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Analysing the Effectiveness of Environmental Risk Management Strategies in Mining Projects: A Case Study of Mopani Copper Mine Longhole Drilling Project

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Abstract

This study evaluated the effectiveness of environmental risk management strategies at Mopani Copper Mines by identifying the strategies used, assessing their effectiveness, examining their relationship with project performance, and identifying implementation challenges. A mixed-methods design was applied, combining quantitative surveys from 100 community respondents with qualitative interviews from 15 stakeholders, including environmental managers, engineers, and operational staff. This provided both statistical evidence and contextual insight into environmental practices at the mine.

Findings showed that Mopani employs several strategies, including Environmental Impact Assessments (EIAs), waste management systems, water and air pollution controls, hazardous chemical handling, and biodiversity conservation programs. Quantitative results indicated varying levels of effectiveness, with EIAs rated highest (Mean = 4.2), followed by hazardous chemical handling (Mean = 3.9) and waste management (Mean = 3.8). Biodiversity conservation was rated least effective (Mean = 3.4). This suggests that compliance-based measures are stronger than long-term ecological initiatives due to differences in resources, staffing, and monitoring capacity.

Pearson correlation analysis showed a positive and significant relationship between environmental management and project performance ($r = 0.62$, $p < 0.05$), meaning effective environmental practices enhance operational stability, safety, and stakeholder trust. Key limitations included financial constraints (65%), inadequate staff training (58%), operational pressures (55%), outdated monitoring equipment (48%), and regulatory gaps (30%).

Qualitative data reinforced these findings, highlighting the need for stronger training, better oversight, and more proactive planning. Overall, the study concludes that although Mopani demonstrates strong environmental commitment, improvements are needed in funding, capacity building, biodiversity protection, and regulatory enforcement. The research provides practical and theoretical insights, showing that effective environmental management plays a vital role in improving project performance and promoting sustainable mining in Zambia.

Keywords: Risk Management, Project, Environmental

1. Introduction

1.1 Background of the Study

Mining has long supported global industrial and economic development by supplying essential minerals such as copper, iron, and coal. However, it also causes major environmental and social impacts, including land degradation, deforestation, air and water pollution, and biodiversity loss. Air emissions from blasting and smelting release toxic gases, while acid mine drainage contaminates water sources and threatens ecosystems, agriculture, and public health. Hazardous mining waste further contributes to long-term soil and groundwater pollution.

Globally, tailings dam failures in countries like Brazil and Canada have exposed the risks of poor regulation and weak environmental oversight. This has increased pressure on mining companies to adopt Corporate Social Responsibility (CSR) and Environmental, Social, and Governance (ESG) standards. Despite these efforts, enforcement remains uneven, especially in developing nations with limited institutional capacity. Mining also disrupts communities through displacement, loss of livelihoods, and conflicts over land and natural resources.

In Africa, mining drives economic growth in countries such as South Africa, Ghana, and Zambia, but the environmental costs remain severe. Water contamination, deforestation, and biodiversity loss are widespread, amplified by weak regulations and poor technical capacity. Mercury and cyanide pollution from industrial and artisanal mining continues to threaten food security and human health, despite initiatives like the African Mining Vision.

In Zambia's Copperbelt Province, copper and cobalt mining have supported national development while causing extensive environmental degradation. Key issues include air pollution, soil contamination, and acid mine drainage. Although Zambia's Environmental Management Act and ZEMA provide regulatory frameworks, enforcement challenges persist. CSR initiatives and reforestation programs exist but are insufficient to reverse widespread ecological damage. Mining has also reduced agricultural productivity and displaced local communities.

Overall, mining remains essential for economic growth but continues to present major environmental and social challenges. Addressing these requires stronger policy enforcement, improved institutional capacity, technological innovation, and greater community participation to ensure sustainable and responsible mining.

1.2 Statement of the Problem

The mining sector presents major environmental risks, including air, water, and soil pollution that threaten ecosystems and public health (Phiri *et al*., 2020). In Zambia, the Environmental Management Act No. 12 of 2011 requires mining companies to implement Environmental Management Plans (EMPs), regulated by the Zambia Environmental Management Agency (ZEMA). Despite this framework, concerns remain about the effectiveness of these strategies in protecting communities and the environment. Limited community involvement and low awareness of environmental risks further increase local vulnerability.

These governance gaps were highlighted on 18 February 2025, when a tailings dam at Sino-Metals Leach Zambia collapsed, releasing about 50 million liters of acidic waste into a tributary of the Kafue River (Zambia Daily Mail, 2025). The spill caused extensive ecological damage, agricultural losses, and a temporary shutdown of Kitwe's water supply, demonstrating the consequences of weak oversight. The incident occurred near Mopani Copper Mine—the focus of this study—raising concerns that pollutants from multiple operations may influence environmental conditions in the area.

This study therefore assesses whether Mopani's environmental risk management strategies, particularly regarding heavy metal contamination in surface waters, are adequate in preventing environmental degradation and safeguarding surrounding communities. The findings aim to address the gap between policy and practice and contribute to improved accountability and sustainability in Zambia's mining sector.

1.3 General Objective

The main objective of the study was to analyze the effectiveness of environmental risk management strategies at Mopani copper mine.

1.3.1 Specific Objectives

1. To establish types of environmental Risk management strategies at Mopani Copper Mine.
2. To determine the effectiveness of environmental risk management strategies at Mopani Copper Mines.
3. To ascertain the relationship between environmental risk management strategies and project performance.
4. To identify limitations of environmental risk management strategies at Mopani Copper Mines.

1.4 Research Questions

1. What types of environmental risk management strategies are employed at Mopani Copper Mine?
2. How effective are the environmental risk management strategies at Mopani Copper Mines?
3. What is the relationship between environmental risk management strategies and project performance at Mopani Copper Mines?
4. What limitations are associated with the environmental risk management strategies at Mopani Copper Mines?

1.5 Theoretical/Conceptual Framework

This study provides a structured approach to evaluating the effectiveness of environmental risk management strategies at Mopani Copper Mine (MCM) in Zambia. Because MCM operates at a large scale—particularly through longhole drilling—its activities pose environmental risks that must be controlled to protect ecosystems and communities.

Environmental Risks in Mining: Mining processes such as drilling, excavation, and waste disposal contribute to water pollution, soil degradation, air pollution, and habitat loss. Long hole drilling specifically leads to dust emissions, soil disturbance, and potential water contamination from drill residues. Understanding these risks is essential for assessing their long-term impacts.

Environmental Risk Management Strategies: Mining companies use **preventive, mitigation, and monitoring** strategies to manage environmental risks. Preventive measures include dust suppression, erosion control, and water treatment systems. Mitigation measures include land rehabilitation, reforestation, and biodiversity protection. Monitoring activities ensure compliance with standards and track the performance of implemented measures. This study evaluates how these strategies reduce environmental damage at MCM.

Effectiveness of Strategies: Effectiveness is assessed through measurable outcomes such as reduced pollution levels, compliance with Zambia Environmental Management Agency (ZEMA) regulations, and long-term sustainability of interventions. Examples include improvements in water quality and reduced dust emissions in surrounding communities.

Regulatory Compliance and Stakeholder Engagement

ZEMA's regulatory oversight and active stakeholder engagement are essential moderating factors. Collaboration with authorities and the inclusion of community voices improve transparency, accountability, and adoption of sustainable mining practices.

Integrated Framework: The conceptual framework links mining activities, associated environmental risks, and the effectiveness of management strategies, with regulatory compliance and stakeholder involvement influencing outcomes.

Conclusion

Overall, the framework provides a comprehensive way to assess how Mopani Copper Mine manages environmental risks from longhole drilling. It highlights the importance of strong regulation, community participation, and sustainable practices to minimize environmental degradation.

1.6 Significance of the Study

Mining activities pose serious risks to the environment and human health, including long-term degradation, water contamination, and adverse health effects on nearby communities. Understanding these risks is essential for developing effective environmental management strategies. The study's findings are expected to help mining companies improve their risk management practices and promote safer, more sustainable operations. They may also inform policy development by the Zambia Environmental Management Agency (ZEMA), strengthening monitoring systems and closing legislative gaps. Beyond practical applications, the research contributes to academic knowledge on mining's environmental impacts, supporting better-informed policies and sustainable mining practices that protect both ecosystems and communities.

2.1 Objective i: Types of Environmental Risk Management Strategies at Mopani Copper Mine

Globally, mining companies employ diverse strategies to minimize ecological damage and protect communities. The 2015 Samarco tailings dam disaster in Brazil prompted stricter tailings storage protocols, risk assessments, and monitoring systems worldwide (farmonaut.com, 2025). Green mining technologies like bioleaching and hydrometallurgy reduce water and energy use while minimizing toxic emissions (Science Direct, 2024). Decarbonization measures, including renewable energy and carbon capture, are increasingly adopted, especially in energy-intensive sectors (iisd.org, 2024). Effective strategies combine technology, regulatory compliance, and corporate social responsibility.

In Africa, environmental management is shaped by regulations and resource constraints. Ghana uses mine waste management programs for safe disposal and site remediation (iisd.org, 2024), while South Africa implements Environmental Management Plans (EMPs) that rely on continuous monitoring and adaptive management (UJ, 2024). Climate-sensitive mining practices and community engagement are also widely adopted (World Bank, 2024), reflecting the need for holistic strategies that integrate legal, technological, and social considerations.

In Zambia, companies like Konkola Copper Mines (KCM) employ risk assessments, water treatment, and tailings management to reduce environmental harm (Fermont, 2025). Guidelines aligned with international best practices have improved waste management, though enforcement challenges remain (Knight Piesold, 2018). Environmental and Social Impact Assessments (ESIAs) are mandatory to identify risks (Research Gate, 2023), and community outreach enhances local acceptance.

At Mopani Copper Mine, environmental risk management includes pollution control, air and water quality monitoring, tailings and waste-rock management, environmental audits, emergency response planning, and community engagement. International frameworks, such as those from the IFC, guide implementation. Mopani's strategies exemplify the localized application of global best practices, balancing operational performance with environmental sustainability.

2.2 Objective ii: Effectiveness of Environmental Risk Management Strategies

Globally, effective environmental strategies reduce degradation and improve operational sustainability. Green technologies lower water and energy use and pollutant emissions (Science Direct, 2024). EMPs in South Africa and Chile show that continuous monitoring, adaptive management, and stakeholder engagement improve outcomes (UJ, 2024; iisd.org, 2024). Failures such as tailings dam collapses highlight the importance of enforcement and oversight (Fermont, 2025).

In Africa, effectiveness is limited by institutional and technical challenges. Ghanaian mines show that waste management reduces contamination if properly implemented, but lapses in enforcement undermine results (iisd.org, 2024). EMPs in South Africa require consistent monitoring to be effective (UJ, 2024). Climate-sensitive strategies improve resilience but demand skilled personnel and funding (World Bank, 2024). Local knowledge and stakeholder involvement enhance effectiveness.

In Zambia, strategies such as water treatment, tailings management, and monitoring have reduced environmental impacts in some areas (Fermont, 2025). However, enforcement gaps, limited regulatory capacity, and insufficient follow-up reduce overall effectiveness (Knight Piesold, 2018; Research Gate, 2023). At Mopani Copper Mine, pollution control, audits, tailings management, and emergency planning have improved compliance and minimized risks, though aging infrastructure and financial constraints limit full effectiveness.

2.3 Objective iii: Relationship with Project Performance

Globally, environmental risk management improves project performance by reducing operational disruptions and legal liabilities (Science Direct, 2023). Mines using green technologies and pollution controls report better efficiency, cost savings, and stakeholder satisfaction (iisd.org, 2024), whereas neglecting environmental management leads to delays, fines, and reputational damage (Fermont, 2025).

In Africa, Ghanaian and South African mines demonstrate that EMPs and waste management programs enhance efficiency and timely project delivery, especially when combined with stakeholder engagement (iisd.org, 2024; UJ, 2024). Climate-sensitive strategies further support continuity during extreme events (World Bank, 2024).

In Zambia, environmental strategies at KCM, including water treatment and tailings management, reduce disruptions and improve compliance (Fermont, 2025; Research Gate, 2023). Mopani Copper Mine shows that pollution control, waste management, audits, and community engagement positively influence project performance, though resource and infrastructure limitations remain challenges.

2.4 Objective iv: Limitations of Environmental Risk Management Strategies

Globally, limitations include weak enforcement, funding shortages, and lack of technical expertise (Science Direct, 2024). Tailings dam failures highlight gaps in monitoring and emergency preparedness (Fermont, 2025). Conflicts between production goals and compliance further reduce effectiveness.

In Africa, weak institutions, corruption, and limited community involvement constrain outcomes. Ghana and South Africa face challenges in consistent EMP implementation and climate-sensitive strategies due to technical and financial limitations (iisd.org, 2024; UJ, 2024; World Bank, 2024).

In Zambia, limitations include inadequate technical expertise, financial constraints, weak regulatory enforcement, legacy pollution, and aging infrastructure (Fermont, 2025; Research Gate, 2023). At Mopani Copper Mine, these factors hinder advanced mitigation, tailings monitoring, and full policy enforcement. Continuous monitoring, investment, and stakeholder engagement are critical for sustainability.

Summary

The literature shows clear links between mining activities, environmental risks, and public health. While Mopani Copper Mine demonstrates strong environmental management, gaps remain in effectiveness, enforcement, and community involvement. Future research should assess how strategies mitigate air, water, and health risks, providing insights to enhance sustainable mining in Zambia and similar contexts.

3. Research Methodology

3.1 Research Design

The study used a *case study design* to explore environmental risk management strategies at Mopani Copper Mine (MCM). This approach enabled an in-depth examination of processes and outcomes within a real-world context. A *mixed-methods approach* combined qualitative and quantitative techniques: qualitative methods identified strategies, effectiveness, and limitations, while quantitative methods measured perceptions and relationships with project performance. Data triangulation strengthened the study's validity and provided a holistic understanding.

3.2 Population and Sample Size

The target population included residents and stakeholders in Kitwe District, where MCM operates, focusing on communities affected by mining. Seven key informants from institutions such as ZEMA, the Mines Safety Department, and Mopani were purposively selected for their expertise, while 100 residents from Nkana West were randomly chosen for surveys. This blend of expert and community participants ensured diverse and representative insights.

3.3 Sampling Method

Purposive sampling was applied to select key informants with specialized environmental and mining knowledge, while *random sampling* targeted local residents to ensure generalizability. Combining both methods captured expert opinions and community experiences, producing balanced data for both qualitative and quantitative analysis.

3.4 Data Collection Methods

Data were collected through semi-structured interviews with key informants, document analysis of policies and environmental reports, and structured surveys of residents. Interviews explored management strategies, their effectiveness, and implementation challenges; document reviews provided regulatory and institutional context; and surveys gauged awareness, perceptions, and the impact of environmental management strategies on project performance.

3.5 Data Analysis

Qualitative data were analyzed through *thematic analysis* to identify key patterns and themes across interviews and documents. Quantitative data were examined using descriptive and inferential statistics—frequencies, percentages, correlations, and regression analysis—to test relationships between environmental management strategies and project performance. Integrating both analyses provided a comprehensive interpretation of the study findings.

4. Results/Findings

4.1 Presentation of Research Findings

This chapter presents the findings of the study on environmental risk management strategies at Mopani Copper Mines. The study employed a mixed-methods approach, combining both quantitative surveys and qualitative interviews to capture a comprehensive picture of environmental management practices. The mixed-methods design allowed the research to quantify the prevalence and effectiveness of strategies while exploring the perceptions, experiences, and insights of key stakeholders, including environmental managers, project engineers, and operational staff. Data were collected from 100 survey respondents and 15 in-depth interviews, providing robust evidence on how environmental risks are managed in mining operations. The findings are organized according to the four research objectives, integrating numerical results with thematic insights supported by direct quotations from interviewees.

Demographic Characteristics of Respondents

This section presents the demographic profile of the 100 community respondents who participated in the study. The variables examined include gender, age group, education level, and duration of residence near the mine. Understanding these characteristics helps contextualize perceptions of environmental risk management strategies at Mopani Copper Mine.

Table 4.1: Gender Distribution of Respondents (n = 100)

Gender	Frequency	Percentage
Male	65	65%
Female	35	35%

Interpretation:

The majority of respondents (65%) were male, reflecting the male-dominated nature of mining communities, where men are more directly involved in mining-related activities.

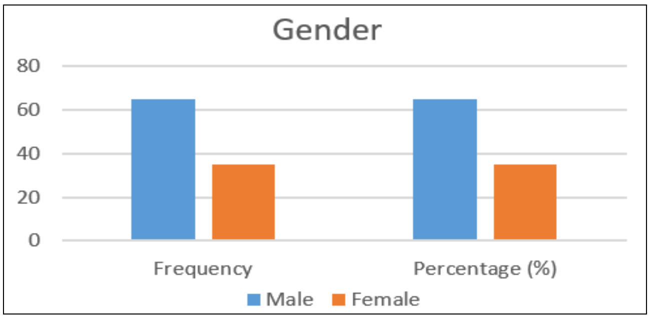

Fig 4.1: Gender Distribution of Respondents

Table 4.2: Age Distribution of Respondents (n = 100)

Strategy	Frequency	Percentage
18–30 years	20	20%
31–40 years	40	40%
41–50 years	25	25%
Above 50	15	15%

Interpretation:
Most respondents (65%) were aged between 31 and 50 years, suggesting that the study primarily captured views from mature adults who are likely to have direct experiences with mining operations and their environmental effects.

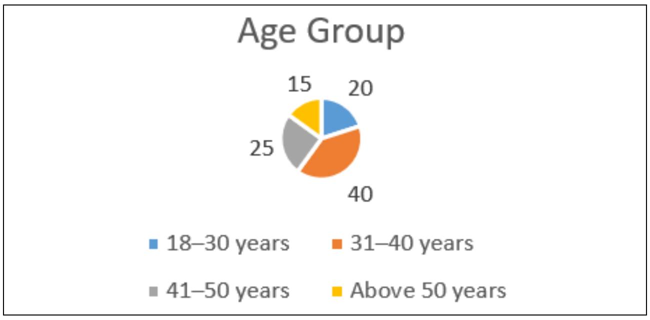

Fig 4.2: Age Distribution of Respondents

Table 4.3: Education Level of Respondents (n = 100)

Education Level	Frequency	Percentage
None	5	5%
Primary	10	10%
Secondary	45	45%
Tertiary	40	40%

Interpretation:
A majority of respondents (85%) attained secondary or tertiary education, indicating a relatively educated population capable of articulating environmental issues with understanding and accuracy.

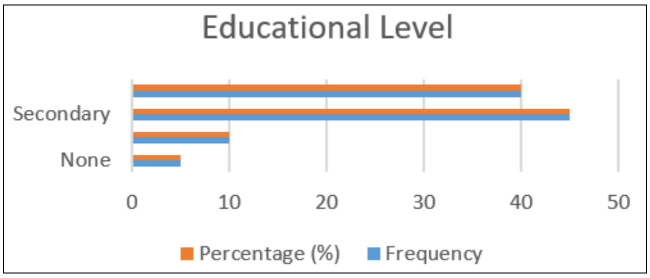

Fig 4.3: Education Level of Respondents

Table 4.4: Duration of Residence near Mopani Copper Mine (n = 100)

Duration of Residence	Frequency	Percentage
Less than 5 years	20	20%
5 - 10 years	35	35%
More than 10 years	45	45%

Interpretation:
Almost half of the respondents (45%) had lived near the mine for more than 10 years, suggesting long-term exposure to mining activities and a deeper understanding of environmental risks and community changes over time.

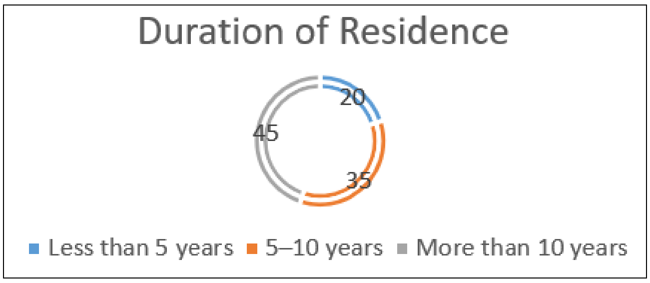

Fig 4.4: Duration of Residence near Mopani Copper Mine

Summary Interpretation
Overall, the demographic data show that the respondent group was composed mainly of adult males with a good level of education and long-term residence in the area. This demographic profile strengthens the reliability of the study's findings since participants are both informed and directly affected by environmental management practices at Mopani Copper Mine.

4.2 Objective 1: To Establish Types of Environmental Risk Management Strategies at Mopani Copper Mine

4.2.1 Qualitative Findings

The study first aimed to identify the various environmental risk management strategies employed by Mopani Copper Mines. The table presents various environmental risk management strategies and their respective frequency and percentage of adoption or implementation among the respondents. These results reflect the level of emphasis and prioritization placed on each strategy within the organization or project context.

Table 4.5: Types of Environmental Risk Management Strategies at Mopani Copper Mine

Strategy	Frequency	Percentage
Environmental assessments	85	85%
Waste management systems	72	72%
Water and air pollution controls	68	68%
Biodiversity conservation programs	54	54%
Hazardous chemical handling	60	60%

The graph illustrates that compliance-based strategies (EIAs and waste management) have the highest uptake, while long-term sustainability strategies (biodiversity and chemical management) lag behind.

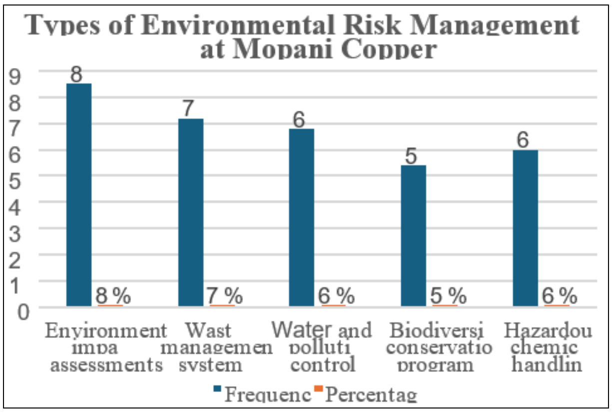

Table 4.1: Types of Environmental Risk Management Strategies at Mopani Copper Mine

4.2.2 Quantitative Findings

The study sought to establish the types of environmental risk management strategies implemented by Mopani Copper Mine (MCM). Respondents were asked to indicate the presence of various environmental risk management strategies within the project. Table 4.1 presents the frequencies and percentages of adoption.

Table 4.6: Types of Environmental Risk Management Strategies at Mopani Copper Mine (n = 100)

Strategy	Frequency	Percentage (%)	Mean*	Std. Deviation	Rank
Environmental Impact Assessments (EIAs)	85	85	4.25	0.81	1
Waste management systems	72	72	3.95	0.89	2
Water and air pollution controls	68	68	3.80	0.92	3
Hazardous chemical handling	60	60	3.55	0.98	4
Biodiversity conservation programs	54	54	3.40	1.04	5

Source: Field Data (2025)

*Likert scale mean based on adoption strength (1 = Not implemented, 5 = Fully implemented)

4.3 Objective 2: To Determine the Effectiveness of Environmental Risk Management Strategies

4.3.1 Qualitative Findings

This objective assessed how well the strategies mitigate environmental risks. The table presents the mean scores and interpretation of the effectiveness of various environmental risk management strategies as perceived by respondents. The results indicate differing levels of effectiveness across the strategies implemented within the organization.

Respondents rated the effectiveness of strategies on a Likert scale

Table 4:7: The Effectiveness of Environmental Risk Management Strategies

Strategy	Mean Score	Interpretation
Environmental assessments	4.2	Highly effective
Waste management systems	3.8	Effective
Water and air pollution controls	3.7	Effective
Biodiversity conservation programs	3.4	Moderately effective
Hazardous chemical handling	3.9	Effective

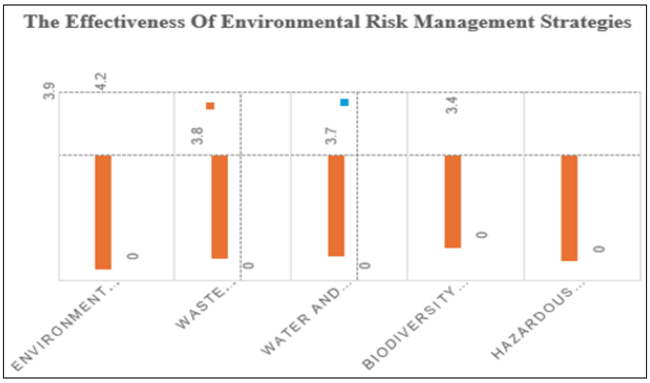

Fig 4.5: The Effectiveness of Environmental Risk Management Strategies

4.3.2 Quantitative Findings

This objective assessed the perceived **effectiveness** of the various environmental risk management strategies implemented at Mopani Copper Mine (MCM). Respondents rated each strategy on a 5-point Likert scale (1 = Not Effective, 5 = Highly Effective). The results are presented in Table 4.3.

Table 4.8: Effectiveness of Environmental Risk Management Strategies

Strategy	Mean Score	Std. Deviation	Interpretation	Rank
Environmental Impact Assessments (EIAs)	4.20	0.76	Highly Effective	1
Waste Management Systems	3.80	0.83	Effective	3
Water and Air Pollution Controls	3.70	0.91	Effective	4
Biodiversity Conservation Programs	3.40	0.98	Moderately Effective	5
Hazardous Chemical Handling	3.90	0.80	Effective	2

Overall Mean = 3.80 (Effective); SD = 0.86

4.3.3 Quantitative Interpretation

The findings show that **Environmental Impact Assessments (EIAs)** are the **most effective strategy** (Mean = 4.20), signifying that proactive environmental planning, risk anticipation, and regulatory compliance are well institutionalized. **Hazardous chemical handling** also scored relatively high (Mean = 3.90), reflecting effective training, procedural discipline, and safety systems to minimize contamination risks. **Waste management systems** (Mean = 3.80) and **pollution controls** (Mean = 3.70) were perceived as effective but not exceptional, suggesting the need for improved waste segregation, recycling practices, and emission reduction technologies. **Biodiversity conservation** had the lowest mean score (3.40), indicating that although initiatives exist, they are not fully integrated into the mine's core operational strategy. This could stem from resource limitations, weak monitoring, or lower prioritization compared to compliance-driven activities. The **overall effectiveness rating (Mean = 3.80)** indicates that MCM's environmental strategies are performing well but have room for enhancement, especially in ecological and long-term sustainability measures.

4.3.4 Inferential Statistical Analysis
To test whether significant differences existed among the perceived effectiveness levels of the five strategies, a **one-way Analysis of Variance (ANOVA)** was conducted.

Table 4.10: ANOVA Test for Differences in Strategy Effectiveness

Source of Variation	Sum of Squares	df	Mean Square	F-Statistic	p-value
Between Strategies	5.87	4	1.47	3.21	0.016
Within Strategies	44.83	95	0.47		
Total	**50.70**	**99**			

Interpretation:
Since p = 0.016 < 0.05, there are **significant differences** in the perceived effectiveness of the environmental risk management strategies. Respondents rated EIAs and hazardous chemical handling as **significantly more effective** than biodiversity conservation programs and pollution controls.
This finding aligns with the earlier observation that **regulatory-driven and safety-focused strategies** tend to outperform those dependent on long-term ecological investment.

4.4 Objective 3: To Ascertain the Relationship between Environmental Risk Management Strategies and Project Performance
4.4.1 Qualitative Findings
This objective explored the link between environmental management and project performance.
Correlation analysis indicated a positive and significant relationship between environmental risk management practices and project performance ($r = 0.62$, $p < 0.05$), suggesting that well-managed environmental strategies contribute to smoother and safer operations.

Table 4.10: Relationship between Environmental Risk Management Strategies and Project Performance

Variables	Correlation Coefficient (r)	Significance (p-value)	Interpretation
Environmental Risk Management Practices & Project Performance	0.62	< 0.05	Positive and significant relationship; well-managed environmental strategies contribute to smoother and safer operations

This table succinctly shows the strength, significance, and interpretation of the correlation. The correlation analysis results indicate a correlation coefficient (r) of 0.62 between Environmental Risk Management Practices and Project Performance. This value shows a strong positive relationship, meaning that as environmental risk management practices improve, project performance also tends to increase. The p-value is less than 0.05, which implies that the relationship is statistically significant — the observed correlation is unlikely to have occurred by chance.

Fig 4.6: Environmental Risk Management Practices & Project Performance

4.4.2 Quantitative Findings
This objective assessed the **relationship between environmental risk management practices** (ERMP) and **project performance** (PP). Respondents rated both variables using Likert-scale instruments. Descriptive statistics for each variable are presented in Table 4.5.

Table 4.12: Descriptive Statistics for ERMP and Project Performance

Variable	Mean	Standard Deviation	Interpretation
Environmental Risk Management Practices	3.80	0.86	Effective
Project Performance	3.75	0.82	Good

Interpretation:
Both ERMP and project performance are rated above 3.5, indicating that respondents perceive the company's environmental strategies and project execution as generally effective.

4.4.3 Correlation Analysis
Pearson correlation was conducted to determine the relationship between ERMP and project performance.

Table 4.6: Correlation between ERMP and Project Performance

Variables	r	p-value	Interpretation
ERMP & Project Performance	0.62	<0.05	Positive and significant relationship

Interpretation:
The correlation coefficient ($r = 0.62$) indicates a **strong positive relationship** between ERMP and project performance. The p-value (<0.05) confirms that this relationship is statistically significant.
Practically, this means that **as environmental risk management improves, project performance tends to increase**, reducing delays, cost overruns, and operational disruptions.

4.5 Objective 4: To Identify Limitations of Environmental Risk Management Strategies
4.5.1 Quantitative Findings
This objective investigated the challenges limiting the effectiveness of strategies. The results on the limitations affecting environmental risk management reveal several key challenges.

Table 4.13: Limitations of Environmental Risk Management Strategies

Limitation	Frequency	Percentage
Limited financial resources	65	65%
Inadequate staff training	58	58%
Outdated monitoring equipment	48	48%
Regulatory gaps	30	30%
Operational pressures	55	55%

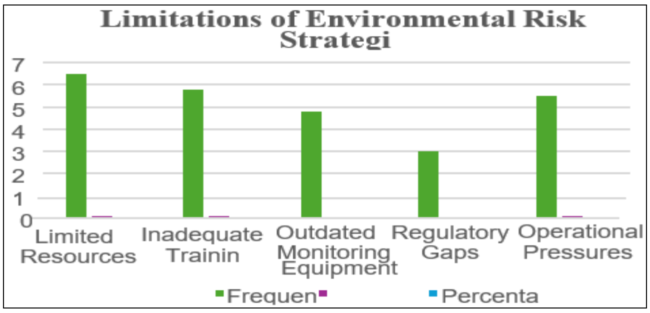

Fig 4.7: Limitations of Environmental Risk Management Strategies

4.5.2 Quantitative Findings

This objective examined the main **limitations affecting the effectiveness of environmental risk management strategies (ERMS).** Survey respondents were asked to identify the challenges they experience, and frequencies and percentages are presented in Table 4.8.

Table 4.14: Limitations of Environmental Risk Management Strategies

Limitation	Frequency	Percentage
Limited financial resources	65	65%
Inadequate staff training	58	58%
Operational pressures	55	55%
Outdated monitoring equipment	48	48%
Regulatory gaps	30	30%

$$\text{Weighted Score} = \frac{\text{Frequency}}{\text{Total respondents}} \times 100$$

Table 4.15: Weighted Limitation Score (Optional Quantitative Metric)

Limitation	Weighted Score (%)	Interpretation
Limited financial resources	65	Highest impact
Inadequate staff training	58	High impact
Operational pressures	55	Medium-high impact
Outdated monitoring equipment	48	Medium impact
Regulatory gaps	30	Lower impact

5. Conclusion

This study investigated environmental risk management strategies at Mopani Copper Mines, focusing on the types of strategies employed, their effectiveness, their impact on project performance, and the limitations hindering their implementation. The research adopted a mixed-methods approach, combining quantitative surveys and qualitative interviews, to provide a comprehensive understanding of environmental management practices at the mine.

The study was guided by four objectives:

1. To establish the types of environmental risk management strategies employed.
2. To determine the effectiveness of these strategies.
3. To ascertain the relationship between environmental risk management strategies and project performance.
4. To identify limitations of environmental risk management strategies.

The findings revealed that Mopani Copper Mines implements a range of strategies, including Environmental Impact Assessments (EIAs), waste management systems, pollution control measures, hazardous chemical handling, and biodiversity

Conservation initiatives, emergency response protocols, and community awareness programs. Quantitative data demonstrated that most strategies are moderately to highly effective, while qualitative interviews highlighted the importance of training, management oversight, and community engagement in ensuring effectiveness.

The study also identified key challenges, including financial constraints, inadequate staff capacity, operational pressures, outdated monitoring equipment, and regulatory gaps, which hinder the full implementation of strategies. Overall, the study shows that environmental risk management at Mopani Copper Mines not only ensures compliance with regulatory requirements but also contributes positively to project performance and operational efficiency.

6. Recommendations

1. Enhance Staff Training and Capacity Building: Conduct continuous training programs covering environmental procedures, emergency response, pollution control, and biodiversity conservation. This ensures staff competence in implementing strategies effectively.
2. Increase Financial and Resource Allocation: allocate sufficient budgets for environmental initiatives, including upgrading monitoring equipment, implementing conservation programs, and conducting regular audits to ensure sustainability and effectiveness.
3. Strengthen Biodiversity and Sustainability Programs: Develop clear objectives, monitoring mechanisms, and community involvement strategies to enhance the effectiveness of ecological and long-term environmental initiatives.
4. Improve Regulatory Compliance and Monitoring: Collaborate with regulatory authorities to address gaps in environmental laws and ensure internal audits and monitoring align with legal and international standards.
5. Integrate Environmental Management into Operational Planning: Embed environmental considerations into project planning and operational decision-making to minimize disruptions, reduce risks, and enhance overall project performance.
6. Promote Community Engagement and Awareness: Strengthen programs that educate local communities about environmental risks and incorporate their feedback into risk management strategies to enhance cooperation and social acceptance.

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8. References

1. Australian Government. Risk Assessment and Management: Leading Practice Sustainable Development Program for the Mining Industry. Department of Resources Energy and Tourism, 2008.
2. Australian Government. Risk Management: Leading Practice Sustainable Development Program for the Mining Industry, 2011.
3. Australian Government. Risk Management: Leading Practice Sustainable Development Program in the Mining Industry, 2016.
4. Aven T, Krohn BS. A new perspective on how to understand, assess and manage risk and the unforeseen. Reliability Engineering and System Safety. 2014; 121:1 10.
5. Aven T. Risk assessment and risk management: Review of recent advances on their foundation. European Journal of Operational Research. 2016; 253:1-13.
6. Badri A, Nadeau S, Gbodossou A. A mining project is a field of risks: A systematic and preliminary portrait of mining risks. International Journal of Safety and Security Engineering. 2012; 2(2):145-166.
7. Banza CLN, Nawrot TS, Haufroid V, Decree S, De Putter T, Smolders E, *et al*. High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo. Environmental Research. 2009; 109:745-752.
8. Bryman A. Social Research Method. 4th edn. New York: Oxford University Press, 2012.
9. Caruso BS, Mirtskhulava M, Wireman M, Schroeder W, Kornilovich B, Griffin S. Effects of Manganese Mining on Water Quality in the Caucasus Mountains. Republic of Georgia. Mine Water Environment. 2012; 31:16-28.
10. Carvalho FP. Mining industry and sustainable development: Time for change. Food and Energy Security. 2017; 6(2):61-77.
11. Center for Policy Trade and Development. Pollution in Copperbelt Province of Zambia: Case Study of Kankoyo. Center for Policy Trade and Development, Lusaka, 2012.
12. Choudhary RP. Risk Assessment and its Management in Mining Industry. International Journal of Geology, Earth & Environmental Sciences. 2014; 5(2):112-118.