Assessment of the Implementation of Controls for Lead (Pb) Exposure Amongst Laboratory Workers at a Science and Research Institution in Gauteng, South Africa

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DECLARATION

I, Faith Motshidisi Motaung do hereby declare that this dissertation is the result of my own investigation and research, and this has not been submitted in part or full for any degree or any other degree to any other University of College.

I confirm that:

1. This work was done wholly while in candidature for a Master of Public Health degree at University of Johannesburg, Republic of South Africa.
2. Where I consulted the published work of others, this is always clearly attributed and cited.

08 December 2021

DATE

MOTSHIDISI FAITH MOTAUNG

DEDICATION

This dissertation is dedicated to my loving family who were more than supportive throughout this programme. A special dedication goes to my children Andile Motaung, Katiso Segapo and Boitumelo Segapo, who were my pillars of strength and motivated me to keep on going. I also dedicate this dissertation to my friends and colleagues who supported me throughout this process. I will always appreciate their support.

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ABSTRACT

Background

The lead regulations under the OHSA (Act 85 of 1993) prescribes guidelines for the control measures that must be put in place to protect workers from Lead (Pb) exposure in the workplace. Even though stringent measures are implemented at the science and research institution, workers exposed to Pb continue to have Blood Lead Levels (BLL) of over 20μg/dL and these high levels exposes workers to amongst others, neurological, cardiovascular, maskulo-skeletal and associated symptoms. While lead exposure has been investigated at the mining sites, in agriculture, households and amongst the vulnerable groups, investigation in the laboratories of a science and research institutions have not been adequately described in literature.

Objective

The study sought to assess the implementation of controls for Pb exposure amongst laboratory workers at a science and research institution in Gauteng, South Africa.

Methods

A quantitative cross section design study was conducted in a science and research council environment with laboratory workers who were more exposed to Pb and those less exposed to Pb. The study sample size was 389 with those exposed to Pb constituting a proportion equal to 181 (46.5%) and those less exposed to Pb 208 (53.5%). The data was collected using an online questionnaire. Secondary data for BLL in the period 2018-2019 was extracted from existing biological monitoring records of the same employees who participated in the online questionnaire. The data management and analysis were performed using EPINFO 7.2 for crude analysis and SPSS version 27 for adjusted odds ratios. Bivariate tests were performed using logistic regression to assess the association between laboratory work and Pb exposure at a confidence interval of 95%.

Results

Scientists and Engineers were more likely to be exposed to Pb (AOR = 3.27, 95% CI 1.60-6. 74) and (AOR = 3.33, 95% CI 1.50-7.41) respectively compared to technicians when operators were a reference group. If they worked in the Analytical Services Department (ASD) and the Pyro metallurgy Department (PDD) department, the association was (OR= 2.49, 95% CI 1.73-3.59) and (OR = 2.58, 95% CI 1.79-3.71) respectively. Those more exposed to Pb had an exposure period from (11 – 20) to >20years (AOR = 2.32 95% CL 1.15-4.67) and (OR = 9.09 95% CI 1.15-71.92) respectively. Those more exposed to Pb undertook periodic medicals (AOR= 8.90 95% CI 2.70-29.40) and presented with > 3 symptoms (AOR= 6.51 95% CI 2.70-15.70. Those more exposed to Pb understood the health and safety policy of the organization (AOR 12.68 95% CI 4.92-32.71) whilst 3.6% were undecided (AOR7.83 95% CI 1.81-33.90). Those more exposed to Pb always used the correct PPE (AOR 26.78 95% CI 5.12-140.4) and believed that the organizations efforts were adequate to prevent harmful exposure from Pb (AOR 12.12 95% CI 4.43-33.20). Those more exposed to Pb had the knowledge of lead storage regulations (AOR 22.43 95% CI 6.10 – 82.9), those unsure (AOR 3.97 95% CI 1.38 – 11.44). Those more exposed to Pb had the knowledge that Pb handling exposed them to harm (AOR 3.21 95% CI 1.77 – 5.82) even though some were unsure or disagreed that, they may still be exposed to harm after experiments (AOR 33.32 95%CI 15.31 – 72.53) and (AOR 3.62 95% CI 1.31 – 9.81) respectively.

Conclusion

This study showed an association between laboratory work and being more exposed to Pb and also highlighted a need for improved interventions to increase the implementation of controls against Pb exposure**.**

Keywords

Lead, exposure, Blood lead levels, control measures and biological monitoring

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LIST OF ACRONYMS

BEL: Biological Exposure Indices

OEL: Occupational Exposure Limits

BLL: Blood Lead Levels

μg/dL: Micrograms per decilitre where 100millilitres is equal to 1decilitre

PPE: Personal protective equipment

DoEL: Department of Employment and Labour

OMP: Occupational medical practitioner

IHME: Institute for Health Metrics and Evaluations

WHO: World Health Organization

ILO: International Labour Organization

DMRE: Department of Minerals Resources and Energy

SANC: South African Nursing Council

DALY: Disability Adjusted Life Years

NICD: National Institute for Communicable Disease

NMD: Notifiable medical conditions

DEFINITION OF TERMS

Lead poisoning: Lead poisoning is a term used to describe a group of symptoms that occurs when lead builds up in the body, often over months or years. Even small amounts of lead can cause serious health problems. (Vella, 2011)

Occupational Health Practitioner: Occupational health practitioner is an occupational medicine practitioner or a person who holds a qualification in occupational health recognized as such by the South African Medical and Dental Council as referred to in the Medical, Dental and Supplementary Health Service Professions Act, 1974(Act 56 of 1974) or the South African Nursing Council as referred to in the Nursing Act, 1978 (Act 50 of 1978)

Biological monitoring: The Occupational Health and Safety Act no.85 of 1993 defines biological monitoring as a planned programme of periodic collection and analysis of body fluid, tissues, excreta or exhaled air in order to detect and quantify the exposure to or absorption of any substance or organism by persons (OHS Act, 1993)

Employee: Any person who is employed by or works for an employer and who receives or is entitled to receive any remuneration or who works under the direction or supervision of an employer or any other person (OHS Act ,1993)

CHAPTER 1: INTRODUCTION

1.1 Introduction

The Department of Employment and Labour of the Republic of South Africa (DoEL of SA) under the Lead regulations have prepared guidelines for workplaces where lead is produced, processed, used, handled or stored in a form in which it can be inhaled, ingested or absorbed by any person in that workplace (Department of Employment and Labour, 1993). The employer has a legal obligation to protect the health and safety of employees in the workplace and to ensure that the hazards in the workplace are not transferred to the community (Hemati & Holthaus, 2018: Martini et al, 2013).

Laboratory workers are exposed to high Lead (Pb) levels such as in the fire assay processes of fusion and cupellation. Research has shown how employers fail to maintain the lead levels below the Occupational exposure limit (OEL) of 20ug/dL due to prolonged hours of exposure and failures in the control measures in place (Emery, 2013). As such employees are exposed to high Pb levels which exposes them to amongst others, neurological, cardiovascular and maskulo-skeletal health problems and associated syndromes (Ibrahim and Mansour, 2019). Above all, there is a high probability of risk transfer by exposed employees to other employees and to their families in the community. While lead exposure has been investigated at the mining sites, in agriculture, households and amongst the vulnerable groups, investigation in the laboratories of a science and research institutions have not been adequately described in literature. The aim of this study is to assess the implementation of the Pb control measures in the laboratories in the science and research institution in Gauteng.

1.2 Background

1.2.1 Lead (Pb) extraction process in the laboratory

Lead has been known to man since ancient times and was probably one of the earliest metals produced from ore by man. Maybe one of the reasons is that, according to WHO (2019), lead is relatively easy to smelt and requires only a moderate temperature (Ye and Wong, 2006). The largest producer of lead materials in the world is Australia followed by the USA, China and Canada.

Lead is extracted from ores brought up from under-ground mines. Of the more than 60 minerals that contain lead, only 3, galena, cerussite and anglesite are commercially viable. Usually, lead is found in conjunction with other metals such as silver and zinc. Lead materials are mined as a by-product of the other valuable metals. (Hilpkins et al, 1998, Ye and Wong, 2006).

In the laboratories, a multi-step process is followed to extract Pb materials. First the lead ore is grounded into small particles that are less than 0.1mm, giving the ore a fine texture similar to table salt (Amalia et al, 2017). Next the lead powder is put through a flotation process, that involves mixing the lead ore with water, the addition of pine oil and the introduction of air bubbles and agitation which forms an oil froth, containing the lead ore, on the surface. The froth is skimmed and then filtered to remove the water. The powder is then sintered at over 25000F to oxidize impurities such as sulphur. The resulting powder is further heated in a blast furnace, with carbon producing molten lead which is drawn off into lead moulds (Worksafe, 2017).

At this stage the lead is about 95% pure and is further refined to reach greater than 99% purity by melting and skimming impurities. Gold and silver can be removed from the bullion by adding to it a small quantity of zinc. The gold and silver dissolves more easily in zinc than in lead, and when the bullion is cooled slightly, a zinc dross rises to the top, bringing the other metals with it. Once the lead materials reach a sufficient level of purity it is cast into lead blocks as the finished product. In some cases, small quantities of impurities, such as copper, antimony, tin and zinc, may be added to form lead alloys with various properties (WHO, 2019).

In another process called cupellation, used in Fire assay, workers are exposed to Pb and its by-products. Cupellation is a refining process in metallurgy where ores or alloyed metals are treated under very high temperatures to separate noble metals from base metals. In this process, noble metals like gold and silver are separated from base metals such as lead, copper, zinc, arsenic, antimony, or bismuth, present in the ore. This process is based on the principle that precious metals do not oxidise or react chemically, unlike the base metals. So when they are heated at high temperatures, the precious metals remain apart, and the others react, forming slags or other compounds (Porter et al. 2015).

Laboratory processes within industrial settings use lead in their day to day work processes that exposes workers to high lead levels which is detrimental to their health (Porter and Cassandra 2015; Brückner et al, 2016). In South Africa, the Lead Regulations (2001) under the

Occupational Health and Safety Act were passed in order to regulate and control the Pb exposure levels in the workplace.

1.2.2 Regulation of exposure to Pb in the workplace

To control this exposure, the DoEL under the Occupational Health and Safety Act (Act 85 of 1993), has promulgated the Lead Regulations for workplaces. The Regulation for lead exposure prescribes standards for permissible exposure limits and biological exposure indices for lead in the workplace and specifies that a blood lead level (BLL) of 40 micrograms per deciliter (µg/dL) triggers more frequent (i.e., every two months rather than every six months) blood lead testing (ILO, 2014).

Monitoring BLL is compulsory to monitor environmental lead levels in the workplace. This helps to assess the need for engineering controls and the use of personal protective equipment (PPE). However, as environmental monitoring only gives an indication of the inhaled fraction, biological monitoring must be undertaken to assess an individual's total lead exposure and its effects. Blood lead levels are done for biological monitoring. Tests to assess biological effects include a full blood count, renal and liver function tests, as well as a clinical assessment of the central and peripheral nervous system. A number of annexures to the South African lead regulations illustrate the actions required at different concentrations of lead. Annexure A shows the maximum intervals for re-assessment of blood lead measurements. Annexure C indicates that as of June 2005, if an individual has a blood lead levels of ≥ 60 µg/dL, he/she must be removed from a lead exposed work area. The table below indicates the BLL and the maximum interval between blood Lead measurements that is used by laboratories when reporting BLL

Table 1. Blood lead reference values *(OHSA, Act 85 of 1993)*

Blood Lead (µg/dL)	Maximum interval between Blood lead measurements
<20	12 Months
20 - 39	6 Months
40 - 59	3 months
60 and over	At the discretion of the occupational medicine practitioner Removal from exposure
Females	Every 3 months

The Occupational health services uses the above schedule to interpret the results, to schedule the frequency of the biological monitoring programme and to determine the fitness of the workers for Pb exposure.

1.2.3 Determining the worker‘s fitness for Pb exposure

The Lead Regulations under the Occupational Health and Safety Act, 1993, requires that an initial medical examination is carried out within 14 days after a person commences employment. The initial medical must comprise of the following:

(i) An evaluation of the employee’s previous medical and occupational history in relation to chemical exposure. It is important that the employee truthfully declares any previous medical history and gives accurate account of previous chemical exposures.

(ii) Clinical examinations to determine the employee’s fitness status for exposure to Pb.

(iii) Measurement of the employee's blood lead and haemoglobin concentrations and other relevant biological tests at the discretion of the occupational medicine practitioner.

The recommendations of the lead exposure guidelines as per the Lead Regulation, 2001 and the testing interval recommended by the Occupational Medical Practitioner (OMP) must be followed to manage and control Pb exposure

Occupational health is the discipline that is recognized to assist workplaces in protecting the workers against harmful exposures that could harm their health and safety and that of others affected by their operations. In general, occupational health practitioners and doctors can potentially influence work practices through their knowledge of regulations and standards, as well as through their advocacy for worker health and safety (Rogers, 1994).

1.2.4 Role of the occupational health practitioners regarding lead exposure

The Lead regulations, 2001, prescribe that an occupational Medical practitioner (OMP) is responsible for the medical surveillance programme of employees exposed to Pb. The OMP, oversees the implementation of these guidelines and prescribes the programs and schedules that must be followed to comply with the regulations. In industry, the OMP is part of the occupational health team which implements the medical surveillance protocols under his direct supervision. In the occupational health setting the Occupational health nurses play a central role in the workplace in the prevention and treatment of work-related illnesses, diseases and injuries

(De Jager: 2011). It is imperative for the Occupational health practitioner to understand the occupational toxicology profile, exposure biomarkers, interpretation of results and meaningful reporting of the results to the business thereby playing a leading role in the monitoring and control of exposure to hazardous chemical substances.

Occupational health practitioners are in strategic positions to advocate for appropriate lead prevention policies (De Jager 2011). In an industry using Pb, the occupational health practitioners can help identify workers at risk and prevent lead poisoning by education and early intervention. In conjunction with carrying out the medical surveillance requirements of the OHSA (Act 1993), it is important to establish written policies and protocols consistent with laws governing the medical practice and clearly outline the roles and responsibilities of the occupational medical practitioner and the occupational health team.

1.2.5 Control of exposure in the workplace

Pb exposure can be prevented in the workplace by minimizing the amount of Pb that can be absorbed by the body. This is only possible where work processes that create the risk of Pb exposure are identified, and controls are put in place to mitigate the risk (OHSA, 1993). The methods that must be used to control and minimize exposure are:

1.2.5.1 Substitution

Substitution entails exchanging the lead materials with another where possible. In other circumstances it might not be possible to substitute Pb with another material that is free from Pb. There are other methods that can be used to substitute Pb fire essay in gold analysis and in reducing the Pb oxide that is absorbed by the Cupel. In such cases Pb can be substituted with Bismuth, but it is costly. As such Pb is still used in the science and research institution under this study (Kelly and Ojebuoboh, 2002)

1.2.5.2 Engineering controls

Engineering controls are physical changes to the way specific tasks are done. Common engineering control measures include:

- Enclosing specific tasks or work processes that produce Pb emissions
- Installing local exhaust ventilation
- Installing dust collection systems equipped with filters, on machines or equipment
- Modification of the process to reduce the amount of Pb fumes or dust generated

- Use barriers and enclosures to separate the work area from adjacent areas
- Use wet methods that can put a damper on lead dust
- Early identification of corrective taken to be taken to reduce exposure to Pb

(Worksafe, 2017)

1.2.5.3 Administrative controls

Administrative controls are changes to the way work is organized and performed, including scheduling of resources and staffing. Administrative controls include providing training related to Pb exposure, procedures and policy to be followed when engaging in projects involving Pb exposure and shift designs that lessen the threat of a hazard to an individual. Administrative controls typically change the behavior of people (e.g., laboratory workers) rather than removing the actual hazard or providing personal PPE (Worksafe, 2017)

1.2.5.4. Correct use of PPE.

All workers exposed to concentrations of airborne Pb in excess of half the occupational exposure limit (OEL) must be provided with the appropriate PPE as specified in the Lead Regulations (2001). The PPE must not have pockets to reduce the contamination due to the accumulation of Pb dust. PPE must prevent skin contact with Pb and must include, head cover, body cover and feet and hands cover which is impermeable to Pb dust. Coveralls must be worn at all times and must be checked regularly for holes. It is important as well to safely handle used PPE or Pb contaminated clothing. It must be washed separately from the other washing. Workers must not take the contaminated PPE home for washing including the safety boots as there is a risk to transfer the risk of Pb exposure to their families. The employees must be supplied with suitable respiratory protective equipment which assists with the control of Pb exposure (CDC, 2019).

1.2.6 Health effects of lead exposure

Workplace Lead exposure continues to pose major public health problems in adults. The Institute for Health Metrics and Evaluation (IHME) estimated that in 2017, lead exposure accounted for 1.06 million deaths and 24.4 million years of healthy life lost counted as disability-adjusted life years (DALYs) worldwide due to long-term effects on health, with the highest burden in low- and middle-income countries (WHO, 2019). In the Notifiable Medical Conditions (NMC) register in South Africa, which is a passive surveillance system administered by the National Institute of Communicable Diseases (NICD), Pb poisoning is under category 2 conditions. In the year 2019, there were no reported cases of Pb poisoning and there were no associated deaths reported. (NICD, 2019).

The health effects posed by Pb exposure depend on how much and how often a person is exposed. Lead enters the body through mostly inhalation and ingestion. Up to 50% of Lead is inhaled and absorbed by the lungs, whilst 10-15% is ingested. Elimination of Lead is slow and occurs via the urine. Lead ends up being deposited on the bones and can stay there for 20-30 years. In the meantime the person experiences a wide range of symptoms of lead poisoning, many of which imitate other diseases. Lead can affect the brain, nerves, red blood cells, kidneys and reproductive systems of both men and women. Common symptoms of acute (short-term) lead poisoning are loss of appetite, nausea, vomiting, stomach cramps, constipation, difficulty sleeping, fatigue, moodiness, headache, joint or muscle aches, anaemia and decreased sexual drive. Chronic (long-term) overexposure to lead may result in severe damage to the blood-forming, nervous, urinary, and reproductive systems. Chronic poisoning is more common in industrial settings where small amounts of lead can gradually build up in the body and result in temporary or permanent damage. Elevated blood lead levels in workers have been associated with decreased kidney and brain function, reproductive problems, and hypertension (Vella and O’Brian 2011; Porter et al, 2015; Xibiao and Wong 2006). In an emerging study, early exposure to Pb is linked to obesity which predisposes a worker to other chronic medical conditions such as hypertension and high cholesterol levels (Park et al., 2017). It is evident that working with Pb is an occupational hazard.

1.2.7 Science and research institution

The science and research institution under this research study has been a minerals research institute for more than 80 years and it continues to work with other Research and Development organizations to research, develop and implement new and improved technologies in the minerals and metallurgical sectors. The institution provides analytical testing services, medical and clinical laboratories and most laboratories are used for research and test work purposes. The nature of the work conducted requires that laboratory workers handle large quantities of chemicals (Mintek, 2019). Chemical substances are hazardous during any of the stages of production, storage, transport and use (Lee et al., 2015).

1.3 Problem statement

The Lead regulations under the OHSA (Act 85 of 1993) prescribes control measures that must be put in place to protect the workers from Lead exposure and the biological exposure indices permissible in the workplace. Research have shown that in various industries, there is some extent of implementation of controls against Pb exposure however, there is a risk of detrimental health effects due to the low levels of Pb exposure. These were attributed to the lack of enforcement of the control measures against Pb exposure in these industries (Ye and Wong, 2006: Ibrahim and Mansour, 2019: Emery, 2013).

Despite the implementation of controls against Pb exposure, there is an alarming number of workers in the laboratory utilizing sick leave more frequently than expected and their BBL are constantly over 20µg/dL (Mintek HRC report, 2019). There remains a need to understand the implementation of controls for Lead (Pb) exposure amongst laboratory workers at a science and research institution in Gauteng, South Africa. Therefore, the investigation of the implementation of control measures against lead exposure in the workplace is key to finding the gap that may lead to opportunities to improve and resolve the harmful exposure to lead (Pb) and other chemicals.

1.4 Aim and objectives

The overall aim of the study is to assess the implementation of the controls for Pb exposure at a science and research institution in Gauteng.

1.4.1 Specific objectives

1. To describe the blood lead levels amongst those who underwent biological monitoring in 2018 and 2019

2. To examine the relationship between Pb exposure and socio-demographics characteristics

3. To assess the Pb exposure by experiences of workers on the perceived health symptoms and the procedures in place for Pb control

4. To assess the Pb exposure by attitudes of workers on the implementation of Pb exposure prevention procedures

5. To assess Pb exposure by knowledge of workers on the control measures to be implemented to control Pb exposure

1.5 Research Questions

The following questions were posed in this study:

1. What are the Blood Lead levels of laboratory workers who underwent biological monitoring in 2018 and 2019?
2. Is there a relationship between socio-demographic characteristics and exposure to Pb?
3. What are the experiences of workers in relation to perceived health symptoms and procedures in place for Pb exposure?
4. What are the attitudes of laboratory workers towards the implementation of Pb exposure preventive procedures?
5. What is the extent of knowledge possessed by laboratory workers towards the implementation of control measures against Pb exposure?

1.6 Study hypothesis

1.6.1 Overall Hypothesis

A positive relationship exists amongst laboratory workers at a science and research institution with the implementation of controls against Pb exposure. The null hypothesis (H0) reflects no relationship whilst the (HA) reflects a positive relationship.

1.6.2 Specific Hypothesis

Objective: 1. *To describe the blood lead levels amongst those who underwent biological monitoring in 2018 and 2019*

H0: There are no BLL above the acceptable level of exposure (> 20ug/dL)

HA: There are BLL above the acceptable level of exposure (>20ug/dL)

Objective: 2.

To examine the relationship between Pb exposure and socio-demographics characteristics

H0: There is no relationship between Pb exposure and socio-demographics characteristics

HA: There is a relationship between Pb exposure and socio-demographics characteristics

Objective: 3. *To assess the Pb exposure by experiences of workers on the perceived health symptoms and the procedures in place for Pb control*

H0: There is no relationship between the experiences of workers on the perceived health symptoms and the procedures in place for Pb control

HA: There is a relationship between the experiences of workers on the perceived health symptoms and the procedures in place for Pb control

Objective: 4. *To assess the Pb exposure by attitudes of workers on the implementation of Pb exposure prevention procedures*

H0: There is no relationship between Pb exposure and attitude of workers on the implementation of Pb exposure preventive procedures

HA: There is a positive relationship between Pb exposure and attitude of workers on the implementation of Pb exposure preventive procedures.

Objective: 5. *To assess Pb exposure by knowledge of workers on the control measures to be implemented to control Pb exposure*

H0: There is no relationship between Pb exposure and the knowledge of workers on the control measures to be implemented against Pb exposure

HA: There is a positive relationship between Pb exposure and the knowledge of workers on the control measures to be implemented against Pb exposure.

1.7 Feasibility of the study

This study was feasible as it was conducted at the researcher's workplace. There were no challenges to get the approval to access secondary data and to conduct the study. The researcher had the advantage of conducting the study during on-duty times and thus had ample time to dedicate to the research study. The online questionnaire was send out to eligible participants and the responses were not influenced by the fact that the researcher is an internal staff member. The researcher also had access to the workplace resources such as stationary, printers and internet thus reducing costs of the research study.

1.8 Purpose and importance of the study

The purpose of this quantitative, descriptive cross- sectional study was to assess the implementation of controls for Pb exposure amongst laboratory workers at a science and research institution in Gauteng, South Africa. The laboratory workers were categorized into those more exposed to Pb and those less exposed to Pb. To assess if the institution had managed to control Pb exposure, the frequency distribution were run for the BLL of those more exposed to Pb in the years 2018 and 2019, to describe the prevalence of the BLL above 20ug/dL. The relationship of socio-demographic characteristics to Pb exposure was assessed on gender, age-group, occupational group, department and years of exposure. To assess the factors that could be associated with the implementation of controls from the worker's perspective, experiences of workers with control measures in place were assessed and the perceived medical symptoms related to Pb exposure were assessed for both groups. The medical symptoms associated with Pb exposure were grouped into 3 categories and rated based on the number of symptoms raised. To assess the behavioural factors that are associated with the worker's attitude and knowledge, towards the implementation of Pb controls, a group of awareness test questions were compiled in the questionnaire.

1.9 Significance of the study

The recommendations from this study may benefit the employer and the employees in improving compliance to legislation and improving workplace interventions aimed at protecting employees from effects of Pb exposure. The study may also help to create awareness of the challenges that employees experience regarding the control measures in place which were created for their benefit. This study might encourage more research on managing exposure to hazardous chemicals in general. The Occupational health clinics might have a better understanding on how current monitoring strategies affect employees and may encourage them to improve on their health and safety interventions against Pb exposure.

1.10 Delimitation

The results of this study will not be generalized to other similar institutions as the study was conducted in one institution. Another limitation of this study was design of the quantitative study questionnaire which did not allow the participant to expand on their responses. Another delimitation was that in as much as the BLL for the selected participants were assessed, they only provided the levels of the internal dose. The causal relationship between Pb exposure and health was not explored further than the listing of suspected symptoms.

1.11 Summary and transition

This chapter provided a thorough theoretical background of this study. The desired objectives and research questions behind this study were described. This study was prompted by the alarming numbers of workers in the laboratory who frequently fall sick and their BLL were constantly over 20µg/dL. Research studies on Pb exposure have indicated how Pb continues to pose an occupational health problem amongst workers even after the promulgation of the Lead Regulations in various countries. It was noted from research findings that the removal level from exposure in South Africa, remain high as compared to those of the United States of America (WHO, 2019; ILO, 2014). A number of studies have shown that the Pb exposure burden is higher in low and middle-income countries (WHO, 2019). Most of research conducted in the USA and Australia, shows an increased lead toxicity at lower levels of exposure (Porter and Cassandra, 2015). Research has shown the long-term effects of lead exposure on the health of the worker as they suffer from various symptoms and are often misdiagnosed. Research studies done on workers, show that there is a high possibility of the workers to transfer the Pb exposure risk to their family members especially the children (Porter and Cassandra, 2015). Most studies on the attitude, desire and knowledge of workers, are for those exposed to hazardous chemical substances and not to Pb specifically. Moreover, literature on Pb exposure investigates exposure in the mining sites, agriculture, households and vulnerable groups and there was limited data found to be investigating the laboratories at the science and research institutions. This research study would help improve the control measures in place at the science and research institution and would form a baseline on which further studies on this subject can be developed and explored.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The literature review highlights the research on the laboratory workers implementation of controls against Pb exposure at a science and research institution in Gauteng. The first part of this review will focus on the conceptual framework used in this study, which is the Health Belief model. The second part will focus on the literature review method used in this study. The last part will focus on the literature review used to channel the focus of this study.

2.2 Theoretical framework

A framework is the structure of the idea or concept and how it is put together. It guides the researcher during the development of the study and enables the researcher to link the findings to the body of knowledge (Burns and Grove 2005). In this study, the researcher identified the Health Belief Model as best fit for this study. The HBM is easy to use relative to other behavior change theories and has guided other research studies about environmental health risks (Cooper et al, 2020)

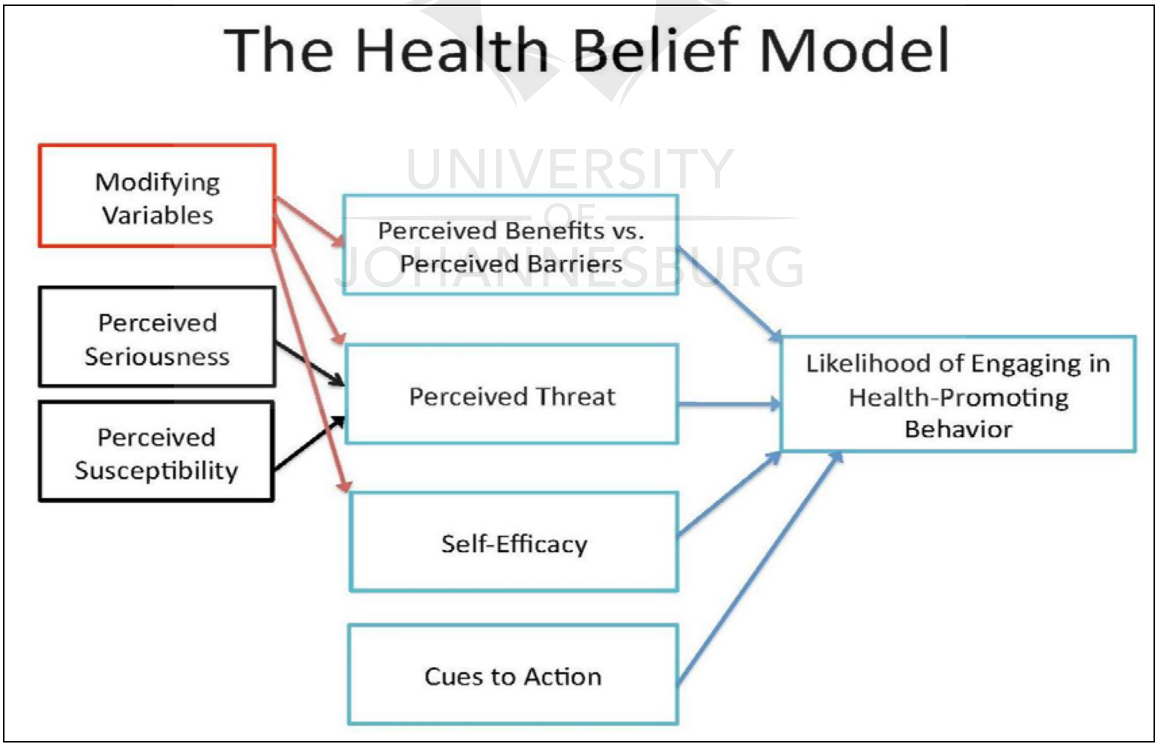

Figure 1 Health Belief Model (Adom et al., 2018)

2.3 The Health Belief Model

The Health Belief Model (HBM) is a psychological model that attempts to explain and predict health behaviours. This is done by focusing on the attitudes and beliefs of individuals. The HBM was first developed in the 1950s by social psychologists Hochbaum, Rosenstock and Kegels working in the United States Public Health Services. The HBM derives from psychological and behavioural theory with the foundation that the two components of health-related behaviour are: 1) the desire to avoid illness, or conversely get well if already ill; and, 2) the belief that a specific health action will prevent, or cure, illness. Ultimately, an individual's course of action often depends on the person's perceptions of the benefits and barriers related to health behaviour. There are six constructs of the HBM. The first four constructs were developed as the original tenets of the HBM. The last two were added as research about the HBM evolved.

This model is also adaptable to the workplace programmes where worker behaviour is targeted for the behavioural change such as the uptake of PPE use.

Table 2: Application of the HBM to the study concept

	Application
Perceived Susceptibility	This refers to a person's subjective perception of the risk of acquiring an illness or disease. There is a wide variation in a person's feelings of personal vulnerability to an illness or disease.
Perceived Severity	This refers to a person's feelings on the seriousness of contracting an illness or disease (or leaving the illness or disease untreated). There is wide variation in a person's feelings of severity, and often a person considers the medical consequences (e.g., death, disability) and social consequences (e.g., family life, social relationships) when evaluating the severity
Perceived Benefits	This refers to a person's feelings on the obstacles to performing a recommended health action. There is wide variation in a person's feelings of barriers, or impediments,

	which lead to a cost/benefit analysis. The person weighs the effectiveness of the actions against the perceptions that it may be expensive, dangerous (e.g., side effects), unpleasant (e.g., painful), time-consuming, or inconvenient.
Perceived Barriers	This refers to a person's feelings on the obstacles to performing a recommended health action. There is wide variation in a person's feelings of barriers, or impediments, which lead to a cost/benefit analysis. The person weighs the effectiveness of the actions against the perceptions that it may be expensive, dangerous (e.g., side effects), unpleasant (e.g., painful), time-consuming, or inconvenient
Cues to Action	This is the stimulus needed to trigger the decision-making process to accept a recommended health action. These cues can be internal (e.g., chest pains, wheezing, etc.) or external (e.g., advice from others, illness of family member, newspaper article, etc.).
Self-Efficacy	Provide training, guidance in performing action. This refers to the level of a person's confidence in his or her ability to successfully perform a behaviour. This construct was added to the model most recently in an attempt to better explain individual differences in health behaviours. Self-efficacy is a construct in many behavioural theories as it directly relates to whether a person performs the desired behaviour (Glanz et al, 2008).

2.4 Application to the study

In this study, the researcher opted to use the HBM and developed this framework which was guided by literature used. The worker who is exposed to Pb is affected by many factors in his internal and external environment which influences his behaviour and performance in the workplace. Some of these factors can be managed by the worker whilst others are the responsibility of the employer. An example are workplace policies which are developed to guide how certain operations must be undertaken, If those policies disregard the rights of the worker, then the worker may not implement them. The workers must be made aware of all these factors that can cause a breakdown in the implementation of controls against Pb exposure and be empowered with knowledge and encouragement to overcome them. Figure 2, indicates the internal and external factors which could be barriers in the implementation of Pb controls.

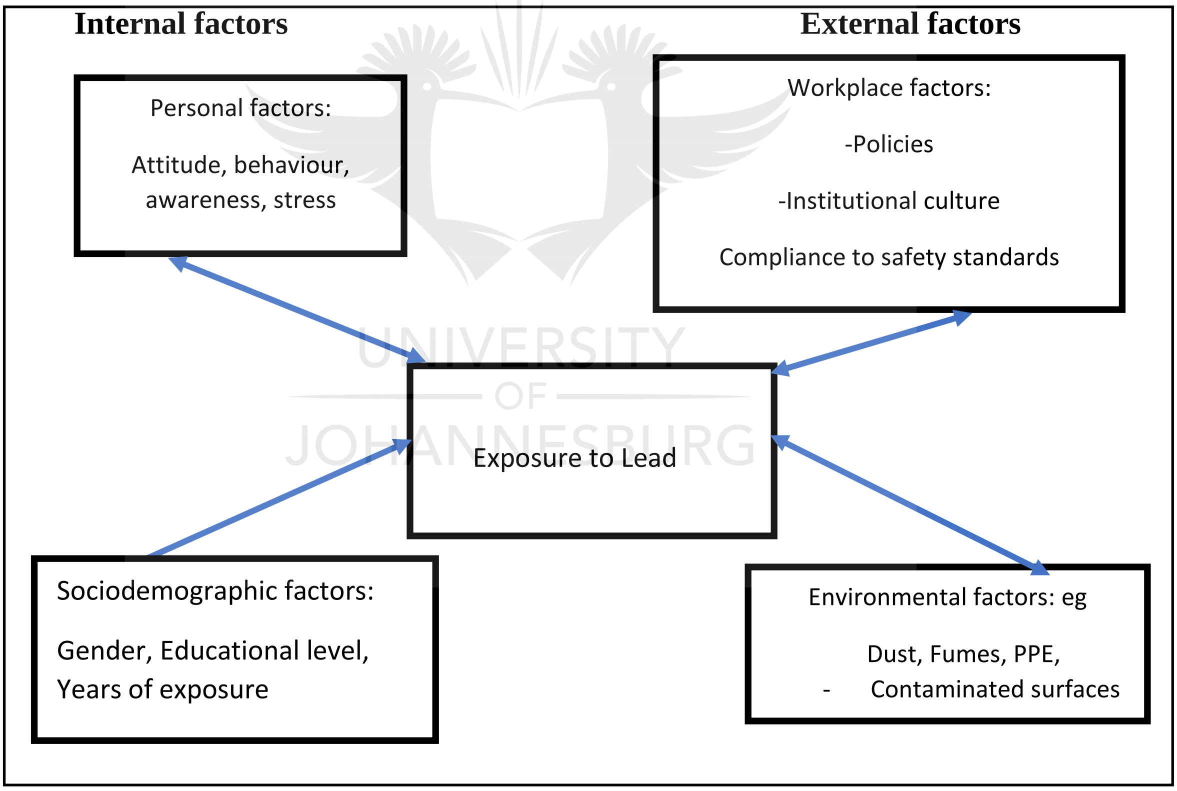

Figure 2*: Application of the theoretical framework to this study (Lungkha& Hinhumpetch, 2020)*

The laboratory workers exposed to Pb are affected by several factors which also form barriers to the implementation of the Pb control measures in the workplace. Based on the literature reviewed, the researcher developed the conceptual framework in figure 2, above. The picture depicts the association of lead exposure to several internal and external factors as depicted by the arrows. Personal factors such as attitude of the worker, influences the implementation of control measures in place. Similarly, literature has shown that increased awareness of the susceptibility to harmful exposure and knowledge of how lead exposure causes Pb poisoning, increases the likelihood of engaging in and attaining a health promoting behaviour (Rodgers, 1994). The workplace can also be the source of barriers against implementing controls. The policies in place must be user friendly and there must be open communication between workers and management. Workers at different levels of position grades and educational standard, must receive training and safety awareness sessions that are created for their level of understanding. Most information in the laboratories is written in scientific language and terms, which the ordinary workers cannot understand (ILO, 2014). Research has shown that when workers are involved in the planning of programmes, they tend to have raised interest in making the program successful. When workers exposed to Pb in the workplace are protected from harmful exposure, their families will be protected from workplace risk transfer which affects their children, mostly. The Institute of Health Metrics and Evaluation, estimated that in 2017, lead exposure accounted for 1.06 million deaths and 24,4million years of healthy life lost counted as disability-adjusted life years (DALYs) word-wide. This is due to long term effects of lead exposure with the highest burden in low and middle-income countries (WHO, 2019). So Pb toxicity remains a public health problem.

2.5 Literature review method

2.5.1 Literature search strategy for the research project, or study

The objective of this search strategy is to identify all published articles on Pb exposure in the workplace and factors associated with it in the laboratories in a science and research institution in Gauteng. For the review of literature, the listed questions were used, key words relevant to this study and search inclusion and exclusion criteria. Lastly the standard search strategies involving the querying of several data bases was used.

2.5.2 Questions raised in this study:

1. What are the Blood Lead levels of laboratory workers who underwent biological monitoring in 2018 and 2019?
2. Is there a relationship between socio-demographic characteristics and exposure to Pb?

3. What are the experiences of workers in relation to perceived health symptoms and procedures in place for Pb exposure?
4. What are the attitudes of laboratory workers towards the implementation of Pb exposure preventive procedures?
5. What is the extent of knowledge possessed by laboratory workers towards the implementation of control measures against Pb exposure?

2.5.3 Key words:

Lead exposure, workplace, laboratory, workers, biological monitoring

Outcome: Implementation of control measures against Lead exposure
Exposure: Lead exposure
Confounders: Age, position group, years of exposure, department, experiences by workers, attitude, desire and knowledge

2.5.4 Data Bases:

- SABINET: there were 886 journals and articles related to Pb exposure.
- PUBMED: PubMed comprises of more than 3910 citations for biomedical literature from life science journals, and online books. Articles on lead poisoning, lead-toxicity were searched from 2009 - 2019
- Science Direct- There were 8 871 articles relating to lead exposure amongst children and adults. The search was further refined by selecting adults in the workplace
- Google Scholar has 610 articles, journals and publications relating to lead exposure in the workplace.

The years selected for the search in all data bases was between the years 2009 – 2019 in order to get articles with recent information. The researcher included some of the articles that are before 2009 as there were limited articles relating to laboratory work in the science and research institutions.

2. 6 Search inclusion and exclusion

2.6.1 Search inclusion:

Articles that provided evidence regarding the key words of the study and articles that addressed one of the dependent variable, independent variables and confounders were included in the literature review.

2.6.2 Search exclusion

Articles that did not match the search key words, that were based on children exposed to Pb and that where exposure was not from the workplace, were excluded in the search for literature review.

2.7 Literature review

This section of the study discusses literature review and comprises of four parts. The first part being on the BLL and exposure levels, extended effects of Pb exposure, Health effects of Pb exposure and lastly the relationship of the attitude, practices and knowledge of workers is reviewed against the implementation of control measures for Pb exposure.

2.7.1 Relationship of blood lead levels and recommended exposure levels

Monitoring BLL is compulsory to monitor body burden of lead levels in the workplace. This helps to assess the need for engineering controls and the use of personal protective equipment (PPE). However, as environmental monitoring only gives an indication of the inhaled fraction, biological monitoring must be undertaken to assess an individual's total lead exposure and its effects. Blood lead levels are done for biological monitoring. Tests to assess biological effects include a full blood count, renal and liver function tests, as well as a clinical assessment of the central and peripheral nervous system (OHSA, 1993).

In the recent actions on Lead Poisoning Prevention in the USA, the National Institute of Health and Safety (NIOSH), changed the case definition for adults to level ≥5 μg/dL and made PB poisoning a nationally reportable condition. In California, the occupational lead standard was updated and the airborne lead exposure level was changes from 50 µg/m3 to 2.1 µg/m3 with goal of keeping the workers blood lead level below 10 µg/dL.

The World Health Organization estimated that 240 million people are overexposed to Pb and 99 % of those with blood levels above 20 µg/dL are in the developing world (WHO, 2019) In South Africa, the Lead Regulations (2001) under the OHSA (Act 85 of 1993) considers the BLL of ≤ 20 µg/dL as an acceptable level of exposure. Whereas developed countries like the USA and Australia recognises BLL of ≤5 µg/dL as their level. . This means that other countries including South Africa have not adopted this cut off therefore the recommended exposure levels are higher in South Africa. As such the employers have to enforce the implementation of the control measures to minimise exposure OHSA (Act 85 of 1993); Porter and Cassandra 2015; Kamunda et al., 2016). In a study of elevated Blood Lead Levels (BLL) among Fire Assay workers and their children in Alaska, there was an increased concern regarding lead toxicity at lower doses. It was further suggested that there was a need for a re-evaluation of the level at which BLLs can be considered safe and the introduction of more strict controls in the workplace. Introducing stringent control measures worked in Korea where the BLL were reduced considerably but in a study done in China by Ye and Wong (2006), workers recorded a Lead poisoning rate of 30% post the implementation of the Lead regulations in 2002. The high lead exposure levels and the lead poisoning rates suggested that the overall occupational health monitoring system was still inadequate and lacked the necessary enforcement power (Ye and Wong, 2006; Porter and Cassandra 2015)

2.7.2 The extended effects of Pb exposure even when control measures are in place

Most of the research conducted to assess the relationship of Pb exposure and sociodemographic factors were done on children. The most common factor that always comes up is the transfer of the exposure risk from the workplace to the worker's homes (Naicker1997: Porter and Cassandra, 2015). In the study conducted in China by Ye and Wong (2006) it is suggested that in addition to adverse impacts on the health of the workers themselves, children of lead-exposed workers have disproportionately higher BLLs when compared with other children whose parents are not exposed (Porter and Cassandra, 2015). Chiandra et al., 1997 have identified that workers exposed to Pb, transport lead-rich dust into their homes through their clothing, hair and shoes which puts their children at risk of exposure. Parents who showered before leaving work and also bathed immediately upon coming home showed reduced BLL.

2.7.3 Health effects as a result of Pb exposure

Workplace Lead exposure continues to pose major public health problems in adults. The Institute for Health Metrics and Evaluation (IHME) estimated that in 2017, lead exposure accounted for 1.06 million deaths and 24.4 million years of healthy life lost counted as disability-adjusted life years (DALYs) worldwide due to long-term effects on health, with the highest burden in low- and middle-income countries (WHO, 2019). This is understandable as the health effects depend on how much and how often a person is exposed to lead. Lead enters the body through mostly inhalation and ingestion. Up to 50% of Lead is inhaled and absorbed by the lungs, whilst 10-15% is ingested. Elimination of Lead is slow and occurs via the urine. Lead ends up being deposited on the bones and can stay there for 20-30 years. In the meantime, the person will experience a wide range of symptoms of lead poisoning, many of which imitate other diseases (Park et al., 2017). In a study by Khalil et al. (2007), on past occupational exposure to Pb, association between current Blood and Bone lead levels, the study results supported the hypothesis that lead stored in bones is a significant source of high BLL later in life. Meaning that older workers with past occupational exposures to Pb may face a risk of recirculation in the blood with advancing age (Hess et al., 2013: Hou et al., 2013). In a study of health outcomes of exposure to biological and chemical components of inhalable and Respirable Particulate Matter (RPM), it was identified that particulate matter (PM) is a key indicator of air pollution and a significant risk factor for adverse health outcomes in humans. Control measures in the workplace are not adequate to reduce these inhalable PM leading to chronic poisoning such as Lead poisoning (Morakinyo et al., 2016).

Chronic lead poisoning is more common in industrial settings where small amounts of lead can gradually build up in the body and result in temporary or permanent damage (Vella and O'Brian, 2011; Porter and Cassandra, 2015; Ye and Wong, 2006). It is evident that working with Pb is an occupational hazard. In a study conducted in the USA, data from the National Health and Nutrition Examination Survey II for persons 12 to 74 years of age was analysed. Significant correlations were found between blood lead and blood pressure for each race-gender group, and blood lead levels were significantly higher in groups with high diastolic blood pressure (greater than 90 mm Hg). These findings and those from other studies confirm the relationship of blood lead and blood pressure at relatively low levels commonly observed in the general population (Harlan, 1988)

2.7.4 Knowledge, Attitude and Practices of workers regarding Pb exposure control

It is imperative for the workers exposed to Pb to have knowledge of how this exposure can affect their health and as such are required to have the positive attitude towards control measures put in place and are expected to fully comply with the guidelines against Pb exposure. Lead poisoning is an important occupational disease that can have life-long adverse health effects (Meyer, 2008). In the research study conducted in 2006, in which an examination of knowledge, attitudes and practices related to Pb exposure in Nigeria was conducted, it was found that there was limited awareness of the sources of lead exposure and that participants had little knowledge of the health effects of chronic low-dose lead exposure (Adebanawo, 2006). Similar findings though much detailed were found in a cross-sectional study conducted in Ohio where rural adults' knowledge of lead poisoning prevention was assessed. Most respondents were able to identify groups at high-risk for lead poisoning, that lead poisoning could occur in ways other than ingestion of lead paint chips, lead poisoning results in long-term learning problems in children, and a blood test is used to determine blood lead levels. Respondents were less knowledgeable about methods of lead exposure and the importance of prevention measures (Polivka.1999).

In Nigeria, like most developing countries, very little attention is currently paid to environmental health problems including chronic lead exposure. Yet these factors are responsible for more morbidity, disability-adjusted quality of life loss and mortality than in developed countries (Adebanawo, 2006). Similarly, the IHME estimated that in 2017, lead exposure accounted for 1.06 million deaths and 24.4 million years of healthy life lost counted as disability-adjusted life years (DALYs) worldwide due to long-term effects on health, with the highest burden is in low- and middle-income countries (World Health Organization, 2019). In a rapidly developing country like Korea, a different picture emerges where there was a rapid introduction of engineering controls, improved occupational health service practice for lead workers, including biological monitoring, that has brought about considerable success in prevention of lead poisoning and in reducing the lead burden among the Korean lead workers (Lee. 2011).

It is evident that more studies are needed to fully understand the knowledge, attitudes and practice of workers exposed to Pb. Gaps in lead poisoning prevention knowledge exist and educational efforts should focus on decreasing these gaps thus develop appropriate health education intervention. In a study done in Nigeria, it is evident that improved knowledge and attitudes are not enough to change the behavior of laboratory workers to work in a healthy and safe way (Adebanawo 2006). The gap between knowledge and practice needs to be bridged by a more interactive and participatory training model (Finn et al., 2015).

2.8 Summary

This report serves as a reminder to employers in this industry that lead exposure during fire assay analysis and other experiments using lead, continues to pose a substantial health hazard to workers and underscores the importance of ensuring that workers exposed to lead and their families are adequately protected against lead exposure. Employers should repeatedly educate all employees who might come in contact with lead in the workplace about the dangers of lead exposure and effective ways to reduce the risk of exposure for themselves and their families (Porter et al., 2015). The HBM is applicable in this study when looking at behaviour change for employees who are laboratory workers and are exposed to Pb. They need to accept the benefits of all the control measures in place to prevent occupational exposure to Pb and also overcome barriers that prevent them from accessing or using the controls. Internal or external factors can make the employees to take action to avoid or control the exposure and finally they will need to develop confidence that they can indeed succeed in the prevention and control of Pb exposure.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter explains and examines how data was collected using primary data collection tool in the form of a questionnaire and secondary data extraction as a means of realizing study objectives and answering research questions. This chapter focuses on the study design, study area, study population, sample size, sampling procedure, data collection tool, data quality control, data analysis and the dissemination of results. The main focus is on the actual research methodology employed to carry out this research study.

3.2 Study design

The aim of the study was to assess the implementation of the controls for Pb exposure at a science and research institution in Gauteng, South Africa. A descriptive cross-sectional quantitative research was therefore found to be an appropriate design for this study (Omair, 2015; Ehlrich and Joubert, 2014). The research study gathered primary data from an online questionnaire and BLL from secondary data based in the medical biological monitoring records.

This study is focused on workers that are more exposed to Pb and those less exposed to Pb. All workers in this population had an equal chance of being selected in the study. There is no time period or time frame of the study as the study is conducted as a snap shot in time.

The study design facilitated the identification of various interrelationships amongst study variables in a short time such as perceptions and satisfaction of workers with Pb controls in place, monitoring and management of health effects (Ehlrich and Joubert, 2014).

3.3 Study area

Figure 3 represents an area map of the science and research institution where this research study was undertaken.

Figure 3: ***Area map accessed from www.mintek.co.za***

This study was performed within the premises (natural setting) of a Science and Research Council situated in Gauteng, which is under the auspices of the Department of Minerals Resources and Energy (DMRE). This Science and Research institution specializes in the extraction of minerals, chemical processing and analysis of samples as well as engineering of mineral products. The institution also has research facilities and mechanical workshops. There are over 10 different departments within the campus. These different departments are responsible for different activities within the company. Some of the departments include Analytical Services division, Pyro metallurgy, Mineralogy, Biotechnology and Materials Processing Division.

Work activities at this institution vary from milling work, mechanical repairs, hot work (tapping), sample crushing (crushing of large rock mineral samples at the crushing plant), laboratory chemical analysis, sample preparation and production of certain products as per customer requests (Mintek,2019). The study area was chosen because it was easy to get authority to conduct the study, the medicals records and study participants will also be easily accessible. Lastly, there were no travelling costs and the study could be done during normal working hours.

Figure 4: ***MINTEK visual map (Mintek, 2019*)**

3.4 Study Population

There is an estimated population of 575 workers, who are exposed to chemicals in their shift in the year 2018 - 2019. The group consists of both male and female of all races between the age group of 20 – 60 and are in all occupational levels except management level. Amongst the population, there are those directly exposed to hazardous chemicals and those not directly exposed to chemicals including Pb. Those directly exposed to chemicals include the Scientists, Engineers, Technicians and laboratory analysts and Operators. These workers conduct test work involving Pb and its products in the laboratories. In this case samples received have been identified to have Pb. In those occupation groups, there are those who are less exposed to Pb. These workers get exposed through secondary exposure such as inhaling fumes or being in contact with various chemical elements as they share laboratories.

3.5 Sample size

The sample size was calculated using the Centre of Disease Control and Prevention (CDC) EPINFO program for a cross-sectional study using a population survey approach

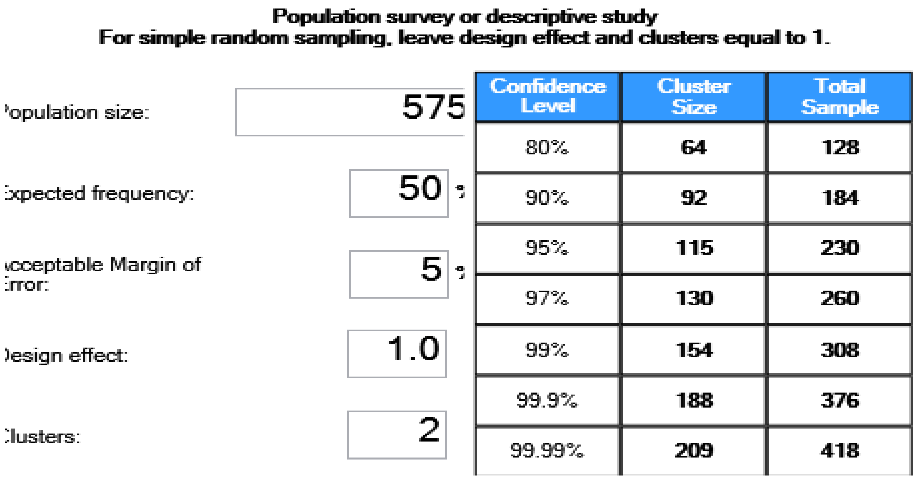

Figure: 5*: EpiInfo Sample size estimation (CDC, 2015)*

The sample size was estimated using EpiInfo version 7.2.3.0, at a 2 sided confidence interval of 95% and 80% study power. The sample size was estimated to be 230 at an acceptable error margin of 5%. A further 45% were added for contingency which is 104. The sample size was 230 + 104 = 334. An additional 55 participants who volunteered to participate in the study were included as they met the inclusion criteria. A total of 94 were sampled from the group exposed to Pb for secondary data extraction of BLL in the period 2018 - 2019.

3.5.1 Inclusion criteria

The following group of employees were included in this study:

Employees in the age groups (25 – 60) and in position groups of scientists, engineers, technicians, analysts and operators, who conduct test work using Pb and its compounds, in the laboratories. The historic records of laboratory workers who were employed during the period, 2018 – 2019, were exposed to Pb and underwent Pb biological monitoring were included in this study.

3.5.2 Exclusion criteria

The following groups of employees were excluded from the study:

Workers not exposed to Pb and any of its compounds, those not working in the laboratories, students and those below the age of 25 were excluded from the study. The assumption was that students and those below the age of 25 years had short duration of exposure due to reduced years of employment.

3.6 Data collection

3.6.1 Sampling

A probability sampling strategy using simple random sampling was used to ensure that each segment of the population is represented in this study. The sample frame which is a list of subjects already identified to have variables of interest such as those more and those less exposed to Pb was identified. The list of this exposure group was accessed at the Occupational Health Clinic. Simple Random sampling was used to randomly select the desired number of subjects from the sample frame, to reach the required sample size (Adwok, 2015; Bonita et al, 2006).

Digital platforms were used to introduce this study especially during the group meetings at different departments. Participants for secondary data extraction were also selected using simple random sampling to obtain the 94 participants. Participants who belonged to the group exposed to Pb and those in the group less exposed to Pb were categorised based on the biological monitoring records, which are kept at the Occupational Health clinic.

3.6.2 Data collection procedure

Primary data were collected through an online platform called Google Forms where a link of the structured Likert scaled questionnaire (Appendix 1) was sent to the participants. The questions included the demographic data, workplace programmes in place, health effects experienced by workers and attitude and knowledge by scientific laboratory workers. The potential subjects received a personalized email with a link to the questionnaire (Grove et al., 2013). The online data management was be supported by the research study sponsor through the provision of information technology (IT) support.

Secondary data were collected from medical records of biological monitoring results dated from 2018 -2019. Records that contain BLL were used to extract the required data (Appendix 2). An application to waiver informed consent for secondary data was granted by the Research Ethics Committee of the University of Johannesburg. The institution under study granted permission to access secondary data (Appendix 4).

3.7 Pilot study

A pilot study was conducted to test logistics and to gather information prior to the research study that would assist to perfect the research tool.

The aims of conducting a pilot study were:

1. To test the research instruments
2. To test the efficacy of the inclusion and exclusion criteria
3. To test content validity of the instrument on the target population
4. To test clarity of the information sheet and consent form
5. To identify barriers to the operational process of data collection
    i. (Thabane et al., 2010)

Selecting participants in the pilot study

The researcher piloted the questionnaire used for collecting primary data, to assess the clarity of the questions in order to rectify the challenges experienced by the testing groups in answering the questions and their perspective of the questions.

In this pilot study, participants were selected from the group that will be excluded in the study. This group has similar exposure as the study subject. They were excluded in the study as they have an exposure of less than 5 years to Pb or have been removed from exposure between the periods 2018 - 2019. Selecting participants who would be excluded from the actual study would help eliminate biasness. The findings of this pilot study were not included in the actual research study (Secomb & Smith, 2011).

Tools used to administer the research questionnaire

The questionnaire was loaded on Google-forms. The participants were send an email inviting them to participate in the pilot study. The purpose of conducting the pilot study was explained. The research information letter was attached to the email and the link to the research questionnaire was clearly identifiable. Once the questionnaire was filled in, it prompted a click on the send button that must be clicked to send back the response. Each participant received an email directed to them. Once send back, the researcher received a responses that was also captured on Google-forms. The email address record was deactivated so that the sender's details remain anonymous.

Evaluation of the pilot study findings

The success of the pilot study was evaluated based on whether the questionnaires used was effective in meeting the objectives of the actual study.

Outcome of the pilot study

An online invite was sent to 10 participants and 7 responses were received in a period of 48hours whilst the 3 other responses were received in 5 days. This assisted the researcher to gauge the response time. All the responses were completed. It was noted that in some parts of the questionnaire, participants could select 2 opposing answers which would affect the validity and reliability of the research tool. The researcher revised the structure of the questionnaire.

3.8 Validity

By conducting a thorough literature review, the researcher theoretically identified and defined concepts and definitions in this study. The data collection instrument was developed to measure the knowledge, attitudes, practices, and experiences for Pb exposure control measures and to capture the BLL for the period 2018 and 2019.for those exposed to Pb around the defined concepts which will also answer the research questions. The questions were short, clear and to the point. The questions progressed logically and the answers to the question were not influenced by the previous questions. The pilot study was conducted to test the validity of the questionnaire and their responses were analysed and tested on the data analysis system, SPSS.

3.9 Reliability

In this study, the measurements were considered reliable if the respondent gives the same answers for the same question asked at different times. It would indicate that the respondent has the same understanding of the question. The data entries on computer were entered twice to check and correct errors. Where entries remained the same it proved reliability of the data. The factors in the study were analysed by SPSS which is a computer program that has been tested and retested over time.

3.10 Study Variables

The study variables for the research study consisted of both independent and independent variables. The dependent variables were mainly derived from the research participant's demographic characteristics. The independent variables were derived from knowledge, attitude, desire and experiences characteristics of the research participants. The variables are shown in table 2.

Table 3: Selected dependent and independent variables used in this study

Variable type	**Variable name**	**Variable source**	**Level of measurement**
Independent	Gender	Questionnaire	Categorical
Independent	Age group	Questionnaire	Categorical
Independent	Occupational group	Questionnaire	Categorical
Covariates	Years of exposure to Pb	Questionnaire	Categorical
Dependent	Smoking	Questionnaire	Nominal
Dependent	Alcohol	Questionnaire	Nominal
Independent	Lead exposure	Medical records	Continuous
Independent	Less exposed to Pb	Medical records	Continuous
Covariates	Periodic medicals	Questionnaire	Nominal
Covariates	Biological monitoring	Questionnaire	Nominal
Covariates	Risk assessment records	Questionnaire	Nominal
Dependent	Inspection records	Questionnaire	Nominal
Dependent	Job observations records	Questionnaire	Nominal
Dependent	Training in Pb chemical handling	Questionnaire	Nominal
Dependent	Supply of PPE	Questionnaire	Categorical
Dependent	Health effects due to Pb exposure	Questionnaire	Nominal
Dependent	Attitude towards health and safety policy	Questionnaire	Continuous
Dependent	Desire to comply to use of correct PPE and to comply to safety standards	Questionnaire	Continuous
Dependent	Knowledge of Pb exposure control measures	Questionnaire	Continuous

3.11 Sources of data

Primary data were collected using a structured online questionnaires and another part of data from secondary data sources. The primary data was collected through an online questionnaire with structured questions. The questions were based on the experiences of workers exposed to Pb with control measures in place to protect them from harmful exposures. Secondary data relating to the blood lead levels in the period 2018 – 2019 were extracted from the Biological monitoring records which are kept as medical records by the occupational health clinic.

3.12 Instrumentation

For this study, an online questionnaire was used to obtain primary data whilst a form of data extraction was used for secondary data extraction relating to BLL. The data extraction form was used to ensure that all the data required for the study is extracted from the medical records at the Occupational Health Unit.

3.13 Data analysis

Data was analysed by running frequencies and descriptive statistics. Frequency distributions tables were computed. Odds ratio and 95% confidence interval was then calculated to ascertain the association between exposure to Pb and other variables. Table shells were also prepared for bivariate analysis.

3.14 Data analysis for each objective

For Objective 1: *To describe the blood lead levels amongst those who underwent biological monitoring in 2018 and 2019.*

The frequency distributions tables were computed and then graphs were generated.

For Objective 2: *To examine the relationship between Pb exposure and socio-demographics characteristics*, logistic regression was used and then the significance of this association was tested at 95% CI. The crude odds and adjusted odds ratios for the group exposed to Pb and those less exposed to Pb were calculated using EPINFO and SPSS at a confidence interval of 95%.

For objective 3: *To assess the Pb exposure by experiences of workers on the perceived health symptoms and the procedures in place for Pb control*, logistic regression was used to determine if worker's experiences were a predictor to exposure to Pb. Socio-demographic characteristics (gender, age-group, occupation, years of exposure, smoking and alcohol) were then added into the model as covariates together with each variable under worker experiences to establish their contribution through adjusted analysis.

For objective 4*: To assess the Pb exposure by attitudes of workers on the implementation of Pb exposure prevention procedures,* a logistic analysis was done by including all the variables in the model at the same time to obtain the odds ratio and respective confidence interval (CI).

For objective 5: *To assess Pb exposure by knowledge of workers on the control measures to be implemented to control Pb exposure,* logistic analysis was done where all variables were included in the model to obtain the odds ratio and the respective confidence interval.

3.15 Ethical Consideration

Permission to conduct this research study was obtained from the institution under research study prior to commencement of this study project as per company policy. Permission has been granted to conduct the study (Appendix 3) and to access secondary data which are BLL records in the medical records (Appendix 4). The institution has a right to terminate the study at any stage if they feel that the rights and protection of information has been bridged. Since secondary data was collected through the use of medical records, neither any of the cases were denied treatment or were exposed to harmful substances in ascertaining the relationship between blood lead levels and being exposed to Pb. During the pilot study phase, the anonymity of the participants was compromised when one email address was recorded on the responses captured on Google-forms. The email record was deactivated and that assisted to maintain anonymity of all study responses. This assisted the researcher to correct the mistakes that could jeopardize the study. Finally, the results of this study would only be used for academic purposes and within the institution where the study was conducted and would not be published without prior consent from all concerned parties.

3.16 Summary

This study was a onetime study that was focused on the implementation of Pb exposure controls in the laboratories of the science and research institution in Gauteng. The study firstly assessed the Pb levels of those exposed to Pb in the period 2018-2019. It went further to assess the relationship of socio demographics factors when compared to Pb exposure, the experiences of those more exposed to and those less exposed to Pb, the association of exposure to health symptoms and the attitude and knowledge of laboratory workers to Pb exposure. The collected data in this study addressed the objectives of the study. The next chapter will present the analysis of the data collected.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents the analysis of data followed by a presentation and interpretation of the research findings. Data analysis was done using the Statistical Package for Social Sciences (SPSS) version 27 and EPINFO 7.2. The result of the analysis is presented using figures and tables. Data were presented according to the sections of the questionnaire which are biographical data, workplace program to control and manage exposure as experienced by workers, health effects experienced by workers due to exposure to Pb, workers attitude and knowledge of Pb exposure controls. Data was collected from 389 laboratory workers who were more exposed to Pb and those who were less exposed to Pb, through an online questionnaire. There was a 100% return on responses. Another part of the data were extracted from secondary data for primary data participants and is represented by BLL in year 2018 and year 2019 from 94 participants. This chapter therefore presents the results for this study.

4.2 Research aim and objectives

The overall aim of the study is to assess the implementation of the controls for Pb exposure at a science and research institution in Gauteng.

1. To describe the blood lead levels amongst those who underwent biological monitoring in 2018 and 2019

2. To examine the relationship between Pb exposure and socio-demographics characteristics

3. To assess the Pb exposure by experiences of workers on the perceived health symptoms and the procedures in place for Pb control

4. To assess the Pb exposure by attitudes of workers on the implementation of Pb exposure prevention procedures

5. To assess Pb exposure by knowledge of workers on the control measures to be implemented to control Pb exposure.

4.3 Data Analysis Process

After the data were entered into SPSS version 27, it was first cleaned before analysis to assess accuracy. This process involved editing and correcting unusual figures in coding and working on data entry typographical errors (Azeroual, et al., 2018). The CDC program EPINFO 7.2 was used to calculate crude odds ratios, while SPSS was used to calculate the adjusted odds ratios using multivariate logistic regression. Descriptive statistical analysis was used to identify frequencies and percentages to answer all questions in the questionnaire. The EPINFO 7.2 program was used to calculate the crude odds ratios, as it helped to visualize the data. Adjusted odds ratios were obtained by using Multivariate Logistic Regression to establish the probability of factors associated with Pb exposure due to working in the laboratories of a science and research institution. The statistical significance of relationships among the variables was determined using the confidence intervals. Data is presented in tables and figures.

4.4 Blood Lead levels (BLL) of workers exposed to Pb

To address objective 1, the BLL were extracted from secondary data for 94 participants who are exposed to Pb in the period 2018-2019. BLL were categorised into action level <20ug/dL, 20-39ug/dL, 40-59ug/dL and >60ug/dL. Figure 4.1 and figure 4.2 will demonstrate the BLL in 2018 and 2019.

4.4.1 Blood level of lead in 2018

The BLL for the selected participants who are exposed to Pb were extracted from secondary data for the year 2018**.** Figure 4.1 demonstrates the BLL extracted through secondary data in year1 (2018) for n=94 workers exposed to Pb.

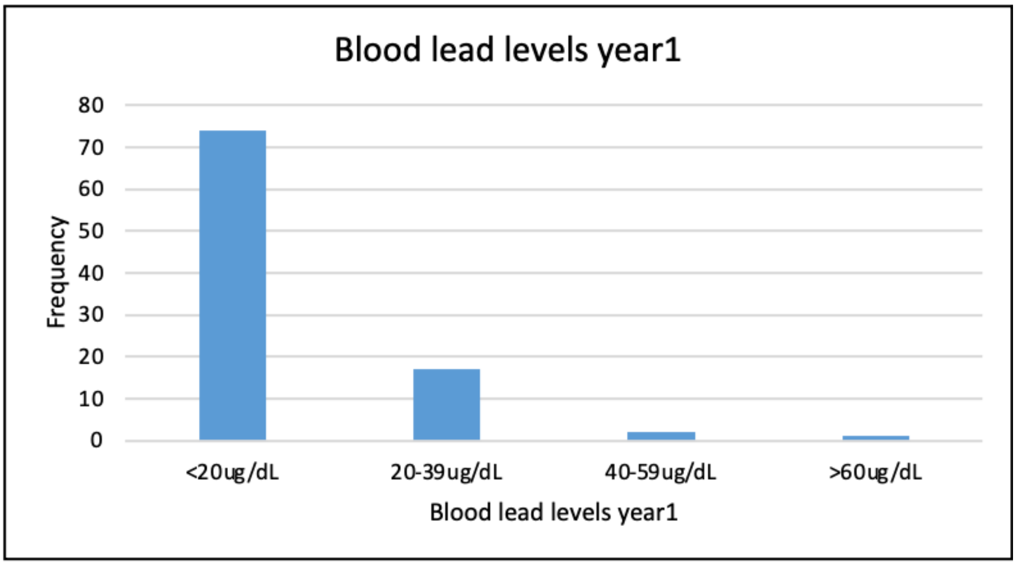

Figure: 6: Blood Pb levels in Year 1

Of the 94 participants with Blood Pb levels in year1, the majority 74(79%) had BLL <20, followed by 17 (18%) of those with BLL ranging from 20-39ug/dl. Fewer participants 2 (2%) had BLL of 40-59ug/dL and 1(1%) at BLL of >60ug/dL.

4.4.2 Blood level of lead in year 2

BLL for the same participants sampled in 2018, were extracted from secondary data for the year 2019. Figure 4.2 demonstrates the BLL extracted through secondary data in year 2 (2019) for n=94 laboratory workers exposed to Pb,

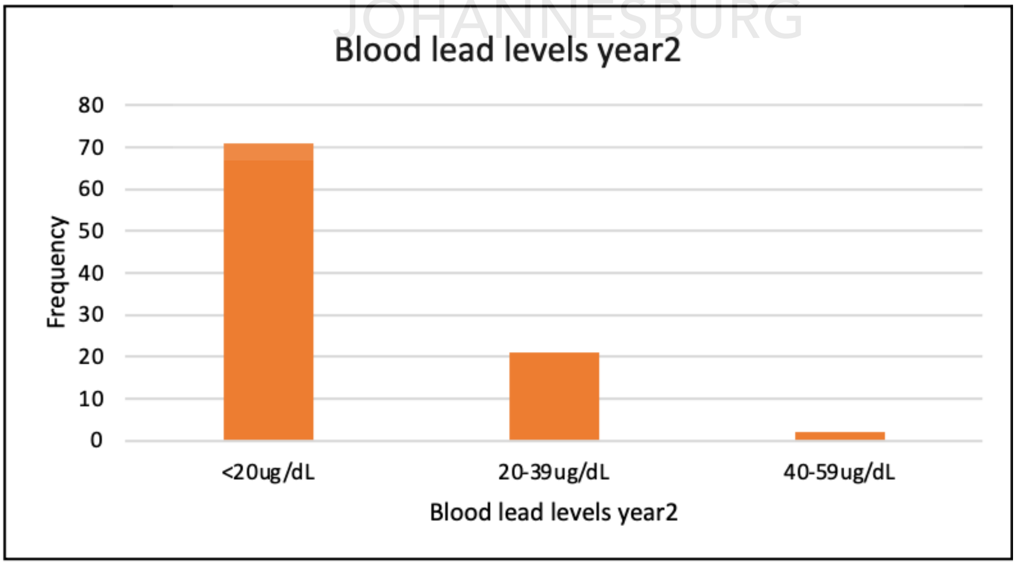

Figure 7: Blood Pb levels in Year 2

The majority of the participants 71(76%) had BLL <20ug/dL followed by 21(22%) with BLL of 20-39ug/dL and a few 2 (2%) with a result of 40-59ug/dL.

4.4.3: Frequency table for Blood Pb levels in Y1 and Y2 for n = 94 workers

BLL in year1 and year 2 for the n=94 participants exposed to Pb were extracted through secondary data for the same participants in 2018 and 2019. Table 4.1 demonstrates the frequency distribution table for the BLL in the following biological exposure levels, <20μg/dl, 20-39μg/dL, 40-59μg/dL and >60μg/dL.

Table 4: Frequency distribution for BLL in 2018 and 2019

	Year 1		**Year 2**	
Characteristics	**n**	**%**	**n**	**%**
Total	**94**	**100%**	**94**	**100**
< 20 μg/dL	74	78.7%	71	75.5%
20-39 μg /dL	17	18.1%	21	22.3%
40-59μg/dL	2	2.1%	2	2.1%
>60μg/dL	1	1.1%	0	0.0%

The Blood Pb levels assessed in 2018 and 2019 for 94 (52%) participants exposed to Pb n=181 revealed y1= 18.1% and y2= 22.3% were within the 20-39ug/dL levels, whilst 2.1% in both years were within the levels, 40-59ug/dL and 1.1% exceeded the level 60ug/dL.

4. 5: Distribution by Socio -Demographic Characteristics

This section presents the socio-demographic characteristics of participants and addresses objective 2. The variables such as age-group, workplace departments and years of exposure to Pb. Figure 4.3 to Figure 4.5 present graphical distributions for age, division and years of exposure to Pb.

4.5.1: Age Distribution of Participants

The age groups of research participants exposed to Pb were divided into 4 groups, 25-34, 35-44, 45-54 and 55-60 which were further stratified into those more exposed to Pb and those less exposed to Pb. Figure 4.3 demonstrates the age group categories for participants in this study.

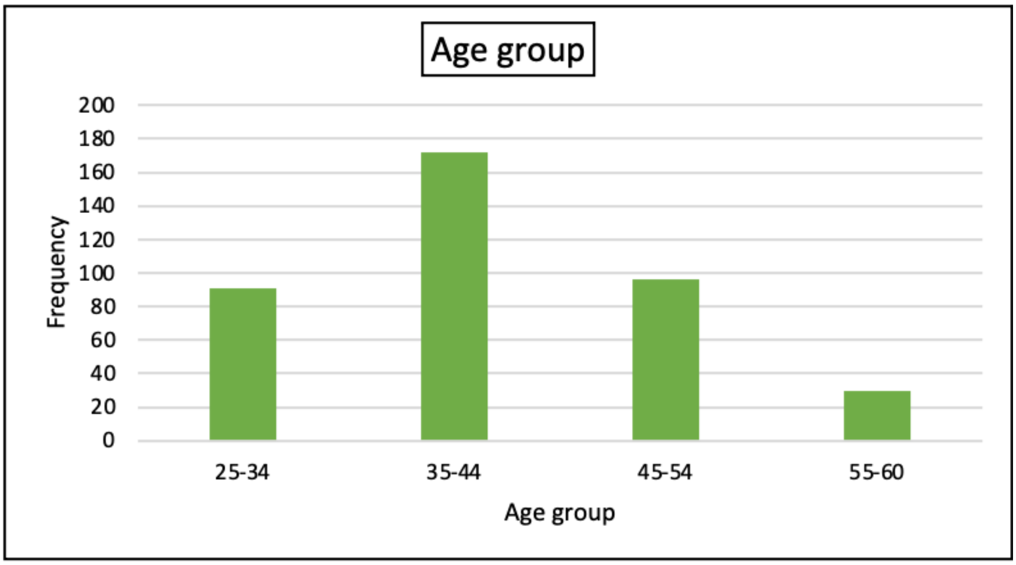

Figure 8: Frequency bar graph for age-groups of research participants

Of the 389 participants, the majority 172 (44.2%) were in the age group 35-44, followed by 96 (24.7%) in the age group 45-54 and 91 (23.4%). A fewer 30 (7.7%) participants were in the age group 25-34.

4.5.2 Distribution of Participants by departments in the workplace.

The workplace departments in which laboratory workers are more exposed to Pb or are less likely exposed to Pb were identified to be ASD, PDD and other supporting departments. Figure 4.4 demonstrates the departments within the science and research institution where laboratory workers are more exposed and less exposed to Pb.

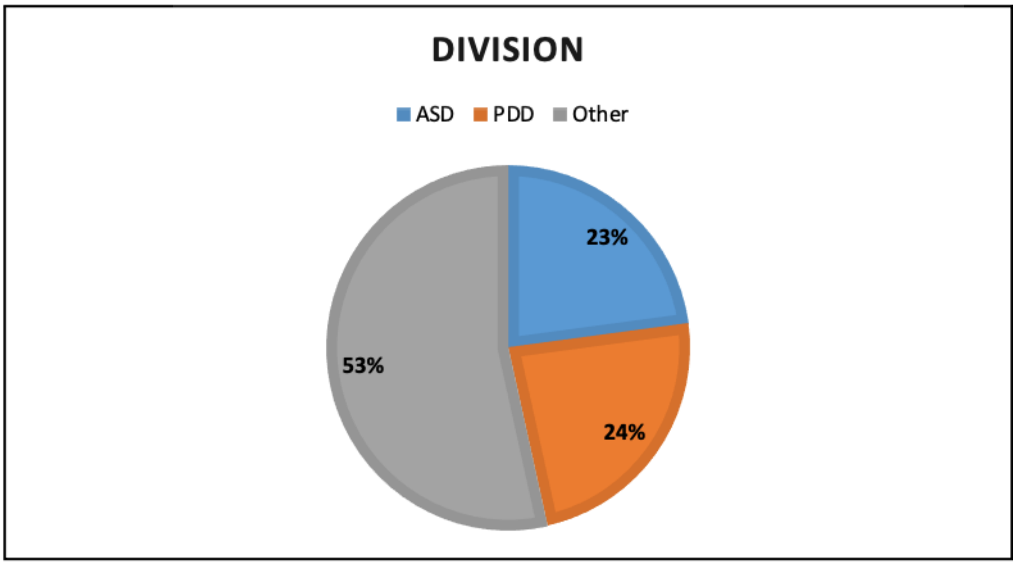

Figure 9: Frequency Pie chart for participants per department in the workplace

Of the 389 participants, a majority 208 (53%) were from other supporting divisions followed by 92(24%) from PDD and 89 (23%) from ASD.

4.5.3 Distribution of Participants by Years of exposure to Pb

The participants in this study were grouped by years of exposure to Pb ranging from <5years, 5-10years, 11-20years and >20years which were further stratified into whether the laboratory workers were more exposed or less exposed to Pb.. Figure 4.5 demonstrates a graphical presentation of the number of workers in each category of years of exposure to Pb.

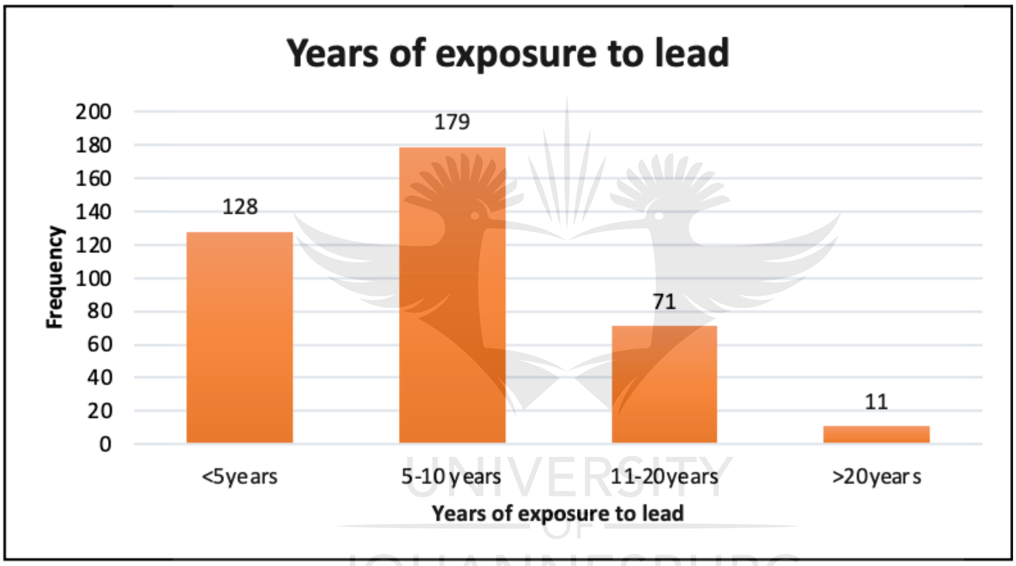

Figure 10: Frequency bar graph into years of exposure to Pb

The majority of the participants 179 (46%) had exposure period ranging from 5-10years, followed by 128 (32.9%) with exposure years <5years and 71 (18.3%) with 11-20years exposure and fewer participants 11 (2.8%) with >20 years exposure

4.5.4 Distribution of Participants by Sociodemographic Characteristics stratified by Pb status

Out of a total 389 participants in this study, (n=181 46.5%) were exposed to Pb compared with (n= 208 53.5%). The numbers, and raw percentages were presented for each socio-demographic characteristic by Pb exposure status. The following characteristics gender, age-group, occupation, years of exposure to Pb, smoking and alcohol were used. Table 4.2 represents biographical characteristics stratified according to degree of exposure to Pb.

Table 5: Frequency distribution table for socio-demographic characteristics

	Total		**More exposed to Pb**		**Less exposed to Pb**	
Characteristics	n	%	n	%	N	%
Total	389	100%	181	46.5%	208	53.5%
Gender						
Female	145	37.3%	74	51%	71	49%
Male	244	62.7%	107	43.9%	137	56.1%
Age-group						
25 - 34	91	23.4%	30	33%	61	67%
35-44	172	44.2%	85	49.4%	87	50.6%
45-54	96	24.7%	49	51%	47	49%
55 - 60	30	7.7%	17	56.7%	13	43.3%
Occupation						
Operator	144	37%	59	41.3%	84	58.7%
Scientist	86	22.2%	54	62.8%	32	37.2%
Technician	104	26.8%	35	33.7%	69	66.3%
Engineer	55	14.2%	33	60%	22	40%
Division						
ASD	89	22.9%	89	100%	0	0.0%
PDD	92	23.7%	92	100%	0	0.0%
Other	208	53.5%	0	0.0%	208	100%
Years of exposure						
<5 years	128	32.9%	24	18.8%	104	81.3%
5-10 years	179	46%	98	54.7%	81	45.3%
11-20years	71	18.3%	48	67.6%	23	32.4%
>20years	11	2.8%	11	100%	0	0.0%
Smoking						
Yes	130	33.4%	55	42.3%	75	57.7%

No	259	66.6%	126	48.6%	133	51.4%
Alcohol						
Yes	208	53.5%	81	38.9%	127	61.1%
No	181	46.5%	100	55.2%	81	44.8%

Overall, 181(46.5%) out of 389 participants are more exposed to Pb. Among these, more males (62.7%) with 43.9% are exposed to Pb. Those more exposed to Pb are mostly in the age-group 45-54 years (51%), are Scientist (62.8%) and are in PDD (100%) and ASD (100%). They have 5-10years (46%) years of exposure and do not smoke (48.6%) or drink alcohol (55.2%).

4.5.5: Crude and Adjusted Odds Ratio by Socio-Demographic Status

EPINFO was used to calculate the crude analysis and SPSS was used to calculate the adjusted analysis. The variables were adjusted for gender, age-group, occupation, years of exposure, smoking and alcohol. Table 4.3 represents the crude odds, adjusted odds ratio and confidence intervals for all the variables in the socio-demographic status.

Table 6: Crude and adjusted odds ratio by socio-demographic status

Characteristics	**Crude odds Ratio**	**95% Confidence Intervals**	**Adjusted* Odds Ratio**	**95% Confidence Intervals**
Gender				
Female	1.33	0.88-2.02	1.35	0.75-2.42
Male	Reference	Reference	Reference	Reference
Age-group				
25 - 34	**0.50**	**0.36-0.85**	0.77	0.41-1.50
35-44	Reference	Reference	Reference	Reference
45-54	1.07	0.65-1.76	1.18	0.63-2.19
55 - 60	1.34	0.61-2.92	1.62	0.60-4.34

Table 6: Crude and adjusted odds ratio by socio-demographic status

Occupation				
Operator	Reference	Reference	Reference	Reference
Scientist	**2.40**	**1.39-4.16**	**3.27**	**1.60-6.74**
Technician	0.72	0.43-1.22	0.86	0.44-1.70
Engineer	**2.14**	**1.13-4.03**	**3.33**	1**.50-7.41**
Division				
ASD¶	**2.49**	**1.73-3.59**	Undefined	Undefined
PDD¶	**2.58**	**1.79-3.71**	Undefined	Undefined
Other	Reference	Reference	Reference	Reference
Years of exposure				
<5 years	**0.19**	**0.11-0.32**	**0.20**	**0.11-0.36**
5-10 years	Reference	Reference	Reference	Reference
11-20years	1.72	0.97-3.10	**2.32**	**1.15-4.67**
>20years	**9.09**	**1.15-71.92**	Undefined	Undefined
Smoking				
No	1.31	0.84-1.98	1.21	0.70-2.18
Yes	Reference	Reference	Reference	Reference
Alcohol				
No	**1.94**	**1.31-2.90**	**2.30**	**1.30-4.02**
Yes	Reference	Reference	Reference	Reference

¶ *Data cantered by a factor of 100*

** Adjusted for gender, Age-group, occupation, years of exposure, smoking and alcohol.*

Using the age group 35-44 as reference, participants in the age group 25-34, were less likely to be exposed to Pb, odds ratio (OR) = 0.50 95% CI (0.36-0.85) but this analysis did not hold in adjusted analysis. Participants who are scientists and engineers were significantly more likely to be exposed to Pb in both crude and adjusted analysis, adjusted odds ratio (AOR) = 3.27 95% CI (1.60-6.74) and AOR = 3.33, 95% CI (1.50-7.41), respectively. The participants more exposed to Pb were significantly more likely to be from ASD and PDD, OR = 2.49, 95% CI (1.73-3.59) and OR= 2.58, 95% CI (1.79-3.71) respectively.

Participants with <5 years exposure were less likely to be exposed to Pb in both crude and adjusted analysis, AOR= 0.20 95% CI (0.11-0.36) whist participants with 11-20 years exposure were significantly more exposed to Pb in adjusted analysis only, AOR = 2.32 95% CI (1.15-4.67) and those >20years exposure were significantly more likely to be exposed to Pb, OR= 9.09 95%CI (1.15-71.92). This association did not hold with adjusted analysis. The participants who are exposed to Pb are significantly more likely not to drink alcohol in both crude an adjusted AOR= 2.30 95% CI (1.30-4.02).

4.6 **Workplace programs to control and manage exposure as experienced by workers.**

In this section, participants were asked to respond to questions relating to their experiences with workplace programmes to control and manage exposure to Pb. The participants were stratified into those more exposed to Pb and those less exposed to Pb.

4.6.1 Distribution table representing responses to worker experiences of workplace programs to control and manage exposure to Pb

To address objective 3, Information was gathered from participants on their experiences relating to workplace programs to control and manage exposure. The responses were stratified by whether the participants were more exposed to Pb or less exposed to Pb. Table 4.4 represents the responses.

Table 7: Workplace programs to control and manage exposure as experienced by workers.

	Total		**More exposed to Pb**		**Less exposed to PB**	
Characteristics	n	%	n	%	N	%
Total	389	100	181	46%	208	54%
I usually undertake periodic medicals						
Strongly agree	154	39.6%	120	77.9%	34	22.1%
Agree	211	54.2%	48	22.7%	163	77.3%
Neutral	6	1.5%	1	16.7%	5	83.3%
Disagree	14	3.6%	8	57.1%	6	42.9%
Strongly disagree	4	1%	4	100%	0	0.0%
I usually undertake biological monitoring						
Strongly agree	113	29%	81	71.7%	32	28.3%
Agree	209	53.7%	71	34%	138	66%

Neutral	17	4.4%	0	0.0%	17	100%
Disagree	48	12.3%	27	56.3%	21	43.8%
Strongly disagree	2	5%	2	100%	0	0.0%
I am a registered radiation worker supplied with a TLD badge						
Strongly agree	92	23.7%	57	62%	35	28%
Agree	238	61.2%	91	38.2%	147	61.8%
Neutral	6	1.5%	1	16.7%	5	83.3%
Disagree	50	12.9%	29	58%	21	42%
Strongly disagree	3	8%	3	100%	0	0,0%
There are risk assessment records for the work processes						
Strongly agree	81	20.8%	46	56.8%	35	43.2%
Agree	250	64.3%	103	41.2%	147	58.8%
Neutral	1.5	3.9%	10	66.7%	5	33.3%
Disagree	37	9.5%	16	43.2%	21	56.8%
Strongly disagree	6	1.5%	6	100%	0	0.0%
There are no inspection records for the fume cupboards						
Strongly agree	13	3.3%	11	84.6%	2	15.4%
Agree	69	17.7%	59	85.5%	10	14.5%
Neutral	36	9.3%	26	72.2%	10	27.8%
Disagree	226	58.1%	70	31%	156	69%
Strongly disagree	45	11.6%	15	33.3%	30	66.7%
There are no records of job observations in the training records						
Strongly agree	4	1%	4	100%	0	0.0%
Agree	33	8.5%	25	75.8%	8	24.2%
Neutral	19	4.9%	12	63.2%	7	36.8%
Disagree	279	71.7%	114	40.9%	165	59.1%
Strongly disagree	54	13.9%	26	48.1%	28	51.9%
There is no record to show that I have undergone training in Lead chemical handling						
Strongly agree	33	8.5%	33	100%	0	0.0%

Agree	89	22.9%	58	65.2%	31	34.8%
Neutral	20	5.1%	6	30%	14	70%
Disagree	207	53.2%	74	35.7%	133	64.3%
Strongly disagree	40	10.3%	10	25%	30	75%
There is a record of reported incident of accidental exposure in my workplace/Division						
Strongly agree	44	11.3%	42	95.5%	2	4.5%
Agree	108	27.8%	87	80.6%	21	19.4%
Neutral	58	14.9%	18	31%	40	69%
Disagree	170	43.7%	33	19.4%	137	80.6%
Strongly disagree	9	2.3%	1	11.1%	8	88.9%
There is an incident of exposure to an unidentified chemical in my workplace/Division.						
Strongly agree	52	13.4%	50	96.2%	2	3.8%
Agree	79	20.3%	76	96.2%	3	3.8%
Neutral	47	12.1%	12	25.5%	35	74.5%
Disagree	174	44.8%	38	21.8%	136	78.2%
Strongly disagree	34	8.7%	5	14.7%	29	85.3%
There is no record to prove that I was supplied with the correct PPE						
Strongly agree	35	9%	34	97.1%	1	2.9%
Agree	61	15.7%	56	91.8%	5	8.2%
Neutral	11	2.89%	4	36.4%	7	63.6%
Disagree	224	57.6%	69	30.8%	155	69.2%
Strongly disagree	58	14.9%	18	31%	40	69%

The respondents were asked if they undergo periodic medicals and of those who responded with strongly agree and agree were 120 (77.9%) and 48(22.7%) respectively were more exposed to Pb. In the question “I usually undergo biological monitoring’ the majority respondents who were more exposed to Pb responded with strongly agree were 81 (71.7%) followed by agree 71(34%). When asked if” they are registered Radiation workers and issued with TLD badge”, the majority of those more exposed to Pb responded with agree were 91(38.2%) followed by 57(62%) of those who strongly agreed. The respondents were further asked if there were records of risk assessment for work processes and the result from those more exposed to Pb was that 103(41.2%) and 46(56.8%) responded with agree and strongly agree respectively. When asked if "there were no inspection records for the fume cupboards", those in the group more exposed to Pb, 70(31%) responded with disagree whilst 15(33.3%) responded with strongly disagree.

In the question" there are no records of job observations" of those more exposed to Pb, 114(40.9%) responded with disagree and 26(48.1%) responded with strongly disagree. The respondents were further asked if "there were no record of Pb handling training" of those more exposed to Pb, 114 (40.9 %) disagreed and 26 (48.1 %) strongly disagreed. The respondents were asked if" there was a record of reported incident of accidental exposure" those more exposed to Pb responded with disagree 33(19.4%) and with agree 87 (80.6%). In the responses by participants for the question "there is an incident of exposure to an unidentified chemical" of these responses, 38(21.8%) who responded with disagree and 76(96.2%) who responded with agree were more exposed to Pb. In the question "there is no record to prove that I was supplied with PPE" those more exposed to Pb responded with disagree, 69 (30.8%) followed by those who responded with agree 56(91.8).

4.6.2: Crude and adjusted odds ratio to worker's experiences of workplace programs to control and manage exposure.

To address objective 3: the worker's experiences of workplace programs to control and manage exposure were assessed using crude and adjusted analysis. Table 4.5 shows the crude odds ratio and adjusted odds ratio for the workers experiences of existing controls in place.

TABLE 8: Odds ratio comparing worker's experiences of those exposed to Pb and those less exposed to Pb

Characteristics	**Crude odds Ratio**	**95% Confidence Intervals**	**Adjusted* Odds Ratio**	**95% Confidence intervals**
I usually undertake periodic medicals				
Strongly agree	**11.99**	**7.28-19.73**	**8.90**	**2.70-29.40**
Agree	Reference	Reference	Reference	Reference
Neutral	0.68	0.08-5.95	0.60	0.06-6.31
*Disagree added with strongly disagree	**6.79**	**2.42-19.05**	**9.23**	**5.20-16.51**

I usually undertake biological monitoring				
Strongly agree	**4.92**	**2.99-8.12**	**2.44**	**1.17-5.10**
Agree	Reference	Reference	Reference	Reference
Neutral	0.39	0.05-3.39	Undefined	Undefined
*Disagree added with strongly disagree	**2.68**	**1.43-5.04**	**3.65**	**2.05-6.50**
I am a registered radiation worker supplied with a TLD badge				
Strongly agree	**2.63**	**1.60-4.31**	**2.81**	**1.34-5.9**
Agree	Reference	Reference	Reference	Reference
Neutral	0.32	0.04-2.81	0.96	0.09 -9.80
*Disagree added with strongly disagree	**2.46**	**1.31-4.53**	**2.17**	**1.21-3.89**
There are risk assessment records for the work processes				
Strongly agree	**1.89**	**1.13-3.11**	**2.42**	**1.08-5.42**
Agree	Reference	Reference	Reference	Reference
Neutral	2.85	0.95-8.60	**3.79**	**1.01-14.24**
*Disagree added with strongly disagree	1.50	0.78-2.86	1.33	0.72-2.45
There are no inspection records for the fume cupboards				
Strongly agree	0.41	0.09-1.88	0.60	0.30-1.30
Agree	**0.38**	**0.18-0.78**	**0.14**	**0.05-0.35**
Neutral	0.86	0.40-1.87	**0.08**	**0.03-0.18**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	1.11	0.60-2.20	**9.80**	**1.90-50.78**
There are no records of job observations in the training records				
*Agree added to strongly agree	**5.25**	**2.31-11.9**	1.50	0.74-2.85
Neutral	1.34	0.75-2.41	**4.70**	**1.51-14.40**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	1.11	0.56-2.20	**4.10**	**1.60-10.70**
There is no record to show that I have undergone training in Lead chemical handling				
*Strongly agree added to agree	**5.28**	**3.21-8.67**	**5.33**	**1.96-14.45**

Neutral	0.77	0.28-2.09	0.54	0.17-1.69
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	0.60	0.28-1.29	**0.19**	**0.10-0.35**
There is a record of reported incident of accidental exposure in my workplace/Division				
Strongly agree	**5.07**	**1.14-22.63**	Undefined	Undefined
Agree	Reference	Reference	Reference	Reference
Neutral	**0.11**	**0.05-0.23**	**0.44**	**0.21-0.93**
*Disagree added to strongly disagreed	**0.06**	**0.03-0.11**	**0.07**	**0.03-0.14**
There is an incident of exposure to an unidentified chemical in my workplace/Division.				
Strongly agree	**0.14**	**0.03-0.62**	0.40	0.13-1.12
Agree	**0.14**	**0.04-0.50**	0.61	0.26-1.45
Neutral	1.23	0.60-2.60	**0.01**	**0.04-0.05**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	0.62	0.22-1.70	**0.02**	**0.01-0.07**
There is no record to prove that I was supplied with the correct PPE				
*Agree added with Strongly agree	**33.69**	**14.06-80.7**	1.73	0.83-3.60
Neutral	1.28	0.36-4.52	0.30	0.07-1.22
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	1.01	0.54-1.89	**0.03**	**0.01-0.10**

- Adjusted for gender, Age-group, occupation, years of exposure, smoking and alcohol.

Participants who answered “strongly agree and disagree or strongly disagree in the questions “ I usually undertake periodic medicals and “ I usually undertake biological monitoring” were significantly more likely to be exposed to Pb in both crude and adjusted analysis,{ AOR= 8.90 95% CI (2.70-29.40) and AOR = 9.23 95% CI(5.20-16.51)} and { AOR= 2.44 95% CI (1.17-5.10) and AOR= 3.65 95% CI (2.05-6.50) respectively as compared to agree as reference. Participants who responded with strongly agree and disagree or strongly disagree, to the question “ I am a registered radiation worker supplied with a TLD badge” are significantly more likely to be exposed to Pb in both crude and adjusted analysis, AOR= 2.81 95% CI (1.34-5.9) and AOR= 2.17 95% CI (1.21-3.89) respectively as compared to agree as reference.

In the question “There are risk assessment records for the work processes” participants who responded with strongly agreed and neutral were significantly more likely to be exposed to Pb AOR= 2.42 95% CI (1.08-5.42) and AOR = 3.79 95% CI (1.01-14.24) respectively when compared to agree as a reference. The participants who responded with agree to the question “there are no inspection records for the fume cupboards” were less likely to be exposed to Pb in both crude and adjusted analysis AOR= 0.14 95% CI (0.05-0.35). Those who answered neutral were also less likely to be exposed to Pb in adjusted analysis AOR = 0.08 95% CI (0.03-0.18) whist those who responded with strongly agree were more likely to be exposed to Pb in adjusted analysis AOR = 4.10 95% CI (1.60-10.70).

In the question “there are no records of job observations in the training records” the participants who responded with agree were more likely to be exposed to Pb in crude analysis OR= 5.25 95% Ci (2.31-11.9) those who answered with neutral and strongly agree were more likely to be exposed to Pb in adjusted analysis AOR = 4.70 95% CI (1.51-14.40) and AOR = 4.10 95% CI (1.60-10.70) respectively when compared to disagree as reference. Participants who responded with strongly agree or agree to the question” there is no record of training in Pb handling” were more likely in both crude and adjusted analysis to be exposed to Pb AOR = 5.33 95% CI (1.96-14.45) whilst those who answered with strongly disagree were less likely to be exposed to Pb when compared to disagree as a reference.

In the question “there is a reported incident of accidental exposure” the participants who responded with strongly agree were more likely to be exposed to Pb in crude analysis OR = 5.07 95% CI (1.14-22.63). This association did not hold in adjusted analysis. The participants who answered with neutral and disagree or strongly disagree were less likely to be exposed to Pb in both crude and adjusted analysis AOR = 0.44 95% CI (0.21-0.93) and AOR = 0.07 95% CI (0.03-0.14) respectively when compared to agree as reference. In the question of incidental exposure to an unidentified chemical, the participants who responded with strongly agree and agree were less likely to be exposed to Pb, AOR = 0.14 95% CI (0.03-0.62) and AOR = 0.14 95% CI (0.04-0.50) respectively. Similarly with those who answered with neutral and strongly disagree with AOR = 0.01 95% CI (0.04-0.05) and AOR = 0.02 95% CI (0.01-0.07) respectively when compared to disagree as a reference.

The participants who answered with agree or strongly agree to the statement, “there is no record of PPE supply” were more likely to be exposed to Pb in crude analysis OR = 33.69 95% CI (14.06-80.7). This association did not hold in adjusted analysis. Those who answered with strongly disagree were less likely to be exposed to Pb in adjusted analysis AOR = 0.03 95% CI (0.01-0.10)

4.7 Health effects experienced by workers due to exposure to Pb

For this section, to further address objective 3, the participants who are exposed and those less exposed to Pb were asked to indicate the number of symptoms they are experiencing due to exposure to Pb. Figure 4.6 depicts the health effects experienced by workers due to exposure to Pb as categorized by the number of symptoms experienced.

4.7.1 Graphical representation of responses relating to the number of symptoms experienced by workers

Participants more exposed to Pb and those less exposed to Pb indicated the number of symptoms they are experiencing due to exposure to Pb in the following categories, None to 1 symptom, 2-3 symptoms and >3 symptoms. Figure 4.6 represents those responses.

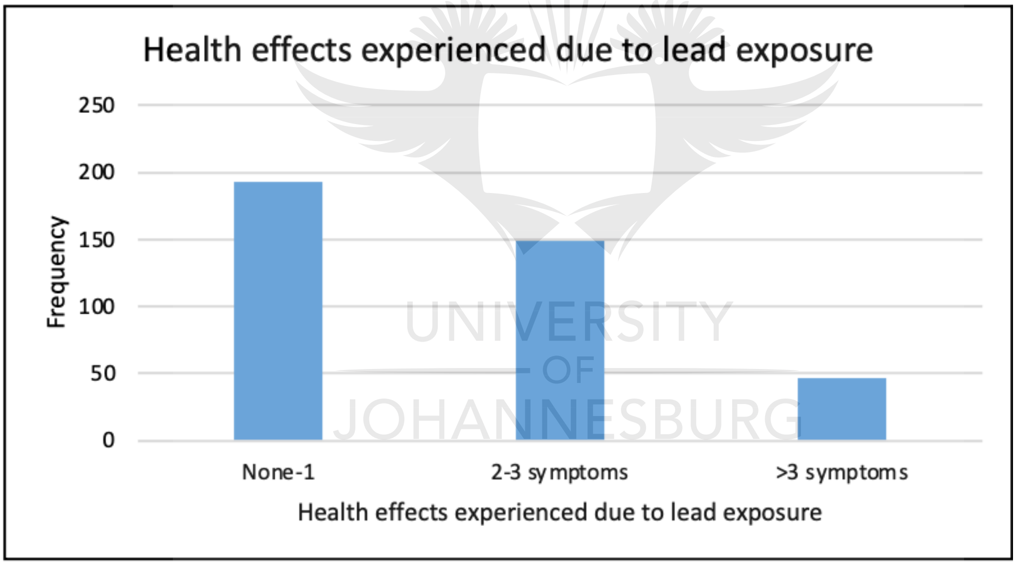

Figure 11: Health effects experienced by worker

The majority of respondents experienced 0-1 symptoms followed by those who experienced 2-3 symptoms. A fewer participants experienced >3 symptoms.

4.7.2 Frequency distribution table for health effects experienced by workers due to exposure to Pb.

The worker's experiences of health effects were examined to assess the relationship to Pb exposure. The health effects were represented by symptoms which were categorized into 0-1 symptoms, 2-3 symptoms and >3 symptoms**.** Table 4.6 shows the health effects experienced by workers more exposed to Pb and those less exposed to Pb.

Table: 9: Health effects experienced by workers due to exposure to Pb

	Total		**More exposed to Pb**		**Less exposed to Pb**	
Characteristics	**n**	**%**	**n**	**%**	**n**	**%**
Total	**389**	**100**	**181**	**46%**	**208**	**54%**
>3 symptoms	47	12.1%	37	78.8%	10	21.3%
2-3 symptoms	149	38.3%	86	57.7%	63	42.3%
1 to no symptoms	193	49.6%	58	30.1%	135	69.9%

Overall, 181(46%) of the 389 participants were more exposed to Pb. Participants who responded to have 1 - no symptoms 193(49.6%) of those 58(30.1%) were more exposed to Pb. Those who responded with 2-3 symptoms 149(38.3%) of which 86(57.7%) were more exposed to Pb. In the category with >3 symptoms, there were 47(12.1%) responses with 37(78.8%) participants more exposed to Pb.

4.7.3 Crude and adjusted odds ratio by health effects experienced by workers

The health effects experienced by workers were assessed in relation to being exposed to Pb. Crude and adjusted odd ratios were performed for this analysis using EPINFO 7.2 and SPSS version 27 respectively. Table 4.7 shows the crude odds ratio and the adjusted odds ratio for the health effects experienced by workers due to their exposure to Pb.

Table 10: Crude and Adjusted odds for health effects experienced by workers

Characteristics	**Crude odds Ratio**	**95% Confidence Intervals**	**Adjusted* Odds Ratio**	**95% Confidence intervals**
>3 symptoms	**8.61**	**4.01-18.47**	**6.51**	**2.70-15.70**
2-3 symptoms	**3.18**	**2.03-4.97**	1.93	0.79-4.70
1 to no symptoms	Reference	Reference	Reference	Reference

- Adjusted for gender, Age-group, occupation, years of exposure, smoking and alcohol.

Participants who recorded >3 symptoms to "health effects experienced by workers" were more likely to be exposed to Pb in both crude and adjusted analysis AOR = 6.51 95% CI (2.70-15.70). Those who recorded 2-3 symptoms are more likely in crude analysis to be exposed to Pb, OR = 3.18 95% CI (2.03-4.97). This association was not proven on adjusted analysis when compared to 1 to no symptoms as a reference.

4.8 Attitude and knowledge test

To address objective 4, an assessment of the attitude of workers exposed to Pb was conducted using the Health and Safety Policy awareness test questions 1-4. The relationship of the responses was assessed in relation to those more exposed to Pb and those less exposed to Pb.

4.8.1 Distribution table for attitude and knowledge test responses by participants

The attitude and knowledge test responses were presented with regards to the degree of being exposed to Pb**.** Table 4.8 shows the results of participants more exposed to Pb and those less exposed to Pb.

Table 11: Distribution table for attitude and knowledge test

	Total		**More exposed to Pb**		**Less exposed to Pb**	
Characteristics	**n**	**%**	**n**	**%**	**n**	**%**
Total	**389**	**100**	**181**	**46%**	**208**	**54%**
Awareness test 1: I understand the Health and Safety Policy of my company						
Strongly agree	**65**	**16.7 %**	**29**	**44.6%**	**36**	**55.4%**
Agree	256	65.8%	94	36.7%	162	63.3%
Neutral	14	3.6%	11	78.6%	3	21.4%
Disagree	42	10.8%	35	83.3%	7	16.7%
Strongly disagree	12	3.1%	12	100%	0	0.0%
Awareness test 2: I understand the reasons why I must use the Health and Safety Policy of my company						
Strongly agree	62	15.9%	20	32.3%	42	67.7%

Agree	258	66.3%	97	37.6%	161	62.4%
Neutral	9	2.3%	7	77.8	2	22.2%
Disagree	52	13.4%	49	94.2%	3	5.8%
Strongly disagree	8	2.1%	8	100%	0	0.0%
Awareness Test 3: I understand what is covered in the Health and Safety Policy of my company						
Strongly agree	62	15.9%	8	44.4%	10	55.6%
Agree	258	66.3%	98	40.7%	143	59.3%
Neutral	9	2.3%	8	29.6%	19	70.4%
Disagree	52	13.4%	60	82.2%	13	17.8%
Strongly disagree	8	2.1%	6	21.4%	22	78.6%
Awareness Test 4: I understand the companies goals and objectives relating to the Health and Safety Policy						
Strongly agree	36	9.3%	18	50%	18	50%
Agree	251	64.5%	89	35.5%	162	64.5%
Neutral	31	8%	14	45.2%	17	54.8%
Disagree	64	16.5%	53	82.8%	11	17.2%
Strongly disagree	7	1.8	7	100%	0	0.0%

Overall, there were 389 responses with 181(46%) being of respondents more exposed to Pb. In the question, "I understand the Health and Safety policy of my company" of those who responded with agree, 94(36.7%) were more exposed to Pb. In the question" I understand the reason why I must use the Health and Safety policy" respondents who answered with agree 97 (37.6%) were more exposed to Pb. When asked if they" understand what is covered in the Health and Safety policy" the majority of research participants answered with agree and of those 98 (40.7%) were more exposed to Pb. When asked if they" understood the companies goals and objectives relating to the Health and Safety policy" those who responded with agree 89 (35.5%) were more exposed to Pb.

4.8.2: Crude and adjusted odd ratios by characteristics of workers attitude towards controls in place.

To address objective 4: an assessment of the attitude of workers exposed to Pb was conducted using the Health and Safety Policy awareness test questions among participants exposed to Pb. Crude analysis was performed using EPINFO 7.2 and the adjusted analysis was calculated using SPSS version 27. Table 4.9 shows the crude odds ratio and adjusted odds ratio for the attitude characteristics for groups more exposed to Pb and those less exposed to Pb.

Table 12: Crude and adjusted odd ratios by characteristics of workers attitude towards controls in place.

Characteristics	Crude Odds Ratio	95% Confidence Interval	Adjusted* Odds Ratio	95% Confidenc e interval
Awareness test 1: I understand the Health and Safety Policy of my company				
Strongly agree	1.39	0.80-2.40	**12.68**	**4.91-32.71**
Agree	Reference	Reference	Reference	Reference
Neutral	**6.31**	**1.72-23.2**	**7.83**	**1.81-33.90**
*Disagree added to Strongly disagree	**11.57**	**5.03-26.63**	1.15	0.60-2.20
Awareness test 2: I understand the reasons why I must use the Health and Safety Policy of my company				
Strongly agree	**0.79**	**0.44-1.42**	**0.04**	**0.01-0.14**
Agree	Reference	Reference	Reference	Reference
Neutral	**5.81**	**1.18-28.53**	5.79	0.94-35.82
*Disagree added to strongly disagree	**31.5**	**9.61-103.4**	**2.21**	**1.08-4.50**
Awareness Test 3: I understand what is covered in the Health and Safety Policy of my company				
Strongly agree	1.17	0.44-3.06	**3.92**	**1.40-11.03**
Agree	Reference	Reference	Reference	Reference
Neutral	0.61	0.26-1.96	**0.11**	**0.05-0.24**
Disagree	**6.73**	**3.50-12.93**	1.00	0.38-3.17
Strongly disagree	1.95	0.65-5.78	1.54	0.49-4.90

Awareness Test 4: I understand the companies goals and objectives relating to the Health and Safety Policy				
Strongly agree	1.82	0.90-3.67	**10.73**	**4.80-24.21**
Agree	Reference	Reference	Reference	Reference
Neutral	1.50	0.71-3.18	**3.00**	**1.21-7.23**
*Disagree added to strongly disagree	**9.93**	**4.97-19.3**	1.11	0.50-2.52

- Adjusted for gender, Age-group, occupation, years of exposure, smoking and alcohol.

Participants who responded with strongly agree, neutral and disagree or strongly disagree, to the question "I understand the health and safety policy of my company "were likely to be more exposed to Pb, strongly agree, AOR = 12.68 95% CI (4.91-32.71), neutral, AOR = 7.83 95% CI (1.81-33.90) and disagree or strongly disagree, OR = 11.57 95% CI (5.03-26.63). In the question "I understand the reason why I must use the Health and Safety policy of my company" the participants who responded with strongly agree were less likely to be more exposed to Pb in adjusted analysis AOR = 0.04 95%CI (0.01-0.14). Those who responded with neutral were more likely to be more exposed to Pb in crude analysis only OR = 5.81 95% CI (1.18-28.53). If they answered with disagree or strongly disagree, they were more likely in both crude and adjusted analysis AOR = 2.21 95% CI (1.08-4.50) to be more exposed to Pb.

Participants who answered with strongly agree in the question "I understand what is covered in the Health and Safety policy of my company" were likely to be more exposed to Pb in adjusted analysis AOR = 3.92 95% CI (1.40-11.03) and were more likely, in crude analysis, to be more exposed to Pb if they answered disagree OR = 6.73 95% CI (3.50-12.93). Participants who responded with neutral were less likely to be exposed to Pb in adjusted analysis AOR = 0.11 95% CI (0.05-0.24). In the question "I understand the company's goals and objectives relating to the Health and Safety policy" the participants who responded with strongly agree and neutral were likely to be more exposed to Pb, in adjusted analysis and if they answered with disagree or strongly disagree, were likely to be more exposed to Pb in crude analysis OR = 9.93 95% CI (4.97-19.3).

4.9 Attitude and Desire

To address objective 4: the worker's desire assessment was conducted on the correct use of PPE and on the responsibility to protect self from exposure to Pb. The responses were stratified from participants more exposed to Pb and those less exposed to Pb.

4.9.1 Frequency distribution table for participants responses for the desire assessment test.

The frequency distribution table demonstrates the responses by participants in the group more exposed to Pb and in those less exposed to Pb. Table 4.10 shows the frequency distribution of the responses by participants.

Table 13: Attitude & knowledge test: Desire.

Attitude & knowledge test: Desire						
	Total		**More exposed to Pb**		**Less exposed to Pb**	
Characteristics	**n**	**%**	**n**	**%**	**n**	**%**
Total	**389**	**100**	**181**	**46%**	**208**	**54%**
Desire 1: I always use the correct PPE						
Strongly agree	169	43.6%	76	45%	93	55%
Agree	192	49.5%	80	41.7%	112	58.3%
Neutral	7	1.8%	7	100%	0	0.0%
Disagree	15	3.9%	13	86.7%	2	13.3%
Strongly disagree	5	1.3%	5	100%	0	0.0%
Desire 2: I understand that if I don't use the correct PPE I will be exposed to LEAD						
Strongly agree	211	54.2%	98	46.4%	113	53.6%
Agree	168	43.2%	73	43.5%	95	56.5%
Neutral	5	1.3%	5	100%	0	0.0%
Disagree	5	1.3%	5	100%	0	0.0%
Strongly disagree	0	0.0%	0	0.0%	0	0.0%
Desire 3: My company does not do enough to prevent exposure against Lead chemicals						
Strongly agree	5	1.3%	3	60%	2	40%

Agree	77	19.8%	52	67.5%	25	32.5%
Neutral	9	2.3%	5	55.6%	4	44.4%
Disagree	252	64.9%	81	32.1%	171	67.9%
Strongly disagree	45	11.6%	39	86.7%	6	13.3%
Desire 4: My company does everything to help me to protect myself						
Strongly agree	40	10.3%	31	77.5%	9	22.5%
Agree	293	75.3%	106	36.2%	187	63.8%
Neutral	12	3.1%	6	50%	6	50%
Disagree	41	10.5%	35	85.4%	6	14.6%
Strongly disagree	3	8%	3	100%	0	0.0%

In the question "I always use the correct PPE" the majority of respondents 80(41.7%) who responded with agree and 76(45%) with strongly agree were more exposed to Pb. In the question "my company does not do enough to prevent exposure against Pb" the majority responses were those who responded with strongly agree 98(46.4%) followed by those who responded with agree 73(43.5%) and were more exposed to Pb. The respondents were further asked if" the company does everything to help protect themselves from exposure", the majority 106(36.2%) responded with agree, and were more exposed to Pb.

4.9.2 Crude and adjusted odds table of workers desire to implement controls in place

To address objective 4, the desire characteristics were examined to assess the relationship to the degree of exposure to Pb. The crude analysis was performed using EPINFO 7.2 to enable visualization of data. The adjusted odds ratios were calculated using SPSS version 27. Table 4.11 shows the crude and adjusted odds ratio for the desire characteristics of participants.

Table 14: Crude and adjusted odds ratio by workers desire to implement controls in place

Characteristics	**Crude Odds Ratio**	**95% Confidence Interval**	**Adjusted* Odds Ratio**	**95% Confidence interval**
Desire 1: I always use the correct PPE				
Strongly agree	1.14	0.75-1.74	**26.78**	**5.12-140.4**
Agree	Reference	Reference	Reference	Reference

Neutral	**9.80**	**1.18-81.23**	Undefined	Undefined
*Disagree added with strongly disagree	**17.5**	**4.03-76.0**	1.20	0.70-2.00
Desire 2: I understand that if I don't use the correct PPE I will be exposed to LEAD				
Strongly agree	1.13	0.75-1.70	1.27	Undefined
Agree	Reference	Reference	Reference	Reference
Neutral	5.50	0.74-56.91	Undefined	Undefined
Disagree	5.50	0.74-56.91	Undefined	Undefined
Desire 3: My company does not do enough to prevent exposure against Lead chemicals				
Strongly agree	3.17	0.52-19.32	**12.12**	**4.43-33.20**
Agree	**4.39**	**2.54-7.58**	2.70	0.62-11.54
Neutral	2.64	0.65-11.27	**5.10**	**2.64-9.73**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	**13.72**	**5.58-33.73**	2.06	0.30-16.40
Desire 4: My company does everything to help me to protect myself				
Strongly agree	**6.08**	**2.79-13.24**	**10.60**	**3.90-28.90**
Agree	Reference	Reference	Reference	Reference
Neutral	1.76	0.56-5.61	1.20	0.32-3.80
*Added disagree and strongly disagree	**11.17**	**4.57-27.3**	**4.10**	**1.70-9.75**

*Adjusted for gender, Age-group, occupation, years of exposure, smoking and alcohol.

The participants who responded with strongly agree to the question "I always use the correct PPE" were likely to be more exposed to Pb in adjusted analysis only AOR = 26.78 95% CI (5.12-140.4) whilst those who responded with neutral and disagree or strongly disagree, were likely to be more exposed to Pb in crude analysis only OR =9.80 95% CI (1.18-81.23) and OR = 17.5 95% CI (4.03-76.0) respectively. In the question "my company does not do enough to prevent exposure from Pb" the participants who responded with agree and strongly disagree were more likely to be exposed to Pb in crude analysis only OR= 4.39 95% CI (2.54-7.58) and OR = 13.72 95% CI (4.57- 27.3) respectively. Participants who responded with strongly agree and neutral were likely more exposed to Pb in the adjusted analysis only AOR = 12.12 95% CI (4.43-33.20) and AOR=5.10 95% CI (2.64-9.73). The participants who responded with strongly agree and disagree or strongly disagree to the question" my company does everything to help me protect myself" were likely to be more exposed to Pb in both the crude and adjusted analysis, AOR = 10.60 95% CI (3.90-28.90) and AOR =4.10 95% CI (1.70-9.75)

4.10 Attitude and knowledge test: Knowledge

To address objective 5: the knowledge characteristics were examined to assess the worker's knowledge of control measures to be implemented to control Pb exposure comparing responses amongst those more exposed and those less exposed to Pb.

4.10.1 Frequency distribution table for the knowledge test responses

The responses of the participants to the knowledge test questions were stratified between those more exposed to Pb and those less exposed to Pb. Table 4.12 presents the results of the knowledge assessment test.

Table 15: Attitude & knowledge test: Knowledge

	Total		More exposed to Pb		Less exposed to Pb	
Characteristics	**n**	**%**	**n**	**%**	**n**	**%**
Total	**389**	**100%**	**181**	**46%**	**208**	**54%**
Knowledge 1: The storage of the Lead chemical is in line with the regulation and the relevant standards						
Strongly agree	44	11.3%	27	61.4%	17	38.6%
Agree	285	73.3%	106	37.2%	179	62.8%
Neutral	20	5.1%	11	55%	9	45%
Disagree	33	8.5%	30	90.9%	3	9.1%
Strongly disagree	7	1.8%	7	100%	0	0.0%
Knowledge 2: The handling and manipulation of Lead chemicals does not expose me to hazards						
Strongly agree	4	1%	4	100%	0	0.0%
Agree	137	35.2%	24	17.5%	113	82.5%
Neutral	17	4.4%	11	64.7%	6	35.3%
Disagree	170	43.7%	95	55.9%	75	44.1%
Strongly disagree	61	15.7%	47	77%	14	23%
Knowledge 3: The clean-up after my experiments is sufficient to remove all traces of						

the Lead chemicals						
Strongly agree	24	6.2%	15	62.5%	9	37.5%
Agree	238	61.3%	54	22.7%	184	77.3%
Neutral	16	4.1%	11	68.8%	5	31.3%
Disagree	91	23.5%	82	90.1%	9	9.9%
Strongly disagree	19	4.9%	19	100%	0	0.0%
Knowledge 4: The disposal team take longer to remove material, and this exposes me to harm						
Strongly agree	18	4.6%	18	100%	0	0.0%
Agree	104	26.7%	93	89.4%	11	10.6%
Neutral	27	6.9%	18	66.7%	9	33.3%
Disagree	222	57.1%	45	20.3%	177	79.7%
Strongly disagree	18	4.6%	7	38.9%	11	61.1%
Knowledge 5: Disposal of hazardous material does not adhere to correct standards						
Strongly agree	15	3.9%	14	93.3%	1	6.7%
Agree	108	27.8%	80	74.1%	28	25.9%
Neutral	26	6.7%	17	65.4%	9	34.6%
Disagree	204	52.4%	60	29.4%	144	70.6%
Strongly disagree	36	9.3%	10	27.8%	26	72.2%

Overall, 389 participants responded to the knowledge test questions and of those 181(46%) were more exposed to Pb. The participants who responded to the question “the storage of Pb is in line with the regulation and relevant standards” the majority of responses who responded with agree 106(37.2%) were more exposed to Pb. In the question “the handling and manipulation of Pb does not expose me to hazards” the majority, 95(55.9%) who responded with disagree were more exposed to Pb. The majority of participants who are handling Pb who responded with agree 54(22.7%) to the question “the clean up after my experiments is sufficient to remove all traces of Pb, “were more exposed to Pb followed by those who responded with disagree 82 (90.1%). In the question “the disposal team takes longer to remove material and this exposes me to harm” 45(20.3%) responded with disagree and 93(89.4%) with agree, from the group more exposed to Pb. In the question “disposal of hazardous material does not adhere to correct standards” of those responses, those more exposed to Pb responded with disagree 60 (29.4%) and with agree 80 (74.1%).

4.10.2 Crude and adjusted odds ratio table by knowledge characteristics.

To address objective 5, the knowledge characteristics were examined to assess the relationship of worker's knowledge of control measures to be implemented to control Pb exposure. Crude and adjusted odds ratios were calculated using EPINFO 7.2 and SPSS version 27 respectively Table 4.13 presents the results of the crude and adjusted analysis for this assessment.

Table 16: Crude and adjusted odds ratio by knowledge characteristics

Characteristics	**Crude Odds Ratio**	**95% Confidence Interval**	**Adjusted* Odds Ratio**	**95% Confidence interval**
Knowledge 1: The storage of the Lead chemical is in line with the regulation and the relevant standards				
Strongly agree	**2.68**	**1.40-5.15**	22.43	**6.10-82.9**
Agree	Reference	Reference	Reference	Reference
Neutral	2.06	0.83-5.14	**3.97**	**1.38-11.44**
*Added disagree and strongly disagree	**20.82**	**6.26-69.20**	2.00	0.93-4.30
Knowledge 2: The handling and manipulation of Lead chemicals does not expose me to hazards				
*****Added agree and strongly agree	**0.20**	**0.12-0.33**	**0.42**	**0.21-0.91**
Neutral	1.45	0.51-4.09	2.50	0.75-8.23
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	**2.65**	**1.36-5.18**	**3.21**	**1.77-5.82**
Knowledge 3: The clean-up after my experiments is sufficient to remove all traces of the Lead chemicals				
Strongly agree	**5.68**	**2.40-13.69**	**43.70**	**18.12-105.2**
Agree	Reference	Reference	Reference	Reference
Neutral	**7.45**	**2.50-22.51**	**12.91**	**3.63-45.9**
* Added disagree and strongly disagree	**38.24**	**18.13-80.64**	**3.62**	**1.31-9.81**

Knowledge 4: The disposal team take longer to remove material, and this exposes me to harm				
* Added agree and strongly agree	**39.69**	**19.69-79.98**	1.34	0.23-2.26
Neutral	**7.87**	**3.30-19.29**	**33.32**	**15.31-72.53**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	2.50	0.91-6.82	**10.39**	**3.76-28.70**
Knowledge 5: Disposal of hazardous material does not adhere to correct standards				
* Added strongly agreed and agree	**7.03**	**4.19-11.8**	1.87	0.80-4.64
Neutral	**4.53**	**1.91-11.13**	**5.80**	**2.10-16.10**
Disagree	Reference	Reference	Reference	Reference
Strongly disagree	0.92	0.42-2.03	**0.14**	**0.08-0.27**

- Adjusted for gender, age-group, occupation, years of exposure, smoking and alcohol

The participants who responded with strongly agree to the question "the storage of Pb is in line with regulations and relevant standards" were likely to be more exposed to Pb in both crude and adjusted odds analysis, AOR= 22.43 95% CI (6.10-82.9). Those who responded with neutral to the same question, were found to be most likely more exposed to Pb in adjusted analysis only AOR = 3.97 95% CI (1.38-11.44) whereas those who responded with disagree or strongly disagree were most likely to be more exposed to Pb in crude analysis only OR= 20.82 95% CI (6.26-69.20). In testing the knowledge 2 statement "the handling and manipulation of Pb does not expose me to hazards", the participants who responded with agree or strongly agree were less likely to be more exposed to Pb in both crude and adjusted odds analysis AOR = 0.42 95% CI (0.21-0.91). Those who responded with strongly agree were likely to be more exposed to Pb in both crude and adjusted analysis AOR= 3.21 95%CI (1.77-5.82) when compared to disagree as a reference.

Participants who responded with strongly agree, neutral and disagree or strongly disagree, to the question," the clean-up after my experiments is sufficient to remove all traces on Pb" were likely to be exposed to Pb both crude and adjusted analysis AOR= 43.70 95% CI (18.12-105.2), AOR = 12.91 95% CI (3.63-45.90) and AOR = 3.62 95% CI (1.31-9.81) when compared to agree as a reference. Participants were found likely to be more exposed to Pb when they responded with agree or strongly disagree and neutral to the question, "the disposal team take longer to remove material and this exposes me to harm" OR = 39.69 (19.69-79.98) and AOR = 33.32 95% CI

(15.31-72.53) respectively. Those who answered with strongly disagree were also likely to be more exposed to Pb in adjusted analysis only AOR = 10.39 95% CL (3.76-28.70) when compared with disagree as a reference.

Participants who responded with strongly agree and agree and neutral to the question “Disposal of hazardous material does not adhere to safety standards were likely to be more exposed to Pb, OR = 7.03 95% CI (4.19-11.8) and AOR = 5. 80 95% CI (2.10-16.10) respectively. Those who responded with less agree were less likely to be more exposed to Pb in adjusted analysis only AOR = 0.14 95% CI (0.08-0.27).

4.11 Summary

This chapter presented the findings of the study beginning with the BLL of the laboratory workers at a science and research institution in Gauteng during 2018 – 2019 period to answer objective 1. To answer objective 2, the results of the socio-demographic assessment were displayed and reported. These were compared by binary grouping “more exposed to Pb” and “less exposed to Pb” by socio demographic characteristics. The crude and adjusted odds ratio were calculated and reported. Some were statically significant, and some were not. Results to answer objective 3, experiences of workers, objective 4, attitudes of workers and objective 5, knowledge of laboratory workers, were also conducted and reported. Those were also compared by binary grouping. Likewise, some of the findings were significant and some were not. The main findings and discussion are presented in Chapter 5.

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter presents a discussion of the results of this study, the study limitations, the strengths, application to conceptual framework, conclusion and implications to public health. Therefore findings of the assessment of the implementation of controls for Pb exposure at a science and research institution in Gauteng, South Africa, are discussed based on findings in chapter 4. Primary data analysed in this study was obtained from the online questionnaire responses and secondary data from the BLL in the period 2018 – 2019. The data analysis examined the BLL in 2018-2019, socio-demographic factors, experiences of workers regarding workplace programs to control Pb exposure, health effects experienced by workers, workers attitude and knowledge test comparing participants more exposed to Pb and those less exposed to Pb. The summary of the main findings are presented in this chapter and are compared to the associated literature. In this way comparisons will be made with previous studies and an explanation of the findings will be made. Furthermore, in this chapter, the strengths, limitations of the study, application to the conceptual framework and Public Health implications will be presented. Conclusions drawn from the study are presented and recommendations are formulated within the local context.

5.2 Summary of all significant findings

In this study BLL were observed in the years 2018 and 2019 and even though the majority of participants recorded BLL < 20 μg/dL there were those who had BLL of 20-39 μg /dL, 40-59 μg /dL and >60 μg/dL. There was no relationship established between gender and Pb exposure when male group was a reference. Participants who are 25-34 years old were less likely to be exposed to Pb (OR= 0.50, 95% CI (0.36 – 0.85) and if they were scientists and engineers in the department ASD and PDD, they were likely to be more exposed to Pb {(AOR = 3.27, 95% CI (1.60-6.74) and AOR = 3.33, 95% CI (1.50-7.41)} and {(OR = 2.49, 95% CI(1.73 – 3.59) and OR=2.58, 95%CI (2.58, 95%CI(1.79 – 3.71)} respectively. The participants with <5 years exposure were less likely to be more exposed to Pb whist those >20 years were likely to be more exposed to Pb (OR = 9.09, 95% CI 1.15 – 71.92). There was no relationship between smoking and exposure to Pb whereas those not drinking alcohol were most likely to be more exposed to Pb. Participants who responded with strongly agree to "undergoing medicals, biological monitoring and being registered radiation workers" were likely to be more exposed to Pb similarly with those who responded with disagree and strongly disagree were likely to be more exposed to Pb. Participants who responded with strongly agree and neutral to "risk assessment records”, agree and neutral to “inspection records” and agree, neutral and strongly agree to job observation records, were likely to be more exposed to Pb. Participants who responded with strongly agree and agree to “Lead handling training” were likely to be more exposed to Pb (AOR= 5.33, 95% CI 1.96 – 14.45).whereas those responded with strongly disagree were less likely to be more exposed to Pb. Participants who responded with strongly agree to incident of accidental exposure were likely to be more exposed to Pb and those who responded with neutral and disagree were less likely to be more exposed to Pb. Those who responded with strongly agree, agree, neutral and disagree to “incident of exposure” were less likely to be more exposed to Pb. If participants responded with agree or strongly agree to the question of “record for supply of PPE” then they were most likely to be more exposed to Pb and less likely to be more exposed to Pb if they answered with disagree.

Participants who responded to have 2-3 symptoms and >3 symptoms were most likely more exposed to Pb (OR= 3.15, 95% CI 2.03 – 4.97) and (AOR = 6.51 95% CI 2.70 – 15.70) respectively. Participants who responded with strongly agree, neutral and disagree or strongly disagree to “I understand the health and safety policy” are more likely to be more exposed to Pb. In indicating whether they understand the reasons why they must use the Health and safety policy” those who answered with neutral and disagree were most likely to be more exposed to Pb whilst those who responded with strongly agree were less likely to be more exposed to Pb. If they indicated that they understand the health and safety policy with agree and disagree, they were likely to be more exposed to Pb and were less likely to be more exposed if they responded with neutral. Participants who responded with strongly agree, neutral and disagree or strongly disagree were more likely to be exposed to Pb. Participants who responded with strongly agree, neutral and disagree or agree to “ I always use the correct PPE” were most likely more exposed to Pb. In the question “my company does not do enough to prevent exposure” if they answered with strongly agree, agree, neutral and strongly agree, they were most likely more exposed to Pb. If the participants responded with strongly agree and disagree or strongly disagree to “my company does everything to protect me from exposure” if they responded with strongly agree and strongly disagree, they were most likely to be more exposed to Pb.

Participants who responded with strongly agree, neutral and disagree or strongly disagree to “storage of Pb is in line with regulation” were most likely to be more exposed to Pb. In the question “the handling and manipulation of Pb does not expose me to hazards” participants who responded with agree or strongly agree were less likely to be more exposed to Pb whilst if they responded with strongly agree, they were most likely exposed to Pb. If they responded with strongly agree, neutral and disagree to the question “the clean-up after my experiment is sufficient to remove traces of Pb” they were most likely more exposed to Pb. In the question “the disposal team takes longer to remove materials” if they responded with agree or neutral or strongly disagree, they were most likely more exposed to Pb. In the question “disposal of hazardous material does not adhere to correct standards” participants who responded with strongly agree or agree and neutral were most likely more exposed to Pb whereas those who responded with strongly disagree were less likely to be more exposed to Pb.

5.3 Blood Lead Levels amongst those who underwent biological monitoring in 2018 and 2019

This section discusses the results of the Blood Lead Levels of participants exposed to Pb in the year 2018 and 2019. Of the 181 participants exposed to Pb, 94 were purposefully sampled to have their BLL assessed from 2018 – 2019. The results are discussed next.

5.3.1 Blood Lead Levels in 2018 and 2019

The majority of the participants had BLL of < 20 μg/dL indicating an occupational exposure which triggers biological monitoring in 12 months, followed by those with BLL 20-39μg/dL who are required to undergo biological monitoring in 6 months whereas those with BLL of 40-59μg/dL are to be monitored every 3 months with those with BLL>60μg/dL, are removed from exposure, OHSA (Act 85 of 1993). The employee who recorded BLL of >60μg/dL in 2018, was removed from exposure and in 2019 he recorded a BLL of <20μg/dL. The reason for permanent removal was based on the other underlying medical conditions. In the USA, the ILO (1993) has prescribed standards permissible for Pb exposure limits and specifies BLL of 40 μg /dL must trigger a monitoring every 2 months. This difference demonstrates the high levels of exposure permissible in South Africa. None of the workers with BLL >20μg/dL were further assessed for signs of Pb poisoning. This finding is in agreement in other studies done in Korea where in 2009 the Korean blood-lead criterion for the diagnosis of lead poisoning in special medical examinations was strengthened further from 60 μg/dL to 40 μg/dL, which is the strictest level in the world. Even with the new criterion, none of the lead workers were classified as having lead poisoning (Lee, 2011). In the studies done in Brazil, the level of 60 μg/dL is still established as a safe limit for BLL, compared to 30μg/dL level defined by the ACGIH (Poaliello and Capitani, 2006).

5.4 The relationship between Pb exposure and Socio-demographic characteristics

Based on the findings of this study, gender of workers in the laboratories does not determine whether they are more exposed to Pb or not when males are a reference group. This is in contrary to other similar studies where the prevalence of males exposed to Pb were higher. This is due to the fact that more males tend to work in hazardous jobs than females (Utembe, 2016). There was a less likelihood of being more exposed to Pb in the age group 25 – 35 years. These findings makes sense in that workers get their first time employment around that age and would have less exposure to Pb and less bone lead concentrations (Harlan 1988 and Schutz et al., 2005). Scientist and Engineers who are assigned in ASD and PDD departments were more exposed to Pb as those are the departments involved with most research work using Pb. The longer the years the person works, the more exposed they are to Pb as in this study those with >20years exposure were most likely more exposed to Pb whereas those with <5 years of exposure were less likely to be more exposed to Pb. In this study, those who did not drink alcohol were more likely to be more exposed to Pb whist there was no relationship established between smoking and being exposed to Pb. This is in contrary to the findings in a study in the USA where it was found that the BLLs in adult smokers (19 years of age or older) were higher than the BLLs for adult non-smokers (Richter et al., 2013)

5.5 Pb exposure by experiences of workers on the perceived health symptoms and the procedures in place for Pb control.

In this section, the results of the analysis of experiences of workers to workplace programs to control and manage Pb exposure as compared to degree of Pb exposure, will be discussed based on the findings in chapter 4.

5.5.1 The relationship between workers experiences to lead exposure controls and exposure to Pb

In this study, the results of the participant's experiences to workplace programmes revealed that participants who were positive in response regarding the variables, " undertaking periodic and biological monitoring, being registered as radiation worker, knowledge of risk assessment and record of accidental exposure " were most likely more exposed to Pb when assessed in comparison with agree as a reference. Participants who also responded positively when compared to disagree as a reference, to the question "no records of fume cupboards, training in lead handling and no proof of PPE supply were more likely to be more exposed to Pb. The workers experiences determines their attitude towards workplace controls against chemical exposure (Meyer 2008). This finding is plausible as participants who are permanent and more qualified to do research work are more likely to run projects involving chemicals. They tend to have more understanding of work processes, undergo training and are responsible to draw procedures for projects in their departments. A simple example is that of understanding Safety Data Sheets (SDS) unlike operators who are less educated and with some not even understanding English and scientific language (ILO, 1993). Safety information is important to improve chemical risk management, self- protection and informed decision making regarding exposure (Polivka 1999). In a study by Asgedom (2019), in Ethiopia, many of the workers (87%) knew some chemical hazards, but their practice of control measures was poor due to the negative attitude about the existing PPE in terms of hazard protection. Similarly in a study conducted in the USA by Cooper et al (2020), amongst the communities in a mining impacted region, it was identified that effective risk communication strategies were critical in reducing Pb exposure. It was also identified that workers negative attitude towards control measures prevented practicing of safety measures against Pb exposure.

5.5.2 Health effects experienced by workers due to exposure to Pb

In this section, the results of the analysis of health effects experienced by workers as compared to Pb exposure are discussed. A list of symptoms associated with Pb exposure were, headaches, dizziness, fatigue, tremors, wrist drop, hearing loss, deficit in visual acuity, deficit in short term memory, dryness of the eyes, irritability, metallic taste, anaemia, renal problems and maskulo-skeletal problems. The results will be discussed based to chapter 4 findings.

5.5.2.1 The relationship between the health effects experienced by workers as compared to Pb exposure.

Based on this study results, the participants who experienced 2-3 symptoms and >3 symptoms were most likely to be more exposed to Pb when compared to those with 1-none symptoms as a reference. Exposure experience incorporates illnesses, either contested or uncontested, that people might get. It is influenced by people's awareness of disease prevalence in their area, their collective exposure experience such as exposure to a common chemical, or their knowledge about the prevalence and types of diseases and conditions potentially related to increasing levels of a particular exposure (Adams et al., 2011). With regards to Pb exposure, it is evident that Pb accumulates in the body with years of exposure as in the study by Khalil (2009) on past occupational exposure to Pb, association between current blood Pb and Bone Pb. This hypothesis is supported by a study that was conducted in Germany where retired lead workers age 44-59 years, duration of employment 20-38 years showed an increase in the bone-Pb with duration of employment (Schutz et al., 2005).

5.6 Assessment of worker's attitude towards Pb exposure and controls in place

The health and safety awareness questions results are presented in this chapter based on the findings in chapter 4. These questions revolves around the participants understanding of the use and purpose of the Health and Safety policy in the organization. The results are presented next.

5.6.1 The relationship between workers attitude towards controls in place and exposure to Pb.

Participants who responded positively with strongly agree, neutral and with disagree or strongly disagree to the questions of whether "they understand the health and safety policy of the organization were more likely to be more exposed to Pb whereas those who answered with strongly agree were less likely to be more exposed to Pb. If they responded with strongly agree to the question 'I understand the reason why they must use the Health and Safety policy" they are less likely to be more exposed to Pb. When asked if they understand the Health and Safety policy, those who answered with disagree or strongly disagree were most likely exposed to Pb. Those with a neutral response were less likely to be more exposed to Pb. Those who responded with strongly agree, neutral and disagree or strongly disagree were more likely to be more exposed to Pb. Awareness test 1 displays that workers exposed to Pb have a positive attitude towards controls in place to protect them from harmful exposure. Some of the results did not show any relationship to being more exposed to Pb. This in line with the study that was conducted in Nigeria by Odebamowo (2006) in which an examination of the knowledge and attitude was conducted. The participants were found to be aware of Pb but there was a low awareness of health implications and understanding of workplace practices to control exposure.

5.7 Worker's desire to implement controls in place

The results of the participants desire to implement controls is presented in this section based on the findings in Chapter 4 which are compared to being exposed to Pb.

5.7.1 The relationship of the desire to implement controls and exposure to Pb

Based on the study results in this chapter, participants who responded with strongly agree, neutral and disagree or strongly disagree to the question "I always use the correct PPE" were more exposed to Pb. A relationship could not be established between more exposure to Pb and the responses to the question, "I understand that not using the correct PPE will expose me to Pb" with agree, as the reference, the adjusted analysis results were undefined. In the question, "my company does not do enough to prevent exposure" participants who responded with strongly agree, agree and strongly disagree were more exposed to Pb. In the question "my company does everything to help me protect myself" participants who responded with strongly agree and disagree and strongly agree were most likely more exposed to Pb. These findings demonstrates the willingness of the participants to implement the control measures against Pb exposure. This desire to implement control measures may be deterred by barriers such as lack of information regarding Pb exposure, inadequate risk communication programmes with workers and the worker's beliefs about health risk posed by Pb exposure (Montanaro & Bryan, 2014; Cooper et al, 2020).

5.8 Assessment of Pb exposure by knowledge characteristics

The health and safety knowledge questions results are presented in this chapter based on the findings in chapter 4. These questions revolves around the participant's knowledge of safe lead handling in the organization. The results are presented next.

5.8.1 Relationship between Pb exposure and knowledge characteristics

Based on the study results in this chapter, the responses towards the knowledge characteristics by those exposed to Pb were positive. The participants who responded with strongly agree and strongly disagree were most likely more exposed to Pb even though the margins of the confidence intervals were wider which could be due to a smaller sample of participants. In the question" the clean up after my experiments is sufficient to remove traces of Pb, if participants responded with strongly agree, neutral and disagree or agree, they were more exposed to Pb. In the questions, the disposal team take longer to remove materials" if participants responded with agree or strongly agree and strongly disagree, they were most likely more exposed to Pb. In the question "disposal of hazardous materials does not adhere to correct standards" if the responses are strongly agree and agree and neutral, then those participants were more exposed to Pb. If they responded with strongly disagree, then the participants were less likely to be more exposed to Pb. Lead awareness and lead handling training are mandatory programmes relating to Pb exposure as per the OHSA (Act 85 of 1993). In a study in Nigeria, it was found that there was no enforcement of minimum standard for lead content of domestic environment. This was attributed to low awareness of the health implications of those exposures and competing attention from infectious diseases like HIV/AIDS and malaria (Odebamowo, 2006)

5.9 Limitations of the study

The limitations of this study include the fact that it was conducted in one occupational setting of a science and research institution. Therefore the results of this study cannot be safely generalized to other similar institutions. Another limitation of this study was design of the quantitative study questionnaire. The questionnaire had close ended questions which did not allow the participant to open up their answers, which could give more information regarding Pb exposure and how they are affected by this exposure. Another delimitation of this study is that the workplace walk-through which could give first-hand account of control measures implemented in the organization and also allow for the participants to be observed whilst conducting experiments in the laboratories was abandoned due to the magnitude of the study. Another delimitation was that the Occupational Exposure Limits (OEL's), air monitoring for fume cupboards and surface wipe analysis results were not part of this study. This analysis could give us the extent of environmental contamination due to Pb dust. In as much as the BLL for the selected participants were assessed, they only provide the levels of the internal dose. The causal relationship between Pb exposure and health was not explored so in this study, it could not be ascertained that the symptoms experienced were due to exposure to Pb.

5.10 Strengths of the study

The strength of the study is that it was conducted in one of the largest research and science institutions in Gauteng. The senior management supported this study and were involved throughout the research stages of this study. This study highlights gaps in the current safety practices and may help improve policy guidelines regarding Pb exposure in the organization. This study could influence the training and information element that should form part of risk management thus improving the knowledge and the implementation of control measures amongst the exposed groups. All of this should improve the safety awareness thus enhancing the culture of safety compliance in the organization.

5.11 Application to the Conceptual Framework

The HBM consists of five dimensions, namely, perceived susceptibility, perceived threat, perceived benefits, perceived barriers and self-efficacy (Montanaro et al., 2014). This model was found to fit this research study in which the assessment of the implementation of control measures by laboratory workers against Pb exposure was done. It was also noted that there is not a vast literature where this model was used in relation to chemical exposure in the workplace. Pb exposure amongst the laboratory workers is still posing health and safety problems in the science and research institution. This exposure poses a public health problem as the health of workers and that of their family members including their kids may be affected if control measures in the workplace are poorly implemented (WHO 2019). In the existence of the control measures in the workplace, what could be the factors affecting laboratory workers in implementing them?

In the HBM, perceived susceptibility is when a worker exposed to Pb perceives that they are susceptible to the effects posed by the exposure and understands the threat posed by their disregard of controls in place. When the laboratory worker has the knowledge and understands the benefit of changing their behaviour, it increases their intention to change how they behave thus increasing compliance to the safety measures in place (Finn & O'Fallon, 2015). This action also increases their confidence to adopt the behaviour and to maintain it as found in a study by Lungkha & Hinhumpetch (2020) on the application of the health belief model to reduce pesticide exposure amongst rice workers.

A laboratory worker who has reached self- efficacy will require that there should be enforcement of the Pb control measures such as air quality measurements, supply of recommended PPE, policies, medical surveillance programmes, open communication channels and support from management. Laboratory workers must be informed of their exposure on employment, be trained on Safe Pb handling and be informed on what to do in cases of suspected accidental exposure (OHSA. 1993). It is important for the workers to be prepared for Pb exposure and its demands. As such they will have realistic expectations which will normalise their anxieties about exposure and increase their attitude towards control measures in place. The attitudes that a person has towards control measures is predictive of the intention to implement them to his benefit and that of others around him. After all, according to OHSA (1993), the employee is responsible for their health and safety and that of others who will be affected by their action.

This sense of responsibility and self- control can only be achieved when the laboratory worker can effectively manage to deal with barriers affecting implementation of control measures. There are perceived barriers which influence the worker from implementing the control measures against Pb exposure, such as influence by other workers, lack of self-confidence to be vocal and raise concerns, workplace bullying and fear of being victimised. Self-efficacy around chemical exposure is achieved when a habit is formed to always use the correct PPE and through safe handling of chemicals. When designing programs and interventions to modify the employee behaviours, all factors affecting workers must be comprehensively considered (Montanaro & Bryan, 2014).

5.12 Public health implications

While the results obtained in this study cannot be generalized to all the science and research institutions, the research results will contribute to various areas of public health within the health delivery system.

1. Creating awareness for the need to design health education programs for all employees exposed to Pb which must be delivered on employee entrance and on-job training.
2. Promoting responsibility and accountability to the Occupational health staff and Safety staff members to improve on the policies and programmes in place to protect workers from exposure
3. Making information regarding Pb exposure accessible to all employees despite their educational level.
4. Ensuring that our Pb protection programs are effective to protect the risk of Pb exposure to be transferred home to family members.

5.13 Conclusions

The purpose of this study was to assess the implementation of controls for Pb exposure amongst laboratory workers at a science and research institution in Gauteng. The findings of the study suggest that the scientists and engineers working in ASD and PDD are aware of the workplace programmes in place to manage exposure to Pb. On the other hand there are workers like operators, who are less educated and were unsure and even unaware of these programmes. Information on health risks posed by Pb exposure must be re-enforced especially to low level workers to ensure that they understand the long term effects of Pb exposure. In assessing the health and safety policy awareness, there were those exposed to Pb, who were not aware of the management intention to protect workers from Pb exposure. As such there is a need to make workers aware of the purpose of the health and safety policy in the workplace. In assessing attitude and desire, there was a relationship between the use of correct PPE and those exposed to Pb. There is a need to improve the Pb exposure awareness sessions especially amongst those less exposed to Pb as the health effects continue to emerge even in low doses of Pb exposure. In the assessment of knowledge of safe Pb handling, there was an understanding of safe storage of Pb and the awareness that Pb is a hazard. Some of the workers exposed to Pb were not aware that the clean-up after experiments can still expose them to dangerous levels of Pb. There is a need to improve on safety communication to increase knowledge, improve the attitude and increase the desire to implement control measures by workers.

5.14 Recommendations

The following are recommendations in response to the findings revealed by this research study. The recommendations below not only serve as guidelines for better management of Pb exposure in the workplace but also focus on the need for further research to identify the extent of Pb exposure at the science and research institutions.

1. The duties of the employer and that of the employee as specified in the OHS act should be taken seriously in the workplace.
2. The organization must improve the training and awareness sessions related to Pb exposure in the workplace.
3. Employers must develop training material that are translated to languages that will be best understood by all employees at entrance and on-job training
4. Workplaces must control chemical exposure to as far as reasonably practicable including use of stringent OEL's where needed

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APPENDICES

Appendix 1: Research questionnaire

Research study online questionnaire					
Title: *Assessment of controls for lead (Pb) chemical exposure amongst scientific laboratory workers at a science and research institution in Gauteng, South Africa* *Select the best option that best describes your experiences, attitude and knowledge of Pb control measures in the workplace.*					
1. BIOGRAPHICAL DATA					
1.1	Gender?		Male		Female
1.2	Age group		25-34		35-44
			45-54		55-60
1.4	Actual age				
1.3	Occupational group?		Operator		Scientist
			Technician		Engineer
1.5	Division		PDD		ASD
1.6	Years of exposure to Lead		<5years		5-10years
			11-20years		>20years
1.7	Habits?		Smoking		Alcohol
			Other:		
2. WORKPLACE PROGRAMS TO CONTROL AND MANAGE EXPOSURE					
2.1	I usually undertake periodic medicals				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.2	I usually undergo biological monitoring				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.3	I Know what to do when I have an exposure incident				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.4	I am a registered radiation worker supplied with a TLD badge				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree

2.5	There are risk assessment records for the work processes in the workplace/division				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.6	There are no inspection records for the fume cupboards				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.8	There are no records of job observations in the training records				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.9	There is no record to show that I have undergone training in Lead chemical handling				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.10	There is a record of reported incident of accidental exposure in my workplace/Division				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.11	There is an incident of exposure to an unidentified chemical in my workplace/Division.				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
2.12	There is no record to prove that I was supplied with the correct PPE				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
3. HEALTH EFFECTS EXPERIENCED BY WORKERS DUE TO LEAD CHEMICAL EXPOSURE					
3.1	Has the employee ever suffered from the following health effect due to suspected exposure to Lead Chemicals?		Headaches		Fatigue
			Dizziness		Wrist drop
			Tremors		Hearing loss
			Deficit in visual acuity		Deficit in short term memory
			Dryness of eyes		Metallic taste
			Irritability		Anaemia
			Renal problems		Maskulo-skeletal

					problems

ATTITDUE & KNOWLEDGE TEST: AWARENESS 1				
I understand the Health and Safety Policy of my company				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITDUE & KNOWLEDGE TEST: AWARENESS 2				
I understand the reasons why I must use the Health and Safety Policy of my company				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITDUE & KNOWLEDGE TEST: AWARENESS 3				
I understand what is covered in the Health and Safety Policy of my company				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITDUE & KNOWLEDGE TEST: AWARENESS 4				
I understand the companies goals and objectives relating to the Health and Safety Policy				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: DESIRE 1				
I always use the correct PPE				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree

ATTITUDE & KNOWLEDGE TEST: DESIRE 2				
I understand that if I don’t use the correct PPE I will be exposed to LEAD				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: DESIRE 3				
My company does not do enough to prevent exposure against Lead chemicals				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: DESIRE 4				
My company does everything to help me to protect myself				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: KNOWLEDGE 1				
The storage of the Lead chemical is in line with the regulation and the relevant standards				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: KNOWLEDGE 2				
The handling and manipulation of Lead chemicals does not expose me to hazards				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: KNOWLEDGE 3				

The clean-up after my experiments is sufficient to remove all traces of the Lead chemicals				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: KNOWLEDGE 4				
The disposal team take longer to remove material, and this exposes me to harm				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
ATTITUDE & KNOWLEDGE TEST: KNOWLEDGE 5				
Disposal of hazardous material does not adhere to correct standards				
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree

End of questionnaire: Thank you for your time and cooperation. Please click on the **"submit"** link **to return the completed form.**

Appendix: 2: Retrieval of secondary data tool

Participant Code: ___________:

	2018	2019
Blood Lead Levels		
<20 μg/dL		
20-39 μg/dL		
40- 59 μg/dL		
>60 μg/dL		

Appendix 3: Research Study Information Letter

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF ENVIRONMENTAL HEALTH

RESEARCH STUDY INFORMATION LETTER

REC 11.0

21/07/2020

Good Day

My name is Motaung Faith **I WOULD LIKE TO INVITE YOU TO PARTICIPATE** in a research study on

Assessment of the implementation of controls for lead (Pb) exposure amongst laboratory workers at a science and research institution in Gauteng, South Africa

Before you decide on whether to participate, I would like you to read this document which will explain to you why the research is being done and what it will involve for you. This should take about 10 to 20 minutes. The study is part of a research project being completed as a requirement for a Master of Public health Degree in Environmental Public through the University of Johannesburg.

THE PURPOSE OF THIS STUDY is to assess the implementation of controls for lead (Pb) exposure amongst laboratory workers at a scientific laboratory. The investigations will establish the extent to which the Pb control measures are implemented, as well assess the laboratory workers knowledge and attitudes towards implementation of the policy and prevention procedures

Below, I have compiled a set of questions and answers that I believe will assist you in understanding the relevant details of participation in this research study. Please read through these. If you have any further questions, I will be happy to answer them for you.

DO I HAVE TO TAKE PART? No, you don't have to. It is up to you to decide to participate in the study. I will describe the study and go through this information sheet. If you agree to take part, you will proceed to fill in the online questionnaire.

WHAT EXACTLY WILL I BE EXPECTED TO DO IF I AGREE TO PARTICIPATE? To share your experiences and knowledge on the effects of Lead exposure, control measures in place and your own experiences with the implementation of the control measures.

WHAT WILL YOUR RESPONSIBILITIES BE, AS THE RESEARCHER I will prepare the questionnaires and load the link to the questionnaire on the computer. I will send out the link to the questionnaire to the participants. I will monitor the responses and attend to any questions regarding the questionnaire.

APPROXIMATELY HOW LONG WILL MY PARTICIPATION TAKE? Your participation to complete the questionnaire will take approximately 30-40 minutes.

WHAT WILL HAPPEN IF I WANT TO WITHDRAW FROM THE STUDY? If you decide to participate, you are free to withdraw your consent at any time without giving a reason and without any consequences. If you wish to withdraw your consent, you should inform me as soon as possible.

IF I CHOOSE TO PARTICIPATE, WILL THERE BE ANY EXPENSES FOR ME, OR PAYMENT DUE TO ME? You will not be paid to participate in this study and you will not bear any expenses.

IF I CHOOSE TO PARTICIPATE, WHAT ARE THE RISKS INVOLVED? There are no risks involved in participating in this study.

IF I CHOOSE TO PARTICIPATE, WHAT ARE THE BENEFITS INVOLVED? The study will help to improve the preventive measures against Lead exposure in the science and research institution.

WILL MY PARTICIPATION IN THIS STUDY BE KEPT CONFIDENTIAL? All reasonable efforts will be made to keep your personal information confidential and respect your right to privacy. This includes replacing your identifying personal information with a number that only I or my research supervisor will know. You will not be identified in any research reports that are published. Under some circumstances, such as when required to do so by a court of law, I may have to disclose your personal information. In addition, it may happen that your information will need to be reviewed by other organization for quality assurance purposes. I will tell you about this if it happens.

WHAT WILL HAPPEN TO THE RESULTS OF THE RESEARCH STUDY? The results will be written into a research report that will be assessed. In some cases, results may also be published in a scientific journal. In either case, you will not be identifiable in any documents, reports or publications. You will be given access to the published results of this study if you would like to see them. You must contact me if you wish to have access to the report. The researcher will keep the research documents for a period of 5 years before destroying them which is as per the policy of the institution under research.

WHO IS ORGANISING AND FUNDING THIS RESEARCH STUDY? The study is being organized by me, under the guidance of my research supervisor from the Department of Environmental Health at the University of Johannesburg. I have received sponsoring for the administrative part of this study.

WHO HAS REVIEWED AND APPROVED THIS STUDY? Before this study was allowed to start, I requested permission to conduct the study from management of the science and research institution which was approved. Then the study proposal was reviewed in order to protect your interests. This review was done first by the Department of Environmental Health, and then secondly by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg. At the level of the institution, the internal research committee will review the study before the final submission to protect the interests of the institution and of the workers.

Consent: I understand the procedure described above and my questions have been answered to my satisfaction. I agree to participate in this study.

You will not be required to sign any declaration, by filling in the questionnaire, you will be indicating that you agree to participate in this study.

WHAT IF THERE IS A PROBLEM? If you have any concerns or complaints about this research study, its procedures or risks and benefits, you should ask me. You should contact me at any time if you feel you have any concerns about being a part of this study. My contact details are:

Motaung Faith

Email address: faithm@mintek.co.za

Contact: 0745510803

You may also contact my research supervisor:

Dr Bernard Hope Taderera (Ph.D.)

Senior Lecturer of Public Health. Health Policy and Systems Management Specialist Master of Public Health Programme Department of Environmental Health Faculty of Health Sciences

Office: 7304c John Orr Building Email: btaderera@uj.ac.za Tel: +27711 559 62

If you feel that any questions or complaints regarding your participation in this study have not been dealt with adequately, you may contact the Chairperson of the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg:

Prof. Christopher Stein

Tel: 011 559-6564

Email: cstein@uj.ac.za

FURTHER INFORMATION AND CONTACT DETAILS: Should you wish to have more specific information about this research project information, have any questions, concerns or complaints about this research study, its procedures, risks and benefits, you should communicate with me using any of the contact details given above.

Researcher: Motaung Faith

Appendix 4: Higher Degrees Committee approval letter

FACULTY OF HEALTH SCIENCES HIGHER DEGREES COMMITTEE

MPH HDC-01-63- 2020

21 September 2020

TO WHOM IT MAY CONCERN:

STUDENT: MOTAUNG, MF
STUDENT NUMBER: 200622209

TITLE OF RESEARCH PROJECT: Assessment of the Implementation of Controls for Lead (Pb) Exposure amongst Laboratory Workers at a Science and Research Institution in Gauteng, South Africa

DEPARTMENT OR PROGRAMME: **MASTER OF PUBLIC HEALTH**

SUPERVISOR: **DR BH TADERERA** **CO SUPERVISOR:** **-**

The Faculty Higher Degrees Committee has scrutinised your research proposal and concluded that it complies with the approved research standards of the Faculty of Health Sciences; University of Johannesburg.

The HDC would like to extend their best wishes to you with your postgraduate studies

Yours sincerely,

Prof A Temane

Chair: Faculty of Health Sciences

HDC Tel: 011 559 6972

Email: anniet@uj.ac.za

Appendix 5: Ethical clearance letter

FACULTY OF HEALTH SCIENCES
RESEARCH ETHICS COMMITTEE

NHREC Registration: REC 241112-035

ETHICAL CLEARANCE LETTER
(RECX 2.0)

Student/Researcher Name	Faith Motaung Motshidisi	Student Number	200622209
Supervisor Name	Taderera, Hope		
Department	Environmental Health		
Research Title	ASSESSMENT OF THE IMPLEMENTATION OF CONTROLS FOR LEAD (PB) EXPOSURE AMONGST LABORATORY WORKERS AT A SCIENCE AND RESEARCH INSTITUTION IN GAUTENG, SOUTH AFRICA		
Date	06 October 2020	Clearance Number	**REC-713-2020**

Approval of the research proposal with details given above is granted, subject to any conditions under 1 below, and is valid until 2021/10/05.

1. Conditions:
Gatekeeper permission, as required.

2. Renewal:
It is required that this ethical clearance is renewed annually, within two weeks of the date indicated above. Renewal must be done using the Ethical Clearance Renewal Form (REC 10.0), to be completed and submitted to the Faculty Administration office. *See Section 12 of the REC Standard Operating Procedures*.

3. Amendments:
Any envisaged amendments to the research proposal that has been granted ethical clearance must be submitted to the REC using the Research Proposal Amendment Application Form (REC 8.0) prior to the research being amended.
Amendments to research may only be carried out once a new ethical clearance letter is issued. *See Section 13 of the REC Standard Operating Procedures*.

4. Adverse Events, Deviations or Non-compliance:
Adverse events, research proposal deviations or non-compliance must be reported within the stipulated time-frames using the Adverse Event Reporting Form (REC 9.0). *See Section 14 of the REC Standard Operating Procedures*.

The REC wishes you all the best for your studies.

Appendix 6: Research approval letter for the research site

P.O Box 880
Naturena
2064
21 July 2020

EXCO
MINTEK
200 Malibongwe Drive
Randburg
2125

Re: Request for permission to conduct research in your organization

Dear Sir/Madam

Permission is hereby requested to conduct a research study in your organization. The title of the study is "Assessment of the implementation of controls for Lead (Pb) exposure amongst laboratory workers at a science and research institution in Gauteng, South Africa"

In this study, a walkthrough survey will be performed in ASD and PDD to assess the implementation of control measures in the workplace. A retrospective cohort design will be used to conduct an exploratory and descriptive research on the implementation of controls for Lead exposure and lastly, an online questionnaire will be used to assess the knowledge and attitude of laboratory workers towards the implementation of control measures for Pb exposure.The study can be beneficial to the organization by making recommendations on protecting the health and safety of employees exposed to Pb.

The name of the organization will not be made known and findings will be made confidential and used solely to recommend guidelines for promoting health and safety of employees exposed to hazardous chemical substances. Information obtained will be kept confidential and anonymous. The findings will be made known after the study is completed. Mintek, may withdraw from the study at any stage of the project.

Ethical clearance to conduct the study will be obtained from the Academic Ethics Committee of the University of Johannesburg prior to executing the survey.

I will be grateful if my request can be accepted.

Kindest regards

Motaung Motshidisi Faith (Researcher)

0745510803

EXCO Representative

Appendix: 7 Time frame

Time frame

Gants Chart for research proposal(2020 – 2021)																												
	June 2020				Jul 2020				Aug 2020				Sep 2020 – June 2021				July 2021				August 2021				September 2021			
Task per week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Proposal writing																												
DRC submission																												
and HDC and Ethics committee																												
Pilot study																												
Data Collection																												
Data Analysis																												
Reporting results																												
First draft finalization																												
Second draft finalization																												
Preparation of final draft																												

Appendix: 8 Cost budget

Budget

Research materials	**Cost**
Internet	1000
Stationary	200
Printing	1000
Statistical analysis	No cost
Editing of document	3000
Total	R 5,200.00

Appendix 9: Editor's Certificate

EDITING/PROOFREADING CONFIRMATION

To whom it may concern

This serves to certify that I, **Dr. Thenjiwe Sisimayi (Ph.D.)** have proofread and/or edited **Motaung Motshidisi Faith's** Masters Dissertation to ensure that the language, grammar, punctuation and spelling are academically sound and appropriate, by rectifying errors, wherever these have been identified, and rephrasing sentences that would possibly make one lose sight of the flow of the argument.

Title of the Dissertation:	**Assessment of the Implementation of Controls for Lead (Pb) Exposure Amongst Laboratory Workers at a Science and Research Institution in Gauteng, South Africa**
Editor's name:	**Dr. Thenjiwe Sisimayi (Ph.D.)**
Qualification:	**PH.D. in Public Health**
Signature	
Date:	9 October 2021

Appendix 10: Turnitin Certificate

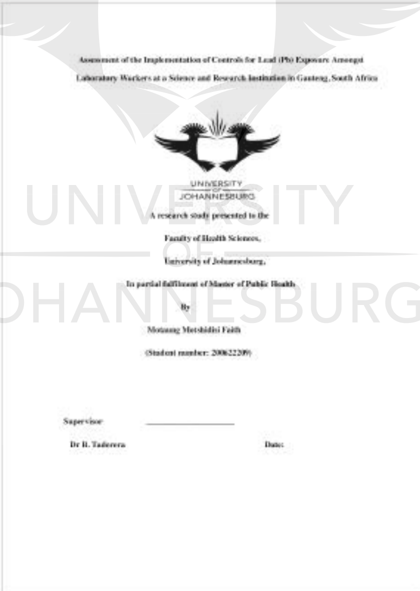
turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	MF MOTAUNG
Assignment title:	Minor Dissertation I: Turnitin Submission
Submission title:	Assessment of the Implementation of controls for Lead(Pb) E...
File name:	tudy_2021_TS_08102021-SF_003__FM_17102021-SF2-clean_20...
File size:	2.09M
Page count:	109
Word count:	28,550
Character count:	151,468
Submission date:	21-Oct-2021 05:15PM (UTC+0200)
Submission ID:	1680130116


Assessment of the Implementation of Controls for Lead (Pb) Exposure Amongst Laboratory Workers at a Science and Research Institution in Gauteng, South Africa

UNIVERSITY OF JOHANNESBURG

A research study presented to the

Faculty of Health Sciences,

University of Johannesburg,

In partial fulfilment of Master of Public Health

By

Motaung Metshidisi Faith

(Student number: 200622209)

Supervisor ____________

Dr B. Tadzerera Date: