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Research Article

RISK ASSESSMENT AND ITS MANAGEMENT IN MINING INDUSTRY

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ABSTRACT
Risk Assessment tools are used to help to prevent major hazards in mining industry, e.g., fire, explosion, wind-blast, outbursts, spontaneous combustion, roof instability, chemical and hazardous substances, etc., from injuring miners. The structured process associated with risk assessment helps to characterize the major hazards and evaluate engineering, management and work process factors that impact how a mine mitigates its highest risk. The degree of success is influenced by the existing risk management culture at the mining operation, identification of risk, the design of the risk assessment, the risk management, the character of the risk assessment process, the extent of the existing controls, and the quality of the new ideas.

Keywords: *Risk Assessment, Risk Analysis, Likelihood, Consequences*

INTRODUCTION
Risk Assessment (RA) is a process used to evaluate hazards that can cause great harm to a mining operation and its workers if they are not adequately controlled. The general consensus was that, the RA process provided information considered beneficial for a safer work environment.

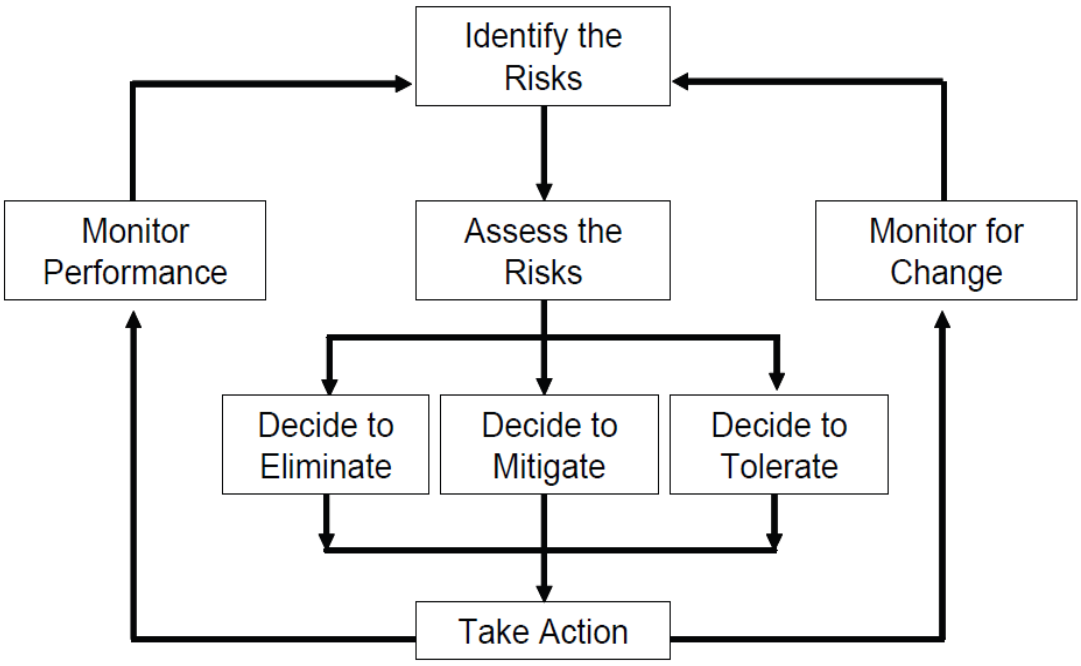

Figure 1: Principal Risk Management Framework (Standards Australia, 2004)

The probability that something will causes injury combines with the potential severity of that injury is known as risk. In mining industry there are number of areas of working personnel, environmental of the neighborhood, financial conditions of the industry or general welfare of the society. Moreover, a mining operation may initial look apparently harmless; however, in future it may give rise to dangerous or hazardous situation. Therefore, it is essential to determine the areas that are at risk or prone to be at risk. Adequate steps to risk management must follow for that (Iannacchione *et al.*, 2008).

The reoccurrence of multiple fatality events in minerals industry supports the need for improvements in the way major hazards are identified, assessed and managed. Many solutions to reduce mining disasters have been proposed including additional regulations, improved training, more reliable equipment, and better technology.

Mining Industry involves working with numerous hazardous situations demanding adequate safety management. Traditionally, risks of accidents are minimized through the command and control approach. Number of technological provisions has been made statutory through Mines Act and Regulations. Development of these provisions was based on safety factors; there is a need of critical analysis to determine the probability of accidents due to modification or deterioration of any of such provisions.

Mining particularly, modern mechanized mining involves high capital investment. The ultimate goal of such investment is to derive profit and welfare as environment puts certain values as risk. The return from investment must be achieved through yearly increment in production. While investing any capital it is essential to assess the financial risks for an ongoing mining operation also determination of values regarding technology upgrading, manpower deployment, marketing strategy or work expansion.

Thus application of risk analysis in mining industry is essential for safety management, environmental management and financial management. The result of such analysis would be an important feedback to the technical management of the overall operations (Moshab, 1999; Lynch *et al.*, 2014).

Risk means Hazard or danger having adverse consequences for individuals. The U.S. Atomic Energy Commission in 1975 has identified risk as 'the probability of occurrence of particular consequences over a specific period of time'. Risk assessment is an exercise made to produce an estimate of the likelihood of getting injury or adverse health condition. Risk management is a discipline that enables people and organizations to cope with uncertainty by taking steps to protect its vital assets and resources. The principle framework of risk management is shown in the Figure 1 (Standard Australia, 2004).

Recent emphasis on environmental protection and sustainable development has made it essential for mining industry to take care of the probable future damages in the environment. Therefore, it is now important to know which of the mining activities and decisions has potential to cause injury to the environment. But not the all risks are created equal. risk management is not just about identifying risks; it is about learning to way various risks and making decisions about which risks deserve immediate attention. Figure1 shows the overview of risk management process; this model is applicable to evaluating risks of all kinds, whether it is a business, project, environment or any specific activity.

The aim in this paper is to study risk assessment and management process as applicable to safety and health management system of a mine. Present paper discuss about the severity of that potential injury in mining industry and the type of analysis involves in risk assessment, risk estimation and risk management in mining industry.

Risk Identification

The principal objective of risk identification program would be to locate risk before it becomes problems and adversely affect the situation under consideration. The situation may be environment, safety or financial aspects of the industry.

Proper identification of risk is prerequisite for effective risk management. Identification of environmental risk requires technical knowledge and adequate techniques so that hidden and dormant risks can also be discovered. The next phases of risk management rely on the exploiting and communicating the knowledge gained during risk identification.

Risk identification is the process of identifying the risk and their causes and determining what, how and why things go wrong. It is necessary to collect and document several item of information.

- A brief description of the risk
- What can happen?
- How it can happen?
- the class of risk

A list of all possible risks is generated using one of the following methods

- fault tree analysis

- mind mapping
- similar projects or activities
- check lists
- specialist techniques

Risk identification is the most significant steps in the risk management process. If the risks are not identified they cannot be managed.

Risk has two dimensions, consequences and likelihood. Once particular risk identified, their consequences and likelihood are established, ranking and prioritizing of risks will automatically follow. This is a great virtue of risk assessment, allowing us to plan and programmed activities and enables us to become proactive, to control and manage to risks present. assessment of the risks aids in the decision making as to whether the risks are acceptably small that they can be ignored, or whether the risk are acceptably small that they can be ignored, or whether action has to be taken to reduce risks (Moshab, 1999; Paithankar, 2011).

A systematic and scientific risk identification program for environmental risk will incorporate the following (Figure 2):

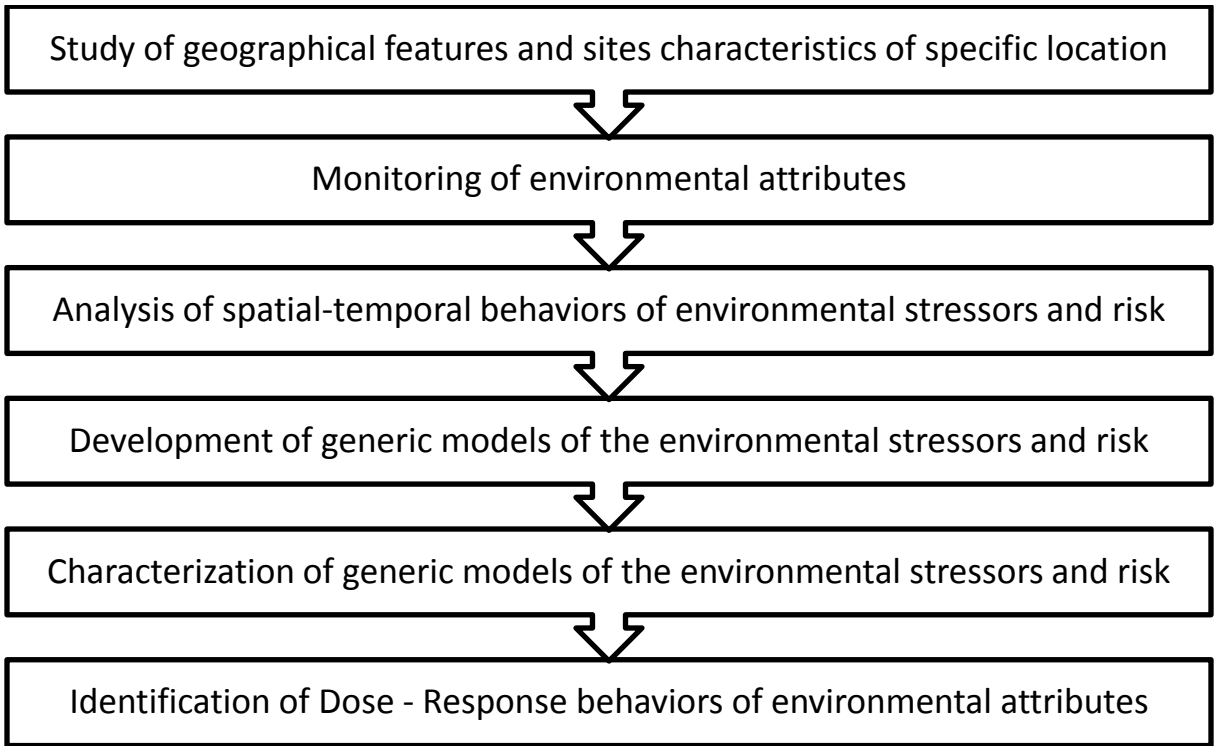

Figure 2: Systematic and Scientific Risk Identification Program

Risk characterization is associated with risk identification. Risk characterization is essential for the estimation of the incidence and severity of the adverse effects that are likely to occur. This is done for finding out the routes and patterns of exposure to harmful environmental attributes. The basic questions asked for risk characterization are:

What constitutes the threats?

How often do the events the causes such threat occurs?

How important is it to estimate the risk?

Risk Analysis- Consequences Analysis and Likelihood Analysis

Risk analysis is a process of identifying the possible outcomes of decisions. Risk analysis is done in two ways i.e. 1. Qualitative analysis 2. Quantitative analysis

Qualitative Analysis

Qualitative approaches to risk assessment are the most commonly applied. Qualitative risk assessment methods are quick and relatively easy to use as broad consequences and likelihoods can be identified and they can provide a general understanding of comparative risk between risk events, and the risk matrix can be used to separate risk events into risk classes (ratings) (Table 1).

A logical systematic process is usually followed during a qualitative risk assessment to identify the key risk events and to assess the consequences of the events occurring and the likelihood of their occurrence.

Since more risk cannot always be calculated accurately, but some way of categorizing risk is useful, we need a pragmatic solution.

Quantitative Analysis

Quantitative risk assessment is increasingly applied in the mining and minerals industry due to business requirements to support financial decisions, evenly compare financial risks with environmental and social risks, and to demonstrate transparency, consistency and logic of approach. However quantitative risk approaches often are not intuitive and require some up-front learning investment by decision makers.

Quantitative risk assessment is used across the full range of risk applications from deriving preliminary first-pass separation of risk events to much more comprehensive assessments. The comprehensive assessments can derive detailed risk profiles for priority ranking, estimates of the costs that may be incurred due to risk events, input to financial models and a basis for cost-benefit analysis.

Quantitative risk assessment follows basic risk assessment approach to its full extent by attributing absolute values to likelihood and consequences. Estimates of likelihood are made in terms of event frequency or probability of occurrence of the risk event.

Estimates of consequence can be made using any consistent measure selected according to the nature of the application. The risk quotient is used to differentiate on a comparative basis between the risks events using a consistent measure of risk and to identify those events that pose the most risk. Where consequences are expressed in financial terms, the risk quotient is equivalent to the commonly used term 'expected cost' or 'expected value'.

Consequences Analysis

After identifying the range of hazards, the next step is to obtain an estimate of the severity, or consequences of the events, should it occur. Consequences analysis concentrates on impacts in one or more area. Area of impact may include: physical assets, resources base, human assets, revenue, direct and indirect cost of the activity, well being, health and safety of the employees, business interruption, the environment, intangibles like reputation/image, goodwill, quality of life etc.

Likelihood Analysis

Likelihood of an event is used as a qualitative description of probability and frequency. Frequency of event is a measure of the rate of occurrence of an event expressed as the number of occurrence of an event in a given time. In risk assessment the given time frame is usually taken as one year. There the frequency can be expressed as the number of the occurrence per year.

Table 1: Consequences and Likelihood

Consequences		**Likelihood**	
Level	Descriptor	Level	Descriptor
1	Insignificant	**A**	Almost certain
2	Minor	**B**	Likely
3	Moderate	**C**	Possible
4	Major	**D**	Unlikely
5	Catastrophic	**E**	Rare

Risk analysis involves estimating the likelihood that things may go wrong and the potential consequences for objective and critical success factor of the activity. The final stage of risk analysis involves estimation for risk levels i.e. risk rating. The estimating of uncertainty in the likelihood estimate, the consequences

estimate and risk estimate is also applied. if uncertainty is high this gives a hint that further work is required or some form of early warning technique may be required.

Risk Evaluation and Estimation

Risk evaluation determines the risks that should be accorded the highest priority in developing responses for risk treatment. The risk analysis process generates a set of risk ratings that are used to set priorities. The aim of risk evaluation is to sort the risks in to groups like extreme risk, high risk, substantial risk, moderate risk and low risk that determine the level of management response and effort required (Morgan *et al*, 2011; Donoghue).

Minerals industry projects are, for the most part, designed on the basis of variables that are subject to extreme uncertainty. This uncertainty is due, in part, to the nature of the variables and, in part, to the cost of obtaining sufficient information about them. Processes for the evaluation of risk include the use of assessment matrices and simulation models (Table 2).

Risk rating = Consequences * likelihood

Risk rating = consequences * probability * exposure

r =P(h)*P(a)*l

Table 2: The grid to identify the level of risk and evaluate the risk

	Consequences				
Likelihood	**Insignificant 1**	**Minor 2**	**Moderate 3**	**Major 4**	**Catastrophic 5**
A-almost certain	High	High	Extreme	Extreme	Extreme
B-likely	Moderate	High	High	Extreme	Extreme
C-possible	Low	Moderate	High	Extreme	Extreme
D-unlikely	Low	Low	Moderate	High	Extreme
E-rare	Low	Low	Moderate	High	High

Risk estimation is the qualification of the likelihood (i.e. probability) that adverse effect will occur due to actual or predicated exposure to a substance. In other words it is estimation of probability that adverse effects will occurs due to the actual or predicate exposure to a substance. In other word it is the estimation of probability of consequences. Three factors are associated with the risk estimation. These are:

- Revelation
- Intuition
- Extrapolation

Environmentalist suggests following stages of risk estimation:

1. Description of intention
2. Hazard identification
3. Identification of consequences
4. Estimation of magnitude of consequences

Table 3: Risk Likelihood for Guidance in Mining Industry

Step 1: Assess the Likelihood				**Step 2 Assess the Consequences**		
L1	Happens every time we operate	Almost Certain	Common or repeating occurrence	**C1**	Fatality	Catastrophic
L2	Happens regularly (often)	Likely	Known to have occurred "has happened"	**C2**	Permanent disability	Major
L3	Has happened (occasionally)	Possible	Could occur or "heard of it happening"	**C3**	Medical/hospital or lost time	Moderate
L4	Happens irregularly (almost never)	Unlikely	Not likely to occur	**C4**	First aid or no lost time	Minor
L5	Improbable (never)	Rare	Practically impossible	**C5**	No injury	Insignificant

Risk projection attempts of rate each risk in two ways:

- Likelihood that risk is real
- Consequences of the problem associated with the risk should it occur (Table3).

The projection or estimation of the risk is essential for evolving and scientific management of environmental risks. The importance of the risk impact and probability is linked to their effect on management concerns.

Identify what happens already to manage the risks and consider how well these strategies are working (good, adequate, variable). How does this affect the level of risk? Fill these items in on the table. What actions are needed to bring risks to an acceptable level (these actions are incorporated into other planning processes and include responsibilities, resources and timelines)? What opportunities are there for improvement? Write these onto the table.

Risk Assessment and Management

Risk assessment is the quantification of risk in terms of probability and product. Modern occupational safety and health and safety legislation usually demands that a risk assessment be carried out prior to making an intervention. it should be kept in mind that risk management requires risk to be managed to a level which is as low as is reasonably practical. The assessment should be recorded and reviewed periodically and whenever there is a significant change to work practices. The assessment should include practical recommendations to control the risk. Following steps are a guideline for risk assessment (Morgan *et al.*, 2011).

- The design of regulation, for instance, in determining societal 'acceptable' risk levels which may form the basis of the environmental standards.
- Providing a basis for the site specific decisions, for instance in land use planning or sitting of hazards installations.
- Prioritization of environmental risk, for instance in the determination of which chemicals to regulates fires.
- Comparison of risks, for instance to enable comparisons to be made between the resources being allocated to the control of different type of risk, or to allow substitution decision to be made.

Once recommended controls are implemented, the risk should be recalculated to determine of it has been lowered to an acceptable level. Any changes to the process or work activity, including change in employees carrying out the task, should initiate a review of the assessment. Follow-up inspections and reviews should be adequately documented and training identified where necessary.

Need for risk management: the mining industry makes a major contribution to the national economy and to the well being of the society as a whole. For continuing viability of the industry, it is important that full advantages be taken of the advances in mining methods and procedures, design of mining machinery and equipment, and advances in approaches to management of all mining activities including health and safety.

Because of the inherent hazards of the mining as an activity, and the complexity of the mining machinery and equipment and the associated systems, procedures and methods, it is not possible to be inherently safe. Regardless of how well the machinery and methods are designed, there will always be potential for serious accidents. It is therefore not possible for any external agency to ensure safety of an organization such as mining company, or of the machinery or methods it uses.

Monitoring and Review

A risk monitoring and review program must be established to ensure that the control measures remain valid, i.e. that they control the risk of exposure to within acceptable standards. Hazards and risks need to be monitored to ensure changing circumstances do not alter the effectiveness of control measures.

The monitoring program should be developed to review changes to the:

The nature of the hazard	Have noise levels increased or have more toxic, or concentrated, ingredients been included in the hazardous substance**.**
Likelihood and frequency of exposure	How many and how often are employees exposed
Severity of the consequences	HIGH level risks should be monitored more closely than LOW level risks.

These are the components of monitoring programs:

Testing and Maintaining Controls	Ensures the integrity of the controls that have been put in place
Inspection	Provides confirmation that the nature of the hazard or the environment in which the hazard exists has not changed.
Consultation	Allows for communication to ensure any changes to the hazard, controls or environment can be appropriately managed.

Conclusion

Mining activity because of the very nature of the operation, complexity of the systems, procedures and methods always involves some amount of hazards. Hazard identification and risk analysis is require to carried for identification of undesirable events that can leads to a hazard, the analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects. Risk analysis is a compulsory element of all stages of mine feasibility studies, planning and production. The most promising approach to the quantification of project risk lies in the area of simulation and the development of methodology to adequately perform in them is growing. The intervention of managers and planners, for the better control of risk, is becoming more established practice, both in the simulation and operational phases of a project. Hazard identification and risk assessment can be used to establish priorities so that the most dangerous situations are addressed first and those least likely to occur and least likely to cause major problems can be considered later.

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