BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF ENVIROMENTAL SCIENCE

AN ANALYSIS OF THE EFFECTIVENESS OF NOISE INDUCED HEARING LOSS CONTROL STRATEGIES: A CASE STUDY OF ZIMBABWE POWER COMPANY - KARIBA SOUTH POWER STATION

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B202504B

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONOURS DEGREE IN SAFETY HEALTH AND ENVIRONMENTAL MANAGEMENT (BSC-SHEM)

2024

DECLARATION

Registration number: **B202504B**

I Ropafadzo K Katyamaenza do hereby declare that this work related project is my original work and has not been submitted before. All the information derived from other sources is indicated in the project.

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DEDICATION

With heartfelt appreciation, this dissertation is dedicated to my family and friends, whose love and support have been a constant source of strength and motivation.

ACKNOWLEDGEMENTS

Before anything else, I would like to offer heartfelt thanks to God for empowering me to stay focused and motivated throughout the whole course of my research. All thanks are offered to University colleagues and collaborators who assisted in the execution and completion of this research. I am also deeply grateful to my supervisor, Mr. Elvis Chiboiwa, whose invaluable guidance, encouragement, and support helped shape my research and bring it to fruition. I would like to extend my sincere appreciation to the Zimbabwe Power Company for granting us permission to conduct our research at the Kariba South Power I would like to extend my sincere appreciation to the Zimbabwe Power Company for granting us permission to conduct our research at the Kariba South Power Station. A special thank you to my industrial attachment mentor, Mr. C Zidaka, for his support and guidance. I also want to thank my mother, Mrs. P Katyamaenza, my father, Mr. C.M Katyamaenza, my siblings, and my friends; Peace Mabvirakare, Onias T Bhebhe, Shingirirai Muvuti, and Michael Nyoni, for their financial and emotional support throughout this project. Your encouragement has pushed me to work harder and strive for excellence. Thank you for all that you did.

ABSTRACT

Studies on noise-induced hearing loss have been conducted in Zimbabwe, but there is no evidence of similar research being done in hydro power industries. The objectives of this research was to (1) to determine the effectiveness of the existing noise control strategies at ZPC-Kariba, (2) to determine and assess the noise production areas, (3) to explore possible ways of reducing Noise Induced Hearing Loss at ZPC Kariba. Data was collected through questionnaires to identify hazards and measure noise levels using a sound level meter. The sample group included employees from various work sections such as mechanical engineering, electrical engineering, SHE, Human Resource, Garage, Finance, Loss Control, and Stores. The research utilized questionnaires, noise measurements, and observations to gather necessary data. A total of 129 questionnaires were distributed to evaluate employees' awareness of common noise hazards and noise-induced hearing loss but only 102 questionnaires were answered. Descriptive analysis was conducted using SPSS version 22 to determine frequencies and percentiles. Results indicated common noise issues such as ringing in the ears (4.9%), pain (13.7%), and difficulty hearing ordinary speech (14.8%). The study findings revealed that noise levels at ZPC-Kariba often exceed the legal limit of 90dB, with areas like turbines reaching 110dB, spillways at 100dB, intakes at 99dB, and penstocks at 94dB. Therefore, it is unsafe to work without noise reduction interventions in place. The study recommended the use of earplugs, earmuffs, and noise reduction techniques as common preventive measures. It also suggested implementing engineering controls by redesigning the workplace, tools, and equipment, as well as utilizing administrative controls through preventive programs and noise-induced hearing loss training. Monitoring and evaluating control measures through regular audits and feedback mechanisms were also recommended by the study.

TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

HPD………………………………… Hearing Protection Devices

NIHL……………………………..... Noise Induced Hearing Loss

NIOSH……………………………… National Institute for Occupational Safety and Health

NIT………………………………….. Noise Induced Tinnitus

PPE………………………………….. Personal Protective Equipment

SOPs………………………………… Standard Operating Procedures

ZPC………………………………….. Zimbabwe Power Company

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Hearing impairment is a significant health issue worldwide, as indicated by the World Health Organization (WHO., 2019). Exposure to loud environments over time can cause permanent damage to the auditory system, resulting in noise-induced hearing loss (NIHL), a type of sensorineural deafness (Natarajan et al., 2023). Hearing loss caused by occupational noise exposure is a widespread problem, ranking among the most common work-related illnesses worldwide (Chen et al., 2020). As reported by Haile et al. (2021), the WHO's Global Burden of Diseases statistics (2019) indicate that hearing loss affects approximately 1.57 billion individuals globally, accounting for 20.3% of the population, with the majority (62%) of cases occurring in individuals above the age of 50. WHO projects that occupational noise exposure is responsible for around 16% of hearing loss cases in adults globally (WHO., 2019). The actual impact of NIHL in developing nations remains unclear due to limited public records and research funding on NIHL, although various studies in Africa have shed light on this issue (Khoza-Shangase et al., 2020).

The impact of occupational NIHL is rarely investigated in Africa. Research done among steel rolling mill workers in Nigeria found that they were not adequately informed about the risks of NIHL and that they were not motivated to wear Hearing Protection Devices (HPDs). A recent South African research found flaws in standard operating procedures for early detection of individuals at risk for NIHL, as well as a lack of proper use of hearing conservation strategies in the iron and steel sector.

NIOSH reports that a significant proportion of workers approximately one in ten, or over 30 million individuals are exposed to unsafe noise levels at workplaces, posing a risk to their hearing and overall well-being. Hearing damage is a prevalent risk in the power generating industry, where workers are constantly surrounded by noisy equipment and gear. In Zimbabwe the power generation industry is especially vulnerable to NIHL due to ageing infrastructure and insufficient maintenance processes. Noise induced hearing loss is one of Zimbabwe’s top 5 work related occupational illnesses it is also one of the top three compensable work-related illnesses, after pneumoconiosis and backaches (Mapuranga et al., 2020). Although studies which has to do with noise caused hearing loss has been done in Zimbabwe, there is little evidence which suggests that it has been done in hydro power sectors (Chigwada et al., 2019 & Mapuranga et al., 2020).

Kariba South Power Station (ZPC Kariba) is a hydro power generating company that is responsible for generating most of the electricity used in Zimbabwe, thus creating employment for many people. These employees are key players in the daily operations at the power station, ensuring its smooth and efficient functioning and are exposed to large amounts of noise in the process. To safeguard the hearing health of workers and comply with occupational safety regulations, hydro power stations implement various control strategies to mitigate noise levels and reduce the risk of NIHL. However, it is important to carefully analyze the effectiveness of these strategies in the context of hydro power.

This research endeavors to examine the effectiveness of ZPC Kariba's hearing conservation programs in reducing the incidence of noise-induced hearing loss among employees. By evaluating the existing control measures and their impact on reducing noise exposure, the study seeks to provide insights into the efficacy of these strategies and identify areas for improvement.

1.2 PROBLEM STATEMENT

The implementation of noise mitigation strategies at ZPC Kariba aims to safeguard workers from hearing loss, but their actual impact remains unclear. Considering the intense noise environment characteristic of hydro power stations, evaluating the success of these initiatives and identifying areas for refinement is crucial to optimize hearing protection for ZPC Kariba’s workforce.

1.3 JUSTIFICATION

This research aims to investigate the effectiveness of noise control initiatives at ZPC Kariba, shedding light on best practices for protecting workers’ hearing. Given the limited research attention devoted to this critical issue in hydro power stations, this research endeavors to fill this knowledge void and expand the existing understanding of occupational diseases in the energy industry. Furthermore, the study's findings can have far-reaching implications, informing the development of best practices for noise management in other high noise risk industries, like construction, manufacturing, and mining, and ultimately contributing to a safer working environment for workers across various sectors.

1.4 AIM

- To evaluate the effectiveness of noise induced hearing loss control strategies at Zimbabwe Power Company – Kariba South Power Station

1.5 OBJECTIVES

- To determine the effectiveness of the existing noise control strategies at ZPC-Kariba.
- To determine and assess the noise production areas.
- To explore possible ways of reducing Noise Induced Hearing Loss at ZPC Kariba.

1.6 RESEARCH QUESTIONS

- How effective are the noise control methods currently in place at ZPC Kariba in protecting workers' hearing and reducing the incidence of noise-induced hearing loss?
- What are the most effective ways to reduce noise levels in the workplace and prevent noise-induced hearing loss among employees?

1.7 LIMITATIONS OF THE STUDY

This research has various potential limitations. First and foremost it may be difficult to account for all the variables that could impact the effectiveness of noise-induced hearing loss control strategies, which could lead to incomplete or inaccurate findings. Secondly, the study's short duration may not capture the long-term effects of these strategies, which could be a crucial aspect of evaluating their success. Additionally, measuring the long-term effects may be complicated by worker turnover, study dropout or changes in job roles over time.

Moreover, the effectiveness of the control strategies relies on consistent implementation and compliance from both workers and management, which can be challenging to ensure. The effectiveness of the control strategies may be impacted by various factors, including inconsistent implementation, use of personal protective equipment (PPE), and exposure to other occupational hazards, which could lead to variable outcomes. Therefore, it is crucial to consider these limitations and potential confounding factors when interpreting the research findings to ensure a comprehensive understanding of the results.

CHAPTER 2: LITERATURE REVIEW

2.1 HYDROPOWER STATIONS

Hydroelectric power stations are of paramount importance in the process of producing electricity on a global scale according to Kumar and Saini (2022). It is widely acknowledged that hydropower stands as the foremost renewable energy source utilized for the generation of electrical power on a worldwide basis, catering to a significant 19% of the total energy demands of the planet. When compared to alternative renewable energy sources, hydropower plants exhibit a level of efficiency that is notably superior, thereby making a substantial contribution of approximately 24% to the overall electricity provision across the globe, thereby positively impacting the lives of more than 1 billion people as highlighted by Kuriqi et al. (2021). As reported by the National Renewable Energy Laboratory, the worldwide hydropower capacity totals 675,000 megawatts, which is equivalent to 3.6 billion barrels of oil in terms of energy output (Kumar& Saini 2022).

2.2 NOISE

Noise, an unwanted sound, is commonly found as a by-product in various industries, especially in hydro power stations. It is identified as a prevalent occupational hazard, impacting around 600 million workers globally. As indicated by Berawi et al. (2019), the arrangement and layout of work environments can contribute to the presence of undesired noise pollution, thereby resulting in stress among workers. Exposure to elevated levels of occupational noise (sound intensity surpassing 90 dB A) has been firmly established as a primary contributor to Noise-Induced Hearing Loss (NIHL) among industrial laborers, thus underscoring noise exposure as a notable hazard in work environments (Abbasi et al., 2024). In actuality, exposure to undue noise constitutes 37% of all instances of hearing disability in grown-ups and remains a significant element in occupational health concerns on a global scale. As per the Factories and Works Act (Chapter 14:08), a noise level of 90dBA is the maximum permissible exposure for individuals without appropriate ear protection.

2.3 NOISE PRODUCTION AREAS AND EQUIPMENT IN HYDROPOWER STATIONS

According to Quaranta &Miller (2021) sources of noise in hydropower stations can be attributed to various factors. Here are some common sources of noise in hydropower stations: The hydro turbine is the central component of a hydropower plant, and the proper functioning and maintenance of its various components are vital for maximizing energy production; Hydropower stations consist of a significant amount of machinery, such as turbines, air compressors, and rotors, which can generate high levels of noise. Water flow: The intense roar of water flowing through the penstocks and over the turbines can contribute to high noise levels in certain areas of the power plant Vibration: Vibrations caused by the operation of machinery and water flow can also generate noise in hydropower stations. Reverberation: The design of some older hydropower plants, with hard concrete walls, can magnify sound and cause reverberation, leading to increased noise levels in Zimbabwe.

2.4 NOISE INDUCED HEARING LOSS (NIHL)

Noise induced hearing loss (NIHL) is a permanent damage to the auditory nerves caused by a number of variables, including the kind of noise (sustained or abrupt), duration of exposure, intensity, and frequency. Research conducted by Hang et al. (2019) highlighted NIHL as a prevalent occupational hazard globally and the second most frequent form of auditory nerve damage. Continuous exposure to loud noise can cause sensorineural deafness, also known as noise induced hearing loss (NIHL) (Golmohammadi & Darvishi., 2019). Chen et al. (2020) emphasized that industrial noise impairs many workers' auditory capability and has a number of well-documented detrimental effects on their health, including tiredness, sleep difficulties, irritability, and work related hearing loss. According to the WHO's estimates, roughly 466 million people worldwide suffered serious hearing impairment in 2020, a figure expected to almost quadruple by 2050, with approximately 60% of cases avoidable (Olusanya et al., 2019).

NIHL is the predominant occupational ailment on a global scale, affecting around 7% of the adult population due to exposure to loud noises in the work setting as stated by the World Health Organization (WHO). Recent scholarly investigations have centered on the identification of noise levels and the most effective strategies for reducing noise in diverse occupational settings. Research has demonstrated that factors such as architectural design, noise-producing machinery, and the overall work atmosphere play a crucial role in determining the noise levels present in workplaces. The severity of NIHL is contingent upon the loudness, duration, and frequency (or pitch) of the noise. According to Golmohammadi and Darvishi (2019), advancing age has been proposed as a potential risk factor for NIHL.

2.5 TINNITUS

Tinnitus, as defined by, Santis et al. (2021) is the conscious awareness of a sound in the head or ears that is not caused by an external source. Exposure to noise has the potential to induce this condition, which can significantly impact the daily life of individuals, particularly workers, and lead to a decline in their overall work productivity. The prevalence of tinnitus and hearing impairment resulting from noise exposure is a prevalent issue among adults, posing a significant health concern in contemporary societies (Kang et al., 2021, Lewkowski et al., 2022, Kohansal et al., 2021). Individuals with occupational noise exposure commonly report challenges in speech recognition and the presence of tinnitus. Occupational noise exposure has been widely linked to the development of Noise-Induced Tinnitus (NIT), affecting a notable percentage of workers, with studies suggesting a prevalence of 8.7% to 29.7%, as reported by Biswas et al. in 2021.

2.6 STRATEGIES FOR REDUCING NOISE INDUCED HEARING LOSS

WHO (2022) reports a significant disparity in noise stimulated hearing loss prevalence amongst underdeveloped and industrialized nations, largely attributed to inadequate noise reduction initiatives and a lack of understanding about excessive noise exposure risks. To combat this, noise surveys are necessary to detect and effectively mitigate overexposure. Moreover, controlling occupational noise in hydropower stations is essential for maintaining a safe and productive work environment. A range of noise-control measures exist, including engineering controls (such as noise source elimination or substitution), administrative controls (like work practice modifications and policy implementation), and personal protective equipment (PPE) for workers, supported by regular surveillance (Chen et al., 2020). Thus, implementing administrative and engineering noise control measures is crucial to address noisy environments in hydropower stations.

2.6.1 ADMINISTRATIVE NOISE CONTROLS

Golmohammadi and Darvishi (2019) define administrative controls as a range of workplace policies, procedures, and practices aimed at reducing employees' exposure to noise hazards. These measures include providing personal protective equipment like earplugs, muffs, and helmets to workers exposed to high occupational noise levels, as well as strategies like limiting work hours in noisy environments, task rotation, training, and regular hearing check-ups (WHO, 2021 & Natarajan et al., 2023). Although administrative controls are essential, they are considered less effective than engineering controls, which directly eliminate the hazard at its source. The Factories and Works (General) Regulations of 1976 in Zimbabwe stipulate that workers must be provided with proper ear protection when working in environments with sound levels above 90 dBA, also highlighting the importance of administrative controls in preventing noise-induced hearing loss.

2.6.2 ENGINEERING NOISE CONTROLS

Engineering controls are physical modifications to tasks, processes, workstations, tools, and equipment that serve to prevent injury or hazard (tikka et al., 2020). Engineering controls can help to limit harm hazards. Engineering controls include selecting a process with reduced sound pressure, using acoustic barriers, and dampening (Israel et al., 2020).

2.6.3 PERSONAL PROTECTIVE EQUIPMENT’s

Evaluation of the effectiveness of the interventions that were put in place has produced different outcomes. Despite this, researches indicate that a holistic hearing conservation program, which involves supplying and using hearing protection devices (HPDs), could be successful, particularly in situations where noise control through administrative and engineering methods is not possible (Gong et al. 2019). This type of intervention has been linked to a decrease in noise-induced hearing loss (NIHL). Personal Protective Equipment (PPE) is usually considered as a last resort since it does not completely remove the noise risks, but it can help in reducing or limiting exposure to the hazards (Khoza-Shangase et al., 2020) & Natarajan et al., 2023). PPE is utilized when the hazards cannot be controlled at the source. Examples of PPE include helmets, safety shoes, gloves, goggles, earmuffs, among others, all of which offer protection and safeguard the worker from the hazards, thereby reducing exposure (Israel et al., 2020).

CHAPTER 3: RESEARCH METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

The Kariba South power station, situated in the Mashonaland West region of Zimbabwe, is a hydroelectric power facility with an installed capacity of 1,050MW, making it the country's largest power plant. Located on the Zambezi River in the Kariba Gorge, the power station is positioned at longitude 28.76476 East and latitude 16.52154 South. The facility was initially commissioned between 1959 and 1962 with six producing units, which have been generating electricity for over six decades. In March 2018, the power station underwent an expansion with the addition of two new units, each with a capacity of 150MW, further increasing its power generation capabilities. This expansion has enabled the Kariba South power station to play an even more critical role in meeting Zimbabwe's electricity demands, supporting economic growth and development in the region.

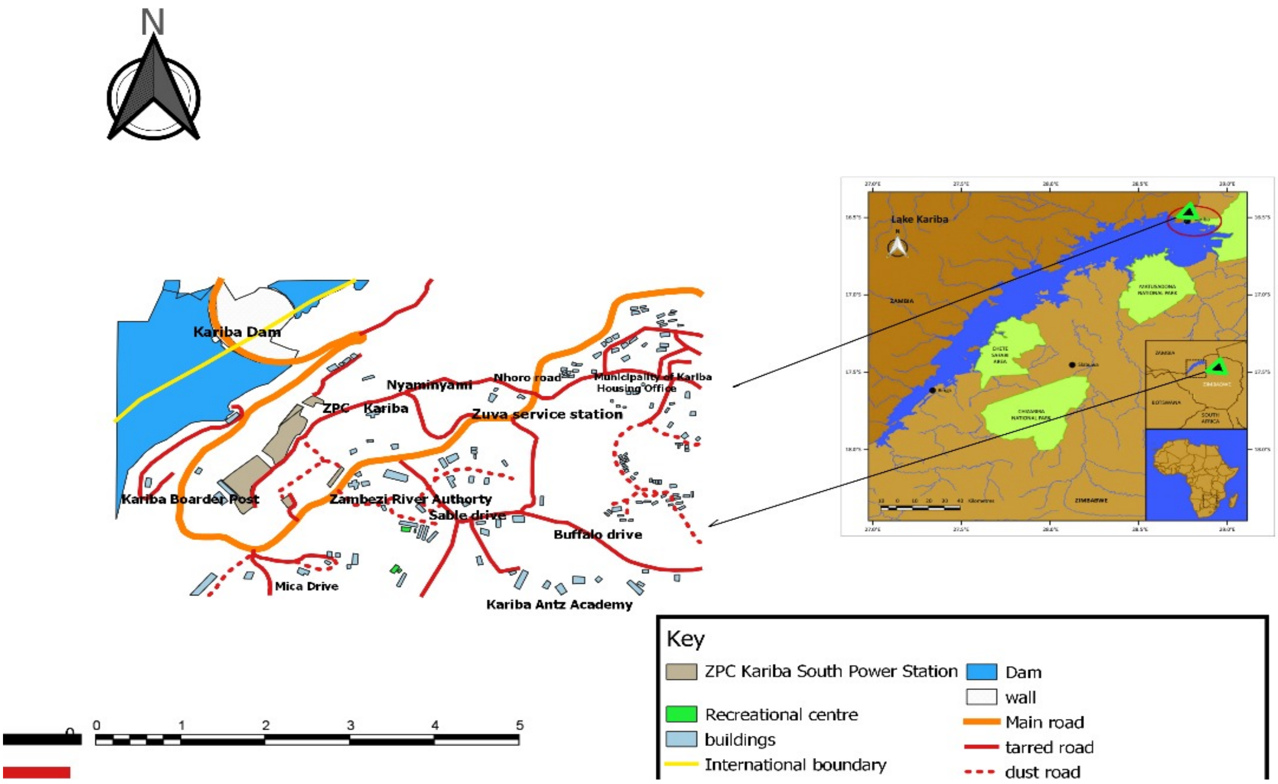


Fig 3.1 Study area map

3.2 THE RESEARCH DESIGN

A cross-sectional research method was used in this study to collect and analyze data at a single point in time. This research approach collects data from a large number of participants at a single time point, providing a cross-section of their experiences, characteristics, and outcomes. Using this strategy, the researcher was able to acquire insight into the noise and noise-related issues at their ZPC Kariba. The research was aimed at both full-time ZPC-Kariba workers and contractors. A quantitative research technique was utilised.

3.2.1 STUDY POPULATION

A study population refers to a total number of people for whom investigational data will be collected. As a result, all ZPC Kariba South Power Station employees are included in the study's target population. This population consists of all of the workers in the company's operational departments. The study also included workers from the departments of administration, HR, SHE, electrical, mechanical, and civils.

3.3 SAMPLE AND SAMPLING PROCEDURES

The researcher employed purposive sampling in the selection of ZPC Kariba as a study area. This was because this is where the researcher was familiar with the organization. Therefore, it was convenient to get information from the employees, management, customers and operations. A random sample of workers with 5 or more years of service, who worked in close proximity to noise production areas and had knowledge of noise induced hearing loss, were selected to participate in the research. The random sampling was done using a formula by Slovin.

Sample Size = N / (1 + N*e2)

n = sample size

N = population size (351)

e = significance level which is 0.07

n = 351 / (1 + (351 * 0.07^2))

n = 351 / (1 + (351 * 0.0049))

n = 351 / (1 + 1.7229)

$n = 351 / 2.7229$

$n \approx 129$

The sample size was 129 workers so the researcher handed out 129 questionnaires but only 102 questionnaires were responded to.

3.3.1 SAMPLING DESIGN

To achieve reliable results, stratified systematic random sampling was utilised in this study, with all elements selected fairly. The researcher collected information from instructive documents and a sample of workers. Departments within the organisation determined strata, and selection was made based on the number of individuals inside them. Mechanical engineering, electrical engineering, SHE, human resources, garage, finance, loss control, and stores were among the departments organised into strata. To reduce bias, simple random sampling was used inside each stratum. The primary researcher enumerated all of the workers who had access to or worked in the power plant and areas where noise was produced, who had 5 or more years of experience working at the hydropower station and documented cases of hearing loss and related symptoms, Those who fell outside the range were excluded until a sample of 129 workers was selected.

3.3.2 INCLUSION AND EXCLUSION CRITERIA

The sample included workers who were directly involved in the underground power plant operations, those who frequently visited the power station, and those who worked in close proximity to the diesel generators. However, full-time office workers were not included in the sample, as they were not directly exposed to the noise hazards

3.4 DATA COLLECTION INSTRUMENTS

This study was based on primary data acquired using self-administered questionnaires and noise measurements.

3.4.1 QUESTIONNAIRES

A pre-designed questionnaire was utilized for data collection from research participants on their demographic attributes, awareness of hearing protection, and its use. The researcher administered 129 questionnaire guides to the employees who were selected within the sample using stratified systematic random sampling. The study also included weekly observations of both surface and underground operations while employees were working. In addition, the researcher conducted informal participant observation by visiting different workstations with a booklet of standard operating procedures (SOPs) relevant to each job. The researcher also conducted planned job observations to check whether employees followed expected standard operating procedures.

3.4.2 MEASUREMENTS

Measurements were taken so as to determine the amount of noise the workers were exposed to. These measurements were taken at different work sites using the sound level meter. Measurements were taken so as to determine the amount of noise the workers were exposed to. These measurements were taken at different work sites using the sound level meter.

The researcher used the following steps in taking the measurements:

1. Choose the suitable sound level meter: The researcher selected a sound level meter that complies with the International Electrotechnical Commission (IEC) standard for reliable sound level meters (IEC 61672-1).

2. Calibrate the sound level meter: The researcher ensured that the sound level meter was calibrated and within the acceptable range, as per the manufacturer's instructions, prior to collecting any data.

3. Identify measurement locations: The researcher determine the specific areas within the hydro power plant where the noise was to be measured. These included turbine halls, control rooms, transformer areas, generator areas and outdoor locations near the plant.

4. Set up the sound level meter: The sound level meter was mounted on a tripod to keep it steady during measurements. The microphone was then situated at a height of

roughly 1.5 meters, corresponding to the average height of a worker's ear, to measure the noise levels they were experiencing.

5. Take measurements: the researcher then turned on the sound level meter and took measurements at each identified location within the hydro power plant. The noise levels were recorded in decibels (dB) at regular intervals, such as after 30 minutes, in order to capture variations in noise levels over time.

6. Analyze the data: After collecting the noise level measurements the data was analysed so as to identify any patterns or trends in noise levels at different areas of the hydro power plant. Then the measured noise levels were compared against applicable regulatory limits.

7. Document and report findings: Lastly the researcher documented the findings summarizing the noise level measurements at each area of the hydro power plant, including any significant findings or observations.

3.5 ETHICAL CONSIDERATIONS

The study was conducted considering moral implications which include informed consent and confidentiality. Informed consent was emphasized to ensure voluntary participation of the respondents. This allowed the participants to willingly contribute to the study. Participation was voluntary and confidential, with participants guaranteed that the study solely was for learning purposes and that their anonymity would be maintained throughout. To prevent any undue influence or intimidation, it was explicitly stated that no names or personal identifiers would be included in the research report.

3.6 DATA ANALYSIS

The questionnaire data was collected, analyzed, and stored using the SPSS software. The collected data was organized and presented in tables, and a descriptive analysis was conducted using the crosstabs function in SPSS version 22.The program was used to gather frequency and percentile data.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

This chapter offers a summary of the research findings, with results displayed in a clear and organized manner through the use of tables, charts, and graphs, allowing for effective communication and understanding of the data.

4.2 DEMOGRAPHIC DETAILS OF WORKERS

Figure 4.1 demonstrates that ZPC Kariba is dominated by male workers, with 17% of the 102 employees being female and 83% male. The respondents' ages ranged from 20 to 60. The age range 31 to 40 had the most replies (44.1%), while the age group 51 to 60 had the fewest (7.8%). The distribution of respondents' occupations reveals that 31.4% work in the mechanical department. This is followed by 25.5% who worked in the operations department, 22.5% in the electrical sector, 11.8% in HR and Administration, and 8.8% in loss prevention.

Table 4.1 Respondents demographic details

Variable	**Frequency**	**Percentage**
Gender		
Male	85	83.3
Female	17	16.7
Age		
20- 30	30	29.4
31 - 40	45	44.1
41 - 50	19	18.6
51 - 60	8	7.8
Department		
Loss Control	23	8.8
Operations	32	25.5
HR & Administration	12	11.8
Mechanical	26	31.4

Electrical	9	22.5

4.3 EFFECTIVENESS OF THE EXISTING NOISE CONTROL STRATEGIES AT ZPC KARIBA.

Table 4.2 shows noise production areas and the levels of noise produced at each area. The level of noise was measured using the sound level meter. Although controls were put in place, some areas still had noise levels above the allowable maximum of 90 dBA, suggesting that additional noise mitigation strategies are necessary to ensure compliance with safety standards. The turbine areas had the most noise production 110dB and the least is the control room with 85dB.

Table 4.2 Noise levels before and after installation of controls

.Location	Noise levels before installation of controls (dBA)	Noise levels after installation of controls (dBA)	Noise level reduction(dBA)
Turbine	115	110	5
Penstock	99	94	5
Cooling Water area	102	92	10
Generator transformer platform	93	91	2
Control room	95	85	10
Main floor	91	87	4
Mechanical workshop	98	93	5
Intakes	100	97	3
Diesel generator	92	88	4
Spillway	103	100	3
Pumping Station	104	101	3

Figure 4.2 below shows the type of hearing problem experienced at the workplace before and after the implementation of controls. Results indicate that the before the implementation of noise controls (1999 and below) the number of workers with hearing problems was high compared to after the controls were put in place (2000 till date). Inability to hear ordinary speech had the highest change of 10.8 (from 25.5% before implementation to 14.7 after implementation), followed by pain in the ears which had a decrease of about 8.7%, ringing in the ears had 6.6% decrease and lastly other hearing problems decreased by 2.7%.

Fig 4.1 Type of hearing problem experienced before and after implementation of controls.

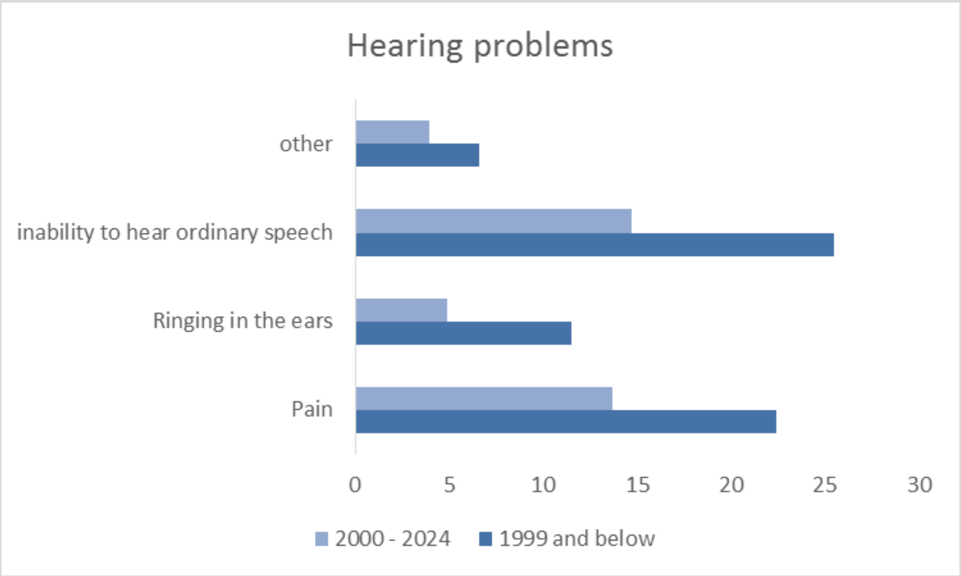


Table 4.3 below displays the distribution of hearing problems among the workers with 44.1% having hearing problems. The department with the highest percent of hearing problem is the mechanical department, this is because these workers work in the underground power plant where there is a lot of noise produced by machinery and also their work station is located there so even if they are not working they will still be exposed to noise. The second is the electrical department followed by the operations department which also works in the underground power plant but they do shifts and rotate to other working stations. The loss control department and the HR department had the least number of participants with hearing problems; this is because they do not work at noise production areas all the time so the

exposure is less. The occurrence of hearing problems indicates that noise the control strategies available are not that effective.

Table 4.3 Distribution of respondents with hearing problems by their department.

Department	Frequency	Percent
Loss control	3	3.3
Operations	9	9
HR and admin	4	2.7
Mechanical	16	16.4
Electrical	13	12.7
Total	**45**	**44.1**

4.4 NOISE PRODUCTION AREAS AT ZPC KARIBA

Table 4.4 below shows the noise production areas and the levels of noise produced at each area. The turbine area had the most noise production with 110dB and the least was the control room with 85dB.

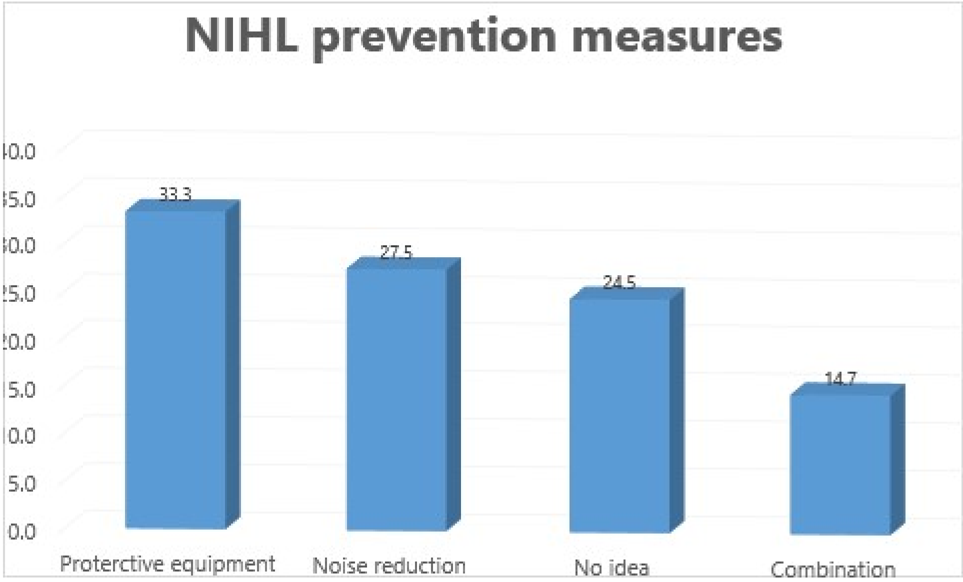
.Location	Noise levels (dBA)
Turbine	110
Penstock	94
Cooling Water area	92
Generator transformer platform	91
Control room	85
Main floor	87
Mechanical workshop	93

Intakes	97
Diesel generator	88
Spillway	100
Pumping Station	101

4.5 NOISE INDUCED HEARING LOSS CONTROL STRATEGIES

Figure 4.2 shows the respondents' recommendations for preventing or minimising exposure to noise and mitigating noise induced hearing loss. The most commonly cited control measure was the use of PPE followed by noise reduction measures, and then the combination of both protective equipment and noise reduction measures.

Fig 4.2 Noise control strategies



CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This chapter provides a comprehensive analysis of the research data, carefully evaluating its alignment with the study's research questions and objectives. The aim of this chapter is to dissect the findings, revealing their underlying meaning and implications in the context of the research questions and goals.

5.2 EFFECTIVENESS OF THE EXISTING NOISE CONTROL STRATEGIES

The findings indicate that the implementation of controls successfully reduced the incidence of hearing issues among workers; nevertheless, their efficacy remains inadequate as a portion of workers continue to experience such problems. These findings also indicate that the current noise control measures at ZPC-Kariba, which involve the utilization of ear plugs and earmuffs, are insufficient, with earplugs and earmuffs being the most commonly employed noise reduction tools. This observation aligns with a research done by Khoza-Shangase et al (2020), revealing that effective hearing protection methods like earmuffs and earplugs can mitigate the impact of loud noise exposure; however, compliance may be hindered by the devices' interference with communication and discomfort during use. The successful prevention of hearing loss due to exposure to loud noise through hearing protection devices hinges on proper training, consistent use, and regular monitoring, as emphasized by Tikka et al.(2020). Nonetheless, the discomfort associated with wearing hearing protectors can significantly influence individuals' adherence to their usage and subsequently impact their effectiveness in reducing NIHL (Barcelos et al., 2023).

Although many survey participants reported using hearing protection devices when around loud noises, observations revealed a lack of adherence to wearing these devices. This noncompliance may be attributed to the discomfort experienced while using hearing protective equipment. HPDs' efforts to prevent hearing loss can be impeded by discomfort, which may result in workers removing them or wearing them incorrectly, thereby reducing their effectiveness. Barcelos et al., 2023 support this idea by suggesting that discomfort from using hearing protectors strongly impacts adherence and, consequently, their ability to prevent NIHL. The World Health Organization (2021) highlights the critical importance of implementing robust hearing protection programs in high-noise environments like hydro power stations, where workers will be prone to developing noise stimulated hearing loss. This concern is supported by previous research (Gong et al., 2019) that identified gaps in the use and effectiveness of HPDs in workplaces, highlighting the need for enhanced hearing protection measures.

The study by Gong et al. (2021) also noted that the mere mandate of wearing earplugs over several years did not show any visible impact on averting hearing impairment at the automobile components plant. Inadequate fitting and irregular usage of earplugs have been identified as directly linked to the excessive exposure of employees to harmful noise. This factor is likely the primary contributor to the heightened prevalence of hearing loss documented within the factory under examination. Suggestions put forth encompass the supervision of workers to ensure consistent earplug usage and the adjustment of workplace policies within the framework of the occupational health and safety initiative. It has been observed that presently, the efficacy of earplug usage in preventing occupational hearing loss at some factories is limited. Furthermore, the exclusive provision of hearing protective devices (HPDs) to the labor force could potentially pose a hindrance to the successful implementation of a comprehensive hearing impairment prevention strategy.

The outcomes of the comprehensive investigation into the efficacy of promoting interventions for hearing protection devices, including earmuffs, among workers indicated a noticeable enhancement in results. These interventions centered on employing suitable communication strategies to modify worker behaviors. It was observed that combined interventions, such as the utilization of posters, distribution of hearing protection devices, noise evaluations, and hearing examinations, proved to be more successful in enhancing worker adherence to hearing protection devices compared to solely conducting hearing tests(Rabinowitz et al. 2021, Fauzan et al. 2023).

5.3 NOISE PRODUCTION AREAS AND NOISE LEVELS IN HYDROPOWER STATIONS

Results show that noise is mostly produced in the underground power station and in areas like the turbines, penstock area and generator transformer. These results are in line with Quaranta & Miller, (2021) who stated that those areas that have noise levels above 90dB which is the standard noise level one should be exposed to or less in an 8hr shift (WHO., 2021).

An agreement among researchers shows that being exposed to noise levels noise as low as 82 dBA, for an extended period, can cause hearing loss in some individuals (Quaranta & Miller, 2021). Power plants, including hydropower facilities, are amongst the noisiest work places, with many workers being exposed to levels of noise between 80-90 dB, according to routine monitoring (Watchalayann & Laokiat, 2019). The hydro turbine, a critical component of hydropower plants, requires regular maintenance to ensure optimal energy generation and also reduced noise levels. However, workers in these plants are often exposed to high noise levels, with a study revealing that employees in a hydroelectric power plant were regularly exposed to noise levels ranging from 95-110 dB, which leads to cumulative hearing loss over time. Prolonged exposure to noise levels exceeding 70 decibels can lead to progressive hearing loss over time, whereas noise exceeding 120 decibels can cause instantaneous and permanent damage to hearing. The results also show that most of the noise levels experienced by most of the workers is between high and very high. According to Watchalayann & Laokiat (2019), hydropower plants produce large amounts of noise which mostly affect workers and therefore cause noise problems like pain and ringing in the ears. In a research by Zahirovic et al, (2021) pain, ringing in the ears and inability to hear ordinary speech where the main noise problems that were stated by his respondents in a mining area. These finding are similar to the results of this research which also shows that the mentioned problems above are the main noise problems experienced by the workers at ZPC Kariba.

5.4 POSSIBLE WAYS OF REDUCING NIHL

The results of measures that can be applied to prevent noise stimulated hearing loss among hydroelectric power plants workers show that use of protective devices for ears such as ear plugs and ear muffs and noise reduction was the commonly known preventive measure that can be applied. This finding is consistent with the research conducted by Tikka et al. (2020), which demonstrated that effective hearing protection devices, such as earplugs and earphones, can significantly reduce the risk of noise-induced damage. However, the study also highlighted that the use of these devices may be hindered by concerns about impaired communication and physical discomfort, leading to limited compliance. Israel et al. (2020) supports these results, and their study emphasizes that ear protection is crucial in reducing noise stimulated hearing loss amongst workers, but also stresses the importance of complementing this with other control measures, such as engineering and administrative interventions, to achieve optimal hearing protection.

Prevention is key in addressing noise induced hearing loss (NIHL), and a multifaceted approach which includes education, regulations, and laws can help mitigate its impact, raise awareness, and prevent noise-related harm (Natarajan et al., 2023). Hearing protection devices (HPDs) like earplugs and earmuffs play a vital role in safeguarding against noise exposure. Correct insertion of earplugs, covering the entire ear canal, is essential for effective protection and minimizing irritation. The cornerstone of reducing NIHL's substantial burden lies in preventing noise-induced cochlear damage, primarily through use of hearing protection in both workplace and leisure environments (Natarajan et al., 2023). Furthermore, a study has demonstrated that effective training in the use of earplug can significantly improve the effectiveness of HPDs, even outperforming devices with higher noise reduction ratings (Smalt et al., 2020).

Besides limiting noise exposure, wearing hearing protection devices like earplugs and earmuffs is a crucial preventive measure. However, the success of these devices in preventing hearing loss hinges on proper usage and maintenance. Unfortunately, the discomfort associated with wearing hearing protection can hinder its consistent use, thereby compromising its effectiveness in preventing NIHL (Barcelos et al., 2023).

When the sound pressure level exceeds 100 or 105 dB, double-hearing protection is recommended (Barcelos et al., 2023). According to NIOSH, if earplugs or earmuffs alone are insufficient to mitigate workplace noise, employers should implement dual protection with amplification to provide additional hearing protection for their employees. The degree of attenuation should be taken into account between 5 and 10 dB (NIOSH 2023) This value can therefore be achieved by combined use of HPDs, such as earmuffs and ear plugs, to prevent hearing loss. However, double hearing protection can hinder spatial perception due to the blocking effect and prevent simultaneous speaker recognition in the working environment.

When engineering and administrative approaches to the control of noise are not possible, a comprehensive hearing protection program that includes providing and using hearing protection devices can still be efficient. Nyarubeli et al. (2020) study found that these interventions are linked to a lower occurrence of noise stimulated hearing loss, highlighting the importance of hearing protection programs in safeguarding hearing health. Monitoring engineering and/or administrative sectors, training professionals on the use of PPEs and HPDs, and implementing hearing conservation program (HCPs) are essential strategies that, combined alone or combined, can affect positive hearing health and/or exposure to noise (Basu and Darvishi, 2022).

The most effective approach to noise control in workplaces is to substitute noisy equipment, a strategy known as 'control at the source.' This method is prioritized based on factors such as feasibility, efficacy, and applicability, as it directly addresses the root cause of noise (Abbasi et al., 2024). Additionally, acoustic enclosures can significantly reduce noise levels by up to 20dB. According to Abbasi et al. (2024), combining noise-resistant metal doors and shutters can lead to a 6dB (A) reduction in noise. While modifying walls may be challenging, simple measures like adding absorption foam to doors or closing windows and doors can effectively block noise transmission.

CHAPTER 6: CONCUSION & RECOMMENDATIONS

6.1 INTRODUCTION

This chapter synthesizes the study's results, deriving conclusions that directly address the research questions and objectives. Furthermore, this chapter provides stakeholders with useful recommendations, outlining steps to take in order to address the study’s findings and improve the current situation. These suggestions intend to inform and guide future actions, ultimately contributing to meaningful improvements and progress.

6.2 CONCLUSIONS

- ❖ The existing noise control strategies are not effective enough as the cases of noise induced hearing loss and hearing problems are still there even after the implementation of these controls.
- ❖ Noise was mostly produced underground where there were machinery like turbines which produce high levels of noise.
- ❖ The majority of respondents emphasized the importance of noise reduction strategies and the use of appropriate protective gear as the most effective ways to minimize noise exposure and reduce the incidence of noise induced hearing loss.

6.3 RECOMMENDATIONS

From the study results it can be recommended that

- ❖ Engineering controls should be implemented through the redesigning of the workplace, tools, and equipment to address the need and create a safer and healthier work environment.
- ❖ The company should implement administrative controls by introducing preventive programs and providing training on noise-induced hearing loss. This will ensure that employees are informed about noise hazards and control measures, such as wearing ear protective equipment in noisy environments.

Ultimately, it can reduce noise-related risks in the workplace, leading to improved employee health and productivity.

- ❖ Awareness training should be carried out at all levels to enhance employees' understanding of noise-induced hearing loss.
- ❖ The organization should promote job rotation and employee movement away from the power station to allow for sufficient rest periods, thereby minimizing exposure time to noise.
- ❖ Collaborate with relevant stakeholders, including regulatory bodies and health professionals, to ensure compliance with noise control regulations and standards.
- ❖ Monitor and evaluate the effectiveness of control measures through regular audits and feedback mechanisms.

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APPENDICES

QUESTIONNAIRE

TOPIC: AN ANALYSIS OF THE EFFECTIVENESS OF NOISE INDUCED HEARING LOSS CONTROL STRATEGIES: A CASE STUDY OF ZIMBABWE POWER COMPANY – KARIBA SOUTH POWER STATION

My name is Ropafadzo K Katyamaenza, a student at Bindura University of Science Education. Currently, I am pursuing a Bachelor of Environmental Sciences honours degree in Safety, Health, and Environmental Management. My research focuses on evaluating the effectiveness of noise control strategies at ZPC Kariba. Your participation in this survey, given your daily involvement with the project, would be greatly appreciated. Your privacy is guaranteed; any information provided will be kept completely confidential and utilized solely for the purpose of academic investigation, with no disclosure to external parties.

May I kindly request you to indicate tick where appropriate.

QUESTIONNAIRE No…..………….
Date ……/……/…….

SECTION A

Occupation ……………………………………. Work Site…………………………….
Age………………………………………………. Sex M/F
Marital status….…………………………

1. Have your ears ever been checked to see whether you have any hearing loss?
   a) Yes ( )
   b) No ( )

If yes, when were you last examined?

………………………………………………………………………..

2. Do you have any hearing problems? …

a) Yes ( )

b) No ( )

If yes, how would you describe them?

a) Pain………

b) Ringing in the ears…

c) Inability to hear ordinary speech

d) Other………

SECTION B

3. How would you describe the level of noise at your worksite?

a) Negligible…………

b) Low……………….

c) High………………

d) Very High…………

4. Do you frequently get ringing in your ears at the end of your shift?

a) Yes ( )

b) No ( )

5. Have you ever heard of Noise Induced Hearing Loss?

a) Yes ( )

b) No ( )

If so, what do you think can cause it in workers?

Loud noise …………………….

No Idea ………………………..

Others………………………….

SECTION C

6. Aside from your current employment, have you ever worked in a workplace with high noise levels?

a) Yes ( )

b) No ( )

7. How would you describe the sort of noise you are exposed to at work?

a) Continuous ( )

b) Intermittent ( )

c) Impact ( )

8. Do you engage in any other tasks that generate excessive noise after work?

a) Yes ( )

b) No ( )

9. Have you ever worked in the police, military or the hunting industry?

a) Yes ( )

b) No ( )

SECTION D

10. How do you suppose this problem should be prevented?

(a) Protective equipment………

(b) Noise reduction………………

(c) No idea…………

11. Do you use any ear protection equipment?

a) Yes ( )

b) No ( )

If yes, please specify the equipment.

Pre molded earplug.……………

Formable earplug..……………

Earmuff……………………………

12. How many hours are you typically exposed to noise per day?

……..……………..

13. How often do you wear hearing protection?

(a) Not at all….….…

(b) 1 hr/shift………….….

(c) 1 to 5 hrs/shift………

(d) 6 to 7 hrs/shift…………

(e) All the time…………..

14. Do you consistently wear hearing protection when exposed to noise?

(a) Yes……………………….

(b) No……………………………

(c) Occasionally…………………………………………………….

Thank you for taking time to participate in this survey.