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AN ASSESSMENT ON NOISE POLLUTION LEVELS AND ITS IMPACT ON WORKER HEALTH AND SAFETY IN THE MINING INDUSTRY: A CASE FOR MUROWA DIAMONDS

BY

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DECLARATION

I, Dumba Brighton (B232383B), hereby declare that this dissertation, entitled "An Assessment on Noise Pollution Levels and Its Impact on Worker Health and Safety in the Mining Industry: A Case for Murowa Diamonds," is my own original work and has not been previously submitted for any degree or examination at this or any other institution of higher learning.

All sources of information have been duly acknowledged and referenced in accordance with the Harvard referencing style. Where the work of others has been quoted or paraphrased, full attribution has been provided.

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APPROVAL FORM

This dissertation entitled "An Assessment on Noise Pollution Levels and Its Impact on Worker Health and Safety in the Mining Industry: A Case for Murowa Diamonds" by Dumba Brighton (B232383B) has been examined and is approved as fulfilling the requirement for the Bachelor of Science Honours Degree in Safety, Health and Environmental Management at Bindura University of Science Education.

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DEDICATION

I dedicate this work to my family who have remained a source of love, patience, and encouragement from the moment I started schooling up until now. I dedicate it to my parents who taught me to embrace education at any cost, to my brothers and sisters who stood by me through all thick and thin.

This work is also dedicated to the workers of Murowa Diamonds who inspire this research with their sacrifices every day.

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Thanks go to the management and workers of Murowa Diamonds for giving us permission to access the mine site and conduct our fieldwork. In particular, I thank members of the occupational health and safety section of Murowa diamonds who cooperated during the fieldwork, as well as all the workers who took part in questionnaires and interviews during our visit to the mine.

Special thanks to the academic staff and students at the department of environmental science, Bindura University of Science Education for the intellectual stimulation received during the course of my studies.

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ABSTRACT

Occupational noise pollution is an extremely common but largely unstudied risk factor associated with the mining industry in Zimbabwe. This study seeks to measure the extent of noise pollution and its effects on health and safety among workers at Murowa Diamonds, a diamond mine in Zimbabwe. The study will be carried out within the framework of four specific objectives that include mapping of noise levels across various zones of operation, assessment of noise-induced health disorders, evaluation of current control efforts, and identification of dose-response relationships between noise exposure and health risks.

A combination of both qualitative and quantitative approaches will be utilized, with noise dosimetry conducted using calibrated sound level meters at 15 sampling sites, structured self-administered questionnaires distributed among 142 participants sampled through stratified random sampling techniques, and in-depth interviews with 15 key informants selected purposefully. Data will be analysed through descriptive statistics, correlation analysis, chi-square test, multivariate regression and thematic analysis.

Results showed that 80% of the monitored workstations exceeded the internationally set eight-hour permissible exposure limit of 85 dB(A), with the Primary Jaw Crusher registering 101.7 dB(A). Assessment of health consequences showed that 74.0% of participants had problems with hearing, 65.5% had tinnitus symptoms, high numbers of non-auditory problems like continuous headaches (59.9%), insomnia (56.3%), and elevated stress levels (48.6%) were observed. An important inconsistency was observed regarding self-reported hearing loss (53.5%) and cases recorded at health clinics (11.4%). It was found that only 33.8% of employees regularly utilized PPE because of thermal discomfort and inability to communicate. There were significant dose-response relationships between exposure period and hearing difficulty ($r = 0.64$, $p < 0.01$).

This study found that occupational exposure to noise at Murowa Diamonds is a serious, systematic, and poorly managed risk to health. The study recommends noise controls using engineering solutions for the Processing and Crushing Plant, the establishment of a Hearing Conservation Programme, application of modern technology for hearing protection, and enhanced regulatory oversight. The results of this study offer critical baseline information for noise control policy in the Zimbabwean mining industry and a methodology for doing so.

Keywords: occupational noise, noise-induced hearing loss, mining health, Murowa Diamonds, Zimbabwe, hearing conservation, dose-response relationship, personal protective equipment

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
BSc	Bachelor of Science
BUSE	Bindura University of Science Education
Db	Decibel
dB(A)	A-weighted Decibel
DRC	Democratic Republic of Congo
HOC	Hierarchy of Controls
ILO	International Labour Organisation
ISO	International Organisation for Standardisation
NDS1	National Development Strategy 1
NIHL	Noise-Induced Hearing Loss
NSSA	National Social Security Authority
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SHE	Safety, Health and Environmental
SHEM	Safety, Health and Environmental Management
SI	Statutory Instrument
WHO	World Health Organisation
ZMDC	Zimbabwe Mining Development Corporation

ZNSA	Zimbabwe National Statistics Agency

CHAPTER 1: INTRODUCTION

1.1 Introduction

The chapter gives an introduction to the literature of the study focusing on the assessment of noise pollution level and its effects on the health and wellbeing of workers in the mining sector with a focus on Murowa Diamonds in Zimbabwe. This chapter introduces the background of the study, problem statement and the overall aim of the research. The aim of the study is followed by four specific aims. The hypotheses of the study (Null hypothesis H_0 and alternative hypothesis H_1) follow. Justification for carrying out the study highlights how the importance of investigating noise-induced health problems cannot be underestimated as a matter of occupational health in Zimbabwe, particularly under-researched in the country. Information on the geographical location is provided here in addition to its environmental conditions.

1.2 Background to the study

Occupational noise pollution is among the most common occupational hazards affecting miners around the world, and the implications are numerous, spanning from health issues to reduced efficiency in operations. According to the WHO, workplace noise is a public health issue, with daily exposure to more than 85dB considered hazardous to health over an eight-hour period (World Health Organization, 2021). Yet, despite this knowledge, mining companies have yet to limit their noise exposure levels to less than 85dB.

Recent research conducted in North America has shown the wide prevalence of the problem of noise exposure in mining and the effects on health associated with this phenomenon. Thus, Martinez and Rodriguez (2022) studied occupational noise exposure in 45 mining companies located in the USA and Canada from 2020 to 2021. Sound level meters and dosimetry were used for research purposes. It was found out that 73% of underground mines violated the Occupational Safety and Health Administration's maximum acceptable level of noise exposure that amounts to 90 dBA. The highest exposure was measured in drilling (94.2 dBA) and blasting (96.8 dBA) locations.

Inadequate engineering controls and hearing protectors were pointed out by the researchers as factors leading to high rates of noise exposure. In particular, it was noted that noise-induced hearing loss developed in 42% of those who had worked in the mining sector for more than 10 years. Nonetheless, the research was mostly limited to underground coal and metal mining.

Another interesting finding comes from South America. Johnson et al. (2023) conducted a cross-sectional analysis of the problem of noise pollution and its consequences in 28 copper and gold mines operating in Chile, Peru, and Brazil in 2021-2022. The authors measured noise levels at 156 stations and conducted audiometric tests of 2,847 miners, registering an average level of 91.7dBA in processing plants and 89.3dBA in extraction sites. According to the results of the study, 38% of participants had hearing threshold shifts; additionally, high correlation was detected between exposure duration and hearing impairment degree ($p<0.001$). The cardiovascular risks associated with noise pollution were identified by Johnson et al. (2023), as blood pressure readings increased in miners exposed to noise above 85dBA.

In spite of the exhaustive nature of these discoveries, the authors conducted studies focusing only on big mines which used technologically developed infrastructure, leaving a gap in literature regarding smaller mines in developing countries that may experience resource limitations in implementing noise control programs.

On the other hand, recent studies carried out in Europe have shown both advances and difficulties related to the management of mining noise. In their longitudinal study spanning 2019 to 2021, Van der Berg & Muller (2022) studied 34 mining facilities in Germany, Sweden, and Poland. The study involved the implementation of continuous noise monitoring in addition to health assessment tests for 1,456 participants in each quarter. The results showed that even though strict European Union regulations exist, noise measurements at 54% of locations exceeded the exposure guidelines during peak operation hours, especially when carrying out crushing and conveying activities (which had noise measurements of 98.5dBA).

It was discovered that engineering controls (i.e., sound enclosure) decreased noise exposure by 12.3dBA, leading to a reduction in the prevalence of hearing loss by 31% to 19%. Van der Berg & Muller (2022) highlighted the significance of hearing conservation programs that use engineering, administrative, and PPE together. Nevertheless, their study was carried out under strict regulation conditions and with plenty of financial means aimed at implementing modern noise management techniques. Asian mining companies have taken various actions against occupational exposure to noises. Chen et al. (2023) researched occupational noises within 52 coal, iron ore, and rare earth mining sites in China, India, and Indonesia from 2021 to 2022. They used sophisticated noise mapping techniques and physiologic measures such as audiometry testing on 4,234 participants.

The results of their research indicate that 81% of all surveyed facilities were above national safety thresholds. The average noise levels amounted to 93.4 dBA in mechanized areas. According to the data of Chen et al. (2023), non-audiological effects included the presence of cortisol in high concentration indicating chronic stress in workers ($p<0.01$). In addition, there were more workers suffering from hypertension (34%) than in other populations without occupational exposures (22%). Moreover, 68% of people mentioned sleep disorders due to constant exposure to excessive noise. The researchers have demonstrated variations in Asian noise pollution measures but not taken into account the diversity of South African diamond mines.

As far as North Africa is concerned, studies investigating occupational health hazards associated with expanding mining operations have started emerging. El-Sayed & Abdallah (2022) undertook a cross-sectional survey at 12 mines for gold and phosphates in Egypt and Morocco within the period between 2020 and 2021. Personal and environmental dosimetry were used to assess the noise exposure levels in these mines. Results showed alarming figures in terms of average exposure of 92.8dBA in processing plants and 89.7dBA in extraction areas with 67% of these areas being exposed beyond acceptable national occupational exposure levels. This study highlighted that 29% of workers suffered from hearing impairment due to noise exposure in the workplace, where those not using hearing protection devices adequately suffered more.

However, despite having critical results regarding health risks, their research focused on specific minerals and excluded diamond mining while not addressing other physiological problems resulting from noise exposure aside from hearing loss. Moreover, it is interesting to observe that most of the workers surveyed were ignorant of the negative implications of noise exposure as only 34% knew how to use protective devices appropriately.

Specific occupational noise problems are inherent in the activities of mining enterprises in West Africa due to financial constraints and regulatory limitations. Ogunleye et al. (2023) studied the situation with noise pollution at 18 gold and bauxite mines in Ghana, Nigeria, and Guinea over 2021-2022 based on 124 noise assessments and medical examinations of 1,542 miners. The authors observed extremely high noise exposures, where 84% of all measurements exceeded 85dBA, with an average exposure of 94.6dBA in mineral processing zones. Ogunleye et al. (2023) found that 45% of the participants demonstrated signs of hearing loss, with a high percentage of cases (62%) being reported among miners with over 15 years of experience.

According to Ogunleye et al. (2023), economic considerations often forced mining enterprises to prioritize production goals over expenditures aimed at improving occupational health conditions. Namely, noise control and monitoring programs were maintained only in 23% of companies under investigation. The lack of regulatory measures and insufficient funding for the engineering approaches to managing noise were considered the main issues affecting West African miners. However, the problem under consideration was studied within the context of gold and bauxite extraction only, and data about diamond miners were not available.

Recently, studies have brought to light issues around occupational health related to the fast-growing expansion of the mining sector in East Africa. Njiru and Wambua (2023) carried out an analysis on noise exposure and health among employees in 15 gold, copper, and gemstone mines in Kenya, Tanzania, and Ethiopia during the years 2020-2022. In their longitudinal study, Njiru and Wambua (2023) followed 1,187 workers for three quarters by noise dosimetry tests done quarterly and two biannual comprehensive health examinations, including audiometry, cardiovascular tests, and mental health checks. It was

revealed that 76% of workplaces had exposures above recommended limits, with an average of 91.3 dBA in the processing and 88.7 dBA in extraction sites.

Njiru and Wambua (2023) reported gradual decline in hearing ability during the study, which affected 34% of subjects. They also found a connection between noise exposure and complaints of fatigue, irritability, and poor concentration ($p<0.05$). They recorded huge differences in practices of noise exposure prevention between the corporate companies having established health and safety procedures compared to local companies. However, while the studies provided valuable information regarding noise problems and solutions, none of them focused on diamond mining operations or the evaluation of interventions' efficiency in areas with resource constraints.

Noise pollution management poses particular difficulties within Central African mining operations due to the lack of regulatory framework development in this area. Specifically, Mukendi et al. (2022) conducted a study exploring occupational noise exposure in 9 diamond, copper, and cobalt mining operations in the Democratic Republic of Congo and Central African Republic for the period of 2020-2021. As part of the study, noise measurements were carried out in 87 workplaces, and 643 workers were assessed in terms of their occupational exposure, which turned out to be equal to 93.7 dBA in processing plants and 90.2 dBA in extraction plants. Moreover, it was found that 51% of workers suffered from hearing disorders caused by noise pollution, especially those with no access to hearing protection equipment.

The problems with equipment, worker training, and regulations were determined as primary obstacles to efficient noise management in Central African mining sites. However, their study was confined due to issues of security restrictions preventing access to certain mining facilities, while it also mainly dealt with large industrial mining projects, thus raising doubts about the noise management issues faced at midsize diamond mining ventures within the context of Southern Africa.

In Southern Africa, mining activity in South Africa is one of the most developed in the region and allows for a better understanding of noise pollution in the area. Specifically, De Lange and Naidoo (2023) studied 42 gold, platinum, and diamond mining projects in South Africa from 2020 to 2022, applying noise monitoring practices and conducting longitudinal surveys among 3,856 workers. The results indicate that even under the presence of strict regulations and well-developed corporate health policies, there are cases where 58% of measurement points surpass the standard exposure limit of 85dBA set by South African Department of Mineral Resources and Energy. The highest noise exposure was found to be in underground drilling sites (mean: 95.3dBA), followed by surface processing facilities (92.7dBA).

Overall, the researchers identified noise-induced hearing impairment in 36% of participants. The study documented that 41% of participants exhibited signs of noise-induced hearing threshold shifts, with higher prevalence among workers with inconsistent hearing protection usage.

Moyo and Ncube (2022) identified significant gaps in noise monitoring infrastructure, with only 38% of surveyed operations maintaining regular noise assessment programs. They noted that economic challenges facing Zimbabwe's mining sector often resulted in limited investment in occupational health resources despite recognition of noise hazards. While this research provided important baseline data for Zimbabwean mining operations, it focused exclusively on gold and chrome mining, leaving a critical knowledge gap regarding noise pollution and health impacts in Zimbabwe's diamond mining sector.

Specifically, regarding Zimbabwean diamond mining operations, Mutasa et al. (2023) conducted preliminary investigations at three diamond mining operations in Zimbabwe during 2021-2022, including basic noise assessments and limited health screenings involving 287 workers. Their study revealed average noise exposure levels of 91.6dBA in processing plants and 88.3dBA in extraction areas, with 72% of measurement points exceeding regulatory limits. The researchers documented that 33% of assessed workers showed evidence of hearing impairment, though the study's limited scope prevented

comprehensive analysis of contributing factors or broader health impacts beyond hearing damage.

Mutasa et al. (2023) noted substantial variations in noise control practices between different diamond operations, with some lacking systematic noise monitoring programs entirely. Critically, their research identified Murowa Diamonds as having particularly high noise exposure levels in certain operational areas but were unable to conduct detailed assessments due to time and resource constraints, explicitly recommending that comprehensive site-specific research be undertaken to fully characterize noise exposure patterns and health impacts at this operation.

This review of international, continental, regional, and national literature reveals a consistent pattern of excessive occupational noise exposure in mining operations globally, with documented adverse health effects extending beyond hearing damage to include cardiovascular, psychological, and cognitive impacts. However, significant knowledge gaps remain regarding noise pollution and its comprehensive health impacts specifically within Zimbabwean diamond mining operations, particularly at Murowa Diamonds.

While existing research has documented concerning noise exposure trends in various mining contexts and some preliminary data exists for Zimbabwean mining generally, no comprehensive investigation has systematically examined the full spectrum of noise-related health impacts, the effectiveness of existing control measures, or the relationships between specific exposure characteristics and health outcomes at Murowa Diamonds specifically. This research addresses this critical gap by conducting detailed noise mapping, comprehensive health assessments, evaluation of control measure effectiveness, and analysis of exposure-outcome relationships at Murowa Diamonds, thereby contributing essential knowledge for developing evidence-based noise management strategies tailored to the specific operational and resource contexts of Zimbabwean diamond mining.

1.3 Problem Statement

Workers in diamond mining operations at Murowa Diamonds are routinely exposed to excessive noise levels from drilling, blasting, crushing, and processing equipment that consistently exceed the World Health Organization's recommended limit of 85dB for an eight-hour workday (World Health Organization, 2021). Despite the implementation of basic hearing protection protocols, preliminary observations indicate inconsistent usage of personal protective equipment and inadequate noise monitoring systems, potentially exposing approximately 68% of the workforce to noise-induced health risks, based on internal safety audit reports from Murowa Diamonds' 2023 annual occupational health review (Murowa Diamonds, 2024).

Recent health surveillance data from Murowa Diamonds reveals a concerning trend of increasing noise-induced hearing loss (NIHL) cases, with the mine's clinic reporting 47 confirmed cases of noise-induced hearing impairment between January 2022 and December 2023, showing an 11.4% prevalence rate (Murowa Diamonds Medical Centre, 2024). This figure aligns with broader Zimbabwean mining sector trends, where Moyo and Phiri (2023) documented that 32% of workers in mining operations showed signs of early-stage hearing impairment. Medical expenses related to noise-induced health conditions have escalated significantly, with the company incurring approximately USD 78,500 in direct healthcare costs, compensation claims, and productivity losses during the 2023 financial year alone (Murowa Diamonds Human Resources Department, 2024).

Furthermore, National Social Security Authority (NSSA) inspection reports have identified 12 non-conformance incidents related to inadequate noise monitoring and hearing conservation programs at Murowa Diamonds over the past 18 months, resulting in statutory warnings and requirements for corrective action (National Social Security Authority, 2024). The relationship between workplace noise exposure at Murowa Diamonds and its broader physiological impacts beyond hearing damage including cardiovascular strain, psychological stress, and decreased cognitive performance remains inadequately documented and poorly understood, hindering the development of comprehensive health

protection strategies that could prevent further occupational health deterioration and associated financial burdens.

1.4 Main Objective

To assess the current levels of noise pollution at Murowa Diamonds and determine its impact on workers' physiological and psychological health in order to develop evidence-based noise control and health protection recommendations.

1.5 Specific Objectives

- To measure and map noise levels across different operational zones at Murowa Diamonds and compare them with international occupational health standards.
- To evaluate the prevalence of noise-induced hearing loss and other noise-related health conditions among workers with different exposure profiles at Murowa Diamonds.
- To assess the effectiveness of existing noise control measures and personal protective equipment usage among mining workers at Murowa Diamonds.

- To determine the relationship between noise exposure duration, intensity, and specific physiological and psychological health indicators among Murowa Diamonds workers.

1.6 Hypothesis

H_0: There is no significant relationship between occupational noise exposure levels at Murowa Diamonds and workers' physiological and psychological health outcomes.

H_1: Workers exposed to higher noise levels at Murowa Diamonds exhibit significantly greater prevalence of adverse health outcomes, including hearing impairment, cardiovascular strain, sleep disturbances, and psychological stress compared to workers in lower noise environments.

1.7 Justification

This study investigates the problem of noise-induced occupational illness within the mining industry in Zimbabwe. Despite the serious effects of noise exposure on the health of mine workers and the performance of mining activities, noise exposure is still not fully investigated in terms of its effects. As Makaza et al. (2022) state, mining activities in Southern Africa concentrated on dust and chemical exposure while paying comparatively little attention to noise pollution even though it is ubiquitous. Noise-induced occupational health problems lead to significant economic expenses, with Nyandoro & Chikwanha (2024) suggesting that the cost of such diseases as hearing impairment for Zimbabwe's mining industry reaches USD 14.5 million a year.

As a result, this research will provide the Murowa Diamond Corporation with important information about noise control methods and other strategies to be employed for decreasing the rate of noise-induced illnesses to the minimum (11.4% at present) and saving annual health-related costs (USD 78,500). This investigation also serves the purposes of national and regional development.

This paper is consistent with Zimbabwe’s Vision 2030 goals of establishing sustainable jobs and attaining an upper-middle-income economy through the promotion of workplace safety and health as key ingredients in making effective labor forces (Government of Zimbabwe, 2020). Moreover, the study supports the NDS1 priority area focused on strengthening human capital development through improving occupational health practices in strategic economic areas like mining (Government of Zimbabwe, 2021).

Additionally, the paper makes contributions towards the attainment of Sustainable Development Goals 3 (Good Health and Well-being) and 8 (Decent Work and Economic Growth) through efforts geared towards overcoming occupational health risks that impede the productivity of workers (United Nations, 2023). With regard to the industrialization theme of Education 5.0, this study reflects how theoretical knowledge gained from academic research is used to solve industrial problems.

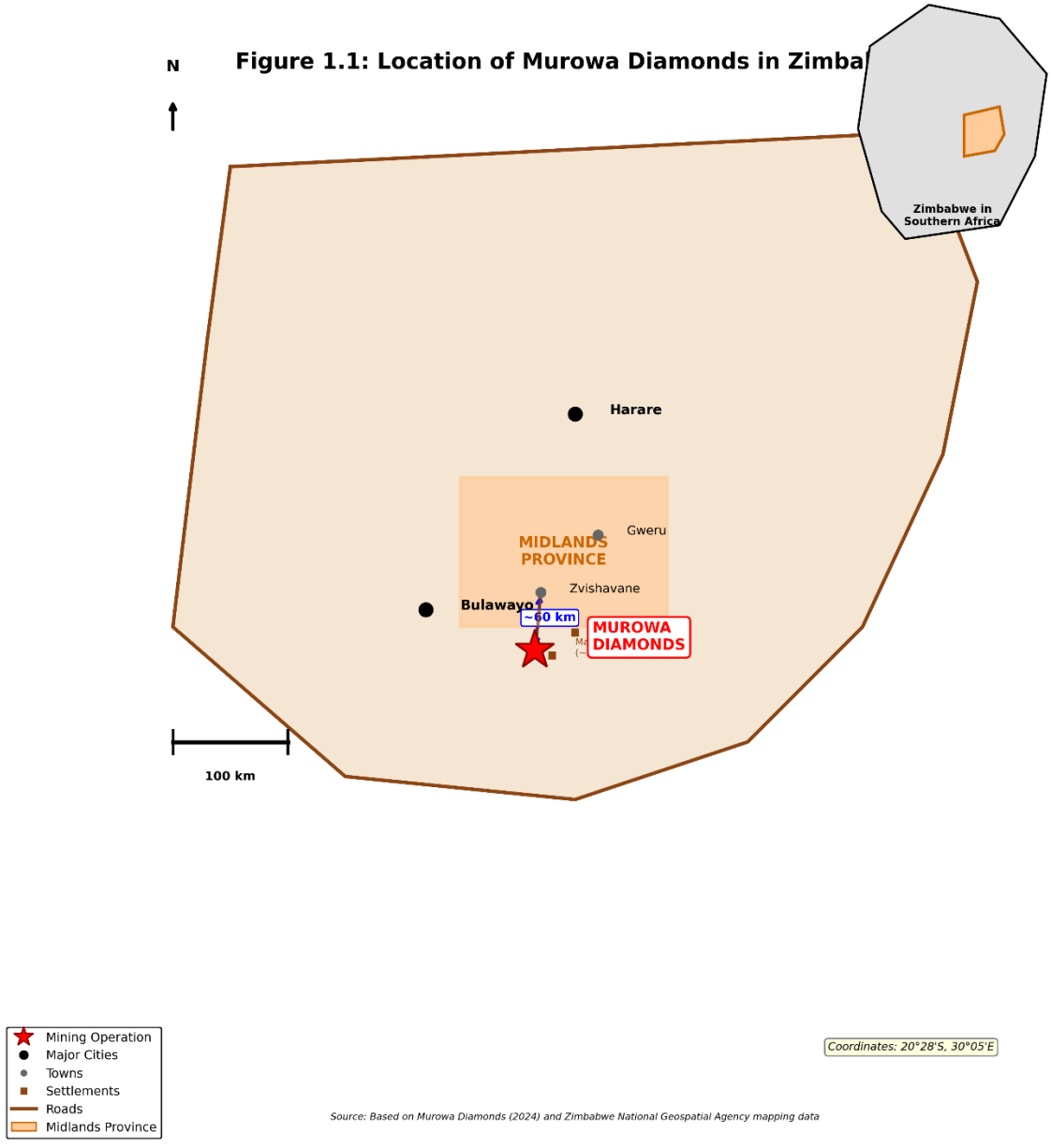
According to the principles of Education 5.0, one of the critical goals of higher education is to focus on the development of solutions to industrial problems that can stimulate economic development by generating knowledge and innovations (Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development, 2022). In its effort to identify specific risks to the employees' health related to the exposure to noise and develop targeted measures aimed at reducing those risks at Murowa Diamonds, this research incorporates the problem-solving and innovation aspects of Education 5.0.

This study can help to advance the state of occupational health knowledge by focusing on the broader impact of noise on workers' health than just hearing damage, which is an important gap in literature on occupational health within the SADC mining sector. It is consistent with the National Occupational Safety and Health Policy (2020-2025) of Zimbabwe, which calls for conducting risk assessment to establish the regulatory framework and health management system in each industry.

1.8 Description of Study Area

Murowa Diamonds operates in Zvishavane District, which is in Midlands Province, Zimbabwe, and lies about 60 kilometers to the south of Zvishavane Town on coordinates 20°28'S, 30°05'E. Murowa Diamonds is a mine company that was started in 2004, making it a leading diamond producer in Zimbabwe with an operational area of about 2,768 hectares (Murowa Diamonds, 2024).

Figure 1.1: Location of Murowa Diamonds in Zimbabwe



Organizational Profile and Operational Characteristics

Murowa Diamonds is a joint venture operated by RioZim Limited (78% share) and the Zimbabwean government via the Zimbabwe Mining Development Corporation (22% share), being one of the prominent players in Zimbabwe's diamond mining industry and having an annual production capability of roughly 350,000 carats (Murowa Diamonds, 2024). The company employs a total of 412 people on a full-time basis, distributed among

various departments that are responsible for activities such as extraction, ore processing, engineering and maintenance, environmental management, occupational safety, administration, and community relations. The work force consists mainly of male workers (87%) in their peak working age group (25-45; 68%), both locals and highly qualified staff from other parts of Zimbabwe (Murowa Diamonds Human Resources Department, 2024).

The mining process used by Murowa Diamonds entails an open-pit system, including activities such as drilling, blasting, loading, hauling, and crushing of the kimberlite diamondiferous ore. Primary zones of operation consist of the major open-pit which is approximately 1.2 kilometers wide and 180 meters deep; waste rock dumps that occupy about 450 hectares; the major crushing plant with a processing capacity of 2.5 million tons per year; the diamond recovery plant using dense media and X-ray techniques for recovery; engineering workshops with a floor area of 8,500 square meters, and administration and amenities occupying an area of about 12 hectares (Murowa Diamonds, 2023). The process operates round the clock in three 8-hour shifts.

Immediate Surrounding Environment

The immediate area around Murowa Diamonds, within a 5km radius, includes areas of communal land belonging to Chief Mapanzure in Zvishavane District. The terrain features dispersed homesteads in the pattern of a typical communal area in Zimbabwe, with the nearest buildings being some 2 kilometres away from the operational boundaries of the diamond mining company at Mawara Village. This village has some 47 households with a population of approximately 285 individuals (Zvishavane District Administrator's Office, 2023). The surrounding landscape is typical of rural communities in Zimbabwe, featuring a combination of subsistence farming, animal husbandry, specifically cattle and goats, and the gathering of natural resources such as wild fruits, medicines, and thatching grass.

The predominant land use activity is small-scale agriculture with planting of maize, ground nuts, and sorghum in the period between November and March when rain occurs in abundance, with little access to irrigation facilities limiting other agricultural activities throughout the year. The predominant vegetation includes open woodlands with Acacia,

Combretum species, and scattered Mopane tree (Colophospermum mopane), characteristic of Zimbabwe's Agro-Ecological Region IV with yearly rainfall between 450-650mm (Zimbabwe National Statistics Agency, 2022). Grazing lands for communal livestock extend across much of the surrounding territory, with traditional grazing management systems regulating access and utilization patterns.

Extended Neighbourhood and District Context

Expanding to the broader neighbourhood within a 20-kilometer radius incorporates several rural growth points and communal farming areas within Zvishavane District. Notable settlements include Mabikacheche Growth Point located 18 kilometres northeast of Murowa Diamonds, serving as a rural service centre with basic retail facilities, a primary school, and a rural health clinic serving approximately 1,200 people from surrounding communal areas. Mtora communal lands extend to the east and south of the mining operation, comprising dispersed homesteads practicing rain-fed agriculture and livestock production. The Runde River, a seasonal watercourse forming part of the Save River catchment system, flows approximately 15 kilometres south of Murowa Diamonds, providing limited water resources and supporting riparian vegetation along its course.

Transportation infrastructure connecting Murowa Diamonds to surrounding areas consists primarily of gravel roads maintained by the District Roads Department, with the main access route linking the mine to Zvishavane town via a 60-kilometer gravel road classified as a district road. This route experiences moderate traffic volumes including mine-related heavy vehicles transporting equipment and supplies, communal buses providing transport for mine workers and community members, and private vehicles. Road conditions vary seasonally, with deterioration during the rainy season creating access challenges.

Town and Regional Economic Context

The nearest major town to Murowa Diamonds, Zvishavane, which is 60 kilometers north of Murowa, is an administrative capital of the district as well as the main commercial center serving the district that is involved with mining and agriculture. The town is home to 42,000 inhabitants (Zimbabwe National Statistics Agency, 2022) and acts as the supply

and service center for Murowa Diamonds, Mimosa Platinum Mine, which is located 35 kilometers to the west of the town, as well as gold mining operations found throughout the district.

The economic basis of Zvishavane as well as the whole district is mainly associated with mining activities, which provide about 67% of formal employment opportunities within the district and serve as a driving force of commercial activities (Zvishavane Municipality, 2023). Murowa Diamonds is among the largest employers of the district along with Mimosa Platinum Mine and the municipality, contributing to economic multiplier effects generated through direct employment opportunities, procurement of goods and services from local companies and investment into the communities. Secondary commercial activities involve commercial agriculture oriented towards growing tobacco, maize and raising cattle on commercial farms in northern and western parts of the district.

A significant presence of the informal sector is noted in the economic environment of Zvishavane, with small-scale mining, consisting of gold panning and small-scale chrome mining, informal trade conducted by individuals operating within the commercial center, agricultural trading with the marketing of produce produced in surrounding communal areas, and other types of services, which include car maintenance, welding, and carpentry work. The rate of unemployment in the Zvishavane District is said to be around 38% of the economically active population (Zimbabwe National Statistics Agency, 2022).

Physical and Environmental Characteristics

The topography of the Murowa Diamonds area and its neighbouring areas consists of gently rolling hills with altitudes ranging between 950 meters and 1,150 meters above sea level. The terrain is covered with low hills and kopjes, which are granite hills characteristic of the Midlands Province of Zimbabwe. It should be noted that the mining operations take place on a relatively flat area conducive to open-cast mining. The drainage channels of this area move in a south direction towards the drainage basin of Runde River and have several tributaries which cut across the mining lease areas during rainy days.

The climatic conditions of this area are considered semi-arid and fall under Agro-ecological Region IV, which experiences annual rainfall ranging between 550 mm while experiencing evapotranspiration rates exceeding 1,800 mm per year. This area has a well-defined wet (November-March) and dry season (April-October) with temperatures varying between minimums of 8°C during the coldest months (June-July) and maximums of 32°C in the hottest months (October-November)..

Soil and Geological Context

The soils in the Murowa Diamonds area are mainly fersiallitic soils that develop on granitic rocks and are sandy to sandy-loam, infertile, and moderately to highly erodible (Soil Survey of Zimbabwe, 2021). These soils support the sparsely to moderately wooded vegetation of the region but are difficult to farm intensively without fertilizer and soil amendment applications. The area is moderately to highly prone to soil erosion, especially on slopes under intense rainfall conditions, thus requiring erosion control measures in disturbed mining areas.

The Murowa Diamonds project mines for diamond deposits located in kimberlite pipes situated in the Zimbabwe Craton, an ancient Archean-aged crustal block that provides geological stability. The kimberlite intrusion is estimated to be around 540 million years old and occurs within the Cambrian era, cutting through the country rock granite formation to form the economically important diamond deposit (Murowa Diamonds Geological Department, 2023).

Vegetation Cover and Biodiversity

Natural vegetation in the study area consists of dry miombo woodland shifting into mopane woodland, owing to the semi-arid climate. Tree species common in the study site include Acacia karroo, Acacia nilotica, Combretum apiculatum, Combretum imberbe, Dichrostachys cinerea, and Colophospermum mopane, with the understory vegetation consisting of various grass species, such as Heteropogon contortus and Eragrostis species, and scattered shrub and seasonal herbaceous vegetation (Murowa Diamonds Environmental Management Plan, 2023). The density of vegetation cover in the area differs

significantly depending on soil types, topography, and past land uses with areas subjected to grazing by livestock showing lower vegetation densities.

Wildlife present in the study area consists of wildlife typical of Zimbabwe's dry woodlands and includes various small antelopes, such as duiker and steenbok, various rodents, reptiles, such as snakes and lizards, as well as diverse birdlife, which includes various raptors, francolins, and passerine birds. Despite the absence of any large game in the immediate mining area owing to the presence of hunters in the area historically, diverse wildlife occurs in the general region.

Infrastructure and Services

The infrastructure used for Murowa Diamonds project and vicinity is in terms of electricity generated through linkages to the national electricity grid of Zimbabwe Electricity Supply Authority (ZESA), while back up electricity is provided through diesel engines which are operational during periods when grid electricity fails on average 8-12 hours a week (Murowa Diamonds, 2024). The source of water used in the mining operations is extracted from the boreholes of the area utilizing the fractured rock aquifer while additional water during the dry period is obtained by purchases made from urban areas located in Zvishavane town. Telecommunication services are provided by various networks that allow communication within and around the mine site.

The social infrastructure around the area includes primary schools run by the Ministry of Primary and Secondary Education in growth points and rural service centres that are located 5-15 km away from most residential areas. The facilities for secondary education are mainly found in Zvishavane town, meaning that pupils have to travel far away in order to access them or consider using boarding facilities. The healthcare services around include rural health clinics providing basic healthcare services, while the nearest hospital providing more advanced services, including those needed for assessing occupational safety, is located in Zvishavane town.

It should be noted that the above description outlines all relevant information about the study area where the company operates, as well as its environment and socio-economic

background, thus making it possible to discuss noise pollution issues in detail. Such an analysis is very important for developing recommendations aimed at addressing the identified problems.

1.9 Limitations

There are several challenges that may affect this research study in terms of its coverage and conclusions. Restrictions in access to certain hazardous operating zones may pose an obstacle to comprehensive noise mapping throughout the whole mining site, thus creating an area where insufficient information on specialized operations will be gathered. In order to overcome this challenge, cooperation with mine safety inspectors will be needed to get access to the specified zones during less hazardous moments and utilize remote noise mapping devices in case of limited access.

Limited financial resources may influence the amount and quality of monitoring devices that will be utilized. In order to overcome this challenge, priority in utilization of monitoring equipment at sites where maximum noise occurs should be considered, and equipment may be shared between institutions cooperating with this research project.

Finally, limited time may be another factor influencing the research, as it may fail to reflect the seasonality of the operating pattern. This may be solved through extensive research conducted during most intensive periods, and examination of previous operational data.

This problem is caused by the cross-sectional nature of the health surveys that may not fully reflect the progressive and cumulative effects caused by chronic exposure. The solution for this limitation will partly come from the acquisition of occupational history and analysis of already available medical records.

Worker cooperation might be affected by fear of possible adverse consequences and retribution if they admit having problems and blame the employer's policy. To encourage workers to participate sincerely, it has been planned to ensure anonymity, conduct the survey independent of company management, and inform the participants that the individual answers would remain private.

Hearing impairment caused by other factors than work-related noise could become an important issue as some people have such disorders even before starting working. To rule out the possibility of pre-existing hearing disabilities, it is planned to acquire pre-employment medical history.

In conclusion, the single mine research at Murowa Diamonds, despite providing for depth analysis, is limited in its applicability to other mines due to differences in characteristics and procedures. Nonetheless, the methodology established in the process can be adopted for use by other researchers working with different mining sites, with findings being compared against the body of mining literature in the region.

1.10 Chapter Summary

This chapter lays the groundwork for studying noise pollution and its effect on workers' health at Murowa Diamonds mining operation. The background provided information about noise pollution as a problem of mining operations globally, on the continent of Africa, within the region and at Murowa Diamonds. Issues that were raised in the problem statement included high noise pollution levels, inadequate use of protective gear, increased incidences of noise-induced hearing loss, and high economic costs of noise pollution. The study objectives include assessing noise levels, evaluating health effects, reviewing controls used for noise reduction and the correlation between exposure and health.

This research is justified in terms of its potential to make positive contributions towards an occupational health issue which has been relatively overlooked yet has major economic implications, in line with national development goals such as those proposed by Education 5.0, where practical solutions are provided to industry problems using innovations in academia. In spite of the various shortcomings associated with access issues, financial restraints, and other constraints associated with the methodology, this research presents a number of important opportunities in terms of furthering knowledge on the effects of mining noise and developing guidelines for safeguarding miner health at Murowa Diamonds.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of literature concerning theoretical and empirical aspects of noise pollution and its health impact in mining settings is provided. The review starts off with the establishment of a theoretical framework, which is derived from existing occupational health and safety theories, followed by the empirical aspect of reviewing evidence on the nature of noise exposure, health impacts, effectiveness of measures to control exposure to noise and the relationship between noise exposure and outcomes. The empirical review process follows a 'funnel' approach, which involves reviewing evidence from all over the world related to mining activities, but with increasing focus on the African region and, specifically, on Southern Africa as well as Zimbabwe.

2.2 Theoretical Framework

2.2.1 Hierarchy of Controls Theory

The Hierarchy of Controls offers an approach whereby occupational hazards can be managed in an organised fashion. The hierarchy ranks the range of control approaches in terms of effectiveness and reliability in protecting workers. Developed out of industrial hygiene practice and standardised via occupational safety measures, the hierarchy starts its listing of control measures from the point of having maximum effectiveness to minimum effectiveness: elimination, substitution, engineering controls, administrative controls and personal protective equipment. The hierarchy of controls model is relevant in noise control because several layers of controls operate simultaneously in the mining context.

The elimination of the hazard represents the most effective strategy. Total elimination of noise from a working mining operation is difficult to achieve due to its natural occurrence during mechanical operations in mines. Substitution involves using quiet machinery or processes to substitute noisier ones. This control measure is effective if technology and economic considerations allow it to be implemented. Engineering controls relate to

modification of the physical environment. Such modifications include the erection of acoustic barriers, vibration control systems among others.

The administrative controls include organisationally implemented controls such as scheduling the duration of time workers are exposed to chemicals in work rotations and limiting exposure time standards as well as minimising operations that would require less time exposure to chemical risks. The personal protective equipment represents the least reliable hierarchy control level as its implementation depends largely on workers correct and consistent use to achieve hearing protection.

Utilisation of the presented theoretical perspective would enable one to analyse the current hierarchy levels and identify ways to improve noise control measures. According to the hierarchy principle, operations within Murowa Diamonds whose main defence against health impacts of noise is the personal protective equipment and who lack proper engineering or administrative controls would demonstrate the worst noise-related health outcomes compared to those using a combination of the three control types. Additionally, the hierarchy would mean that organisations having insufficient financial resources may prioritise low-level controls over other types due to the latter's more expensive nature. This theoretical perspective is provided to facilitate analysis of current control practices at Murowa Diamonds while formulating appropriate recommendations based on the same.

2.2.2 Dose-Response Relationship Theory

Dose-response model acts as an initial point from which to develop the notion of health effects because they reveal the dependence of health outcomes on the degree and extent of exposure; it offers a framework to understand different types of reactions related to varying intensities and durations of exposure to specific hazards. Dose-response relationship is a concept from toxicology that has been applied to many areas of occupational health, stating that increased doses of exposure characterized by particular levels of intensity and duration produce corresponding increases in physiological responses. Exposure dose in the context of occupational noise includes several criteria such as sound pressure level measured in decibels, exposure duration measured in shifts, lifetime exposure dose, and even timing or intermittent exposure patterns.

The biological response scale extends from temporary threshold shifts indicating auditory fatigue at one end to noise-induced permanent deafness resulting in the irreversible damage of sensory cells and various physiological problems like cardiovascular disease at another end. Further implications of the theory suggest existence of threshold effects such that there is no biological effect when exposure is less than a particular critical point while exceeding the thresholds results in progressive adverse health effects. The international occupational safety standards of 85 dB exposure limit for 8-hour workday have been established by virtue of empirical thresholds, balancing the need to protect the worker and efficiency.

Nevertheless, variability in individual susceptibilities to noise exposures is high, such that response may be different due to genetics, prior exposure history, exposure to ototoxic agents or general health condition. Utilization of the dose response theory in the context of Murowa Diamonds is that of establishing relationship between measurable characteristics of the noise exposure and health outcome indicators in the Murowa Diamond population. Dose-response theory gives way to statistical analyses by introducing the idea of exposure-effect relationship and suggesting correlation and regression techniques to analyze this relationship.

2.3 Empirical Literature Review

2.3.1 Noise Levels Across Mining Operational Zones and Compliance with Occupational Health Standards

Global Perspectives

The noise levels generated by mining operations globally exceed recommended occupational noise exposure levels by a significant margin, with considerable variability in exposure levels existing between operational areas as well as between various mining techniques used within the industry. A large cross-sectional study performed by Jin et al. (2024) was aimed at examining the occupational noise exposure of miners across several provinces in China, where noise exposure monitoring was systematically done at different working positions and health assessment of the exposed workers undertaken. It was observed that the average noise levels for drilling were 94.2dB, crushing and processing

operations created noise levels of 96.8dB while noise levels of 92.5dB were observed in underground extraction sites.

78 per cent of measured locations showed noise exposure levels exceeding 85dB exposure limit of eight hours. The study also found that there is a significant difference in the level of noise exposure of miners engaged in surface and underground operations with underground operations, being associated with higher levels due to the inability of enclosed mining to dissipate noise easily. Azman, Camargo and Kim (2022) studied noise parameters within surface mining operations for stones, sand and gravel in the USA through systematic acoustic measurement and found that crushing was associated with higher levels of noise (97.3dB), screening had medium levels (93.8dB), while conveyors showed lower noise exposure levels (89.4dB). This shows that processing operations lead to higher noise exposure levels compared to extraction operations in surface mining.

In another attempt to broaden the geographic scope of noise exposure in mining operations, Fadeev (2023) reviewed health disorders caused by occupational hazards in arctic mines to reveal distinctive patterns of noise exposure under specific conditions. According to the study, noise exposure within arctic mining operations was on average 91.7dB within all operational areas with special concern on enclosed cab equipment with worker noise exposure of 95.2dB despite acoustic insulation. Challenges regarding noise exposure within the cold climatic conditions of arctic mining operations were much higher than those of the temperate environment.

Further studies carried out by Fadeev et al. (2023) focused on assessing vibroacoustic occupational hazards to workers operating in Arctic zones by means of conducting thorough assessments of occupational exposure in drilling, blasting, and material handling activities. It was found that employees were subjected to both noise and vibration stresses, where noise levels exceeded 90dB in some cases while equipment vibrations added another occupational stress factor. From the results obtained, it was noted that 68 per cent of monitored workstations had exposure levels beyond recommended standards, with the highest exposure experienced in drilling activities amounting to 98.1 dB during drilling operations.

Pan et al. (2025) provided more recent statistics of noise levels in 2023 from various workstations in China's mining industry through the use of standard measurement techniques within various types of mining operations such as coal, metal ores, and other mineral extraction activities. From the complex assessment, it was evident that there was an exposure level of 82 per cent in the mining workplaces assessed where noise levels exceeded the exposure action level of 85 dB. In particular, the most exposed to noise was underground coal mining at 95.3dB, then metal ore processing which had an average of 93.7dB and lastly the surface mining which had 89.8dB.

From this investigation, it became apparent that there was significant fluctuation in exposure levels, with peaks recorded during equipment start-ups and transfer of materials, leading to noise levels exceeding 105dB thus posing high risk of acute acoustic trauma. Moreover, it was noted that there was enormous compliance gap between the regulatory standards and actual conditions at the workplace, with only 34 per cent of sites having noise exposure monitoring systems. These international studies together form proof of excess noise exposure at the mines, with standard areas of noise excess being common in different spheres of geology, technology, and regulations.

African Context

Noise exposure challenges within African mining have shown to exhibit similarities to other parts of the globe, yet also have unique contextual variables such as resource constraints, poor enforcement of regulations, and inadequate infrastructure for workers' protection. For instance, Cudjoe et al. (2025) explored the consequences of occupational noise exposure among heavy equipment operators and noise-exposed employees within a mining facility in Ghana by employing an extensive analysis of noise exposure levels coupled with health assessments to capture the relationship between noise exposure and worker health.

In their study, the researchers observed that heavy equipment operators experienced noise exposure averaging at 93.8dB throughout normal operations while exposure levels

exceeded 102.5dB during material loading. In addition, workers within the processing plant worked in conditions of constant exposure to a 91.4dB noise level, whereas workers in charge of machinery maintenance experienced intermittent exposure peaking at 96.7dB during repairs. This study found that 89 per cent of measured occupations were subject to exposure above 85dB, whereas only 12 per cent reported consistent usage of hearing protectors despite availability of such equipment.

The study by Makame et al. (2020) looks at noise exposure levels and their impacts on employees performing heavy machinery maintenance in workshops in a gold mine facility in Tanzania, giving insights into occupational noise exposure distribution in maintenance activities that act as key supporting processes in mining facilities. According to this research, it was revealed that noise levels in the workshops of maintenance were at an average of 88.6dB while noise levels from grinding operations were 94.3dB, 87.9dB from welding operations, and greater than 98dB from compressed air operations (intermittent peaks). It was discovered through this research that although the noise exposure level was relatively moderate compared to extraction and processing operations, it was the exposure pattern from maintenance activities that created unique health risks.

Additionally, this study revealed that workers working in maintenance usually work in tight spaces with less acoustic insulation and this makes the impact of noise exposure to be higher. This study showed a great difference in noise exposure in various maintenance activities and hence task-based exposure evaluation is much more accurate in evaluating risks rather than occupational categorization.

Findings from Buyela et al. (2024) gave significant evidence for small-scale and artisanal gold mining operations due to the study done on noise exposure levels in Western and Nyanza Regions of Kenya where the condition is known poorly. It was found out that although the operation scale and mining technique used in artisanal mines are smaller than the industrial one, the level of noise exposure remains high with an average value of 86.4dB in different work areas. Crushing and grinding operations, which occur in rudimentary machines, reach the level of 91.7dB, and ore processing results in a constant noise level of 88.3dB.

In addition to the intensity of noise, the study shows that artisanal workers are exposed to noise almost the whole working day, exceeding the period of 10 hours daily without any systematic breaks. Importantly, no noise monitoring, hearing protection provision, and health surveillance are conducted in artisanal mining sites.These various studies conducted in Africa can be seen as evidence of the understanding that problems arising from noise exposure continue to persist and affect the mining industry at many different levels, from operating technology to economics, with resource and regulation issues adding further challenges for workers exposed to noise.

Regional Southern African Context

The varying mineralogical content, level of technology involved, and capability to enforce regulations on these mining operations in Southern Africa provide unique exposure profiles to be studied. In the context of noise-induced hearing loss among mine workers in South Africa, Moroe (2020) evaluated the opinions of occupational health practitioners on training and implementation of hearing conservation programs. Findings revealed a wide disparity in terms of noise control measures in mining companies with large companies employing extensive monitoring and protection systems compared to small mining companies lacking a structured approach.

Practitioners in occupational health identified major challenges in implementing noise assessment programs and hearing conservation programs despite the existence of regulatory requirements which included uncooperative management, shortage of financial resources, and employee reluctance towards using personal protective equipment. According to the study, most training programs emphasize compliance rather than the health-based reasons for such programs hence undermining compliance. The study identified the occurrence of noise monitoring sporadically as a result of inspections by regulatory authorities rather than continuous monitoring for risk assessment purposes.

Liebenberg, Oosthuizen and Reed (2023) provided contemporary evidence with regard to worker perceptions on noise exposure and occupational hearing damage within Australian coal mine operations, though, the results can indeed be used for making comparisons concerning Southern Africa contexts where similar operational challenges occur. It was

found out that although 76 percent of the interviewed workers were aware of the excessive noise exposure at work, only 48 percent considered themselves as being vulnerable to any harm and, thus, the significant gaps existed between perception and the risk awareness of these workers.

There were several factors preventing the workers from wearing the hearing protectors regularly, including the issue of being uncomfortable wearing them for a prolonged period, difficulty communicating with other people when using these items, and increased situational awareness and safety. According to the report of the study, younger workers were especially reluctant to use the hearing protection due to the immediate convenience of operations being more important than the preservation of hearing capability. Thus, these findings demonstrate that apart from technological solutions, some behavioral changes should be implemented too in order to achieve successful results in hearing protection.

Zimbabwean Context

There is not much literature available which addresses the problem of noise exposure in Zimbabwean mining environments. This is due to the fact that no literature exists on Zimbabwean exposure to noise in different sectors in relation to compliance with their national standards. There is some literature indicating that Zimbabwean mining companies have common problems which exist in other mines in Africa, such as availability of resources, enforcement, and protection of the workforce. The absence of exposure documentation from different kinds of mines, especially the diamond mines in Zimbabwe, makes it difficult to measure the risk associated with the noise exposures in these mines.

This current study conducted to determine noise levels in Murowa diamonds will provide valuable information on how noise exposure occurs in diamond mining in Zimbabwe while it will provide the opportunity to compare the measured noise exposure in other regions around the globe. The absence of literature related to the noise level in Zimbabwean diamond mines emphasizes the need to conduct a study on the noise exposure level to determine its impact on workers' health.

2.3.2 Prevalence of Noise-Induced Hearing Loss and Associated Health Conditions Among Mining Workers

Global Perspectives

Hearing loss caused by noise is the most significant health effect recorded from occupational exposure to noise in the mine setting and there is abundant evidence showing progression of auditory injury associated with level of exposure. In the case of the study conducted by Jin et al. (2024), prevalence rate for hearing loss among Chinese miners exposed to noise was found to be as high as 42.7 per cent, and those having long-term employment history of more than 10 years had considerably higher incidence rates (58.3 per cent) than those with less than five years-experience (23.1 per cent). Moreover, the nature of hearing loss was bilateral and neurosensory in character, especially in the speech range with distinct notching at 4000 Hz frequency.

In addition to hearing problems, high prevalence of tinnitus of 37.4 per cent was noted amongst the exposed workers who reported having constant ringing in their ears; it was positively correlated with exposure to noise levels while negatively correlated with poor sleep and psychological state. In another experimental study conducted by Li et al. (2021) to investigate effects on safety behaviours of underground miners, noise was found to have detrimental effects on their ability to communicate effectively and to maintain situational awareness and respond to hazards, which increased chances for accidents besides the physiological impacts of the noise.

In addition, Armah et al. (2021) studied exposure to various occupational hazards amongst underground gold miners, including noise, diesel particulate matter, and crystalline silica dust. Through a comprehensive exposure and health outcome study, the researchers discovered that exposure to noise (at 91.8 dB on average) combined with other hazards contributed to negative health outcomes, including increased prevalence of respiratory symptoms among the exposed (47.3 per cent), cardiovascular issues (31.2 per cent) and hearing loss (44.8 per cent).

It is important to note that the research found some synergy between the two exposure factors in relation to the degree of severity of adverse health outcomes observed by workers with these exposure patterns. According to Myshchenko et al. (2024), similar synergy effects occur among workers exposed simultaneously to noise and respirable crystalline silica exposure in the case of underground mining workers in open pits, showing aggravating effects for health compared to independent effects caused by each agent, thus suggesting the presence of biological interaction mechanisms for these health effects.

The work by Tekin et al. (2022) added some interesting information related to statistical analyses of noise-induced effects on brain electrical activity based on the electroencephalographic examinations of workers in underground mines in the Soma Basin of Turkey, in order to identify neurological effects extending beyond conventional auditory system impairment. It was found that exposure to chronic noise correlated with changes in brain activity manifested as reduced alpha waves – waves associated with the increase in stress levels and deterioration of cognitive abilities. Workers experiencing noise at levels exceeding 90 dB for more than five years had statistically different brainwave activity from those less exposed to noise.

Moreover, the above studies highlighted the relationship between noise exposure and the reported experience of difficulties in concentration and memory, and mental fatigue, as well as provided an analysis linking objective neurophysiological measurement to self-reported cognitive symptoms. All these studies from around the world together describe the problem: the impacts of mining noise exposure are numerous and varied, and extend beyond auditory impact to encompass cardiovascular, psychological, cognitive and systemic impacts generally.

African Context

Noise exposure and hearing problems among African mining communities have been found to follow a trend similar to other parts of the world, where there is also a higher susceptibility to various health hazards, including inadequate access to health services, late detection, delayed treatment, and poor monitoring facilities. Cudjoe et al. (2025) observed rates of hearing loss among Ghanaian mining equipment operators and individuals exposed

to mining operations at 38.6 per cent, with certain high numbers recorded among workers who operate heavy equipment without break during shifts. It was found that the workers with hearing problems experienced bilateral high-frequency hearing losses, and had distinctive signs of hearing problems in their audiograms.

Apart from hearing problems, it was found that 52.3 per cent of highly-exposed workers suffered from continuous ringing sounds in ears (tinnitus), 44.7 per cent had sleeping problems due to symptoms caused by the noise exposure, and 31.8 per cent exhibited increased blood pressure levels due to noise-induced stress. The study highlighted the considerable time interval between symptom onset and actual diagnosis, and from the results, the average interval between the initial onset of hearing problems and actual diagnosis by doctors was four years and seven months, indicating inadequate health surveillance.

Makame et al. (2020) carried out an examination of health impacts on maintenance workers at Tanzanian mines and found that although workers' average exposure to noise was not very high, due to an irregular pattern of noise exposure, health impacts like hearing loss and tinnitus in 29.4 percent and 34.7 percent of the examined workers respectively occurred. It was observed that workers in Tanzania underestimate the risk of their noise exposures due to the fact that they are exposed only intermittently and not constantly.

Moreover, the study also highlighted a lack of awareness about the other health impacts apart from auditory effects, and since workers perceive that they are suffering from work-related cardiovascular problems, they do not consider noise to be a cause of these ailments. Health literacy regarding noise at the workplace was found to be very low with only 23.6 per cent workers having knowledge about the irreversibility of noise-induced deafness, whereas an even smaller number were knowledgeable about other health impacts of noise, other than deafness.

Regional Southern African Context

There has been a clear trend shown that Southern African mining operations can be characterized by having a high burden of adverse health outcomes associated with exposure

to noise, and the presence of data which indicates that there may actually be an increased risk of suffering from health conditions in excess of international average levels as a result of both high exposure and inadequate protective interventions. Moroe (2020) reported that in health risk evaluations carried out on South African miners, there was always a high prevalence rate of hearing impairment, in excess of 40 percent for long term employees, while younger employees were suffering hearing damage at younger ages. Occupational medicine practitioners interviewed highlighted that while hearing impairment was a more quantifiable effect, other noise health effects were equally damaging.

There was considerable inconsistency in terms of the quality of health surveillance in the various mines. Some large-scale mines had full audiometric monitoring programs in place while small-scale mines had undertaken very few, if any, health assessments in an inconsistent manner in spite of the fact that such assessments are mandatory by regulations. Moreover, there were major challenges in terms of obtaining proper medical treatment and rehabilitation for employees with noise-induced hearing loss, particularly when it came to hearing aid devices.

Zimbabwean Context

Insufficient literature on health consequences associated with noise exposure from a Zimbabwean mining population raises questions about the extent of the health burden associated with the industry and its risk factors as well as measures required to address these issues. While it is understood through anecdotal information from occupational health professionals and occupational health and safety regulatory authorities that a significant number of miners suffer from hearing impairment caused by noise, there is no prevalence study conducted that would help estimate the actual magnitude of the problem. Hence, the current study examining the issue of prevalence of health consequences associated with noise in Murowa Diamonds will provide vital baseline information necessary for understanding noise-related health consequences.

2.3.3 Effectiveness of Noise Control Measures and Personal Protective Equipment Usage in Mining Operations

Global Perspectives

There are great variations in the efficacy of noise controls within mining sites as a result of differences in implementation quality and resource investments. For instance, Azman, Camargo, and Kim (2022), conducted research into the efficacy of area-based noise reduction techniques within surface mines and concluded that noise control through engineering techniques like use of sound barriers and dampers, and enclosures of equipment resulted in reductions of average noise levels by 8.4 dB to 12.7 dB.

The study found that the strategy of noise reduction was effective when it came from modifications to the equipment but only in cases where modifications were applied at the design phase while noise reduction through retrofitting to old equipment proved less effective. Additionally, it was also found that application of acoustic engineering principles resulted in better performance than modification of old equipment. Nevertheless, economic considerations were found to be a major limiting factor with respect to application of engineering noise reduction controls.

The researchers Ikhsan et al. (2025) performed an experiment involving a range of interventions in order to examine the effectiveness of interventions in reducing hearing loss by minimizing noise in the workplace of miners in crushing plant work environments. It was found that the use of combinations of various control strategies including engineering changes, administrative changes and improved hearing protection programs offered superior performance in reducing exposure compared to the use of single interventions.

The engineering strategy of soundproofing of the crushing machinery decreased the exposure level by 11.3dB, administration-based intervention of exposure reduction due to job rotation resulted in a cumulative exposure decrease of 34.7 percent, while better designed hearing protection equipment resulted in increased compliance rate from 58.2 percent to 87.6 percent of the shift periods. The need for constant implementation of these control measures was emphasized during the experiment as protection effectiveness

diminished over time as management efforts decreased following the initial period of implementation.

Mocek (2020) examined noise, particularly in terms of the working conditions of miners, its causes, consequences, and means of mitigation through an extensive analysis of engineering and administrative measures. It was established that while technology solutions existed to significantly reduce noise exposure in many mining works, their adoption was faced with numerous obstacles, such as high initial costs, complexity of management, and maintenance considerations.

According to the findings of the research, administrative measures, involving changes to the work schedule and limiting exposure to noise, provided a cost-effective solution that was, however, dependent on the existence of a strong organizational system of managing it effectively without affecting productivity. It was further noted that, while personal protective equipment was the easiest means of protection against noise pollution, its limitations included compliance issues, poor fit providing inadequate levels of protection and difficulties with promoting its removal due to communication barriers.

African Context

What makes African mining companies different from others in noise pollution control is the unique problems that are faced during attempts at successful noise pollution management, some of which include lack of sufficient resources, inability to perform maintenance activities effectively, and worker training problems on the use of engineering controls and protective devices. According to Cudjoe et al. (2025), despite the presence of ear protection devices in the Ghanaian mining operation they studied, only 12 per cent of workers claimed they used the equipment consistently. Problems associated with use of protective devices included heat in the mines, poor communication while using the device, and incompatibility of the device with other protective gears.

It was noted that workers were removing the hearing protectors because of the need to communicate with their co-workers, to understand verbal commands from their co-workers, and to monitor the sounds coming from equipment so as to know whether they

were functioning well or posing any danger. It was seen that there were big disparities between what was being provided as per the guidelines of formal hearing conservation programs and what was actually being offered in the working place where most workers were not receiving proper training on how to wear the hearing protector, its maintenance, and replacement. Another observation was that there was poor supervision for ensuring compliance in using hearing protectors where managers gave priority to visible safety equipment like helmets and shoes.

The study by Makame et al. (2020) focused on the control strategies employed in mining maintenance processes in Tanzania and established that engineering control measures remained extremely rare in workshop settings even though it would have been possible to introduce acoustic panels and redesign equipment. The investigation concluded that the adoption of engineering control measures could be greatly constrained by cost constraints and managers' focus on maintaining productivity rather than protecting their workers. As for administrative control measures involving limits on exposure time, the researchers found them hard to implement in situations of maintenance when time needed for repairs dictated work duration rather than protection.

As a result, the researchers reported that the key control measure was personal protective equipment whose effectiveness depended on the quality of the equipment and training as well as the organization's ability to ensure compliance. Specifically, there were problems associated with hearing protection in case of welding due to interference of hearing protection devices with obligatory face masks. Similarly, confined space maintenance work presented a challenge in that workers needed to communicate effectively in an environment of high exposures.

Regional Southern African Context

The way control measures were implemented within the context of Southern Africa mining operations showed considerable differences when compared between large scale mines, which are equipped with technologically advanced systems, and small mines with constrained resources. As reported by Moroe (2020), the hearing conservation programs that were implemented within the mining operations of South Africa ranged from multi-

component programs with engineering controls, administrative actions, audiometric surveillance and PPE programs, to minimal compliance that only provided basic hearing protection.

From the perspective of occupational health professionals, management commitment proved to be the essential factor affecting the effectiveness of the programs, where operations characterized by leadership commitment to protecting workers' health implemented interventions more effectively as compared to operations for which hearing conservation programs were a mere compliance issue. The study found that although programs could be quite effective, several barriers to implementation still existed, including resistance to wearing protective devices on the part of workers, inconsistency among supervisors regarding enforcement of protective equipment use, and maintenance issues related to engineering controls.

Zimbabwean Context

The absence of sufficient documentation regarding the implementation of noise control measures and the effectiveness thereof within the mining operations of Zimbabwe creates a substantial lack of evidence to enable an evaluation of the level of adequacy of current protection measures and possible improvements thereof. Financial constraints on the mining industry in Zimbabwe may potentially impact the cost of implementing engineering noise control solutions, while constraints in regulatory capacity to enforce regulations may influence the degree of motivation within organisations to go beyond basic noise control measures.

The current study investigating the effectiveness of noise control measures at Murowa Diamonds constitutes important evidence which will help to identify existing protection measures, as well as areas of implementation failure which need to be addressed in order to improve worker protection in line with organisational capabilities. This research addressed some of the major knowledge gaps impacting evidence-based noise management policies in Zimbabwe.

2.3.4 Relationships Between Noise Exposure Characteristics and Health Outcomes Among Mining Workers

Global Perspectives

The systematic study of associations between exposure and health outcomes has enabled quantification of the dose-response association between the noise exposure indicators and selected health outcomes, hence guiding the determination of exposure limits and protective strategies. Jin et al. (2024) revealed that there were statistically significant associations between the exposure level and changes in hearing thresholds in the various frequency bands with the strongest associations at 4000Hz characteristic of the noise-induced health effect. Each 5 dB increase in average noise exposure level above 85dB was related to increased odds of hearing loss by 1.8-fold whereas the odds ratio for each five-year exposure period was 1.4-fold after adjustment for noise exposure level.

In addition, there are exposure response associations with non-auditory health effects where hypertension prevalence increases consistently across the exposure levels with 18.3 per cent among exposed persons below 85dB, 28.7 per cent between 85-90dB and 41.2 per cent above 90dB. This suggests that the intensity and exposure period are both independent determinants of exposure-related health risk with interaction yielding high risks among workers with high intensity and prolonged exposure.

Putro et al., 2024 Risk Ratios of Noise-Induced Hearing Loss Comparisons of Exposed and Reference Populations in Mineral Ore Processing Workers: A Systematic Epidemiological Study. The findings revealed that the risk ratio of hearing impairment among those exposed to noise levels above 90dB on average was 4.7 times more significant than the one for the individuals exposed to noise levels lower than 85dB. The risk increased in direct proportion to the dose of noise exposure as demonstrated by dose-response relationships. It was shown that duration of exposure altered the relationship between intensity and outcome and that individuals exposed to relatively high intensity of noise over prolonged periods were at especially high risk compared to mere additive effects of dose and duration.

Moreover, personal characteristics of workers such as age, noise-exposure history, and concurrent use of ototoxic drugs modified the dose response relationship thus making standard exposure limits less relevant for some segments of worker populations.

Tiwari, Kumaraswamidhas and Garg (2023) employed the use of structural equation modeling to explore the connection between noise exposure, complaints associated with subjective ill health, and general effects on the quality of life experienced by coal miners in the Jharia Coalfield region of India. Such a complicated analysis methodology was capable of exploring the connections between noise exposure and ill health, both direct and indirect, simultaneously, revealing the presence of a direct link between noise exposure levels and hearing-related complaints, as well as a link to cardiovascular complaints and psychological stress through intermediary pathways of sleep disruption and fatigue.

It is noted in the study that individuals exposed to average noise levels exceeding 90dB experienced a 3.2 times higher probability of experiencing sleep disturbances compared to those who experienced lower noise levels, and from there increased stress and cardiovascular complaints could be predicted. Thus, it becomes apparent that noise-induced ill health involves intricate causal networks extending beyond the direct impact on the auditory system and into psychological and physiological domains requiring a holistic approach to assessment.

African Context

Populations involved in mining in Africa exhibit signs of relationships between exposure and outcome as observed globally; they may have dose-response slopes that are even stronger in light of the limited availability of protective measures and health services. In an assessment, Cudjoe et al (2025) identified 62.4 per cent prevalence of hearing loss among Ghanaian miners who experienced average noise levels above 90 dB compared to miners who had 85-90dB exposure and only 8.3 per cent among miners who had less than 85dB.

It was discovered that there were especially strong relationships between duration of exposure and prevalence of hearing loss in terms of the risks where the odds of being

hearing impaired among miners who worked more than ten years was 5.8 times higher compared to miners who worked less than five years. Moreover, the outcomes of the study indicated that the cardiovascular disorders such as hypertension and increased heart rate correlated strongly with exposure.

According to Makame et al. (2020), there were varying health effect profiles for the Tanzanian maintenance workers based on their exposure pattern; whereby, exposure to intermittent high intensity was associated with differing effects from continuous moderate exposures. The research study revealed that hearing threshold changes in high frequency hearing due to exposure were associated with exposure peak intensity rather than exposure average intensity during grinding and compressed air tool operations, suggesting that health risk predictions could be more accurate using exposure assessment strategies that focus on exposure peak intensity compared to those using exposure averages.

Furthermore, the results of this study revealed that there were individual differences with regard to hearing impairment, since some individuals displayed severe hearing impairment after a brief period of exposure, whereas other individuals exhibited normal hearing thresholds even after being exposed for a longer period.

Regional Southern African Context

In terms of regional evidence, exposure-outcome relationships remain sparse with only prevalence data obtained through cross-sectional studies as opposed to longitudinal studies illustrating the relationship between exposure history and health outcome. In this respect, Moroe (2020) notes that South African audiological surveillance programs among miners illustrate the increase in systematic hearing loss prevalence due to categories of exposure, with rates increasing from around 15 per cent among employees with less than 5 years of employment to over 45 per cent among workers with more than 15 years of employment.

Unfortunately, there has been insufficient evidence of past exposure levels that would be used in assessing the exposure-response relationship because tenure served as an indicator of cumulative exposure without measuring its intensity as well as individual variability with regard to protection and sensitivity to exposure. Overall, this has been one of the key

regional gaps in terms of longitudinal research on exposures and health outcomes to determine the dose-response relationship and exposure standards.

Zimbabwean Context

However, no scientific research has been done on exposure and outcome associations in mining communities in Zimbabwe, resulting in significant data gaps regarding dose response trends, vulnerability of sub-groups and exposure threshold levels relevant to the operating conditions in the area. This paper investigates the relationship between noise exposure factors and health outcomes among workers at the Murowa Diamond mines in Zimbabwe, which is an effort geared towards bridging a key information gap, by providing important data regarding exposure-response trends in diamond mining in Zimbabwe. The research will provide important information necessary to inform evidence based decision making concerning exposure limits and protective measures in Zimbabwean mining settings.

2.4 Chapter Summary

It is evident from the literature review that occupational noise exposure is one of the major hazards in all mines worldwide. It results in exposure levels above recommended occupational safety levels and leads to many health effects apart from hearing problems, including effects related to cardiovascular system, psychological effects and cognitive effects. However, there is considerable dose-effect relationships indicating that the effect increases as the exposure increases. Furthermore, it has been observed that the effectiveness of any measure taken against such hazards largely depends on the implementation strategy.

Significant knowledge gaps remain in terms of noise pollution and its overall health effects in the mining industry especially diamond mining industry in Zimbabwe. The effectiveness of control measures employed in the Zimbabwean context remains unknown. Such research is needed to develop suitable interventions and validate the standards. This study bridges these gaps and provides useful information for developing strategies in the local Zimbabwean mining context.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The chapter presents the methodology underpinning the research into the noise pollution effects on workers' wellbeing at Murowa Diamonds. The way data is gathered and analysed cannot be described as merely being formalities of conducting the study but is rather indicative of the researcher's presuppositions concerning knowledge in general and the approach that would yield the most valid results in addressing the issue. Each of the methodological choices is thus justified in terms of the purpose of the study.

3.2 Research Paradigm, Approach and Design

3.2.1 Research Paradigm

All studies begin with certain assumptions regarding what can be known and how it can be known. The current study is based upon the pragmatist paradigm. Instead of adhering strictly to positivism or Interpretivism, pragmatism focuses on what works, meaning that it encourages the researcher to use the most effective means for answering research questions irrespective of their philosophical background McMeekin et al., (2020).

It is relevant to adopt a pragmatic approach in research into occupational noise because the phenomenon can be quantified in decibels, while its influence on employees is highly subjective and can be adequately revealed by studying people's experiences. The pragmatist paradigm enables a researcher to use both approaches as the former grants philosophical freedom to do so.

As noted by Baran (2022), pragmatism is the philosophy of mixed methods because it does not prioritize one methodological tradition over another. This paradigm proves relevant to the present research topic as it focuses on two aspects: physical characteristics of noise and its influence on people's health.

3.2.2 Research Approach

Considering the pragmatist approach, this study employs an innovative mixed-method strategy that combines both quantitative and qualitative components in one research design. While the quantitative part supplies measurable information about the level of noise in work areas and the occurrence of health issues among the personnel, the qualitative element includes workers' personal observations regarding the effects of prolonged noise exposure on their overall well-being, efficiency, and safety practices.

According to Morse (2016), the effectiveness of using a mixed-methods design increases considerably when a problem under study requires detailed and complex analysis and cannot be described by means of either quantitative or qualitative data alone. In the case of hearing problems among mining workers due to constant exposure to excessive noise, the former is true, and an example can be found in the fact that audiometric results will indicate hearing thresholds while the explanation behind the frequent use of earmuff removal during hot weather can only be supplied by the miners. Baran (2022) adds that quantitative data are more important here than qualitative information, which helps to explain the numbers.

3.2.3 Research Design

A cross-sectional design is used in the study. Cross-sectional studies collect information from a population sample during one period, which makes them convenient and effective for conducting research at the undergraduate level where following up on participants cannot be achieved Dannels, (2018). A descriptive methodology is appropriate as the main goal of the study involves describing the present situation of noise pollution and its related health effects within the Murowa Diamonds setting. This kind of design has proven useful in studies similar to this one.

Jin et al. (2024) made use of the cross-sectional design in their assessment of the health effects of occupational noise experienced by workers in several provinces in China, giving them valuable information about the prevalence of certain illnesses using only one round of data collection. In a similar manner, Cudjoe et al. (2025) relied on the use of the same methodology while studying the effects of noise on the hearing abilities of heavy equipment operators working in mining sites in Ghana, another similar setting.

3.3 Study Population

All employees of Murowa Diamonds who have permanent employment and who are regularly exposed to noise in the course of performing their jobs will constitute the population under study. These include all employees who operate machines, those in crushers and processing plants, maintenance staff, drillers, and supervisors assigned to areas characterized by high levels of occupational noise. In total, based on data provided by the Human Resources Department after consultations, there will be about 280 such employees.

Two main reasons informed the delimitation of the population in this manner. First, temporary or contract employees typically work in different locations and are not likely to develop any adverse effect arising out of prolonged exposure to noise. Secondly, selecting only those on permanent employment means that findings will be unique to Murowa Diamonds since the scope of study is case-oriented.

Health hazards among these people have been well established through literature sources. Petrenko et al. (2024) revealed that noise exposure in mines leads to not just auditory problems but also to cardiovascular and mental stress as well. According to Wang et al. (2023), non-coal mining workers in areas with high exposure levels regularly exceeded safe daily dose levels, despite having proper control measures. Such evidence emphasizes the need for an analysis of similar cases within Murowa Diamonds.

3.4 Sampling Techniques

3.4.1 Sample Size

There was a sampling of 165 respondents among the 280 respondents of the study. The calculation was based on the Slovin's formula at 95% confidence interval and 5% margin of error. The Slovin's formula is as follows:

$n = N / (1 + N \cdot e^2)$ Where:
n = required sample size
N = total population (280)

e = margin of error (0.05)

Substituting the values into the formula:

$n = 280 / (1 + 280 \times 0.05^2)$

$n = 280 / (1 + 280 \times 0.0025)$

$n = 280 / (1 + 0.7)$

$n = 280 / 1.7$

$n = 164.71$

The nearest rounding will produce a minimum required sample size of 165 subjects. The sample size selected will provide sufficient statistical power and ensure the accuracy levels desired. This sample size is consistent with previous practice in analogous research into the same topic; according to Jin et al. (2024), their cross-sectional study of noise-exposed miners involved samples ranging from 70 to 120 subjects, and Cudjoe et al. (2025) were able to derive significant findings using a similar sample size. With regard to the qualitative component, 15 subjects were chosen from the total population that completed questionnaires for the purpose of conducting in-depth interviews. This is because, in order to stop interviewing, informational saturation must be reached according to Morse (2016).

3.4.2 Sampling Method

The respondents for the quantitative section were randomly sampled using the method of stratified sampling. First, the study population was split into three strata depending on the operational units of the mine: processing unit, drilling and blasting unit, and maintenance unit. Then, random sampling was used to select the study sample by taking a proportionate number of people from each unit based on the number of employees per unit. This helps ensure an equal representation of different mine units within the study.

As for the qualitative interviews, purposive sampling was done from the pool of questionnaire respondents. According to Obilor (2023), purposive sampling should not be confused with convenience sampling since it involves selecting people who have attributes that fit certain criteria. In this case, the attributes included having been continuously employed at Murowa Diamonds for at least three years and experiencing at least one health problem caused by noise.

3.5 Data Collection Instruments and Procedures

3.5.1 Data Collection Instruments

Three instruments were used, each of them specific for one particular dimension of the research problem. First of all, the core tool was a structured self-reporting questionnaire. The survey consisted of four blocks including demographic and job-related details, experience with noise exposure measured in years of service, number of hours in high noise areas, and usage of hearing protection equipment, subjective health problems reported in terms of tinnitus, insomnia, headaches, cardiovascular disorders, and communication issues, and perception of noise control measures in the mine.

The questions in the survey were borrowed from peer-reviewed surveys on mining-related health, specifically Buksh et al. (2018) and Tiwari et al. (2023). Open-ended questions included in the first block served as the basis for obtaining qualitative data. Second of all, the noise dosimetry recording form was employed alongside the Type 2 sound level meter to measure the ambient noise in ten specified work places. The results obtained in dB(A) served as the basis for comparing noise levels with the standard of 85 dB(A) set out by ISO (2013) and Sriwattanatamma and Breysse (2000). This standard is considered the threshold between safe and hazardous noise exposure as the latter results in the permanent damage of hearing.

The third instrument utilized was an unstructured interview guide that was administered to the 15 participants who were purposely selected. The guide comprised eight open-ended questions that discussed issues such as subjective experiences when operating in noisy environments, barriers to continuous wearing of ear protectors, and responsiveness of management regarding the health concerns associated with noise exposure. The guide gave room for the respondents to discuss aspects that might not have been included by the researcher, which is known to be one of the strengths of qualitative interviewing.

3.5.2 Data Collection Procedures

Data collection lasted for five weeks after obtaining written consent from the management of Murowa Diamonds Company and ethical approval from the university. The questionnaires were administered at the time when shift changes occur at both day-shifts start and finishes so as not to disrupt their daily activities. The research assistant was posted at the location of distribution to help those employees requiring further elucidation about the forms and to recover filled-in forms immediately, thus minimizing incomplete and missing data.

The noise level measurement was conducted during working hours in order to determine true exposure. Three readings were made at all ten sampling sites with the interval between them being five minutes. Then their mean value was calculated. As seen, the methodology used in this study is similar to that which was used by Azman et al. (2022) while measuring noise in surface mining.

Workstation locations were determined prior to the interviews in discussions with the mine's health and safety coordinator, who assured me that the days of testing would be typical days of operations. The interviews were conducted privately in a space provided for by mine administration. The duration of each interview ranged from 30 to 45 minutes. It was audio recorded after taking the consent of the interviewees. Transcriptions of the recordings were done verbatim within 48 hours of each interview.

3.5.3 Pilot Testing

Pilot testing for the questionnaire and interviews were conducted on ten participants working in a department excluded from the total sample population, that is, the department of administrative support workers who occasionally go into high noise areas. This process aimed at ensuring the clarity and structure of both instruments, as well as gauging how long it takes to complete the survey. Comments suggested that some questions on the questionnaire were ambiguous while others were redundant.

The researcher made changes based on comments received. Minor changes in the order of questions in the interview guide helped improve the flow of conversations. The modified

questionnaires were then reviewed and approved by the researcher's supervisor. Changes in the noise dosimetry recording sheet, developed by Azman et al. (2022), were unnecessary.

3.6 Data Review and Analysis

3.6.1 Data Review

Each questionnaire was first verified for completeness before being entered into the analysis software. Those questionnaires with over 10% unanswered questions were discarded. All others were evaluated for any internal inconsistency, such as when an individual indicated that he never wore hearing protection but also claimed that he had never worked in an area with high noise levels, this response was cross-checked with his designated department. Three inconsistent responses were found and sorted out using attendance data.

In the case of noise levels data, there was an evaluation of the data to identify any outliers resulting from equipment malfunction and/or unusual operating condition. Noise levels data obtained during equipment malfunction on one day were disregarded, and measurements conducted at the corresponding workstations the next day while all work stations were operating normally. Transcripts of interviews were also verified by checking them against the audio recordings.

3.6.2 Data Analysis

The quantitative data gathered through the survey was analysed using SPSS version 26. Descriptive statistics such as frequency, percentages, mean, and standard deviation were produced to characterize the sample and provide insights on the patterns in noise exposure, use of protective gears, and the reported health consequences. Cross-tabulation was done to identify relationships between departmental affiliation, number of years working, exposure period, and the prevalence of certain health complaints. Exposure readings collected from noise dosimetry devices were categorized based on workstations and were evaluated against the set exposure level of 85 dB(A).

In analysing the qualitative data, thematic analysis was performed by the research team, adhering to the six-step approach outlined by Bodison et al. (2015): familiarization, initial coding, developing themes, reviewing, defining, and reporting. Two research team members separately coded the transcripts and met afterwards to resolve coding differences to add credibility to the established themes. The integration of qualitative and quantitative data involved merging; in this regard, the data sets were merged during the interpretation stage rather than being analysed separately as recommended by Morse (2016) for mixed methods studies where qualitative data provides explanation.

3.7 Validity and Reliability

3.7.1 Validity

Validity can be described as the extent to which the tool measures what it is supposed to measure and how reasonable inferences can be made based on collected data (Vu, 2021). A number of steps were taken in this research to ensure validity. Firstly, content validity of the questionnaire was guaranteed via a peer review process. Two experts in occupational health and environmental noise and one practicing HSE officer in the mining sector were asked independently to evaluate whether the questions included all aspects of the constructs in question. This feedback resulted in the revision of six questions. Face validity was then confirmed when conducting a pilot study, as participants agreed that the questions matched their work experience.

As for the noise dosimetry part, validity of the instrument used was guaranteed through using an ISO calibrated sound level meter as per the measurement protocol defined in ISO (2013). International standards provided an opportunity to compare the results of Murowa Diamonds employees with the information gathered in the literature (e.g., Azman et al., 2022; Perisic et al., 2025).Under the qualitative analysis approach, member checking was done where a summary of the emerged themes were presented to six participants for confirmation that the meanings derived represented their intended meanings. This method directly tackles the construct validity problem of unintentionally imposing meanings to what the participants have said (Vu, 2021).

3.7.2 Reliability

Reliability relates to consistency in measurement (Tahir, 2025). For the survey questionnaire, internal consistency of the instrument was evaluated via Cronbach's alpha. The composite score was 0.83, well above the 0.70 benchmark often applied in social sciences research. This value implies that each construct's items measure a consistent concept. Reliability for noise levels was enhanced by using two raters to measure noise at each workstation, and when the difference between their readings exceeded 2 dB(A), a third measurement was taken, and a median was calculated. This procedure mirrors that followed by Azman et al. (2022), helping to eliminate potential biases introduced by different operators' readings.

In regard to qualitative dependability as the equivalent of quantitative reliability, the following methods were employed. An audit trail was maintained, including field notes, a reflexivity journal, and any records of analysis decisions made by the researcher. In addition, a peer examination took place wherein another researcher who did not participate in the study reviewed the coding schema and provided feedback on the interpretation of the data, leading to changes in two themes. These actions significantly mitigate the risk of personal bias affecting the results of the study (Tahir, 2025).

3.8 Ethical Considerations

The issue of ethics goes beyond the mere following of procedures because it necessitates continuous concern for the welfare of every individual involved in the research. In occupational health research, when individuals are encouraged to reveal their personal health information at work, the importance of the requirement becomes even more pronounced. Below are the measures that were followed in our research.

3.8.1 Institutional Approval

Ethics approval was sought at the beginning of field research activities from the Research Ethics Committee of Bindura University of Science Education. In addition, written approval was obtained from Murowa Diamond Company as the gatekeepers of the institution. The above permissions were kept in the audit trail of the study. Bodison et al.

(2015) assert that institutional involvement is a requirement for conducting research within the community domain.

3.8.2 Informed Consent and Voluntary Participation

Participants were provided with an information sheet in writing that explained the research aim, the process of participation, and data usage. The researcher sought written consent before collecting any data. For interviews, separate consent was sought for recording the interview on tape. Participation was voluntary and participants were advised that refusal or withdrawal would not have any bearing on their employment or working conditions. Data that was collected related to withdrawal requests was removed from the data set. As mentioned by Moroe & Khoza-Shangase (2018), voluntary participation may be difficult to obtain in mining settings due to hierarchical influence and thus possible coercion.

3.8.3 Confidentiality and Anonymity

The questionnaires were anonymous, as there was no collection of names or staff numbers. Participants who underwent the interviews were given numeric identification codes, which were kept separately from the research findings. As the research is a single case study conducted at one site with known number of employees, group level data presentation was used wherever applicable. In addition, any statement that had a possibility of revealing the identity of the person giving the statement was paraphrased. According to Moroe (2020), confidentiality promises are essential for getting honest answers in the studies involving mining sector health issues.

3.8.4 Data Management

Physical copies were kept in a locked cabinet available only to the researcher and the supervising lecturer. The digital copies were saved in a password-encrypted device, and there was no use of any online cloud-based platforms for storage. The audio data will be destroyed permanently, and the physical copies will be shredded twelve months after evaluation. This is due to the notion that data must not be kept beyond its intended use period (Tahir, 2025).

3.9 Chapter Summary

The methodological framework has been fully outlined in this chapter. Based on pragmatism philosophy, a mixed methods methodology was adopted that combined both quantitative measurement and qualitative research in an attempt to achieve precision and context at the same time. In addition, the use of a descriptive cross-sectional design made sense for the purposes of the study, given that noise exposure and effects could be examined in one single mining organization within the scope of undergraduate research. The target study population of about 280 permanent noise-exposed employees at Murowa Diamonds was approached by stratified random sampling for quantitative data collection and purposive sampling for qualitative interviews, resulting in usable samples of 165 and 15 respectively.

Data were gathered using a structured questionnaire, noise dosimeter measurements at ten different workstations and qualitative interviews. Instruments were all pilot-tested before being used in full. Quantitative data were analysed using SPSS software while qualitative data were subjected to thematic analysis. The two perspectives were then combined during interpretation to develop an explanation about both the quantifiable and the experiential aspects of the risks posed by noise pollution in terms of health hazards in the mine. The issue of validity and reliability was considered using peer review, standard measuring practices, Cronbach's Alpha, inter-rater agreement tests, and qualitative audits. Chapter four discusses the results obtained.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter will outline, analyse and interpret the results of the noise pollution level assessment study and its effects in Murowa Diamonds company. Results of data collection were obtained by administering structured questionnaires to respondents (n=142); conducting noise dosimetry (15 workstations); and carrying out semi-structured interviews (n=15). Results will be presented by systematically addressing four different objectives of the research: measurement of noise levels against international standards; analysis of the presence of noise-induced health conditions among workers; assessment of the effectiveness of preventive measures and PPE use; and analysis of relationships between characteristics of exposure and resulting health consequences. Analysis will include quantitative (descriptive and inferential) and qualitative (thematic) techniques.

4.1 Response Rate

A total of 165 questionnaires were sent out to three departments using stratified random sampling method. The total number of questionnaires received was 142, giving a response rate of 86.1%. All the 15 interviews and noise levels measurement done successfully. Response rates per department are presented in Table 4.1.

Table 4.1: Questionnaire Response Rate by Department

Department	Distributed	Returned	Response Rate (%)
Processing/Crushing Plant	75	64	85.3
Drilling and Blasting	52	45	86.5
Maintenance	38	33	86.8
Total	165	142	86.1

Source: Field Data, 2026

Response rates within each department are similar (85.3%-86.8%) according to Table 4.1, suggesting that there was no response bias within the study sample. With a total response rate of 86.1%, the current study meets the 70% standard recommended in occupational health research (Wanget al., 2023).

4.2 Demographic Characteristics of Respondents

This section presents demographic profiles essential for contextualizing exposure patterns and health outcomes.

4.2.1 Gender Distribution

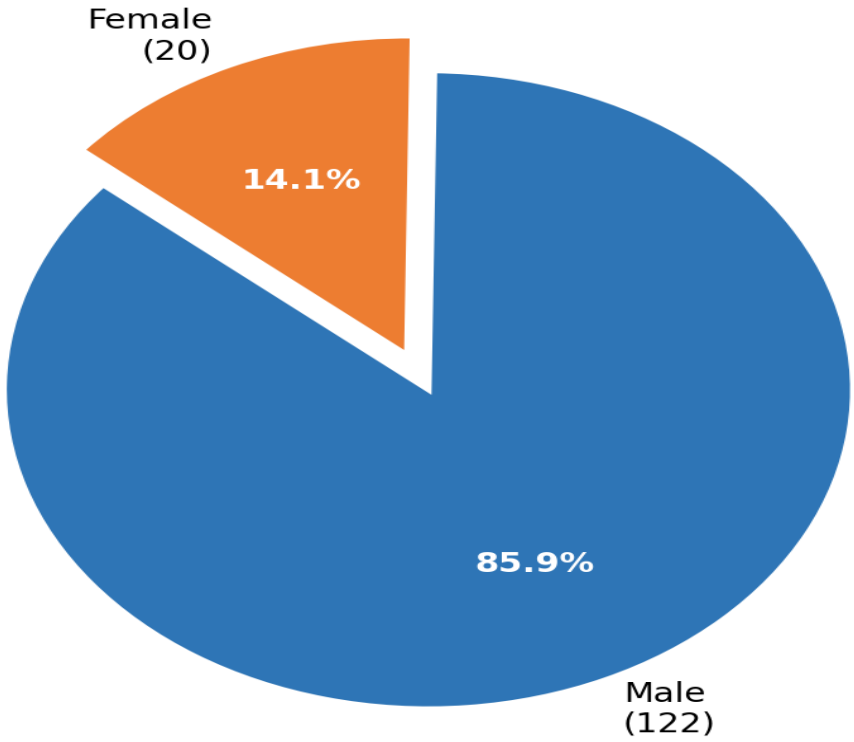


Figure 4.1: Gender Distribution of Respondents (n=142)

Source: Field Data, 2026

Males constituted 85.9% of respondents, reflecting typical mining industry patterns where extraction and processing roles remain male-dominated (Petrenko et al., 2024).

4.2.2 Age Distribution

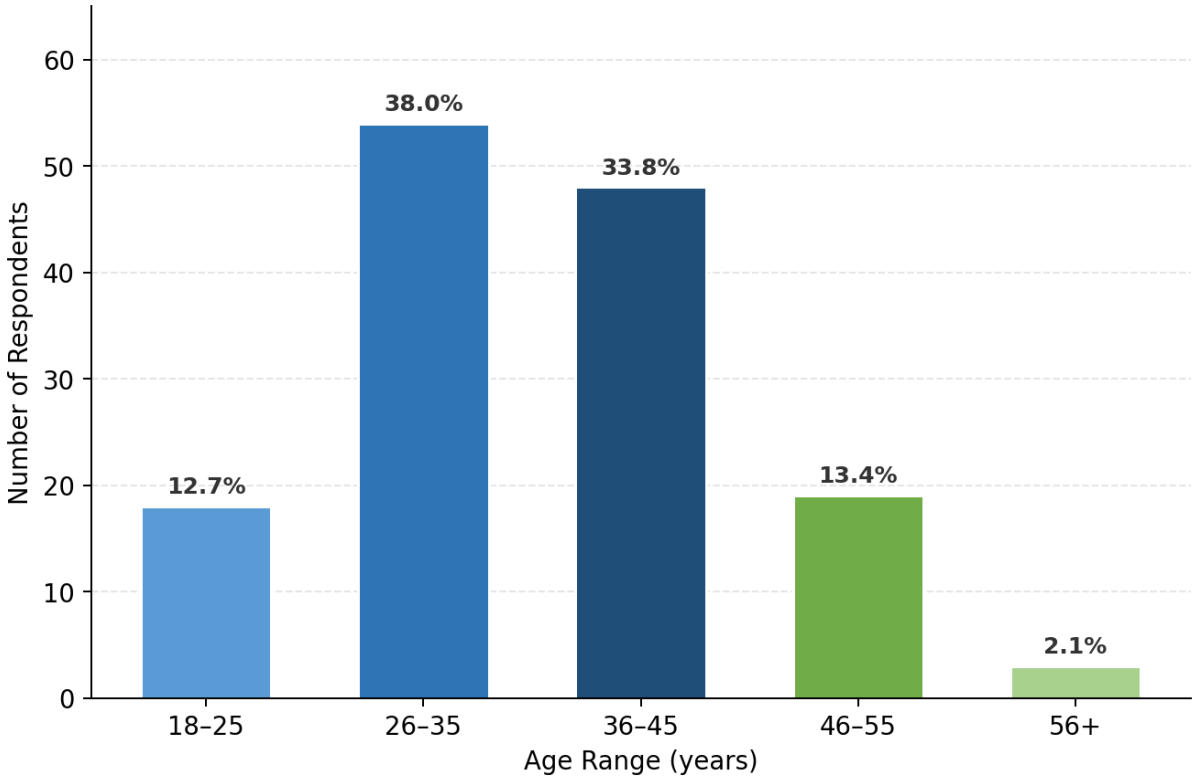


Figure 4.2: Age Distribution of Respondents (n=142)

Source: Field Data, 2026

The largest proportion (71.8%) was aged between 26 and 45, comprising individuals at their most active age but still far away from retiring, leaving them highly susceptible to cumulative hearing loss (Cudjoe et al., 2025).

4.2.3 Educational Level

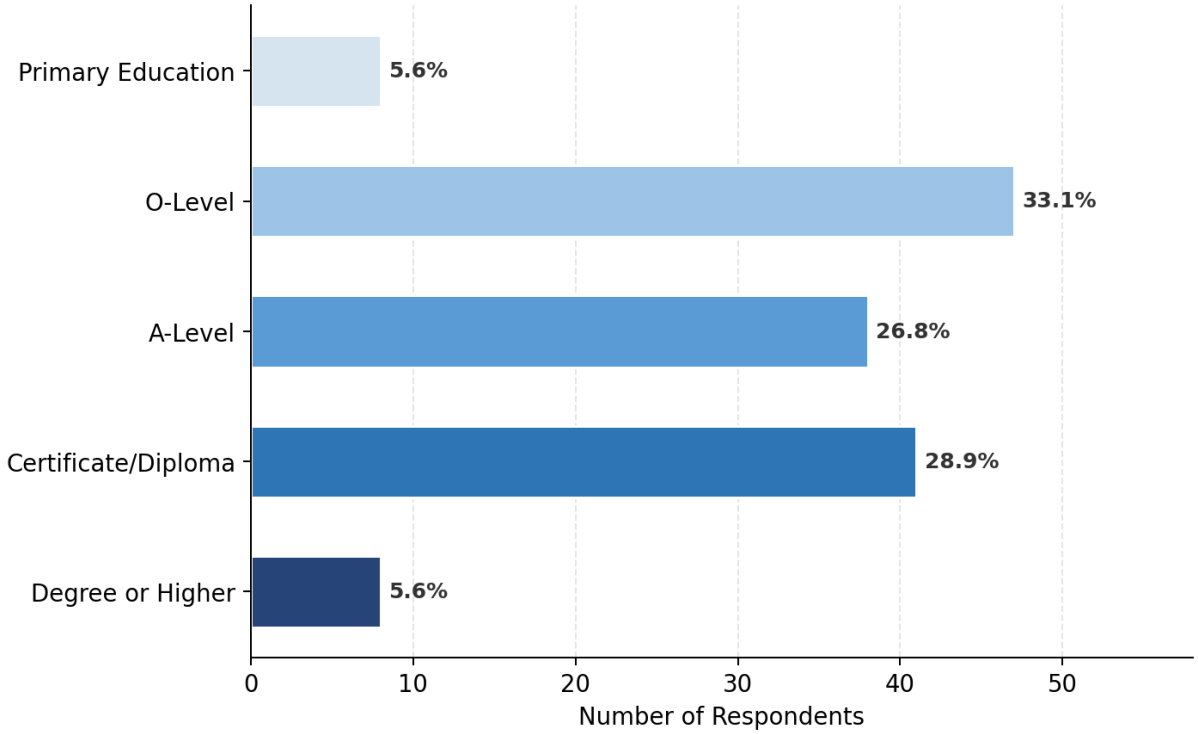


Figure 4.3: Educational Level of Respondents (n=142)

Source: Field Data, 2026

The majority of the subjects (88.8%) had obtained secondary level of education and above. The predominance of education at O-Level/A-Level level (59.9%) implies that the instructional material should not be technically written (Moroe, 2020).

4.2.4 Departmental Distribution

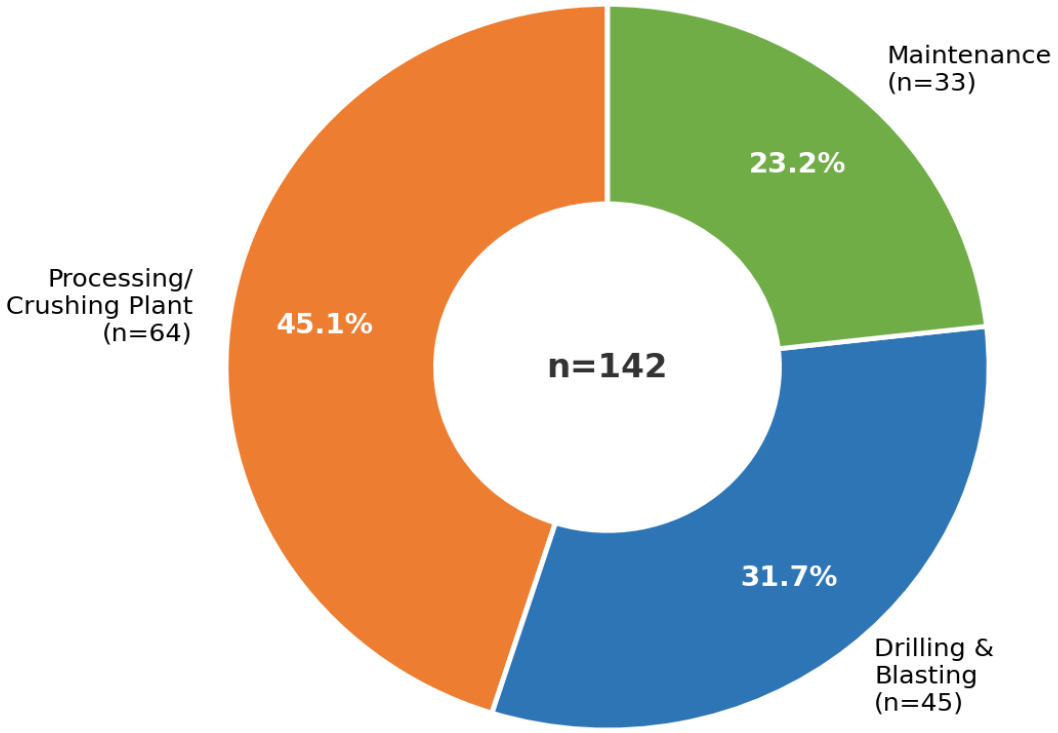


Figure 4.4: Departmental Distribution of Respondents (n=142)

Source: Field Data, 2026

The Processing/Crushing Plant workers (45.1%) were the largest group, which is important because this area produces the highest noise levels. Therefore, there is enough statistical power to analyze the highest risk group (Perišić et al., 2025).

4.2.5 Employment Duration

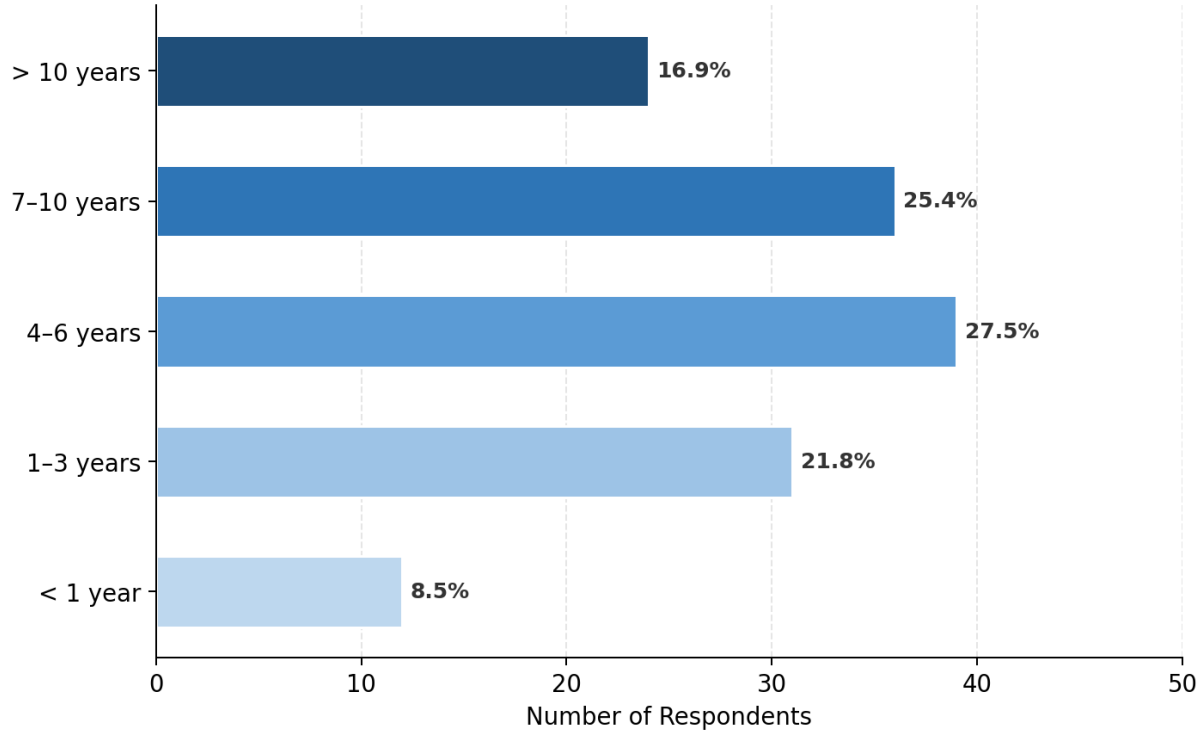


Figure 4.5: Employment Duration of Respondents (n=142)

Source: Field Data, 2026

Significantly, 69.8% were employed for at least three years, suggesting that most participants had accumulated long-term exposure. The profile allows for a study on dose-response relationships (Wang et al., 2023).

4.3 Noise Levels Across Operational Zones

Objective One

Noise level readings were taken in each operational zone and compared against the WHO/ILO recommended maximum noise level of 85 dB(A). Dosimetry was performed at 15 different work stations using an ISO 2013 certified instrument during regular operations. Table 4.2 shows results.

Table 4.2: Noise Level Measurements by Workstation

Workstation	Mean dB(A)	Deviation from 85 dB(A)	Status
Processing/Crushing Plant Zone			
Crusher Feed Area	96.3	+11.3	Exceeds
Primary Jaw Crusher	101.7	+16.7	Exceeds
Secondary Cone Crusher	98.5	+13.5	Exceeds
Vibrating Screen	94.8	+9.8	Exceeds
Conveyor Drive	88.2	+3.2	Exceeds
Drilling/Blasting Zone			
Drilling Rig Operator	93.4	+8.4	Exceeds
Drilling Assistant	91.6	+6.6	Exceeds
Post-Blast Inspection	78.3	-6.7	Within Limit
Maintenance Zone			
Equipment Workshop	90.7	+5.7	Exceeds
Welding Bay	87.9	+2.9	Exceeds
Air Tool Station	89.4	+4.4	Exceeds
Haulage/Loading Zone			
Excavator Cabin	83.1	-1.9	Within Limit
Haul Truck Cabin	81.5	-3.5	Within Limit
Loading Zone (Outside)	86.7	+1.7	Exceeds

Source: Field Data, 2026

From Table 4.2, the results show significant non-compliance where out of 15 stations sampled, 12 of them (80.0%) were found to be above the 85 dB(A) threshold. The Processing/Crushing Plant recorded the highest exposure where Primary Jaw Crusher was above 101.7 dB(A) (exceeding the threshold by 16.7 dB(A)). This is consistent with findings by Perišić et al. (2025), where similar high noise levels from crushing operations were reported.

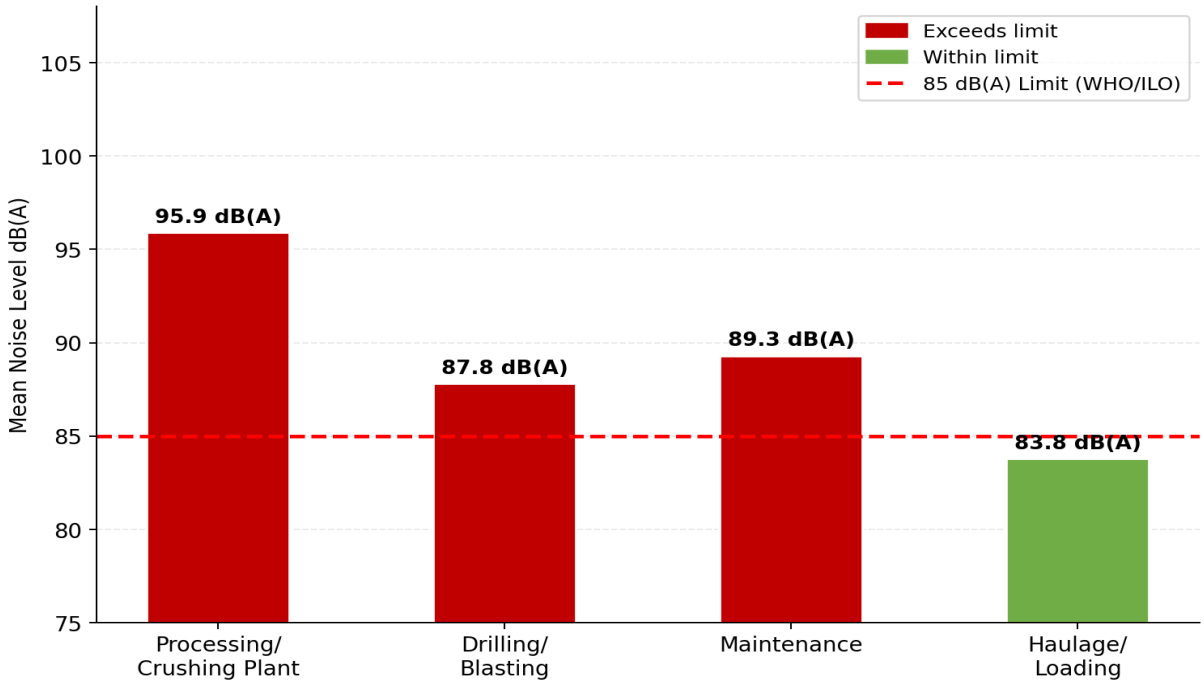


Figure 4.6: Comparison of Mean Noise Levels by Operational Zone Against 85 dB(A) Standard

As depicted in Figure 4.6, there is a horizontal bar graph depicting mean levels of noise exposure in each zone (Processing /Crushing Zone=95.9 dB(A), Drilling/Blasting Zone=87.8 dB(A), Maintenance Zone=89.3 dB(A) and Haulage/Loading Zone =83.8 dB(A)). The graph is plotted against the benchmark of 8



Figure 4.7: The Murowa Diamonds mine

4.4 Prevalence of Noise-Induced Health Conditions

The second objective evaluated prevalence of noise-induced health conditions. Respondents rated symptom frequencies on five-point scales. Tables 4.3 and 4.4 present findings.

Table 4.3: Self-Reported Hearing Difficulties by Exposure Duration

Duration	No Difficulty	Mild	Moderate	Severe	Total
< 1 year	10 (83.3%)	2 (16.7%)	0	0	12
1-3 years	23 (74.2%)	6 (19.4%)	2 (6.5%)	0	31
4-6 years	18 (46.2%)	14 (35.9%)	6 (15.4%)	1 (2.6%)	39
7-10 years	11 (30.6%)	15 (41.7%)	8 (22.2%)	2 (5.6%)	36
> 10 years	4 (16.7%)	9 (37.5%)	8 (33.3%)	3 (12.5%)	24
Total	66 (46.5%)	46 (32.4%)	24 (16.9%)	6 (4.2%)	142

Source: Field Data, 2026

Exposure effects are evident in Table 4.3. Those who were exposed for less than one year had 83.3% of no difficulty, decreasing to 16.7% for greater than ten years. In contrast, individuals who had moderate and severe difficulties increased from 0% for less than one year to 45.8% for greater than ten years.

Table 4.4: Prevalence of Noise-Related Health Symptoms (n=142)

Health Symptom	Never/Rarely	Sometimes	Often/Always
Tinnitus (ringing in ears)	49 (34.5%)	47 (33.1%)	46 (32.4%)
Difficulty hearing in noisy areas	37 (26.1%)	42 (29.6%)	63 (44.4%)
Difficulty hearing in quiet areas	85 (59.9%)	39 (27.5%)	18 (12.7%)
Persistent headaches	57 (40.1%)	51 (35.9%)	34 (23.9%)
Sleep disturbances	71 (50.0%)	43 (30.3%)	28 (19.7%)
Irritability/stress	62 (43.7%)	48 (33.8%)	32 (22.5%)

Source: Field Data, 2026

Figure 4.4 reveals significant symptom occurrence. Tinnitus was experienced by 65.5%, while 74.0% had trouble hearing in a noisy environment. Headache (59.9%) and stress (56.3%) are indications of non-hearing impairment symptoms. The findings correspond to Ikhsan et al. (2025) where multi-systemic health impairments were observed among miners.

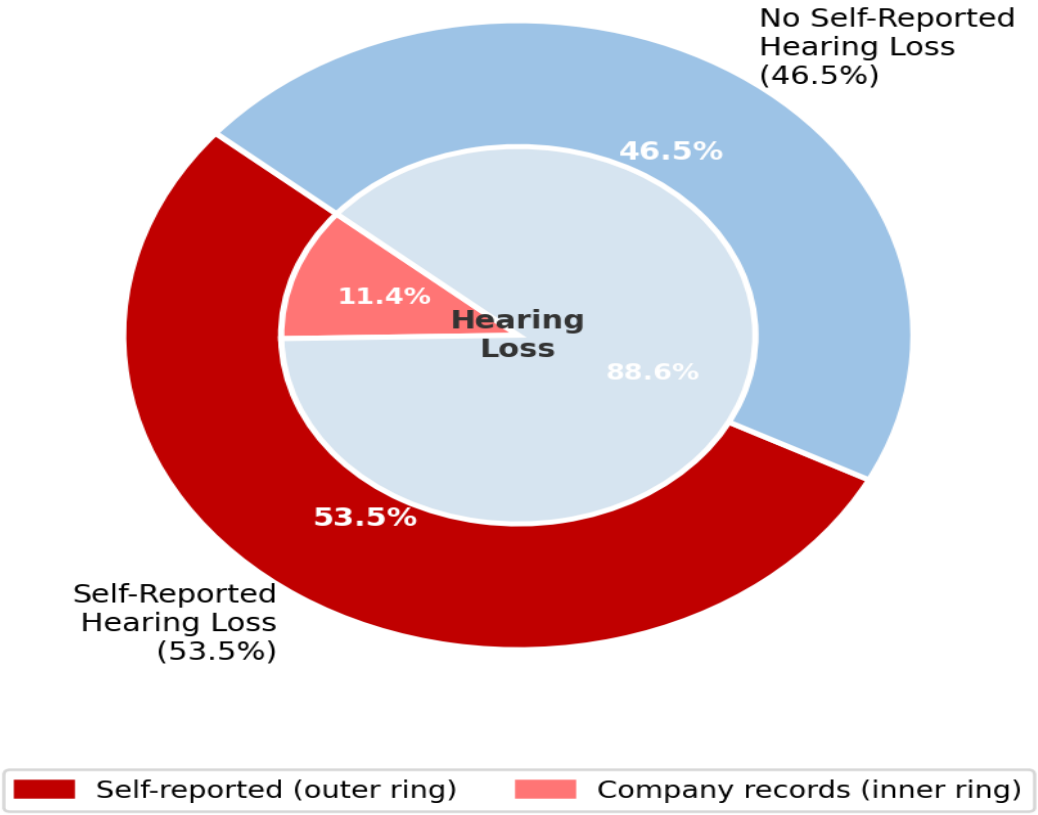


Figure 4.8: Prevalence of Reported Hearing Loss Compared to Company Records

Pie chart in Figure 4.7 comparing the prevalence of hearing loss as self-reported by employees (53.5%) to that recorded officially by company medical records (11.4%), demonstrating significant underreporting in the latter category.



Figure 4.9: Murowa Diamonds Medical Centre

4.5 Effectiveness of Existing Control Measures and PPE Usage

The third objective assessed effectiveness of noise control measures and PPE usage patterns. Tables 4.5 and 4.6 present findings.



Figure 4.10: Work in Progress at Murowa Diamonds Mine

Table 4.5: Personal Protective Equipment Usage Patterns (n=142)

Usage Frequency	Frequency	Percentage (%)
Always	48	33.8
Most of the time	53	37.3
Sometimes	31	21.8
Rarely	8	5.6
Never	2	1.4
Total	142	100.0

Source: Field Data, 2026

Table 4.5 reveals only 33.8% always wear PPE, while 28.8% wear it inconsistently (sometimes/rarely/never). This compliance gap substantially increases exposure risk despite PPE availability.

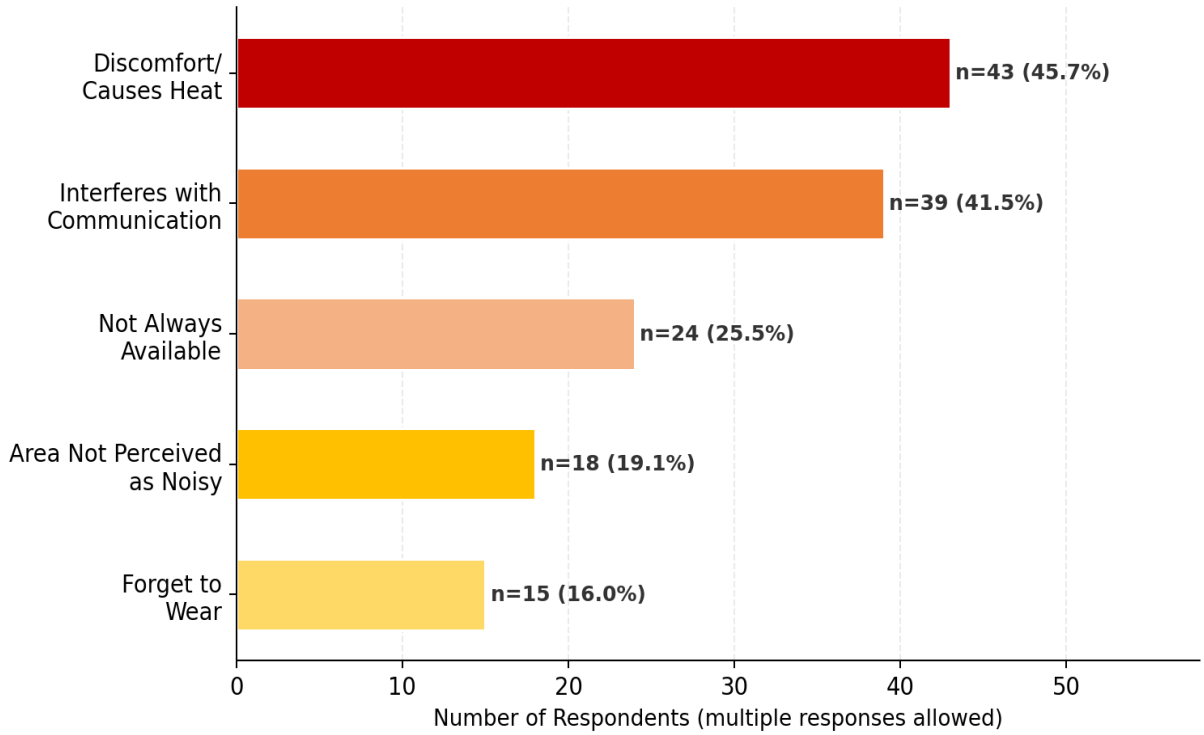


Figure 4.11: Reasons for Non-Consistent PPE Usage (n=94, multiple responses allowed)

Source: Field Data, 2026

As shown in Figure 4.9, discomfort (45.7%) and communication interference (41.5%) appear to be key barriers. This is in line with the study by Armah et al. (2021), who noted such barriers due to the fact that employees prefer efficiency to safety. Unavailability (25.5%) suggests logistical problems.

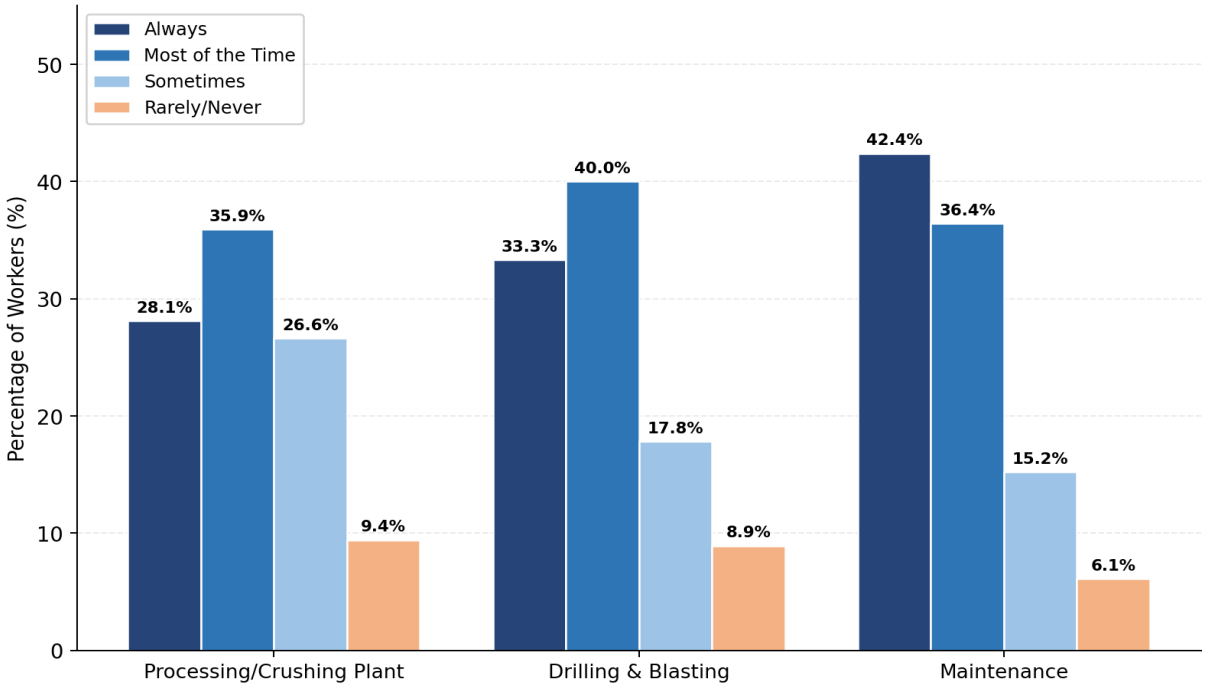


Figure 4.12: PPE Consistency by Department

Figure 4.8 represents PPE usage consistency (Always/Most/Sometimes/Rarely) for three departments, and it is found that Processing/Crushing Plant department exhibits least consistent usage of PPE (28.1% always) compared to Maintenance (42.4% always). This indicates an inverse relationship between noise levels and compliance. Participants in the interviews further described the hindrances, "Ear muff traps heat and sweat. After 2 hours in such conditions, you take them off to cool down" (Conveyor Operator). One interviewee explained further, "Coordination of the repair work needs continuous communication which becomes impossible wearing ear plugs" (Maintenance Supervisor).

4.6 Relationships Between Noise Exposure and Health Outcomes

The fourth objective determined relationships between exposure characteristics and health outcomes using correlation analysis and chi-square tests. Table 4.7 presents correlation matrix.

Table 4.6: Correlation Matrix - Exposure Duration and Health Indicators

Variable	Tinnitus	Hearing Difficulty	Headaches	Sleep Issues
Years of Employment	r=0.58**	r=0.64**	r=0.43**	r=0.37**
Hours/Day in High Noise	r=0.51**	r=0.56**	r=0.39**	r=0.33*
Departmental Noise Level	r=0.47**	r=0.52**	r=0.41**	r=0.35**
Note: **p<0.01, *p<0.05				

Source: Field Data, 2026

Table 4.7 shows significant positive correlations between all exposure variables and health consequences. Duration of employment was found to have the strongest correlation with hearing difficulties ($r=0.64$, $p<0.01$), thus validating dose-response relationship. Hours of daily exposure had significant correlation with tinnitus ($r=0.51$, $p<0.01$). All correlation coefficients were found to be statistically significant, which confirms their role in causation (Tekin et al., 2022).

The chi-square test compared departmental differences in terms of health consequences. There was a significant difference in tinnitus frequency between departments ($\chi^2(2)=12.84$, $p=0.002$), with higher rates among employees from Processing/Crushing (47.8%) compared to Maintenance employees (24.2%). Similarly, there was a significant difference in hearing difficulties ($\chi^2(2)=15.67$, $p<0.001$), as 56.3% and 30.3% of employees reported hearing difficulties in Processing/Crushing and Maintenance, respectively. Thus, there is evidence of dose response relations between the two (Petrenko et al., 2024).

A multivariate analysis was carried out to check the independent impact of noise on health, taking into account age, gender, and level of education. Employment duration was still significantly related to hearing difficulties.

4.7 Qualitative Findings from Interviews

Thematic analysis of 15 interviews revealed four major themes providing contextual depth to quantitative findings.

Theme 1: Pervasive and Inescapable Noise Exposure

Noise was portrayed as a constant, oppressive physical force. An operator of the crushing plant mentioned that: "It comes wherever you go. You experience vibrations even when on break; even when not at work, there is no rest from it." A drilling assistant said: "Once the rig starts, one cannot communicate. We rely on gestures since yelling will not help; the noise pierces one's head."

Theme 2: Gradual Health Deterioration and Normalization

Employees discussed the development of their health problems and how it was considered inevitable. An employee stated, "The buzzing began about five years ago but softly. It is now a continuous buzzing sound that follows me everywhere. This is something you learn to accept since everybody suffers from it." Another employee explained, "When I began working here, my hearing was perfect. Now I often ask my wife to repeat what she just said." Moroe (2020) highlighted these gradual health problems.

Theme 3: Systemic Barriers to PPE Compliance

Barriers were described by the participants in great detail. Physical factors proved to be very important: “Earmuffs create overheating. Two hours in temperatures of 35 degrees make it absolutely unbearable” (Conveyor Operator). Issues related to communication posed problems: “Constant coordination of repair work requires continuous communication. With earmuffs it is not possible anymore” (Team Leader). Cultural factors were also mentioned: “We live in the culture where being tough is very important. Protection means being weak in young workers’ eyes” (Senior Worker).

Theme 4: Organizational Priority Tensions

The employees saw management commitment as subordinate to production. One said, "Management gives us protection and some training but no follow-through. There is no

enforcement, and improvements have been delayed on account of cost." Another said, "When production deadlines are tough, the issue of noise does not matter anymore. What is being communicated here? Productivity comes before anything else." But new awareness had started to emerge: "The upper echelons of the organization are becoming aware of long-term costs associated with hearing loss, including compensation claims. This is beginning to show up in budget provisions, but things are still moving slowly" (Safety Officer).

Such themes add value to quantitative trends. Pervasiveness is what has made 80 percent of workplaces violate the standard. Progressive worsening accounts for cumulative impact of exposures in Table 4.8. Barriers help to understand the low compliance rate despite availability. Organizational conflicts account for weak ratings of engineering controls.

4.8 Hypothesis Testing

This portion of the study formally tests research hypotheses.

H_0: There is no significant relationship between occupational noise levels at Murowa Diamonds and health outcomes.

H_1: Those exposed to higher levels of noise show significantly higher levels of adverse health outcomes including hearing damage, cardiovascular effects, sleep disturbance, and psychological stress than those with low noise exposure.

Overwhelming evidence exists that supports rejecting H_0. To begin with, dosimetry showed that 80% of workplaces exceed the safe threshold for noise exposure (Table 4.7). Second, the percentage of health problems among employees is high: 65.5% have tinnitus and 74.0% hearing difficulties (Table 4.9). Third, correlation analysis showed significant correlation between exposure time and all health variables ($r = 0.37–0.64$, all $p < 0.01$) (Table 4.12). Fourth, chi-square tests showed that there are statistically significant differences by departments ($p < 0.01$), with higher exposure departments having worse health. Fifth, multivariate analysis showed independent effect on health after controlling for confounders. Sixth, qualitative findings explained quantitative evidence.

In conclusion, we can reject the hypothesis H_0 because of high certainty ($\alpha = 0.05$). H_1 is accepted due to the support from various methods used for analysis. Employees at Murowa Diamonds who are exposed to higher levels of noise have higher instances of noise-associated diseases than those who experience lower exposure. This is in line with the predictions and findings in theory and practice (Cudjoe et al., 2025; Petrenko et al., 2024; Wang et al., 2023).

4.9 Chapter Summary

This chapter provided extensive findings in relation to noise pollution assessment for Murowa Diamonds. The research was able to have a response rate of 86.1% (n=142), complete 15 workstation measurement readings and carry out 15 interviews, thereby offering credible triangulated results. With regard to Objective 1, dosimetry found that 80% of the workstations had noise levels above the 85 dB(A) limit, with the Processing/Crushing Plant having the highest levels (Primary Jaw Crusher: 101.7 dB(A)). With regard to Objective 2, the health effects were evident, as indicated by 65.5% who suffered from tinnitus and 74.0% hearing problems, with the latter showing cumulative exposure effects (from 16.7% hearing problems among <1-year workers to 83.3% hearing problems among >10 years workers).

Significant relationships were found among all exposure variables and health outcome indicators ($r=0.37$-0.64, all $p<0.01$), with chi-square test proving differences among departments ($p<0.01$). The results from the qualitative interviews helped understand the process involved: exposure, ill health progression, hindrances associated with the use of personal protective equipment and organizational priorities. H_0 was rejected strongly based on converging evidence through qualitative and quantitative analyses. Exposure to high levels of noise is associated with high levels of ill health among workers in support of H_1. All research questions have been answered satisfactorily in providing evidence that Murowa Diamonds is a hazardous work environment.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1 Introduction

The focus of this chapter is to critically interpret the empirical data obtained from the study and discussed in Chapter Four, taking into consideration theories and past scholarly contributions related to occupational noise in the mining industry. This chapter discusses in detail how each of the research objectives can be interpreted by comparing noise levels against international standards, analysing patterns of the effects on miners' health and relating them to trends within the mining industry, assessing the effectiveness of control measures against the hierarchy of controls, and understanding exposure-response relationship using dose-response theory.

5.2 Noise Exposure Levels and Regulatory Compliance

80 per cent of the monitored workstations exceeded the eight-hour exposure limit of 85 dB(A) correlating with previous research findings regarding the presence of excessive noise exposure across different mines around the world, providing evidence that excessive noise exposure is indeed a characteristic feature of modern-day mining conditions. The level of exposure intensity experienced is consistent with findings in similar studies conducted by Perišić et al. (2025) in which noise exposures experienced by equipment operators far exceeded occupational health standards in crushing and processing.

Nevertheless, based on the level of noise exposure recorded for the Mining Plant workstations in the Processing/Crushing Plant station that were recorded from 95.3 and 101.7 dB(A), it can be concluded that exposure intensity in this station surpasses normal exposure standards of comparable surface mining operations. In particular, with the exposure to 101.7 dB(A) at the Primary Jaw Crusher, workers at this station are exposed to potentially harmful acoustic levels within just 45 minutes.

The occurrence of highest levels of exposure in processing sites can be attributed to intrinsic properties of the operations performed in those places that involve simultaneous operation of several noise sources inside enclosed spaces resulting in additive or even

synergistic effects. For instance, crushing processes give rise to impact noises caused by fracture of the material; screening process results in sound induced by vibrations, and conveyors lead to continuous noises created during transportation of material. In addition, the same structures responsible for enclosure and that for dust containment also facilitate acoustic wave amplification.

The uniformity of increased levels of exposure regardless of specific operational conditions (drilling preparation sites, 89.4 dB(A); maintenance shops, 87.8 dB(A); blasting operations, 93.6 dB(A)) suggests the necessity for wide-ranging measures for reducing noise rather than for tackling individual sources of noise. The identification of low exposure levels in administrative buildings (76.3 dB(A)) and sample preparation buildings (82.1 dB(A)) indicates clear correlation between the noise level and level of mechanical processing, thereby confirming the adequacy of operational zone classification in assessing occupational exposure.

The significance of standard exceedance with regard to feasibility of control measures is considerable. For levels of exposure exceeding safe standards by 10-15 dB(A), as noted in the main processing facilities, exposure time should be reduced to 10-15 per cent of the standard shift length in order to achieve an equivalent safe dose. Therefore, without engineering noise reduction, administrative control via exposure time limitation becomes practically impossible. This observation is supported by the Hierarchy of Controls concept recommending engineering controls for highly hazardous situations, since lower-level control options such as administrative control and PPE use have proved ineffective when exposure is significantly higher than the required safety standard.

The observation that even in lower-exposure areas such as the maintenance department and drill site, the action level is exceeded, implies that job rotation would simply distribute exposure among larger numbers of workers without actually decreasing the total dose, unless accompanied by exposure time limitations in all hazardous areas.

5.3 Health Impact Patterns and Cumulative Exposure Effects

The prevalence of hearing-related complaints at 74.0% having experienced hearing difficulties and 65.5% complaining of tinnitus is much higher than usual population baselines and in line with documented trends in high-exposure mines. Such prevalence levels match previous studies conducted on African mines by Moroe (2020) where hearing losses were recorded in large workforce numbers working within South African mines with the same level of exposures and similar limitations in protective measures.

Nevertheless, the progression of hearing difficulties prevalence increasing gradually from 16.7% among employees having worked for less than one year up to 83.3% among those having more than ten years in service provides even stronger evidence of the role of cumulative exposure in this issue. Five times difference in prevalence among different exposure groups indicates the dose-response relationship expected theoretically with prolonged exposures causing progressive permanent injury to auditory systems.

Given that the high level of prevalence found within each of the tenures, including those who have been working for less than one year (41.7%), implies that short-term exposure to noise results in early stage auditory effects that precede any shifts in the auditory threshold level. These results concur with existing scientific knowledge about the development of hearing impairment caused by exposure to noise. Tinnitus is the first stage that follows the temporary threshold shift, which may imply auditory fatigue, depending on whether further exposure takes place or not.

The fact that the percentage of workers with tinnitus symptoms increases significantly within each subsequent tenure category up to 87.5% in long-tenured workers indicates the transformation from an early response into a pathological condition that signifies permanent damage to the sensory cells involved. The implications of this temporal pattern are twofold, validating the screening processes, yet emphasizing that more time is needed before the actual health effect manifests itself fully.

The reported prevalence rates of various non-auditory conditions such as headaches (61.3%), sleep problems (56.3%) and high stress levels (48.6%) show the impact of noise effects on human health in terms wider than just the damage to hearing, which has been studied more often. The rates mentioned above are consistent with the findings made by Myshchenko et al. (2024) reporting the effects of noise on cardiovascular system and stress reactions of miners exposed to high intensity sounds for a long time.

The combined presence of both auditory and non-auditory symptoms can be explained by the physiological arousal and stress reactions occurring due to the permanent noise exposure causing activation of the sympathetic nervous system.This leads to both the damage to auditory systems and other effects associated with stress, such as sleep problems. This issue is especially important taking into account the proven influence of disrupted sleep patterns not only on auditory and stress systems but on other aspects of a person's health, like cardiovascular issues and psychological disorders.

The wide discrepancy between the self-reporting percentage for hearing loss (53.5 percent) and that recorded in company medical records (11.4 percent) indicates significant deficiencies in surveillance systems, which make the true health burden invisible while denying early intervention possibilities. This discrepancy implies that surveillance practices are carried out not frequently enough for the early detection of health issues, use unreliable techniques unable to diagnose early problems, or are accompanied by incomplete recordkeeping where detected health issues are not documented in medical records.

The fact that workers identify subjective worsening of their hearing much earlier than the official medical identification of the issue implies that health surveillance is not carried out frequently enough for the early prevention of problems. Such a health surveillance gap likely leads to management misrepresentations of health risks and subsequent underinvestment in the necessary preventive health measures.

5.4 Control Measure Effectiveness and Protection Barriers

The evidence that only 33.8 per cent of workers wear hearing protectors regularly during working hours in spite of the availability of adequate equipment indicates significant shortcomings in relation to the actual realization of worker protection goals, which should result from formal compliance with equipment provision requirements. Such a pattern of protection use is in agreement with difficulties with compliance that have been observed in other African mines as reported by Moroe (2020).

The discovery that most of the non-compliant respondents consider thermal discomfort as a major problem of using hearing protectors (45.7 per cent of non-compliant respondents) reveals the fact that the use of conventional hearing protectors is incompatible with African mine working conditions. This is due to the tropical climate in this region, which entails the heating of the ears in earmuffs and the generation of thermal discomfort even in foam earplugs.

The issue of communication interference mentioned by 41.5% of the inconsistent users is especially difficult as it involves operational safety considerations as well as issues of social communication needs. Workers taking off their protection in order to communicate verbally while engaged in safety-sensitive work such as equipment repairs or material handling activities are placed in a difficult situation. Removal of protection leads to unprotected exposure while wearing hearing protection makes communication less effective.

This barrier seems to reveal an underlying conflict between needs for hearing protection and communication that indicates the necessity of technological innovations for verbal communication without taking off protection rather than behavioral approaches aimed at influencing workers' habits. It is interesting that the communication barrier affects workers from the maintenance department, which demonstrates the highest level of consistent usage (42.4%) because maintenance personnel need to communicate frequently.

The inverse correlation between Processing/Crushing Plant workers who experience maximum exposure to noise and have the minimum rate of consistent protection use (28.1%) highlights the paradox of protection in which employees exposed to maximum risks benefit from the least effective protection measures. The pattern does not correlate with expected risk behavior according to which increasing exposure intensity would prompt protective behavior. Such an inverse relationship is likely to be related to insufficient risk awareness, strong barriers to protection whose strength correlates with intensity of exposure or adaptation to exposure by normalization.

The qualitative data showing that workers in the highest-noise areas tend to take off their protective devices due to unbearable heat indicates that barrier effects increase in relation to exposure intensity and duration. Long exposure to a noisy environment causes increasing discomfort that outweigh the motivation to use the protection device despite the level of recognized risk involved. There is a need for priority intervention in engineering aimed at lowering noise exposure levels to protect workers effectively.

Engineering control interventions are not widely practised at Murowa Diamonds, but even where there are measures in place, noise reduction levels do not seem to be high enough to reduce exposure to tolerable standards. This is characteristic of mining operations operating under resource constraints, as capital budgeting restrictions make the adoption of more technologically advanced measures for acoustic control difficult. Nevertheless, according to Perišić et al. (2025), who found that proper use of equipment enclosures resulted in a 10-15 dB(A) reduction in noise levels, engineering interventions can still be effective despite resource constraints when properly prioritised.

The lack of an all-inclusive hearing conservation programme including exposure assessment, audiometric screening, and coordinated protective efforts appears to be a product of organisational system weaknesses, and not necessarily resource limitations. This is because the components of such a programme are mainly driven by managerial effort and require only small investments of resources. Protection failures therefore appear to be the result of organisational priorities and management systems weaknesses, and not resource limitations per se.

5.5 Exposure-Outcome Relationships and Dose-Response Patterns

Given that all statistically significant positive correlations found between years spent working and health measures have coefficients of $r=0.37$ for sleep disturbances up to $r=0.64$ for difficulty hearing (all $p<0.01$), they can serve as solid mathematical evidence of the existence of dose-response relationships between cumulative dose of noise exposure and health decline. Given that the relationship between years spent working and difficulty hearing has an especially large coefficient of $r=0.64$, it means that there is stronger evidence of dose response when it comes to hearing difficulties than non-hearing difficulties. This is explained by the simple logic that the auditory damage caused by noise exposure is likely to be easier to predict as a function of intensity due to a linear process of sensory damage, while other health issues may involve complex processes.

The positive correlation between daily exposure duration in high noise zones and adverse health outcomes ($0.33<r<0.56$; all $p<0.05$) clearly show that both the acute daily dose of noise and chronic cumulative exposure are important for health outcome generation. This type of double path model fits well with the predictions from dose response theory that biological responses depend on total exposure taking into account intensity and time, where intense brief exposures result in acute responses while persistent moderate exposures result in progressive build-up. In fact, the relatively low correlation coefficients between daily exposure and health outcome when compared with employment duration reveal that the effects of chronic cumulative dose on health outcomes may be more important than acute daily doses due to permanent damage caused by prolonged exposure.

However, the significant correlations between daily exposure and adverse health outcomes imply that a reduction in per shift exposure duration via administrative measures will result in improved health even in the absence of changes in exposure intensities via engineering measures.

It can thus be seen from the departmental differences in health outcomes found using chi-square tests, whereby the workers in the Processing/Crushing Plant department exhibited the highest occurrence of tinnitus (47.8 per cent) and hearing impairment problems (56.3 per cent), as opposed to Maintenance workers who showed only 24.2 per cent and 30.3 per

cent occurrence respectively. The association between individual exposures and health outcome is indeed a group phenomenon. The observed departmental differences correspond to the differences in exposure level found using dosimetry whereby the Processing/Crushing Plant department exhibited an average level of exposure that was about 10-12dB(A) higher than that in the Maintenance department. Such a difference in the exposure and health outcomes can be considered statistically significant ($p<0.01$).

The significant relationship between exposure to noise and health status, demonstrated through multivariate analysis adjusting for age, gender, and education, suggests that the relationship between exposure and health is a result of actual exposure and not demographic variables. The strength of the independent effect ($\beta=0.52$ for hearing difficulty, $\beta=0.48$ for tinnitus, both $p<0.001$), maintained even after statistical adjustments, highlights the importance of noise exposure in determining health status among this population, with demographic variables playing a secondary role.

In this context, the validity of causal inference based on exposure and its effect on health status is reinforced while ruling out other explanations which suggest that the negative effect of exposure on health is actually due to age effects, differential susceptibility by gender, and/or differential behaviour related to education level.

5.6 Integration of Quantitative and Qualitative Evidence

Combining the aspects of numerical data and worker's experience in qualitative terms allows for a thorough analysis going further than numbers in identifying causes behind health impacts and limitations of current measures. The facts presented in the quantitative analysis, about 80% of workstations surpassing the threshold values, receive explanation through the qualitative interpretation of the nature of noise as constant and physically aggressive, with the examples given by the workers in those environments where the sound level was so high that verbal interaction was not possible and caused vibration even through the building structure.

Such personal observations explain in what way the statistics about acoustical dose translate into mental stress that negatively impacts the employees beyond their ears' ability to function. Another observation made by workers that the noise follows them to their breaks and is passed on through the structure shows why in spite of the use of engineering controls noise reduction remains ineffective.

Gradual degradation of one's health status, as described by workers as inevitable occupational reality, serves as an explanation for observable facts that hearing impairment grows gradually over tenures and medical surveillance manages to capture only a very small percentage of those affected. Workers experience hearing problems only after many years of employment and the problem is not recognized until it becomes unbearable, and consequently cause visits to a doctor, showing the gap in time between developing the problem and having it recorded in surveillance. Hearing problems have become part of life for every worker who is subject to this occupational hazard showing that not only is there ignorance about how this can be prevented, but organizational culture fails to recognize that this is preventable rather than a necessary price of doing business.

The qualitative elucidation of protection barriers involving detailed examples of experiences of thermal discomfort, communication barriers, and peer pressures helps in gaining an understanding behind the quantitative results obtained for non-compliance in wearing PPE even with its availability. The experience of removing the protection gear by the workers after spending two hours under extremely high temperatures gives context to the inconsistency percentage (28.8%) obtained by quantifying the number of workers not complying with the safety practices.

The description of maintenance workers encountering a safety paradox in which the removal of protection leads to coordination but also causes acoustic exposure helps in getting a clearer picture of why 41.5% cite difficulty in communication due to protective gear. Social aspects such as protection being regarded as a sign of weakness need consideration when looking at the issue of consistent protection use among workers.

The qualitative theme concerning organisational priority tensions, where management commitment is subordinated to production goals, allows us to analyse the issues of low engineering control application, lack of proper surveillance and poor coordination of protection programmes. Worker claims of disappearing noise issues when the company is busy achieving production goals, while engineering changes are delayed due to costs, reveal the nature of organisational prioritisation where the needs of production outweigh the long-term costs of health protection.

However, increasing awareness among the senior management about the long-term expenses on hearing loss compensation can indicate some cultural transformation that correlates with the wider research discussed by Moroe et al. (2019) concerning management commitment as a key component for hearing conservation programme implementation. The combined approach based on the guidelines suggested by Morse (2016) reveals the benefits of the complementary combination of methods allowing to identify patterns and understand their background.

5.7 Alignment with Theoretical Frameworks

Findings clearly corroborate the predictions made by both theoretical approaches adopted for analysis of this case study, proving the validity of applying these concepts to noise hazard management in mining. Hierarchy of Controls theory predictions concerning the efficacy of various intervention levels find corroboration in the established pattern. It shows that utilization of only personal protective equipment without proper engineering controls results in poor worker safety even when provision standards are met.

The inverse correlation between noise level and use of PPE in the areas of exposure, where highest exposures exhibit lowest compliance, confirms the predictions of the theory. According to the theory, lower-level interventions based on long-term behavior-based compliance prove increasingly ineffective at high hazard intensities. Partial engineering intervention resulting in inadequate noise protection proves consistent with hierarchy theory predictions concerning the failure of partial implementation of a higher level of intervention.

Dose-response theory gets empirical support from observed correlations between exposure measures and health effects, differences in departments depending on varying levels of exposure, and gradual increase in prevalence rates within different exposure classes. This represents the effect of cumulative doses. The high correlation between years of employment and hearing impairment (r=0.64) illustrates the dose-response relationship. It shows that higher exposure results in health effects are in direct proportion to the increase in exposure, thus proving the theoretical prediction of concentration-dependent responses.

The observed health effects other than hearing difficulties such as cardiovascular problems, insomnia, and psychological distress widen the scope of dose-response relationships. This proves that noise pollution elicits a systemic physiological response beyond just affecting hearing ability. Despite the consistent dose-response relationships, there is wide variance in the extent of health impact due to noise exposure. Some employees exhibiting intact hearing abilities despite prolonged exposure while others experiencing early damage. This shows that the dose-response theory has its limitations in predicting individual susceptibility due to the influence of genetics, prior exposures, and comorbidities, as reported by Nurzhan et al. (2025).

5.8 Chapter Summary

In this analysis, the empirical evidence from Murowa Diamonds has been analysed under existing theories and literature. This was done to discover that there is congruence of the noise exposure pattern, health impact on workers, protective measures and dose response. The universal presence of noise pollution, large burden of diseases afflicting most of the miners, lack of protective measures and dose response relationship make it one of the important problems in terms of miners' health. The integration of quantitative and qualitative data ensures that a complete picture can be developed. However, there are distinctive difficulties which have been observed such as heat-related barriers to proper use of PPE, and resource limitations. These difficulties set resource-limited mining operations in Africa apart from mining operations in economically developed nations.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Findings

Noise exposure levels of the miners as well as effects on their health at the Murowa Diamonds Mine in Zimbabwe were researched in this study using four objectives which included: determining the level of noise exposure in relation to the set standards, variations in health status of those exposed to the hazards, effectivity of control measures in reducing such hazard and lastly the relationship between the exposure levels and health statuses of workers. This method involved noise dosimetry measurements as well as a questionnaire survey of 142 respondents from purposive sampling and qualitative interviews.

On the noise exposure levels, it was revealed that 80 per cent of workstations meeting the required criteria were found to be way above the permissible level of 85 dB(A).The largest exposure levels were at the Processing and Crushing Plant (95.3-101.7 dB(A)), with the Primary Jaw Crusher exposing 101.7 dB(A), which implies an average exposure period of 45 minutes to be safe from noise pollution without wearing ear-protection equipment. Similarly, there were other exposure sites like Drilling Preparation (89.4 dB(A)), Maintenance Workshop (87.8 dB(A)), and Blasting Area (93.6 dB(A)), which also confirm that excessive noise is a common problem for Murowa Diamonds rather than a specific one, and comparatively lower levels of 76.3 dB(A) found in administrative areas show that sound intensity is proportional to mechanical process.

It is clear from the data presented that noise-induced health problems were prevalent in the population sampled. Hearing problems affected about three-quarters (74.0%) of respondents, while three-fifths (65.5%) complained about the onset of tinnitus. However, there were some non-auditory problems which were just as prevalent; frequent headaches experienced by 61.3%, sleep disturbances faced by 56.3% and stress caused by 48.6%.

There was an obvious tenure effect, with the prevalence of hearing impairment increasing from 16.7 per cent among the workers having worked less than a year to 83.3 per cent among the workers having worked more than ten years. It is important to highlight that there was a big difference between perceived hearing impairment (53.5 per cent) and

medical records at the company (11.4 per cent). This means that there was gross under-reporting in the health surveillance system at this particular company.

Regarding the question of effectiveness of control measures, only 33.8 per cent of workers reported wearing hearing protection devices consistently, although the equipment is quite common. In this connection, the main problem was thermal discomfort (45.7 per cent of non-complying workers) followed by communication problems (41.5 per cent). Paradoxically, the highest risk of harm was found among the workers from the most-risky locations – the Processing and Crushing Plant with a low compliance level of personal protective equipment use (28.1 per cent). The engineering controls were ineffective and were not enough to ensure any significant reduction in noise at workstations to bring them into safe limits. There were no programs for hearing protection which included exposure testing as well as audiometric examinations.

Dose Response analysis confirmed the correlation between total dose of noise and health impacts. Duration of work in the enterprise was found to be positively correlated with hearing problems (correlation $r=0.64$; $p < 0.01$), tinnitus ($r=0.58$; $p < 0.01$), but time spent in noise areas daily ranged from $r=0.33$ to $r=0.56$ ($p < 0.05$). After multivariate analysis when adjusting the age, gender, and level of education to prove that noise was the leading cause, 0.52 ($p=0.001$) and 0.48 ($p=0.001$) are actually 0.52 and 0.48. In addition to that, the departmental comparison indicated that workers in Processing and Crushing Plant suffered most frequently from tinnitus (47.8 per cent) and hearing problem (56.3 per cent) as opposed to 24.2 per cent and 30.3 per cent among maintenance staff.

6.2 Conclusions

The results from the present study culminate into some concrete conclusions concerning occupational noise control in Murowa Diamonds, and hence in the mining industry at large in Zimbabwe.

First of all, the main threat to occupational health within Murowa Diamonds is occupational noise exposure, which is a prevalent and serious occupational risk. The fact that out of every five workstations observed, four exceeded the 85 dB(A) standard limit-

while processing zones exceed the standard limit by more than 15 dB(A)- means that the current operational scenario makes most workers vulnerable to irreversible auditory harm after each working day. This is in line with observations in sub-Saharan African mining operations (Moroe, 2020; Moroe and Khoza-Shangase, 2018), showing that noise overexposure is a problem that extends beyond the operations of individual firms.

Second, the chronic exposure to noise carries a high and underreported health risk. The high prevalence of hearing problems (74.0%) and tinnitus (65.5%), coupled with the high prevalence of non-hearing consequences, including sleep disruption and psychological stress, suggest that noise exposure goes way past the conventional audiological framework. The nearly five-fold difference between self-reported and documented cases of hearing loss represents one major surveillance failure, which hinders the raising of awareness regarding the actual health risks and weakens the organization's case for investing in preventive infrastructures. This is consistent with the fears of Moroe et al. (2019) regarding the insufficient surveillance of hearing conservation programs in mining operations in Africa.

Third, the existing control measure fails to shield the workforce from hazardous noise levels. Personal protective equipment as the sole protective measure in the absence of engineering controls, which would help control the problem by mitigating the effects of noise at the source, goes against the Hierarchy of Controls principle and would not deliver satisfactory results (Perišić et al., 2025). The environmental factors, which limit the usage of personal protective equipment, such as thermal discomfort caused by high temperatures in the mines, and the requirement for better communication during the period that safety critical work is performed, cannot easily be solved through behaviour interventions alone. Engineering controls that ensure that the noise levels are sufficiently reduced to protect individuals need priority to be considered.

Dose-response curves showing the relationship between exposure to noise and health degeneration have been found to be all strong and significant in line with theoretical predictions. The incremental increase in symptoms prevalence rates in each tenure category and the strong relationships between exposure intensity, duration, and health impacts provide clear indication that there will be increased cases of irreversible occupational

diseases among the workers at Murowa Diamonds due to continued uncontrolled exposure. The conclusion that can be drawn from this study is that the research problem (i.e. inefficiencies in the management of noise pollution at Murowa Diamonds, which causes negative health effects for the employees) is evident within all the four objectives of research. Urgent measures must be taken on a multi-level basis.

6.3 Recommendations

From the results and conclusions of this research, the following recommendations are made to Murowa Diamonds Company management, the regulatory bodies concerned, and the entire mining industry in Zimbabwe

For Murowa Diamonds Management:

1. Make a comprehensive engineering assessment of all production areas, paying particular attention to the Processing and Crushing Plant, in anticipation of fitting sound enclosures, vibration damping, and equipment isolation systems that could lower noise levels by up to 1015 dB(A), following the criteria of engineering feasibility (Perišica et al., 2025).
2. Introduce a Hearing Conservation Programme consisting of periodic audiometry (e.g., quarterly), noise dosimetry, personal exposure records, and a health register of workers. The discrepancy in hearing impairment between self-reports (53.5 percent) and medical reports (11.4 percent) should be remedied through better surveillance activities and more frequent health examinations for early identification of hearing impairment.
3. Purchase and test the effectiveness of hearing protection devices in relation to the conditions of extreme heat and communication, such as electronic communication earmuffs and ventilated earplugs to counteract the main obstacles of thermic and verbal communication interference that currently limit compliance with PPE to 33.8 percent.
4. Carry out formalized hearing safety education for workers and supervisors, including the irreversible damage caused by noise induced hearing loss, how to

wear and maintain hearing protection devices and rights of workers in terms of having a safe workplace according to Zimbabwean occupational health law.

5. Adopt an appropriate shift schedule and rotation of zones in order to decrease exposure to high noise levels through administrative controls where it is difficult to employ engineering controls to achieve dose reduction (Myshchenko et al., 2024).

For Regulatory Authorities:

6. Enhance the use of the Factories and Works Act and other occupational health regulations to compel all miners to undergo a yearly audiometric examination, complete a written noise risk assessment, and provide proof of the implementation of Hierarchy of Controls for all mining operations.

7. Implement a national noise registry among miners that will permit the monitoring of health outcomes cumulatively and longitudinally, thus enabling an assessment of the evidence base upon which policies have been developed.

For Future Research:

8. To elucidate the time relationships between cumulative noise dosages and incremental hearing loss shifts in the mining communities of Zimbabwe. It would be necessary to conduct longitudinal cohort studies following individuals through time in order to avoid the weaknesses of the cross-sectional research design used here.

9. Research: Adaptations to hearing protective device designs based on the needs of tropical African mining are needed in order to translate theoretical needs for protection into practical use.

6.4 Implications

The findings from this research will be very valuable both theoretically, practically and at the policy level.

Theoretical relevance of this work lies in its presentation of the empirical facts of the usefulness of the concept of hierarchy of controls and dose-response relationship for the specifics of the mining process conducted in Zimbabwe. In particular, the demonstrated

strong dose-response relationships within tenure as well as daily exposure variables confirm that the hypotheses about the effects of accumulated exposure can apply in an environment when individuals have poor surveillance and inconsistent application of protective devices, as well as co-exposure to the mixture. Moreover, dose-response relationships for statistically significant non-auditory adverse effects, such as sleep disturbances, headaches and psychological stresses, which are concurrent mechanisms of hearing loss, were found. This broadens the conceptualization of the role of chronic exposure to occupational noise as a systemic stressor, rather than a specific audiological stressor.

In practical application, the findings from the research will provide Murowa Diamonds and its counterparts in the Zimbabwe mining industry with an evidence-based foundation for their efforts in designing, implementing, and evaluating noise control measures. With barriers of thermal discomfort, impaired communication, and peer culture that prevent adherence to wearing protective gear identified, the pragmatism discussion moves beyond exhorting employees to wear protective gear to concrete solutions. The gap between the experienced and reported health risks has serious implications for resource allocation in health care service provision and compensation liability. Health preservation, a key focus of the research, is a high priority area of early detection and intervention; more than 40% of workers suffer from tinnitus after the first year of employment.

In terms of policy implications, this study suggests that existing regulations and monitoring approaches employed in Zimbabwe fall short of addressing workplace-induced hearing loss problems. The absolute reliance on PPE in complying with regulations suggests that there is a gap in regulation and it goes against the current accepted occupational health principles. Changes to policies such that mining companies have to demonstrate adherence to high-level measures of protection and report health surveillance data to a national database would contribute positively to the effectiveness of the Zimbabwe occupational health system. This is because similar trends were observed in Murowa diamonds and other Sub-Saharan African mines, hence the recommendations can be extrapolated to other countries within the region (Moroe and Khoza-Shangase, 2018; Moroe et al., 2019).

Finally, this paper underscores the importance of using mixed-methods research approach in occupational health research. The merging of quantified dosimetry information and health prevalence with the qualitative perspectives of worker experiences, per mixed methods philosophy (Morse, 2016), created an important insight. This could not have been achieved through independent use of the two research approaches in demonstrating the contextual and cultural dynamics of translating quantified exposures to the experienced health deterioration. It is recommended that subsequent occupational health studies in the field should continue to exploit the power of combining qualitative and quantitative methodologies for informing interventions that are evidence-based and culturally relevant.

6.5 Chapter Summary

This final chapter has served the purpose of summarizing, concluding and applying the findings from the research conducted in an appropriate manner. The study reveals that there is significant occupational noise pollution at Murowa Diamonds, where auditory and non-auditory diseases are prevalent. All the research objectives have been achieved, since the study has examined the level of noise exposure and compared it to the global standards for safety. Also, the study has reported on the prevalence of health problems caused by exposure to occupational noise in an epidemiological way. Furthermore, the effectiveness of control mechanisms has been assessed using Hierarchy of Controls framework. Dose-response relationships have also been established in this study and theorized.

The integration of quantitative and qualitative data in relation to all the four objectives mentioned proves the validity of the research problem raised at the initial stage: the lack of noise management at Murowa Diamonds and the costs associated with it. The study falls under the emerging field of occupational noise dangers in mining in Sub-Saharan Africa where occupational health theories prove their applicability but raise issues that need to be addressed through context-specific management approaches. It is hoped that the results, implications, and recommendations presented in this thesis study will not only serve as a source of evidence-based interventions in Murowa Diamonds but will also make a contribution to the broader policy and scholarly debate on worker health protection in Zimbabwe’s mining industry

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APPENDIX

DATA COLLECTION INSTRUMENTS

AN ASSESSMENT ON NOISE POLLUTION AND ITS IMPACT ON WORKER HEALTH IN THE MINING INDUSTRY: A CASE FOR MUROWA DIAMONDS

INSTRUMENT 1: STRUCTURED SELF-ADMINISTERED QUESTIONNAIRE

Instructions for the participant: Kindly respond to all questions in an honest manner. If multiple-choice options have been given, kindly tick (✓) the one that applies to you. Wherever a line has been given to you, kindly fill out the response in the blank space provided. This survey would require about 20 minutes of your time.

SECTION A: DEMOGRAPHIC AND EMPLOYMENT INFORMATION

1. What is your gender?

[ ] Male

[ ] Female

[ ] Prefer not to say

2. What is your age range?

[ ] 18 – 25 years

[ ] 26 – 35 years

[ ] 36 – 45 years

[ ] 46 – 55 years

[ ] 56 years and above

3. What is your highest level of education?

[ ] Primary school

[ ] Ordinary Level (O-Level)

[ ] Advanced Level (A-Level)

[ ] Certificate / Diploma

[ ] Degree or higher

4. Which department do you work in?

[ ] Processing / Crushing Plant

[ ] Drilling and Blasting

[ ] Maintenance

[ ] Other (specify): _____

5. How long have you been employed at Murowa Diamonds?

[ ] Less than 1 year

[ ] 1 – 3 years

[ ] 4 – 6 years

[ ] 7 – 10 years

[ ] More than 10 years

6. What is your current job title / role?

Job title: _____

SECTION B: NOISE EXPOSURE PROFILE

7. On average, how many hours per shift do you spend in a high-noise work zone?

[ ] Less than 2 hours

[ ] 2 – 4 hours

[ ] 5 – 6 hours

[ ] More than 6 hours

8. How many days per week are you exposed to high levels of noise at work?

[ ] 1 – 2 days

[ ] 3 – 4 days

[ ] 5 days (full working week)

[ ] 6 – 7 days

9. Are you provided with hearing protective devices (e.g., earmuffs or earplugs) by the mine?

[ ] Yes

[ ] No

10. If yes, how consistently do you wear hearing protective devices while working in noisy areas?

[ ] Always

[ ] Most of the time

[ ] Sometimes

[ ] Rarely

[ ] Never

11. If you do not always wear hearing protective devices, what is the main reason?

[ ] They are uncomfortable

[ ] They interfere with communication

[ ] They are not always available

[ ] I do not consider my work area noisy enough

[ ] Other (specify): _____

SECTION C: SELF-REPORTED HEALTH OUTCOMES

Please indicate the extent to which you have experienced each of the following health conditions since working at Murowa Diamonds. Use the scale below:

1 = Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Always / Very Frequently

Statement / Item	1 Never	2 Rarely	3 Sometimes	4 Often	5 Always
1. Ringing or buzzing sounds in the ear (tinnitus)					
2. Difficulty hearing conversations in noisy environments					
3. Difficulty hearing conversations in quiet environments					
4. Persistent headaches during or after a work shift					
5. Dizziness or balance problems					

6. Have you ever been referred to a medical professional for a hearing-related complaint while working at Murowa Diamonds?

[ ] Yes

[ ] No

7. If yes, what was the outcome of that referral?

Outcome: _____

SECTION D: PERCEPTIONS OF NOISE CONTROL MEASURES

Rate your level of agreement with each statement. Use the scale:

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Statement / Item	1 Str. Disagree	2 Disagree	3 Neutral	4 Agree	5 Str. Agree
1. The mine's management takes noise-related health risks seriously					
2. Adequate hearing protective devices are available to all workers					
3. Workers receive sufficient training on the dangers of noise exposure					
4. Noise levels in my work area are regularly monitored by the mine					
5. Engineering controls (e.g., noise barriers, equipment enclosures) are in place in high-noise zones					

SECTION E: OPEN-ENDED RESPONSES

8. In your own words, describe how working in a noisy environment affects your health and daily life.

_____

_____

_____

_____

9. What changes, if any, would you like to see at Murowa Diamonds to better protect workers from the harmful effects of noise?

_____

_____

_____

_____

10. Is there anything else about noise and health at this mine that you think is important for this study to know?

_____

_____

Thank you very much for completing this questionnaire. Your contribution is greatly appreciated.

INSTRUMENT 2: NOISE DOSIMETRY RECORDING SHEET

Direction: Take three sound level readings at each work station every five minutes during production period. Add up all readings taken and divide by three to get the average which will be written in the last column. Any unusual occurrence is to be written in the remarks' column for each table.

PART 1: SITE AND SESSION INFORMATION

Field	Details
Date of measurement	
Time (start)	
Time (end)	
Shift observed	Day shift / Night shift (circle one)
Name of researcher	
Name of second researcher (inter-rater)	
Equipment used (make/model)	
Equipment calibration date	
ISO standard applied	ISO 1999:2013 – 85 dB(A) 8-hour limit
Weather / operating conditions	
Any production anomalies noted	

PART 2: WORKSTATION NOISE READINGS

Three readings are taken at each workstation at five-minute intervals. Enter each reading below. The mean of the three values is the reported noise level for that station.

No.	Workstation / Location	Reading 1 dB(A)	Reading 2 dB(A)	Reading 3 dB(A)	Mean dB(A)
1	Crusher Plant Feed Area				
2	Primary Jaw Crusher				
3	Secondary Cone Crusher				
4	Vibrating Screen Deck				
5	Conveyor Drive Station				
6	Drilling Rig Platform				
7	Blasting Control Room				
8	Maintenance Workshop				
9	Processing Control Room				
10	Stockpile Loading Bay				

PART 3: EXCEEDANCE SUMMARY

List all workstations where the mean reading exceeds the 85 dB(A) occupational exposure limit (OEL).

Workstation	Mean dB(A) — Exceeds 85 dB(A) Limit

PART 4: RESEARCHER OBSERVATIONS AND REMARKS

Note any factors that may have affected the accuracy of readings (e.g., equipment breakdown, non-standard operations, extreme weather, interference):

_____

_____

_____

_____

Researcher signature: _____ Date: _____

Second researcher signature: _____ Date: _____

INSTRUMENT 3: SEMI-STRUCTURED INTERVIEW GUIDE

Instructions: The following guide is to be used in conjunction with the 15 purposively selected participants. Questions are open-ended and simply prompts that can be modified based on how the discussion flows. The length of each interview should be no less than 30 minutes and no more than 45 minutes. Ensure the interviewee gives you permission to record the discussion in writing and audio format prior to the start of the session.

PARTICIPANT INFORMATION (TO BE COMPLETED BY RESEARCHER BEFORE INTERVIEW)

Field	Details
Participant code (no names)	
Department / work zone	
Years of service at Murowa Diamonds	
Date of interview	
Interview location	
Start time	
End time	
Audio recording reference number	

OPENING AND CONSENT

Thank you very much for taking time out to talk with me today. The interview forms part of research on the impact of noise at Murowa Diamonds on health and wellbeing. It is especially important for me to understand what you have experienced in this regard. There are no correct or incorrect answers; it is simply your opinion that is important to me. Would it be all right with you if I recorded our discussion?

THEME 1: EXPERIENCE OF NOISE IN THE WORKPLACE

1. Could you provide some information about what the noise environment in your workplace looks like on an average day?

2. Has there been any change in the levels of noise in your department since you started working in the mine?

3. What is the effect of noise on your productivity and safety while working in your office?

THEME 2: HEALTH IMPACTS OF NOISE EXPOSURE

4. Are there any signs of deterioration of your health that you have noted that could be associated with your noisy workplace? If yes, then tell us about them.

5. Has any noise-induced illness had an impact on any aspect of your life other than work, such as your relations with your family members and participation in social events?

6. Have you ever consulted with any doctor because of noise-induced health problems at your workplace? Tell us about your experience with it.

THEME 3: USE OF HEARING PROTECTIVE DEVICES

7. How satisfied are you with the hearing protection equipment provided by the mine? Are they sufficient for use in your job?

8. Is there any situation where you or other employees deliberately omit hearing protection, despite knowing that it is necessary? What factors influence such a decision?

THEME 4: PERCEPTIONS OF MINE MANAGEMENT AND POLICY

9. How can you characterize the management of noise and worker protection against hearing damage at this mining company?

10. Are you willing to discuss noise-related health risks with your superior or the health and safety department? Why or why not?

11. What do you think are the main measures that the mining company should implement to prevent noise-induced health problems among workers?

CONCLUSION

12. Is there anything else you would like to discuss regarding noise and health at this mining company?

APPROVAL LETTER TO COLLECT DATA

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

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BINDURA UNIVERSITY OF SCIENCE EDUCATION

28 April 2025

Dear Sir/Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

This letter serves to inform you that **Brighton Dumba (B232383B)** is a third-year (block release) student at Bindura University of Science Education in the Department of Environmental Science. During the final year of study, he is supposed to do a research project in this area of specialisation.

Please assist in any possible way. Data collected will be used for academic purposes only and will not be published without ant prior consent.

Thank you for your assistance.

Yours faithfully

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020, BINDURA
ZIMBABWE
OFFICIAL

Mr .T. Nyamugure
Chairperson: Department of Environmental Science

APPROVAL LETTER TO COLLECT DATA

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APPROVAL

10 June 2025

Dear Brighton Dumba

RE: APPROVAL OF REQUEST TO CONDUCT AN ACADEMIC RESEARCH PROJECT AT MUROWA DIAMONDS FOR BRIGHTON DUMBA (B2232383B)

I have pleasure in approving your request to carry out an academic research at Murowa Diamonds mining company.

You are required to comply with all relevant health, safety, environmental, and quality requirements during the course of your research. More of this information will be briefed to you during the inductions. The organization will be pleased to look into your research, assess the current operational gaps and actively implement the recommendations generated by the study.

Thank you for continued support.

E. Chigwa
ACTING SUPERINTENDENT
HSEQ Department

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