Noise exposure levels and associated effects among workers in heavy machine maintenance workshops; a study in gold mining site

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NOISE EXPOSURE LEVELS AND ASSOCIATED EFFECTS AMONG WORKERS IN HEAVY MACHINE MAINTENANCE WORKSHOPS; A STUDY IN GOLD MINING SITE

By

Khadija Ramadhan Makame

A Dissertation Submitted in (Partial) Fulfilment of the Requirements for the Degree of Master of Science in Environmental and Occupational Health of

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by Muhimbili University of Health and Allied Sciences a dissertation titled: **"Noise Exposure Levels and Associated Effects Among Workers in Heavy Machine Maintenance Workshops; A Study in Gold Mining Site",** in (partial) fulfilment of the requirements for the degree of Master of Environmental and Occupational Health of the Muhimbili University of Health and Allied Sciences.

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DECLARATION AND COPYRIGHT

I, **Khadija Ramadhan Makame**, declare that this **dissertation** is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

Signature: …….....…… **Date:** ……....….....

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DEDICATION

I dedicate this dissertation to my children Khalisa, Khayra and Masoud as a future inspiration of academic success

ABSTRACT

Background: Mining sector is among the fastest growing economies worldwide. The processes associated with mining activities generate tremendous noise. Excessive noise exposure in the workplace can limit worker's ability to communicate and hear warning signals as well as temporary hearing problems and permanent noise induced hearing loss. This may have huge impact on worker's safety and productivity.

Objective: This study assessed Noise Exposure Levels and Associated Effects among Heavy Machine Maintenance Workshop workers in Gold Mine Site in Tanzania.

Methods: One hundred and nineteen (119) workers at maintenance workshop in gold mine site participated in this cross-sectional study. Information on demographic characteristics, hearing problems experienced and attitudes toward hearing protective devices were collected using questionnaire. Personal noise exposure levels (n=62) and area noise levels (n=18) were measured were measured using Larson Davis noise dosimeters. Frequencies were generated, logistic regression and chi-square test were used to determine association of the study variables.

Results: All respondents were male with arithmetic mean age 35.1, the mean noise exposure level was 85.68 dB(A). Among workers with recent audiometry, 3.2% had severe hearing loss that required referral, 12.9% had moderate hearing loss (warning level). Prevalence of self-reported hearing problems was (56.5%) for workers with noise exposure of above 85 dB (A). Major hearing problems reported include speech interference (7%), reduction in hearing (56%) tinnitus (31%) and ear infections (6%). About 93.3% of workers regularly using hearing protection devices. Factors associated with hearing problems include noise exposure levels (AOR=1.71,p=0.002),age (AOR=2.01,p=0.005), exposure duration (AOR=1.91,p=0.009), organic solvent use (AOR=1.20,p=0.009) and hearing protection device usage (AOR=1.87,p=0.025)

Conclusion: Findings from this study indicate workers in maintenance workshop at gold mine site were exposed to noise levels higher than the occupational exposure limit (OEL) and may develop hearing problems like any other workers in the mine.

Recommendations: The mine management should institute more measures like regular training on hearing protection devices use and hearing conservation program to reduce the risk of developing noise induced hearing loss.

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ABBREVIATIONS

CDC	Centres for Disease Control and Prevention
ES	Engineering Services
GDP	Gross Domestic Products
HME	Heavy Machine Equipment
HPD	Hearing Protective Devices
HSE	Health and Safety Executive
MUHAS	Muhimbili University of Health and Allied Sciences
NIHL	Noise Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health
NORAD	Norwegian Agency for Development Cooperation
NORHED	Norwegian Programme for Capacity Development in Higher Education and Research for Development
NRR	Noise reduction rate
OEL	Occupational Exposure Limits
OHS	Occupational Health and safety
OSHA	Occupational Safety and Health Authority
PPEs	Personal Protective Equipment
SEG	Similar exposure groups
SPSS	Statistical Package for Social Sciences
SLM	Sound Level Meter
TWA	Time-Weighted Average
TLV	Threshold limit value
UNO	United Nations Organization
WHO	World Health Organization

DEFINITIONS OF TERMS

Personal protective equipment refers to anything used or worn by a person to minimize risk to the person's health or safety and include a wide range of clothing and safety equipment (14).

Occupational disease refers to any disease arising out of or in the course of employment (34).

Ototoxic drugs include antibiotics such as gentamicin, loop diuretics such as furosemide and platinum-based chemotherapy agents such as cisplatin. A number of nonsteroidal anti-inflammatory drugs are ototoxic. This can result in sensorineural hearing loss, disequilibrium, or both (34).

Noise-induced hearing loss (NIHL) Noise-induced hearing loss is a sensorineural hearing deficit that begins at the higher frequencies (3,000 to 6,000 Hz) and develops gradually as a result of chronic exposure to excessive noise levels (1).

Noise reduction rate (NRR) is a unit of measurement used to determine the effectiveness of hearing protection devices to decrease sound exposure within a given working environment(2).

Hearing protection devices refers to anything used or worn by a person inside or around the ear to minimize risk to the person's health or safety and include a wide ear plug, ear muffs etc. (14).

Heavy machines maintenance workshops

Decibel, A-weighted (dB (A)): A scale weighted toward sounds at higher frequencies, to which the human ear is more sensitive (13).

Time-weighted average (TWA): The averaging of different exposure levels during an exposure period. For noise, given an 85-dB (A) exposure limit and a 3-dB exchange rate (13).

Organic solvents refer to carbon-based substance that is used to dissolve another substance or substances e.g. lacquers, varnishes and adhesives (31)**.**

Sound Exposure level is the constant sound level that has the same amount of energy in one second as the original noise event (13).

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Mining sector has become the fastest growing economy worldwide. In Tanzania it is the leading economic sector estimated to contribute about 8.5% of countries economic growth, and have contributed about 4% in country's' Gross Domestic Products (GDP) with about 1.1 % employment with the value of exported minerals said to increase each year (3). With massive development of mining industries there is great concern of environment and health risks that are associated with mining activities. Those impacts include air and water pollution and land degradation as well as effects on workers' health and wellbeing(1,17). Excessive noise exposure in the workplace can limit workers' ability to communicate and hear warning signals and can affect their safety and productivity. A more significant risk is that long-term noise exposure increases the risk of hearing problems and hearing loss, with great implications to workers' health, employment prospects and overall quality of life(2). High levels of occupational noise exposure pose a significant risk to health, safety, and hearing ability. It has been estimated that worldwide, 16% to 24% of hearing impairment is work-related with quantification of the health impact estimated to be over 4 million disability-adjusted life-years (DALYs). The DALYs is a measure of the years lost from the ideal lifespan due to morbidity and premature death, and therefore represents the gap between the current and ideal situation where everyone achieves standard life expectancy in perfect health (2).

Different studies have been done to show the effects of excessive noise exposure on hearing capacity. The major effects associated with excessive exposure to workplace noise is said to be Noise Induced Hearing Loss (NIHL). These studies include, the prevalence of NIHL at mining industry in Zimbabwe was 37%(7). A study by Musiba Z, in Tanzania found that the prevalence of NIHL to be about 47% (8). And the study on prevalence of NIHL in South Africa was observed to be 39.3% (9).Noise is one of the important harmful factors in the working environment which is produced by various machineries and processes. Employees'

exposure to noise is considered to be one of the prevalent problems in working environments around the world that can lead to several problems, among which hearing loss is the most prevalent (10).

There are several factors which contribute **to** hearing problems, these include infection and injuries (17.1%), ageing (28%), inborn hearing problems (4.4%), and prolonged noise exposure especially at work place contribute about (33.7%) of hearing problems worldwide(4).

Maintenance is an essential function in mining workplace. Maintenance workers are more likely to be exposed to a wide variety of risks than other employees, which may lead to various occupational diseases and/or injuries. A Spanish working conditions survey indicated a higher exposure of maintenance workers to noise, vibration and different kinds of radiation when compared to the rest of the working population. Studies also indicate that the repair phase poses the greatest risk with 46% of maintenance related accidents (11). Participants in Gas-fired Electric Plant Workers in Tanzania operation and maintenance departments had a higher mean equivalent sound level (12). In another study done in Turkey the findings also prove that the labour force is affected from occupational noise approximately 60% of the workers complain from hearing problems (5).

Different regulatory bodies have set occupational exposure limits for workplace hazards including noise. National Institute for Occupational safety and Health (NIOSH) Recommended Occupational Exposure Limit (OEL) for noise exposure is 85 decibels A-weighted at an 8-hr Time Weighted Average (i.e. 85 dB(A) TWA). Exposures above this level are considered hazardous (13).The Occupational Safety and Health Administration of Tanzania (OSHA TZ) has set the noise OEL to be 85 dB(A) for 8 hours working time (14). NIOSH recommended a lower 8-hour TWA exposure limit of 85 dB(A), based on a more protective 3-dB exchange rate and an 80-dB(A) threshold level. These recommendations are based on risk assessment analyses indicating that the excess risk of developing noise-induced hearing loss with a 40-year lifetime exposure of 85 dB(A) of 8%, is considerably lower than the 25% excess risk at the 90-dB(A) Permitted Exposure Levels (PEL) enforced by OSHA.

Little is known about noise exposure level and its resulting effects among workers at different units in maintenance department in major mining sites in Tanzania. This study therefore aims at evaluating personal noise exposure levels and its effects among workers working at heavy machine equipment workshop in Gold mining. The findings will help mining management to improve the current control measures into appropriate and effective control measures. This in turn will help reduce exposures hence improve health and social wellbeing of the workers and community in large. It will help to address important risk factors for noise exposure in maintenance workshops in mining industries and could be useful for building up appropriate interventions for managing noise exposure.

1.2 Problem Statement

There is great concern on health and environment in Mining sector, among major health hazard is noise exposure which introduces the risk of hearing loss. Number of people affected by noise exposure is estimated to be around 250 million. Worldwide, 16% of all adult hearing loss problem is attributed by occupational related noise exposure. There are various factors associated with noise exposure at Gold mining sites, these include use of machine which emit excessive sound, blasting, drilling and extraction processes.

In maintenance workshops excessive noise is from grinding cutting operation of steam boilers and excessive noise exposure to workers can be contributed by factors such as prolonged exposure duration, long working shift, Inadequate/improper control measures, poor working environment, and improper use of hearing protection devices (HPD). Currently studies have also show hearing loss due to recreation activities such as use of ear phones exposure to loud sounds of music and diving.

In Tanzania the prevalence of occupational noise induced hearing loss among miners is about 47%**.** The study done in Zimbabwe found the prevalence of Noise Induced Hearing Loss among workers in mining maintenance workshop was about 37% (7). Studies done in

Tanzania in gas fired electric power plant workers operation and maintenance departments indicate higher mean equivalent sound level above 85 dB(A) OSHA standard Refs. Though different working areas it gives indications where servicing and maintenance of big machines and equipment may involve high noise exposure.

Most studies on noise exposure in mining sector have not included maintenance workers as they have varied exposures and mixed exposures. Most studies in mining concentrated on miners and mining activities leaving behind the maintenance workers who are at great risk of exposure as other mining workers. Thus, little is known on noise exposure level among workers in maintenance department although they could be exposed to noise and other hearing impairing factors such as use of organic solvents. Therefore, this study aims at assessing noise exposure levels among workers at heavy machine and equipment workshop in mining site.

1.3 Conceptual Framework on hearing problems associated with noise exposure

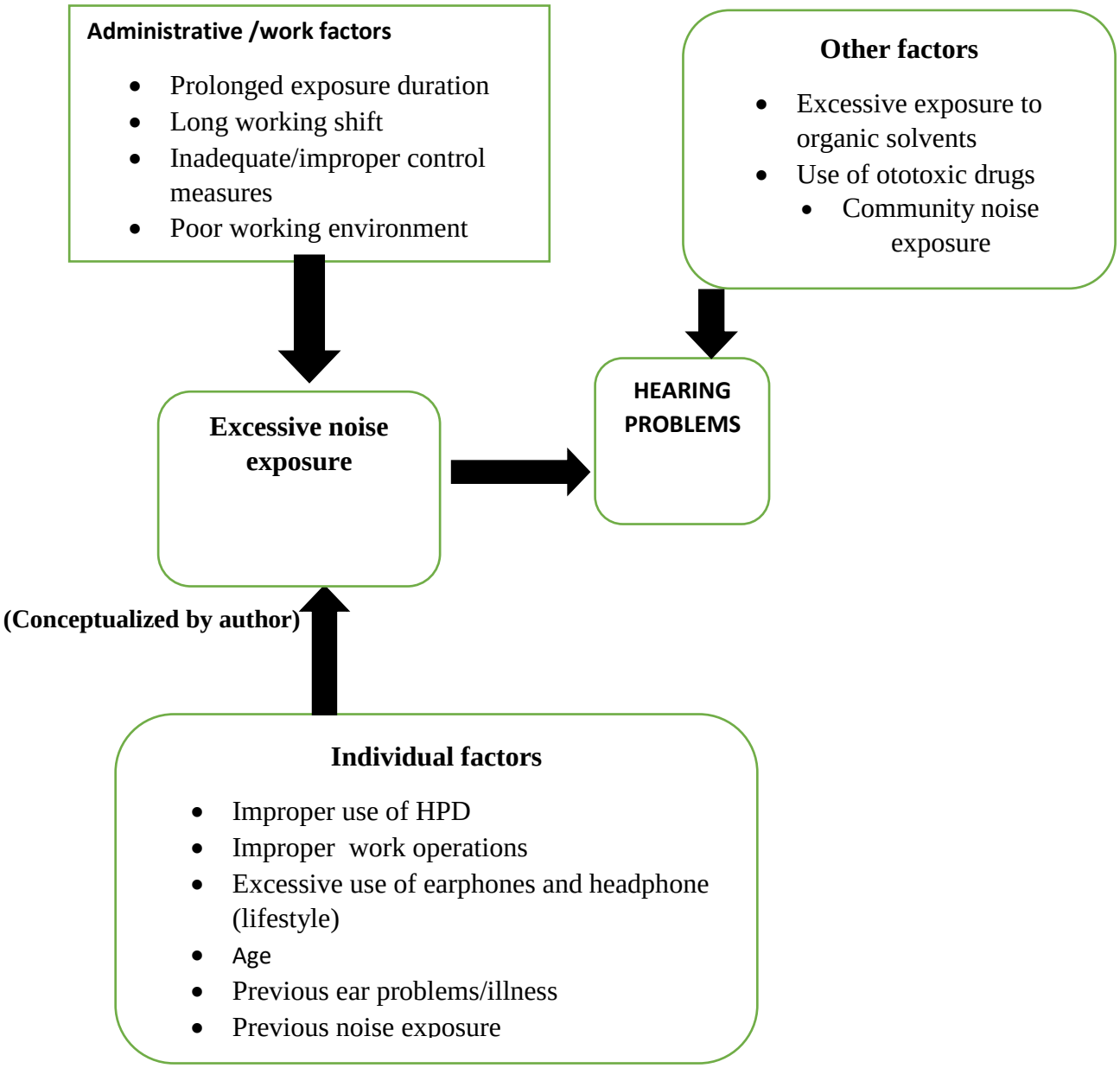


Figure 1: Conceptual framework on noise exposure and hearing problems at mine workshop

From the conceptual framework (Fig 1) it indicates that hearing problems (which include Noise Induced Hearing Loss, Temporary Hearing Loss, Permanent Hearing Loss, Tinnitus, etc) can be directly or indirectly influenced by excessive exposure to noise at workplace usually above 85 dB(A) sound level over long period of time. The concept also included possibility of noise exposure from recreational activities such as listening to music or radio through earphones. These exposures are influenced by different factors. The exposure may lead to hearing loss. There are other factors, which act synergistically with noise exposure and/or may directly cause hearing loss.

Individual factors: These include those things in which a person behavior influences exposure these include individual protective attitudes, knowledge effects exposure and safety habits. Presence of previous history of diseases such as diabetes, ear infections, Tuberculosis (TB) are said to accelerate hearing problems. Age of worker; as one become older his/her hearing capacity is decreased due to reduction in sensory cells in the ear. Use of ototoxic drugs as treatment for some disease that interfere with hearing mechanism. Use of organic solvents at a prolonged period of time can increase hearing problems.

Administrative factors: These are the factors that are influenced by the way management handle or mishandle workers or working environment hence results to workers to be exposed to noise, these include things like: prolonged exposure duration, improper control measures, poor working conditions, improper or inappropriate control measures.

Hearing protection devices usage and attitude: They include improper size and fitting of protective device, poor compliance of HPD, uncomfortable working environment, and long wearing time and discomfort issues. Noise not only lead to hearing problems among workers but also can influence other health problems such as hypertension. Also, it can interfere with communication at workplace which can lead to accidents and injuries. All in all, can reduce workers efficiency hence reduce production.

1.4 Rationale of the Study

The data generated from this study will add into scientific knowledge about workplace noise exposure, this will help to provide occupational noise exposure data from mining sectors. These data are vital for regulatory authorities such as OSHA and WCF because they will provide baseline information on occupational exposure and noise induced hearing loss situation in mine workshops Tanzania. Level of noise exposure among workers in maintenance workshops will be identified and the health effects they might develop. This will in turn help in preventing further health effects and develop proper occupational health and safety programs.

The findings will help mining management to improve the current control measures into appropriate and effective control measures. This in turn will help reducing exposures hence improve health and social wellbeing of the workers and community in large. Also helped to address important risk factors for noise exposure in mining industries and could be useful for building up baseline information for developing exposure limit values for noise as well as appropriate interventions for managing noise exposure. This study will also help in implementing global sustainable development goals especial Sustainable Development Goal number three which aim at ensuring good health and wellbeing of the people by reducing excessive exposure to workplace hazards.

1.5 Research Questions

1. What is the mean noise exposure levels among workers at heavy machine maintenance workshop in mining site?
2. What is the prevalence of hearing loss of workers at heavy machine maintenance workshop in mining site?
3. How is noise exposure and organic solvents is associated with hearing loss to workers at heavy machine maintenance workshop in mining site?
4. What are the sources of noise exposure and control measures available at heavy machine maintenance workshop in mining site?

1.6 Research Objectives

1.6.1 Main Objectives

- To assess noise exposure levels and its associated effects among workers working at heavy machine maintenance workshop in gold mining site.

1.6.2 Specific Objectives

1. To determine noise exposure levels among workers working in heavy machine maintenance workshop in gold mining site.
2. To assess prevalence of hearing problems among workers in heavy machine maintenance workshop in gold mining site
3. To identify determinants contributing to hearing problems among workers working at heavy machine maintenance workshop in gold mining site
4. To assess noise control measures available at heavy machine maintenance workshop at gold mining site.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Occupational noise exposure in mining industries.

Different work environment may expose workers to various health hazards such as dust, heat, noise, injuries and psychosocial or work stress. The processes associated with mining generate remarkable noise as a result of activities such as drilling, blasting and crushing of ore, often aggravated by confined and reflective spaces (5). Various aspects of the working environment could expose an individual to potential hazardous elements. Noise is one of potential hazards and it is currently a global health concern(2). Noise, which is defined loosely as annoying sounds, is part of the everyday human activity. Excessive noise beyond tolerable levels could be hazardous and cause hearing impairment. In general, sounds above 85dB(A) are considered harmful, depending on how long and how often one is exposed to them and whether you properly wear hearing protection devices (11).

Worldwide, 16% of the disabling hearing loss in adults is contributed to occupational noise, ranging from 7% to 21% in the various sub regions (15). Occupational exposure to elevated noise levels is dependent on a variety of factors, including: a) occupation and industry; b) workplace-specific factors, such as type of facility and process, raw materials, machinery, tools; the existence of engineering and work practice controls; and existence, condition, and use of personal protective devices(2). A study done in wheat industry indicated that the noise exposure limit in maintenance office was as high as 99.4 dB(A) which is greater than the recommended limit of 85 dB(A) (16).

2.2 Hearing loss associated with exposure to noise at mining areas

Exposure to high occupational noise that causes health risks is common in a variety of industrial processes. Its effects depend not only on the intensity, but also on exposure time, frequency and the type of noise as well as control measures available. According to the WHO, high levels of noise may lead to speech interference, reduction in productivity, high blood

pressure, hearing defects, health disorders, sleep interference, cardiovascular effects, loss of concentration and absenteeism, and fatigue(17).

Noise induced hearing loss (NIHL) generally occurs over a long period of exposure to high noise levels, developing unnoticeably and gradually as time passes. Detrimental effects from noise are 100% preventable. Noise exposures contributing to NIHL can be continuous or intermittent in nature and cause hearing loss as a result of damage to the hair-like cells structure of the cochlea. NIHL is prevalent across industries and countries, as hearing loss accounts for approximately one third of the occupational illnesses reported in Europe. In a study on occupational noise exposure, 23% of workers who were exposed to noise presented with difficulty in hearing, compared with only 7% of those not exposed (5).

According to the WHO sub-region classification where Tanzania is included, the burden of hearing impairment attributed by occupation is estimated to be 18%, where 23% is for male and 12% for female workers.

In the study done in US, about 41% of workers had significant noise exposure above limits and 37% reported hearing problems (10). About 73.2% of miners in the mining industries in South Africa are exposed to noise level above exposure limits (9). In Zimbabwe it has been found that the prevalence of Noise Induced Hearing Loss among workers in mining sector is about 37%(7). Spanish working conditions survey indicate a higher exposure of maintenance workers to noise. Studies also indicate that the repair phase poses the greatest risk with 46% of maintenance related accidents. (8).

There is significant association between occupational noise induced hearing loss with age and duration of exposure. In the study of South African gold miners, the youngest age group (aged under 29) had a mean pure tone threshold of hearing 2 dB higher than the older 30–39 age group at the frequencies examined. There was a greater NIHL prevalence (72%) among those with >10 years' exposure. There was little difference in NIHL prevalence between those with 1–5 and 6–10 years' exposure (42 and 40%, respectively)(19). A study conducted to assess noise induced hearing loss among employees at a mining industry in Zimbabwe revealed 53%

of workers who are exposed develop NIHL and the exposure increase with age and duration of exposure (7).

A study done in mining areas in Tanzania indicated that there was a high prevalence (47%) of NIHL among miners with mild hearing impairment of 35% and poor hearing of 12% among miners (8). Other hearing symptoms include feeling disturbed during work, failure of talking to coworkers in normal conversation during work, temporary hearing decreased after work and ringing/ roaring/ buzzing in the ear (18).

2.3 Noise exposure organic solvents exposure and hearing loss

In most workplaces, workers are exposed to noise and solvents simultaneously, so the potential risk of hearing loss due to solvents may be attributed to noise. In this study we aimed to assess the effect of exposure to mixed aromatic solvents on hearing in the absence of exposure to hazardous noise (20, 22, 28, and 29).

Despite its widespread occurrence within various production processes, noise is not the only determinant of work-related hearing loss. Currently there are studies, which provide evidence of potentially otoneurotoxic occupational exposures, comprising the exposure to chemical agents, whether alone or in combination with noise. Chemicals are considered exogenous ototoxic substances capable of inducing ototoxic hypoacusis in workers of different occupational sectors(29,31).

There is increasing evidence from epidemiological and clinical studies that occupational exposures to organic solvents may have detrimental effect on hearing system and their interaction with noise(20,22,28,29). Hence these relationships need to be assessed in different work area especially in maintenance departments.

NIHL may be aggravated by exposure to chemical solvents in environments with the presence of noise, both of them being above or even within legally allowed levels. By means of an interaction mechanism, the combined action of the agents may aggravate their isolated adverse effects on hearing. Impairment caused by agents acting together may exceed the simple sum of impairment produced by each agent separately (31).

2.4 Sources of occupational noise exposure

Mining activities involves the use of heavy machines, equipment and vehicles such as dump-tracks, excavators, bulldozers, cranes, rigs etc. that generate high noise levels. Heavy machines maintenance workshops offer a technical design and support throughout the mine site. In mining site there are various machines and equipments that require maintenance; hence maintenance is essential function in mining workplace. Corrective maintenance at mine ensures the expected performance and life support for the equipments or vehicle is achieved. The units in the maintenance workshops are such as:

Boilermakers who manufacture, install, and maintain boilers, tanks, and closed vauts at different areas of the mine site. Boilermakers heat the liquid, usually water that is used to generate electric power or provide heat necessary to melt iron or metal parts.

Auto-electricians specialize in installing and maintaining electrical systems contained in automotive vehicles and machines where they install, inspect, repair, and maintain all the electrical parts contained in a vehicle or machine.

Fitter mechanics are responsible for fitting and assembling parts made from metal and other materials to make production machinery.

Mechanics repair or servicing vehicles and other mining machines like light vehicles, heavy equipments machines and heavy trucks. Their responsibilities include diagnosing automotive problems and making the necessary repairs. They also perform routine maintenance, like oil changes and tune-ups, to prevent future problems (16). These, activities are said to cause higher noise levels which are harmful to people they are exposed. A study done among workers in mechanical repair shop recorded varying noise levels depending on the task and tools that were used, they reported sources of noise exposure included compressors, sprayers, grinding cutting machines (20).

2.5 Hearing protection devices usage

Hearing protection devices (HPDs), are devices worn in or over the ears while exposed to excessive noise in order to prevent noise induced hearing problems. These devices only reduce the level of noise exposure but not entirely eliminate the noise from entering the ear There are many different types of HPDs available for use, these include earmuffs, earplugs, electronic hearing protection devices and semi-inserted devices (18). HPDs can also protect against other effects of excessive noise exposure such as tinnitus and hyperacusis.

Hearing loss due to industrial noise normally increases and progresses during the years of noise exposure and is an irreversible damage. However, it is preventable through avoiding excessive exposure to noise and proper use of personal protective equipment such as HPDs Studies have found that the prevention of hearing damage through the use of Hearing Protective Devices (HPDs) in the industry is low, varying from 20% usage in some studies to 30% - 50% in others (19).

Although HPDs are seen to be a temporary solution, due to some economics and applicability aspects, they are widely used as the only measure against noise exposure. However, it is also well known that non-usage of hearing protectors 100% of the time when the noise is at a high level will significantly reduce HPDs' effectiveness (18).

2.6 Occupational noise control measures

Occupational Safety and Health professionals use the hierarchy of control to determine how to implement practical and effective risk management programs to tackle noise-related issues in the workplace. The hierarchy of noise control includes elimination or substitution of noise sources, collective control measures through engineering and work organization, and personal protective equipment (21). There are several ways in which noise is controlled; they can vary from one workplace to another or one noise source to another. There is no single standard technique appropriate for every situation. Good understanding of plant operations and work processes is necessary to determine the most effective method of eliminating, minimizing or controlling the noise(8). Factors the employers should consider include; the scale of the noise

problem and its impact on the business (including workers), cost and effort required to reduce noise exposure, effectiveness of planned control measures, the number of individuals who would benefit from those control measures(15). Engineering controls are all about making changes to processes, machinery or equipment so that the workers are exposed to less noise. For example, using screens, barriers, enclosures and absorbent materials help to reduce workers' noise exposure (21).

Administrative controls are the way work is organized to reduce either the number of workers who are exposed or the length of time they are exposed to noise. These should be used when it is not possible to reduce noise exposure through elimination, substitution or engineering noise control measures(12). Personal protective equipment protects the users from any adverse effects on hearing caused by exposure to high levels of noise. It is the last option in the hierarchy of control and should be used as a last resort after all efforts to eliminate or reduce the noise levels have been exhausted through technical and organizational means (13). Noise exposures can be controlled by reducing the amount of noise generated by equipment or by protecting the workers' operating position by an enclosure.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Design and duration

This study employed a cross-sectional descriptive study design conducted in August 2019. Noise levels were measured and the associated factors were assessed using questionnaire and walkthrough survey.

3.2 Study Area

The study was conducted in maintenance workshops in an active gold mine in North-West of Tanzania. The Gold mine has two major operating maintenance workshops; which are Heavy Machine Engineering workshop (HME) and Engineering Service workshop (ES) the total number of workers in both workshops is 183. Workshop operates in two shifts of 12 hours. Job categories performed at these workshops are mechanical works, auto-electrical services, boiler makers operations, fitting mechanics as well as rigging and scaffolding.

Major activities performed at HME workshop include repair, maintenance and servicing of heavy mining machines such as damp trucks and excavators as well as fixing and maintenance of different items that required maintenance. On the other hand, at ES workshop major activities performed are welding and fabrication of other items apart from heavy machines, masonry, light vehicle maintenance, carpentry and masonry. All maintenance for equipment and instruments used in the mine are conducted in these workshops or by workers from the workshop when such services are needed elsewhere in the mining site.

3.3 Study Population

This study involved workers working at heavy machine maintenance workshops in the gold mine who were present at the mine site during data collection.

3.3.1 Inclusion Criteria

Workers at the maintenance workshops who had worked for at least one year were included in this study.

3.3.2 Exclusion Criteria

Workers at the maintenance workshops who had worked for less than one year were excluded from this study.

3.4 Sampling Size

The total sample size for the study was estimated using Open-Epi version 3, open source calculator (40).

Where,

Sample size n = [DEFF*Np(1-p)]/ [($d^2/Z^2_{1-\alpha/2}$*(N-1) +p*(1-p)]

Where by:

N	=	Population size (for finite population)	=	183
p	=	Hypothesized % frequency of outcome factor in the population. This have been obtained from the study of the prevalence of noise-induced hearing loss among Tanzanian miners (Musiba Z,2015) (8)	=	47%
d	=	Confidence limits as % of 100(absolute +/- %)	=	5%
DEFF	=	Design Effect	=	1

Sample size (n) = [1*183*0.47(1-0.47)]/ [5^2 /$1.96^2_{1-\alpha/2}$*(183-1) +0.47*(1-0.47)] =125

Therefore, the sample size = 125

Adjusting for 10% non-response rate= 125x1.1=138

The required sample size (n) = 138 workers.

3.5 Sampling and sampling procedures

Convenient sampling procedure was used to obtain the number of participants that were involved in this study. The number of sample size estimated for this study was 138 workers. Participants for noise exposure survey were obtained using the National Institute for Occupational Safety and Health (NIOSH) Guideline for Random Sampling of Homogeneous Risk Group Workers (27) depending on the number of workers in the sections assumed to be of Similar Exposure Groups (NIOSH, 1977). The list of sections and the number of workers in each section were obtained from the mine administration, the number of participants is elaborated in the Table 1 below.

Table 1: Sample size determination for maintenance workshop workers (base on NIOSH guideline)

Job section	Total number of workers in each section	Number of participants in the study (n)	Number of workers involved in personal noise measurement	Number of repeated samples
Mechanics	66	37	21	9
Boiler maker	39	27	14	7
Rigger operators	21	16	8	4
Auto electricians	37	25	13	6
Fitter mechanics	20	14	6	3
Total	183	119	62	29

From the above table total number of workers participated for personal noise exposure assessment were 62 from different job sections. 29 sample were repeated to assess the difference in results under varying time and conditions however the repeated samples were not included in the results as the workers were performing different operations at different places each day**.**

3.6 Data Collection Tools and techniques

The data collection process involved following procedures which were essential to achieve the objectives and scope of the study. Those were:

1. Area noise measurements
2. Personal noise measurements
3. Questionnaires
4. Audiometry data

3.6.1 Area noise measurement

Survey of workshops noise sources and levels was carried out by taking measurement of sound level in each particular area of workshops. An S1.4 Type 2 digital sound level meter (SLM) was used to measure noise level at different points in two workshops, the SLM was placed about 5m from the noise source activity while worker perform their tasks and about 1.2-1.5m above the floor and 3.5 m from away from sound-reflecting structures in the work site. Nine points were measured in each workshop, i.e. HME and ES. The SLM was shielded with cover that act as wind shield so as to minimize the wind interference.

3.6.2 Personal noise measurements

Integrated noise dosimeters Larson Davis Spark model number 705+ and 706 were used to measure personal noise exposure levels during 8 hours working time, pre and post calibration was done before and after each measurement. The dosimeter microphone was attached to the workers collar at the hearing zone approximately 10 cm from the ear, the dosimeter was set to run for 8 hours of working shift. After completion the dosimeter was connected to the computer and data were downloaded and presented in excel worksheet.

The dosimeter settings were; Detector (SLOW), Sample Interval (60 seconds), Peak weigh (C), Exchange rate (3dB(A)), Threshold level (80dB(A)), Criterion level (85dB(A)), Criterion duration (8 hours.

The 8-hour Time Weighted Average (8-hr TWA), Sound Exposure (SE) levels and maximum noise peak (Lpeak, max) were recorded. 8-hr TWA was used as a guideline because most of the OEL are using (8-hr TWA), in dB(A) as references (13). The OEL used was 85 decibels, A-weighted, as an 8-hr time-weighted average (85 dB(A) as an 8-hr TWA) for occupational noise exposure established by the National Institute for Occupational Safety and Health (NIOSH) in 1972 as regarded. Exposures at or above this level are hazardous (27).

3.6.3 The questionnaire assessed the following:

i. Demographic information of the workers (age sex education and job history).
ii. Hearing protection usage and attitude, hearing capacity and hearing problems of the workers.
iii. Use of organic solvent and ototoxic drugs.

The total number of participants who were involved in the questionnaire survey were 119 as elaborated in Table 1 above.

3.6.4 Audiometry

Audiometry results for 62 participants who were involved in the noise survey were obtained from previous audiometry test records at the mining clinic these are from pre-employment and normal periodic and screening examinations. SmartTone audiometer with serial number 70338 was used to test hearing. Health and safety Executive (HSE)-UK Classification of Audiograms were used to categorize hearing loss as normal, warning and referral. HSE categorization scheme based on sum of hearing at 1, 2, 3, 4 and 6 kHz was used to assess hearing loss (35).

Table 2: Age band and gender in standardized HSE-UK classification of audiogram.

Health and safety Executive (HSE)-UK Classification of Audiograms-Warning and Referral levels Sum of hearing levels 1,2,3,4,5 and 6 kHz				
	Males		**Females**	
Age	**Warning level**	**Referral level**	**Warning level**	**Referral level**
18-24	51	95	46	78
25-29	67	113	55	91
30-34	82	132	63	105
35-39	100	154	71	119
40-44	121	183	80	134
45-49	142	211	93	153
50-54	165	240	111	176
55-59	190	269	131	204
60-64	217	296	157	235
65	**235**	**311**	**175**	**255**

Table 3: HSE Categorization Scheme Based on Sum of Hearing at 1, 2, 3, 4 And 6 kHz

Category	Calculation (Compare value with figure given for appropriate age band and gender in standardized tables)	Action
1. Acceptable hearing ability. Hearing within normal limits.	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz.	Normal hearing. No action needed.
2. Mild hearing impairment. Hearing within 20th percentile, i.e. hearing level normally experienced by one person in five. May indicate developing NIHL.	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz.	Warning. This means the employee has mild hearing impairment and needs training and counselling on how best to prevent further deterioration. No referral is warranted
3. Poor hearing. Hearing within 5^{th} percentile, i.e. hearing level normally experienced by 1 person in 20. Suggests significant NIHL	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz.	Referral. This means that the employee has hearing worse than would be expected for their age and referral to an occupational physician, audiologist or an ENT specialist for further evaluation is indicated.

3.7 Study Variables

3.7.1 Dependent variables

Noise exposure levels and Hearing problems such as (NIHL, and Tinnitus)

3.7.2 Independent variables

The following were categories as independent variables as far as the research scope:

- Age of the respondent
- Duration of exposure to noise
- Work history
- Use of organic solvents
- Previous illness such as, Ear infections.
- Using of ototoxic drugs.
- Hearing protection device usage and compliance attitudes
- Nature of work environment

3.8 Validity and reliability

The questionnaire used have been validated as it was used in Tanzania by John and colleagues, 2018 (12) who assess noise exposure and self-reported hearing impairment among gas fired electric plant workers in Tanzania. The questionnaire was modified to fit the Tanzania mining environment and the scope and objective of the study. To ensure the validity and reliability of measurements and results the instrument used (i.e. dosimeters and sound level meters) were calibrated measurements. Pre and post calibration of noise dosimeter and sound level meter were set to 114 dB(A). Questions were translated to Kiswahili and back- translated to English. Errors were corrected to get the required meaning.

3.9 Pre-test

Prior to data collection, data collection tools were pre-tested to workers of a small mechanic workshop in Zanzibar town before commencing of the study. This was done to check if the questions are well understood, with proper logic and sequence to generate meaningful information and know if objectives could be answered. Restructuring, modifications and amendments of the questions were done where necessary before producing a final data collection tool.

3.10 Data Processing and analysis

The data processing and analysis was conducted using SPSS version 22 based on each study objective. Descriptive statistics was performed for all variables. The bivariate and multiple logistic regression were run for assessing association between risk factors that contributed to hearing problems. Multivariate analysis using mixed effects models and logistic regression models was done to explain determinants for noise exposure and hearing loss, respectively confidence interval level of 95% and p-value< 0.05 were considered to indicate statistically significant association between dependent variables and independent variables.

Objective 1: To determine noise exposure levels in heavy machine maintenance workshop in mining site.

Descriptive statistics analysis was used to compare the mean noise level of the workers in different section workshops. Descriptive analysis of percentage of people with hearing problems. Mean personal noise levels were computed using SPSS by descriptive analysis. The mean noise levels were compared with respective job/tasks and were related with OEL. Descriptive statistics were used to compare noise levels measured at different points in the workshops with the limits value using descriptive statistical analysis.

Objective: To assess prevalence of hearing problems among workers in heavy machine maintenance workshop in mining site

Together with: **Objective 3: To identify determinants contributing to hearing problems at heavy machine maintenance workshop in mining site.**

Prevalence of hearing problems among workers were computed using descriptive statistics. The frequencies of hearing problems such as speech interference, ringing ear (tinnitus), reduction in hearing, ear infections were analysed. Chi square test were used to analyze association between hearing problems with other factors such as age, duration of exposure, use of ototoxic drugs and organic solvents, previous work in noise environment, HPD usage. Logistic regression was used to associate the variables.

Objective 4: To assess noise control measures in heavy machine maintenance workshop at mining site.

Information from questionnaire response, walkthrough survey and checklist were used to provide the basis for determining noise exposure control measures available and effectiveness. Descriptive analysis was used to determine frequencies of use and type of HPD usage as well as assessing of functional control measures in place, effectiveness, workers attitude and prevalence and trainings on proper used of control measures.

3.11 Ethical Considerations

The ethical clearance for conducting this research was granted from Muhimbili University of Health and Allied Sciences (MUHAS) research and publications' Ethical Review Committee with reference number DA.287/298/01A. An introduction and permission request letter was sent to mine manager prior to commence of data collection.

Consent for the inclusion of subjects in this study was sought through a consent form that was read and presented to workers for their approval or disapproval. Privacy and confidentiality of the information was provided, voluntary participation and withdrawal from the study at any stage without victimization. The anonymity of the subjects was assured where the identity of the individuals was protected by using numbers. Participants were given the contact address of the chairman of MUHAS research and publication Committee and they were free to contact him in case of any issues arise during data collection.

CHAPTER FOUR

4.0 RESULTS

4.1 Socio-Demographic characteristics of the study participants

The study consisted of 119 participants from different sections at maintenance workshops who were at work at the time of the study making a response rate of 86.2%. All participants were male with mean age of 35.19(SD=7.23) with mode of 33 years range 22 to 51 years. Majority 64(53.8%) of respondents attained secondary education, 23(19.3%) vocational education, 13(10.9) tertiary education and 18(15.1%) primary education. About 93(78.2%) of maintenance workers live outside mine camp and 26(21.8%) live inside the camp. The mean duration of work in noise environment was 7.76 years (SD=3.79), with 5 years mode, minimum duration was 2 years and maximum duration was 20 years. The study participants consist of 37(31.1%) mechanics, 27(22.7%) boiler makers, 25(21.8%) auto electricians, 16(13.4%) rigger operators and 14(11.8) fitter mechanics. (Table 4).

Table 4: Socio-demographic characteristics of the study population (n=119)

Parameters	Maintenance workers n (%)
Age	
18-25	10 (8.4)
26-35	58(48.7)
36-45	39(32.8)
>45	12(10.11)
Education	
No formal education	1 (0.8)
Primary education (< standard 7)	18(15.1)
Secondary education	64(53.8)
Tertiary education (college and above)	13(10.9)
Vocational training	23(19.4)
Accommodation	
Inside mine camp	26(21.8)
Outside mine camp	93(78.2)
Job Description	
Boiler maker	27(22.7)
Mechanics	37(31.1)
Rigger operator	16(13.4)
Auto-electrician	25(21.0)
Fitters mechanics	14(11.8)

4.2 Noise exposure levels in heavy machine maintenance workshop in mining site.

4.2.1 Personal noise exposure levels

Sixty-two personal noise exposure assessment were done for workers in five sections in the workshops (boiler makers, mechanics, rigger operators, auto electricians and fitter mechanics). Mean noise exposure level in 8 hours (TWA) scale was 85.68 dB(A) (SD=6.56) ranging from (68.00 dB(A) to 100.10 dB(A)). Mean noise exposure for mechanics was 85.9 dB(A) (ranging from 73.9 to 99.9) with 11(31.4%) samples exceeding OEL, 85.3dB(A) for boiler makers (ranging from 68 dB(A) to100.1 dB(A)) with 9(5.7%) samples exceeded OEL.

Auto electricians are exposed to mean noise of 86.7 dB(A) (ranging from 78 dB(A) to 98.3dB(A)) with 9(5.7%) samples exceeding noise levels above 85 dB(A). Mean noise exposure levels for fitter mechanics was 87.3 dB(A) (ranging from 71.8 dB(A) to 99. 8dB(A)) with 4(11.5%) exceeding 85 dB(A), rigger operators mean noise exposure 83.3 dB(A) (ranging from 78.9 dB(A) to 92.3 dB(A)) with 2(5.7%) exceeding 85 dB(A) (Table 5).

Table 5: Noise exposure levels of >85 dB and <85 dB(A) between sections of maintenance workshop (n=62)

Job category	N	Mean	Min	Max	>85 dB(A) n (%)	<85dBA(n(%)
Mechanics	21	85.9	73.9	99.9	11(31.4)	10(37)
Rigger operators	8	83.3	78.9	92.3	2(5.7)	6(22.3)
Boiler makers	14	85.3	68	100.1	9(25.7)	5(18.5)
Auto electricians	13	86.7	78	98.3	9(25.7)	4(14.8)
Fitter mechanics	6	87.3	71.8	99.8	4(11.5)	2(7.4%)

4.2.2 Aerial Noise exposure levels in different selected points in HME and ES workshops.

The mean noise level in two maintenance workshops were 88.1 dB(A) and 95.04 dB(A) in HME and ES workshops respectively. Minimum noise level in HME was 81.9 dB(A) and in ES was 84.5dB(A). Maximum noise levels in HME was 104.2 dB(A) and in ES was 106.9dB(A) (Figure 2).

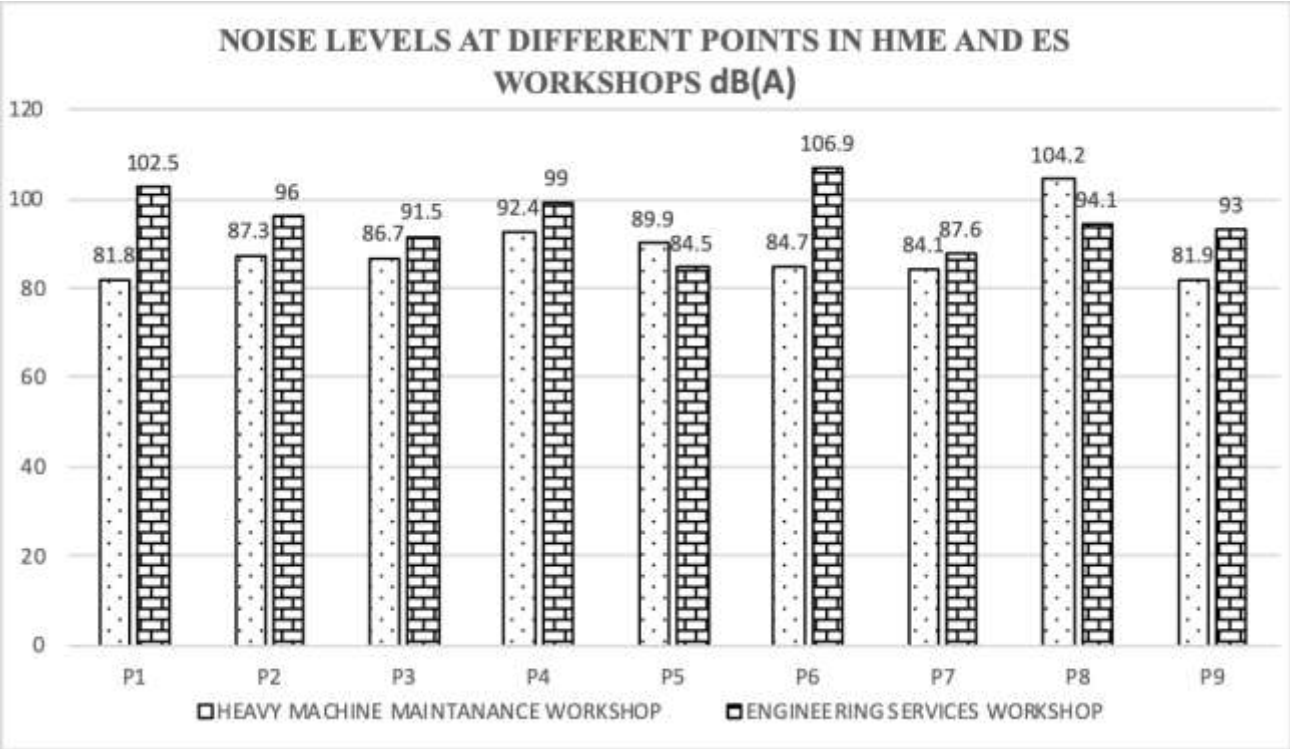


Figure 1: Noise Levels at different points of HME and ES workshops (dB(A))

4.3 Prevalence of hearing problems among workers in heavy machine maintenance workshop in mining site.

4.3.1 Prevalence of self–reported hearing problems

Out of 119 workers who were asked for hearing problems using the questionnaire, 32(26.9 %) reported to have hearing problems. Among 32 who had reported to have hearing problems; 18(56.25%) reported reduction in hearing, 10(31.25 %) reported ringing ear (tinnitus), speech interference and ear infections both account 2(6.25%) of all hearing problems experienced, (Figure 3).

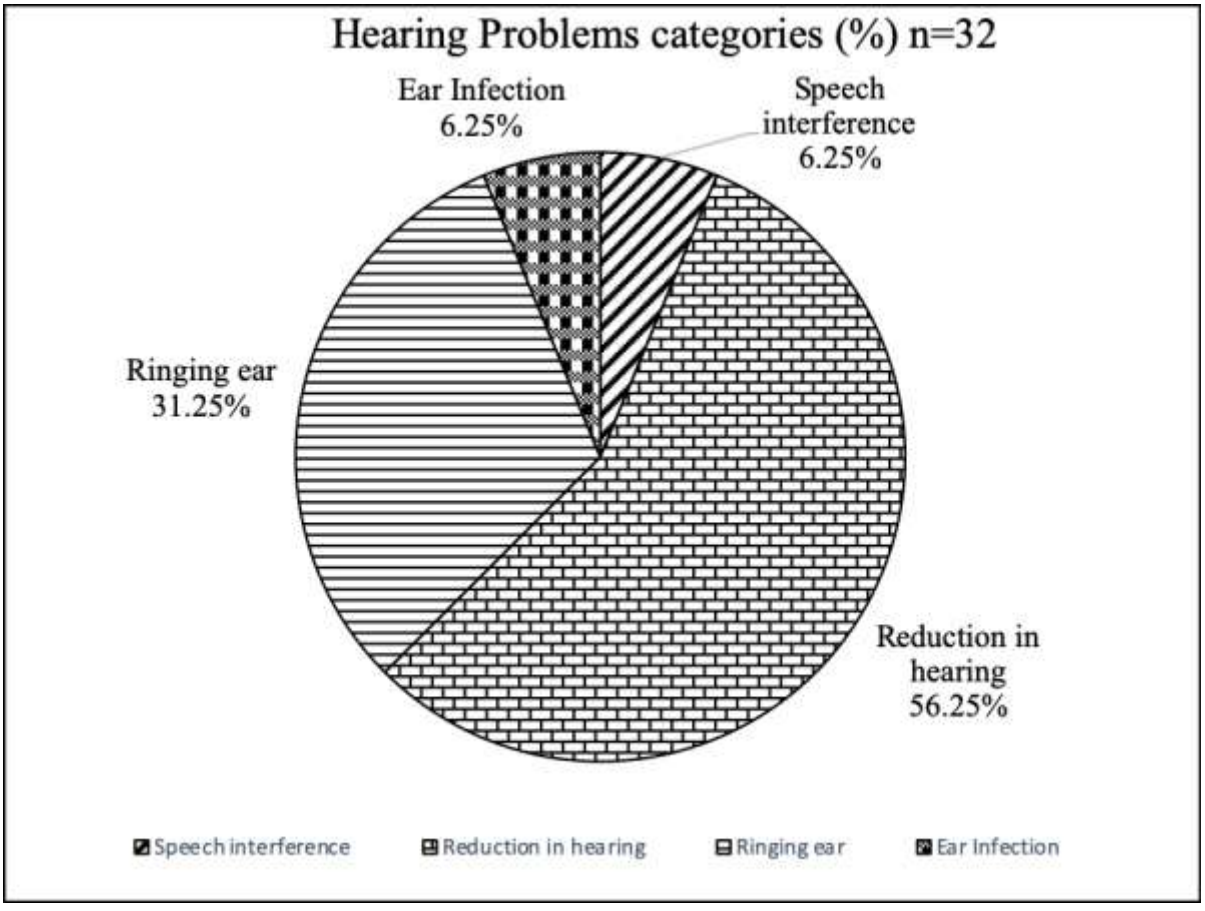


Figure 2: Prevalence of self-reported hearing problem categories among workers.

4.3.2 Factors influencing self-reported hearing problems among heavy machine maintenance workshop workers.

Various factors that may influence occurrence of hearing problems were assessed. This included age, work duration in noise environment, noise exposure levels, organic solvents, ototoxic drug use and HPD utilization.

The age group ≤35 years had 28(40.6%) prevalence of hearing problems while age group >35 had 33(66.0%) (p= 0.006), those with work duration of more than 10 years had hearing problems prevalence of 35(67.3%) (p=0.002).Workers who reported used organic solvents had a prevalence of 60(56.1%) (p=0.002), for hearing protection devices usage frequencies, those who rarely use hearing protective devices had hearing problems prevalence of about 6(75.0%) (p=0.025). Noise exposure levels of >85 dB(A) have contributed to 19(50.0%) (p=0.749) of hearing problems among workers. (Table 6).

Table 6: Prevalence of self-reported hearing problems with various factors among heavy machine maintenance workshop workers (n=119)

Variable factors	Reported hearing problems n (%)		χ^2	p-value
	None	Present		
Age group of respondents				
≤ 35 yrs(n=69)	41(59.4)	28(40.6)		
>35 yrs(n=50)	17(34.0)	33(66.0)	7.498	0.006*
Duration of work				
<10 years(n=67)	41(61.2)	26(38.8)		
>10 years(n=52)	17(32.7)	35(67.3)	9.519	0.002*
Organic solvents usage in working area				
Not use(n=12)	11(91.7)	1(8.3)		
Use(n=107)	47(43.9)	60(56.1)	9.843	0.002*
Ototoxic drugs usage				
Use(n=8)	2(25.0)	6(75.0)		
Not use(n=111)	56(50.5)	55(49.5)	0.468	0.523
Frequency of using HPD				
Regular (n=111)	72(64.9)	39(35.1)		
Sometimes/rarely (n=8)	2(25.0)	6(75.0)	5.04	0.025*
Noise exposure levels				
>85 dB(A)(n=24)	13(54.2)	11(45.8)		
<85 dB(A)(n=38)	19(50.0)	19(50.0)	0.102	0.749

χ^2=chi-square value, *Statistical significance

4.3.3 Audiometry screening test results among workers in heavy machine maintenance workshop

Audiometry results reviewed were for 62(52.1%) workers among 119, the rest 57(47.9%) had not done audiometry screening test. Among 62 workers whose audiometry results were analysed, 60 had normal hearing at baseline taken at employment date, remaining 2 have warning level (i.e. initial stage of NIHL). From the most recent audiometry data (2018 and Jan 2019) only 45(72.6%) had done the periodic audiometry 17(27.4%) had not done any since baseline. Those with recent audiometry, 2(3.2%) had hearing loss that required referral, 8(12.9%) had warning hearing loss and 35(56.5%) had normal hearing. (Figure 4).

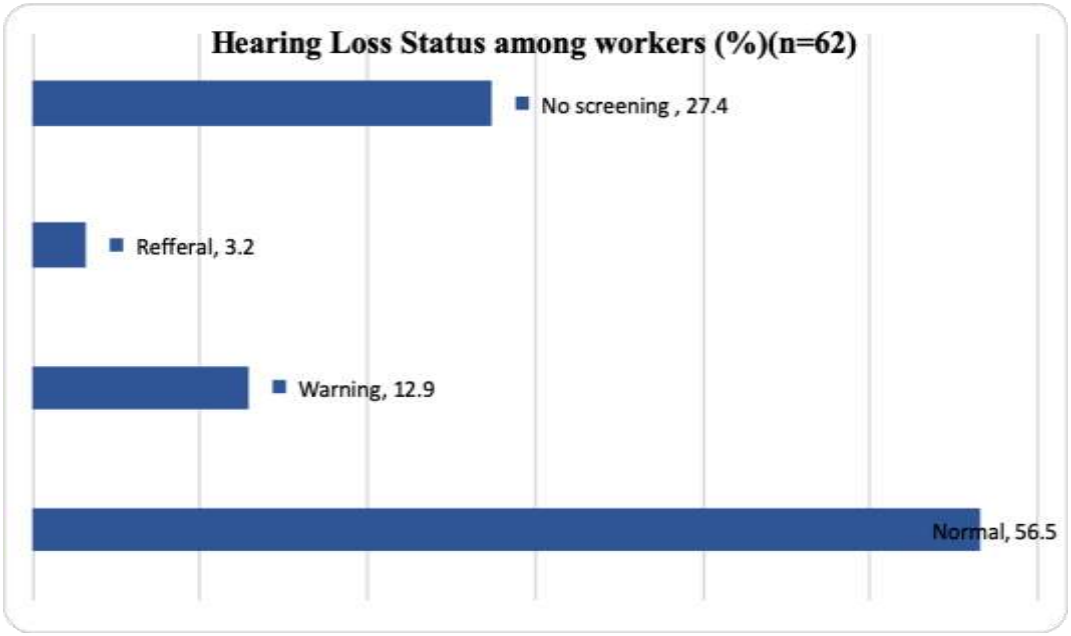


Figure 3: Proportion of hearing capacity status among workers at heavy machines maintenance workshops in gold mine site.

Note: *Normal indicate normal hearing capacity, Warning means the employee has mild hearing loss. Referral means employee has severe hearing loss (worse than would be expected for their age). No screening represents those who did not perform any periodic audiometry screening test.*

Noise exposure levels and Audiometry Hearing status.

Eighteen (51.4%) of respondent who have normal hearing, 6(75%) of those in warning condition. Workers who have referral condition 2(100%) are exposed to noise levels above 85dB(A), and those who have not done routine audiometry test 9 (52.9%) are exposed to levels above 85dB(A) (Fig 5).

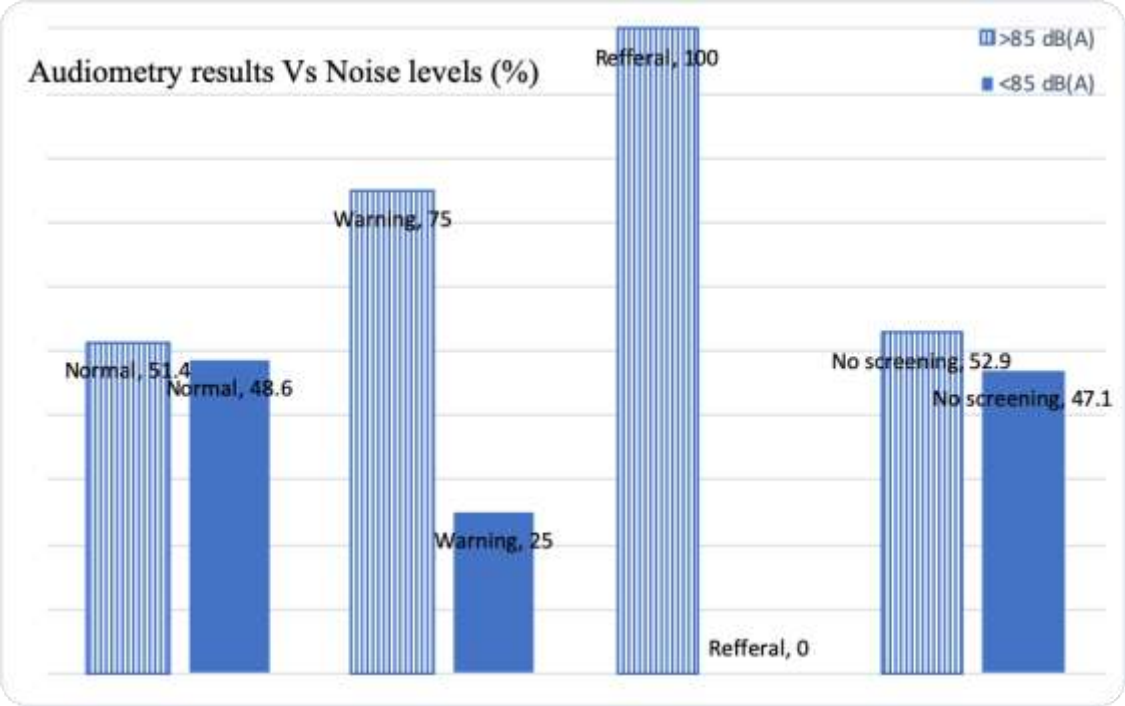


Figure 4. Comparison of audiometry hearing status with percentages of noise levels of below and above 85 dB(A) limit among workers.

4.4 Noise control measures in heavy machine maintenance workshop at mining site

The survey revealed that all workers were supplied with formed ear plugs as HPD with noise reduction rate (NRR) of 25 dB, of those who are using HPD all the time, 39(35.1) have hearing problems. It has been found that hearing protection usage found to be statistically significant with developing hearing problems (p=0.025). Those who receive frequently training on HPD 27(37.0) have hearing problems. The results also revealed that 17(40.5) of workers who have hearing problems are not satisfied with the HPD provided, and workers who only use HPD just to abide with company mandatory HPD use policy have hearing problems of 33.9%.

Table 7: Hearing problems in relation to protection factors (n=119).

Hearing protection variables	Hearing problems present n (%)	Hearing problem absent n (%)	p-value
Frequency of using HPD			
Regularly (n=111)	39(35.1)	72(64.9)	0.025*
Sometimes/rarely (n=8)	6(75.0)	2(25.0)	
HPD training			
Regularly (n=73)	27(37.0)	46(63.0)	
Rare (n=46)	18(39.1)	28(60.9)	0.840
HPD satisfaction			
Very satisfaction (n=23)	8(34.8)	15(65.2)	0.746
Slightly satisfied (n=54)	20(37.0)	34(63.0)	
Not satisfied (n=42)	17(40.5)	25(59.5)	
Reasons for HPD usage			
For manager requirements (n=62)	21(33.9)	41(66.1)	0.602
For personal protection (n=25)	12(48.0)	13(52.0)	
Both (n=32)	12(37.5)	20(62.5)	

Logistic regression of risk factors of hearing problems at maintenance workshops

Prediction of hearing problems using identified risk factors of noise levels, ototoxic drug use, organic solvents and exposure duration was done by. A binary logistic regression was conducted for every single factor alone and then adjusted for age. While adjusting for age, duration of work, use of organic solvents at work, and HPD use was found to influence hearing problems (OR>1). Duration of exposure to noise environment COR is significant without adjusting to age.

Table 8: Odds ratios predictors of hearing problem predictors. (n=119)

Variables	Hearing problems n (%)	COR (95%CI)	AOR (95%CI)	p-value
Noise exposure levels				
>85 dB(A)	11(45.8)	1.688(1.58-5.07)	1.71(1.69-1.97)	0.002
<85 dB(A)	19(50.0)	1		
Age (years)				
≤ 35 years	28(40.6)	1		
>35 years	33(66.0)	1.919(1.67-3.97)	2.01(1.981-4.09)	0.005
Duration of exposure (years)				
>10 years	35(67.3)	1.87(1.81-2.96)	1.91(1.86-3.11)	0.009
<10 years	26(38.8)	1		
Organic solvent				
Use	60(56.1)	1.124(1.04-2.22	1.20(1.06-2.23)	0.009
Not use	1(8.3)	1		
Frequencies of using HPD				
Regularly	39(35.1)	1		
Sometimes/rarely	6(75.0)	1.37(1.29-7.340	1.87(1.38-8.98)	0.025

Adjusted for age; *Significant at $p < 0.05$. Note: CI = confidence interval; C*OR* = crude odds ratio; AOR= Adjusted odds ratio

CHAPTER FIVE

5.0 DISCUSSION

The aim of this study was to assess noise exposure levels and the identified factors that may influence occurrence of hearing. The study had 119 participants making a response rate of 86.2%. Mean noise exposure level for 8 hours was 85.68 dB(A) which is above OEL. The prevalence of self-reported hearing problems was (26.9%). Using audiometry results hearing loss among workers was found to be (16.1%). Risk factors for hearing problems were observed to be noise exposure levels, using of organic solvent, age of worker, duration of work in noise environment, HPD use and HPD training. These could lay foundation for developing interventions for managing noise exposure in similar work environment.

5.1 Noise Exposure Levels

Mean personal noise levels in TWA scale was 85.68 dB(A) (Range 68.00 dB(A) to 100.01 dB(A)) (Table 5), in which 34(54.8%) of workers in all job sections exceeded the OEL recommended by NIOSH (13), WHO (29), and OSHA Tanzania (15). However, the workers in maintenance workshop are working for 12 hours shift that exceed the required standard work time of 8 hours. In that case, noise exposure limits for a 12-hour shift using an exchange rate of 3 dB and limit of 85 dB(A), based on the equal energy rule, is supposed to be 83.24 dB(A) (13) instead of 85 dB(A). Therefore, basing on OEL of 83.24 dB(A) these workers are at risk of developing hearing problems mainly NIHL.

Other studies reported exposure to high levels of noise at workplace (7, 12). *John W et al,* (12) did a study in Tanzania which indicated that workers in maintenance section of gas fired electric plant are exposed to mean noise levels of 89.64 dB(A). A study done to assess prevalence of noise induced hearing loss among employees at a mining industry in Zimbabwe (7) indicated that mean noise exposure levels are for maintenance workers in mining was 103 dB(A). These noise levels are potentially hazardous and might result in hearing impairment among workers in that environment.

Noise levels between different section of workshops was found to differ basing on the job or task performed, in this study (31.4%) of mechanics are exposed to noise of above 85 dB(A), followed by boiler makers and auto electricians with (25.7%) are exposed to noise above 85 dB(A) (Table 5). In a study to review occupational noise exposure and hearing loss in Australia concluded that boilermakers exhibited mean noise exposure of 95.3 dB(A) and almost 100% of boiler makers were exposed to noise levels above 85dB(A) regulatory limit (39). In addition, a noise survey of boiler makers and welders for shipbuilders in India measured noise levels beyond 90 dB(A) (38).

Assessment of noise exposure levels of workers in ES and HME workshops indicate that mean 8-hour TWA are 85.04dB(A) and 88.11dB(A) respectively which also are above the required 85 dB(A) OEL, hence we conclude that the workers are highly exposed with noise levels of above OEL.

5.2 Prevalence of Hearing Problems

Audiometric evaluation of NIHL shows among 62 workers 10 (16.1%) have hearing loss at different levels, in which 8 (12.9%) warning level (moderate hearing loss) and 2 (3.2%) referral level (severe hearing loss) (Figure 3). The results of this study indicate the prevalence of NIHL was slightly lower compared with other studies done in Africa. The study done by *Musiba* 2015 indicated 47% prevalence of NIHL among miners, with 35% mild hearing impairment and 12% poor hearing (8).

When a questionnaire was used the prevalence of self-reported hearing problems was observed to be higher than that from audiometric test i.e 32 (26.9%). The difference between the two assessments could be due to the number that had no audiometry results 74(62.2%). The difference could also be due to the occurrence of the audiometry versus the reported information. This prevalence was lower compared to that reported among gas- fired electric plants, 53.8% (12). The difference could be the due to the different working environment and the age of the workers. Another study reported prevalence of NIHL of 37% among workers in mining industry in Zimbabwe (7). A study of on hearing impairment among workers in gold mining in Ghana reported a prevalence of 23% (6) which is slightly similar to our study.

The results also reveal that self-reported hearing problem categories were, 18(56.25%) report reduction in hearing, 10(31.25%) ringing ear (tinnitus) and ringing ears and speech interference both scored 2(6.25%) (Figure 4). This prevalence is slightly lower than those reported in a South African study among miners where reduction in hearing was 38% and tinnitus 45 % (9). *Nelson D et al* who reported that 16% of the disabling hearing loss in adults is contributed to occupational noise, ranging from 7% to 21% in the various regions (15).

5.3 Determinants of hearing problems at heavy machine maintenance workshop in mining site.

Age

This study also associated hearing problems with other factors such as age of respondents in which workers within above 35 years have highest prevalence of hearing problems about 33(66.0%), the odds of increasing hearing problems with age was statistically significant at (p= 0.006) as the age increase so do hearing problems (Table 6). This correspond with the study of *Musiba 2015* which indicate age group of 30-39 have 21% and 6% of developing mild and poor hearing impairment (8). In a Zimbabwean study (7) the prevalence of NIHL among employees at a mining industry was found to increase as a function of age in which 29-39 age group was observed to have 25% NIHL(7). The South African study reported the youngest age group to be highly affected with NIHL which is different to this study. In another study of Occupational NIHL in auto part factory workers in welding units in Thailand (33) found that workers with > 30 years of age had 86.7% of abnormality in both ears.

Duration of noise exposure

Workers with >10 years of employment had higher prevalence of hearing problems 67.3%. This opposed with the study done in Tanzanian mines which indicated that the workers with > 10 years of exposure had 7% prevalence of poor hearing compare to the lower groups (Table 6). In another study done in Thailand (33) indicate those who are exposed in work environment for >10 years had relative higher 26.7% of developing hearing loss in both ears compare to those with low exposure duration. Nevertheless, this association is not significant

compared with the study of prevalence and degree of noise- induced hearing loss in South African gold miners (9) which showed that 66.7% had no NIHL among those worked 10-15 years this might be due to small sample size used. NIOSH has found that 8% excess risk of developing occupational noise-induced hearing loss during a 40-year lifetime exposure at the 85-dB(A) OEL, this means within prolonged exposure of noise even below 85 dB(A) there is high probability of developing NIHL (13).

Organic solvents

The very significant result has been observed in the use of organic solvents at the workshops in which 60(56.1%) of people who use organic solvents have reporting experience hearing problems (Table 6). These results are associated with many previous studies such as, in a small cross-sectional study, *Fuente et al* reported that solvent exposure is associated with hearing loss (28). Chang et al. compared hearing capacity in 58 employees with exposure to noise and toluene with 58 employees with noise exposure only and 58 non exposed workers. The prevalence of hearing loss >25 dB was higher in the noise plus toluene group compared to the noise group and lowest in none exposed group (30). *Sliwinska-Kowalska et al* reported that the combination of noise and solvents, such as styrene, xylene, n-hexane and toluene, caused a hearing loss in a study of 1117 workers from different industries (29). Those solvents such as toluene, styrene, xylene, isopropyl alcohol, and ethyl benzene they tend to damage the cochlea (predominantly the supporting and outer hair cells) and provoke irreversible sensorineural hearing loss (32).

Hence, this study supports the hypothesis that co-exposure to excessive noise and organic solvents at workplace may increase the risk of hearing loss employees are susceptible to such risks (31).

Hearing protection devices usage

All 119 workers reported using HPD provided, this can be due to the company mandatory HPD use policy, as indicated in the study of Corbett et al which found that the institution of a mandatory hearing protection policy ($p = <0.01$) was determined to be the most significant positive predictor of self-reported HPD use by study workers (39). However, the use of HPD vary with conditions, 111(93.3%) of workers reported using HPD all the time while working, 8(6.7%) use sometimes depending on circumstances (Table 7). This HPD use proportion can be related to the study of *John et al* which indicated majority of participants in gas-fired electric plants (95.3%) use hearing protective devices (12). About 7.5% participants use ear plugs, 38.7% participants use ear muffs and 53.8% participants use both ear plug and ear muff
All time use of HPD (in this case ear plugs) had an indicative relationship with reduced chances of having hearing problems 35% compared to 75% for rare use (Table 6). A study done among gold miners in Ghana indicated a protective effect with frequent use of earplugs (OR 0.46) (6).

The mine safety management provide form earplugs with noise reduction rate (NRR) of 25 dB to all workers, this is the major HPD provided. About 19.3% and 45.4% among workers showed that they are *very satisfied* and slightly *satisfied* respectively, with the type of hearing protection provided while 35.3% are not satisfied with HPD provided.
Moreover 61.3% of workers frequently receive training on effectiveness and awareness of PPE use and safe work practices, this result is similar with the findings of John et al who report about 85(80.2) participants had training on the hearing protective devices (Table 7). In another study done to evaluate occupational noise exposure and hearing defects among sawmill workers in Thailand a smaller number of workers (25.0%) had received training in proper use of PPE and half of them reported never or only rarely wearing PPE while working (37).

5.4 Other noise control measures

Additional noise control measures apart from provision of HPD include engineering design of mine workshop itself as the workshop building is wide open during operations hence reduce noise accumulation, distance from one section and another eliminated some workers to be exposed, design of machines i.e. compact operating cabins is all design to prevent noise from reaching the operators. Provision of training on proper use of PPE, enforcement of rules, regulations and safety policies, comply with professional consultancy while procurements and supply of machines and equipment and regular maintenance of those machines. Although workers claim proper use of HPD However through observations it reveals otherwise, thus the ear plugs are not properly fit to the ears, because most workers do not know proper fixing of ear plugs. The danger is that the protection factor of HDP declined with poor compliance or ineffective fit hence control is not efficient.

5.5 Limitations of the Study

- Although the study assessed the exposure to noise, there might still be other underlying factors, which might have contributing to hearing loss that were not studied.
- There was also a possibility of recall bias with respect to previous history of hearing problems as the author depend on self-reported responses. Therefore, possibilities of under or over reporting. However, research assistants were trained personnel hence comparability in the administration of questionnaires across the study centers was to ensure the response are true and valid.
- The study methodology was cross-sectional type thus no causal relationship could be established over the outcome hence there is a need for further study that could establish the causality.

5.6 Strength of the study

- The noise exposure levels were identified and found to exceed OEL as well as the hearing protection attitude was revealed hence it will help in improving noise exposure control and proper hearing management programmes
- The Noise Assessment questionnaire tool modified and used in data collection for interviewing participants on hearing problems and other associating factors seem to be valid tool, hence it can be used in similar studies in the country thus enabled comparison of results.
- The findings that there is association between hearing problems, noise exposure levels and organic solvents use is an important milestone as will initiate further studies to establish association between those variables taking into consideration little studies of that sort have been done in Tanzania workplace environments.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Findings from this study indicate that personal noise exposure levels for maintenance workshop workers at gold mine site in Tanzania were above required occupational exposure limits set by different organizations such as WHO, NIOSH and OSHA Tanzania. Prevalent self-reported hearing problems facing workers in heavy machine maintenance workshops include reduction in hearing, ringing ear (tinnitus), speech interference and ear Infection. The use of organic solvents, exposure duration and prolonged twelve-hour work shift may have influence on noise exposure levels and hearing status of workers. Besides being provided with HPD and mine safety regulations (mandatory HPD usage policy) there were workers who did not use HPDs as required. Hence the issue of satisfaction with HPD may be of importance to adherence usage.

6.2 Recommendations

i. The 8 hours OEL which is 85 dB(A) used by the mine is technically not accepted as the workers work for 12 hours shift, the OEL that should be used in that case is supposed to be 83.24 dB(A).

ii. The mine management should increase efforts in ensuring all workers are routinely examined for hearing capacity by audiometry measurements on planned schedule, as well as increasing the efforts on individual follow-up of each worker.

iii. Regular training on effective use and proper fitting of all types of PPE should be provided to different workers, this is because most workers tend to forget the fitting test for particular PPE. These can be done on morning meetings done in each departments of the mine.

iv. The mine health and safety department must implement hearing conservation program sufficiently.

6.3 Future Perspective

i. Use of cohort study designed will be able to establish other factors which relate to noise exposure and occurrences of hearing problems.

ii. Organic solvent contamination in the workplace should be measured quantitatively because other workers may also be exposed even though they do not use the compounds.

6.4 Dissemination plan

i. The results will be presented to the mine management and the workers. This will also include a health education to workers on the consequences of intermittent use of HPDs.

ii. The dissertation will be made available at the MUHAS library repository and a manuscript submitted to peer reviewed journals for publication.

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APPENDICES

Appendix 1: Questionnaires in English version

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES

SCHOOL OF PUBLIC HEALTH AND SOCIAL SCIENCES

P.O.BOX 65015, DAR ES SALAAM, TANZANIA,

Date of interview_____ Identification number _____

Name of interviewer_____

Please, put check (√) in front of the correct respond and write a correct number example age put in years or put the correct answer.

PART I: SOCIO AND DEMOGRAPHIC CHARACTERISTICS

1. **Date of birth**

Day Month Year

2. **Sex**

1 Male 2 Female

3. **Level of education**

1 No formal education 2 Primary education (< standard 7) 3 Secondary education (form 4,form 6) 4. Vocational trainings 5.Tertiary education (college and above)

4. **Residence**

1 Inside mine camp 2 Outside mine camp

5. **Current job/activities**

	Type of job	Place/ section	From (year)	To (year)
1	Boiler maker			
2	Fitter mechanics			
3	Mechanics			
4	Auto electricians			
5	Rigger operator			
6	Others			

6. **Duration/experience in noise work environment**

Job	Duration
1	
2	
3	
4	
5	

7. **Working hours per day.** 1. 8hours 2. 12 hours

PART II: NATURE OF WORK

8. **Are there any organic solvents used in your working area?** 1. Yes 2. No

PART III: USE OF OTOTOXIC DRUGS

9. **Have you ever used any ototoxic drugs for long time?** 1. Yes 2. No

10. **For how long have you use such drugs?**

1. 1-5 years 2. 6-10 years 3. 11-15 years 4. > 15 years

PART IV: HEARING PROBLEM SYMPTOMS

11. **Do you have hearing problems?** 1. Yes 2. No

12. **For how long?**

`1 Since birth 2 _____years_____months

13. **What hearing problems do you experience?**

1 Speech interference	4 Nervous and annoyance
2 Reduction in hearing	5 Long term hearing problems
3 Ringing ear (tinnitus)	6 Ear infections 7. Others

14. **Have you done Hearing capacity test?**

1 Yes **2** No

PART V: HEARING PROTECTIVE EQUIPMENTS USAGE

15. **Are you provided with Hearing Protection Equipment?**

1 Yes **2** No

16. **What type of PPE are you provided? (Researcher: Inspect to see the type)**

1 Foam earplugs	3 Earmuffs
2 Moulded (flanged)	4 other types …….

17. **How often you use HPD?**

1 All the time 2 Frequently 3 Rarely 5 Never

18. **If never use why? Reason for not using HPD**

1 Make me feel uncomfortable	4 Sweating and itching of ears
2 Difficult to use	5 I don't know when I need it
3 Difficult to communicate	6 I don't know the importance of using it

19. **Reason for using HPD**

1 To abide with manager demands
2 To protect myself
3 Both 1 and 2

20. **Have you been provided with HPD usage training?** 1 Yes 2 No

21. **How often you receive training?**

1. Often **2.** Rarely

22. **Do you know how to use HPD effectively?**

1. Yes 2. No

Appendix 2: Questionnaire - Swahili version

CHUO KIKUU CHA AFYA NA SAYANSI SHIRIKISHI MUHIMBILI

SHULE YA AFYA YA JAMII NA SAYANSI

SLP 65015, DAR ES SALAAM, TANZANIA,

Tarehe _____ namba ya dodoso _____

Jina la mdadisi_____

Tafadhali, weka cheki (√) mbele ya jibu sahihi na uandike nambari sahihi ya mfano wa nambari iliyowekwa katika miaka au weka jibu sahihi.

SEHEMU YA 1 TAARIFA ZA KIJAMII

1. **Tarehe ya kuzaliwa**

Siku	Mwezi	Mwaka

2. **Jinsia**

1 Mme	2 Mke

3. **Kiwango cha elimu**

1 Sikusoma	2 Elimu ya msingi	3 Elimu ya sekondari kidato cha 4-6)	4.Mafunzo ya amali	5 Elimu ya juu (chuo)

4. **Makazi**

1 Ndani ya eneo la mgodi	2 Nje ya eneo la mgodi

5. **Kumbukumbu za kazi**

	Aina ya kazi	Mahali/kitengo	Kutoka (mwaka)	Hadi (mwaka)
1	Boiler maker			
2	Fitter mechanics			
3	Mechanics			
4	Auto electricians			
5	Rigger operator			
6	Nyengine			

6. **Historia ya kufanya kazi katika maeneo yenye kelele.**

1. < Chini ya mwaka 1	2. Mwaka 1-5
3. Miaka 6-10	4. Miaka 11-15
5. Zaidi ya miaka 15	

7. **Muda wa kazi kwa siku**

Masaa 8	Masaa 12

SEHEMU YA PILI -MAZINGIRA YA KAZI

8. **Je mnatumia kemikali aina ya solvent kwa mfano thinner (organic solvents)?**

1 Ndio 2 Hapana

SEHEMU YA TATU-MATUMIZI YA DAWA

9. **Je umetumia au umewahi kutumia dawa za kutibu zinazoleta shida ya kusikia kwa muda (ototoxic)?**

1 Ndio 2. Hapana

10. **Kwa muda gani umekuwa ukitumia dawa hizo?**

1 Chini ya mwaka mmoja	2 Miaka 1-5
3 Miaka 6-10	4 Miaka 11-15
5 Zaidi ya miaka 15	

SEHEMU YA NNE: DALILI ZA MATATIZO YA USIKIVU

11. **Je una tatizo lolote la kusikia?** 1 Ndio 2 Hapana

12. **Kwa muda gani sasa?**

1 Kuzaliwa	2 _____miaka_____miezi

13. **Je ni tatizo gani ulilonalo?**

1 Muingiliano wa sauti	4 Kero
2 Usikivu hafifu	5 Matatizo ya kusikia mengineyo
3 Milio ya filimbi kwenye sikio (tinnutis)	6 Kutoka usaha
7 Mengineyo Taja	

14. **Je umewahi fanya kipimo cha usikivu?** 1 Ndio 2 Hapana

SEHEMU YA TANO – MATUMIZI YA VIFAA VYA KUJIKINGA

15. **Je umepatiwa vifaa kinga?** 1 Ndio 2 Hapana

16. **Je ni kifaa gani**

1 Foam earplugs	3 Earmuffs
2 Moulded (flanged)	4 aina ingine …….

17. **Je kwa muda gani unatumia vifaa kinga?**

1 muda wote	2 mda mwingi	3 mara chache	5 situmii

18. **Kama hutumii ni kwanini**

1 sijisikii huru	4 jasho na muasho
2 matumizi yake ni magumu	5 sijui nitumie wapi na kwanini
3 siwezi kusikia vizuri	6 sioni umuhimu wa kutumia

19. **Sababu zinazokupelekea kutumia vifaa kinga**

1. kutekeleza matakwa ya utawala
2. kujikinga kutokana na athari
3. zote 1 na 2
4. Sijui

20. **Je unapewa mafunzo ya jinsi ya kutumia vifaa kinga?** 1 Ndio 2 Hapana

21. **Je mafunzo hayo unayapata kila baada ya muda gani?** 1 Mara kwa mara 2 Mara chache

22. **Je unajua jinsi ya kutumia vifaa kinga kwa usahihi?** 1 Ndio 2 Hapana

Appendix 3: Consent Forms – English Version

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES

DIRECTORATE OF RSEARCH AND PUBICATIONS, MUHAS

INFORMED CONSENT FORM

ID-NO [ ]

Consent to Participate in a Study

Greetings!

My name is Khadija Makame. I am a student at Muhimbili University of Health and Allied Sciences pursuing Master of Sciences in Environment and Occupational Health.

Purpose of the study

The purpose of this study is to **assess noise exposure levels and associated effects among workers in heavy machine maintenance workshops; a study in gold mining site**.

What Participation Involves

If you agree to join the study, you will be interviewed face to face with me in order to answer a series of questions in the questionnaire prepared for this study as well as wearing the noise dosimeter for measurement of noise while you are working.

Confidentiality

I assure you that all the information collected from you will be kept confidential. Your name will not be written on any questionnaire or in any report/documents that might let someone identify you. Confidentiality will be observed and unauthorized persons will have no access to the data collected. And the information collected during interview will be analyzed by using identification number. If, this study is published or presented at a scientific meeting, names and other information that might identify you will not be used.

Right to Withdraw and Alternatives

Taking part in this study is voluntary. You can stop participating in this study at any time, even if you have already given your consent. Refusal to participate or withdrawal from the study will not involve penalty.

Risk

No harm is anticipated to you because of participating in this study

Benefits

You will derive no direct benefit from participating in this study; however, the results of this study will provide valuable information regarding the noise exposure levels and what interventions should be applied to reduce noise exposure as well as the hearing status of the participant.

In Case of Injury

We do not anticipate that any harm will occur to you.

Whom to contact

Thank you for taking time to read this information letter. If you have any question regarding this study you may contact

Khadija Ramadhan Makame,

Muhimbili University of Health and Allied sciences,

P.O Box. 65004, Dar-es-Salaam,

Phone number; 0777023505.

In case you have questions regarding your rights as a participant, you may contact

Chairperson Senate Research and Publications at MUHAS,

P.O. Box 65001, Dar-es-Salaam. Tel: 2150302-6

or

Dr. Gloria Sakwari,

Mobile 0767591202 from MUHAS who is supervising this study.

Signature:

Do you agree?

Participant agrees ……..…Participant does NOT agree..……

I ……. have read the contents in this form. My questions have been answered. I agree to participate in this study.

Signature of participant …….

Signature of Research Assistant

……..

Date of signed consent……..

Appendix 4: Consent Forms – Swahili Version

CHUO KIKUU CHA AFYA NA SAYANSI SHIRIKISHI MUHIMBILI

KURUGENZI YA UTAFITI NA UCHAPISHAJI

FOMU YA RIDHAA

Namba ya Utambulisho ☐

Ridhaa ya kushiriki katika utafiti

Salaam!

Jina langu ni Khadija Ramadhan Makame mwanafunzi katika Chuo Kikuu cha Tiba na Afya shirikishi Muhimbili, ninasoma shahada ya pili za uzamili katika fani ya mazingira na afya za wafanyakazi. Utafiti wangu unahusu athari za kelele zilizopitiliza katika maeneo ya kazi Kama utakubali kujiunga katika utafiti huu utatakiwa kujibu maswali utakayoulizwa.

Kushiriki kunahusisha nini?

Ukikubali kushiriki katika utafiti huu utahitajika kutumia muda mchache kwaajili ya kujibu maswali utakayoulizwa na mtafiti na kuvaa kifaa cha kupimia kiwango cha kelele.

Usiri

Majibu yote yatakusanywa kutoka katika eneo la utafiti na yataingizwa kwenye compyuta kwakutumia namba ya utambulisho tu. Hakuna jina la mshiriki litakalochapishwa.

Haki ya Kutoka na Mbadala

Kushiriki katika utafiti huu ni uchaguzi wako, una uhuru wa kukubali au kukataa kushiriki katika utafiti huu. Pia unaweza kuacha kushiriki katika utafiti huu muda wowote utakapojisikia hivyo hata kama umeshakubali kushiriki. Kukataa kushiriki au kuacha kushiriki katika utafiti huu hakutakufanya upate adhabu.

Faida

Ukikubali kushiriki katika utafiti huu hakuna faida ya moja kwa moja utakayopata lakini tunaamini maelezo utakayoyatoa yatasaidia; Hata hivyo, matokeo ya utafiti huu yatatoa habari muhimu kuhusu na athari zinazokunyemelea na jinsi ya kujikinga kuepuka madhara ya kelele zilizopitiliza katika eneo la kazi

Madhara

Hatutegemei kwamba utapata madhara yoyote ya kimwili kwakushiriki katika utafiti huu

Mawasiliano

Kama utakuwa na swali lolote kuhusu utafiti huu unaweza kuwasiliana na mkuu wa utafiti huu **Khadija Ramadhan Makame Chuo Kikuu cha Afya ya Tiba ya Sayansi Muhimbili, S.L.P. 65004, Dar es Salaam kwa simu namba 0777023505**

Ukiwa na lolote kuhusu haki zako kama mshiriki, wasiliana na **Mwenyekiti wa Kamati ya Utafiti ya Chuo, S.L.P. 65001, Dar es Salaam. Simu: 2150302-6 na Daktari Gloria Sakwari, kwa simu namba 0767591202 ambaye ni Msimamizi Mkuu wa Utafiti huu.**

Sahihi

Je umekubali?

Mshirikia amekubali……..…Mshiriki Hajakubali…….……

Mimi.....nimesoma maelezo ya fomu hii. Maswali yangu yamejibiwa. Nimekubali kushiriki katika utafiti huu.

Sahihi ya mshiriki……...

Sahihi ya shahidi (kama mshiriki hawezi kusoma) ……..

Sahihi ya mtafiti……..

Tarehe ya ukubali wakushiriki……...

Appendix 5: Noise Survey Checklists

AUDIOMETRY RESULTS INTERPRETATIONS

IDNO	RESULT PRE-MEDICAL EXAMINATION	Screening audiometry

DOSIMETER READINGS

Individual IDNO	Dosimeter IDNO	Activity	Work section	TWA	SE	Lpeak max	Sampling Time

HEARING PROTECTION DEVICES (HPD) DETAILS

Individual IDNO	HPD type	Model	NRR	Condition

NOISE MAPPING

SOUND LEVEL MEASUREMENTS RECORDINGS

	Location	Activities	No. of workers	SPL		Time
				Max	Min	