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Physical Risks in terms of Occupational Health and Safety in Underground Coal Mines

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Abstract: Mining is one of the oldest professions in history. Along with the development of human life, mines also give direction to civilization and the economy. Mining activities carry various risks in terms of occupational health and safety (OHS). These risks can be examined under the main headings of work accidents and occupational diseases. As a result, thousands of workers face illness and death every year. Additionally, economic losses occur as a result of production interruption and stopping. Despite all the efforts to reduce mining accidents, statistics show that underground mining is one of the riskiest among all working industries. It is seen that the physical risk factors encountered in the mining sector line are remarkable in terms of risk factors. Physical risk factors that may be encountered in mines are dust, noise, vibration, lighting problems, and thermal conditions. It is essential to take measures to assess these risks and ensure the comfort of employees where each physical risk factor needs to be examined separately. In this study, physical risks being frequently encountered in underground coal mines are taken into account with recommendations for the risks.

Keywords: Underground coal mining, work accidents, occupational disease, occupational health, and safety.

Introduction

Minerals have been mined in many parts of the world since prehistoric times. Today, mining is carried out in most countries. Modern mining processes involve prospecting for ore, analyzing a mine's sustainable profit potential, extracting desired materials, preparing the extracted material (including crushing, grinding, concentrating, and washing), and finally reclamation and rehabilitation of the land after seized mining. Mining methods can be divided into two common classes, the most commonly known as open-pit mining and underground mining (Burström et al., 2017).

Considering the world's most dangerous business lines; construction, metal, agriculture, and mining sectors are the most prominent. The activities or production processes carried out in these and other sectors pose serious dangers to human health and life.

Mining is one of the oldest known business lines in history. However, it is one of the riskiest work sectors known in the world. Many risks are encountered during both preparation and production activities. As a result of the increase in the production speed along with the increase in demand, mining activities have started to be more mechanized over the centuries. With the increase in mechanization, some risks have unfortunately increased more. Physical risk factors such as noise, vibration, and dust have also increased with the increase in mechanization.

With the augment in risks of occupational health and safety, the increase in the need for raw materials makes mining an indispensable line of business, and mineral production through mining continues to increase all over the world.

The increase in energy demand in the world has led to an increase in the interest in coal over the years. Although there have been restrictions on coal production for the last few decades due to reasons such as air pollution, human health, and carbon-neutral concerns, coal still plays an active role in energy production.

Coal is produced by open and underground mining methods. While both methods have risks in terms of OHS, underground coal mining indisputably carries more risks, such as roof collapse, firedamp explosions, floods, and dust diseases. Related studies have also been carried out on lighting, noise, and vibration risks in recent years.

In this study, information about some physical risks encountered in underground coal mining is given and suggestions are made to eliminate these risks.

Physical Risk Factors

If the risks in occupational health and safety are subject to the main classification, in the first place; physical, chemical, biological, psychosocial, and ergonomic risk factors appear. Depending on the work and the environment, one, some, or all of these factors pose risks to the employees.

When it comes to physical risk factors, employees are exposed to; noise, vibration, dust, lighting, pressure, thermal discomfort, and radiation. When exposed to these risks, the human body may directly or indirectly get affected (Dudek, et al., 1998; Feng & Wang, 2011). Therefore, the importance of these risks in mining is mentioned one by one.

Thermal Comfort

Thermal comfort is the state of being satisfied with the thermal environment in the environment where the employee is located. This satisfaction can be understood from the positive psychological, physiological, social, and cultural conditions of the employees. Work efficiency increases in environment with high thermal comfort (Olesen, 1982). The environment where the employees are located should be in accordance with the thermal comfort conditions (Official Gazette, 2013).

Thermal comfort; while it depends on environmental factors such as air temperature (T), relative humidity (RH), air velocity (V), and average radiant temperature (Tg), it also depends on personal factors such as the person's age, gender, nutrition, metabolism level, and clothing thermal resistance. Clothing thermal resistance is a factor for heat conduction between the worker and the working environment (Arıtan et al., 2021).

In an underground mining operation, the temperature of the rock increases as the working place goes deeper. Parallel to this, the temperature of the moving underground air increases as it is in constant contact with the surrounding rocks. With the contribution of the factors such as keeping the production speed high, the higher number of working panels, the use of mechanization excavation method, the intensive use of mechanical equipment etc., more temperature problems occur in deeper mines (Önder and Saraç, 2003).

In addition, spontaneous combustion in coal mining also causes deterioration of thermal comfort in the environment. With the spontaneous heating of the coal, the ambient temperature increases, thus causing a deterioration in the thermal comfort of the employees.

In underground coal mines; excessive exposure of workers to heat and humidity can also cause fatigue in their bodies. This can also bring about health problems such as heat stroke or rheumatism.

Vibration

Vibration is defined as mechanical oscillations that occur with periodic movements felt in the human body and spread in solid environments with high amplitude and low frequency, which occur when potential energy is transformed into kinetic energy and kinetic energy into potential energy (Cardinale et al., 2003; Şahin and Işık, 2007). Vibration value is directly proportional to frequency (Hz) and magnitude (m/s^2) (Akduman, 2008).

The vibration occurs in the human body and machine. The vibration that occurs in the human body is divided into two hand-arm vibration and whole-body vibration. According to the vibration regulation, transferred to the hand-arm system in humans. The mechanical vibration that poses a risk to worker health and safety by causing vascular, bone, joint, nerve, and muscle disorders is called hand-arm vibration. The mechanical vibration, which is felt throughout the human body, especially in the waist and spine, causing a risk for worker health and safety, is called whole-body vibration (Official Gazette, 2013; Arıtan et al., 2016).

About 95% of mining equipment is below the exposure limit value. 50% of the equipment exceeds the exposure action value and causes vibration risks. This shows the necessity of risk assessment and management for vibration in mining. It is recommended to reduce vibration levels and train employees (Aye et al., 2011).

Pneumatic hand pick used in production and other works in underground coal mines creates hand-arm vibration exposure in workers. In addition, whole-body vibration exposure occurs in mines where trucks, loaders, etc. are used. Values related to vibration exposure in Turkey are given in Table 1 (Official Gazette, 2013).

Table 1. Vibration exposure limit and action values in Turkey.

Vibration Type	Exposure Limit Value (m/s^2)	Action Limit Value (m/s^2)
hand-arm vibration	5	2,5
whole-body vibration	1,15	0,5

Lighting

Light is a part of electromagnetic vibrations that the eye is sensitive to (Sönmezyuva, 2009). Good lighting speeds up production and is a fundamental factor for employee health and safety. As a result of a work carried out in a poorly lit environment, eye disorders, and accidents occur and production slows down (Ilıcak, 1988).

Some basic concepts in lighting technique: luminous strength in lux (lx), the luminous intensity in candela (cd), and the luminous flux in lumens (LM). Illumination strength is the luminous flux per unit area and is measured with a lux meter. The age of the employee is also important among the factors that determine the lighting intensity (Çınar and Şensöğüt, 2017; Dülger, 2015; Sönmezyuva, 2009).

Lighting is one of the important physical risk factors, especially in underground mining. Underground mines are environments without natural lighting. In these environments, artificial lighting is provided with appropriate installations and equipment. However, this is not possible in all mines, where they work with only a miner's head lamp by illuminating a limited area. As a result of this situation, eye diseases and accidents occur.

Noise

The noise can be defined as undesired, disturbing sounds that cause hearing loss or deterioration of health. Noise is considered an event that reduces the feeling of comfort (Akbulut, 1996). The energy emitted by the sound source per unit of time is called the power of the sound and is measured in Watts (Bell, 1966).

While a person working in a noisy environment is exposed to physical, psychological, and bodily risks, low performance is also caused (Velicangil, 1970). Noise in humans causes restlessness and is a risk that prevents verbal communication and reduces work efficiency. It is also known to cause sleep problems (Clark, 1992).

Crushers, loaders, etc. used in mining are high-noise causing equipment. Underground coal mines are working environments where there is continuous operation (support workings, production, transportation, water discharge, etc.), where noise occurs due to machinery and equipment. For this reason, they are workplaces, where the potential for hearing problems in employees is quite serious (Sensogut, 2007; Sensogut and Cinar, 2007).

Values related to noise exposure in Turkey are given in Table 2.

Table 2. Noise exposure values in Turkey.

Exposure Type	Minimum Exposure Action Value dB(A)	Maximum Exposure Action Value dB(A)	Exposure Limit Value dB(A)
Noise	80	85	87

Dust

It is a term used for solid particles of different sizes and diameters. It is formed by the separation of ore and surrounding rock into particles as a result of mechanical works realized especially during production. In general, dust is the name given to particles smaller than 1 mm in diameter, which can remain suspended in the air and settle over time (Güyagüler and Durucan, 1985).

Dust is formed in the production, crushing-grinding works and during other activities in the mining sector and dispersed into the working environment. Therefore, it is very important in terms of both mine safety and employee health.

While the works carried out in mines directly constitute the primary source of dust formation, the dust settled to the bottom mixes into the air again due to mobility in the mine (ventilation, walking of the workers, transportation, etc.) can be defined as the secondary source (Ediz et al., 2001).

The gravimetric method (mg/m^3) and particle counting method (particle count/cm^3) are methods used to determine dust concentration in general. Dust measurements are made in two ways as both ambient and personal exposure.

Dust problem in mining is examined under two main headings as stone dust and coal dust. Unfortunately, these two problems coexist in coal mines. While stone dust is harmful to health, coal dust is both harmful to health and has the feature of explosion.

Stone Dust

Stone dust formed during primary or secondary processes spreads in the mine (Sarac et al., 1998). The suspended part of this emitted dust can reach the lungs of the workers while they are breathing, and can cause pneumoconiosis, a pulmonary dust disease.

Pneumoconiosis can occur with exposure to high concentrations of harmful dust. This situation can occur in certain professions and fields of work. For this reason, pneumoconiosis is considered an occupational disease. Another important factor other than the composition, concentration, and exposure time of the dust is the effectiveness of the respiratory system of the person in the dust removal system. The effective factors in the formation of pneumoconiosis can be examined in two groups dust and personal factors (Vidinel, 1981).

The parameters that are effective in the reactions of the lungs to mineral dust are the size, shape, water solubility, and reactivity of the dust particle. A large amount of accumulation of coal dust is necessary for clinical findings in the lung. Coal dust is dust that can be considered inert if there is not much exposure.

Quartz, asbestos, and beryllium are more reactive than coal dust and disrupt the normal structure of the lung even at low concentrations. The concentration of the particles of these clouds of dust and, of course, the exposure time are factors that determine the progression of the disease. Large amounts of exposed particles can cause acute lung inflammation, while small amounts of dust accumulated in the lungs over time cause progressive lung shrinkage (Robbins, 1995; Ediz et al., 2001).

About 60% of the earth is made up of quartz. Many rocks also contain quartz. The risk of exposure to quartz dust during mining activities is very high. There is also a risk of exposure to this dust during underground coal mining. Quartz is commonly found in most coals. Detritic, angular quartz is frequently encountered in the clay-rich bands. On the other hand, it can also form in the form of chalcedony in the cell spaces of the coal or in the cracks-fractures of the macerals during peatification by chemical precipitation (Ward, 1984). As a result of the presence and breathing of quartz in the host rock, silicosis disease may occur in workers.

Coal dust

Dust inhalation or coal dust formation during coal mining is one of the most common risks for miners.

Those working in underground coal mines work in a mine air containing various combinations of coal and silica dust. Pneumoconiosis caused by continuous breathing of coal and silica dust is called coal workers' pneumoconiosis.

Anthracosis occurs with the accumulation of coal dust in the lung. In underground coal mines where there is intense exposure, changes in the lung are also observed intensely. In the 1940s, Social Insurance practices started in different insurance branches on disability in Turkey. Occupational Health and Safety Center (İSGÜM) was established in 1969, and the legal definition of occupational disease and work accident was made in 1972. Occupational diseases began to be associated with a disability after this date. Disability procedures have also come to the fore together with pulmonary dust diseases. Dust diseases that occur as a result of not taking the necessary health precautions in the work environment are named occupational diseases (Erboy, 2019).

According to Article 14 of the Social Insurance and General Health Insurance Law No. 5510, occupational disease is temporary or permanent illness, physical or mental disability, which the insured suffers due to a recurring reason caused by the nature of the work he/she works or performs or due to the conditions of the work" (Official Gazette, 2006-1).

Results and Discussion

Underground coal mines are one of the working lines in the very dangerous group. It contains many risks for employees. One of these risks is physical risk factors. Noise, vibration, dust, thermal comfort, and lighting are among the physical risk factors that can be seen in underground coal mines.

Employers are required to have risk assessments supported by measurements against these risks. It is necessary to make determinations for each risk and to ensure that the necessary measures are taken or the risks are minimized. While this is the case in general, let's look at what can be done for each physical risk factor;

1) When it is looked at the main criteria in thermal comfort, air temperature (ambient temperature), air humidity (relative humidity), air flow rate (ventilation), radiant heat (thermal radiation), metabolic rate, and clothing insulation factors appear. In underground coal mines, the main rock is coal and the ambient temperature rises excessively in the mines where spontaneous combustion events occur. In addition, if the water income of the mines is high, the humidity is high. In work areas where heat stress is likely to occur, the employer should carry out a risk assessment that takes into account the duration of exposure, the work environment, workers' clothing, and respiratory protective and supportive equipment. It is well known that insufficient ventilation of the mine disrupts the thermal comfort of the environment. When it is focused on the solution of the problem, it is seen that the biggest role in the regulation of the factors that create thermal comfort in underground coal mines is ventilation. Thermal comfort conditions can be kept at a level that makes the employees comfortable by keeping the mine ventilation at an optimum level, preventing short circuits, installing auxiliary ventilation circuits in areas where the temperature rises and supplementing it. Personal protective equipment such as special protective clothing with personal cooling systems and specially produced fabrics to provide thermal comfort should also be provided to employees. In addition, the employer should provide training to employees and monitor the health of employees at risk.

2) Machines used in mines cause two types of exposure: hand-arm and whole-body vibration. In order to get rid of these vibrations, it is necessary to use less exposed machinery, equipment, and vehicles. Anti-vibration gloves should be worn to reduce exposure to hand-arm vibration. In order to prevent whole-body vibration, arrangements should be made especially for suspension systems in vehicles and seats used by operators.

3) Lighting problems should be solved as effectively as possible in the mine and especially in the arrival and departure areas of the transportation equipment. Artificial lighting is used to solve these problems. However, since there is a fire hazard in coal mines, the installation must be in the appropriate category of the I. Group equipment is specified in the regulation on equipment and protective systems used in potentially explosive environments (94/9/AT) so as not to trigger an explosion (Official Gazette, 2006-2).

4) In underground mechanized coal mines, the noise generated by the machines can be 90 dBA or more. Replacing machines with less noisy ones should also be considered if possible. Regular maintenance of the machines should be done in order to reduce the noise. The employer should provide employees with the necessary health and safety training, keep up-to-date health surveillance records, and ensure that earplugs are used appropriately to prevent noise exposure among employees who are exposed to noise.

5) Dust is generated at many stages of the process, from production to transportation in underground coal mines. Precautions should be taken such as eliminating dust at its source, taking precautions in the environment, and using personal protective equipment. Measures can be taken at the source of dust, such as absorbing water on the excavation surface, applying wet excavation methods, and using dust extraction systems on the excavation surface. Precautions can be taken in the environment by making effective ventilation in the mine and installing exhausting and blowing ventilation in the production areas. Despite all these precautions, personal guards (masks) should be used if the amount of dust still does not fall below the limit value in the dust measurements made in the environment.

All risks of work areas should be determined. Necessary precautions should be taken for these identified risks. Employers must constantly monitor the environment to ensure that preventive measures are working. A better-quality working environment should be created for the employees by performing the audit-correction processes continuously.

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