International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

Hazards Mitigation and Risk Controls in Various Mining Methods

S Saravanakumar[1], P D Gopakumar[2]
[1]Assistant professor, Dept. of Safety and Fire Engineering Excel Engineering College, Namakkal, Tamilnadu, India.
[2] PG-Student, M.E-Industrial Safety Engineering, Dept. of Safety and Fire Engineering Excel Engineering College, Namakkal, Tamilnadu, India.
Email ID: *7mechsaravanan@gmail.com[1], pdgopakumar@gmail.com[2]*

Abstract
Hazard mitigation and risk controls are fundamental aspects of ensuring safety and mitigating potential dangers in the mining industry. The mining sector, by nature, involves numerous inherent risks due to the extraction and processing of minerals. This project underscores the significance of robust hazard identification and risk analysis methodologies in this context. Through comprehensive hazard identification, the mining industry can proactively identify potential sources of harm, including geological, chemical, mechanical, and human factors. Subsequently, risk analyses techniques help assess the likelihood and consequences of these hazards, enabling the industry to prioritize preventive measures and safety protocols. By systematically integrating these practices, mining operations can reduce accidents, injuries, and environmental impacts, fostering a safer and more sustainable mining environment. This project serves as a concise overview of the critical role hazard identification and risk analysis play in ensuring the safety and sustainability of the mining industry.
Keywords: *Hazard mitigation, risk controls, mining methodology, hazard assessment, risk management, safety measures, mining safety, blasting controls, open mines, rock blasting, excavation.*

1. Introduction
Mining is the process of extracting valuable minerals, metals, and other geological materials from the Earth. These materials are crucial to various industries, including construction, technology, energy production, and manufacturing. The minerals extracted through mining provide raw materials for everything from everyday household items to advanced technologies like smartphones and renewable energy systems. Mining has been an essential activity for humanity for thousands of years, shaping economies, cultures, and even entire civilizations.

2. Mining Hazard
2.1. Physical Hazards
Physical hazards are the most prevalent and immediate dangers in mining operations, arising from the inherent nature of mining activities. These hazards stem primarily from excavation, material transport, and the use of heavy machinery, all of which are integral to the mining process. One of the most significant physical hazards is ground instability, which can lead to rock falls, cave-ins, or tunnel collapses in underground mining. Poorly supported mine tunnels, unstable rock formations, and geological shifts can cause serious accidents, often resulting in fatalities or severe injuries. (Figure 1)

Figure 1 **Hazards Associated with Mining Industries**

2.2. Chemical Hazards
Chemical hazards in mining are prevalent at multiple stages of the mining process, from the extraction of

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

minerals to the transportation and processing of ores. Mining operations often involve the use of hazardous chemicals such as cyanide, mercury, sulfuric acid, and solvents, all of which can pose serious risks to the health of workers and the environment. Exposure to these chemicals can lead to a range of acute effects, including poisoning, burns, or respiratory distress, depending on the substance involved. Chronic exposure to toxic chemicals can result in long-term health problems, such as liver or kidney damage, neurological disorders, respiratory diseases, and even cancer. For example, cyanide is frequently used in gold extraction, and workers exposed to it in high concentrations can suffer from severe symptoms, including headaches, dizziness, and, in extreme cases, death. Similarly, mercury is used in small-scale mining, posing a significant health risk due to its toxicity when inhaled or ingested. Beyond their impact on miners, hazardous chemicals used in the mining process can also have severe environmental consequences.

2.3. Biological Hazards

In underground mines, the confined spaces and high humidity can also foster the growth of fungal spores that lead to diseases like histoplasmosis, which affects the lungs when spores are inhaled. The risk of exposure is heightened when workers do not have access to proper sanitation, hygiene facilities, or personal protective equipment (PPE). Furthermore, miners may be exposed to various bacteria and viruses that thrive in the unclean, humid environments typical of some mining operations. In addition to infectious diseases, biological hazards also include the risk of vector-borne diseases. For instance, mosquitoes or ticks in certain mining regions may transmit diseases such as malaria or Lyme disease.

2.4. Abbreviations and Acronyms

HIRA- Hazard Identification and Risk Assessment, JSA- Job Safety Analysis, FMEA- Failure Mode Effective Analysis, ETA- Event Tree Analysis, FTA- Fault Tree Analysis, THA- Task Hazard Analysis, NIOSH- National Institute for Occupational Safety And Health, OSHA – Occupational Safety and Health Administration, HAVS- Hand Arm Vibration Syndrome, COPD- Chronic Obstructive Pulmonary Disease.

2.5. Units

- Ppm- Parts Per Million, Kg- Kilograms

2.6. Equations

The mining risk assessment is a systematic approach to identifying potential hazards associated with mining operations. The goal is to quantify the likelihood and severity of risks and to determine effective strategies for mitigating those risks. This process is essential to maintain safety, reduce downtime, and minimize the environmental impact of mining activities. The Risk evaluation formula used is as mentioned below.

$$\textbf{Risk (R)} = \textbf{P X S}$$

Note Where "*P"* is the Probability or Likelihood of an occurrence to happen and "*S*" is the severity (consequences) of the occurrence.

2.7. Risk Matrix

A Risk Matrix is a visual tool that helps to assess the level of risk by plotting the likelihood of a hazard occurring against its potential severity. The matrix typically divides risks into categories such as low, moderate, high, and very high, allowing operators and safety personnel to prioritize which risks need immediate attention. This tool is particularly useful in determining which hazards require further mitigation measures, whether through engineering controls, administrative actions, or PPE.

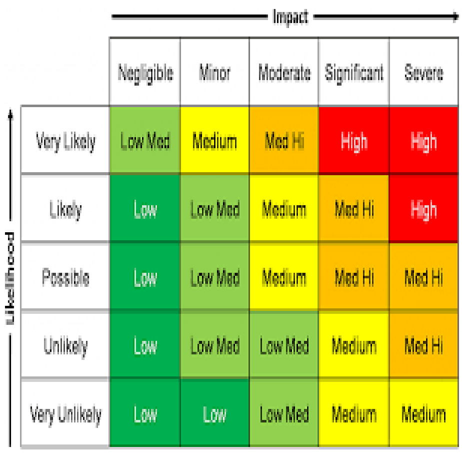

Figure 2 Risk Matrix for Qualitative Risk Evaluation

This is a quantitative method of Risk Assessment where the probability and Severity scale very from 1

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

to 5. So the Risk level vary from 1 to 25 scale.

3. Methodology

The methodology for this project is structured to systematically address hazards and risk controls in mining. It begins with a Literature Review to understand the various mining methods and the associated hazards, exploring previous research, safety standards, and best practices. Next, Hazard Identification is conducted to identify physical, chemical, biological, and environmental hazards specific to each mining method (underground, open-pit, placer mining). A thorough Risk Assessment follows, where each identified hazard is evaluated in terms of likelihood and severity, prioritizing those requiring immediate attention.

3.1. Risk Quantification & Prioritation Tools

To quantify and prioritize risks in mining operations, several risk assessment tools and methodologies are commonly used. These tools, such as Failure Mode and Effect Analysis (FMEA), Hazard and Operability Study (HAZOP), and the Risk Matrix, provide structured approaches to evaluate both the likelihood and severity of hazards. FMEA helps identify potential failure points in equipment or processes, allowing for a proactive approach to mitigation. HAZOP focuses on identifying hazards through a systematic review of operations, enabling the identification of potential operational risks.

3.2. Failure Mode Effect Analysis (FMEA)

FMEA (Failure Mode and Effect Analysis) is a widely used and effective tool in the mining industry for systematically evaluating potential failures within mining equipment and processes. The technique focuses on identifying all possible failure modes, which refer to the various ways in which a system, process, or piece of equipment can fail during operation. Once failure modes are identified, the next step is to assess the impact of these failures on key factors such as safety, environmental consequences, and production efficiency. To assess these risks more accurately, FMEA assigns a Risk Priority Number (RPN), a numerical value that helps prioritize which failure modes require immediate attention and corrective actions. The RPN is derived by evaluating three key factors: Severity, Occurrence, and Detection. Each factor is rated on a scale from 1 to 10, where 1 represents the lowest risk and 10 represents the highest risk. Severity refers to the seriousness of the effect if a failure occurs, focusing on the potential consequences for safety, the environment, or the operation. For instance, a failure that leads to a major explosion or toxic gas release may be rated as a 10, while a failure causing minimal disruption may be rated as a 1. Occurrence assesses the likelihood that a failure will actually happen, based on historical data, equipment reliability, and operational conditions. A failure mode that has occurred frequently in the past or is related to equipment known for high wear rates will be rated higher, while a rare failure mode might receive a lower score. Detection refers to the ability to detect the failure before it causes significant harm or damage. This factor evaluates how likely it is that preventative maintenance, monitoring systems, or operator vigilance can identify a failure before it becomes catastrophic. A failure that is difficult to detect, such as an internal mechanical failure in a critical machine, would be rated higher than a failure that is easily identified during routine inspections. Once these three factors have been rated, they are multiplied together to calculate the RPN. The RPN is a useful tool for ranking failure modes by their risk, with higher RPNs indicating a more urgent need for corrective action. The RPN serves as a guide for decision-making, allowing mining operations to focus resources and efforts on addressing the most critical failure modes that could have severe consequences. By using FMEA, mining operations can proactively identify risks, improve safety measures, reduce environmental impact, and minimize production downtime, leading to more efficient and safer mining practices overall.

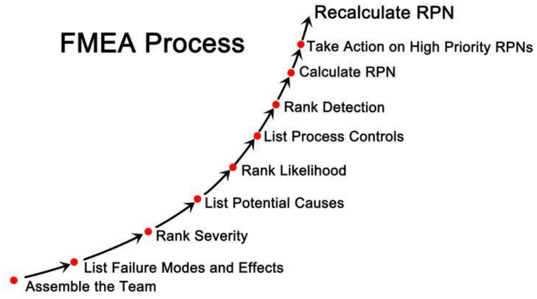

Figure 3 FMEA Methodology

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

3.3. Hazard Operability Study

HAZOP is a qualitative risk assessment tool that is particularly useful for evaluating the risks associated with the operational procedures in mining. This method focuses on identifying potential hazards through structured brainstorming sessions with team members from different disciplines, such as engineers, safety officers, and operators. The team assesses the mining operations step by step, considering possible deviations from normal operation and their potential consequences. HAZOP is ideal for analyzing complex systems, such as ore processing plants, where human error or equipment failure could have cascading effects. The study categorizes each hazard based on its likelihood, severity, and potential operability issues, providing a comprehensive risk profile for the operation.

3.4. Risk Mitigation Strategy Development

Mitigation strategy development is a critical process in managing and controlling risks in various industries, particularly in mining operations where hazards can have severe consequences on workers, the environment, and production. The first step in mitigation strategy development is hazard identification, where all potential risks associated with mining activities are recognized The implementation of risk control measures begins with the formulation of a clear and structured plan. This plan should outline key actions, responsibilities, and timelines to ensure that all tasks are completed efficiently. It must be adaptable to accommodate any unforeseen challenges that may arise during the implementation phase. Below is a step-by-step approach to this implementation process toolbar. This involves assessing various aspects of the mining operation, such as equipment, workforce, environmental conditions, and operational procedures, using tools like hazard checklists, site surveys, and worker input. Once the hazards are identified, the next crucial step is to assess the severity and likelihood of each risk. This is typically done using risk assessment tools such as Failure Mode and Effect Analysis (FMEA) or a Risk Matrix, which allows mining operations to prioritize hazards based on their potential impact. Personal protective equipment (PPE), such as helmets, gloves, and respirators, is then provided to protect workers directly. Once the mitigation measures are defined, it's essential to allocate the necessary resources to implement them. This includes securing funding for equipment upgrades, ensuring that workers are trained, and setting up necessary infrastructure for monitoring systems. A detailed budget is prepared, considering the costs of each measure and the timeline for implementation, with resources being directed toward addressing the most critical risks first. (Figure 4)

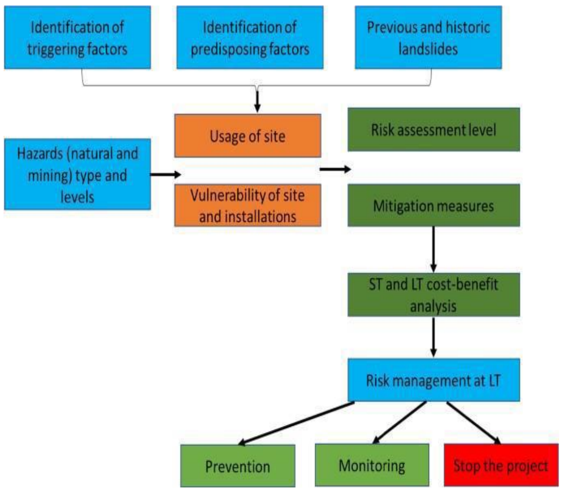

Figure 4 Risk Mitigation Flow Chart

3.5. Engagement with Mining Companies, Safety Experts, and Regulatory Authorities

Engaging with mining companies, safety experts, and regulatory authorities is a foundational step in the consultation process. Mining companies bring first-hand knowledge of the operational challenges, equipment, and safety procedures that are implemented on a daily basis. They understand the intricacies of mining methods and can provide valuable feedback on the feasibility of proposed risk controls and mitigation strategies.

3.6. Engagement with Mining Companies, Safety Experts, and Regulatory Authorities

While engaging with experts and regulatory bodies is essential for technical and legal validation, consulting with miners and safety managers provides invaluable insights into the practical challenges faced by workers

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

on the ground. Miners and safety managers are the individuals directly exposed to the risks and hazards inherent in mining operations. They possess firsthand experience of the challenges and dangers they encounter during daily operations, and their input is vital in shaping realistic and effective safety strategies. Interviews with miners and safety managers allow for the collection of qualitative data regarding their perceptions of existing safety measures, the effectiveness of current risk controls, and any gaps they may have observed in safety protocols. These personal accounts provide an opportunity to uncover challenges that may not be immediately apparent through technical assessments alone. For example, miners may highlight issues related to PPE (personal protective equipment), such as discomfort, poor fit, or inadequate protection, which could lead to non-compliance or compromised safety. They may also report operational hazards, such as poorly maintained equipment or areas of the mine with inadequate ventilation.

3.7. Consultation with Environmental Organizations

The concerns related to worker safety, mining operations must also consider their impact on the environment. Environmental organizations play a crucial role in ensuring that mining operations are sustainable and minimize harm to surrounding ecosystems. These organizations have expertise in assessing environmental risks, such as water contamination, soil erosion, air pollution, and the impact on local wildlife. Consulting with these stakeholders is essential for ensuring that environmental protection strategies align with best practices and regulatory standards.

3.8. Integrating Stakeholder Feedback into Mitigation Strategies

After gathering feedback from mining companies, safety experts, miners, safety managers, and environmental organizations, the next step is to integrate this input into the risk mitigation strategies. This stage involves reviewing the data and insights collected, identifying common themes and areas of concern, and using this information to refine the proposed mitigation measures and safety personnel to prioritize

3.9. Ongoing Consultation and Communication

Implementation Plan The implementation of risk control measures in mining operations is a vital step in ensuring worker safety, environmental protection, and operational efficiency. Developing a detailed and structured implementation plan is critical to ensure that the proposed risk controls are effectively executed and continually assessed for their effectiveness. This plan should clearly outline the actions to be taken, the timeline for implementation, the responsible parties, and the resources required to carry out the necessary activities

3.10. Implementation of Risk Control Measures

The implementation of risk control measures begins with the formulation of a clear and structured plan. This plan should outline key actions, responsibilities, and timelines to ensure that all tasks are completed efficiently. It must be adaptable to accommodate any unforeseen challenges that may arise during the implementation phase. Below is a step-by-step approach to this implementation process.

Define Key Actions

- Risk Control Measures Identification
- Developing Standard Operating Procedures (SOPs)
- Resource Allocation

3.11. Risk Control Measures Identification

Begin by clearly defining the risk control measures to be implemented. These measures can include engineering controls, administrative controls, and the use of personal protective equipment (PPE). It is crucial to ensure that each measure directly addresses a specific identified hazard, such as improving ventilation systems in underground mines, upgrading equipment, enhancing emergency response protocols, and introducing dust suppression systems.

3.12. Developing Standard Operating Procedures (SOPs)

For each mitigation measure, develop SOPs that provide detailed instructions on how the control measures should be carried out. These procedures should include guidelines for equipment use, maintenance, emergency response, and general safety standards, ensuring that all workers are clear about the safety protocols they need to follow.

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

3.13. Resource Allocation

Ensure that all the necessary resources whether financial, material, or human are allocated for the successful implementation of the risk control measures. This includes procuring equipment, hiring additional safety staff, setting aside funds for training programs, and purchasing any materials required for risk control (e.g., ventilation systems, dust suppression machines).

3.14. Assign Responsibilities

Assign specific tasks and responsibilities to designated personnel or teams. Clear ownership of each task is crucial to ensure accountability and the timely completion of activities. For instance, safety managers could be responsible for overseeing the entire implementation process, while equipment engineers may be tasked with the installation of specific safety equipment.

3.15. Develop a Timeline

Well-defined timeline is essential to track the implementation progress of risk control measures. Create a detailed schedule that breaks down each phase of implementation, from the initiation of the project to the final assessment of effectiveness. Assign target completion dates to each task, with milestones to evaluate progress at each stage.

3.16. Training and Awareness Programs for Workers

One of the most important elements of any implementation plan is ensuring that workers fully understand the new safety protocols and are equipped to adhere to them. Training and awareness programs are essential for fostering a culture of safety and ensuring that employees are well-informed about the risk control measures in place.

4. Design Tailored Training Programs

Develop a comprehensive training program tailored to different roles within the mining operation. This can include general safety training for all workers, as well as specialized training for those who handle high-risk equipment or work in hazardous areas.

4.1. Continuous Education and Refresher Courses

To maintain high safety standards and ensure workers remain up-to-date with evolving safety protocols, implement refresher courses and continuous education. These can be conducted annually or biannually, depending on the complexity of the changes to safety measures and regulatory updates. Provide opportunities for feedback after each training session, so workers can voice concerns or request clarification on any aspects of the training. This feedback is critical for improving the effectiveness of the program.

4.2. Monitoring and Evaluation of Risk Control Measures

Monitoring the effectiveness of implemented risk controls is essential to ensure that the mitigation strategies are working as intended and to identify areas for improvement. Continuous evaluation and oversight can help detect gaps in the system and provide opportunities for timely corrective actions.

4.3. Establish Monitoring Systems

Install real-time monitoring systems to track the performance of key safety measures. For instance, in underground mining, gas detectors and air quality monitors can be used to assess the effectiveness of ventilation systems in preventing dangerous gas buildup. Similarly, vibration sensors and equipment failure detectors can monitor mining machinery to ensure that early signs of malfunctions are detected before they lead to accidents.

4.4. Conduct Regular Inspections and Audits

Implement regular inspections of mining sites and equipment to ensure that safety measures are being followed and that equipment is functioning properly. Inspections should be conducted by trained safety personnel who are able to assess compliance with safety protocols, review risk control measures, and recommend improvements if necessary.

4.5. Conduct Safety Drills and Simulations

Regular safety drills should be conducted to assess how well workers respond to emergencies. These drills should simulate real-life situations, such as equipment failure, fire outbreaks, or gas leaks. They help workers practice their emergency response protocols, test the functionality of emergency systems, and ensure that all personnel know their roles in the event of a crisis.

4.6. Evaluation and continual improvement

In mining operations, risk control measures are critical to ensuring the safety and well-being of

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

workers, protecting the environment, and maintaining operational efficiency. However, the effectiveness of these measures should not be assumed or static; instead, they must be evaluated regularly and improved over time. Evaluation and continuous improvement are central to adapting risk controls to emerging risks, technological advancements, and changes in regulations. Mining operations need to create a feedback loop that allows for ongoing assessment of their safety strategies, based on real data and stakeholder input, ensuring that risk management practices remain dynamic and effective.

4.7. Implementing a Feedback Loop to Assess the Effectiveness of Risk Controls

To ensure that risk control measures are effective and appropriate, it is essential to implement a structured feedback loop**.** This loop involves gathering and analyzing data over time to assess whether the risk controls are achieving the desired outcomes. Feedback is collected from various sources, including incident reports**,** health screenings**,** and environmental monitoring**.**

- Incident Reports and Analysis
- Health Screenings and Monitoring
- Environmental Monitoring

4.8. Regular Review and Updates of Hazard Mitigation Strategies

The risk landscape in mining is constantly evolving due to various factors, including emerging risks, advancements in technology, and changes in regulatory standards. It is crucial that mining companies regularly review and update their hazard mitigation strategies to ensure they remain relevant and effective in addressing these changes. This process is an essential part of maintaining a proactive risk management approach.

- Identifying Emerging Risks
- Adapting to Technological Advancements
- Compliance with Changing Regulations

4.9. Promoting a Culture of Continuous Improvement

Creating a culture of continuous improvement is crucial to ensuring that risk controls evolve alongside changes in mining practices, technology, and regulations. A proactive culture ensures that all stakeholders are engaged in safety and risk management and that everyone, from senior management to the workforce, is committed to improving safety and operational standards.

- Employee Involvement and Feedback
- Training and Skill Development

4.10. Final Report and Recommendations

The safety and well-being of workers, the protection of the environment, and the efficiency of mining operations are critical concerns in the mining industry. Over the course of assessing hazards, evaluating risks, and implementing mitigation strategies, it is vital to compile the findings and insights into a comprehensive final report. This report serves not only as a summary of the entire risk assessment process but also as a critical tool for making data-driven recommendations to improve mining safety.

- Improved Safety Measures
- Reduction of Hazards
- Enhancement of Risk Management Practices

The final report should begin by offering an overview of the scope of the project. This includes a clear explanation of the purpose of the assessment, the methodologies used to identify and evaluate hazards, and a brief description of the mining operations being analyzed.

- Improved Safety Measures
- Reduction of Hazards
- Enhancement of Risk Management Practices

4.11. Risk Assessments and Findings

One of the most important sections of the final report will be the presentation of risk assessments and the analysis of findings from the hazard identification process. This should include a detailed discussion of the risks that were identified in the mining operation and how each risk was evaluated in terms of likelihood, severity, and impact on workers, the environment, and operational efficiency.

- Hazard Identification
- Risk Evaluation
- Mitigation strategies and implementation

Once the risks are identified and evaluated, the next section of the report should outline the mitigation strategies that were proposed to reduce or eliminate these hazards. It is essential to explain the rationale

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

behind each recommended risk control measure and how these strategies will address the identified risks.

- Engineering Controls
- Administrative Controls
- Personal Protective Equipment (PPE)
- Training and Awareness Programs
- Stakeholder feedback and consultation

The next section should focus on the consultation with stakeholders throughout the risk assessment and mitigation process. Engaging with key stakeholders such as mining companies, safety experts, regulatory bodies, and environmental organizations is crucial for validating the proposed risk controls and ensuring their practicality.

- Interviews and Surveys with Miners and Safety Managers
- Regulatory and Environmental Consultation
- Technology Integration for Safety and Efficiency

4.12. Continuous Improvement and Feedback Mechanism

A culture of continuous improvement is essential to ensure that mining operations remain as safe, efficient, and sustainable as possible. Implementing a feedback mechanism that allows workers to report hazards, suggest safety improvements, and share ideas for operational enhancements helps identify potential issues before they escalate into significant problems. Feedback should be gathered regularly from all levels of the workforce, including on-the-ground workers, supervisors, and safety officers. Anonymity in reporting hazards or unsafe practices encourages more honest feedback and allows workers to voice concerns without fear of retaliation. Regular safety meetings should be held to discuss reported issues and explore solutions collaboratively. Additionally, mining companies should continuously review and update their safety protocols, equipment, and training programs based on feedback and new industry developments. This includes incorporating lessons learned from near-misses or incidents, as well as adopting new technologies and best practices from other industries.

Reference

[1]. Dariusz Ignacy, The hydrological hazard in artificially-drained mining and post-mining areas–A significant environmental aspect requiring systemic management, Water Resources and Industry Volume 33, June 2025, 100275, https:// doi.org/ 10.1016/ j.wri.2024.100275

[2]. Milad Mousavi, Xuesong Shen, Zhigang Zhang, IoT-Bayes fusion: Advancing real-time environmental safety risk monitoring in underground mining and construction, Reliability Engineering & System Safety, Volume 256, April 2025, 110760, https://doi.org/10.1016/j.ress.2024.110760.

[3]. Soili Solismaa, Kirsti Loukola-Ruskeeniemi, Kristiina Nuottimaki, Historical mining towns: The establishment of 'Soil Planning Areas' for the risk management of contaminated soil, https://doi.org/10.1016/j.jhazmat.2024.136962

[4]. Ming Cai, Rockburst risk control and mitigation in deep mining, Deep Resources Engineering Volume 1, Issue 2, June 2024, 100019, https://doi.org /10.1016/j. deepre. 2024.100019.

[5]. Minglan Xiong, Huawei Wang, Yiik Diew Wong, Enhancing aviation safety and mitigating accidents: A study on aviation safety hazard identification, Advanced Engineering Informatics Volume 62, Part B, October 2024, 102732, https://doi.org/10.1016/j.aei.2024.102732.

[6]. Allanson, C. (2002): Strata control in underground coal mines: a risk management perspective. In: Proceedings of Coal 2002: Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, p 135.

[7]. Iannacchione, A.et.al. (2008): The application of major hazard risk assessment to eliminate multiple fatality occurrences in the US minerals industry. Information Circular 9508, National Institute for Occupational Safety and Health (NIOSH), USA.15-1Peter, B.H.et.al (2010): "Risk management Procedures, Methods and Experiences." Reliability: Theory & Applications 1:79.

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2025.0148
e ISSN: 2584-2854
Volume: 03
Issue:03 March 2025
Page No: 900-908

[8]. Sutrisno, A. et.al., (2011): "Service reliability assessment using failure mode and effect analysis (FMEA): survey and opportunity roadmap." International Journal of Engineering, Science and Technology 3: 25.

[9]. Thompson, S. et.al., (1999): Risk assessment for mines. In: Proceedings of Queensland Mining Industry Health and Safety Conference, p 89.

[10]. Xue, S., et.al. (2010): "Coal mine health and safety project for report hazard identification and risk management." Report no: EP106662. CSIRO Earth Science and Resource Engineering. Australia..187–196.

[11]. Sinha, et.al.,(2022) Energy Factor-Based Blast Design in Large Opencast Coal Mines , Journal of Mines, Metals and Fuels: Volume 70, Issue 6, June 2022.11-26.

[12]. Jayanth Bhattacharya.et.al.,(2022) Cat's Divesture and Exit Does Not Bode Well for the Underground Mining Industry (Part-1) , Journal of Mines, Metals and Fuels: Volume 70, Issue 6, June 2022.313-334.