Risk Evaluation of a Boron Mine and Processing Plant with respect to Dust

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ABSTRACT

The technological developments affect mining sector directly since the machineries and equipment used in this sector changes along with constantly developing technology. So, the risks of occupational accidents and occupational diseases are quite high in this sector. It is necessary to focus on occupational health and safety in the mining sector regarding the machineries and equipment used. This study was carried out in an open pit mine of boron minerals with class of very dangerous in the scope of occupational health and safety. The workplace on scope is evaluated in terms of the health and safety risks of employees. In this context, one of the major types of risk is dust, originated from machineries and equipment. The stages of open pit operation, crushing, screening, grinding and bagging are evaluated regarding dust formation and control. Risks that may arise due to the use of equipment and preventative measures have been determined. Such studies impose great affect in the development of occupational health and safety with the developing mining sector and prevention of accidents that may occur.

Keywords: Risk evaluation, Boron, Dust, Processing plant

1. INTRODUCTION

It is very usual to encounter dust problems in various sectors in industry. Quarries, mining and metal industries are among the first. The dust occurs wherever the mine is extracted, transported or processed. Dust is formed during the drilling, blasting, crushing, screening, grinding, transportation and storage operations in surface mining operations [1,2]. The danger represented by the dust depends on composition, size, concentration of dust and exposure of the worker. The greatest danger is due to dust particles that are small enough to reach the alveolar bulbs and may cause changes in the lung tissue [2]. This study was carried out on a boron mine, operating as open pit and has a processing plant. Production stages in the enterprise are open pit operation, concentrator plant, grinding and bagging plant activities respectively. Among these main activities, inter-facility transport activities are carried out. In order to prevent dust, the possible effects of the machinery and equipment used in the extraction, transportation and processing stages of the mine were evaluated. Preventative measures have been tried to be determined by focusing on machinery and equipment where dust risk is originated.

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L type risk assessment matrix was utilized to evaluate these risks. L matrix method is the simplest one among the other calculation methods of quantitative risk evaluation methods. The equation for this method is as follows;

$$\text{Risk Score} = \text{Likelihood (L)} \times \text{Consequences (C)} \quad (1)$$

Equation includes two different terms namely likelihood and consequence (severity). Consequence describes ''how bad'' level of any risks. It is important to define consequences with objective ways. According to the rules of method, consequence is rated as; 1. Insignificant; 2. Minor; 3. Moderate; 4. Major; 5. Catastrophic [3,4]. To simplify, the L type risk assessment matrix can be stated as the method to calculate the risk scores by multiplication of probability and intensity. The highest risk score is 25 and is expressed as unbearable risk. Risk scores between 16 and 20 are called high risk. Within the scope of the research, the risks between 16-25 points were evaluated. Because the probability of accidents and occupational diseases is very high. Therefore, work should be stopped. Risk levels should be brought to an acceptable level with preventive measures. In this context, studies should be initiated to bring the risks to insignificant and tolerable levels (1-6 points) and work should be stopped until preventive measures are taken.

2. DEFINITION, CAUSES AND CONSEQUENCES OF DUST

Dust is solid pieces that are wide variety of shapes and sizes. Dust is caused by the disintegration of the materials in the ground into smaller pieces as a result of the mechanical processes. There can be dusts that are clearly visible with the naked eye, or dusts that are difficult to see with a microscope [5,6]. Dusts are particles that are emitted or potential of propagating to ambient air. Dusts that may remain suspended in air may be dangerous to the health of workers depending on their size. The largest particle that can stay suspended in the air for a long time is about 60 µm which is near human hair thickness [6].

The impact of mining and mining related activities on the environment in the form of air pollution depends on numerous meteorological conditions, such as wind speed, wind direction, temperature, amount of rainfall, atmospheric stability, etc [7,8]. Exposure to airborne particulate pollution is associated with premature mortality and range of inflammatory illnesses, linked to toxic components with the particulate matter assemblage. Concentrations of SO_2 and NO_2 due to mining activities generally remain within the standard limit (CSIR-CIMFR, 2017). Thus, the control of dust emission is a matter of utmost importance for any mining region as it contains free silica and respirable particulate matter which causes lung diseases [8,9,13].

In case of inhalation of dusts suspended in the air for a certain period of time, various lung diseases are encountered. These dust-related diseases are all commonly referred to as pneumoconiosis. Dust disease of lung, defined as pneumoconiosis, describes the occupational disease caused by the reaction formed in the tissues due to the accumulation of dust in the lungs. The type of pneumoconiosis is also named according to the type of dust. For example, anthracosis is formed due to coal dust, silicosis is formed due to quartz dust, siderosis is formed due to iron dust [10,13].

Colemanite ore which is type of boron contains CaO (%28), SiO_2 (%6.5), B_2O_3 (%42) and H_2O (%23.5) in its composition [11]. Silicon dioxide (SiO_2) is one of the most common types of dust during the extraction of natural minerals and rocks (drilling, blasting, loading, handling and unloading) and production activities (crushing, screening, grinding) in mines and quarries [12].

Silicosis is the most common occupational disease in the world caused by respiration of silica crystals (SiO_2). Silicosis is an incurable and potentially fatal lung disease caused by inhalation of respirable crystalline silica. Quartz is the only common mineral in earth crust, and many mining processes involve direct contact with quartz. For this reason, workers in the majority of the mining industry are exposed to breathable crystalline silica during routine mining operations, such as drilling, crushing, sizing, transportation and loading [6].

3. PRECAUTIONS AND PROTECTIVE MEASURES

Open pit operations include drilling, blasting, loading, transporting and unloading. Before the blasting operation the area to be drilled is prepared using drilling equipment. Dust emitted during drilling is inevitable [14]. Therefore, dust emission systems should be utilized in the working environment. In the same way, after the blasting operation, large scale of dust is spread out to the environment. The dust that is created by explosion must be suppressed by wet systems or equipment to prevent the dust spreading through. The dust formed during the production stages are spread to the environment by weather conditions. In order to prevent the dust from being transported in the open pit operations, it is possible to take measures by using some models in the planning stage [15,16]. In addition, maintenance of the roads and wetting at certain intervals in summer will be useful in preventing dust. Placing traffic signs with reflectors on both sides of the intersections and regular cleaning of these signs against dust will prevent the potential accidents.

It is useful to equip the drilling machine with systems in such a way that it does not expel the dust, and use water during the drilling process. After blasting, it is possible to suppress dust by using aqueous spray systems. It can be ensured by tightening the operating roads and taking into account the seasonal conditions. Spray irrigation systems or dust filters for dust suppression can be used in stockpiles. The risk assessment of the related open pit mine with respect to dust control is given in Table 1.

Table 1. Risk assessment of dust in the open pit mine

Activity	Identification or Sources of Hazard	Damage/Risk	Risk Assessment			Necessary Precautions To Be Taken / Actions	Revised Risk Assessment		
			Probability	Intensity	Risk		Probability	Intensity	Risk
Open pit works	Heavy Equipment and Machinery	Traffic accidents due to reduced visibility, property damage, serious injury, death, occupational lung disease due to inhaled dust.	4	5	20	The drill bit of the drilling machine must be closed. After blasting dust suppression must be ensured with spray systems.	1	5	5
Transportation	Heavy Equipment and Machinery	Vehicle overturning, slipping, property damage, serious injury, death.	4	5	20	Reflector barriers should be placed on both sides of the road to ensure that roads are clear. These barriers must be cleaned against dust in certain time intervals, and those which are damaged, should be replaced with new ones.	1	5	5

According to the risk assessment mentioned above in Table 1, working machines were identified as high-risk dust (20 points) source in the open pit mine. Property damage, serious injury, death, occupational lung disease can be emerged due to dust in open pit mine. The risk score which is very dangerous is to be lowered to a bearable level (1-6 points) for preventing occupational hazards and health diseases. To avoid them, bit of the drilling machine must be closed. Preventing dust suppression, spray systems must be used after blasting. Reflector barriers can help to warn drivers to be careful about roads of open pit mine. Cleaning of these barriers must be checked, cleaned and old ones must be changed by responsible staff.

Dust may also occur at transfer points of transporting systems, discharging from the belt conveyor to another belt conveyor or crusher, due to the natural events like wind, roads of transport and stockpiles. Due to its special working mode, the transfer point of conveyor belt makes it one of the main dusts generating sources in the production process of coal mine. According to relevant data, the concentration of dust detected at the transfer point of belt conveyor greatly exceeds the relevant national standards [17,18]. In this context; wet and dry control methods and combination of both methods are used to prevent dust. Water is used in the wet method while filtering and closing the dust source are utilized in dry control methods. Dry methods are used in cases where the extracted ore is not desired to come into contact with water. In this case, the filter systems can be installed, the dust source can be surrounded by dust curtains [6,19].

If the future ore will enter the crusher dry, the area of the inlet is closed so that dust does not come out and the filter system is used for preventing dust. If there is any problem in the wetting of the ore, it will be useful to turn the surrounding area in such a way that dust does not come out, such as isolation. Also, dust is suppressed by spray systems during the unloading of the ore. The choice of spray systems to be used is important for suppressing dust. The smaller the size of the sprayed water, the easier it will be to depress the dust. Again, transfer points of conveyor belts can be closed with curtains and spray systems can be used. Spray systems have two important purposes. They are dust prevention and suppression. The spray systems used during the transfer of conveyor belts at transfer points are intended to suppress. Spray systems used during the conveyance of the same belt conveyor are intended to prevent dust from re-forming. In addition, the presence of local dust filters at the bagging site and the use of personal protection equipment by the personnel or operators is essential for occupational health [6,19]. During the cleaning, maintenance and repair of bunkers, crushers and grinders, workers must be informed and equipped with personal protective equipment. The risk assessment of the concentrator plant and conveying systems related to dust is given in Table 2.

Table 2. Risk assessment about dust in concentrator plant and conveying systems

Activity	Identification or Sources of Hazard	Damage/Risk	Risk Assessment			Necessary Precautions To Be Taken / Actions	Revised Risk Assessment		
			Probability	Intensity	Risk		Probability	Intensity	Risk
Concentrator plant	Crushers, screens, bunkers	Occupational diseases due to dust. Injury, serious injury, death due to unaware operation of the screens during maintenance.	4	5	20	Screen and crusher systems should be closed systems, closure of these systems for suppression of dust can be ensured with using curtains. If there is no harm to the mine, aqueous systems can be used. Dust collection systems can use. Maintenance must be performed regularly and not at the time of work.	1	5	5
Conveying systems	Belt conveying systems	Occupational diseases due to dust.	4	4	16	The inlet and outlet of the conveyor belt systems should be closed, curtained and water spray systems should be used. Dust collection systems should be used.	1	4	4

According to the risk assessment related to concentrator in Table 2; crushers, screens, bunkers (20 points). and belt conveying systems (16 points) were identified as high-risk sources of dust. Occupational lung disease and serious injury, death due to unaware operation of the screens during maintenance can be emerge due to dust in concentrator plant and conveying systems. The risk score which is very dangerous is to be lowered to a bearable level (1-6 points) for preventing occupational hazards and health diseases. To avoid them, screen and crusher systems should be closed systems, closure of these systems for suppression of dust can be ensured with using curtains. If there is no harm to the mine, aqueous systems can be used. Also, dust collection systems can be used for preventing dust diffusion. Maintenance must be performed regularly by experts and not at the time of work. The inlet and outlet of the conveyor belt systems should be closed, curtained and water spray systems should be used. In addition to these precautions, dust collections systems can be beneficial.

There should be careful in the grinding plants because the particle size of the dust is smaller and finer. Due to the use of water in the operations carried out in concentrator plants, the important problem of dust is prevented in some extent. However, it is essential to use personal protective equipment due to the small size of the dust in the grinding facilities and bagging and storage in this area. Therefore, training of employees on these issues and raising awareness on possible risks will prevent the emergence of significant fatal problems [6,19]. The risk assessment of the grinding plant related to dust is given in Table 3.

Table 3. Risk assessment of dust in grinding plant

Activity	Identification or Sources of Hazard	Damage/Risk	Risk Assessment			Necessary Precautions To Be Taken / Actions	Revised Risk Assessment		
			Probability	Intensity	Risk		Probability	Intensity	Risk
Grinding plant	Grinders	Dust explosion, occupational health disease.	4	5	20	Dust collection systems should be used, masks should be distributed to workers and dusts in the working environment should be cleaned with certain periods. In order to prevent the risk of explosion, dust suppression systems should be installed, smoking shouldn't be used in the working environment and materials that would cause sparks.	1	5	5

According to the risk assessment in Table 3, grinders were identified as high-risk sources of dust (20 points) in grinding plant. Occupational lung disease and dust explosion can be emerged due to dust in grinding plant. The risk score which is very dangerous is to be lowered to a bearable level (1-6 points) for preventing occupational hazards and health diseases. To avoid them, dust collection systems should be used in facilities, masks should be distributed to all workers and dusts in the working environment should be cleaned with certain periods by workers. In order to prevent the risk of explosion, dust suppression systems should be installed. With instructions smoking shouldn't be used and materials that would cause sparks in the working environment.

4. CONCLUSION

It is evident that dust is an important risk due to the machinery and equipment used in mining operations. Different types of machinery and equipment are used in every stage of the mining operation; therefore, the required measures must be taken to suppress dust. It is possible to avoid the risk of dust by closing the existing dust sources, using water during operations, dust collection, use of spray systems and, finally, use of dust masks as a personal protective equipment. With the implementation of appropriate systems and measures, health of the employees will be protected and work efficiency will enhance. Taking precautions against the risk factors shouldn’t be recognized as an obligation by the administrative personal, on the contrary, they should be aware of the benefit originated from application of health and safety measures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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