres of wastewater (Table 4.1).

Table 4.1 The distribution of patients, restorative procedures, amalgam procedure, amalgam used, wastewater generation, and mercury concentration in control and wastewater samples from P1

Day of the study	1st	2nd	3rd	5th	6th	7th	Total
Patients (no)	37	67	18	59	18	12	**211**
Restorative procedures (no)	3	4	3	6	6	3	**25**
Amalgam procedures (no)	2	4	0	0	0	0	**6**
One-spill capsules used (no)	0	1	0	0	0	0	**1**
Two-spill capsules used (no)	2	2	0	0	0	0	**4**
Total amalgam used (mg)	2304	3068	0	0	0	0	**5372**
Wastewater in (ml)	4600	5720	11700	800	4200	3600	**30620**
Control -mercury conc. (µg/L)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Wastewater- mercury conc.(µg/L)	3130	18843	8094	4457	2436	2170	

The median mercury levels in wastewater generated in P1 was 3793.5µg/L with the interquartile range of 8412 µg/L (2369.5µg/L – 10781.25µg/L).

4.2.2 Polyclinic 2 (P2)

The number of patients seen in P2 during the study period was 309; 74 patients received restorative treatments, and the clinic generated 45.55 litres of wastewater (Table 4.2).

Table 4.2 The distribution of patients, restorative procedures, amalgam procedure, amalgam used, wastewater generation, and mercury concentration in control and wastewater samples from P2

Day of the study	1st	2nd	3rd	4th	5th	6th	7th	Total
Patients (no)	80	85	56	5	20	42	21	**309**
Restorative procedures (no)	8	14	8	5	5	16	18	**74**
Amalgam procedures (no)	1	5	0	0	0	3	2	**11**
One-spill capsules used (no)	0	7	0	0	0	5	3	**15**
Two-spill capsules used (no)	0	0	0	0	0	0	0	**0**
Total amalgam used (mg)	0	5348	0	0	0	3820	2292	**11460**
Wastewater in (ml)	6700	6350	9800	800	5100	10700	6100	**45550**
Control -mercury conc. (μg/L)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Wastewater- mercury conc.(μg/L)	1449	1134	7135	3342	2881	2857	1508	

The median mercury levels in wastewater generated in P2 was 2182.5μg/L with the interquartile range of 2574μg/L (1370.25μg/L – 3944.5μg/L).

4.2.3 Polyclinic 3 (P3)

The number of patients seen in P3 during the study period was 300. A total of 68 restorative procedures were performed, and the amount of wastewater generated was 32.55 litres (Table 4.3).

Table 4.3 The distribution of patients, restorative procedures, amalgam procedure, amalgam used, wastewater generation, and mercury concentration in control and wastewater samples from P3

Day of the study	**1st**	**2nd**	**3rd**	**5th**	**6th**	**7th**	**Total**
Patients (no)	46	59	41	48	37	69	**300**
Restorative procedures (no)	13	15	15	7	14	4	**68**
Amalgam procedures (no)	1	10	2	0	0	0	**13**
One-spill capsules used (no)	0	18	7	0	0	0	**25**
Two-spill capsules used (no)	1	2	0	0	0	0	**3**
Total amalgam used (mg)	1152	16056	5348	0	0	0	**22556**
Wastewater in (ml)	4200	7550	6400	5400	6600	2400	**32550**
Control -mercury conc. (µg/L)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Wastewater- mercury conc.(µg/L)	3750	4553	9047	4509	1385	1048	

The median mercury levels in wastewater generated in P3 was 4129.5µg/L with the interquartile range of 4376µg/L (1300.75µg/L - 5676.5µg/L).

4.2.4 Multi Skill Techniques Laboratory (MSTL)

The first-year students used the MSTL, for removal and placement of class I amalgam restorations on the first day of the study. The second-year students used the MSTL for removal and placements of class II amalgam restorations on the third, fifth and seventh day. The number of dental amalgam procedures performed was 163, and the amount of wastewater generated was 6.53 litres (Figure 4.4).

Table 4.4 The distribution of students, restorative procedures, amalgam procedure, amalgam used, wastewater generation, and mercury concentration in control and wastewater samples from MSTL

Day of the study	1st	2nd	3rd	5th	6th	7th	Total
Students using MSTL (no)	48	0	27	27	0	27	**129**
Amalgam procedures (no)	82	0	10	52	0	19	**163**
One-spill capsules used (no)	37	0	2	23	0	5	**67**
Two-spill capsules used (no)	50	0	27	31	0	38	**146**
Total amalgam used (mg)	85868	0	32632	53284	0	47596	**219380**
Wastewater in (ml)	1900	400	750	1400	380	1700	**6530**
Control -mercury conc. (µg/L)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Wastewater- mercury conc.(µg/L)	85373	17371	48572	67744	37943	108762	

The median mercury levels in wastewater generated in MSTL was 58158µg/L with the interquartile range of 91391µg/L (32800µg/L -91220.25µg/L).

The total amount of wastewater collected from the WOHC was 108.72 litres (Figure 4.6)

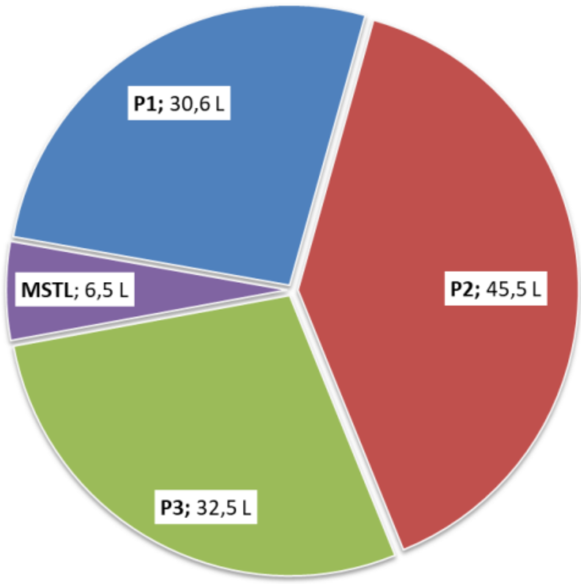

Figure 4.6 The wastewater generation from the polyclinics and MSTL of WOHC

The levels of mercury (Annexure F) in all the control samples was <1.0 µmg/L, while the levels of mercury from the wastewater samples ranged from a minimum of 1048 µmg/L in P2 to a maximum of 108762 µmg/L in MSTL (Figure 4.7).

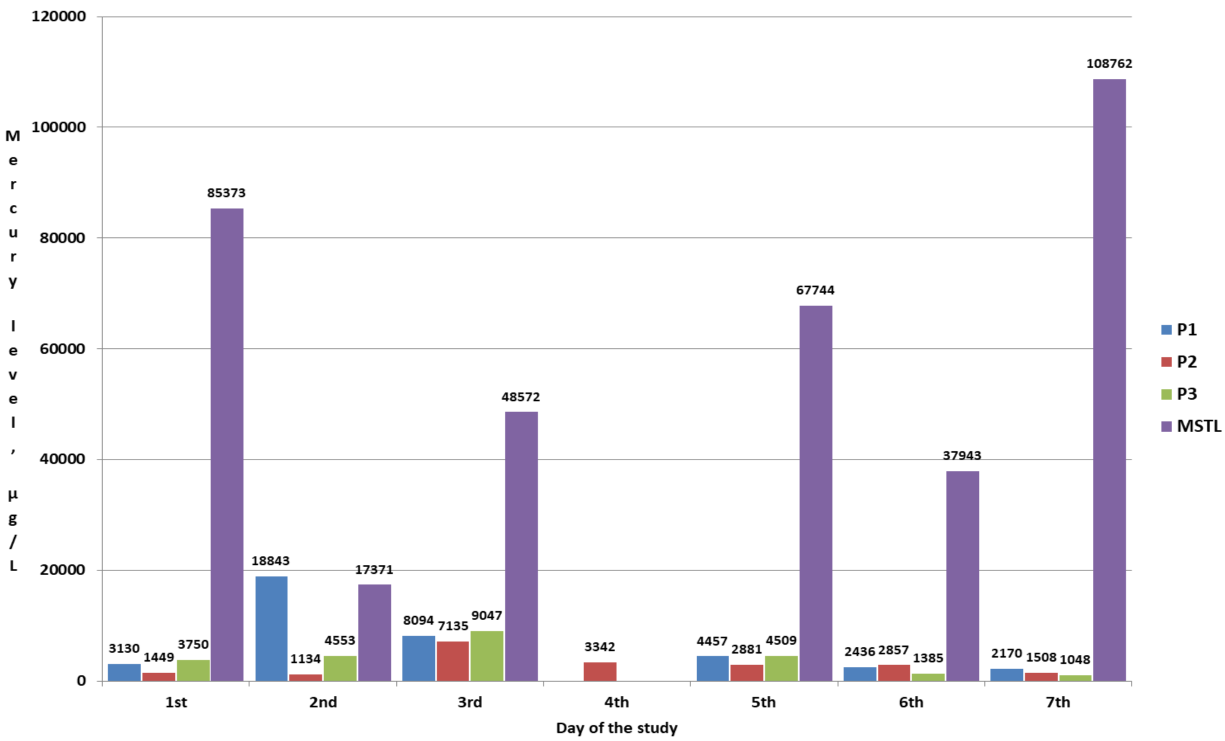

Figure 4.7 The levels of mercury in wastewater from different sources at WOHC

The total amount of dental amalgam used at WOHC during the study period was 258,768 mg. The amount of amalgam used and corresponding mercury concentration in wastewater are summarized in Table 4.5.

Table 4.5. Dental amalgam restorative material used and mercury levels in wastewater for the polyclinics and MSTL.

	Dental amalgam used- mg	Mercury in wastewater - µg/L
P1	2304	3130
	3068	18843
	0	8094
	0	4457
	0	2436
	0	2170
P2	0	1449
	5348	1134
	0	7135
	0	3342
	0	2881
	3820	2857
	2292	1508
P3	1152	3750
	16056	4553
	5348	9047
	0	4509
	0	1385
	0	1048
MSTL	85868	85373
	0	17371
	32632	48572
	53284	67744
	0	37943
	47596	108762

There was a statistically significant ($p=0.0181$), moderate correlation between dental amalgam used and mercury level in wastewater ($r_s = 0.4688$).

4.3. THE APPLICATION OF BEST MANAGEMENT PRACTICES AT THE WOHC

The application of BMPs for amalgam use at the polyclinics and the MSTL of WOHC are summarized (Table 4.6).

Table 4.6 The application of best management practices at WOHC

Procured dental amalgam capsules				
PRACTICE	**P1**	**P2**	**P3**	**MSTL**
The dental amalgam available for use is of various spill sizes	Yes	Yes	Yes	Yes

Non-contact amalgam and used amalgam capsules				
PRACTICE	**P1**	**P2**	**P3**	**MSTL**
Non – contact amalgam/used amalgam capsules are stored in a wide mouthed, airtight, marked container is marked **"Non-contact Amalgam for Recycling"**	Yes	Yes	Yes	Yes

Contact Amalgam, Extracted teeth, Chair-side Traps, Vacuum filters, Amalgam separators, Line cleaners				
PRACTICE	**P1**	**P2**	**P3**	**MSTL**
Contact amalgam is stored in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**	No	No	No	No
Extracted teeth with amalgam fillings are stored in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**	No	No	No	No
The re-usable traps contents are emptied in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**	No	No	No	No
The re-usable traps are rinsed in running water	Yes	Yes	Yes	Yes
The disposable traps are removed with contents and placed in a wide mouthed airtight containers **marked "Contact Amalgam for Recycling"**	No	No	No	No
The vacuum pump filter contents are emptied in a marked container wide mouthed airtight containers marked **"Contact Amalgam for Recycling"**	No	No	No	No
The vacuum pump filter and contents are emptied in a marked container wide mouthed airtight containers marked **"Contact Amalgam for Recycling"**	No	No	No	No

Amalgam separators are installed in the clinic's wastewater system	No	No	No	No
Disinfectant/ Line cleaners used in the clinic does not contain chlorine or bleach	No	No	No	No

Disposal				
PRACTICE	**P1**	**P2**	**P3**	**MSTL**
The wide mouth, airtight, marked containers filled with contact, non-contact and extracted teeth containing amalgam are disposed for recycling	No	No	No	No
The dental amalgam waste is handled by a recycler known to the clinic, and a disposal certificate is issued	No	No	No	No

CHAPTER FIVE
DISCUSSION

The objectives of this study were, to determine the dental amalgam procurement patterns, determine levels of mercury in dental wastewater samples and correlate the mercury levels with dental amalgam use and lastly to investigate the application of BMPs for dental amalgam use at WOHC. The main findings of the study were, WOHC still uses a substantial amount of mercury-containing dental amalgam, resulting in high concentration of mercury in wastewater, and the BMPs for dental amalgam use are not adequately applied.

5.1 DENTAL AMALGAM PROCUREMENTS AT WOHC

Dental amalgam restorative material continues to play an essential role in the pre-clinical training of dental students and provision of restorative treatment at the Wits Oral Health Centre (WOHC). There was a slight increase in the amount of dental amalgam procured during the study period. This increase might be due to an increased intake of first-year dental students. The number of first-year students doubled from 25 students in the year 2011 to 50 students in the year 2014.

The use of regular setting amalgam capsules for training may contribute to the high amount of dental amalgam used in the MSTL. The introduction of extended carving time (ECT) and slow carving (SC) dental amalgam formulations (The Dental Advisor, 1998), which afford the operator longer working time may lower the amount of dental amalgam used in the MSTL.

This study suggests that the bulk of dental amalgam procured at WOHC is used for preclinical training with limited use in the clinical setting as part of student training. This finding appears in line with recent reports of a decline in dental amalgam use among private dentists in South Africa (Adam & Naidoo, 2017). The demand of aesthetic restorations, the reduced need for cavity preparations, and the strengthening effect of resin composite on the remaining tooth led to a gradual shift from dental amalgam to resin composite in preclinical curricula at Nijmegen Dental School (Roeters, et al., 2004). There is a need for further investigations on the demand and use of dental amalgam among dentists in South Africa.

The considerable variations in yearly procurement of dental amalgam capsules and spill type observed in this study revealed a need for accurate dental amalgam demand forecasting. The procurement office should establish a stable dental amalgam inventory based on realistic lead times and safe stock volume. The oversupply in dental amalgam inventory not only locks capital in a slow-moving product but also carries a risk of stock losses and potential environmental contamination during long-term storage.

5.2 MERCURY LEVELS IN WASTEWATER GRAB SAMPLES.

The wastewater generated by training and restorative operative care delivery at the WOHC contains significant levels of mercury from dental amalgam. The total mercury concentration in wastewater from the WOHC was similar to that reported in a previous study: 45182.11 µg/L (n=13; SD=68562.42) for the chair-side samples, 13439.13 µg/L (n= 13; SD=9898.91) for the 107-chair clinic and 5350.74 µg/l (n=12; SD =2672.94) for the 30-chair clinic (Stone, et al., 2003).

The mercury in all wastewater samples from WOHC is higher than the maximum concentration limit of 1,0mg/L for mercury allowed in any sewage, industrial effluent or other liquid discharged to the sewer by the City of Johannesburg Metropolitan Municipality – Water services by-laws. Under the same by-laws, the discharge of wastewater with a high concentration of mercury is not acceptable as it may prejudice sewage effluent re-use and affect water downstream to treated sewage effluent discharge (COJMM, 2003).

The City of Tshwane Metropolitan Municipality in the Gauteng Province, which hosts two dental schools with a similar group of students and curriculum to WOHC, but slightly higher numbers, has less stringent maximum concentration limits. In the City of Tshwane Metropolitan Municipality by-laws, the maximum concentration for mercury in wastewater discharge to the city sewers is 5mg/L (COTMM, 2014). The less stringent mercury concentration qualifies 15 out of 25 samples of wastewater from the WOHC. There is a need for standardisation of the maximum allowable concentration of mercury in Gauteng Province to ensure compliance and benefits to the environment.

5.3 MERCURY LEVELS IN WASTEWATER AND DENTAL AMALGAM USE.

The mercury levels in wastewater samples obtained from the polyclinics were lower compared to the MSTL by a factor of 10. The lower mercury levels in the polyclinics were due to lower dental amalgam use and procedures other than those using dental amalgam. The lower wastewater mercury concentration in clinics not offering or with lower numbers of dental amalgam treatment compared to those, which offer mostly dental amalgam treatment, was described by Al Kawas (Al Kawas, et al., 2008).

The moderate correlation between the amount of dental amalgam used in the polyclinics and the MSTL and level of mercury in wastewater can be attributed to higher settling velocities of dental amalgam particles in the wastewater flow. The detection of mercury in the wastewater samples due to continuous leaching of dental amalgam particles was described as the main reason for lack of correlation between dental amalgam use and mercury concentration in dental wastewater (Arenholt-Bindslev, 1998). An average mercury deposition of 1097 mg per kilogram of copper pipe with a potential for solubilisation and release by disinfectant has been reported (Stone, et al., 1999). The limited number of samples collected could not be used to confidently ascertain the correlation between dental amalgam use and mercury levels within the polyclinics and MSTL.

The wastewater system layout at the WOHC necessitated the installation of the sampling valve proximal to the vacuum pump location in the main vacuum line for each polyclinic and MSTL. The vacuum trap protects the pump from solids in the wastewater and captures 40% of the amalgam particles. The wet-ring vacuum pumps used at the WOHC, use water to lubricate and cool the pump housing seal. The water requirements for, "matrix minimizers 2000" as an example, is 2.27 litres of water per minute. In a typical eight-hour working day, the pump uses 1089.6 litres of water (Midmark Corporation, 2016). The above conditions make the mercury concentration of wastewater samples collected before the wet-ring vacuum pump higher than the concentration of wastewater entering the sewer. A possible reduction of 40% in mercury concentration reduces the number of samples with a concentration above limit from 25 to 20, and a further hypothetical dilution with 1000 litres of water from the vacuum pumps lowers the mercury concentration further, to levels below detection. Previous studies have used wastewater collected directly from the dental chair (Al Kawas, et al., 2008), as well as dental chair and settling tanks (Stone, et al., 2003).

The different options in layouts, sampling points and pump types used in dental clinics might lead to acceptance of diluted wastewater mercury levels from clinics using wet-ring pumps and penalties incurred in clinics using dry vacuum pumps whose effluent is not diluted. The South African national norms and standards for sanitation services prohibit dilution of the effluent in order to comply with set concentration limits (Department of Water and Sanitation, 2017). Rising utility costs and environmental concerns have led to a shift to the more efficient dry vacuum system and recycling of wet ring pumps (Alliance for Water Efficiency, 2008). Thus, a clear description of generation and sampling points for dental wastewater by the authorities is necessary when monitoring wastewater outputs from dental clinics.

The WOHC is part of Charlotte Maxeke Johannesburg Academic Hospital and is located in Johannesburg Water Region B. The Water Region B serves Rosebank, Randburg, Emmarentia, Greenside, Melville, Northcliff, and Parktown areas. The treatment plant for wastewater from region B is the Johannesburg Northern wastewater works (Johannesburg Water SOC(Ltd), 2015). The treated effluent from Johannesburg Northern wastewater works flows into the Jukskei River, Crocodile West River and ultimately the Limpopo river (Department of Water Affairs and Forestry, 2009). The department of water and sanitation is in the process of re-instituting the monitoring of sewerage and wastewater treatment plants in South Africa (Farmers Weekly, 2019). The last audit, published in 2013, reported poor performance of wastewater treatment works in South Africa (Ntombela, et al., 2016). The increased monitoring of wastewater treatment plants will improve the enforcement of upstream influent limits. The control and monitoring of influent from various sources by local authorities will likely expose the impact of using dental amalgam without the implementation of BMPs and the use of amalgam separators. The dental fraternity must take the lead in ensuring wastewater from dental clinics do not affect the environment and the health of communities. The contamination of wastewater treatment works effluent reduces the possibility of wastewater re-use and lowers the potential for wastewater sludge fertilisation in South Africa.

5.4 THE APPLICATION OF BEST MANAGEMENT PRACTICES AT THE WOHC

This study described a partial application of BMPs for dental amalgam use at the WOHC leading to further contamination of the wastewater and the environment by mercury and other dental amalgam constituents. The dentists qualifying from the institution are likely to have inadequate exposure to practices aimed at reducing environmental mercury contamination.

Oral health services in such a scenario may cause damage to the environment through the release of dental amalgam mercury. The regulations relating to healthcare waste management in South Africa, state that establishments have a responsibility for the waste from the point of generation until its final treatment and disposal (Department of Health, 2014). The current national sanitation policy emphasises the importance of industries and businesses connected to the sewerage system ensuring discharge does not pose a risk to the treatment process, quality and quantity of effluent (Department of Water and Sanitation, 2016). The Oral Health Professionals have a responsibility to adhere to National/Local government acts and regulation, thus avoiding situations predisposing to litigation.

The current guidelines on the management of healthcare risk waste in South Africa were developed by the South African Bureau of Standards and The Health Professions Council of South Africa (HPCSA) (HPCSA, 2018). The guidelines do not adequately meet the current standards in amalgam waste management. The provision for separation of amalgam waste into contact and non-contact waste, amalgam spill kits, specification of amalgam waste containers in line with United

Nations regulations, measures to mitigate wastewater mercury contamination, as well as methods of disposal, are lacking or not clearly described.

Development of a new healthcare waste guideline in line with internationally recognised standards will facilitate proper management of amalgam waste and enable the regulatory authorities to create mechanisms to enforce adherence. Voluntary adherence to best management practice resulted in lower success in King County/Seattle Metropolitan Area. In the USA, successful implementation of best management practices for dental amalgam waste requires support by legislation and enabling the infrastructural environment (Savina, 2003). The guidelines will also enable the country to meet a measure stipulated in the Minamata Convention on Mercury.

The Republic of South Africa is embarking on a process of establishing universal health coverage (Department of Health, 2017). There is a likelihood that, dental amalgam use, will continue as it offers affordability and practicality in rural settings. The cost and processes of preventing environmental contamination by dental amalgam constituents must be taken into account to ensure benefit to the country.

CHAPTER SIX

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusions

The study revealed a slight increase in the procurement of dental amalgam over the 8 years a period. The levels of mercury in wastewater were above limits allowable by the City of Johannesburg Metropolitan Municipality – Water services by-laws. The application of BMPs for dental amalgam use was inadequate.

There is an urgent need for implementation of the BMPs at the need to implement best management practices at the WOHC.

The waste generated during dental amalgam procedures can be captured before leaving the clinic in wastewater or as solid waste. The means for the capture are available and known to oral health professionals.

There is an urgent need for the training of health care workers, the development of infrastructural support, and the establishment of regulatory mechanisms to prevent environmental contamination by mercury from dental amalgam use in South Africa.

6.2 Limitations

The limitations of the study were**:**

- A short duration was due to the budgetary constraints.
- The different species of mercury, as well as the nature of mercury, was not established due to analytical limitation in the laboratory services.
- The actual demand and use of dental amalgam by different clinics and MSTL was not determined due to the cross-sectional nature of the study.

6.3 Recommendations.

The following recommendations resulted from the findings of the study;

- The central procurement office of the WOHC should establish a stable dental amalgam inventory based on realistic lead times and safe stock volume.

- The WOHC should investigate the possibility of introducing the extended carving time (ECT) and slow carving (SC) dental amalgam formulations for the training of restorative dentistry

- The WOHC should develop and implement the appropriate BMPs for dental amalgam use.

- There is a need for standardisation of the maximum allowable concentration of mercury in wastewater influent among the different municipalities of Gauteng Province.

- The dental amalgam procurement/use, potential mercury contamination, and application of BMPs in three other dental schools in South Africa should be investigated.

- The Department of Health, The HCPSA and the SABS, should develop, advocate and implement, appropriate guidelines for the management of dental amalgam waste in South Africa.

- The current acceptance and use of dental amalgam among dentists and the population of South Africa should be investigated to inform the training priorities and planning of waste management programs.

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ANNEXURES

ANNEXURE A

The datasheet for dental amalgam procured by WOHC.

1 Spill

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Boxes (no)	25	10	14	60	0	0	10	40	60	**219**
Capsules (no)	1250	500	700	3000	0	0	500	2000	3000	**10950**
Alloy (kg)	0,5	0,2	0,28	1,2	0	0	0,2	0,8	1,2	**4,38**
Mercury (kg)	0,46	0,182	0,25	1,092	0	0	0,18	0,728	1,09	**3,9858**

2 Spill

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Boxes (no)	30	5	40	20	40	0	10	60	30	**235**
Capsules (no)	1500	250	2000	1000	2000	0	500	3000	1500	**11750**
Alloy (kg)	0,9	0,15	1,2	0,6	1,2	0	0,3	1,8	0,9	**7,05**
Mercury (kg)	0,83	0,138	1,1	0,552	1,1	0	0,28	1,656	0,83	**6,486**

ANNEXURE B

The datasheet for dental amalgam issued to WOHC clinics.

	2013-2014		2014-2015		2015-2016		2016-2017		2017-2018	
Spill type	1	2	1	2	1	2	1	2	1	2
Boxes (no)	15	25	5	23	20	3	38	39	34	53
Capsules (no)	750	1250	250	1150	1000	150	1900	1950	1700	2650
Alloy (kg)	0,3	0,75	0,1	0,69	0,4	0,09	0,76	1,17	0,68	1,59
Mercury (kg)	0,273	0,69	0,091	0,6348	0,364	0,0828	0,6916	1,0764	0,6188	1,4628

	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Total Dental Amalgam (kg)	2,013	1,5158	0,9368	3,698	4,3516
Total Alloy (kg)	1,05	0,79	0,49	1,93	2,27
Total Mercury (kg)	0,963	0,7258	0,4468	1,768	2,0816

ANNEXURE C

The datasheets for P1, P2, P3, and MSTL.

P1								
Day of the Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Patients (No)	37	67	18	0	59	18	12	**211**
Restorative procedures (No)	3	0	3	0	6	6	3	**21**
Amalgam Procedures (No)	2	4	0	0	0	0	0	**6**
Amalgam Removal – Restorations (No)	1	2	0	0	0	0	0	**3**
Amalgam Removal – Surfaces (No)	2	3	0	0	0	0	0	**5**
Amalgam Placement- Restorations (No)	1	2	0	0	0	0	0	**3**
Amalgam Placement – Surfaces (No)	3	3	0	0	0	0	0	**6**
1 Spill Capsule used (No)	0	1	0	0	0	0	0	**1**
2 Spill Capsule numbers (No)	2	2	0	0	0	0	0	**4**
1 Spill Amalgam used (mg)	0	764	0	0	0	0	0	**764**
2 Spill Amalgam used (mg)	2304	2304	0	0	0	0	0	**4608**
Total dental amalgam used (mg)	2304	3068	0	0	0	0	0	**5372**
1 Spill used mercury content - (mg)	0	364	0	0	0	0	0	**364**
2 Spill used mercury content - (mg)	1104	1104	0	0	0	0	0	**2208**
Total mercury used mgs (mg)	1104	1468	0	0	0	0	0	**2572**
Wastewater collected (ml)	4600	5720	11700	0	800	4200	3600	**30620**
Control samples mercury conc. (µg/L)	<1.0	<1.0	<1.0	0	<1.0	<1.0	<1.0	
Wastewater – mercury conc. (µg/L)	3130	18843	8094	0	4457	2436	2170	

P2								
Day of the Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Patients (No)	80	85	56	5	20	42	21	**309**
Restorative procedures (No)	8	14	8	5	5	16	18	**74**
Amalgam Procedures (No)	1	5	0	0	0	3	2	**11**
Amalgam Removal – Restorations (No)	1	2	0	0	0	1	0	**4**
Amalgam Removal – Surfaces (No)	2	5	0	0	0	2	0	**9**
Amalgam Placement- Restoration (No)	0	1	0	0	0	2	2	**5**
Amalgam Placement – Surfaces (No)	0	3	0	0	0	3	2	**8**
1 Spill Capsule used (No)	0	7	0	0	0	5	3	**15**
2 Spill Capsule numbers (No)	0	0	0	0	0	0	0	**0**
1 Spill Amalgam used (mg)	0	5348	0	0	0	3820	2292	**11460**
2 Spill Amalgam used (mg)	0	0	0	0	0	0	0	**0**
Total dental amalgam used (mg)	0	5348	0	0	0	3820	2292	**11460**
1 Spill used mercury content - (mg)	0	2548	0	0	0	1820	1092	**5460**
2 Spill used mercury content - (mg)	0	0	0	0	0	0	0	**0**
Total mercury used mgs (mg)	0	2548	0	0	0	1820	1092	**5460**
Wastewater collected (ml)	6700	6350	9800	800	5100	10700	6100	**45550**
Control samples mercury conc. (µg/L)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Wastewater – mercury conc. (µg/L)	1449	1134	7135	3342	2881	2857	1508	

P3								
Day of the Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Patients (No)	46	59	41	0	48	37	69	**300**
Restorative procedures (No)	13	15	15	0	7	14	4	**68**
Amalgam Procedures (No)	1	10	2	0	0	0	0	**13**
Amalgam Removal – Restorations (No)	0	1	1	0	0	0	0	**2**
Amalgam Removal – Surfaces (No)	0	1	2	0	0	0	0	**3**
Amalgam Placement- Restoration (No)	1	9	1	0	0	0	0	**11**
Amalgam Placement – Surfaces (No)	2	20	3	0	0	0	0	**25**
1 Spill Capsule used (No)	0	18	7	0	0	0	0	**25**
2 Spill Capsule numbers (No)	1	2	0	0	0	0	0	**3**
1 Spill Amalgam used (mg)	0	13752	5348	0	0	0	0	**19100**
2 Spill Amalgam used (mg)	1152	2304	0	0	0	0	0	**3456**
Total dental amalgam used (mg)	1152	16056	5348	0	0	0	0	**22556**
1 Spill used mercury content - (mg)	0	6552	2548	0	0	0	0	**9100**
2 Spill used mercury content - (mg)	552	1104	0	0	0	0	0	**1656**
Total mercury used mgs (mg)	552	7656	2548	0	0	0	0	**10756**
Wastewater collected (ml)	4200	7550	6400	0	5400	6600	2400	**32550**
Control samples mercury conc. (µg/L)	<1.0	<1.0	<1.0	0	<1.0	<1.0	<1.0	
Wastewater – mercury conc. (µg/L)	3750	4553	9047	0	4509	1385	1048	

MSTL								
Day of the Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Students per session (No)	48	0	27	0	27	0	27	**129**
Amalgam Removal – Restorations (No)	32	0	2	0	20	0	3	**57**
Amalgam Removal – Surfaces (No)	32	0	6	0	22	0	9	**69**
Amalgam Placement- Restoration (No)	50	0	8	0	32	0	16	**106**
Amalgam Placement – Surfaces (No)	50	0	24	0	32	0	40	**146**
1 Spill Capsule used (No)	37	0	2	0	23	0	5	**67**
2 Spill Capsule numbers (No)	50	0	27	0	31	0	38	**146**
1 Spill Amalgam used (mg)	28268	0	1528	0	17572	0	3820	**51188**
2 Spill Amalgam used (mg)	57600	0	31104	0	35712	0	43776	**168192**
Total dental amalgam used (mg)	85868	0	32632	0	53284	0	47596	**219380**
1 Spill used mercury content - (mg)	13468	0	728	0	8372	0	1820	**24388**
2 Spill used mercury content - (mg)	27600	0	14904	0	17112	0	20976	**80592**
Total mercury used mgs (mg)	41068	0	15632	0	25484	0	22796	**104980**
Wastewater collected (ml)	1900	400	750	0	1400	380	1700	**6530**
Control samples mercury conc. (µg/L)	<1.0	<1.0	<1.0	0	<1.0	<1.0	<1.0	
Wastewater – mercury conc. (µg/L)	85373	17371	48572	0	67744	37943	108762	

ANNEXURE D

The questionnaire for Best Management Practices for Dental Amalgam use

Procured dental amalgam capsules		
PRACTICE	**YES**	**NO**
The dental amalgam available for use is of various spill sizes		
Non-contact amalgam and used amalgam capsules		
PRACTICE	**YES**	**NO**
Non – contact amalgam/used amalgam capsules are stored in a wide mouthed, airtight, marked container is used for container marked **"Non-contact Amalgam for Recycling"**		
Contact Amalgam, Extracted teeth, Chair-side Traps, Vacuum filters, Amalgam separators, Line cleaners		
PRACTICE	**YES**	**NO**
Contact amalgam is stored in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**		
Extracted teeth with amalgam fillings are stored in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**		
The re-usable traps contents are emptied in a wide mouthed, airtight container marked **"Contact Amalgam for Recycling"**		
The re-usable traps are rinsed in running water		
The disposable traps are removed with contents and placed in a wide mouthed airtight containers **marked "Contact Amalgam for Recycling"**		
The vacuum pump filter contents are emptied in a marked container wide mouthed airtight containers marked **"Contact Amalgam for Recycling"**		
The vacuum pump filter and contents are emptied in a marked container wide mouthed airtight containers marked **"Contact Amalgam for Recycling"**		
Amalgam separators are installed in the clinic's wastewater system		
Disinfectant/ Line cleaners used in the clinic does not contain chlorine or bleach		
Disposal		
PRACTICE	**YES**	**NO**
The wide mouth, airtight, marked containers filled with contact, non-contact and extracted teeth containing amalgam are disposed for recycling		
The dental amalgam waste is handled by a recycler known to the clinic, and a disposal certificate is issued		

ANNEXURE E

The ethics Clearance Certificate

R14/49 Dr Stephen Mughanga Sudi

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M170908

NAME: (Principal Investigator)	Dr Stephen Mughanga Sudi
DEPARTMENT:	School of Oral Health Department of Oral Medicine and Periodontics Wits Oral Health Centre's Dental Clinic
PROJECT TITLE:	Dental Amalgam Procurement Patterns and Mercury Levels in Wastewater Grab Samples at Wits Oral Health Centre
DATE CONSIDERED:	29/09/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Sindisiwe Shangase and Dr Julitha Molepo
APPROVED BY:	Prof P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	27/10/2017

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 in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. 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 resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting `the study was initially reviewed. In this case, the study was initially reviewed in September and will thêrefore be due in the month of September each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

16-11-2017

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

ANNEXURE F

The certificate of analysis for mercury from the CSIR.

Tel (+27) 012 841 4145
Fax (+27) 012 841 4653/3691
Email MGovenderKirkpatrick@csir.co.za

T0007

CSIR: Implementation Unit
P.O.Box 395, Pretoria
Building 10, Room A048
Meiring Naude Road, Brummeria, Pretoria
VAT NO: 4470114283

CSIR Environmental Laboratory - Pretoria

Amended Certificate Of Analysis

Report NO: I-2018-21000-C
Sample Description: Waste

Customer: Dr Stephen Sudi(Private)
Address: Private Bag 3
Johannesburg 2020
No of Samples: 50
Date Received: 01-Oct-2018
Sample Condition: Room Temperature
Date Completed: 26-Oct-2018

Phone:
Contact: Stephen Sudi (stephen.sudi@gmail.com)

Analysis	Unit	Lab No / Sample ID / Method	I-18-167456 TC1	I-18-167457 TS1	I-18-167458 TC2	I-18-167459 TS2	I-18-167460 TC4
Mercury (Total) *	µg/L Hg	CMP 33	<1.0	85373	<1.0	17371	<1.0

Analysis	Unit	Lab No / Sample ID / Method	I-18-167461 TS4	I-18-167462 P1C1	I-18-167463 P1S1	I-18-167464 P1C2	I-18-167465 P1S2
Mercury (Total) *	µg/L Hg	CMP 33	48572	<1.0	3130	<1.0	18843

Analysis	Unit	Lab No / Sample ID / Method	I-18-167466 P1C4	I-18-167467 P1S4	I-18-167468 P2C1	I-18-167469 P2S1	I-18-167470 P2C2
Mercury (Total) *	µg/L Hg	CMP 33	<1.0	8094	<1.0	1449	<1.0

Analysis	Unit	Lab No / Sample ID / Method	I-18-167471 P2S2	I-18-167472 P2C4	I-18-167473 P2S4	I-18-167474 P3C1	I-18-167475 P3S1
Mercury (Total) *	µg/L Hg	CMP 33	1134	<1.0	7135	<1.0	3750

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.

J. Dikobe - Technical Signatory

A copy of the original of this certificate is available from the CSIR on request. This certificate is issued without any alteration or erasure.
This certificate supersedes all previous documents bearing the reference (I-2018-21000)

Date Printed 26-Oct-2018
Page 1 of 4

CSIR: Implementation Unit
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Building 10, Room A048
Meiring Naude Road, Brummeria, Pretoria
VAT NO: 4470114283

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CSIR Environmental Laboratory - Pretoria

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Email MGovenderKirkpatrick@csir.co.za

Amended Certificate Of Analysis

Report NO:	I-2018-21000-C	Sample Description:	Waste		
Customer:	Dr Stephen Sudi(Private)				
Address:	Private Bag 3	No of Samples	50	Sample Condition:	Room Temperature
	Johannesburg 2020	Date Received:	01-Oct-2018	Date Completed:	26-Oct-2018
Phone:					
Contact:	Stephen Sudi (stephen.sudi@gmail.com)				

Analysis	Unit	Lab No / Sample ID / Method	I-18-167476 P3C2	I-18-167477 P3S2	I-18-167478 P3C4	I-18-167479 P3S4	I-18-167480 P2C6
Mercury (Total) *	µg/L Hg	CMP 33	<1.0	4553	<1.0	9047	<1.0

Analysis	Unit	Lab No / Sample ID / Method	I-18-167481 P2S6	I-18-167482 TC8	I-18-167483 TS8	I-18-167484 TC9	I-18-167485 TS9
Mercury (Total) *	µg/L Hg	CMP 33	3342	<1.0	67744	<1.0	37943

Analysis	Unit	Lab No / Sample ID / Method	I-18-167486 TC10	I-18-167487 TS10	I-18-167488 P1C8	I-18-167489 P1S8	I-18-167490 P1C9
Mercury (Total) *	µg/L Hg	CMP 33	<1.0	108762	<1.0	4457	<1.0

Analysis	Unit	Lab No / Sample ID / Method	I-18-167491 P1S9	I-18-167492 P1C10	I-18-167493 P1S10	I-18-167494 P2C8	I-18-167495 P2S8
Mercury (Total) *	µg/L Hg	CMP 33	2436	<1.0	2170	<1.0	2881

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.

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Date Printed 26-Oct-2018

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Meiring Naude Road, Brummeria, Pretoria
VAT NO: 4470114283

CSIR Environmental Laboratory - Pretoria

Amended Certificate Of Analysis

Report NO: I-2018-21000-C

Sample Description: Waste

Customer: Dr Stephen Sudi(Private)

Address: Private Bag 3
Johannesburg 2020

No of Samples: 50

Sample Condition: Room Temperature

Date Received: 01-Oct-2018

Date Completed: 26-Oct-2018

Phone:

Contact: Stephen Sudi (stephen.sudi@gmail.com)

Analysis	Unit	Lab No / Sample ID / Method	I-18-167496 P2C9	I-18-167497 P2S9	I-18-167498 P2C10	I-18-167499 P2S10	I-18-167500 P3C8
Mercury (Total) *	µg/L Hg	CMP 33	<1.0	2857	<1.0	1508	<1.0

Analysis	Unit	Lab No / Sample ID / Method	I-18-167501 P3S8	I-18-167502 P3C9	I-18-167503 P3S9	I-18-167504 P3C10	I-18-167505 P3S10
Mercury (Total) *	µg/L Hg	CMP 33	4509	<1.0	1385	<1.0	1048

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.

J. Dikobe - Technical Signatory

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This certificate supersedes all previous documents bearing the reference (I-2018-21000)

Date Printed 26-Oct-2018

CSIR: Implementation Unit
P.O.Box 395, Pretoria
Building 10, Room A048
Meiring Naude Road, Brummeria, Pretoria
VAT NO: 4470114283

T0007

our future through science

Tel	(+27) 012 841 4145
Fax	(+27) 012 841 4653/3691
Email	MGovenderKirkpatrick@csir.co.za

CSIR Environmental Laboratory - Pretoria

Amended Certificate Of Analysis

Report NO:	I-2018-21000-C	Sample Description:	Waste		
Customer:	Dr Stephen Sudi(Private)				
Address:	Private Bag 3	No of Samples	50	Sample Condition:	Room Temperature
	Johannesburg 2020	Date Received:	01-Oct-2018	Date Completed:	26-Oct-2018
Phone:					
Contact:	Stephen Sudi (stephen.sudi@gmail.com)				

Comments *

Reason for Amendment for I-2018-21000 A: Changed sample ID of sample 167460 and 167461.
Reason for Amendment for I-2018-21000 B: Chenged sample IDs for sample 167460 and 167461.
Reason for Amendment for I-2018-21000 C: Changed Accreditation status of sample 167460 and 167461

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.

J. Dikobe - Technical Signatory

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This certificate supersedes all previous documents bearing the reference (I-2018-21000)

Date Printed 26-Oct-2018

ANNEXURE E

Turnitin Report

Submission date: 24-Oct-2019 02:16PM (UTC+0200)
Submission ID: 1199428450
File name: Stephen_Mughanga_Sudi.docx (15.17M)
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Dr

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