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Risk factors for the occurrence of occupational accidents in small-scale mines under resource-constrained settings: case of Athens Mine, Zimbabwe

By

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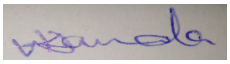
DECLARATION

To be complied by the student

Registration number B201315B

I, Wendy Kaunda, do hereby declare that this work is entirely the product of my own research and it was never used on any other academic work. All reference to previously published work has been clearly shown.

Student signature  Date: May 2024

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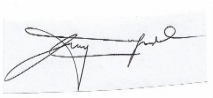
Chairman's signature:  Date: 10/10/24

DEDICATION

This Dissertation is dedicated to the Kaunda family. Thank you for your unwavering support and guidance.

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With deep gratitude, I acknowledge the role of God in granting me life, education, and the successful completion of my learning experience. I would like to extend my heartfelt appreciation to my parents, for their unwavering support and love throughout my academic journey. I would also like to acknowledge the academic and social support provided by my colleagues, S. Nyakunhuhwa and T. Dowera. I would like to express my sincere gratitude to my supervisor Dr. Artwell Kanda, for his invaluable guidance and support throughout my dissertation journey.

ABSTRACT

Background: The risk factors for the occurrence of occupational accidents in Zimbabwe are considered to be relatively well documented, but the extent and comprehensiveness of reporting vary. The study determines the significant risk factors associated with the occurrence of accidents, and the prevalence of occupational accidents using a small-scale mine in Zimbabwe as a case study.

Methods and materials: A longitudinal descriptive case study design was employed out at Athens mine in Chirumhanzu district. A closed-ended questionnaires and safety records from 2019 to 2023 were utilized to collect data from participants. The analysis of the risk factors for the occurrence of occupational accidents utilized the multinomial logistic regression analysis.

Key findings: The findings revealed an upward trend in accident prevalence over the five years, with a concerning lack of proper Personal Protective Equipment (PPE) use, high-risk tools and equipment operation (71.6%), and negative safety attitudes among workers (75.3%). Inadequate maintenance and inspection procedures were also identified as significant contributors (40.7%). The multinomial logistic regression analysis highlighted the following key risk factors lack of adequate safety training ($p=0.000$), outdated and poorly maintained equipment ($p=0.005$), pressure to prioritize production over safety, insufficient safety oversight and leadership, and poor safety culture ($p=0.020$).

Conclusion: the study emphasizes the need for a multi-pronged approach to improve safety at Athens Mine. This includes interventions targeting safety leadership, training programs, equipment upgrades, and cultural change to establish a robust safety management system. Further research is recommended to track the effectiveness of implemented improvements and identify best practices for similar resource-constrained mining operations.

Key terms: Occupational accidents, Small-scale mining, Risk factors, Safety culture

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CHAPTER 1: INTRODUCTION

1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

About 2.3 million women and men around the world succumb to work-related accidents or diseases every year. Worldwide there are around 340 million occupational accidents and 160 million victims of work-related illness annually (ILO 2020). Mining is generally considered as one of the most dangerous professions globally (Colemen & Kerkering, 2020) with respect to occupational injuries and fatalities, and long-term human health impacts such as silicosis and pneumoconiosis (Stephens & Ahern, 2019).

Occupational accidents in small-scale mines, such as Athens Mine in Zimbabwe, are influenced by various risk factors. These include inadequate safety measures and practices due to resource constraints, limited training and awareness among miners, hazardous working environments, and socioeconomic factors. Understanding and addressing these risk factors are crucial for enhancing occupational safety in small-scale mines, reducing accidents, and promoting the well-being of miners.

The mining industry is a vital source of economic activity in many countries in Africa (Sapulete et al., 2023). However, it is also associated with a high incidence of accidents and fatalities (Ajith et al., 2020). The continent's mining sector faces challenges related to safety standards, regulatory enforcement, and infrastructure development (Mhlongo & Akintola, 2021). In some African countries, informal or artisanal mining activities further contribute to safety risks and environmental concerns. The mining industry is a vital source of economic activity in many countries in Africa (Sapulete et al., 2023). This highlights the urgent need for improved regulations, safety measures, and environmental management practices.

Zimbabwe is a country which is rich minerals particularly gold and diamond (Singo et al., 2022). The country's mining sector has experienced both successes which is the abundance of minerals and challenges which are the mining accidents. The risk factors of small-scale mining accidents in Zimbabwe are diverse and they include factors such as inadequate safety protocols, lack of proper equipment maintenance, geological hazards, and human error.

1.2 PROBLEM STATEMENT

The resumption of operations at Athens mine resumed in 2018 after its closure in 2007. Since then, the mine has experienced an increase in risks to occupational accidents leading to increasing prevalence of occupational accidents. Despite attempts implemented to address the risk factors associated with the occurrence of occupational accidents over the past five years, accidents continue to occur. It remains unclear why accidents are still on the rise. Despite the inherent dangers associated with small-scale mining activities, there is a lack of comprehensive understanding regarding the specific risk factors that contribute to occupational accidents in the small-scale mining sector (Singo et al., 2022). The current study seeks to assess the risk factors contributing to occupational accidents in small-scale mine using Athens mine in Zimbabwe as a case study.

1.3.1 AIM

- To assess risk factors for the occurrence of occupational accidents at a small-scale mine (Athens mine, Zimbabwe).

1.3.2 OBJECTIVES

- To determine significant risk factors for the occurrence of mining accidents at Athens mine.
- To establish a pattern for the occurrence of occupational accidents at Athens mine from 2019 - 2023.

1.4 SIGNIFICANCE OF STUDY

The beneficiaries of this study include the workers and the mining operation as a whole. Trends in accident rates can be identified whether they are increasing or decreasing over time, using this study. The study can provide insights onto how workers at Athens mine can reduce the risk of injuries from accidents, leading to healthier and safer work environment. It can also help raise awareness of safety issues among workers and encourage them to report unsafe conditions so they can be addressed. For the mining operation, it can help maintain a good reputation and reduce the costs associated with accidents such as loss of productivity, medical expenses, and legal fees. This study also helps in identifying the factors that increase the risk of accidents and when this is done safety measures can be put to mitigate those risks.

1.5 RESEARCH QUESTIONS

- What are the significant risk factors associated with the occurrence of accidents at Athens Mine
- What was the prevalence of occupational accidents at Athens mine from 2019 - 2023?

1.6 ASSUMPTIONS

- The data obtained is relevant and, accurate and reliable.
- Secondary data will be available for literature review.
- Respondents will provide meaningful and truthful expressions of their knowledge of the asked questions.
- Questions will be easily converged and understood by the participants.

1.7 LIMITATIONS

- The resistance by the target participants in releasing information.
- The working conditions in the small-scale mine can be dangerous and challenging, making it difficult to obtain accurate information from workers.
- It can be difficult to obtain reliable and accurate data on the number and type of accidents that occur, as well as causes of these accidents.

1.8 DELIMITATIONS

- The study will be limited to a specific geographical area, and would not include small-scale mining operations in other parts of the country.
- The study will focus on small-scale mining operations in resource constrained settings, and not include large-scale mining operations.
- The study will focus on risk factors associated with the occurrence of accidents, and will not examine the consequences of accidents.

CHAPTER 2: REVIEW OF LITERATURE

2. LITERATURE REVIEW

2.1 INTRODUCTION

This chapter give an insight of what was already found and said on risk factors for occurrence of occupational accidents in small-scale mining operations.

2.2 SMALL-SCALE MINING IN ZIMBABWE

Small-scale mining plays a significant role in Zimbabwe's mining industry, contributing to employment generation, income generation for local communities, and rural development (Mensah et al., 2015). The sector consists of small-scale mining operations, characterized by their relatively small size and limited access to capital and modern technology (Site et al., 2021). However, small-scale miners face various challenges, including inadequate infrastructure, limited technical capacity, and environmental and social impacts (Zvarivadza, 2019.).

2.3 PREVALENCE OF ACCIDENTS IN SMALL-SCALE MINES

Small-scale mining in Zimbabwe poses a high risk of injuries and fatalities, with an estimated 1.5 million people involved in this sector (Singo et al., 2022). Accidents in small-scale mining often result in various injuries ranging from fractures to cuts, and even loss of life (Stemn et al., 2021). The primary cause of these injuries is the collapse of underground mining pits. Stemn (2021) reported an approximate annual death toll of 100 to 300 in the small-scale mining sector. However, the rate of non-fatal accidents is challenging to determine due to underreporting, estimated to be between 2000 and 4000 incidents each year (Singo et al., 2022).

2.4 PERCEIVED RISK FACTORS FOR THE PREVALENCE OF ACCIDENTS IN SMALL-SCALE MINING

Table 2.1 shows that common risk factors are risk-taking behaviour, stress and fatigue. The studies identified common risk factors such as inadequate equipment maintenance, lack of safety protocols and training, poverty and resource constraints, worker fatigue and stress, and insufficient regulatory enforcement. The studies found that these factors contributed to

increased risks of accidents, injuries, and unsafe mining practices in mines like Bulyanhulu, Eureka, Kamoto, Lumwana, Namoya, Morila, Nmanhumbir, Bendigo, Manica, and Jena. Addressing these multifaceted safety challenges through improved training, equipment, resource allocation, and regulatory oversight emerged as critical steps to enhancing safety and reducing accidents in these small-scale mining operations.

2.5 OCCUPATIONAL HEALTH ISSUES ASSOCIATED WITH SMALL-SCALE MINING

Small-scale mining poses significant occupational health risks for miners. Exposure to silica dust can lead to respiratory diseases like silicosis, while repetitive manual labour and heavy lifting contribute to musculoskeletal disorders (Banda et al., 2022.). High noise levels in mining environments can cause hearing loss, and contact with hazardous chemicals may result in dermatitis (Landrigan et al., 2022). The psychological stress and isolation experienced by small-scale miners can lead to mental health issues (Adu-baffour et al., 2019).

Table 2.2. shows the occupational health issues associated with small scale mining in literature. Common occupational health issues include respiratory diseases, musculoskeletal disorders, skin conditions, accidents and injuries, heat-related illnesses, waterborne diseases, and heavy metal poisoning. Dust exposure is a common cause of respiratory issues, while physical strain and repetitive tasks contribute to musculoskeletal disorders. Skin conditions arise from exposure to chemicals and harsh environmental conditions. Accidents and injuries can occur due to various risks in mining operations. Heat-related illnesses are a concern in high-temperature environments, and waterborne diseases may arise if water sources become contaminated.

Table 2.1 Common risk factors for the occurrence of accidents in small-scale mines under resource-constrained settings

Reference	Country/mine	Risk factors	Key findings
Lyatuu et al. (2018).	Bulyanhulu Gold Mine Tanzania	• Equipment used • Mining procedures • Education of miners	• Inadequate maintenance and malfunctioning equipment contributed to accidents and injuries. • Lack of proper safety protocols and adherence to mining procedures increased the risk of accidents • Insufficient knowledge and awareness among miners about safety practices and potential
Landrigan et al. (2022)	Eureka Gold Mine Zimbabwe	• Inadequate training • Fatigue and stress • Inadequate HIRA	• Inadequate training programs for miners resulted in a lack of necessary skills to mitigate risks of accidents. • Fatigue and stress among miners led to decreased alertness and increased likelihood of accidents • Lack of Proactive identification and assessment increases accidents.
Cuvelier (2020)	Kamoto Copper Mine DRC	• Risk taking behaviour • Level of education of miners • Ventilation and control of hazardous substances.	• Risk-taking behaviours, such as taking shortcuts, increases the chances of accidents occurring. • Lower levels of education – prevalent insufficient knowledge and understanding of safety practices. • Inadequate ventilation and poor control of hazardous substances

Banda & Chanda (2021)	Lumwana Copper Mine Zambia	• Poverty • Mining practices • Fatigue and stress of miners	• Miners faced economic pressures that compromised safety measures and led to riskier mining practices. • Unsafe mining practices e.g. unstable excavation methods • Fatigue and stress – led to decreased alertness and increased risk of accidents in small-scale mining
Geenen & Marijsse (2024)	Namoya Gold Mine DRC	• Equipment used • Regulatory compliance • Leadership commitment	• Inadequate maintenance and malfunctioning equipment. • Non-compliance with safety regulations increases the risk of accidents in small-scale mining. • Lack of leadership commitment to safety measures and safety culture - higher occurrence of accidents.
Duarte et al. (2021)	Morila Gold Mine Mali	• Safety procedures/protocols • Risk taking behaviour • Adequate PPE	• Lack of proper safety procedures and protocols increased the risk of accidents in small-scale mining. • Engaging in risk-taking behaviours e.g., taking shortcuts. • Insufficient provision and use of PPE e.g., helmets, gloves
Kwadwo et al .(2022)	Nmanhumbir Graphite Mine Mozambique	• Availability of resources • Stress and fatigue od miners • Education of miners	• Lack of resources e.g., finance, training programmes, and safety equipment, increases accidents. • Stress and fatigue • Inadequate education of miners contributed to a higher risk of accidents in small-scale

			mining.
Rakete, (2020)	Bendigo Gold Mine- Zimbabwe	• Training of miners • Safety procedures/protocols • Risk taking behaviour	• Insufficient training programmes for miners • Lack of necessary skills to mitigate risks • Lack of proper safety procedures and protocols increased the risk of accidents in small-scale mining. • Stress and fatigue - decreased alertness and increased likelihood of accidents in small-scale mining.
Ajith et al. (2020)	Manica Gold Project - Mozambique	• Poverty • Access to resources • Education of miners	• Limited access to resources and economic pressures that compromise safety. • Lack of resources e.g., financial resources, training programs, and safety equipment, increases accidents. • Low education level - in insufficient knowledge and awareness about safety practices and potential
Rakete (2020)	Jena Gold Mine - Zimbabwe	• Regulatory enforcement • Equipment used • Stress and fatigue of miners	• Non-compliance with safety regulations raises accident risk. • Poor maintenance, and utilization of equipment increased the accident likelihood. • Stress and fatigue among workers lead to decreased alertness and increased likelihood of accidents.

2.6 THEORATICAL FRAMEWORK

The Swiss Cheese Model of accident causation, developed by James Reason, provides a comprehensive theoretical framework for understanding the complex and multi-faceted factors that contribute to the occurrence of occupational accidents in small-scale mines under resource-constrained settings, such as the case of the Athens Mine in Zimbabwe. The model conceptualizes an organization's defences against accidents as a series of "slices of Swiss cheese", where each slice represents a layer of defence, and the "holes" represent weaknesses or failures in these defences including organizational factors like safety culture and resource allocation, unsafe individual worker behaviours such as the use of improper PPE and high-risk tools/equipment, latent conditions within the organization like changes in maintenance and inspection procedures, and gaps or lapses in the organization's defences, such as insufficient safety enforcement and training (Mabeti, 2021). By applying this framework, researchers can holistically examine the interplay between these various factors and guide the development of targeted interventions to strengthen the organization's defences and create a more robust safety system at the Athens Mine.

2.7 SUMMARY

The risk factors for the occurrence of occupational accidents in Zimbabwe are considered to be relatively well documented, but the extent and comprehensiveness of reporting vary. The literature review highlights the key risk factors contributing to occupational accidents in small-scale mining in Zimbabwe. There is a need for further research to address these gaps and improve our understanding of the specific risk factors contributing to occupational accidents in small-scale mines operating under resource-constrained settings, such as the case of Athens mine, in Zimbabwe.

Table 2.2 Occupational health issues associated with small scale mining

Reference	Country /mine	Health issues	Causes
Cossa et al. (2021)	Yanfolila Gold Mine, Mali	• Silicosis • Heat stress. • Induced hearing loss	• Prolonged exposure to silica dust • heat exposure • high levels of noise
Lyatuu et al. (2018)	Bulyanhulu Gold Mine, Tanzania	• Musculoskeletal disorders. • Heavy metal poisoning	• Repetitive manual labour and heavy lifting. • Exposure to heavy metals
Geenen & Marijsse (2024)	Namoya Gold Mine DRC	• Induced hearing loss • Respiratory diseases. • Dermatitis	• Exposure to high noise levels, • exposure to dust, • skin contact with chemicals
Cuvelier (2020)	Kamoto Copper Mine, DRC	• Respiratory diseases • waterborne diseases and cholera • musculoskeletal disorders	• Inhalation of toxic fumes and dust, • Contaminated water and food • Repetitive manual labour and heavy lifting
Duarte et al. (2021)	Morila Gold Mine, Mali	• Cyanide poisoning • Eye injuries	• Exposure to cyanide • insufficient eye protection

Adu-baffour et al. (2019)	Bibiani Gold Mine, Ghana	• Mental health issues • Hearing loss • Heavy metal poisoning	• Psychological stress and isolation • exposure to high noise levels • Exposure to heavy metals
Rakete (2020)	Zepline Gold Mine, Zimbabwe	• Mercury poisoning • Respiratory diseases, • Musculoskeletal disorders	• Exposure to mercury • Exposure to dust • Heavy lifting
Banda & Chanda (2021)	Lumwana Copper Mine, Zambia	• Eye injuries, • Respiratory diseases e.g., silicosis • Musculoskeletal disorders,	• Insufficient eye protection, • dust exposure • heavy lifting
Rakete (2020)	Bendigo Gold Mine, Zimbabwe	• Tuberculosis, • induced hearing loss,	• Overcrowded living and working conditions, • Exposure to high noise levels
Mhlongo & Akintola (2021)	Giyani Gold Mine, South Africa	• Respiratory diseases, • musculoskeletal disorders, • injuries	• dust exposure, • repetitive manual labour and heavy lifting, • accidents

CHAPTER 3: METHODS AND MATERIALS

3. METHODS AND MATERIALS

3.1 DESCRIPTION OF THE STUDY AREA

Athens mine is a small-scale gold producing and processing company in Zimbabwe. It is located about 192 km south of Harare in Mvuma mining town (19° 17' 5" South, 30° 32' 16") (Fig.3.1). Mvuma has sandy loam soil and it is mainly used for crop and livestock production (Muvengwi et al., 2018).

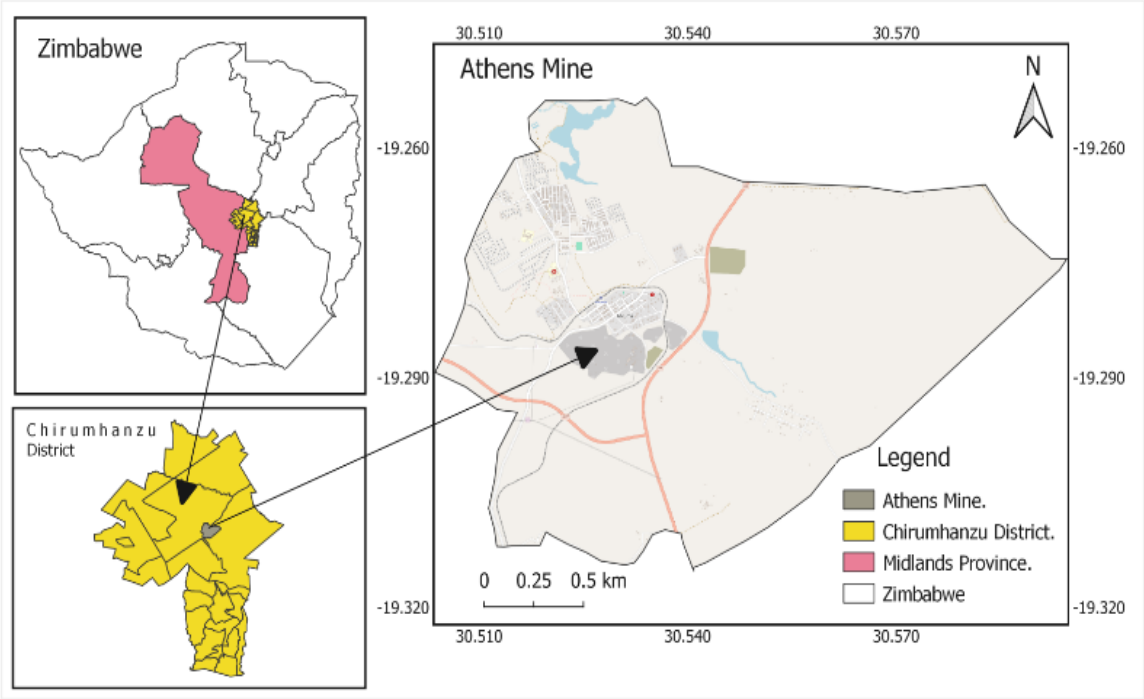

Figure 3.1 Map showing the location of Athens mine

3.2 RESEARCH DESIGN

A longitudinal descriptive case study design was used to identify potential risk factors of accidents at Athens mine from 2018-2023. This design allows for examining changes over time. The case study approach provides an in-depth understanding of the specific context of the mine (Qiao et al., 2021). The descriptive design aims to accurately describe the characteristics and challenges related to accidents. The study aims to explore complex, context-specific phenomena and inform safety measures in real-life mining situations. (Siedlecki, 2020). This design was used in a similar study which was on assessing risk

factors for the number of sustained injuries in artisanal and small-scale mining operation which was done by Ajith et al., (2020).

3.3 DETERMINATION OF SAMPLE SIZE

In this study, the Slovin's formula ($n = \frac{N}{1+Ne^2}$) was used to determine the sample size. The Slovin's formula is used when nothing is known about the behaviour of a population. N represents the total population which is 126; e^2 represents the margin of error which is 0.05%; and n represents the sample size which is 96.

3.4 RECRUITMENT AND SELECTION OF PARTICIPANTS

Stratified random sampling was utilised by distributing the sample size into five departments (strata): Human Resources and Administration, Plant, Mining, Engineering, Safety and Health, and Security. After dividing the target population into strata (departments), random sampling was used to select individual participants from each stratum (Table 3.1). The inclusion and exclusion criteria that was used to recruit and select participants was done by creating slips with names of employees for each department. The slips were then placed in department-specific containers. The researcher had to close her eyes or look away, and then randomly select specific number of slips from each container. This ensured that participants were selected from each department in a random manner.

Table 3.1 Determination of the sample size for the study

Department	N	n	Sampling intensity (%)
HR and Admin	15	12	80.00
Plant	29	22	75.86
Mining	49	37	75.51
Engineering	8	6	75.00
Safety and Health	5	4	80.00
Security	20	15	75.00
Total	126	96	76.19

3.5 ETHICAL CONSIDERATIONS

The American Psychological Association (2017) ethical guidelines for conducting research when dealing with human subjects were used in the study.

These included informed consent, privacy and confidentiality, minimization of harm, deception, use of debriefing, and reporting of results. Permission to carry out the study was granted from Department of Environmental Science, Bindura University of Science Education, and the premise safety department where the research was carried out through verbal agreement.

3.6 RESEARCH INSTRUMENTS

3.6.1 CLOSED-ENDED QUESTIONNAIRE

The close ended questionnaire was designed using literature as a guide (Marshall et al., 2021, Fife-Shaw et al., 2020). It consisted of 24 questions in two sections which were demographic data for participants, and risk factors (Appendix 1). A questionnaire comprises a series of questions to gather information that could be converted to variable measures under research (Shrestha, 2021). It was evaluated by an independent experienced person who was the safety officer mentor and pre-tested on randomly selected participants not from the study area (Schools, 2017).

A closed-ended questionnaire was used because it reaches participants quickly compared to other data collection methods such as interviews or focus groups it is relatively inexpensive and (Meirte et al., 2020). A questionnaire was found to be an appropriate research instrument for this study because it collects and achieves data accuracy (Marshall et al., 2021), easy to use (Shrestha, 2021), and requires fewer resources (Marshall et al., 2021). The instrument was used in similar studies (Shrestha, 2021). However, its main disadvantage is that questions may not be easily converged and understood by the participants (Meirte et al., 2020). This was addressed by providing clear instructions on how to complete the questionnaire and the relevance of their responses (Meirte et al., 2020).

3.6.2 SAFETY AND HEALTH RECORDS

Safety and health records were utilized to gather data for this study. These records included incident reports, accident logs, near-miss reports, and any other relevant documentation related to safety and health incidents at Athens mine. They provide a long-term perspective, allowing researchers to identify trends over time (Cossa et al. (2021)). Safety records offer objective and reliable data, verified by the mine management and safety department (Issn, 2017). The records provided valuable information on the types of accidents, their frequency, severity, and any patterns or trends that may emerge from 2018-2023. The challenges

associated with using safety records as a research instrument include data availability and quality, interpretation complexities, reporting bias, and also there may be data privacy concerns (Issn, 2017).

3.7 DATA COLLECTION

3.7.1 CLOSED-ENDED QUESTIONNAIRE

The questionnaire was self-administered to 96 randomly selected and recruited employees at Athens mine. These had given their oral consent to participate in the study. The questionnaires were distributed to participants, who were given two days to complete and return them. In the questionnaire interview, the introduction comprised self-introduction, explaining the purpose of the study, nature of questions in the questionnaire, interview duration, how the participant would be involved and whether there was consent to do so.

3.7.2 SAFETY AND HEALTH RECORDS

The safety and health records (2019 – 2023) were obtained from the Athens mine management and safety department. The records were reviewed to identify patterns of accidents. The records complemented the questionnaire in data collection.

3.8 DATA MANAGEMENT

The questionnaires were checked for completeness and correctness. Data were entered into MS Excel and imported into SPSS version 20 (IBM Corp, 2011)) for analysis. The numbers of accidents in a year from safety records were retrieved to represent data graphically.

The analysis of the risk factors for the occurrence of occupational accidents utilized the multinomial logistic regression analysis, the final model with all the independent variables would be assessed using the Model Fitting Information table to determine if it fits the data significantly better than the null model ($p < 0.05$), the Goodness-of-Fit tests would evaluate if the model adequately fits the data ($p > 0.05$), the Nagelkerke R-Square would indicate the strength of the relationship between the independent variables (demographic and risk factor characteristics) and the dependent variable (the occurrence of occupational accidents), the Likelihood Ratio Tests would identify the independent variables with a significant influence ($p < 0.05$), and the Parameter Estimates table would provide the regression coefficients, odds ratios, and 95% confidence intervals to determine the significant risk factors for the occurrence of occupational accidents.

CHAPTER 4: RESULTS

4. RESULTS

4.1 CHARACTERISTICS OF PARTICIPANTS

The response rate was 84%. Table 4.1 shows that the majority of participants were male (76.5%). The workforce has a good mix of experience with a significant portion having 2-5 years (34.6%) and 6-10 years on the job (30.9%). Nearly half of the participants had tertiary education (48.1%) and only (16%) of the participants did not receive any relevant training on safety.

4.2 REPORTED RISK FACTORS FOR THE OCCURRENCE OF OCCUPATIONAL ACCIDENTS

Table 4.2 shows the risk factors for occurrence of occupational accidents at Athens Mine found using closed ended questionnaire. The risk factors with high reports from participants were pressure of time or production targets (56.8%), challenges with maintenance and inspection of equipment/machinery (40.7%), use of tools/equipment that potentially pose high risk (71.6%) and negative attitudes towards safety (75.3%).

4.3 PREVALENCE OF OCCUPATIONAL ACCIDENTS AT ATHENS MINE

Fig. 4.1 shows the prevalence of accidents from 2019-2023 at Athens mine. Results show an upward trend in the number of accidents over a five-year period with fewer accidents being recorded in 2020. The mean annual prevalence rate was 20%. The lowest prevalence rate with 6.6% was recorded in 2020. The highest prevalence rate with 30.9% was recorded in 2023.

Table 4.1: Demographic information of participants

Questionnaire item	Response category	Frequency (%)
Department	HR & Admin	12 (14.8)
	Plant	22 (27)
	Engineering	6 (7.4)
	Mining	22 (27.2)
	Safety & Health	4 (4.9)
	Security	15 (18.5)
Gender	Male	62 (76.5)
	Female	19 (23.5)
Highest level of education attained	No formal education	4 (4.9)
	Primary	7 (8.6)
	Secondary	31 (38.3)
	Tertiary	39 (48.1)
Age group (years)	18 – 25	7 (8.6)
	26 – 35	23 (28.4)
	36 – 45	31 (38.3)
	46 – 55	16 (19.8)
	56 and above	4 (4.9)
Years of work experience in the current mine	Less than 2	16 (19.8)
	2 – 5	28 (34.6)
	6 – 10	25 (30.9)
	Above 10	12 (14.8)
Did you receive any relevant training on mining safety	Yes	68 (84)
	No	13 (16)

Table 4.2 Risk factors for occurrence of accidents at Athens Mine.

Questions	Yes (%)	No (%)	Not sure (%)	At times (%)
Are you involved in activities with high-risk for accidents?	48 (59.3)	21 (25.9)	12 (14.8)	0
Do you use tools/equipment that potentially pose high risk?	58 (71.6)	18 (22.2)	5 (6.2)	0
Is your workplace associated with particular hazards that are high risk?	57 (70.4)	12 (14.8)	12 (14.8)	0
Do you use specified personal protective equipment at work?	53 (65.4)	13 (16)	15 (18.5)	0
Do you face any challenges with maintenance and inspection of equipment/machinery?	33 (40.7)	40(49.4)	8 (9.9)	0
Do you face pressure of time or production targets that may contribute to unsafe work practices?	46 (56.8)	29 (35.8	6 (7.4)	0
Do you carry out hazard identification and risk assessments?	32 (39.5)	11 (13.6)	38 (46.9)	0
Do you always comply with safety regulation and protocols?	37 (45.7)	1 (1.2)	0	43 (53.1)
Are you always supervised at work?	20 (24.7)	15 (18.5)	0	46 (56.8)
Is there effective communication about your work activities with your superiors?	32 (39.5)	1 (1.2)	0	48 (59.3)
Have you observed a working culture or negative attitudes towards safety that you think may contribute to accidents?	61 (75.3)	15 (18.5)	5 (6.2)	0

If you were diagnosed with a disease (in B14 above) did you receive medical treatment?	40 (49.4)	8 (9.9)	1 (1.2)	0

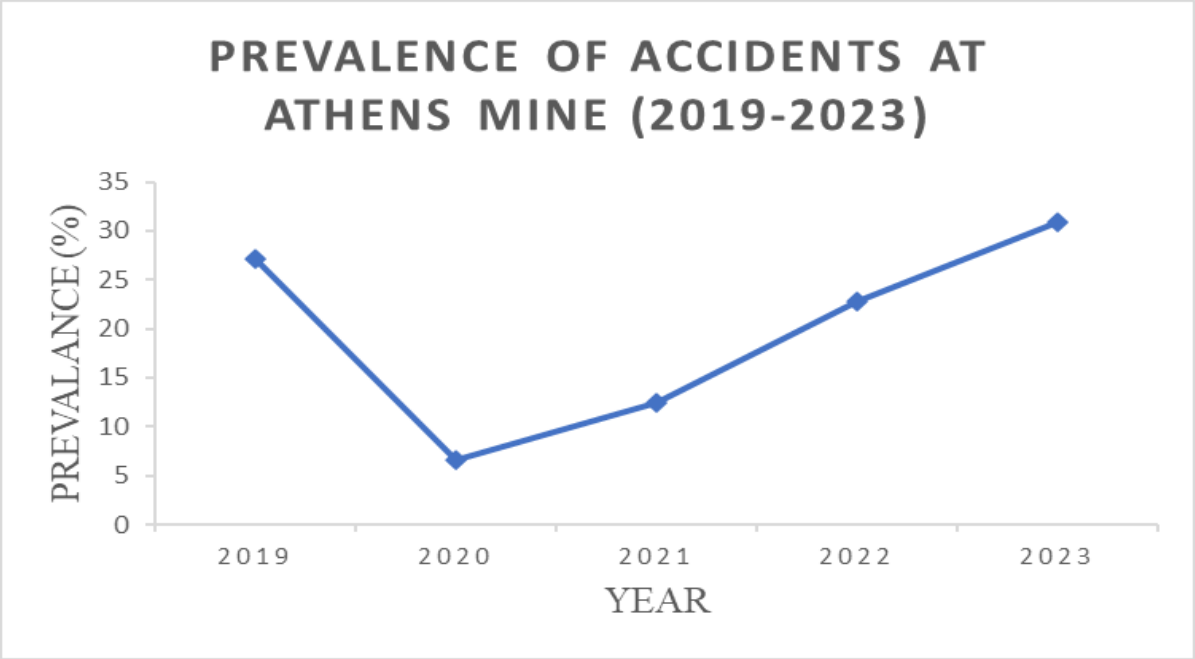

Figure 4.1: Annual prevalence of occupational accidents at Athens mine from 2019 to 2023.

4.4 SIGNIFICANT RISK FACTORS FOR THE OCCURRENCE OF OCCUPATIONAL ACCIDENTS AT ATHENS MINE

Table 4.3 shows the significant risk factors for the occurrence of occupational accidents at Athens mine. Likelihood ratio tests was used to assess whether specific factors are statistically significant risk factors for an event. The "Sig." value for some factors indicates they are statistically significant risk factors ($p < 0.05$). Not using proper PPE significantly increases the likelihood of the event ($p=0.004$). Using high-risk tools/equipment significantly increases the likelihood of the event ($p=0.005$). Observing negative safety attitudes is significantly associated with an increased likelihood of the event ($p=0.020$). Changes in maintenance and inspection procedures are significantly associated with an increased likelihood of the event ($p=0.000$).

Table 4.3: Likelihood ratio tests of the risk factors

Effect	Model Fitting. Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	34.659a	0.000	0	
Do you use specified protective personal equipment at work	45.702	11.043	2	0.004*
Do you use tools/equipment that potentially pose high risk	49.489	14.830	4	0.005*
Have you observed negative attitudes towards safety	29.323	7.858	2	0.020*
Any changes with maintenance and inspection of equipment	65.456	43.990	4	0.000*

* Denotes significant risk factor ($p < 0.05$)

CHAPTER 5: DISCUSSION

5. DISCUSSION

5.1 INTRODUCTION

This chapter discusses the key findings of the study. It provides an overview of the demographic characteristics of the participants. It then examines the reported risk factors for the occurrence of occupational accidents, followed by an assessment of the prevalence of such accidents within the study population. Finally, the chapter discusses the significant risk factors identified through the logistic regression analysis.

5.2 DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

The demographic profile of the participants in this study provides important context for understanding the risk factors associated with occupational accidents in the resource-constrained setting of the Athens Mine in Zimbabwe. The mining industry is traditionally a male-dominated workforce (Zvarivadza, 2019), and this is reflected in the demographics of the participants. This is also a notable factor, as gender has been linked to differential risk-taking behaviours and safety attitudes that can impact accident rates (Site et al., 2021). Additionally, the mix of work experience levels, from newer employees to those with 6-10 years on the job, suggests a need to account for both inexperience and potential complacency when evaluating safety risks. The relatively high proportion of participants with tertiary education indicates the workforce has technical knowledge, but the resource constraints of a small-scale mine operation may limit the ability to effectively apply this expertise to accident prevention (Mensah et al., 2015).

5.3 REPORTED RISK FACTORS FOR THE OCCURRENCE OF OCCUPATIONAL ACCIDENTS

The mining operations themselves carry the highest risks, including the use of explosives, heavy equipment, and exposure to underground hazards (Singo et al., 2022). The reported risk factors for occupational accidents at the Athens Mine in Zimbabwe reveal several systemic issues contributing to the high accident rates. The most prominent risk factor, cited by most of the participants, is a negative safety culture and attitudes towards safety within the organization. This suggests safety is not prioritized, allowing unsafe behaviours and practices to become normalized. Another major risk is the use of high-risk tools and equipment, as reported by most of the participants, exacerbated by challenges with equipment maintenance and inspection. The security department faces risks around firearms, use of force, and threat response (Ajith et al.,2020).

A significant proportion of participants also face pressure from time or production targets, which can lead workers to take shortcuts and engage in unsafe practices to meet operational demands. This pressure creates a volatile work environment where stress, fatigue, and anxiety hinder concentration (Adu-baffour et al., 2019). While personal protective equipment (PPE) usage is reasonably high, workers perceive their workplaces to have particular high-risk hazards, indicating the PPE alone is insufficient (Landrigan et al., 2022). According to Geenen (2024), underlying many of these risks appears to be a general lack of robust safety management systems, evidenced by uncertainties around hazard identification and risk assessments, as well as breakdowns in communication and supervision. Addressing this multifaceted set of risk factors, from safety culture to equipment safety and management systems, will be critical for improving occupational safety outcomes at the Athens Mine.

5.4 PREVALENCE OF OCCUPATIONAL ACCIDENTS

The prevalence of occupational accidents at Athens Mine has been on an upward trend over the past five years (2019-2023), with an average annual rate of 20%. While there was a decrease in 2020, the rate rose significantly in 2023. This highlights the urgency of addressing risk factors for accidents in small-scale mines like Athens, especially considering the resource-constrained setting in Zimbabwe. Accidents in small-scale mining often result in various injuries ranging from fractures to cuts, and even loss of life (Stemn et al., 2021). The primary cause of these injuries is the collapse of underground mining pits. By understanding

these factors through the analysis in this chapter, we can develop targeted interventions to improve safety and prevent future injuries.

5.5 SIGNIFICANT RISK FACTORS IDENTIFIED BY THE MULTINOMIAL LOGISTIC REGRESSION ANALYSIS

The analysis of the significant risk factors for occupational accidents at the Athens Mine reveals several concerning issues that require immediate attention. The most alarming finding is that not using proper personal protective equipment (PPE) is a statistically significant risk factor, indicating a lack of consistent PPE usage despite the reported 65.4% of participants using PPE. This points to lapses in safety enforcement and training around the importance of PPE (Rakete, 2020). Equally concerning is the finding that using high-risk tools and equipment is a significant risk factor, aligning with the earlier reported risk factor around the use of potentially hazardous equipment. The mine management must urgently address the safety engineering, maintenance, and controls around the tools and machinery employed in operations.

Another significant risk factor is the observation of negative attitudes towards safety, supporting the earlier finding about the predominance of a poor safety culture at the mine. Tackling these entrenched negative attitudes through improved safety leadership, training, and incentives will be crucial (Stemn et al., 2021). The most concerning statistically significant risk factor is the changes in maintenance and inspection procedures for equipment, pointing to severe deficiencies in the mine's asset management and preventive maintenance systems, which are directly jeopardizing worker safety. Strengthening these systems should be a top priority.

5.6 SUMMARY

The findings indicate serious issues with occupational safety at the Athens Mine. The workforce demographics, with a male-dominated and experienced but technically constrained staff, set the stage for safety challenges. The most prominent risks were from a poor safety culture, the use of high-risk equipment with maintenance issues, and worker production pressures that encourage unsafe shortcuts. Underlying these risks is an apparent lack of robust safety management systems. Addressing this complex issue will demand significant efforts to comprehensively overhaul the mine's safety leadership, training programs, equipment engineering, and maintenance procedures. While a significant undertaking, these changes are

essential for improving occupational safety outcomes at this resource-constrained mining operation.

5.7 STUDY LIMITATIONS

The study has limitations that need to be considered when interpreting the findings:

- It only focused on resource-constrained settings.
- It focused on Athens Mine as of August 2023, may not generalize or reflect current conditions
- Lack of longitudinal data
- The study relied heavily on questionnaires, which can be subject to response bias and inaccuracies.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The analysis found a concerning prevalence of occupational accidents at the Athens Mine, with rates increasing from 2019 to 2023. Significant risk factors identified through the multinomial logistic regression analysis included lack of adequate safety training, outdated and poorly maintained mining equipment, pressure on workers to prioritize production over safety, insufficient safety oversight and leadership, and a poor safety culture. This comprehensive, data-driven assessment provides novel insights into the complex interplay of technical, organizational, and human factors contributing to the increased accident rates at this resource-constrained mining operation. Addressing the occupational safety crisis will require a multi-pronged approach targeting safety leadership, training programs, equipment upgrades, and cultural change to create a robust safety management system. Further research, such as longitudinal studies and comparative analyses, could track the long-term impacts of recommended improvements and identify best practices across similar mining operations.

6.2 RECOMMENDATIONS

- Improvements in equipment maintenance and inspection
- Addressing time pressure and production targets
- Modernize mining equipment and maintenance

- Strengthen safety culture and worker engagement
- Enhance safety oversight and accountability

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APPENDICES

APPENDIX 1 QUESTIONNAIRE ON RISK FACTORS FOR THE PREVALENCE OF OCCUPATIONAL ACCIDENTS AT SMALL-SCALE MINES

BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF ENVIRONMENTAL SCIENCE

Questionnaire ID:

Dear respondent

My name is Wendy Kaunda (B201315B), an undergraduate 4th year student studying towards obtaining a BSc (hons) degree in Safety Health and Environmental Management with Bindura University of Science Education. I am undertaking research entitled *"Risk factors for the occurrence of occupational accidents in small-scale mines under resource-constrained settings: case of Athens Mine, Zimbabwe'.* The research is purely for academic purposes. The information shared will be kept confidential and anonymous. To ensure the success of this research, I kindly request for your participation by honestly and truthfully answering the following questions. It will take not more than 10 minutes. If I have your consent, I will begin.

Instructions

Please do not write your name on the questionnaire.

Tick the appropriate response

Section A: Demographic characteristics of participants

A1. Department: **1**. HR & Admin **2**. Plant **3**. Engineering **4**. Mining **5**. Safety & Health **6**. Security

A2. Gender: **1**. Male **2**. Female

A3. Marital Status: **1**. Single **2**. Married **3**. Divorced. **4**. Widower/widowed

A4. Religion: **1**. Traditional **2**. Christian **3**. Islamic **4**. Other

A5. Highest level of education attained: **1**. No formal education **2**. Primary **3**. Secondary **4**. Tertiary

A6. Age group (years): **1**. 18 – 25 **2.** 26 – 35 **3**. 36 -45 **4**. 46 – 55 **5**. 56 and above

A7. Years of work experience in the current mine: **1**. Less than 2 **2**. 2 – 5 **3**. 6 – 10 **4**. Above 10

A8. Did you receive any relevant training on mining safety? **1**. Yes **2**. No

Section B: Risk factors for the occurrence of occupational accidents

B1. Are you involved in activities with high-risk for accidents? **1**. Yes **2.** No **3**. Not sure

B2. Do you use tools/equipment that potentially pose high risk? **1**. Yes **2**. No **3**. Not sure

B3. Is your workplace associated with particular hazards that are high risk? **1**. Yes **2**. No **3**. Not sure

B4. Do you use specified personal protective equipment at work? **1**. Yes **2**. No **3**. Not sure

B5. Do you face any challenges with maintenance and inspection of equipment/machinery? **1**. Yes **2**. No **3**. Not sure

B6. Do you face pressure of time or production targets that may contribute to unsafe work practices? **1**. Yes **2**. No **3**. Not sure

B7. How long is you work shift (hours)? **1**. No shift work **2**. 8 **3**. 12 **4**. 16 **5**. > 16

B8. Do you carry out hazard identification and risk assessments? **1**. Yes **2**. No **3**. Not sure

B9. Do you always comply with safety regulation and protocols? **1**. Yes **2**. At times **3**. No

B10. Are you always supervised at work? **1**. Yes **2**. At times **3**. No

B11. Is there effective communication about your work activities with your superiors? **1**. Yes **2**. At times **3**. No

B12. Have you observed a working culture or negative attitudes towards safety that you think may contribute to accidents? **1**. Yes **2**. No **3**. Not sure

B13. In the past year, which injuries your workplace? **1.** None **2**. Bruises, cuts and lacerations

3. Crush/hit by falling objects **4**. Burns **5**. Other

If other, please specify: ……

B14. In the past year, which occupational disease where you diagnosed of?

1. None **2**. Respiratory **3**. Food poisoning **4**. Skin **5**. Sight/optical **6**. Musculoskeletal disorders **7**. Induced hearing loss **8**. Other

If other, please specify: ……

B15. If you were diagnosed with a disease (in B14 above) did you receive medical treatment?

1. Yes **2**. No **3.** Not sure

END OF QUESTIONNAIRE

APPENDIX 2: ATHENS MINE ACCIDENT REGISTER

APPENDIX 3: INSTITUTION PERMISSION LETTER

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE
DEPARTMENT OF ENVIRONMENTAL SCIENCE

P. Bag 1020
Bindura, Zimbabwe
Tel: 263 - 71 – 6505
Cell : 0778371588
Email : tnyamugure@buse.ac.zw

BINDURA UNIVERSITY OF SCIENCE EDUCATION

4 April 2024

Dear Sir/Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

This letter serves to inform you that VICTORY KAUNDA (B2063108) is a fourth year student at Bindura University of Science Education, in the Department of Environmental Science. During his/her fourth year of study he/she is supposed to do a research project in his/her area of specialisation.

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

Thank you for your assistance.

Yours faithfully.

OFFICIAL

Mr .T .Nyamugure
Chairperson - Department of Environmental Science

APPENDIX 4: LOGISTIC REGRESSION ANALYSIS OUTPUTS

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	74.916			
Final	21.466	53.451	6	.000

Pseudo R-Square

Cox and Snell	.483
Nagelkerke	.569
McFadden	.350

Likelihood Ratio Tests

Effect	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	34.659a	112.169	1.622[a]	.000	0	.
In_the_past_year_which_injury_did_you_encounter	53.622	108.075	1.622[b]	.000	1	.999
Which_occupational_disease_were_you_diagnosed_of	59.746	114.199	7.746	6.124	1	.013
If_yes_did_receive_medical_treatment	67.961	122.414	15.961	14.339	1	.000
Are_you_involved_in_activities_with_high_risk_for_accidents	67.961	122.414	15,961	14.339	1	.000
Do_you_use_tools_equipment_that_potentially_pose_high_risk	49.489	103.980	1.622[b]	14.830	4	0.005
Is_your_workplace_associated_with_hazards_that_are_high_risk	51.622	103.980	1.622[b]	.	2	.

Do_you_use_specified_protective_personal_equipment_at_work	45.702	103.980	1.622[b]	11.043	2	0.004
Any_challenges_with_maintenance_and_inspection_of_equipment	51.622	115.970	9.022[b]	.000	4	.000
Do_you_face_pressure_of_time_or_production_targets	59.746	114.199	7.746	6.124	1	.013
How_long_is_your_work_shift_in_hours	51.622	103.981	1.622[b]	.000	2	1.000
Do_you_carry_out_hazard_identification_and_risk_assessment	51.622	103.980	1.622[b]	.000	2	1.000
Do_you_always_comply_with_safety_regulations_and_protocols	60.038	112.397	10.038[b]	8.416	2	.015
Are_you_always_supervised_at_work	51.622	103.980	1.622[b]	.000	2	1.000
Is_there_effective_communication_with_your_superiors	62.814	117.267	10.814	9.192	1	.002
Have_you_observed_negative_attitudes_towards_safety	65.612	113.470	10.044	7.858	2	.020

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

b. Unexpected singularities in the Hessian matrix are encountered. This indicates that either some predictor variables should be excluded or some categories should be merged.