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Defining Safety Hazards & Risks in Mining Industry: A Case-Study in United States

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ABSTRACT

There are generally hazards associated with working in many industries. Mining industry has been always ranked among the ones that have the most dangerous working environments. Underground mining is a highly dangerous and hostile environment and there are several factors regarding this issue. It is, therefore, important to create a safe workplace that reduces these challenges so that mining can sustain. In this paper, the safety issues related to mining industry is discussed. Then, a risk matrix is developed to define the importance of these factors and their impact on the industry. Finally, the most important elements are explained and some solutions to solve them are presented.

Keywords: Hazards, Mining Industry, Risk Management, Safety.

1. INTRODUCTION

Mining is a hazardous operation and consists of considerable environmental, health and safety risk to miners. (Chu, Sasanipour, Saeedi, Baghban, & Mansoori, 2017) Unsafe conditions in mines lead to a number of accidents and cause loss and injury to human lives, damage to property, interruption in production etc. (Cox, 2008) But the hazards cannot be completely obliterated and thus there is a need to define and reckon with an accident risk level possible to be presented in either quantitative or qualitative way (Mutekede, 2014). Safety is paramount in the mining environment. The mining industry has for many years focused on injury prevention at the workplace through procedures and training, and has achieved considerable success (Paithankar, 2011). However, the statistics on major accident events such as fatalities and reportable incidents has not shown the corresponding levels of improvement. In the area of major hazards control, the mining industry approach has emphasized mainly on past experiences and lessons learnt, while other high hazard industries such as the chemical process industry and oil and gas industry have taken system safety techniques to new highs (Parand & Foster, 2006).

The objective of hazards and risk analysis is to identify and analyze hazards, the event sequences leading to hazards, and the risk of hazardous events (Hessami, Sun, Odreman, Zhou, Nejat, & Saeedi, 2017). Many techniques, ranging from simple qualitative methods to advanced quantitative methods, are available to help identify and analyze hazards. In this paper, the analyses used and recommendations based on them will be discussed.

The objective of risk matrix is to produce outputs that can be used to evaluate the nature and distribution of risk and to develop appropriate strategies to manage risk (Slattery, Slattery, & Bruce, 2011). Events or issues with more significant consequences and likelihood are identified as "higher risk" and are selected for higher priority mitigation actions to lower the likelihood of the event happening and reduce the consequences if the event were to occur (Torabi, Kiaian Mousavy, Dashti, Saeedi, & Yousefi, 2018). Qualitative methods use descriptive terms to identify and record consequences and likelihoods of the events and resultant risk. Quantitative methods identify likelihoods as frequencies or probabilities. They identify consequences in terms of relative scale (orders of magnitude) or in terms of specific values (for example estimate of cost, number of fatalities or number of individuals lost from a rare species) (Cox, 2008).

For both qualitative and quantitative methods it is important to invest time in developing appropriate rating scales for likelihood, consequence and resultant risk. The full range of risk situations likely to be encountered within the scope of the exercise should be considered when developing rating scales (Cox, 2008).

2. LITERATURE REVIEW

Overview of the state of the mining sector in terms of health and safety: According to ILO (2001), Occupational Safety and Health aim at the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations. The research and regulation of Occupational Safety and Health (OSH) is relatively a recent phenomenon (WHO 2003). As labor movements arose in response to worker concerns in the beginning of the industrial revolution, the employee‘s health began to be considered as a labor related issue. According to Leigh *et al* (1999) 100 million occupational injuries occur throughout the world each year. Some of these occupational injuries end up as fatalities. Chen and Zorigt (2012) contend that 150 000 non-fatal accidents are reported each year and an estimated 200 workers lose their lives at mining work in Britain. Two million mine workers suffer from work related illnesses in Britain. In America the OSH administration has made significant efforts in the general reduction of injuries, fatalities and illnesses in mining operations by enacting the OSH Administration Act. According to Chen and Zorogt (2012) occupational injuries and illnesses in mining operations in America has declined by 36% between 1992 and 2003. Murray et al (2000) note that the investigation of occupational exposures and illnesses is weak in South Africa notwithstanding efforts of the Department of Mineral Resources to maintain registers of the South African mining occupational diseases databases initiated in 1998. Mining workers in Zimbabwe are also at high risk of contracting work-related illnesses and injuries. The injury rate among mining workers in Zimbabwe was 131/1000 exposed workers per year as of 1998 and this figure rose to 789/1000 workers in 2008 (NSSA 2012). Stellman and McCann (1998) contend that although the mining industry only accounts for 1% of the global workforce, it is responsible for about 8% of the fatal accidents at work (Paithankar, 2011).

Occupational hazards: A hazard only represents the potential to cause harm (NSSA 2012). Occupational hazards can result in illnesses, injuries, disability as well as fatalities. Occupational hazards need to be controlled since they are an economic burden to the world as a whole. The most important issue is to control hazards so as to avoid a number of safety and health risks to the workers. This can merely be accomplished through training employees to identify hazards as well as training them the ways of assessing and controlling those hazards. Occupational hazards are therefore increasingly becoming an issue of concern at global, regional as well as at local levels since they pose a gigantic threat to a large proportion of the world’s working population. According to (ILO 2001), occupational hazards can be divided into health hazards and safety hazards. Health hazards are those hazards that result in the development of illnesses or diseases.

However, safety hazards are those hazards that cause accidents at workplaces which results in physical harm to the workers. The duration of exposure and the toxicity of the safety and health hazards determine the nature of the injuries and illnesses to the exposed workers. Hazards can also be rated according to the severity of the harm they cause. A major hazard being one with the possibility to cause a critical damage or death.

Occupational Safety and Health hazards in mining companies: Mining practices generate numerous conditions that have huge consequences on human safety and health. These safety and health problems emanate as a result of biological, chemical, psychosocial and physical risk factors.

3. METHODOLOGY

The method used in this research to evaluate and analyze the risk of a coal mine was quantitative method. Quantitative risk matrix 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 matrix approaches often are not intuitive and require some up-front learning investment by decision makers (Cox, 2008).

In his article 'What's Wrong with Risk Matrices? Tony Cox argues that risk matrices experience several problematic mathematical features making it harder to assess risks. These are: (Mutekede, 2014)

a. **Poor Resolution.** Typical risk matrices can correctly and unambiguously compare only a small fraction (e.g., less than 10%) of randomly selected pairs of hazards. They can assign identical ratings to quantitatively very different risks ("range compression").
b. **Errors.** Risk matrices can mistakenly assign higher qualitative ratings to quantitatively smaller risks. For risks with negatively correlated frequencies and severities, they can be "worse than useless," leading to worse-than-random decisions.
c. **Suboptimal Resource Allocation.** Effective allocation of resources to risk-reducing countermeasures cannot be based on the categories provided by risk matrices.
d. **Ambiguous Inputs and Outputs.** Categorizations of severity cannot be made objectively for uncertain consequences. Inputs to risk matrices (e.g., frequency and severity categorizations) and resulting outputs (i.e., risk ratings) require subjective interpretation, and different users may obtain opposite ratings of the same quantitative risks. These limitations suggest that risk matrices should be used with caution, and only with careful explanations of embedded judgments. (Mutekede, 2014).

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. (Cox, 2008).

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 (Cox, 2008).

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" (Cox, 2008).

On the other hand, qualitative approaches are best used as a quick first-pass exercise where there are many complex risk issues and low-risk issues need to be screened out for practical purposes. Qualitative approaches have some shortcomings compared with more quantitative approaches. Key criticisms are that qualitative methods are imprecise it is difficult to compare events on a common basis as there is rarely clear justification of weightings placed on severity of consequences and the use of emotive labels makes it difficult for risk communicators to openly present risk assessment findings (Cox, 2008).

4. PHYSICAL HAZARDS

4.1 Dust

The mining process involves breaking the rock or removing the soil. These activities generate a lot of dust and pebbles. These dust and pebbles can be a nuisance and they can also be harmful to the worker's body. According to Stellman and McCann (1998), free crystalline silica is the most abundant compound in the earth's crust and consequently is the most common airborne dust that miners face. Respirable particles are formed whenever silica bearing rock is drilled, blasted and crushed into fine particles. Dust and pebbles can physically harm employees or may lead to physiological harm. Dust may get into the eyes of the workers involved if Personal Protective Equipment (PPEs) are ineffectively used. Dust and pebbles may also interfere with vision and this increase the chances of accidents occurrences and it can also affect the skin causing all kinds of skin problems. Moreover, dust can also lead to occupational health problems if inhaled. Prolonged exposure to mining dust containing silica can result in silicosis which is a typical pneumoconiosis that develops insidiously after years of exposure. Exposure to silica is also associated with an increased risk of tuberculosis, lung cancer and some autoimmune diseases. NSSA (2012) assets that some dusts when inhaled can contaminate the blood leading to damage to other parts of the body such as the brain and the nervous system.

4.2 Noise

Noise also presents a fairly common workplace hazard. It is all unwanted sound which causes annoyance and interferes with efficiency, induces stress and disturbs concentration (Stellman and McCann 1998). Donoghue (2004) highlighted that noise is ubiquitous in mining and it is generated by powerful machines, fans, blasting and transportation of the ore. Higher noise levels hinder communication resulting in accidents. Controlling noise levels has proven difficult in mining and Noise-Induced Hearing Loss (NIHL) remains a common health problem. The primary health effect of prolonged exposure to high levels of noise in the work place is the development of occupational deafness or Noise-Induced Hearing Loss. Noise-induced hearing loss can be temporary or permanent. WHO (2003) notes that noise has contributed about 13% hearing loss worldwide. It can be controlled at the source by identifying the source of noise and replace or remove the noise machinery or part of the machine. The use of silencers and vibration isolation can also be done to reduce high noise levels. The mining industry is most affected by noise due to the use of huge machinery for example jackhammers and locomotives.

4.3 Heat

Donoghue *et al* (2000) point out that heat and humidity are encountered in deep underground mines where the virgin rock temperatures and air temperatures increase with depth. Surface mining may be associated with solar heat or cold weather whereas underground mining is associated with hot temperatures most of the time (Campbell *et al* 1983). The principal source of heat in underground mines is from the rock. Other sources of heat stress include the amount of physical activity workers are doing, the amount of air calculated, ambient air temperatures, humidity and the heat generated by mining equipment principally diesel powered (Stellman and McCann 1998). These conditions take a heavy toll on the exposed worker's body and they affect attention and concentration and thus increasing the risk of more accidents occurrences. Bell (1983) argues that hot environments results in the worker's body losing more water and salts leading to collapse. Heat stress can cause head stroke, cramps, exhaustion and rashes. Workers near hot surfaces are at risk of burns.

Dehydration may also result from over exposure to heat. Preventative efforts like an adequate ventilation system, cooling high temperature machinery, limiting physical activity and regular fluid intake can reduce occupational illnesses and injuries arising from exposure to heat.

4.4 Ionizing radiation

Stellman and McCann (1998) promulgate that radon gas can be liberated from rocks during the blasting process or it may also enter a mine through underground streams. It is a gas and therefore it is airborne. Though not perceived by a normal human eye, radon and its decay products emit ionizing radiation some of which have enough energy to produce cancer cells in the lungs.

5. MECHANICAL HAZARDS

The tools and machinery used in undertaking mining operations can cause a number of negative health effects to the workers. Many machines used in carrying out mining tasks involve moving parts, sharp edges and hot surfaces which have the potential to cut, stab, crush, struck or wound workers if used unsafely. Mining machines may also indirectly result in deaths and injuries to the exposed workers in cases where a worker slips and falls upon a sharp or pointed object. (Heyns *et al* 2000)

5.1 Vibration

Vibration is separated into two well defined categories, whole body vibration and hand transmitted vibration (Griffin 1990). Whole body vibration result in back problems, gastrointestinal and reproductive system disorders. Hand arm vibration is a form of vibration where the hand is in contact with the vibrating piece of equipment. According to Heyns *et al* (2000), prolonged exposure to vibration lead to hand arm vibration syndrome a chronic and progressive disorder that affects the vascular, neurological and musculoskeletal system. The early stages of hand arm vibration syndrome are characterized by blanching of the fingers, tingling and loss of sensitivity when touching. This health effect can progress to loss of effective hand function and necrosis of the fingers. Machinery like jackhammers and heavy vehicles used in mining operations cause significant illnesses like hand-arm vibration syndrome and back pain to most of the exposed workers. Vibration also affects the musculoskeletal system and results in severe destruction to the tendons, muscles, joints and nerves (Campbell *et al* 2002).

5.2 Fires

The mobile equipment used in mining activities contains large quantities of highly flammable diesel, lubricating oils and hydraulic fluids (Bickel 1987). The energized electrical equipment that are used in mining operations also presents an elevated fire risk. Mitchell and Burns (1979) argue that materials or fluids coming in contact with hot exhaust or engine parts or an electrical fault can quickly erupt into a fast spreading fire that can result in severe destruction to machinery and to the exposed workers., Hanson (2010) assert that management should ensure that their health and safety management plans include a fire protection plan in cases where there are risks of fire at any mining operations. The plan should take into consideration the potential sources of fire and the precautions to be taken to protect workers against fire outbreaks as well as the evacuation procedures to the safe havens. Mining inspections should include fire safety checks to ensure that all fire precautions are in place and that nothing that will burn is in contact with a potential ignition source. Campbell *et al* (2002) advocate that fire extinguishers should be sited at places where flammable materials are stored and at conspicuous positions close to any machinery or equipment that gives rise to fire risks. Electricity also poses risks to many works since it results in accidents and fires. Electrical injuries can be divided into four categories namely fatal electrocution, burns, electric shock and falls caused by contact with electric energy.

Chemical Hazards: Many chemicals are used in mining operations in particular in laboratories. Explosives which are used to break the rock are made of chemical materials which if not properly managed cause illnesses as well as physical harm to the exposed workers. According to (Elliot 1981), these chemicals can enter the body through inhalation by breathing in dust, gas fumes or vapor through the mouth or nose. They can also enter the body by way of absorption through the skin. In underground mines where ventilation is in adequate, chemicals cause various health problems including lack of oxygen, skin and eye problems. When toxic chemicals enter the body, they cause long term health effects for example headaches, tiredness, dizziness and loss of breadth. Smoke or fumes from smelters affect air quality and thus cause respiratory problems. Moran (2000) argues that chemical substances for example cyanide are used as a solvent for metals like gold in hydrometallurgical processes. Exposure to high levels of cyanide damages the heart and brain and can lead to death. Low level exposure of long periods to cyanide result in breathing difficulties, chest pain, vomiting, blood changes, headaches and enlargement of the thyroid gland.

***Psychosocial hazards**:* Lehtinen and Joronen (2011) contend that psychosocial hazards are related to the way work is designed, organized and managed as well as the economic and social context of work. These hazards are also associated with psychological and physical injury or illnesses. The mining operations are associated with long working hours. Many workers travel long distances and may be away from homes for many days or even weeks. Loneliness and isolation can therefore be experienced. These situations cause anxiety in many workers and their families and many people are adversely affected in their personal lives. Violence in the mines arises from different situations including mobbing and bullying. Places of work may be the most important sources of health stresses if workplace operations have not been studied thoroughly and the associated health hazards have not been eliminated or controlled. According to the American Psychological Association (2007), the feeling of job insecurity, poor work life balance, poor remuneration and long working hours as well as unrealistic job expectations cause severe stress which may increase workers' vulnerability to other forms of work place hazards. Prolonged stress can raise the risk for developing chronic and costly diseases for example heart diseases, diabetes and cancer. Stress can also lower the immune system and play a role in a person's susceptibility to more colds, flu and other infectious diseases.

Biological hazards: Mining is also associated with poor working conditions, with the limbs exposed to biological hazards. (Driscoll *et al* 2005). Among the various dangers involved are the risks of snakebites and injuries. Bacteria, virus, fungi and blood borne pathogens also present significant hazards to mine workers.

6. CONCLUSION & RECOMMENDATIONS

BBS: We are motivated by consequences, however, so we should consider certain benefits we can expect to gain from a successful behavior-based safety management process as reviewed in this research. Since most injuries are caused in part by at-risk behavior, a reduction in at-risk behavior and an increase in safe behavior will lead to injury prevention. However, five other benefits that result from people contributing interdependently to an effective behavior-based safety process.

These outcomes are critically important, and relate to much more than safety. In fact, they can benefit every important function of your organization. These five benefits are: 1- It Focuses Evaluation on the Right Numbers 2- It Builds Positive Attitudes 3- It Increases Personal Responsibility for Safety 4- It Facilitates Interpersonal Coaching and Teamwork 5- It Teaches and Promotes Systems Thinking

Preventive Maintenance: Since coal mining utilizes numerous electrical and mechanical equipment, Preventive maintenance is a proven way to make mining equipment more productive and reliable, as well as to reduce repair costs. Major machine malfunctions can more easily be avoided with regular PM and mining machine check-ups reducing the amount of time and money lost while machines are down for repair. In this way, it is recommended to take stock of organizational goals and establish an overall plan of attack. Decision makers can then determine what areas within the machines they'd like to address first and identify how these tasks will be developed. Recognizing how the equipment will be used is also a key factor to consider, along with the business's key production areas. Once equipment is inventoried and machinery maintenance history is gathered, workers can define the requirements of the systems to be included in the PM plan. Using this information, employees and managers can work together to develop an annual maintenance schedule for PM.

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