THE PREVALENCE OF NOISE INDUCED HEARING LOSS AT A NICKEL MINE IN ZIMBABWE.

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Public Health (Occupational Hygiene).

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DECLARATION

I, Edmore Masaka declare that this research report is my own work. It is being submitted for the degree of Master of Public Health (Occupational Hygiene) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

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E Masaka

12th January, 2009.

ABSTRACT

BACKGROUND

Hearing loss from occupational exposures is a serious and widespread problem and in underground nickel mining. This is a major contributor to compensable illnesses resulting not only in costly compensation but posing a serious threat to safety and also reducing the quality of working life.

OBJECTIVES

The objectives of this study were to identify the prevalence of noise induced hearing loss amongst underground nickel miners with at least 5 years of exposure as well as describe some risk factors for noise induced hearing loss in this occupational setting.

METHODS

One hundred and sixty eight underground nickel miners, or one hundred percent of eligible workers' medical records with baseline and periodic audiograms were reviewed to identify the prevalence of noise induced hearing loss and also evaluate some of the risk factors for noise induced hearing loss namely age, duration of exposure, use of oto-toxic agents, high ambient noise levels, hearing impairment, high pre-employment noise levels, history of acoustic trauma, history of ear injury and history of previous military, hunting or police work. One hundred underground mine workers were interviewed to give insight into their pre-employment noise exposure history, non-occupational noise exposure, perceived noise levels at work, knowledge of noise hazards and their control, and the use of hearing protection devices. One hundred and sixty eight workers were observed in their various tasks over a 14 day period and their work practices were scored to identify compliance to the use of hearing protective devices as well as confirm the presence or absence of oto-toxic agents like heavy metals and solvents. Data were analyzed using the EpiInfo software version 3.4.3: 1997 as well as the online statistical package Vassar Stats.

RESULTS

A noise induced hearing loss prevalence of 27.4% was identified with 42% being mild hearing loss, 28.8% moderate hearing loss and 28.8% moderate to severe noise induced hearing loss. The highest noise induced hearing loss prevalence of 60% was found in the 50 and above years age group whilst 45.5% was found in the 40 – 49 year age group, 20% in the 30- 39 year age group and 5.3 % in the 20 – 29 year age group. This difference was statistically significant ($\chi^2_1 = 19$ $p < 0.001$). Age with a $\chi^2 = 24$, $p< 0.002$ and duration of exposure with a $\chi^2 = 19$, $p< 0.001$ were found to be major determinants of noise induced hearing loss at the mine. Jackhammer operation and machine operation were found to be associated with noise induced hearing loss compared to the other tasks; Tukey's Honestly Significant Difference 0.05 = 12.23 $p<0.01$. The following risk factor was found to be related to noise induced hearing loss: use of quinine OR = 2.16 with CI 95% = 0.12 – 1.72. Ninety seven percent of the workers confirmed exposure to high noise levels. The knowledge of noise induced hearing loss at the mine was high (85%). Compliance with the use of hearing protective devices was found to be low with optimum usage only being achieved during the last 4 days of the 14 day observation period.

CONCLUSIONS

These findings attest to the relatively high prevalence of noise induced hearing loss at the mine. It can also be concluded that though the knowledge of noise induced hearing loss is high, the effective use of hearing protection still needs improvement through the implementation of comprehensive hearing conservation programs which adequately screen workers at pre-employment stage as well as consider the workers' perceived knowledge, attitudes as well as practices in an occupational setting.

DEFINITION OF TERMS

DB –	Decibel. A dimensionless unit used to express a logarithmic variation between a measured quantity and a reference quantity. It describes levels of acoustic intensity, acoustic power, sound pressure levels, and hearing threshold when a reference quantity is specified
HCP –	Hearing Conservation Program
HL –	hearing Loss
HPD –	Hearing Protective Device
HPE -	Hearing Protective Equipment
HTL –	Hearing Threshold Level
NIHL –	Noise Induced Hearing Loss
NIOSH –	National Institute of Occupational Safety and Health
NIPTS –	Noise Induced Permanent Threshold Shift
NITTS –	Noise Induced Temporary Threshold Shift
NSSA –	National Social Security Authority
OSHA –	Occupational Safety and Health Administration
PPE –	Personal Protective Equipment
SIMRAC –	Safety in Mines Research Advisory Committee
TWA –	Time Weighted Average. The average exposure of an individual over a given working period as identified by sampling at given times during the period
WHO –	World Health Organization

CASE DEFINITION OF NOISE INDUCED HEARING LOSS

Any underground mine worker whose audiogram depicts the classical sign of noise induced hearing loss with the characteristic notch at 4 kilohertz.

The degree and type of noise induced hearing loss was identified according to Goodman[1] and Cahart[2] as follows:

10-25dB HTL (Normal hearing)

26-40dB HTL (Mild hearing loss)

41-50dB HTL (Moderate hearing loss)

56-70dB HTL (Moderate to severe hearing loss)

71-90dB HTL (Severe hearing loss)

91dB and over HTL (Profound hearing loss)

The type of hearing loss includes conductive, sensorineural and mixed hearing loss.

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CHAPTER 1 INTRODUCTION

This chapter briefly outlines the problems of noise. An overview of the effects of noise on health is then presented followed by a review of the literature on noise induced hearing loss and noise induced hearing loss in Zimbabwe workplaces. Then follows a justification of why a study on noise induced hearing loss is important in Zimbabwe, and why a nickel mine was selected for study. The mine is then described. The chapter ends with the aims and objectives.

Noise influences man physiologically and socially. It can impair hearing, intrude on communication, be disturbing, lead to fatigue and reduce effectiveness and productivity [3]. Exposure to intense noise or long term exposure to noisy environments can lead to permanent impairment of a person's auditory cells and consequent diminished hearing ability.

When a person is exposed to noise for a short period, the hair cells become exhausted. This causes a temporary decrease in a person's auditory threshold [3]. Noise also has an effect on the person's blood pressure, levels of alertness, blood composition, stress levels and psychological conditions [4]. Noise can also be an accident risk due to the fact that warning and information signals are less well heard [3].

Although excessive noise exposure has been recognized to be harmful to the ears, but in some enterprises very little attention has been paid to reducing noise at source or to preventing its transmission from the source to the worker.[5] It is important for an employer in an industrial setting to obtain baseline audiograms so as to identify the amount of hearing loss for which he/she is responsible [6].

The generally acceptable standard regulation in most countries is that a noise level of 85dBA or more for an 8 hour daily exposure is potentially dangerous[6]. The Zimbabwean equivalent 8 hour daily exposure limit is 90dBA, although efforts are currently under way to reduce this to 85dBA [7]. In Africa, noise is increasingly being recognized as a significant hazard for workers and a serious threat in many industries. The South African mining industry introduced its Hearing Conservation Programme (HCP) in 1998 [8]. Hearing Conservation Programmes subsequently became compulsory, since labour intensive methods common to many mining extraction and processing operations were resulting in large numbers of people being exposed to noise beyond the recognized safe limit of 85dBA. For these reasons, a study was done on a nickel mine in Zimbabwe to examine noise induced hearing loss.

1.2 STATEMENT OF THE PROBLEM

The mine extracts nickel ore, which is dressed on site and then shipped to another mine for further processing. The company employed 600 workers with 495 of these working underground. The nickel mine runs a hearing conservation programme that was adopted from the Anglo American Corporation, which used to own and run the mine. According to this policy, noise was identified as a hazard to both underground and surface workers. (Refer to Table 1.1 below)

Table 1.1 Average noise levels (in dBA) at the nickel mine, underground and surface activities.

UNDERGROUND		**SURFACE**	
Activity	Average noise (dBA)	Activity	Average noise(dBA)
Jackhammer	125.48	Mechanical workshop	86.3
Rig	102.90	Hoist room	85
Diamond Driller	113.60	Compression House	85.4
830 Crusher	87.40	Electrical Workshop	75
Tractor	81.20	Machine Workshop	82
670 Rock Drill	86.30	D/W Workshop	81.40
Scoop Tram	88.90	Crusher	120.40
Fans (Production)	94.50	Screens	105.90
Fans (Development)	93.20	Mills	98.60
Fans (Main Tips)	82.70	Magnate House	85.34
Donsa (Locomotive)	83.50	Sample preparation room	121.14
Pump station	120.50	Metallurgical laboratory	68.50
Normal Areas	84.90	Tails thickener channel	120.30
Workshop	88.29	Guard Room	73

Source: Nickel Mine's Occupational Hygiene Statistical Digest (2003).

A hearing conservation programme is in place and medical surveillance of employees working in noisy environments is performed in accordance with the requirements of this programme. All workers at the mine undergo a pre-employment medical examination at which baseline audiograms are done. Periodic medical examination is also done on workers working in identified noise zones. Workers found to have noise induced hearing loss are relocated to tasks with minimal noise exposure. None of the diagnosed cases of noise induced hearing loss was medically boarded due to noise induced hearing loss between 2000 and 2004.

Cases of noise induced hearing loss have been identified since January 2001 when the hearing conservation program was instituted. (Refer to Figure 1.1 below)

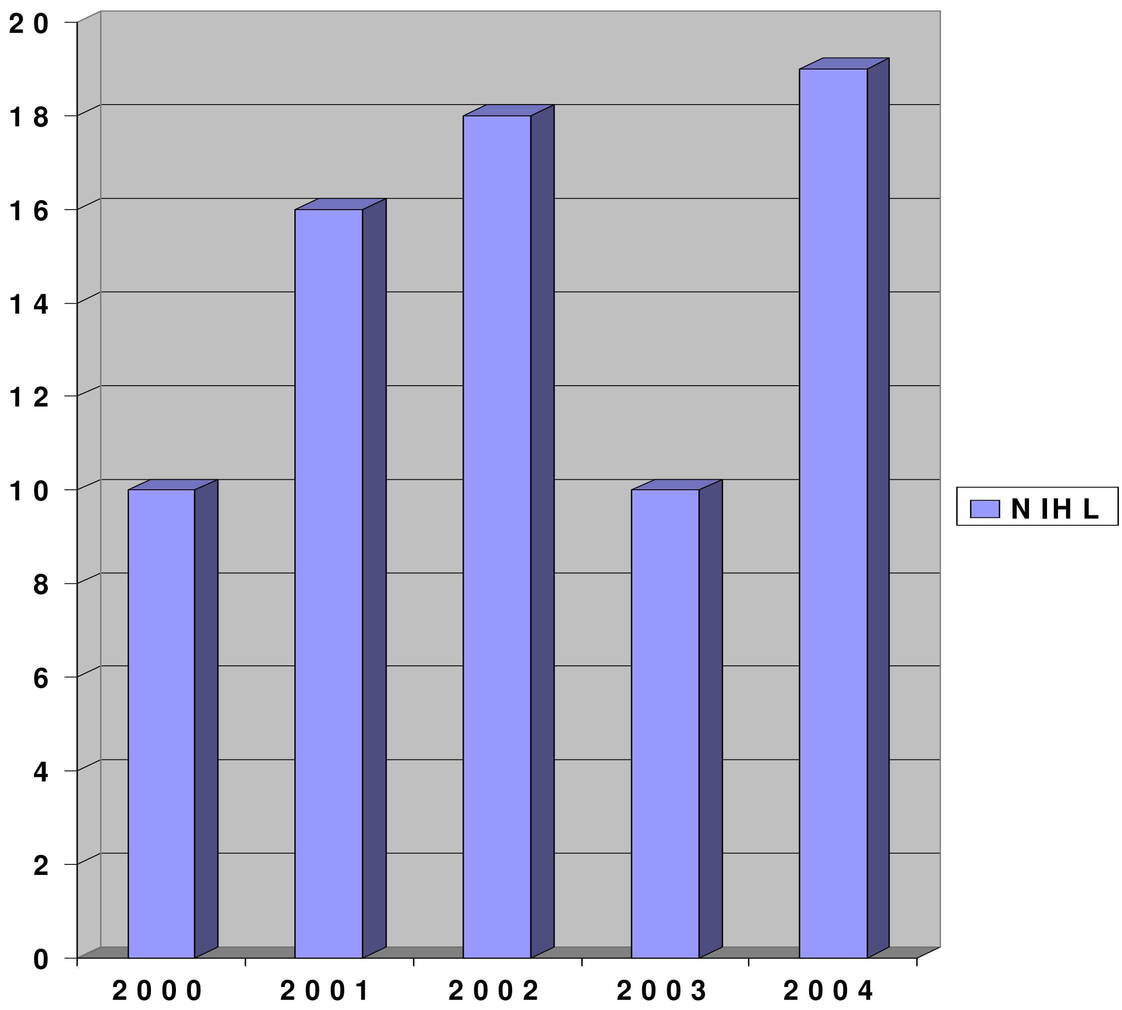

Fig. 1.1 Identified cases of NIHL amongst underground mine workers at a nickel mine in Zimbabwe from January 2000 to December 2004.

The lowest noise level to which underground mine workers were exposed to was 81.20dBA with an upper extremity of 120dBA. This was well above the legal limit of 90dBA[7]. The increasing number of noise induced hearing loss cases amongst underground mine workers warranted further investigation.

All underground mine workers at the mine worked an 8 hour shift a day. A total of twelve out of fourteen underground tasks were shown to expose workers to noise levels above the national exposure standard of 90dBA.

This study intended to identify and describe the prevalence of noise induced hearing loss amongst underground mine workers at the nickel mine in Zimbabwe with at least five years of exposure and having undergone baseline audiometric tests.

1.3 JUSTIFICATION

In Zimbabwe noise induced hearing loss is within the top five occupational illnesses and among the top three compensable occupational illnesses after backache and pneumoconiosis [10]. Zimbabwe has a law which specifically protects workers exposed to several hazards in industry including mining establishments[7]. However, there is no law, which specifically requires the implementation of comprehensive hearing conservation programs in mining companies even though the potential damage of noise induced hearing loss in this industrial setting has been recognized.

The mining industry in Zimbabwe employed in excess of 100000 workers in 2004, contributing about $ USD 1.2 million in Gross Domestic Product (GDP). In 1996, a total tonnage of 10863 of nickel was produced contributing $USD 0.2 million in revenue [10].

Occupational health and safety in Zimbabwe is still growing, with little emphasis on the integration of occupational health and occupational hygiene in most industrial set ups. A study done on occupational injuries and illnesses in Zimbabwe in 1993 reported that 73% of companies did not carry out systematic tests on occupational diseases and in 57% of companies, injury recording or reporting was unsatisfactory, missing or outdated [11]. One unpublished study on occupational hearing loss among workers in gold mines was done in Zimbabwe. A study of noise induced hearing loss at a nickel mine in Zimbabwe was therefore needed in order to identify the prevalence of this occupational illness and gather baseline information for further studies in this regard. The importance of noise induced hearing loss and the available data suggests that it is a significant occupational health and safety issue in the Zimbabwean mining industry and in the nickel mines in particular.

1.4 LITERATURE REVIEW

1.4.1 Effects of noise induced hearing loss

The health effects of noise induced hearing loss have been widely documented. Sufficiently intense sounds have the potential of disrupting all parts of the peripheral and central auditory system. Noise can have direct mechanical effects on the middle ear such as osicular discontinuity, tympanic membrane perforation or fistula of the oval window[12].

Chronic exposure to noise levels >85dBA leads to an onset of hearing loss that may not become noticeable until people can no longer comprehend speech. One of the first signs of noise induced hearing loss that individuals notice is difficulty in understanding speech, especially in noisy surroundings. Another is a ringing in the ears in very quiet settings. This condition is indicative of a condition called "Temporary Threshold Shift" which represents transient hair cell dysfunction and occurs in patients who have had an exposure to excessive noise. Repeated temporary threshold shifts may ultimately cause a "Permanent Threshold Shift" or hearing deficit[13].

1.4.2 Epidemiology of noise induced hearing loss

Noise induced hearing loss is a major health issue worldwide. In Europe, about 35 million people are exposed to detrimental noise levels >85dBA in industrial plants and occupational deafness is a leading compensable disease in most countries[1]. The problem of noise induced hearing loss is prevalent in both developing and industrialized countries. The Department of Social Security in the United Kingdom estimated that 13 000 workers in 1992 received benefits related to noise induced hearing loss[14]. It is also estimated that loud noises cause noise induced hearing loss in an estimated 10 million Americans every year, despite the fact that noise induced hearing loss is absolutely preventable[4]. In Africa, noise is increasingly being recognized as a significant hazard for workers and a serious threat to many industries. Noise induced hearing loss has been identified as a major occupational health risk in several gold mines[6].

1.4.3 Audiometric evaluation of noise induced hearing loss

Excessive noise exposure has been recognized to be harmful to the ears, and a lot of attention has been paid to reducing noise at source or to preventing its transmission from the source to the worker. It is important for an employer in an industrial setting to obtain baseline audiograms so as to identify whether subsequent noise induced hearing loss is occurring so that intervention can be undertaken to reduce noise. Audiometric evaluation of a worker's hearing is part of the success of any hearing conservation programme. This is the only way to be certain that occupational hearing loss is being prevented. Because noise induced hearing loss occurs gradually, affected workers may not notice a change in hearing until significant damage has occurred. Catching small changes through audiometric evaluation can trigger prompt action that can help prevent further hearing loss[15]. Workers' hearing is tested on an audiometer, a machine that generates sound signals at different frequencies. The worker's hearing is usually tested in seven different frequencies, between 500 hertz and 6 000 hertz, as specified by the Occupational Safety and Health Administration (OSHA). The National Institute of Occupational Safety and Health of the United States of America (NIOSH), recommends testing also at 8 000 hertz because hearing loss in this frequency can indicate other causes, such as aging (presbyacusis). It is imperative that the worker sits in an audiometric test booth and is asked to respond when he or she can first hear a pure tone sound through a set of earphones. The softest sound the worker can hear at a given frequency is called the threshold for that frequency. The hearing threshold for each frequency tested is plotted on a graph called an audiogram and is expressed in dBA, which is a scale used for measuring noise exposure and is weighted towards sounds at higher frequencies to which the human ear is more sensitive[15]. For workers whose noise exposure is at or above 80dBA or if it may occur later, a baseline audiogram is required. The purpose is to document the worker's hearing ability early on so that changes can be seen when hearing is tested in the future. Annual or periodic audiograms are also required for the above-mentioned category of workers. The type of hearing loss caused by work frequently shows a notch, or dip in the audiogram at 4 000 hertz with better hearing at 8 000 hertz and at lower frequencies.

1.4.4 Risk factors for noise induced hearing loss

Individual susceptibility to noise induced hearing loss varies greatly, but the reasons that some people are more resistant to it while others are more susceptible are not well understood[16]. The presence of certain conditions and attributes are capable of pre-disposing workers to noise induced hearing loss. It is useful to describe these "risk factors" in any study of noise induced hearing loss. Audiometric records, therefore, must include the employee's auditory history, which is the history of diseases and disorders of hearing and related factors, and history of exposure to noise and other oto-toxic agents, both on and away from the job. This information provides insight concerning probable causes for threshold shifts[16].

1.4.1.1 Noise exposure and noise induced hearing loss

Noise induced hearing loss is a hearing deficit caused by chronic exposure to excessive sound levels[17]. The recognized safe limit for exposure to noise is 85dBA in most countries and 90dBA in Zimbabwe. This standard regulation is for an eight-hour daily exposure believed to be safe. Noise levels over 85dBA to 90dBA for more than eight hours can be damaging to the ear. Noise is described as intensity (perceived as loudness) and frequency (perceived as pitch). Both the intensity and the duration of noise exposure identify the potential for damage to the hair cells of the inner ear. Even sounds that have been considered comfortably loud can be harmful[18].
Once exposure to damaging noise levels is discontinued, a further significant progression of hearing loss stops.

1.4.1.2 Knowledge of noise control and noise induced hearing loss

The ability of workers to fully participate in any hearing conservation program is dependant on adequate knowledge of noise hazards and to some extent its control. This therefore, underscores the important role of hazard communication in the workplace[17]. Providing information to employees about noise hazards and noise induced hearing loss serves to empower employees to be active participants in any hearing conservation program. The ideal scenario is optimum worker involvement in any hazard control program. Workers who are knowledgeable about noise hazards are more likely going to change their behaviour regarding hearing protection. Employee actions, in almost all situations, can significantly reduce exposures. The goal should be to make the workers as knowledgeable as practicable[19].

1.4.1.3 Hearing protective equipment and noise induced hearing loss

A study by Amedofu et al on hearing impairment among workers in a surface gold mining company in Ghana (1998), revealed that noise induced hearing loss is absolutely preventable through the consistent and proper use of ear protection[6]. Besides avoiding excessive noise, wearing hearing protection such as ear-plugs and earmuffs constitute an important preventive measure. The effectiveness of hearing protective equipment in preventing noise induced hearing loss is greatly dependent on the correct use and wearing of the equipment[20].

1.4.1.4 Ototoxic agents and noise induced hearing loss

Noise induced hearing loss may be promoted by concurrent exposure to oto-toxic agents such as solvents and heavy metals[21]. The use of chemo-therapeutic agents like cisplatin (platinol), nitrogen mustard, amino glycosides, furosimides (lasix), salicylates and quinine could increase the potential damage of noise on the human ear[22]. Clinical and experimental studies indicate a harmful effect of chemicals, especially organic solvents on the hearing system. In combined exposure to noise and solvents, very common in industry, it is most likely that synergistic action of these factors enhances the effect of noise. A study to assess the incidence and the risk of hearing impairment in 117 paint and lacquer factory workers exposed to a mixture of organic solvents was carried out in Poland and revealed that xylene and ethyl-acetate were the major components. Pure tone audiometric evaluation revealed the highest hearing threshold in workers exposed to solvents, low thresholds in those exposed to noise, and the lowest in the non-exposed individuals. Hearing loss was found in 30% of workers exposed to organic solvents, in 20% of noise-exposed subjects, and in only

6% of non-exposed subjects[16]. Trichloroethylene has been used in several industrial processes. This chemical has been identified as an oto-toxic agent and is known to produce an unusual pattern of hearing impairment in laboratory animals marked by a preferential loss of threshold sensitivity in mid-frequencies[21].

1.4.1.5 Age and noise induced hearing loss

Most mining and industrial concerns employ workers of varying ages. The need to benefit from skilled labour has made it necessary for several companies to retain the services of workers who are in their middle ages and in some cases nearing retirement age. The risk of noise induced hearing loss in these older workers has been seen to be higher as compared to the younger workers Age related hearing loss, also called presbyacusis, has a gradual onset and normally presents as a bilateral high frequency loss (8 000 hertz). In a study on the epidemiology of noise induced hearing loss in Poland, the majority of cases observed were those workers aged 50-59 years old and exposed to noise over 20 years[20].

1.4.1.6 Type of noise exposures and noise induced hearing loss

There are three general classes into which occupational noise exposure can be grouped. These are continuous noise, intermittent noise and impact noise. It is well known that high frequency noise is worse in terms of noise induced hearing loss[17]. However, it is not really understood well yet what noise level is safe. There is a growing consensus that noise exposure as low as 82dBA on a regular basis, eight hours a day for a long period of time for example, will cause hearing loss in some people[22]. It is however, widely accepted that fireworks, gunshots and explosions produce bursts of noise as loud as 130dBA to 190dBA, which can cause hearing loss in a matter of seconds. Handgun and rifle fire reach 160dBA to 170dBA, which, if close to the ear, can cause hearing loss, almost instantaneously [23].

In conclusion, noise is a well recognized health hazard in underground mining operations, but recent data on noise induced hearing loss cases in nickel mines in Zimbabwe are scarce, partly due to the lack of research in this area. Hence this research project to identify the prevalence of noise induced hearing loss in an underground nickel mine in Zimbabwe in 2004.

1.5 OBJECTIVES

1.5.1 Broad aim of the study

1.5.1.1 To identify the prevalence of noise induced hearing loss in underground mine workers at a nickel mine in Zimbabwe.

1.5.2 Specific objectives

1.5.2.1 To identify the prevalence of noise induced hearing loss in underground mine-workers employed at a nickel mine in Zimbabwe in 2004 and with at least five years of service.

1.5.2.2 To identify and describe some occupational risk factors for noise induced hearing loss amongst underground mine workers at a nickel mine in Zimbabwe.

CHAPTER 2 METHODOLOGY

This chapter begins with an outline of the study setting and describes specific methodologies applied. A description of the sources of bias and data quality control issues is given where relevant. Methodologies were described for the following:

a) Sample size determination
b) Sampling technique
c) Inclusion and exclusion criteria
d) Data collection- records review, selection of qualifying audiograms and the calculation of noise induced hearing loss
e) Data collection- Questionnaire
f) Recording of workplace daily observations of work tasks and practices
g) Quality control of data
h) Statistical analysis of the data

2.1 STUDY TYPE

A descriptive cross sectional survey was conducted at the nickel mine.

2.2 SETTING

The study involved the review of medical records of 168 qualifying workers and determining the prevalence of noise induced hearing loss from their latest audiograms as well as identifying, describing and evaluating possible risk factors for noise induced hearing loss. Data obtained from a questionnaire administered to a sample of 100 qualifying workers and also from observed daily work tasks and practices were obtained. The researcher personally obtained this data with the assistance of the mine's qualified occupational health and safety superintendent.

2.3 STUDY POPULATION

All underground mine workers employed in 2004 at the nickel mine and with at least five years service formed the study population.

2.4 STUDY UNIT

One underground mine worker employed at the nickel mine for a period of at least five years and having undergone baseline audiometric evaluation.

2.5 SAMPLE SIZE

All underground mine workers employed in 2004 and with 5 years service and having undergone baseline and periodic medical examination including audiometery had their medical records examined to identify the prevalence of noise induced hearing loss and a sample of 100 underground mine workers from this same group employed in 2004 and with 5 years service were randomly selected for the purpose of administering the questionnaire. The questionnaire collected data on demographic status, medical information, audiometric examination, hearing condition, knowledge of noise hazards; use of hearing protective equipment, duration of noise exposure, history of previous noise exposure and predisposing noise induced hearing loss risk factors (Appendix 3).

2.6 SAMPLING TECHNIQUE

2.6.1 Sampling procedure for the workplace

The nickel mine was selected for the study because of convenience in terms of access and accessibility to the researcher.

2.6.2 Simple random sampling procedure for the questionnaire

The primary researcher enumerated all underground mine workers employed in 2004, with 5 years service and having undergone baseline and periodic medical examination including audiometery according to mine numbers, and assigned random numbers to the first three digits of the mine numbers following with the range of the total number qualifying in terms of the 5 years of service and presence of baseline and periodic audiograms. Those falling outside this range were discarded until a sample of 100 interviewees had been picked.

2.7 INCLUSION AND EXCLUSION CRITERIA

Only underground mine workers who underwent baseline audiometric examination and who had been employed for at least five years were included in the study.

2.8 THE CASE DEFINITION OF NOISE INDUCED HEARING LOSS

The case definition of noise induced hearing loss was taken as any underground mine worker whose audiogram depicted the classical sign of noise induced hearing loss with the characteristic notch at 4 kilohertz.

Only current audiograms of workers who had five or more years of exposure and were preceded by a baseline audiogram were considered in the determination of noise induced hearing loss prevalence. The presence of the following information was also considered:

a. A detailed case history with special attention to the following

b. Any diseases or sicknesses of the ear suffered by the worker, which could have affected his or her hearing ability.

c. Any exposure to sudden loud noises such as explosions etc.

d. Any exposure to continuous loud noise, its source and its type.

e. The length of time that the worker was exposed to continuous loud noise.

d. The age of the worker

e. The presence of a baseline or follow up audiogram

f. An audiometric test history showing that the test was conducted in accordance with the 29CFR 1910.95 standard or its equivalent or better standard

2.8 DATA COLLECTION TECHNIQUES

2.8.1 Records review

A checklist for audiometric records review was used to collect data on the prevalence of noise induced hearing loss (Appendix 4). A questionnaire was also used to collect data on noise exposure and use of personal protective equipment.

2.8.2 Interview

The primary researcher conducted face-to-face interviews with workers. The data tool used was a standardized, anonymous questionnaire with both open and closed ended questions (Appendix 3). The questionnaire was created by the student using Epi-Info version 3.4.3. Each interview took about 8 minutes to complete. The questionnaire comprised seven sections, A, B, C, D, E, F and G. Section A sought demographic information of the subjects. Section B was created based on literature review and sought medical information on audiometric examination and hearing conditions. Section C sought information on the subject's knowledge of noise hazards and Section E sought information on the use of hearing protective equipment and the duration of exposure. Section F sought information on previous noise exposure and Section G sought information on some noise induced hearing loss risk factors.

The principal researcher conducted the interviews. These interviews were carried out in English, or translated into Ndebele and Shona languages where necessary for ease of comprehension by the subjects. The questionnaire was designed to identify the following variables:

- Whether the respondents had knowledge/awareness of the audiogram and its significance
- Hearing disorders
- Perceived noise levels at work
- Knowledge of noise hazards and their control
- Use and type of hearing protective equipment including the frequency of its use
- Previous noise exposure

Some factors associated with noise induced hearing loss including exposure to oto-toxic agents like solvents and heavy metals, type of noise exposure, non-occupational exposure to excessive noise, previous ear infections and head injuries.

2.8.2.1 Pretest

The pre-test of the questionnaire was carried out on 10 conveniently sampled workers attending the Occupational Health Clinic at the nickel mine. Special attention was paid to the sensitivity and acceptability of the questions, as well as ambiguity. This was also necessary to ensure that questions were set in a logical manner, were appropriate and obtained useful answers. The primary researcher carried out the pre-test.

2.9.1 Plan for data collection

2.9.1.1 Permission to proceed

Prior to proceeding with the study, permission was formally sought from the following authorities: University of the Witwatersrand School of Public Health, internal and external supervisors and the manager of the nickel mine.

2.9.2 Data collection

2.9.2.1 Researcher

The primary researcher was involved in and monitored all processes in the various stages during the study.

2.9.2.2 Logistics

Data collection was completed in 14 days. Times of interviews were identified according to accessibility and availability of the subjects. Where the sampled subject was on leave or sick, a replacement subject was selected randomly. The work tasks were observed over a 14 day period.

2.9.2.3 Quality control

Audiograms

The audiometric testing procedure was evaluated against the American National Standard C 29 CFR 1910.95 (Appendix 5) and found to comply in terms of instrumentation, qualifications of the person performing the audiometric test, criteria for the audiometric test booth, calibration of the audiometer and measurement method. The workers' latest audiograms were selected for the purpose of determining hearing loss. The existence of a baseline audiogram was confirmed for each worker's records. Where a worker had more than one audiogram, the latest of these was selected and used for the calculation of noise induced hearing loss.

Questionnaire

Before each questionnaire was processed, it was checked to ensure completeness. If any anomaly was found, the primary researcher validated this with the interviewee.

2.9.4 Data handling

The primary researcher ensured completeness of questionnaires by daily checking data collected. Completed questionnaires and checklists were labelled according to file numbers. All completed questionnaires and checklists were strictly handled by the primary researcher, organized in sequential order of numbering and kept by the primary researcher in a labelled box reserved for them. The only person who had access to the data was the primary researcher.

2.9.5 Data processing

All medical records, questionnaires and checklists were coded with unique identity numbers. No other form of labelling was required.

2.9.6 Data analysis

Determination of noise induced hearing loss prevalence

2.9.7.1.1. Hearing loss was calculated according to American National Standard C29 CFR 1910.95 as follows:

2.9.7.1.2. Calculate the hearing threshold level for each ear at 500, 1000, 2000, 3000 and 4000 hertz.
2.9.7.1.3. Calculate the average hearing loss for each ear (monaural loss) by dividing by 5.
2.9.7.1.4. Identify binaural hearing loss by multiplying the smaller percentage (better ear) by 5, adding it to the larger hearing loss (poorer ear) and dividing the total by 6.
Audiograms were considered normal if no hearing loss exceeded 25dB in the frequencies 500 hertz through to 4000 hertz. A case of noise induced hearing loss was defined as an underground mine worker at the nickel mine with at least five years service and whose audiogram depicted the classical notch at 4 000 hertz and whose binaural hearing loss as identified in 2.9.7.1.4 above exceeded 25dB. The degree and type of hearing loss was classified according to Goodman[1] and Cahart[2]. This is illustrated below:
10 to 25 dB HTL (normal hearing)
26 to 40 dB HTL (mild hearing loss
41 to 55 dB HTL (moderate hearing loss)
56 to 70 dB HTL (moderate to severe hearing loss)
71 to 90 dB HTL (severe hearing loss)
91 dB and over HTL (profound hearing loss)
Raw data captured from the audiograms, questionnaires and checklist was analyzed using a statistical software package (EPI Info version 3.4.3 of November 2007), Microsoft Excel as well as Vassar Stats. Ratios and frequencies were used to describe noise induced hearing loss prevalence, whilst statistical significance test indicators like the student's t-test, chi-square (χ^2), probability value (p-value) were applied in some tables for scientific confirmation of variations among tested variables. Odds ratios, scatter diagrams and Tukey's honestly significant difference (HSD) were used to show relationships and associations where possible. For this study, a 95% confidence level was accepted where a probability value of less than 5% (p-value of <0, 05) was accepted as a true difference.

2.9.7 Ethical issues

Approval to carry out the study was obtained from the University of the Witwatersrand, from the Human Research Ethics Committee (Medical). The ethics clearance certificate (R14/49) (Appendix 1) is attached. The Mine Manager gave his approval for the study. Written informed consent from all participants in the study was obtained (Appendix 2). Subjects were asked to sign the consent form prior to the day of the interview to ensure anonymity on the questionnaire. An information sheet that introduced the researcher, described the proposed research, reasons and duration, participant's expectations, any risks, assured confidentiality and invited the participant to take part and gave the option not to participate was given to the participants prior to the signing of the informed consent form. All selected participants agreed to sign the consent form.

CHAPTER 3 RESULTS

A total of 168 out of 495 sets of medical records and audiograms were identified as representing workers with 5 years or more of exposure. A baseline audiogram and a follow up audiogram were reviewed during the study. A sample of 100 workers from the above set was selected randomly. Their medical records were reviewed and they participated in the questionnaire. They were also observed during the work practice observation exercise. All the selected workers cooperated in the study. The results are presented as follows:

3.1 MEDICAL RECORDS

3.1.1. Age distribution

3.1.2. Duration of exposure

3.1.3. Task (type of job)

3.1.4. The prevalence of noise induced hearing loss

3.1.4.1. The distribution of noise induced hearing loss cases by age groups and the duration of exposure

3.1.4.2. The distribution of noise induced hearing loss cases by task.

3.1.5 The severity of noise induced hearing loss

3.1.5.1. The relationship of noise- induced hearing loss severity, age and duration of exposure.

3.1.5.2. The relationship of noise induced hearing loss severity and the task.

3.1.6 The risk factors for noise induced hearing loss

3.1.6.1 Age

3.1.6.2 Duration of exposure

3.1.6.3 Acoustic trauma

3.1.6.4 Oto-toxic drugs

3.1.6.5 Ear injuries and ear diseases

3.1.6.6 Heavy metals

3.1.6.7 Previous exposure to gunfire

3.1.6.8 Solvents

3.2 QUESTIONNAIRE RESULTS

In this section, the questionnaire results are presented in the following order

3.2.1. Distribution of questionnaire respondents by age
3.2.2. Distribution of questionnaire respondents by the duration of exposure
3.2.3. Perceived hearing problems, ambient noise levels and noise exposure duration.
3.2.4. The type of hearing problems experienced by workers at the nickel mine
3.2.5. The perceived noise levels in the work environment
3.2.6. The knowledge of noise induced hearing loss
3.2.7. The use of hearing protective equipment
3.2.8. Noise induced hearing loss risk factors

3.3 WORK PRACTICES OBSERVATION CHECKLIST RESULTS

In this section, the work observation checklist results are presented in the following order

3.3.1 Trend analysis of work practice observation scores

3.4 SUMMARY OF RESULTS

The chapter ends with a brief summary of results as follows:

3.4.1. Summary of medical records review results
3.4.2. Summary of questionnaire results
3.4.3. Summary of work practice observation checklist results

3.1 MEDICAL RECORDS REVIEW RESULTS

A total of 168 out of 465 underground mine workers employed in 2004 had their audiograms reviewed. All the medical records reviewed were for workers who had more than 5 years of exposure to high noise levels > 80dBA.

Table 3.1.1: The age distribution of study subjects employed at a nickel mine in Zimbabwe in 2004 by age groups (n = 168).

	50+years	***40-49years***	***30-39years***	***23-29years***
Mean	**53.2**	**43.4**	**35.2**	**27.2**
Standard Error	0.7	0.4	0.2	0.3
Median	53	44	35.5	27
Standard Deviation	2.1	2.7	2.8	1.5
Sample Variance	4.4	7.8	8.0	2.3
Kurtosis	-1.7	-0.6	-0.9	-0.2
Skew-ness	0.2	0.5	-0.4	-0.5
Minimum	51	40	30	24
Maximum	56	49	39	29
Sum	479	1867	3312	490
Count	**10**	**44**	**95**	**19**

Table 3.1.1 above shows the distribution of the subjects by age groups. The average age of the workers whose audiograms were reviewed was 37 ±6.7 (minimum = 24, maximum 56). The table shows the distribution of subjects by age groups and mean age for each age category. The age group 30-39years constituted 56 % (95) of the workers whose medical records were reviewed.

Table 3.1.2: The exposure distribution of study subjects employed at a nickel mine in Zimbabwe in 2004 (n = 168).

	5-9years	***10-14years***	***15-19years***	***20-24years***	***25-29years***	**30+years**
Mean	7.6	11.6	16.4	21.4	27	
Standard Error	0.1	0.1	0.2	0.6	0.9	
Median	8	11	16	22	27	
Standard Deviation	1.1	1.5	1.3	1.3	1.8	
Sample Variance	1.3	2.3	1.7	1.8	3.3	
Minimum	5	10	15	20	25	
Maximum	9	14	19	23	29	
Sum	405	921	346	107	108	
Count	**54**	**80**	**22**	**6**	**5**	**1**

Table 3.1.2 above indicates the duration of exposure of the sample population as expressed by years and grouped into 6 categories. The mean exposure period of the sample population was 12 years ± 0.3 years, with the maximum exposure period being 30 years and the minimum being 5 years. About 47% (80) of the subjects had exposure periods falling into the 10 -14 years category whilst only one subject had an exposure period falling into the 30+ year age group.

A total of five tasks were performed by the underground mine workers whose medical records were examined. Table 3.1.3 below shows the distribution of the mine workers by their tasks or type of job at the mine as well as their age groups.

Table 3.1.3: The task distribution of study subjects employed at a nickel mine in Zimbabwe in 2004 by age groups (n =168).

Age Group (Years)	Charger	Construction	Jackhammer	Tramming	Machine Operator	TOTAL
20-29years	**0**	**6**	**0**	**10**	**3**	**19**
Row %	0	31.6	0	52.6	15.8	100
Col %	0	19.4	0	19.6	9.4	11.3
30-39years	**13**	**22**	**18**	**32**	**10**	**95**
Row %	13.7	23.2	18.9	33.7	10.5	100
Col %	61.9	71	54.5	62.7	31.3	56.5
40-49years	**7**	**3**	**13**	**9**	**12**	**44**
Row %	15.9	6.8	29.5	20.5	27.3	100
Col %	33.3	9.7	39.4	17.6	37.5	26.2
50+years	**1**	**0**	**2**	**0**	**7**	**10**
Row %	10	0	20	0	70	100
Col %	4.8	0	6.1	0	21.9	6
TOTAL	**21**	**31**	**33**	**51**	**32**	**168**
Row %	12.5	18.5	19.6	30.4	19	100
Col %	100	100	100	100	100	100

At 30%, the less skill demanding operation of tramming had the highest number of people. The skilled operations of jack-hammering and machine operation, though, tended to employ more of the older workers falling in the 30 -39 years and 40 -49 year age groups.

Figure 3.1.4 below indicates the prevalence of noise induced hearing loss amongst underground nickel mine workers employed at the mine in 2004 and with at least 5 years exposure. The prevalence was identified to be 27.4 %.

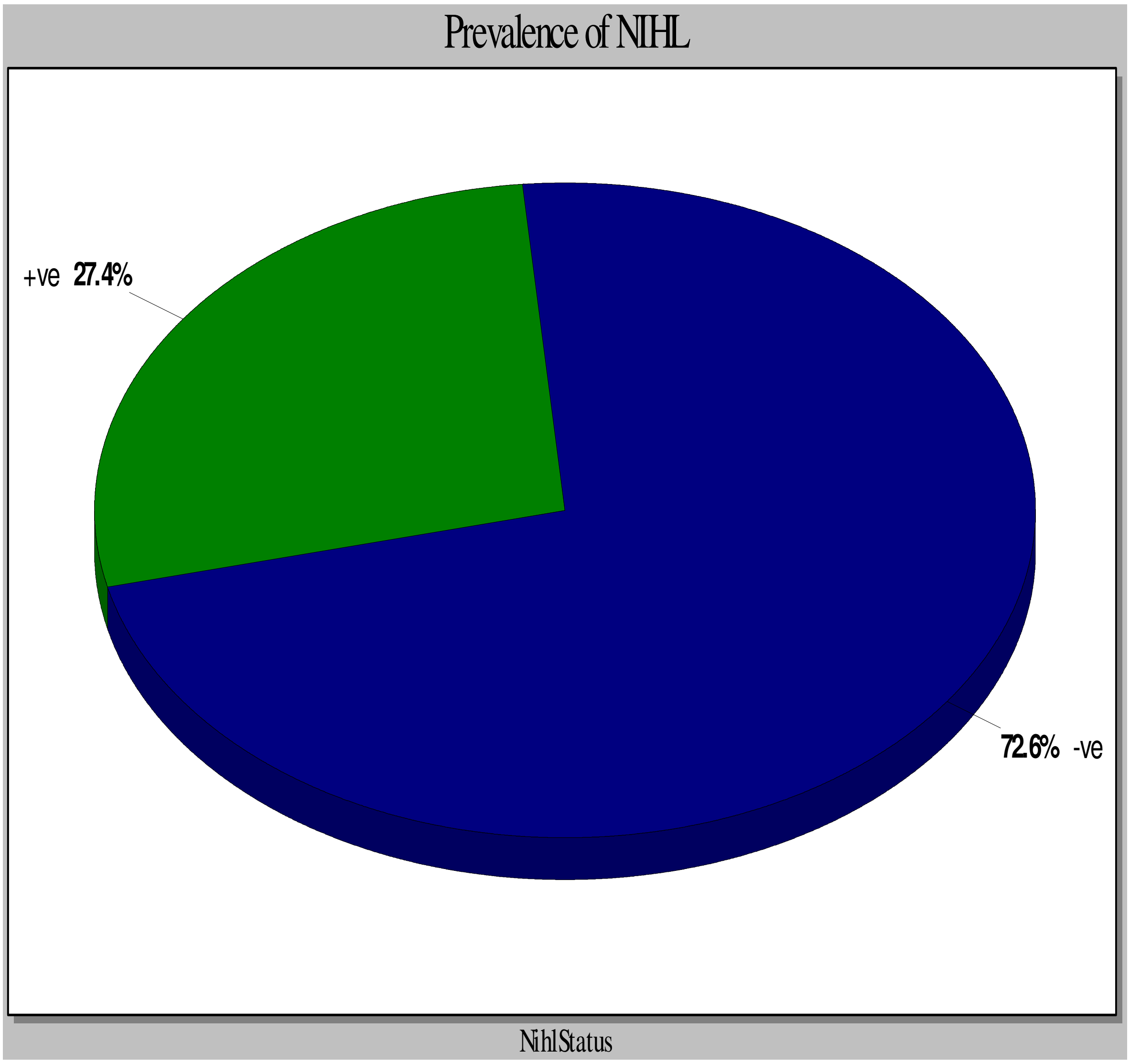

Figure 3.1.4: The prevalence of noise induced hearing loss among workers employed at an underground nickel mine in Zimbabwe in 2004 (n = 168).

The distribution of the noise induced hearing loss cases was examined according to both age and duration of exposure. Table 3.1.4.1 below shows that the highest prevalence of noise induced hearing loss was recorded in the 50+ year age group

(60%) although the highest number of noise induced hearing loss cases (20) was recorded in the 40 – 49year age group. The workers who had 21 – 25 years of exposure to high noise levels manifested the highest prevalence of noise induced hearing loss (60%). It was also established that the prevalence of noise induced hearing loss tended to increase with exposure time as shown in table 3.1.4 below. There was a statistically significant difference in the prevalence of noise induced hearing loss by age group $\chi^2 = 19$, $p = 0.01$, with the oldest group having the most noise induced hearing loss. There was also a statistically significant difference in the prevalence of noise induced hearing loss by duration of service with the longest service workers having the most noise induced hearing loss $\chi^2 = 24$, $p = 0.02$.

Table 3.1.4.1: The age and service duration distribution of noise induced hearing loss cases employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Age Group (years)	+ve	-ve	TOTAL
20-29years	**1**	**18**	**19**
Row %	5.3	94.7	100.0
Col %	2.2	14.8	11.3
30-39years	**19**	**76**	**95**
Row %	20.0	80.0	100.0
Col %	41.3	62.3	56.5
40-49years	**20**	**24**	**44**
Row %	45.5	54.5	100.0
Col %	43.5	19.7	26.2
50+years	**6**	**4**	**10**
Row %	60.0	40.0	100.0
Col %	13.0	3.3	6.0
TOTAL	**46**	**122**	**168**
Row %	27.4	72.6	100.0
Col %	100.0	100.0	100.0
Age Group Exposure Time (years)	**+ve**	**-ve**	**TOTAL**
5-10years	**9**	**72**	**81**
Row %	11.1	88.9	100.0
Col %	19.6	59.0	48.2
11-15years	**22**	**38**	**60**
Row %	36.7	63.3	100.0
Col %	47.8	31.1	35.7
16-20years	**10**	**8**	**18**
Row %	55.6	44.4	100.0
Col %	21.7	6.6	10.7
21-25years	**3**	**2**	**5**
Row %	60.0	40.0	100.0
Col %	6.5	1.6	3.0
26-30years	**2**	**2**	**4**
Row %	50.0	50.0	100.0
Col %	4.3	1.6	2.4
TOTAL	**46**	**122**	**168**
Row %	27.4	72.6	100.0
Col %	100.0	100.0	100.0

χ^2_1 = Age versus NIHL Status; χ^2_2 = Exposure time versus NIHL status

$\chi^2_1 = 19$, $p = 0.01$: $\chi^2_2 = 24$ p, = 0.02

Table 3.1.4.2 below shows the prevalence of noise induced hearing loss within each of the five tasks performed by the underground mine workers. The highest prevalence of noise induced hearing loss (61%) was recorded in the jackhammer operators whilst the tramming operators recorded the lowest prevalence of 9.8%. This difference was found to be significant $\chi^2 = 29$ $p = 0.001$.

Table 3.1.4.2: The task distribution of noise induced hearing loss cases employed at a nickel mine in Zimbabwe in 2004 (n =168).

Type of Job	+ve	-ve	TOTAL
Charger	**3**	**18**	**21**
Row %	14.3	85.7	100.0
Col %	6.5	14.8	12.5
Construction	**7**	**24**	**31**
Row %	22.6	77.4	100.0
Col %	15.2	19.7	18.5
Jackhammer	**20**	**13**	**33**
Row %	60.6	39.4	100.0
Col %	43.5	10.7	19.6
Machine Operator	**11**	**21**	**32**
Row %	34.4	65.6	100.0
Col %	23.9	17.2	19.0
Tramming	**5**	**46**	**51**
Row %	9.8	90.2	100.0
Col %	10.9	37.7	30.4
TOTAL	**46**	**122**	**168**
Row %	27.4	72.6	100.0
Col %	100.0	100.0	100.0

3.1.5. Severity of noise induced hearing loss

The noise induced hearing loss cases were further examined to find out the severity or extend of the hearing loss and the degree of hearing loss was used to categorize them into the 5 groups as previously explained in 2.9.7.2.

Figure 3.1.5 below shows the frequency and severity of the noise induced hearing loss cases identified at the nickel mine.

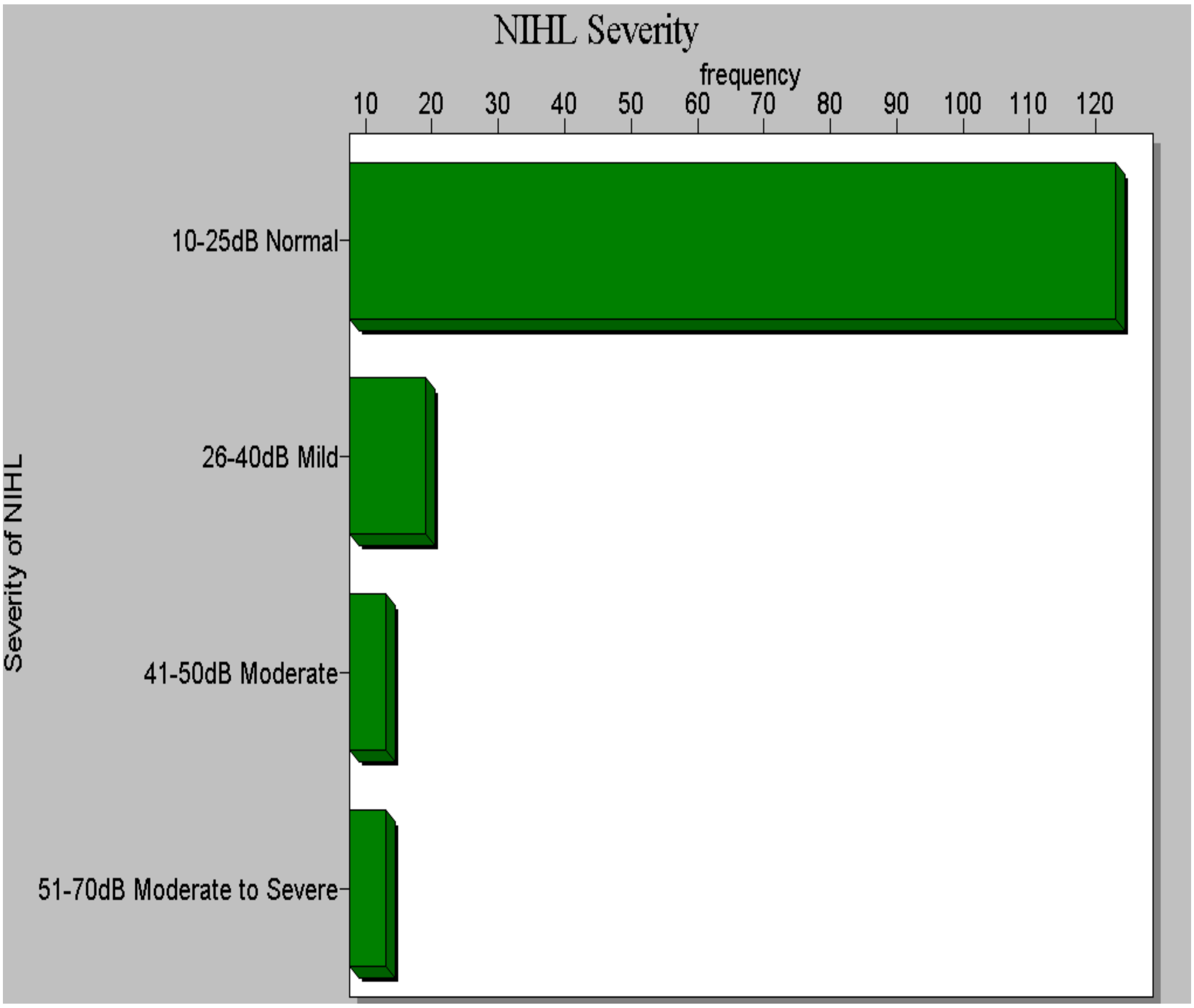

Figure 3.1.5: The frequency and severity of noise induced hearing loss cases in underground mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

The most prevalent category of noise induced hearing loss recorded was the mild category (26 – 40dB hearing loss). No cases of severe and profound noise induced hearing loss cases were identified. The distribution of the various noise induced hearing loss categories across all age groups and amongst workers with varying exposure duration was also examined and the following pattern observed.

Table 3.1.5.1: The age and service duration distribution of noise induced hearing loss cases employed at a nickel mine in Zimbabwe in 2004 by severity (n =168).

Age	10-25dB Normal	26-40dB Mild	41-50dB Moderate	51-70dB Moderate to Severe	TOTAL
20-29years	**18**	**1**	**0**	**0**	**19**
Row %	94.7	5.3	0	0	100
Col %	14.6	5.3	0	0	11.3
30-39years	**77**	**8**	**6**	**4**	**95**
Row %	81.1	8.4	6.3	4.2	100
Col %	62.6	42.1	46.2	30.8	56.5
40-49years	**24**	**10**	**5**	**5**	**44**
Row %	54.5	22.7	11.4	11.4	100
Col %	19.5	52.6	38.5	38.5	26.2
50+years	**4**	**0**	**2**	**4**	**10**
Row %	40	0	20	40	100
Col %	3.3	0	15.4	30.8	6
TOTAL	**123**	**19**	**13**	**13**	**168**
Row %	73.2	11.3	7.7	7.7	100
Col %	100	100	100	100	100
Exposure Time	**10-25dB Normal**	**26-40dB Mild**	**41-50dB Moderate**	**51-70dB Moderate to Severe**	**TOTAL**
5-10years	**73**	**6**	**0**	**2**	**81**
Row %	90.1	7.4	0	2.5	100
Col %	59.3	31.6	0	15.4	48.2
11-15years	**38**	**9**	**8**	**5**	**60**
Row %	63.3	15	13.3	8.3	100
Col %	30.9	47.4	61.5	38.5	35.7
16-20years	**8**	**4**	**3**	**3**	**18**
Row %	44.4	22.2	16.7	16.7	100
Col %	6.5	21.1	23.1	23.1	10.7
21-25years	**2**	**0**	**2**	**1**	**5**
Row %	40	0	40	20	100
Col %	1.6	0	15.4	7.7	3
26-30years	**2**	**0**	**0**	**2**	**4**
Row %	50	0	0	50	100
Col %	1.6	0	0	15.4	2.4
TOTAL	**123**	**19**	**13**	**13**	**168**

$\chi^2_1 = 34.7$, $p = 0.001$ Age versus NIHL Severity: $\chi^2_2 = 38$, $p = 0.001$ Duration of exposure versus NIHL Severity.

According to Table 3.1.5.1 above, the moderate and moderate to severe hearing loss categories had the same frequency of 7.7%. Neither severe hearing loss (71-90dB HTL) nor profound hearing loss (91dB and over HTL) was found. The severity of noise induced hearing loss though tended to increase with age as indicated in the above table, with the highest severity recorded (moderate to severe) being 0% in the 20 -29 year age group, 4.% in the 30 – 39 year age group, 11.% in the 40 -49 year age group and 40% in the 50+year age group. There was a statistical difference between the age groups $\chi^2_1 = 34.7$, $p= 0.001$. This must be read with caution due the small sample sizes. The duration of exposure was another factor found to be affecting the prevalence and severity of noise induced hearing loss at the mine. According to the same table above, all the subjects' duration of exposure was above 5 years. The mild noise induced hearing loss (26 – 40dB HTL) was more prevalent in those workers with 11 – 15 years exposure (9%) than in the other groups. However, the prevalence of the moderate noise induced hearing loss (41- 50dB HTL) tended to increase from 13.3 % in the 11 – 15 years exposure group, to 40% in those with 21 – 24 years exposure. Moderate to severe noise induced hearing loss (51 – 70dB HTL) also increased from 15% in those with 5-9years exposure to a high of 50% in those with 26 -30 years exposure. This difference in the noise induced hearing loss severity in each exposure group was statistically significant $\chi^2_2 = 38$ p, = 0.001.

Because of the variability of task specific noise exposure patterns, the distribution and relationship of noise induced hearing loss severity and undertaken tasks was explored and the results presented in table 3.1.5.2 below.

Table 3.1.5.2: The task distribution of noise induced hearing loss cases employed at a nickel mine in Zimbabwe in 2004 by the severity of NIHL (n =168).

Type of Job	10-25dB Normal	26-40dB Mild	41-50dB Moderate	51-70dB Moderate to Severe	TOTAL
Charger	**18**	**3**	**0**	**0**	**21**
Row %	85.7	14.3	0	0	100
Col %	14.6	15.8	0	0	12.5
Construction	**25**	**4**	**2**	**0**	**31**
Row %	80.6	12.9	6.5	0	100
Col %	20.3	21.1	15.4	0	18.5
Jackhammer	**13**	**5**	**7**	**8**	**33**
Row %	39.4	15.2	21.2	24.2	100
Col %	10.6	26.3	53.8	61.5	19.6
Machine Operator	**21**	**4**	**4**	**3**	**32**
Row %	65.6	12.5	12.5	9.4	100
Col %	17.1	21.1	30.8	23.1	19
Tramming	**46**	**3**	**0**	**2**	**51**
Row %	90.2	5.9	0	3.9	100
Col %	37.4	15.8	0	15.4	30.4
TOTAL	**123**	**19**	**13**	**13**	**168**
Row %	73.2	11.3	7.7	7.7	100
Col %	100	100	100	100	100

According to table 3.1.5.2 above, the jackhammer operations and the machine operations recorded the highest prevalence of all the noise induced hearing loss categories. The only exception is the mild noise induced hearing loss which recorded a prevalence of 14.3% in the charging operations. A significant difference was found between charging and construction, charging and jackhammer and charging and machine operation. (Tukey's Honestly Significant Difference (0.05) = 12.23, $p < 0.01$).There was no significant difference between the other tasks.

3.1.6 Noise induced hearing loss risk factors

Some risk factors for noise induced hearing loss were examined based on historical information extracted from the medical records. Scatter plots accompanied by the Student's t-test, were used to relate numerical variables. Odds ratios were calculated for categorical data. It is however critical to mention that the odds ratios must be viewed with caution since they may obscure an association between variables due to the small sample sizes. It is important to read these results in conjunction with the subsequent questionnaire results and also the work observation checklist results since these aimed at going further to identify the actual exposure of the workers to some of the risk factors.

3.1.6.1 Age as a risk factor for noise induced hearing loss

According to the scatter diagram below, age and noise induced hearing loss were identified to be positively correlated.

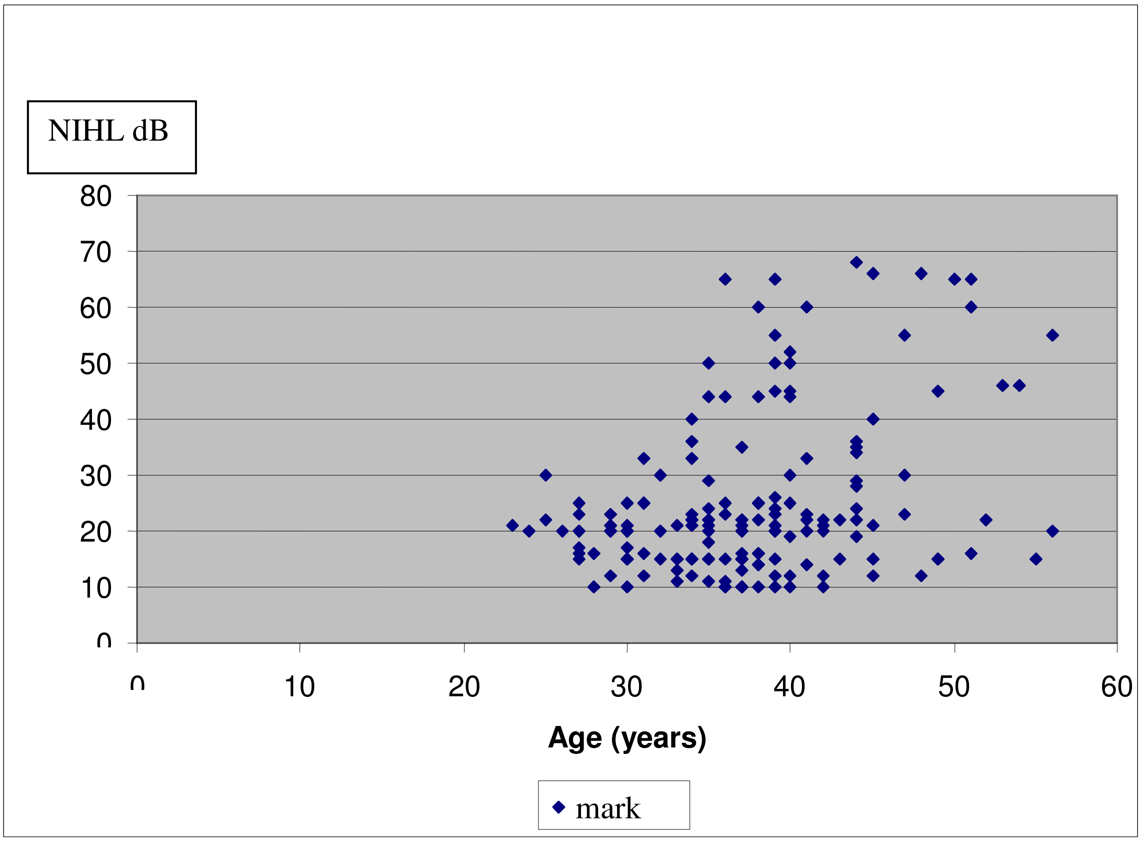

Fig. 3.1.6.1: The relationship between age and NIHL in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

3.1.6.2 Duration of exposure as a risk factor for noise induced hearing loss

According to figure 3.1.6.2 below, duration of exposure to high noise levels was identified to be positively correlated with noise induced hearing loss.

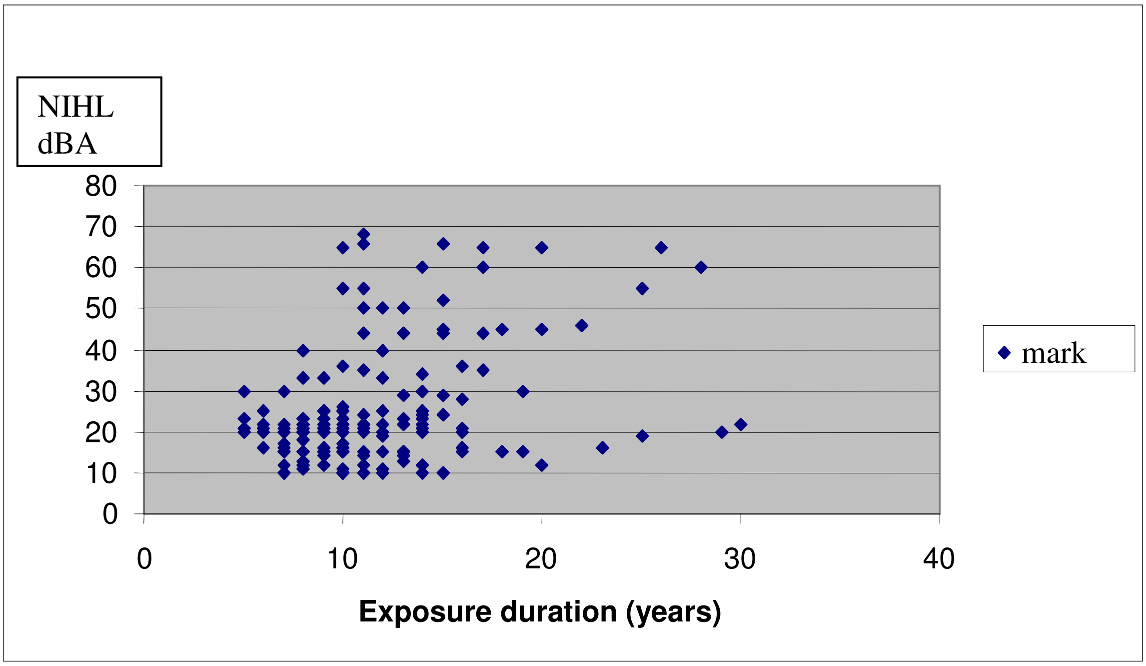

Fig. 3.1.6.2: The relationship between exposure duration and noise induced hearing loss in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

3.1.6.3 History of acoustic trauma as a risk factor for noise induced hearing loss

Medical records of workers with a history of exposure to acoustic trauma were evaluated and related to noise induced hearing loss. According to table 3.1.6.3 below no significant difference could be established between noise induced hearing loss status in those who had been exposed to acoustic trauma and those who had not (Odds Ratio 0.27, CI = 0.03 - 2.3). The small sample size makes calls for caution in interpreting the measures of association.

Table 3.1.6.3: The relationship between history of acoustic trauma and noise induced hearing loss in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Acoustic trauma	**NIHL status**		
	+ve	**-ve**	**TOTAL**
Yes	1	9	10
No	45	113	158
TOTAL	46	122	168
Odds Ratio (OR) 0.279			
95% Conf. Limits (0.03, 2.3)			

3.1.6.5 The use of oto-toxic drugs as a risk factor for noise induced hearing loss

The exposure of workers to quinine, furosimides, nitrogen mustard, platinol was evaluated considering their well documented potential as risk factors for noise induced hearing loss. The medical records indicated that none of the workers had exposure to all the above mentioned oto-toxic drugs except quinine which is widely used in Zimbabwe as an anti malarial drug. As shown in table 3.1.6.5 below, only 3 workers who had previous use of quinine developed noise induced hearing loss giving an odds ratio of 0.46, CI = 0.12 – 1.72). The small sample size calls for caution in interpreting this result.

Table 3.1.6.5: The relationship between the use of quinine and noise induced hearing loss in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Quinine	**NIHL status**		
	+ve	**-ve**	**TOTAL**
Yes	3	16	19
No	43	106	149
TOTAL	46	122	168
Odds Ratio (OR) 0.46			
95% Conf. Limits (0.12, 1.720)			

3.1.6.6 Ear injury and ear diseases as risk factors for noise induced hearing loss

The medical records were examined to establish whether cases of ear injuries and some ear diseases like mastoiditis and otitis-media were potential risk factors for noise induced hearing loss at the nickel mine. Whilst no cases of mastoiditis could be picked up from the medical records, 6 cases of ear injury were isolated with one of these developing noise induced hearing loss (OR = 0.52, CI = 0.06 – 4.6). The small sample size though calls for caution in this measure of association.

Table 3.1.6.6: The relationship between the history of ear injury and noise induced hearing loss in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Ear injury	**NIHL status**		
	+ve	**-ve**	**TOTAL**
Yes	**1**	**5**	**6**
No	**45**	**117**	**162**
TOTAL	**46**	**122**	**168**
Odds Ratio (OR) 0.5			
Standard Error (SE) 1.0			
95% Conf. Limits (0.06, 4.6)			

3.1.6.7 Use of mercury and arsenic as a risk factor for noise induced hearing loss

According to table 3.1.6.7 below, a total of 10 workers had exposure to the use of mercury and 2 of these developed noise induced hearing loss (OR = 0.65, CI = 0.1 – 3.2). No worker at the mine had exposure to arsenic or any other heavy metal.

Table 3.1.6.7: The relationship between the use of mercury and noise induced hearing loss in mine workers employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Mercury	**NIHL status**		
	+ve	**-ve**	**TOTAL**
Yes	**2**	**8**	**10**
No	**44**	**114**	**158**
TOTAL	**46**	**122**	**168**
Odds Ratio (OR) 0.6			
Standard Error (SE) 0.7			
95% Conf. Limits (0.1, 3.2)			

3.1.6.8 Previous exposure to gunfire as a risk factor for noise induced hearing loss

By examining the medical records to identify any workers' previous military, hunting or shooting exposure, the potential of gunfire as a risk factor for noise induced hearing loss could be assessed. Table 3.1.6.8 shows that a total of 16 workers were exposed to previous gunfire, and 3 developed noise induced hearing loss (OR = 0.58, CI = 0.2 -2.1). This result must once again be read with caution in view of the small sample size.

Table 3.1.6.8: The relationship between previous gunfire exposures in military, police or hunting operations and noise induced hearing loss in mine employed at a nickel mine in Zimbabwe in 2004 (n = 168).

Previous military or police or hunting exposure to gunfire	**NIHL status**		
	+ve	**-ve**	**TOTAL**
Yes	**3**	**13**	**16**
No	**43**	**109**	**152**
TOTAL	**46**	**122**	**168**
Odds Ratio (OR) 0.585			
Standard Error (SE) 0.5			
95% Conf. Limits (0.2, 2.1)			

3.1.6.9 Exposure to solvents as a risk factor for noise induced hearing loss

By examining the medical records to identify the number of workers who had exposure to toluene and trichloroethylene, it was intended that these solvents could be assessed as possible risk factors for noise induced hearing loss at the nickel mine. However there was no use of any solvents recorded in the medical records.

3.2 QUESTIONNAIRE RESULTS

In this section, results of the questionnaire administered to a sample of 100 underground nickel mine workers are presented. The intention of the questionnaire was to get a deeper understanding of the workers' work environment, some risk factors for noise induced hearing loss, the workers' knowledge of noise induced hearing loss and its control.

3.2.1**.** The maximum age recorded was 56 years with a minimum age of 23 and a maximum age of 56.

3.2.2. Questionnaire respondents' duration of exposure

3.2.1.1. The questionnaire respondents' length of service at the nickel mine was analyzed to identify their exposure duration to noise. The highest individual exposure period was 30 years (± 5.6) and the minimum exposure period was 5 years.

3.2.4 Perceived hearing problems, ambient noise levels and noise exposure duration
One of the questionnaire's objectives was to establish what the workers perceived as hearing problems associated with their work, the level of ambient noise that they were exposed to as well as the duration for which they were exposed. This was necessary because the effectiveness of any hearing protection has been widely documented to be dependant on workers' understanding of noise and its effects.

Table 3.2.4 below shows the questions that were asked and the frequency of the responses. Sixty three percent of the respondents acknowledged experiencing ear problems at the workplace whilst almost all the workers described their work noise levels as high during the greater part of their working shift.

Table 3.2.4: Perceived hearing problems, ambient noise levels and noise exposure duration among questionnaire respondents employed at a nickel mine in Zimbabwe in 2004

Do you experience any ear problems?	**Frequency**	**Percent**	**Cum Percent**
Yes	63	63%	63%
No	37	37%	100%
Total	**100**	**100%**	**100%**
How many hours per day are you exposed to high noise?	**Frequency**	**Percent**	
>4-6hrs	3	3%	
≥8hrs	96	97%	
Total	**99**	**100%**	

3.2.5: The type of hearing problems experienced by workers at the nickel mine.

The workers were asked to describe the type of hearing problems which they were experiencing at the mine. Four categories were used to classify each answer ranging from none, pain in the ears, poor hearing of normal speech and ringing in the ears (tinnitus). Table Figure 3.2.5 below shows that about 30% of the workers reported poor hearing of normal speech whilst slightly more than half this number reported experiencing tinnitus.

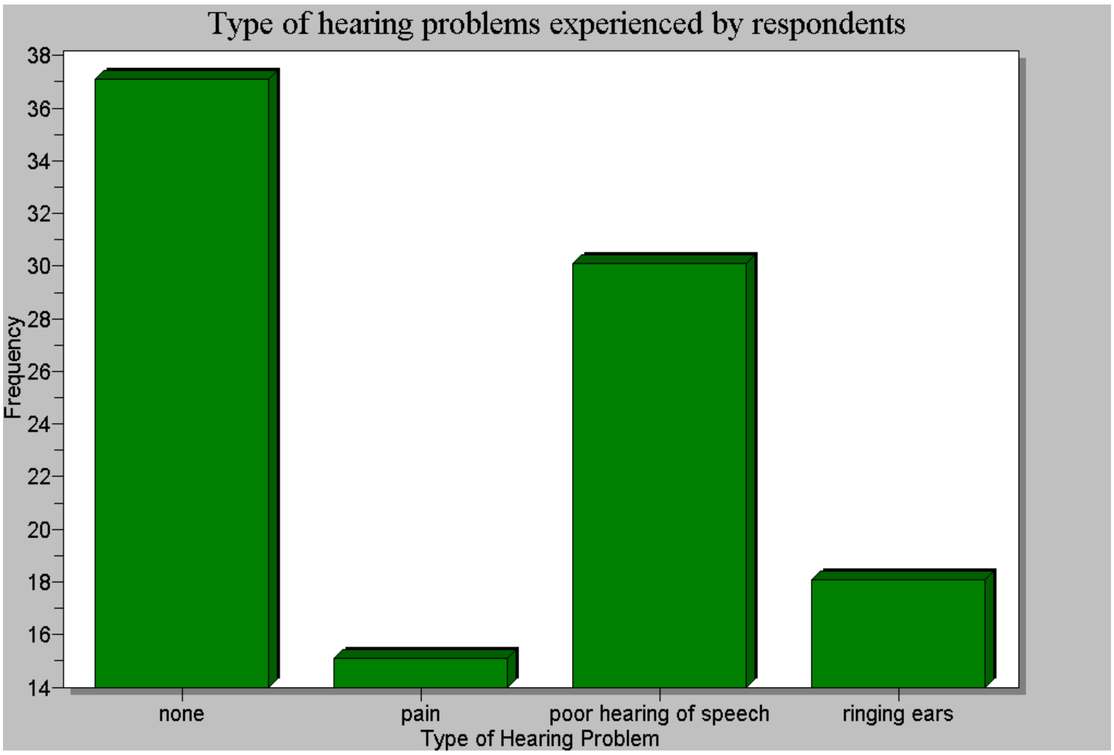

Figure 3.2.5: The type of hearing problems experienced by questionnaire respondents employed at a nickel mine in Zimbabwe in 2004, (n = 100).

3.2.6: The perceived noise levels in the work environment**.**

Figure 3.2.6 below shows the way in which the workers perceived the level of noise in their work environment. This was necessary to enable comparison between the perceived noise levels and the measured noise levels as well as the impact of this aspect on the workers' use of hearing protective devices.

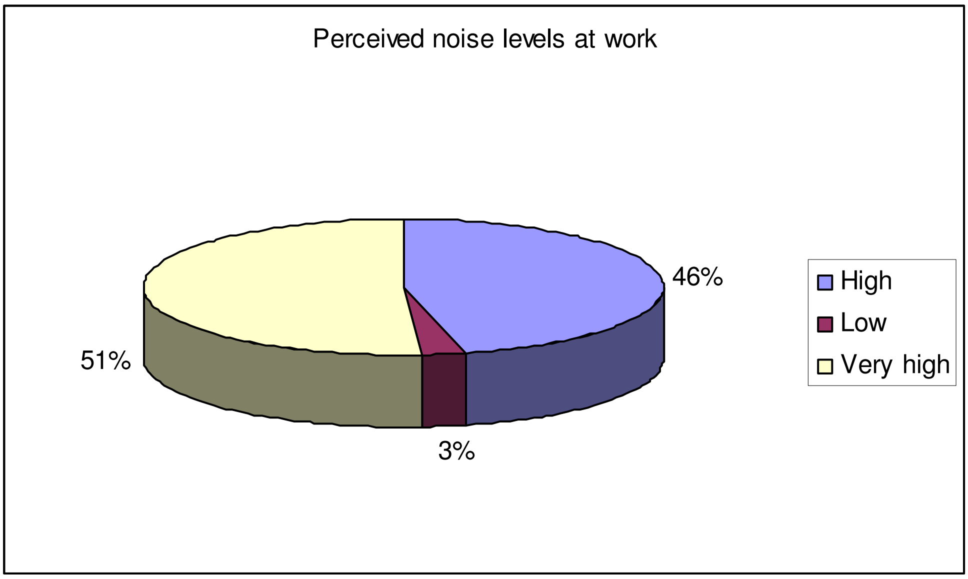

Figure 3.2.6: The perceived noise levels in the work environment according to questionnaire respondents employed at a nickel mine in Zimbabwe in 2004 (n = 100).

Almost 50% of the workers described the noise levels in their work environment as very high, whilst an almost equal number (46%) described the noise levels as high.

3.2.7: The knowledge of noise induced hearing loss among questionnaire respondents employed at a nickel mine.

In an effort to identify the workers' understanding of noise induced hearing loss and its causes, several questions were asked of the workers. Table 3.2.7 below shows the results of this investigation. Whilst 85% of the workers reported having heard of noise induced hearing loss before, only about 50% of them attributed its causes to loud noise exposure and about a third attributed the disease to other things besides noise.

Table 3.2.7: The knowledge of noise induced hearing loss among workers employed at a nickel mine in Zimbabwe in 2004 (n = 100).

Have you ever heard of noise induced hearing loss?	Frequency	Percent
Yes	85	85
No	15	15
Total	100	100

What do you think causes noise induced hearing loss?	Frequency	Percent
Do not know	19	19
loud noise	49	49
others	32	32
Total	100	100

3.2.8: The use of hearing protective equipment by workers employed at the nickel mine**.**

Hearing protective equipment usage by the workers was assessed during the interviews by seeking response to questions concerning the workers' practice regarding when they wear hearing protection, the actual duration of hearing protection usage during a shift and the type of hearing protection that was used. Table 3.2.8 below shows that 89 % of the workers reported using hearing protective devices whenever they are exposed to noise, whilst an equal number of workers reported the actual use of hearing protective devices during a full shift. Only pre-moulded ear plugs and ear muffs were used as hearing protective devices at the mine, with 85% of the workers using the former.

Table 3.2.8: The use of hearing protective equipment amongst workers employed at a nickel mine in Zimbabwe in 2004 (n = 100).

Do you always wear hearing protective equipment when exposed?	**Frequency**	**Percent**
Yes	85	85%
No	15	15%
Total	100	100%
How often do you put on hearing protection in an 8hr shift?	**Frequency**	**Percent**
>2-4hrs	1	1%
>4-6hrs	10	10%
8hrs	89	89%
Total	100	100%
Which of the following hearing protective equipment do you use?	**Frequency**	**Percent**
Earmuffs	15	15%
Pre-moulded plugs	85	85%
Total	100	100%

3.2.9: Noise induced hearing loss risk factors

Besides age and the duration of exposure, the workers were asked for possible exposure to any or a combination of the following risk factors for noise induced hearing loss; the use of oto-toxic drugs, organic solvents, heavy metals, exposure to tasks involving the use of gunfire and a history of several ear diseases. These results are presented in Appendix 8. About 13 % of the workers reported a history of mumps, whilst an equal number reported having previous exposure to tasks in the hunting, military and police which involved exposure to gunfire. About 11% of the workers reported having used quinine as an anti-malarial drug.

3.3. WORK PRACTICE OBSERVATION RESULTS

In this section the results of the work observations carried out over a 14 day period are presented in the form of a trend graph. Definitions of work practices are presented in Appendix 6.

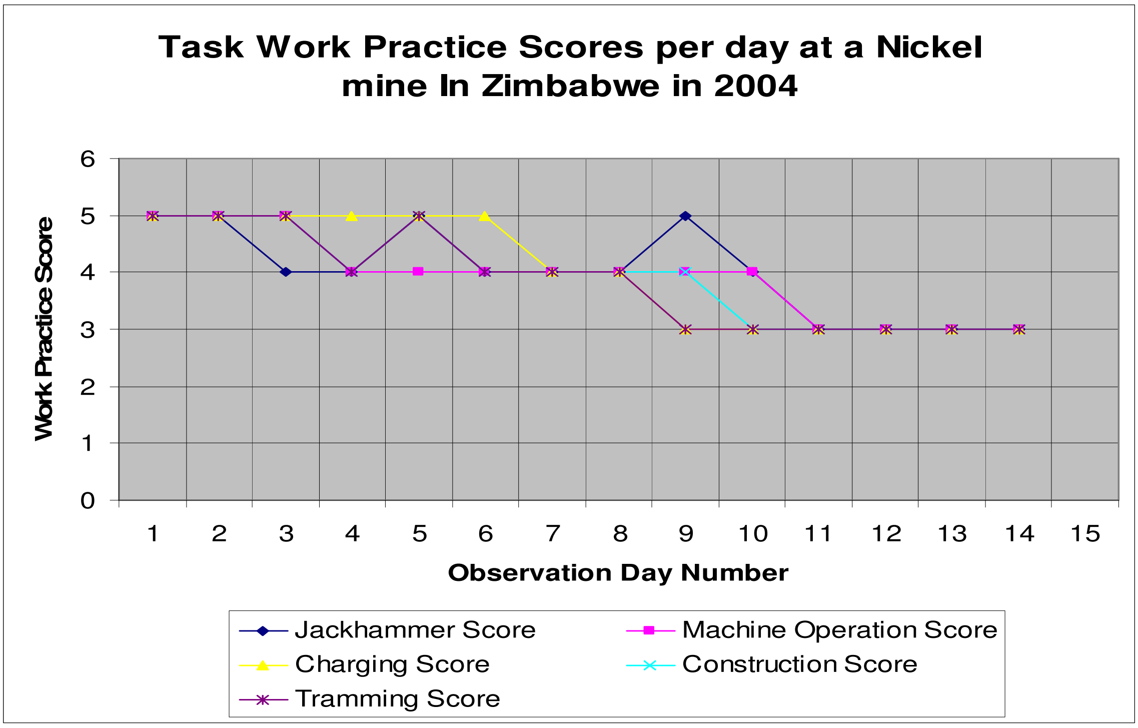

Figure 3.3.1: Trend analysis of work practice observation scores among 168 underground mine workers employed at a nickel mine in Zimbabwe in 2004.

The Work Practice figure 3.3.1 above shows numerical values assigned for each Work Practice. These values represent and describe the closest estimation of observed Work Practices undertaken during the 14 day observation exercise. The optimum work practices theoretically assigned for the least exposure to noise induced hearing loss conditions i.e. work practice score of 3 were achieved on the 9th day of observation for tramming operations, 10th day for construction and charging operations and 11th day for jackhammer and machine operations. The worst practice for the whole study group was observed during the first 2 days of observation. The gradual improvement in the work practice could be attributed to the psychological effect on workers who became aware that they are being observed and tended to do the right things[18].

3.4 SUMMARY OF RESULTS

3.4.1. Summary of medical records review results

3.4.1.1. All medical records reviewed were for workers who had baseline audiograms, follow-up audiograms and had at least 5 years exposure. The difference between the various age groups was found to be statistically significant as follows: (20-29years and 30-39year age group ($t = 1.98$, $p <0.05$), 30-39years and 40-49years ($t= 1.96$, $p <0.05$) and also between the 40 years and 50+year age group ($t =2$, $p <0.05$).
3.4.1.2. The sample population had a mean exposure period of 12years ± 0.3 years (minimum 5 years and maximum 30 years). The duration of exposure difference between the age groups was statistically significant at $p < 0.05$.
3.4.1.3. A noise induced hearing loss prevalence of 27.4% was identified at the nickel mine, comprised of 19 (42%) mild noise induced hearing loss, 13 (28.8%) moderate hearing loss and 13 (28.8%) moderate to severe noise induced hearing loss.
3.4.1.4. Neither severe nor profound noise induced hearing loss was identified. The highest noise induced hearing loss prevalence (60%) was identified in the 50 and above years age group whilst 45.5% was identified in the 40 – 49 year age group, 20% in the 30- 39 year age group and 5.3 % in the 20 – 29 year age group.
3.4.1.5. Age was significantly associated with noise induced hearing loss ($\chi^2 = 19$, $p = 0.001$).

3.4.1.6. The highest prevalence of noise induced hearing loss (60%) was identified in those workers who had 21 – 25 years of exposure, whilst 50% prevalence was identified in those with 26 – 30 years exposure, 55.6% in those with 16 – 20 years exposure, 36.7% in those with 11 – 15 years exposure and 9 % in those with 5 – 9 years exposure. This difference was statistically significant ($\chi^2_1 = 24$, $p = 0.002$).

3.4.1.7. The correlation between age and noise induced hearing loss and duration of exposure was found to be positive.

3.4.1.8. A positive correlation between age and duration of exposure among the interviewed workers was found.

3.4.1.9. The prevalence of noise induced hearing loss in the different task groups was statistically significant ($\chi^2 = 29$, $p = 0.001$).

3.4.1.10. The severity of noise induced hearing loss was identified to increase with age as well as duration of exposure. The prevalence of the moderate and moderate to severe hearing loss was 20% and 40 % respectively in the 50+ year age group and 11.4% in the 40 – 49 year age group as compared to 6.3% and 4.2 % in the 30 -39 year age group.

3.4.1.11. A significant difference was established between charging and construction, charging and jackhammer and charging and machine operation. (Tukey's Honestly Significant Difference score (0.05) = 12.23, $p < 0.01$).There was no significant difference between the other tasks.

3.4.1.12. Age was identified to be significantly related to both noise induced hearing loss status and its severity, $\chi^2 = 34.7$, $p = 0.001$.

3.4.1.13. The duration of exposure to high noise levels > 80dBA was identified to be significantly related to noise induced hearing loss status, $\chi^2 = 34$, $p = 0.001$.

Table 3.4.1.13: Statistical significance test results for some risk factors for noise induced hearing loss at a nickel mine in Zimbabwe in 2004.

Noise induced hearing loss risk factor	Odds ratio	95% Confidence	Fisher's exact 1-tail
hearing impairment history	0	N/A due a value of zero	0.27
Acoustic trauma	0.4	0.0 – 2.3	0.18
Previous exposure to military, hunting gunfire	0.4	0.2 – 2.1	0.31
History of ear injury	0.21	0.1 – 4.6	0.47
Use of mercury	0.31	0.1 – 3.2	0.45
Use of quinine	2.16	0.1 – 1.7	0.17

3.4.1.14. Table 3.4.1.13 above shows that history of hearing impairment, history of acoustic trauma, previous exposure to military, police or hunting gunfire, history of ear injury, the use of mercury (heavy metal) and the use of the oto-toxic drug quinine were all not significantly related to noise induced hearing loss status as shown by the low odds ratios as well as Fisher's exact χ^2 which were > 0.05 in all cases.

3.4.2: Summary of questionnaire results

3.4.2.1: Sixty-three percent of the workers reported experiencing ear problems whilst 97 % reported exposure to high noise levels for the full 8 hour shift.

3.4.2.2: Poor hearing of normal speech was the most common hearing problem reported (30%), followed by tinnitus (18%).

3.4.2.3: More than 50% of the workers reported exposure to very high ambient noise levels.

3.4.2.4: A high knowledge of noise induced hearing loss was identified within the workers interviewed (85%), however only 50% of these workers attributed noise induced hearing loss to high noise.

3.4.2.5: A high personal protective equipment compliance was reported amongst the interviewed workers, 85% wearing hearing protection whenever exposed to noise induced hearing loss and 89 % wearing hearing protection for the full duration of an 8 hour shift.

3.4.2.6: Almost 13% of the workers interviewed reported a history of mumps, whilst an equal number reported a history of military, hunting and or police gunfire exposure. Almost 11 % had exposure to the use of quinine.

3.4.3: Summary of work practice observation checklist results

3.4.3.1: The observations recorded in the 14 day work practice observation checklist indicate the optimum operating conditions for the prevention of noise induced hearing loss were only achieved by all task groups on the 11th to the 14th day. Non compliance with the use of hearing protective devices could have resulted in over-exposure of the mine workers to high noise levels.

CHAPTER 4: DISCUSSION

This chapter starts by restating the aim of the study and the major findings. The limitations are discussed and the findings related to the published literature.

4.1 AIM OF THE STUDY

The aim of this study was to review medical records of underground mine workers at a nickel mine in Zimbabwe to identify the prevalence of noise induced hearing loss as well as describe some risk factors for noise induced hearing loss by analyzing data from the medical records, questionnaire and a work practice observation checklist.

4.2 SUMMARY OF MAJOR FINDINGS

The main findings of the study showed that the prevalence of noise induced hearing loss was 27.4% (46), with 42 %(19) of these falling into the mild category, 28% (13) in the moderate category and 28% (13) in the moderate to severe category. Neither severe nor profound noise induced hearing loss was found. Based upon levels of significance, the data indicates that age, duration of exposure and task were significantly related to noise induced hearing loss as well as its severity ($p < 0.05$). Whilst the perceived knowledge of noise induced hearing loss amongst the workers was high (85%), and the reported use of hearing protective devices per shift was also high (89%), the actual practices as observed over a 14 day period showed that 100% compliance to hearing protective devices usage was only achieved during the last 4 days of the exercise.

4.3 LIMITATIONS OF THE STUDY

The following limitations need to be borne in mind when interpreting the results since they could have influenced the sample in ways that are not readily evident.

4.3.1**:** The extent to which the study sample was representative relative to the underground nickel miners in Zimbabwe could not be identified because of the small study population at one mine.

4.3.2 Random sampling was used to select study subjects for the questionnaire. This type of selection of respondents can be expected to produce samples that are reasonably representative of the underground nickel miners. However, there were some individuals who could not participate because they were on their annual leave. This may serve to bias the sample in ways that are not readily evident.

4.3.3 The research design was a one-time survey that produced a profile of the characteristics of underground nickel mine workers. This type of cross-sectional design precludes being able to draw conclusive cause and effect relationships between these characteristics. A healthy worker effect may have biased the samples to less severe cases, but no worker had been retrenched since 2000 for noise induced hearing loss.

4.3.4 The study was conducted over a one month period (August to September 2004) producing a snapshot of underground nickel mine workers who were present during that particular period. It is possible that the make-up of the underground mine workers may differ depending on the period of the year. As well, the make-up of underground mine workers may change over time in response to changing production and economic conditions in the company.

4.3.5 Information collected via the questionnaire was of a self-reported nature which, depending on the subject areas being queried, may be prone to some inaccuracy as a result of less than accurate recall, lack of information, or discomfort with self-disclosure.

4.3.6 The small sample sizes and frequencies in several instances restricted options of conclusive statistical measures of association and or significance, thus restricting generalization to the study population.

4.3.7 The measured noise levels at the mine as well as the audiogram results were taken and read as they are from the mine’s occupational health and safety unit. It was assumed that the quality control and qualification of technicians using the equipment was accurate as stated.

4.3.8 The workers' behaviour as observed during the 14 day period could have been influenced by the psychological effect when workers tend to do the right thing during observation as compared to their normal behaviours when not being watched[18]. This might have introduced bias.

4.4 MAJOR FINDINGS

4.4.1 Research objective one (1). To identify the prevalence of noise induced hearing loss.

The data presented has shown that the prevalence of noise induced hearing loss at the nickel mine was 27.4% (Figure 3.1.4). This prevalence of noise induced hearing loss was closely similar to the one of 23.8% reported by Amedofu in a study of hearing impairment among workers in gold mining in Ghana [6]. The mining of gold and nickel employ similar processes due mainly to the hardness of the ores. This therefore means that the noise levels in both underground mining setups are likely to be similar with equally the potential to cause noise induced hearing loss. The ambient noise levels for most of the underground mine tasks which were 80dBA (Table 1.1), combined with the poor compliance with hearing protective devices usage as shown by the work practice observation data (Figure 3.3.1) suggest that over-exposure of the underground nickel mine workers could be resulting in the high noise induced hearing loss prevalence. This over exposure was corroborated by the interviewed workers' of whom 97% confirmed being exposed to high ambient noise levels and 30% reported poor hearing of normal speech and 18% reported experiencing tinnitus. Difficulty in understanding speech in noisy environments and tinnitus (temporary threshold shift), have since been identified as the early signs of noise induced hearing loss [13].

The significant relationship of noise induced hearing loss and age as well as the duration of exposure ($p < 0.05$) confirms the effect of presbyacusis or hearing loss due to aging. The composition of the underground mine workers show a domination of middle aged workers 30 -39 years old, 56% (94) followed by the 40 – 49 year age group who form 26% (43). This pattern is the same with the duration of exposure where 47% (79) and 32% (53), have 10 – 14 years and 5 -9 years exposure respectively. This profile suggests that these two risk factors for noise induced hearing loss could have a significant bearing on the prevalence of noise induced hearing loss at the mine. This finding agrees with the findings of Abel SM who, after studying 1057 individuals working in air, land and sea-trades discovered that the prevalence of moderate to severe hearing loss progressed with age; hearing thresholds in those over 45 years ranging broadly from normal to over 70dB HL[23].

At 60% prevalence, the jackhammer operators exhibited the highest noise induced hearing loss as compared with the other tasks (Table 3.1.5.2). The jackhammer operators were exposed to an ambient noise level of 125dBA (Table 1.1). The high noise levels coupled with the poor usage of hearing protective equipment as shown by the work practice observation (Figure 3.3.1) suggest overexposure of this group to high noise levels. The World Health Organisation mentions the need for effective hearing protection programmes for workers exposed to high noise levels in such as jackhammers[24]. The underground nickel miners use either ear plugs or ear muffs for hearing protection. Surprisingly, those exposed to noise levels above 100dBA such as the jackhammer operators are not required to wear both ear plugs and ear muffs as a standard practice in hearing conservation.

The severity of noise induced hearing loss showed a significant relationship with age $\chi^2 = 34.7$, $p = 0.001$ and also with the duration of exposure $\chi^2 = 34$, $p = 0.001$. This association between noise induced hearing loss and these same two variables is the same with the one illustrated with noise induced hearing loss status. The scatter diagrams shown in Figure 3.1.6.1 and 3.1.6.2 confirm this. It is however very important to note that this relationship could be coincidental due mainly to the small sample size. Several studies have nevertheless come out with similar findings. In a study by Cordeiro, Lima-Filho and Nascimento, on noise induced hearing loss and its association with cumulative working time among urban workers, a positive association between hearing loss and cumulative working time was established [25]. Another study by Rabinowitz, Galusha and Dixon on whether ambient noise exposure levels predict hearing loss in a modern industrial setting, established an association between the severity of hearing loss and the duration of noise exposure [26]. This result shows that noise in the work environment must be controlled.

The severity of noise induced hearing loss varied from one task to another. A significant difference was demonstrated between charging and construction, charging and jackhammer and charging and machine operation, Tukey's Honestly Significant Difference score 0.05 = 12.23, $p < 0.01$.There was no significant difference between the other tasks. The fact that charging operations tended to employ less of the older workers as compared to the other operations which are skilled could suggest that the effect of age and duration of exposure was less dominant in this group (Table 3.1.3).

4.4.2. Research objective (2) Description of some risk factors for noise induced hearing loss

The data presented has shown that age $\chi^2 = 19$, $p = 0.001$, and duration of exposure $\chi^2 = 24$, $p = 0.002$ were significant risk factors for noise induced hearing loss at the nickel mine. Almost 87% (146) of the workers were over 30 years old and all the workers had at least 5 years exposure. The questionnaire sample also depicted the same pattern, with 85% (85) of the workers being over 30 years old and all of them having at least 5 years exposure. In view of these similarities, this statistic is not surprising. This result was similar to that of a study on the epidemiology of noise induced hearing loss in Poland, which showed that the majority of cases observed were those workers aged 50-59 years old and exposed to noise for over 20 years [20]. The effect of age and duration of exposure has already been discussed above. According to the data collected (Table 3.4.1.13), all the possible risk factors described were not significant at the nickel mine. Odds ratios and Fisher's exact chi-square scores were used to test the significance of these risk factors after which no association could be demonstrated: History of hearing impairment Fishers exact $\chi^2 = 0.27$ $p > 0.05$), previous exposure to military and or hunting gunfire and noise induced hearing loss OR= 0.4 CI = 0.2 – 2.1, Fisher's exact $\chi^2 = 0.31$ $p > 0.05$, history of ear injury and noise induced hearing loss OR= 0.21 CI = 0.1 – 4.6, Fisher's exact $\chi^2 = 0.47$ $p > 0.05$, use of mercury OR= 0.31 CI = 0.1 – 3.2, Fisher's exact $\chi^2 = 0.45$ $p > 0.05$, and the use of quinine OR= 2.16 CI = 0.1 – 1.7, Fisher's exact $\chi^2 = 0.17$ $p > 0.05$.

These results were corroborated by the questionnaire results (Appendix 7), which showed only 13 workers reporting a history of mumps, 13 reporting a history of using quinine and a similar number reporting a history of previous military exposure. The reported use of quinine within the workers was not surprising in view of the prevalent use of this drug for malaria treatment in Zimbabwe. The small sample sizes in this instance could mask any hidden relationships. According to the World Health Organization, hearing impairment from oto-toxic drugs is commonly caused by a variety of drugs, chemical substances or heavy metals such as amino glycosides, mercury, solvents and others [22].

The data obtained from the interviews and the work observation checklist revealed that although the workers claim to be aware of noise induced hearing loss (85%), a knowledge gap exists as depicted by 19% who did not know the causes. Although 89% claimed to wear hearing protection for a period ≥ 8hours, the practices as observed during the 14 days revealed non compliance to the use of hearing protective equipment. These findings are similar to those of Kahan and Ross who in their study on the knowledge and attitudes of a group of South African mine workers towards noise induced hearing loss and the use of hearing protective devices, established that respondents were poorly informed about noise as a health hazard and tended to rely on perceived knowledge and consequently mainly wearing hearing protection in situations perceived as noisy by the workers themselves. They also established that consequently, use of hearing protective devices was poor [19].

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This study done at a nickel mine in Zimbabwe has shown that the prevalence of noise induced hearing loss was 27.4 %, with 11.3 % (19) being mild noise induced hearing loss, 7.7% (13) being moderate noise induced hearing loss and 7.7% (13) being moderate to severe noise induced hearing loss. Age and the duration of exposure were significantly related to noise induced hearing loss. There was no significant association or correlation between noise induced hearing loss and the following risk factors, acoustic trauma, previous exposure to military, hunting and or police gunfire, history of ear injury, use of mercury and the use of quinine. A knowledge gap exists amongst the mine workers as far as the prevention of noise induced hearing loss is concerned. The actual use of hearing protective devices is not as good as the workers claim it to be.

The use of hearing protective devices was the primary control of noise induced hearing loss at this mine. The effectiveness of this method relies on a well informed and pro-active workforce. It is therefore recommended that the following additional hearing conservation strategies be adopted to reduce the prevalence of noise induced hearing loss at the nickel mine:

5.1. Revision of the current hearing conservation program to appraise engineering control of noise as the first line strategy.

5.2. This disparity between perceived knowledge of noise induced hearing loss and its prevention and the actual use of hearing protective devices needs redress by effective company sponsored education programs. It is also recommended that these education programs take into consideration workers' perception of noise induced hearing loss since this has been proved to be a key predictor of the effective use of hearing protection. It is also recommended that these education programs stress the importance of good hearing conservation practices on and off the job and should also inform employees about other conditions and diseases that affect hearing.

In concluding this research, it is important to note that the incongruence between the high knowledge and prevention methods of noise induced hearing loss and the low compliance in the use of hearing protection devices definitely indicate the need for further research.

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Appendix 1: Participant information sheet and consent form

Introduction

Good Day, my name is Edmore Masaka from the School of Public Health at the University of Witwatersrand. I am doing a research to find out how many workers have hearing loss caused by noise at the nickel mine.

What am I going to do and how?

I would like to ask you to help me do this research. If you are prepared and able to assist me carry out the research, I will ask for your permission to examine your medical records kept at the clinic to find out how many workers have been affected by noise at the mine. I am also going to observe you as you work in your working environment to find out about the use of hearing protective devices as well as your work practices and processes and materials.

I will also ask you questions to find out about your medical history, working areas, use of hearing protective equipment, the type of noise coming from your work areas and the type of chemicals that you use when doing your work. The questions will take about 8 minutes to answer

Confidentiality

The information that I get from examining your medical records and that you volunteer by answering questions will be confidential. All results of the study will also be confidential. I will not identify individual people in any report or publication.

Benefits.

The benefits to you if you agree to participate in the study is that I will be able to recommend better measures to improve the current system for managing noise induced hearing loss at the nickel mine. In addition, at the end of the study I will present my findings and answer questions at a meeting of workers and management.

May I withdraw from the study?

Participating in the study has no disadvantages to you. If you decide not to participate there will be no disadvantages to you as this information will be confidential. You may do this at any time without having to give a reason. You can decide not to answer any questions and you are free to stop an interview at any time at no disadvantage to you.

Contact details

Whenever you want to know anything about the study, please feel free to contact me on telephone number +263-9-470551/2/3/4/5/6 or cell phone number +263-9-1162375

CONSENT FORM

I agree to the interview and the examination of my medical records to assist in research to find out how many workers have hearing loss caused by noise at the nickel mine as explained in the Information sheet. I understand that if I decide not to participate there will be no disadvantages to me, as no one on the mine will know. I also understand that I can decide not to answer any questions and also to stop the interview at any stage at no disadvantage to me.

Name --------------------- Signature --------------------

Date ----------------------

Appendix 2 Ethics Clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Masaka

CLEARANCE CERTIFICATE **PROTOCOL NUMBER M040720**

PROJECT	Noise Induced Hearing Loss at a Nickel Mine in Zimbabwe
INVESTIGATORS	Mr E Masaka
DEPARTMENT	School of Public Health
DATE CONSIDERED	04.07.30
DECISION OF THE COMMITTEE*	APPROVED UNCONDITIONALLY

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 07.01.28 **CHAIRPERSON** ....
(Professor M Vorster)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof D Rees

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 3: Questionnaire

No…………………………………………………………

Place……………………………………………………….

Date…………………………………………………………

Time…………………………………………………………

Interviewer………………………………………………

SECTION A

I am going to ask some questions, mainly about your job, hearing ability, and work environment. You are free to refuse to answer any question that you do not wish to respond to.

PERSONAL DETAILS

Task…………………………………………. Work Site…………………………….

Age………………………………………………. Sex M/F

Length of service in this task……………………………

SECTION B

MEDICAL HISTORY

1. Have you ever had ears examined to assess hearing damage yes( )/No ( )

If yes, when were you last examined?…………………………………………………………………..

2. Do you experience any ear problems? …Yes( )/No ( ).

If Yes, how would you describe them?

a) Pain……… b) ringing in the ears… c) poor hearing of normal speech

d) other………

SECTION C

WORK ENVIRONMENT

3. How would you describe the noise levels at your work site?

a) Negligible……………b) Low……………c) High…………………….d) Very High……………………..

4. Do you some times feel ringing in the ears at the end of the day? Yes ( )/ No ( )

SECTION D

KNOWLEDGE OF NOISE HAZARDS

5. Have you ever heard of Noise Induced Hearing Loss? Yes ( )/ No ( )

If yes, what do you think causes this in workers?

a) Loud noise……………b) Don't Know……………………………….. c) Others…………………………………….

6. How do you think this condition should be prevented?

a) Protective equipment………b)Noise reduction………………c)Don't know…………d) Others……

SECTION E

USE OF HEARING PROTECTIVE EQUIPMENT

7. Do you use any protective equipment for ears? Yes( )/ No( )

If yes, state what equipment.

a) Premolded earplugs…………... b) Formable earplugs………………c) Earmuffs……………………………

8. How many hours per day are you usually exposed to noise?…………………..

9. How often do you put on hearing protection?

a) Not at all…… b) 1 hr/shift…. c)1-5 hrs/shift…… d)6-7 hrs/shift…………e) All the time……

10. Do you always wear the hearing protection when you are exposed to noise?

a) Yes………………………. b) No…………………………….c) Occasionally…………………………………………………….

SECTION F

PREVIOUS NOISE EXPOSURE HISTORY

11. Besides this current job, have you ever worked in any environment with excessive noise level? Yes( )/ No( )

12. Could you state the last task that you have undertaken previously?

a)……………………………b)………………………………c)……………………………………..d)…………………SECTION G

NOISE INDUCED HEARING LOSS RISK FACTORS

13. Do you use any organic solvents in your job? Yes( )/ No( )

If Yes, which ones do you frequently use?

a) Styrene………b)Toluene………c)Xylene………d)Trichloroethylene…….e)Others…

14. How would you describe the type of noise that you are exposed to in your work environment?

a) Continuous (Non stop)
b) Intermittent (irregular or broken)
c) Impact (banging)

15. Do you do any other task with excessive noise after work? Yes( )/ No( )
16. Have you ever worked in the military, police or hunting business? Yes( )/ No( )
17. Do you use any mercury or arsenic metals in you job? Yes( )/ No( )
18. Have you ever used any of the following drugs? Platinol, Nitrogen Mustard, Amino glycosides, Furosemides, Quinine. Yes ( )/ No ( )
19. Have you ever suffered from any of the following diseases? Herpes, Meningitis, Mumps, Syphilis, Tuberculosis, Head Injury. Yes( )/ No( )

Appendix 4: Audiometric data review sheet

1. Number	
2. Age	
3. Year of Service	
4. Present Occupation	
5. Previous Occupation	
6. Military Service	Yes
	No
7. Diseases Affecting	Yes
	No
8. Head / ear injury	Yes
	No
9. Hearing impairments in Family	Yes
	No
10. Present State of Health	Good
	Fair
	Poor
11. Own Opinion of Hearing	Good
	Fair
	Poor
12. Noise Exposure	Yes
	No
13. Expressed in dB	Yes
	No
14. Case: Redeployment	
Management; Hearing Protection	
15. Typical case of N.I.H.L.	Yes
	No
16. Otoscopy	Yes
	No
17. Baro Trauma	Yes
	No
18. Acoustic Trauma	Yes
	No
19. Ear Infection	Yes
	No
20. Otitis Media	Yes
	No
21. Mastoiditis	Yes
	No
22. Head Injury	Yes
	No
23. Oto Toxic Drug Use and use of organic solvents	Yes
	No

Appendix 5: C 29 CFR 1910.95

1. In the event that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.
2. Self-recording audiometers shall comply with the following requirements:

(A) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned
by the audiometer. The lines shall be equally spaced and shall be separated by at least 114 inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(B) It shall be possible to set the stylus manually at the 10-dB increment lines for calibration purposes.

(C) The slowing rate for the audiometer attenuator shall not be more than 6 dB1sec except that an initial slowing rate greater than 6 dB1sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(D) The audiometer shall remain at each required test frequency for 30 seconds (+ or – 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than + or - **3** seconds.

(E) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

OSHA 29 CFR 1910.95 Rooms used for audiometric testing:

Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table D- 1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S 1.4-1 971 (R1976), and to the Class I1 requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.ll-1971 (R1976).

TABLE D-1 - MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST ROOMS

Octave-band center frequency (Hz)	**500**	**1000**	**2000**	**4000**	**8000**
Sound pressure level (dB).	**40**	**40**	**47**	**57**	**62**

OSHA 29 CFR 1910.95 (E 29 CFR 191 0.95)
Audiometer calibration

Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to identify that the audiometer is within the tolerances permitted by American Standard Specification for Audiometers, S3. 6- 1969.

(1) "Sound Pressure Output Check"
A. Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

B. Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

C. Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

D. At each frequency the readout on the sound level meter should correspond to the levels in Table E-1 or Table E-2, as appropriate, for the type of earphone, in the column entitled "sound level meter reading."

(2) "Linearity Check"
A. With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

B. Measure the sound levels in the coupler at each 10-dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

C. For each 10-dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

D. This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) "Tolerances"
When any of the measured sound levels deviate from the levels in Table E-1 or Table E-2 by + or - 3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at 6000 Hz, an exhaustive calibration is advised. An exhaustive calibration is required if the deviations are greater than 15 dB or greater at any test frequency.

Appendix 6: Work observation checklists

Jackhammer Operations

DAY	Hearing Protection Device usage *			Heavy Metal Usage **			Organic Solvents Usage***			Work practice Score #
#	1	2	3	1	2	3	1	2	3	
DAY 1			3	1			1			5
DAY 2			3	1			1			5
DAY 3		2		1			1			4
DAY 4		2		1			1			4
DAY 5			3	1			1			5
DAY 6		2		1			1			4
DAY 7		2		1			1			4
DAY 8		2		1			1			4
DAY 9			3	1			1			5
DAY 10		2		1			1			4
DAY 11	1			1			1			3
DAY 12	1			1			1			3
DAY 13	1			1			1			3
DAY 14	1			1			1			3

***Use of HPE**
1 = Good
2 = Fair
3 = Poor

****Use of organic solvents**
1 = Nil
2 = Minor
3 = Significant

*****Use of heavy metals**
1 = Nil
2 = Minor
3 = Significant

Machine Operation

DAY	Hearing Protection Device usage*			Heavy Metal Usage**			Organic Solvents Usage***			Work practice Score #
#	1	2	3	1	2	3	1	2	3	
DAY 1			3	1			1			5
DAY 2			3	1			1			5
DAY 3			3	1			1			5
DAY 4		2		1			1			4
DAY 5		2		1			1			4
DAY 6		2		1			1			4
DAY 7		2		1			1			4
DAY 8		2		1			1			4
DAY 9		2		1			1			4
DAY 10		2		1			1			4
DAY 11	1			1			1			3
DAY 12	1			1			1			3
DAY 13	1			1			1			3
DAY 14	1			1			1			3

***Use of HPE** 1 = Good
2 = Fair
3 = Poor

****Use of organic solvents** 1 = Nil
2 = Minor
3 = Significant

*****Use of heavy metals** 1 = Nil
2 = Minor
3 = Significant

Charging

DAY	Hearing Protection Device usage*			Heavy Metal Usage**			Organic Solvents Usage***			Work practice Score #
#	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
DAY 1			3	1			1			5
DAY 2			3	1			1			5
DAY 3			3	1			1			5
DAY 4			3	1			1			5
DAY 5			3	1			1			5
DAY 6			3	1			1			5
DAY 7		2		1			1			4
DAY 8		2		1			1			4
DAY 9	1			1			1			3
DAY 10	1			1			1			3
DAY 11	1			1			1			3
DAY 12	1			1			1			3
DAY 13	1			1			1			3
DAY 14	1			1			1			3

***Use of HPE** 1 = Good
2 = Fair
3 = Poor

****Use of organic solvents** 1 = Nil
2 = Minor
3 = Significant

*****Use of heavy metals** 1 = Nil
2 = Minor
3 = Significant

Construction

DAY	Hearing Protection Device usage*			Heavy Metal Usage**			Organic Solvents Usage***			Work practice Score #
#	1	2	3	1	2	3	1	2	3	
DAY 1			3	1			1			5
DAY 2			3	1			1			5
DAY 3			3	1			1			5
DAY 4		2		1			1			4
DAY 5			3	1			1			5
DAY 6		2		1			1			4
DAY 7		2		1			1			4
DAY 8		2		1			1			4
DAY 9		2		1			1			4
DAY 10	1			1			1			3
DAY 11	1			1			1			3
DAY 12	1			1			1			3
DAY 13	1			1			1			3
DAY 14	1			1			1			3

Use of HPE
1 = Good
2 = Fair
3 = Poor

**Use of organic solvents
1 = Nil
2 = Minor
3 = Significant

***Use of heavy metals
1 = Nil
2 = Minor
3 = Significant

Tramming

DAY	Hearing Protection Device usage*			Heavy Metal Usage**			Organic Solvents Usage***			Work practice Score #
#	1	2	3	1	2	3	1	2	3	
DAY 1			3	1			1			5
DAY 2			3	1			1			5
DAY 3			3	1			1			5
DAY 4		2		1			1			4
DAY 5			3	1			1			5
DAY 6		2		1			1			4
DAY 7		2		1			1			4
DAY 8		2		1			1			4
DAY 9	1			1			1			3
DAY 10	1			1			1			3
DAY 11	1			1			1			3
DAY 12	1			1			1			3
DAY 13	1			1			1			3
DAY 14	1			1			1			3

***Use of HPE** 1 = Good
2 = Fair
3 = Poor

****Use of organic solvents** 1 = Nil
2 = Minor
3 = Significant

*****Use of heavy metals** 1 = Nil
2 = Minor
3 = Significant

Appendix 7: Oto-toxic agents and the presence of ear damaging diseases among questionnaire respondents employed at a nickel mine in Zimbabwe in 2004 n = 100.

Amino glycosides	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Furosemides	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Nitrogen Mustard	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Platinol	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Herpes	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Meningitis	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Mumps	Frequency	Percent	Cum Percent
Yes	13	13.00%	13.00%
No	87	87.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Styrene	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Do you use any organic solvents in your job?	Frequency	Percent	Cum Percent
Yes	1	1.00%	1.00%
No	99	99.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Have you ever worked in the military, police where you fired guns?	Frequency	Percent	Cum Percent
Yes	13	13.00%	13.00%
No	87	87.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Do you use any heavy metals like mercury or arsenic in your job?	Frequency	Percent	Cum Percent
No	100	100.00%	100.00%
Total	**100**	**100.00%**	**100.00%**
Quinine	Frequency	Percent	Cum Percent
Yes	11	11.00%	11.00%
No	89	89.00%	100.00%
Total	**100**	**100.00%**	**100.00%**