Int. J. Econ. Environ. Geol. Vol. 11 (1) 113-117, 2020
Journal home page: www.econ-environ-geol.org

Open Access
ISSN: 2223-957X

Analysis of Underground Mining Accidents at Cherat Coalfield, Pakistan

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Received: *20 May, 2019* ***Accepted:*** *28 January, 2020*

Abstract: Coal is the most extensively used nonrenewable energy source worldwide. In Pakistan coal is mostly mined by underground mining methods under poor and unsafe working environment. In this study, accident records of underground coal mines of Cherat coal field were collected and analysis was carried out to understand the consequences, time of occurrence and causes of accidents. Besides, occupation of a victim, responsible party and effects on production were also considered in present study. The relationship between workers' age and severity rate was examined using regression analysis. The main causes of accidents were the fall of the roof, mine gases, electrocution, oxygen deficiency and slip fall. At Cherat coalfield, for every two mines, there is one fatality and most of the accidents occur due to roof fall between 10:00 am to 12:00 noon. It is due to the stress of production efficiency. Moreover, there is a negligible impact of accidents on coal production at Cherat coalfield from 1994 to 2015.

Keywords: Accidents, injuries, coal mines, roof fall, gases.

Introduction

In Khyber Pakhtunkhwa coal is exploited from Paleocene Hangu Formation (Jiskani, et al., 2019, Ahmed, et al., 1986, Warwick and Shakoor, 1988, Malkani, 2012). In Pakistan coal is mostly extracted by underground mining methods, that are usually the worse working conditions and accidents leading to injuries, low production and reduced labor efficiency (Shah et al., 2019). To reduce the adverse effects of these incidents, safety regulations are established throughout the world (Fu, et al., 2019, Albulescu, et al., 2020). Mining accidents cannot be controlled entirely, but the strategy is adopted all over the world to control the accident frequency and severity rate for saving human life and increasing the production rate. In mining operations accidents are still continuous at some unacceptable rate. Occurrence of accidents are due to the failure of workers, types of machinery and surroundings. For reduction of mine accidents, recognition of responsible factors for these failures plays an important role (Paul and Maiti, 2001, Robinson, 2017, Hsu and Robinson, 2019).

The factors having a key relation to mine accidents are age and experience, occupation, body parts (Ajith and Ghosh, 2019, Shahani, et al., 2019, Jiskani, et al., 2020). Many researchers have studied the effect of age on accidents. According to the National Research Council (1982), there is a negative correlation between age and accidents in coal mining and the rate of accidents experienced by younger workers is higher than the older one. However, according to Bennett and Passmore (1984), older miners are seriously injured than younger ones and the severity rate of miner's injuries was not related to experience. Barry (1971) studied and concluded that the most dangerous occupation related to mining are loading machine operators, roof bolters and working supervisors. According to Bennett (1982) severity rate of injuries at shaft/slope is less concerning as compared to the ones taking place at the mine face. Leigh et al. (1990) also concluded that half of the accidents occur at the mine face. Filiz et al. (2015) revealed that the leading causes of mine accidents are dangerous working conditions, profit maximization and cost minimization, occupational health and safety measures not implemented properly and inspection is not done sufficiently.

In developing countries, the rate of accidents is much higher than the developed world (Alarcón, et al., 2020). In Pakistan, roof falls contribute a major portion of the mine accidents and the other primary reasons for accidents are poor quality timber, negligible support system and inadequate inspection and supervision (Ullah, et al., 2018). In Khyber Pakhtunkhwa mine owners use local mining methods due to limited financial resources, quality and narrow coal seams. Thus, inadequate support, mechanical ventilation, and lighting system which make the working conditions in mines more hazardous (Jadoon et al., 2004). In Pakistan, the lack of mine supervision or absence of occupational health and safety management system leads to numerous fatal and non-fatal accidents. Accidents in underground coal mines mostly result from roof fall, mine machinery, released of toxic gases, electric current. Pakistan, therefore should take major structural and safety management reforms like the application of engineering design, adoption of effective technology, implementation of safety laws and additional efforts to educate the work force related to safety as a prerequisite (Jiskani et al. 2019).

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The study area Cherat is a hill station situated in the Nowshera district of Khyber-Pakhtunkhwa province in Pakistan located 34 miles southeast to the city of Peshawar (Fig. 1).

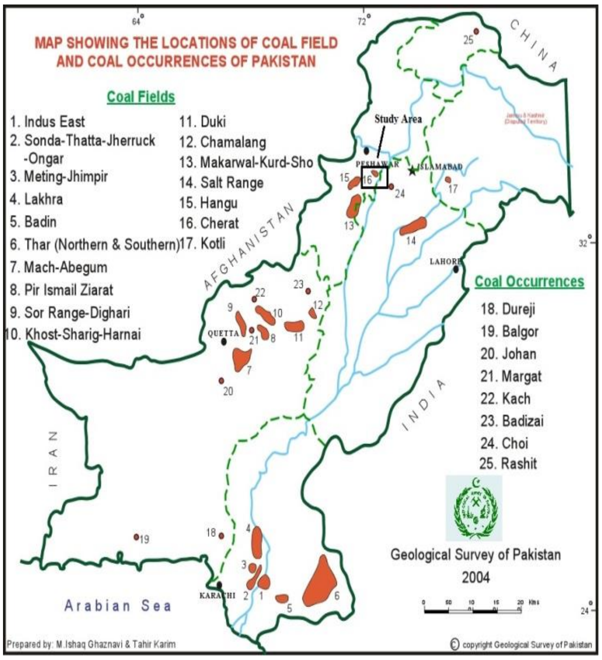

Fig. 1 Location map showing study area of Cherat coalfield (Geological Survey of Pakistan).

There are six coal areas identified in Cherat coalfield; which are Shahkot-1, Shahkot-2, Jaba husky, Jaba thar, Bakhtai and Dag Ismael Khel. The data required for this study were taken from Shahkot-1, Shahkot-2 and Bakhtai coal mines located in district Nowshera, at 33°51'44.39"N latitude and 71°53'26.07"E longitude. The geology of the study area consists of interbedded slaty shale and dark gray limestone (Tahirkheli, 1970) and quartzite of Devonian and Silurian age (Yeats and Hussain,1987). The total number of mines in these three leased areas are thirty-five, which are in production or development stages. In 2016, Inspectorate of mines and minerals department started a model mine in Shahkot-1. The thickness of coal seams varies from 0.19 m to 1.7 m with volatile matter content of 4.5 to 21%, moisture content (1 to 5%), ash (21.7 to 45 %) and sulfur 1 to 5 %. The coal has a calorific value of 6400 to 9000 BTU/lb and classified as sub-bituminous coal (Hussain et al. 1990).

Materials and Methods

Data of accidents that occurred at Cherat coalfield from 1998 to 2019 were collected from the company records and Inspectorate of mines and minerals, Khyber Pakhtunkhwa. According to coal mines regulations, all the accidents occurred during the surface or underground mining activities are mentioned in the report form and sent to Inspectorate of Mines and Minerals Department for further investigation and necessary action. The accident notice form IX served as the key source of data for the present study. Discussion with inspectors of mines, mine managers and other staff members provided additional information.

Simple regression analysis was performed to evaluate the relationship between age and severity rate. Correspondingly, the effect of accidents on coal production was evaluated. Furthermore, the available data were analyzed to identify causes of accidents and assessing their remedial measures. Similarly, accidents by the time of occurrence were estimated.

Results and Discussion

Incidents Statistics

The total underground mining incidents reported from 1998 to 2019 as recorded in incident occurrence report Form IX, 145 comprising 69 fatalities, 21 serious injuries, 5 minor injuries and 130 nearly misses (Fig. *2*). Detail of underground mining incidents at Cherat coal field shows an average proportion of 58% of nearly misses. According to Bird's (1976) triangle the ratio of injury/fatality**,** property damage, mine injuries, nearly misses is 1**:**10**:**30**:**600 respectively. It means that for every 600 nearly misses there should be 1 fatality. In the case of the Cherat coalfield, there is 1 fatality for every 2 misses. It is a fact that most of nearly miss incidents are not reported. But reports of these nearly miss incidents can help minimizing accidents and hazards.

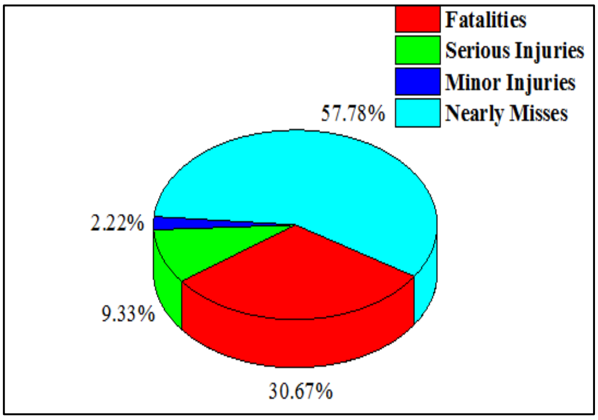

Fig. 2 Incident and accidents statistics from 1998 to 2019 at Cherat coalfield.

Underground Accidents at Cherat Coalfield

Most of the accidents occurring at Cherat coalfield are fatal (Fig. 2). It can be concluded that the severity rate in 2006 is high, which revealed that most of the accidents caused serious injuries and fatalities. Data show an increase in severity rate from 2005 but there is a decrease in incident rate (Fig. 3). Figure 5 shows that the value of the lost time injury frequency rate is fluctuating throughout, but it was high in 1999. According to National Occupational Safety Association (NOSA), the value of the average severity rate should not be greater than 50 (Rimington,1992). The severity rate at Cherat coalfield for 2010, 2011 and 2012 was found more than 60.

Accidents and Injuries Statistics

Fig. 2 gives accidents statistics from 1998 to 2019 for severity rate (SR), incident rate (IR) and lost time frequency injuries rate (LTIFR), which are calculated using following relationships.

$$SR = \frac{Total\ \text{Number lost workdays}}{Total\ \text{Number of Recordable Incidents}} \quad (1)$$

$$IR = \frac{Number\ \text{of Recordable incidents} \times 200{,}000}{Number\ \text{of Employee labor hours worked}} \quad (2)$$

$$LTIFR = \frac{Number\ \text{of Recordable Injuries} \times 200{,}000}{Number\ \text{of Employees labor hours worked}} \quad (3)$$

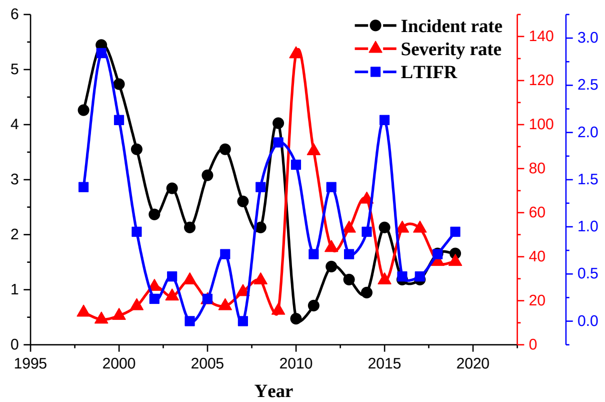

Fig. 3 Underground mine accident incident rate, severity rate and LTIFR from 1998 to 2019 at Cherat coalfield.

Furthermore, the relationship between mine workers age and injury severity rate was examined using a simple regression technique (Fig. 4). The outcome variables of interest are SR considered continuous for simple regression analysis.

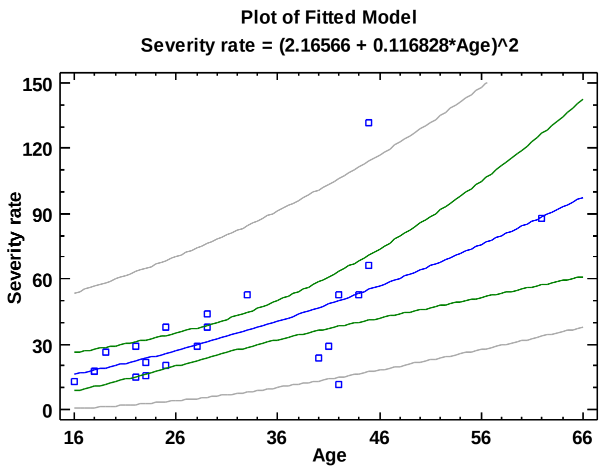

Fig. 4 Plot of a fitted model for severity rate vs age of mine workers.

Fatal Accidents

The data reveal that most of the fatal accidents occur due to falling of the roof followed by obnoxious gases, electric current and oxygen deficiency (Fig. 5). Maximum mineworkers involved in accidents are generally unqualified, followed by coal cutters and blast man. Here general workers are coal or waste handlers and support system installers. Since these types of miners work at mine face, they are more exposed to accidents. According to Leigh et al. (1990), half of the accidents occur at the mine face.

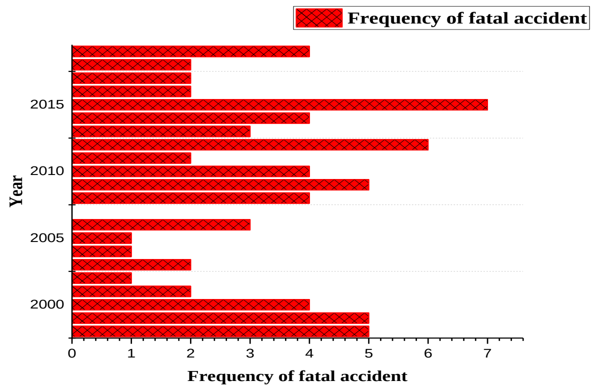

Fig. 5 Frequency of fatal accidents at Cherat coalfield (1998 to 2019).

Underground Accidents by Time of Occurrence

Analysis of accidents by time of occurrence show that most of the accidents in mines occur at peak hours 10:00 am to 12:00 noon (Fig. 6). Subsequently, a decrease towards 2 pm was found because of the end period of the shift. In the early period of shift, workers are in the stress of increased output and production, which leads to an unsafe act, correspondingly, leading to unsafe conditions. Mining accidents in Khyber Pakhtunkhwa are due to conventional mining methods. There are no safety measures in mines and ventilation system is also negligible.

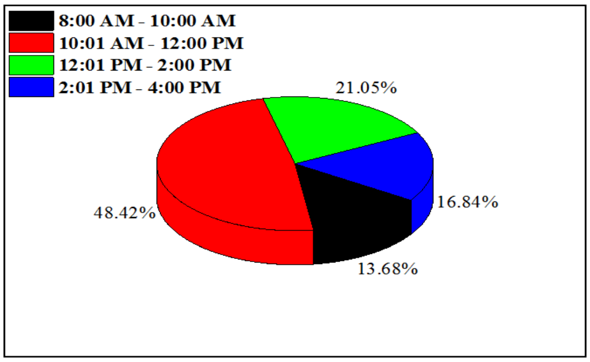

Fig. 6 Underground accidents by time of occurrence.

Effect of Accidents on Total Production

Mining field has the highest rate of accidents compared to other sectors. These accidents lead to loss of mine workers and production. Several factors distinguish the harsh working environment of mining from other sectors. In Pakistan, mining accidents have an impact on production but compared to other countries, it is negligible. The impact of the accident on coal production in the Cherat coalfield is almost negligible because fatal accidents in Pakistan are a routine. Every year, a number of miners become victims either due to discharging poisonous gases or collapsing of mine. In case of an accident, working is just stopped for a day, therefore, there is a negligible effect on production (Fig. 7).

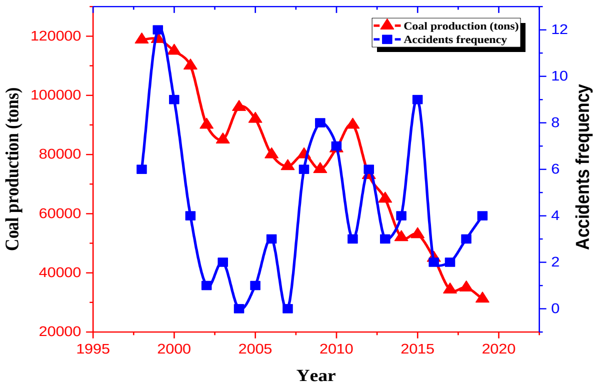

Fig. 7 Effect of accidents on total coal production at Cherat coalfield (1998 to 2019).

In order to meet production demand, mine working poses significant health, social and economic problems. Between production demands and fewer expenses, workers lack the awareness of their safety. However, in Pakistan, mining accidents have less impact on production because a small amount of compensation is paid, and the mine is closed for a few days after the accident. Adverse geological conditions, inadequate timber supports, improper blasting, the practice of the conventional and outdated mining methods lead to worker fatality. Consequently, roof fall mostly occurs due to the use of pickaxes to dig coal and a working face.

There is a clear link between the most frequent accidents and changed shift times. An increase in accident frequency rate towards peak hours is related to production pressure. At the start of the shift greater preventive steps are taken to ensure working place safety. Consequently, workers are left on their own in the intermediate period. Therefore, accidents are mostly causing due to unsafe acts.

Conclusion

Coal mine accidents are not rare in Pakistan, which damages Pakistan's international image and endanger workers health and lives. Risk of intrinsic hazards, particularly roof falls and gas explosions due to poor maintenance and supervision at working face in underground coal mine remain high. The risk of danger increases manifold due to unskilled workers. Therefore, educational programs should be arranged to eliminate fatigue-induced errors and manage the workload that instigates accidents. Productivity influences safety because employer with low production always avoids investment in safety due to limited resources. The study revealed that severity increases with an increase in age. This relationship may be because old workers are less resilient than younger ones due to some energy impacts encountered in underground coal mines.

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