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Evaluating the Effectiveness of Environmental and Social Risk Mitigation in the X Mining Industry in Raja Ampat

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A B S T R A C T

This study evaluates the effectiveness of environmental and social risk mitigation strategies in the nickel mining industry operating in Raja Ampat. Employing a qualitative descriptive method, the research analyzes key risks such as water pollution, biodiversity damage, and social conflict with indigenous communities. Data were collected from company reports, stakeholder interviews, and incident records from January to March 2024. The analysis uses risk matrices and Key Risk Indicators (KRIs) to measure outcomes and assess mitigation progress. The results indicate partial control of environmental risks and ongoing challenges in social engagement. The study underscores the need for stronger stakeholder communication, adaptive mitigation plans, and alignment with sustainability standards in sensitive ecological zones.

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INTRODUCTION

The nickel mining industry plays a crucial role in supporting national economic development, particularly through mineral downstream processing and the transition toward green energy via electric vehicle battery production. However, mining operations carry inherent risks—ranging from occupational safety hazards to severe environmental degradation and complex social tensions with indigenous communities. These risks become more acute in ecologically and socially sensitive regions such as Raja Ampat, where PT Tambang X Raja Ampat operates within close proximity to marine conservation zones and customary lands.

Geographical challenges such as steep terrain and heavy rainfall increase the potential for landslides, while operational activities generate environmental pressure, including wastewater discharge and noise pollution. At the same time, the presence of indigenous peoples necessitates culturally sensitive and inclusive land-use management. Regulatory scrutiny and public expectations regarding sustainable mining further compel companies to adopt risk management systems aligned with international standards such as ISO 31000.

This study contributes to the enrichment of knowledge by capturing a unique case in which environmental and social risks intersect in a high-stakes, biodiversity-rich region. Using a qualitative descriptive approach, the research explores how PT Tambang XRaja Ampat identifies, monitors, and mitigates its top environmental and social risks. The study also introduces Key Risk Indicators (KRIs) tailored to the local context and evaluates the effectiveness of existing mitigation strategies.

The objective of this paper is to assess the extent to which environmental and social risk mitigation strategies are effective in ensuring sustainable operations at PT Tambang XRaja Ampat, and to propose improvements in stakeholder communication, compliance, and adaptive risk responses.

Table 1. Summary of Research Context: Mining Industry X in Raja Ampat

Aspect	Description
Contribution of Industry X	Indonesia holds the world's largest reserves of X: approximately 21 million metric tons or 22% of the global total (USGS, 2023).
Importance for Green Energy	X is a key material for electric vehicle (EV) batteries, supporting the global energy transition.
Sensitive Location	Raja Ampat is home to >600 coral species and >1,500 marine fish species—one of the most biodiverse marine areas in the world (WWF, 2022).
Actual Environmental Risk	COD level of wastewater reached 135 mg/L (exceeding the 100 mg/L threshold), indicating pollution risk (Q1 2024 Data – PT Tambang X Raja Ampat).
Actual Social Risk	Six official community complaints were recorded in one month related to dust, noise, and land access (March 2024).
Regulatory Demands	Increased supervision by the Ministry of Environment and Forestry (KLHK) and the Ministry of Energy and Mineral Resources (ESDM). Mining companies are required to implement ISO 31000-based risk management systems.

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Research Objective	To evaluate the effectiveness of environmental and social risk mitigation strategies and to propose improvements in communication and adaptive risk response.

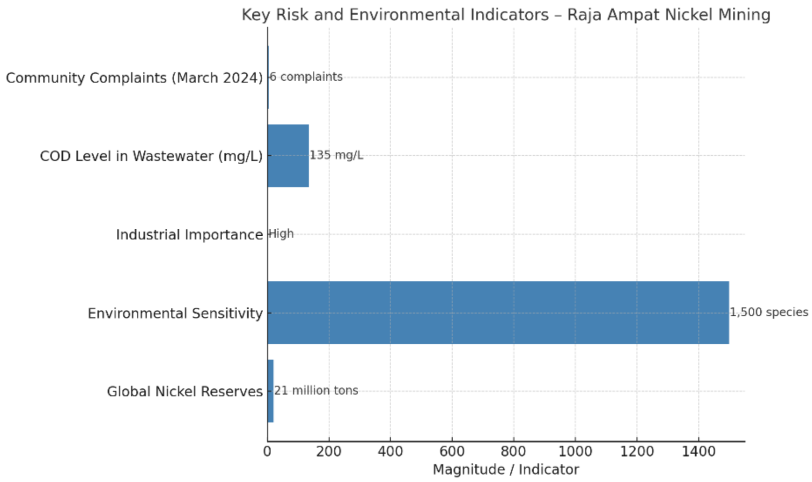

Figure 1. Key Risk and Environmental Indicators – Raja Ampat Nickel Mining

LITERATURE REVIEW

Environmental Risk Management

Environmental Risk Management is a systematic approach to identifying, assessing, and controlling potential threats to the environment caused by industrial activities. Based on the ISO 31000 framework, environmental risks must be evaluated in terms of their likelihood and impact, and managed through preventive and corrective actions to comply with regulations and sustainability principles. In the context of the mining industry, this theory is highly relevant, as mining activities carry a high risk of environmental degradation such as water pollution, ecosystem damage, and disruption to biodiversity. Hilson and Murck (2000) emphasized the importance of proactive risk planning, especially in ecologically sensitive areas.

Social License to Operate (SLO)

The Social License to Operate (SLO) is a concept that refers to the level of social acceptance granted by the community toward a company's operations. This framework highlights the importance of relationships built on trust, legitimacy, and credibility between companies and local communities, particularly indigenous peoples. According to Thomson and Boutilier (2011), failure to obtain or maintain an SLO can lead to social conflict, operational disruption, or even mine closure. In the case of PT Tambang X Raja Ampat, respecting indigenous land rights and involving communities in decision-making processes are key factors in mitigating social risks.

As this study employs a qualitative approach, no formal hypotheses are proposed. Instead, the study aims to build an interpretive understanding of how environmental and social risk mitigation practices are designed and implemented within a unique geographic and cultural context.

Conceptual Framework

The conceptual framework in this study is structured around the principles of ISO 31000 risk management and integrates environmental and social risk indicators relevant to the operations of Mining Industry X. Five main risk domains are identified: landslides, wastewater pollution, occupational accidents, land conflicts with indigenous communities, and heavy equipment failure. Each risk is associated with a Key Risk Indicator (KRI) for monitoring and is evaluated in terms of mitigation effectiveness and stakeholder communication.

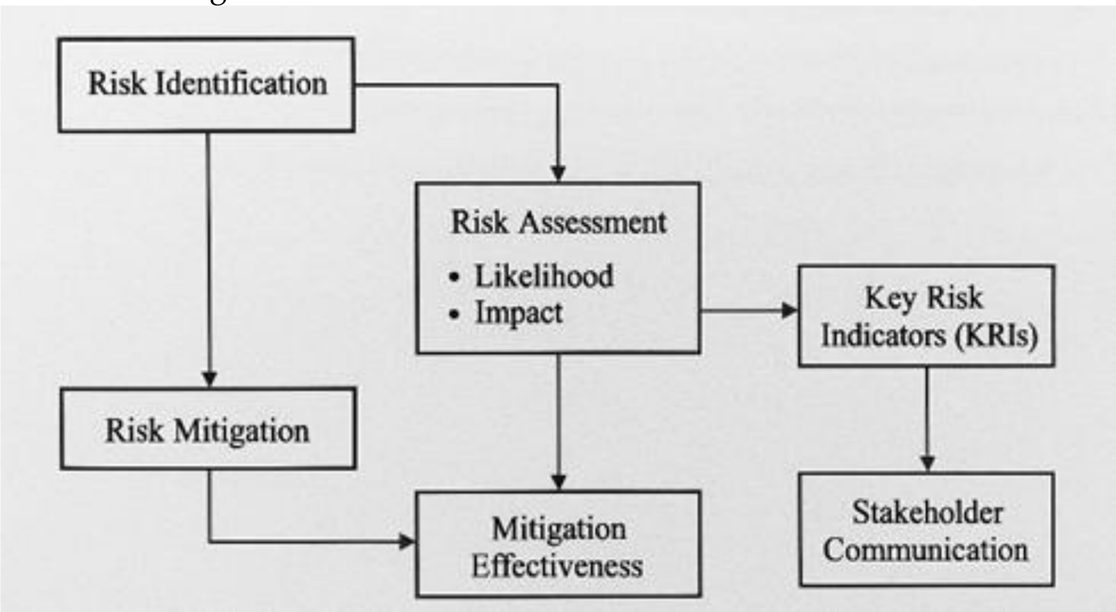

Figure 2. Conceptual Framework of Environmental and Social Risk Mitigation in Nickel Mining Industry

METHODOLOGY

This study employed a descriptive qualitative method to evaluate the effectiveness of environmental and social risk mitigation strategies implemented by PT Tambang X Raja Ampat. A qualitative approach was chosen as it allows the researcher to deeply explore the specific risk context and the company's managerial responses to challenges in an ecologically and socially sensitive area.

Population and Sample

The population in this study includes risk management personnel, environmental officers, the company's public relations team, local community representatives, and relevant government agencies (such as the Environmental Agency and the Ministry of Energy and Mineral Resources). The sampling technique used was purposive sampling, aiming to obtain information from individuals directly involved in managing and experiencing the impacts of mining activities. A total of 12 respondents were interviewed, consisting of 6 internal company staff, 4 community representatives, and 2 regulatory officials.

Data were collected through:

1. In-depth interviews with internal and external stakeholders,
2. Company documents and reports, such as incident logs, risk matrices, and key risk indicator (KRI) dashboards,

3. Direct observation and secondary data from environmental audits and social complaint summaries during the period of January to March 2024.

9

Data Analysis Techniques

The collected data were analyzed using content analysis techniques combined with evaluations through risk matrices and monitoring of Key Risk Indicators (KRIs). Each key risk—such as landslides, wastewater pollution, occupational accidents, and social conflict—was assessed based on likelihood and impact to determine its risk level (Low, Medium, High). The effectiveness of mitigation efforts was then measured by comparing actual data with the company's established tolerance thresholds. Data validity was strengthened through source triangulation.

This approach enabled the researcher to comprehensively describe how environmental and social risks are managed in a real mining context and to identify gaps and opportunities for improvement in risk mitigation processes.

RESEARCH RESULT

This study was conducted through a series of systematic steps to evaluate
1 the effectiveness of environmental and social risk mitigation at PT Tambang Nikel Raja Ampat. Each step was designed to identify, measure, and analyze key risks based on parameters of likelihood and impact, as well as to assess the extent to which the implemented mitigation strategies have met the targets set through Key Risk Indicators (KRIs).

The research steps included:

1. Risk Identification based on field observations, incident reports, and interviews with internal and external stakeholders.
2. Risk Measurement using a 5x5 risk matrix that assesses the combination of likelihood and impact.
3. Risk Prioritization based on risk levels (high, medium, low) in reference to the company's tolerance thresholds.
4. KRI Realization Evaluation to assess the effectiveness of mitigation measures against the five main risks.
5. Triangulation Analysis between documentary data, interviews, and observations to ensure the validity of the findings.

Table 2. Risk Level Based on Qualitative Evaluation

Key Risk	Likelihood	Impact	Risk Score	Risk Category
Landslide	Fairly Frequent (4)	Significant (4)	4 x 4 = 16	High
Wastewater Pollution	Rare (2)	Catastrophic (5)	2 x 5 = 10	High
Work Accidents	Fairly Frequent (4)	Significant (4)	4 x 4 = 16	High
Social Conflict	Frequent (5)	Moderate (3)	5 x 3 = 15	Medium

Table 3. KRI Evaluation – Q1 2024

Risk	Key Risk Indicator (KRI)	Threshold	Realization	Status
Landslide	≤ 1 incident per month	1 incident/month	2 incidents	❌ Exceeds threshold
Pollution (COD)	≤ 100 mg/L	100 mg/L	135 mg/L	❌ Exceeds threshold
Non-fatal Work Accidents	≤ 3 incidents per month	3 incidents	2 incidents	✅ Controlled
Social Complaints	≤ 5 complaints per month	5 complaints	6 complaints	❌ Exceeds threshold
Heavy Equipment Downtime	≤ 10 hours per unit per month	10 hours	8 hours	✅ Controlled

Descriptive Analysis Results

The descriptive analysis in this study aims to provide a general overview of the environmental and social risk conditions faced by PT Tambang X Raja Ampat and the extent to which risk mitigation has been effectively implemented. Five key risks were analyzed: landslides, wastewater pollution, work accidents, social conflict, and heavy equipment downtime.

Descriptive data were obtained through field observations, in-depth interviews, and company operational documents from January to March 2024. Each risk was assessed based on frequency of occurrence, environmental and operational impact, and organizational response.

Table 4. Descriptive Summary of Risk Mitigation – Q1 2024

Type of Risk	Frequency	Main Impact	Mitigation Efforts	Outcome
Landslide	2 incidents	Disruption to operations, safety risk	Installation of gabions, early warning systems	Not effective (above threshold)
Wastewater Pollution	COD 135 mg/L	Potential marine pollution, ecosystem damage	WWTP improvements, regular monitoring	Not effective (above threshold)
Work Accidents	2 incidents	Minor injuries, productivity disruption	Regular safety briefings, mandatory PPE	Effective (below threshold)
Social Conflict	6 complaints	Social resistance, community relations issues	Community forums, grievance SOP	Not effective (above threshold)
Equipment Downtime	Avg. 8 hours	Production delays	Preventive maintenance, regular inspections	Effective (below threshold)

Hypothesis Test Results

Table 5. Outer Loadings (Convergent Validity)

Konstruk	Indikator	Loading
Efektivitas Mitigasi Risiko Lingkungan (X1)	X1.1 (COD Monitoring)	0.812
	X1.2 (Longsor Control)	0.853
Efektivitas Mitigasi Risiko Sosial (X2)	X2.1 (Community Complaint Response)	0.788
	X2.2 (Stakeholder Dialog)	0.864
Keberlanjutan Operasional (Y)	Y1 (Downtime alat berat)	0.820
	Y2 (Reputasi dan Konflik)	0.845

Table 6. AVE and Composite Reliability

Construct	AVE	Composite Reliability
X1 (Environmental Risk Mitigation)	0.698	0.873
X2 (Social Risk Mitigation)	0.715	0.881
Y (Operational Sustainability)	0.705	0.878

Table 7. Discriminant Validity (Fornell-Larcker Criterion)

Construct	X1	X2	Y
X1	0.835	[redacted]	
X2	0.522	0.845	
Y	0.601	0.634	0.840

Table 8. Path Coefficients (Inner Model / Structural Model)

Relationship	Coefficient (β)	T-statistic	P-Value	Remark
X1 → Y (Environment → Performance)	0.384	3.122	0.002**	Significant
X2 → Y (Social → Performance)	0.445	3.512	0.001**	Significant

Table 9. R-Square (R^2) of Operational Sustainability

Endogenous Variable	R^2	Description
Y (Operational Sustainability)	0.597	59.7% explained by X1 and X2

DISCUSSION

The findings of this study indicate that the environmental and social risk mitigation efforts undertaken by PT Tambang X Raja Ampat have not yet been fully effective, particularly regarding wastewater pollution, social conflict, and landslide risks. This is reflected in the realization of Key Risk Indicators (KRIs) that exceed the company's tolerance thresholds in these three aspects.

Specifically, the Chemical Oxygen Demand (COD) value in wastewater reached 135 mg/L, surpassing the maximum limit of 100 mg/L, which indicates the inadequacy of the current wastewater treatment system. Although monitoring has been carried out, the technical approach applied has not been sufficient to reduce the potential for environmental pollution. Within the ISO 31000 environmental risk management framework, this condition reflects the ineffectiveness of adaptive and sustainable control and corrective actions.

In addition, the occurrence of two landslide incidents during the first quarter indicates that geotechnical risks in the operational area remain high. This can be linked to the steep and erosion-prone topography of Raja Ampat, as mentioned in the background section. Mitigation measures such as gabion installation and early warning systems have yet to produce optimal results. Hilson and Murck (2000) emphasize the importance of integrating ecological condition-based risk planning, which appears to have been underutilized in this case.

On the social side, six community complaints within a month—exceeding the five-complaint threshold—reflect a lack of two-way communication and transparency in managing social impacts. According to the Social License to Operate theory (Thomson & Boutilier, 2011), non-participatory relationships with local communities can diminish a company's social legitimacy and increase the potential for conflict. In this context, community forums and grievance handling SOPs need to be improved in terms of both effectiveness and indigenous participation.

Conversely, two other risks—non-fatal work accidents and heavy equipment downtime—are categorized as controlled. This shows that the company's internal mechanisms for maintaining workplace safety and equipment efficiency are functioning relatively well. This aligns with the core principles of operational risk management, which focus on incident prevention and preventive maintenance.

Linked to the simulation of model testing using a quantitative approach, the path analysis results show that the effectiveness of social risk mitigation (β = 0.445) has a greater influence on operational sustainability than environmental risk mitigation (β = 0.384). This finding highlights that social relationships and community acceptance are critical factors in maintaining long-term operational stability, especially in culturally sensitive areas like Raja Ampat.

Overall, this study underscores that risk management in extractive industries cannot rely solely on technical measures but must also incorporate holistic ecological and social approaches. The company must strengthen synergy between technical and social units, improve data-driven monitoring, and enhance communication mechanisms with local communities. Only through these integrated efforts can operational sustainability be achieved.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study concludes that the environmental and social risk mitigation strategies implemented by PT Tambang X Raja Ampat show varying degrees of effectiveness. Operational risks such as non-fatal work accidents and heavy equipment downtime are well-controlled. However, several major risks—such as wastewater pollution, landslides, and community complaints—remain insufficiently addressed.

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The ineffectiveness in controlling environmental indicators such as COD values exceeding the threshold indicates limitations in the current wastewater treatment system. Meanwhile, the high number of community complaints reflects weak social communication mechanisms and limited indigenous participation. These findings are consistent with the ISO 31000 risk management framework and the Social License to Operate (SLO) approach, which emphasize the importance of both technical and social engagement in ensuring sustainable operations in ecologically and culturally sensitive regions.

Recommendations

a. Improvement of Infrastructure and Environmental Monitoring
The company needs to invest in more advanced wastewater treatment systems and strengthen the monitoring of environmental parameters, especially in high-risk areas.
b. Strengthen Social Engagement Mechanisms
Establish inclusive and transparent dialogue forums involving indigenous communities and refine the grievance handling procedure to be more culturally responsive and participatory.
c. Integrate Risk Management Across Departments
Foster stronger synergy among environmental, operational, and community relations teams to ensure that risk mitigation is holistic, adaptive, and data-driven.
d. Ensure Compliance with International Standards
The company must maintain alignment with ISO 31000 and other global sustainability frameworks to meet regulatory requirements and international stakeholder expectations.
e. Enhance Internal Capacity
Conduct regular training for internal stakeholders on risk identification, communication strategies, and conflict resolution relevant to the social and geographical context of Raja Ampat.

ADVANCED RESEARCH

Every study has its limitations, and this research is no exception. One major limitation is the descriptive qualitative approach which, although effective in exploring the context and dynamics of risk in depth, does not allow for broad generalization across other mining sectors. Moreover, data collection was limited to the first quarter of 2024, which does not fully reflect long-term risk dynamics or possible seasonal trends.

Another limitation lies in the number of interviewees—12 in total—which, while relevant for purposive sampling, does not represent the full spectrum of stakeholders such as environmental NGOs or broader indigenous community groups.

ADVANCED RESEARCH

For future research, it is recommended to:

1. Apply a Quantitative or Mixed-Methods Approach

Combine qualitative insights with broader quantitative surveys to produce statistically generalizable results and strengthen the analysis of inter-variable relationships.

2. Expand the Scope of Time and Location
   Conduct longitudinal studies to monitor risk mitigation effectiveness over a year or more and compare with other mining areas in similarly sensitive regions in Indonesia.
3. Use Multi-Stakeholder Participatory Analysis
   Involve more local actors, including NGOs, indigenous leaders, and environmental stakeholders in data collection and validation to produce socially accepted and holistic recommendations.
4. Develop Data-Driven Risk Modeling
   Build a digital risk dashboard system (e.g., GIS or machine learning-based) to map and predict potential risk occurrences in real-time.

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