Health and Safety Assessment in Lakhra Coal Mines and Its Mitigation Measures

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ABSTRACT
The coal mine excavation, transportation and coal cutting process are involved in hazards and risks that can result in fatalities, injuries and diseases, if these are not properly managed. This study has been undertaken for assessment of the safety and health issues amongst the mines workers. Convenience sampling technique was exercised upon 97 mine workers and interviewed with the help of set questionnaire. Personnel protection to workplace environment was monitored by using physical observation and scientific analysis. All parameters were measured against national and international protocols pertaining to labor law at coal mines. It has been determined that very high risk was persisting while mine excavation, coal cutting and transportation processes. Previous record of last five years was suggesting that 04 deaths happened due to roof fall, 03 fatalities occurred through suffocation by inhaling toxic gases, one causality happened via rope haulage pulley, and also one death due to stone fall down from mine shaft. 121 workers injured in different kinds of accidents within five years. It has been learnt from in-depth analysis that maximum of health risk and subsequent health damages are triggering due to lack of awareness, non-compliance of labor as well as mines laws. Thus, it is recommended that government should not allow coal mining contractors and companies, those which are failing in compliance with the suggested standards.

Key words: Lakhra Coal Mines, Mine Workers, Hazards, Risk Assessment, Occupational Health, and Safety

INTRODUCTION
The occupation of underground mining is counted among one of the very dangerous job and most of mine workers often suffer from respiratory diseases such as, lung infection, skin diseases, heart burn, and psychological associated stress. Similarly, some others hazards also remain occurring in coal mines such as coal dust, permanent injury due to the improper safety methods and management [1-2]. These problems can be redressed by adopting adequate techniques. On the other hand, these issues can also be resolved by continuous training and regular mine inspection by concerned authorities [3]. It is established that there is no definite shape and size of the workplace in underground mining that is why poor natural ventilation and deficient work place illumination leads to accidental situations [4-5]. Every year, several fatalities and injury accidents happen across the world those often cause significant loss of lives [6]. The physical activities undertaken while coal extraction, transportation and handling are accounted for health and safety hazards [7-8]. Numerous studies have explored that mine workers face several hazards during blasting and subsequent roof and side fall accidents [9]. Another study has reported that common respiratory diseases were found in mine workers due to the inadequate usage of safety measures during the work, such as symptoms of lung disease including cough and trouble in breathing, suffered in heart diseases, back pain and pain in their hands [10]. Methodological advancements in risk assessment of roof and side fall accidents have played significant role for maintenance of hazard-free working environment. [11]. Improvement in occupational health and safety at coal mine can enhance productivity of the industry. Therefore, this study would be beneficial for the decision makers to avoid on overcome issues those were identified. The overall aim of this study is to identify and analyze the risks and major hazards that were happening in Lakhra coal mines.

MATERIALS AND METHODS
The Study Area
The Lakhra coalfield is situated near Indus highway and in proximity of about 50 kilometers from

Hyderabad on the west side of the Indus River Valley in the southern part of Pakistan and 175 kilometers from Karachi city. It covers an area of 80 sq. miles. The total coal reserves in the area are about 43.8 million tones. Coal mines depth normally ranges between 83 to 439 ft. and type of coal has been reported as sub bituminous and lignite. Pakistan Mineral Development Corporation Company (PMDC) has a two lease with covered area of about 5096.49 acres. The annually coal production in (2011 - 2012) was 204,688.410 tons [12].

Data collection

The survey was carried out at Lakhra coal field which was supervised by Pakistan Mineral Development Corporation Mine Company from March 2014 to January 2015. Total seven coal mines were selected for the sampling, physical observation and scientific analysis. The selected coal mines were, "48-B, 61-C, 115, 114-C, 112-C, 61-B and 54-B". All coal mines were selected from PMDC Coal Mine Company and about 25 to 35 workers were working in one coal mine. Risk analysis was done on the regular basis in order to assess the likelihood of unforeseen hazards such as, outburst, poisonous gases, explosion and roof and side fall uncertainties [13]. Primary data was collected through mines survey with the help of questionnaire. The set questionnaire was explained to the sampled workers and they were also briefed about the purpose of this study. 97 workers were interviewed through convinced sampling technique with the help of set questionnaire on schedule basis. Secondary data about health, safety and fatal and non-fatal accidents was collected from PMDC, methodology followed by Azad, *et al.*, [14]. The severity was established from the number of fatalities and injuries accidents were happened in coal mines and the probability were calculated on the basis of reappearance of fatalities and injuries accidents in mines and also risk factors was calculated on the cause of Probability * Severity as per OSHAS 18001 standards quantitative analysis of risk was calculated and estimated. The quantitative value of risk level was such as Very high risk 12-16, High risk 8-9, and Medium risk 4-6 Low risk 1-3. Initially constructed questionnaire was tested over 10 randomly selected workers and afterward the feedback was checked against set objectives of the study and later-on duly discussed with experts of this field. After making nominal modification the entire survey was completed and at the end same 10 workers were contacted and from answers of them, validly of the questionnaire were proved.

RESULTS AND DISCUSSIONS

Analysis of Safety Measures

Hazards and risk were continuously involved in the coal mine excavating and in cutting practices. The chances of fatal and injury accidents increase, if improper safety measures are occupied in the mines during work. The coal mine workers were least caring about their safety because of some reasons like lake of training, awareness and limited facilities provided by the company as regards safety therefore fatal and injury accidents were arisen in mines. Fig. 1 shows that 71.1% workers were not using cap lamp and safety helmet, 90.7% were not using safety hand gloves and it was seen that overall coal mines workers were not using safety mask and shoes during the work. The most of the mine workers were unaware about the occupational safety at coal mines and they were underestimating the usefulness of the protective gears and other safety measures. Occupational safety in our country like others less developed countries is not receiving proper attention by all concerned definitely; prevention measures for accidents or occupational safety, if they exist are insignificant and rarely enforced.

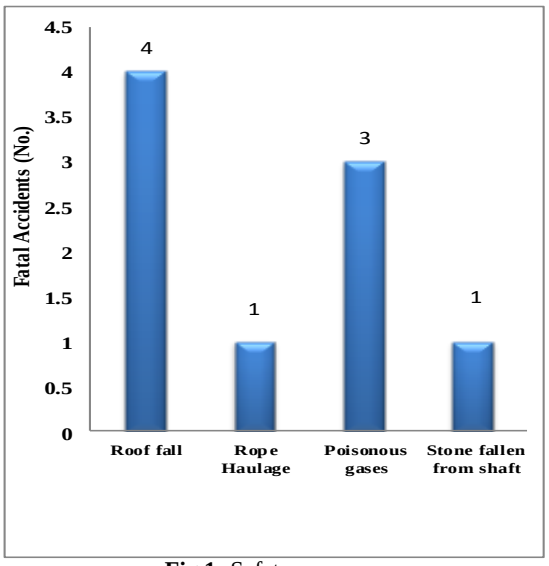

Fig.1: Safety measure

Death Accidents and its Causes

Fig. 2 discloses that the different natures of death occurred in between 2010 through 2014. Fatal accidents data was collected from the mine company, 04 death accidents happened due to roof fall, during the coal cutting piece of black shell fallen down from mine roof on the workers legs, head, and back side, 03 fatalities occurred by suffocation of poisonous gases such as, Carbon monoxide (CO) and Hydrogen sulfide (H_2S) were coming from gob area when fired occurred in mine. Most of fatal accidents occurred due to carbon monoxide gas which was toxic at low concentrations because it may be the cause of loss of consciousness, and later collapse & death and

Hydrogen sulfide is a poisonous gas, lower, longer term exposure caused eye irritates, headache, fatigue, lungs and respiratory tract. One death accidents happened via rope haulage pulley, while it was separated from trolley and hit with the worker and one fatal accidents occurred by the stone fallen down from mine shaft.

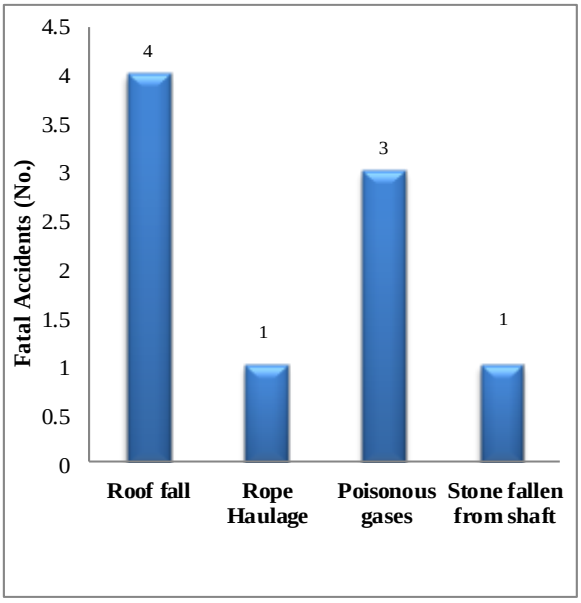

Fig.2: Death accidents

Injury Accidents and its Causes

Fig. 3 shows different types of accidents happened in coal mines during in 2010 to 2014. 47 injured due to roof fall, during coal cutting process a piece of black shell dropped from mine roof on the workers, legs, and head, back side and on feet. 26 injuries were recorded due to side fall, 17 have been injured from back side due to over lifting coal bags and similar articles, 06 were injured due to foot slipping, 05 were injured in rope haulage machine due to inappropriate control, 05 were injured by flying particles while coal cutting process, 07 injured due to failure of wooden supporting, 05 workers were injured by stone fallen from coal mine shaft due to improper filling mine shaft with fine materials and 03 became unconscious due to inhalation of poisonous gases and resultantly suffocation happened as result of inadequate ventilation.

Working Condition of Coal Mines

Good working condition is basic necessity of every worker. It was founded that the mine workers were not entirely aware about the health and safety that is why hazardous incidents leading to fatalities were happening continuously. Fig. 4 apprises the numbers of workers were got any training prior to joining the job, but very rare workers at the initial stage received training related to safety. Lack of access to fresh water seems to be major issue in the coal mines,

Workers were drinking contaminated water and in some mines portable water was not available at the place of work. They were working many hours without portable water which may cause serious dehydration. It was seen in coal mines toilet facility was not given in mines and workers were using abandoned work area. This situation was adding problems related to hygiene and bad odor.

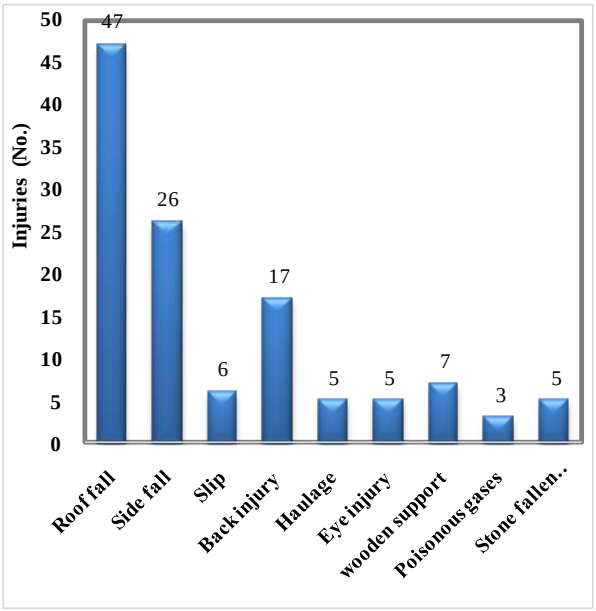

Fig.3: Injury accidents

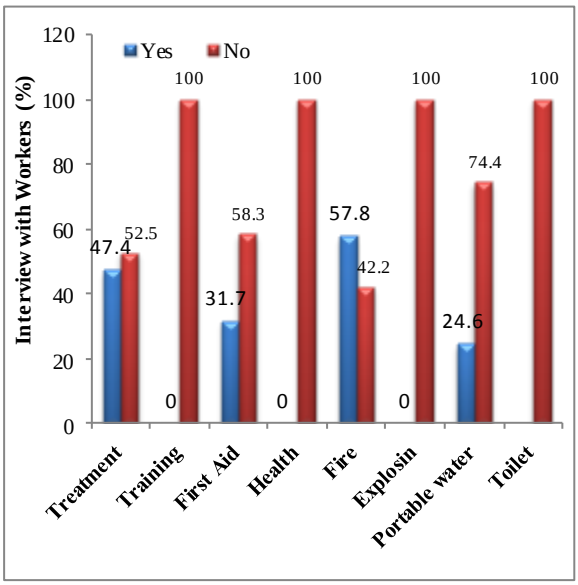

Fig.4: Mine working codition

Occupational Diseases and its Reason

Mine excavation was the most dangerous job and sometimes taken as dangerous which threatens to the

life of the mine workers. It was seen on the physical observation basis that the most of coal mine workers were using improper safety measure consequently it may causes the disease and others symptoms for the workers 23.7% workers have been suffered in cough and in breathing problem, they were not using safety mask, 19.5% were suffered in back pain and pain their hand, they remained over lifting the coal begs and other objects in confined area,17.5% were involved in skin infections and 11.3% had been suffered in heart burn revealed in Fig. 5.

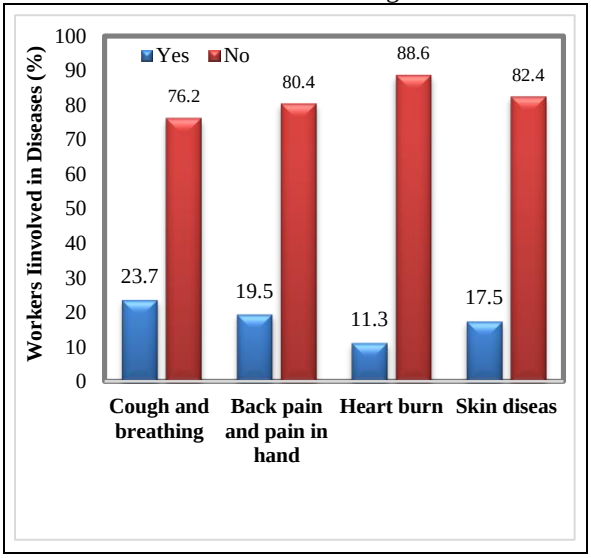

Fig. 5: Occupational diseases

Risk Assessment

Risk Assessment of Coal Mine

Combination of probability and severity constitutes the hazard [15]. Therefore, risk assessment is a regular investigation of any movement or work practice to identify the risk and recognize the likelihood and consequences of associated hazard. In this study the risk was identified, analyzed and evaluated based on fatalities and injuries record collected from Pakistan Mineral Development Corporation Coal Mine Company, Lakhra. Quantitative analysis of hazard was undertaken by using a more widely used "risk matrix" that ranks the risk according to its occurrence probability and severity in coal mines.

This study examined the relationship between the number of fatal and injury accidents those occurred in coal mines. The severity was established from the number of fatalities and injuries accidents happened from 2010 through 2014. Revealed severity and probability of the accidents is shown in Table 1. After that, we performed the quantitative risk assessment [16]. The collected data was already segregated, however, probability and severity of each category was defined in light of visual inspection and prevailing method of judgment [17, 16, 20, 21].

Table 1. Risk assessment coal mine

Item no.	Hazards	Injury accident	Fatal accident	Probability	Severity	Risk factor
1	Roof fall accidents	47	4	4	4	16
2	Side fall accidents	26		3	4	12
3	Slip and Trip	6		3	2	6
4	Rope Haulage	5	1	3	3	9
5	Back injury	17		4	3	12
6	Eye injury	5		2	3	6
7	Wooden support failure	7		3	3	9
8	Poisonous gases	3	3	3	4	12
9	Stone fallen from mine shaft	5	1	3	4	12
10	Coal dust			2	3	6
11	Blasting fumes			2	3	6
12	Manual handling & objects			3	2	6
13	Contaminated drinking water			2	2	4
14	Ventilation fan			2	2	4
15	Physiological effects			1	2	2

Classification of Risk on the Basis of Risk level

A risk matrix supports to quantify and rank the impact of major hazards [18]. The risk level has been categorized into four risk levels namely, very high risk level from 12-6 almost sure to happen that can pose terrible consequences (red color), high risk level 8-9 likely to happen and have serious consequences (orange color), medium risk level since 4-6 have possible happen with moderate consequences (yellow color) and low level risk from 1-3 unlikely happen with negligible or minor consequences (green color), are revealed in Table 2-3 [19,20]. The hazard analysis and risk assessment were determined for this study that was established on the nature of fatalities and injuries accidents occurred in the coal mines and some risk factors were identified and analyzed on the basis of questionnaire and physically observation. It was noted that five hazards, roof and side fall, poisonous gases, back injury and stone fallen from mine shaft were falling in "very high" risk level with higher corresponding probability and severity

category. Risk was classified by establishing a risk matrix of probability and severity of harms as its variable in this matrix risks are shown in the Table 3.

Table 2: description of scale used for definition of probability and severity

Scale	Probability	Severity
1	Unlikely	Considers
2	Occasional	Serious
3	Likely	Sever
4	Very Likely	Disaster

Table 3: Rrisk level (Product of risk probability and severity)

Quantitative values	
Very high	12-16
High	8-9
Medium	4-6
Low	1-3

Two hazards rope haulage and wooden supports failure were detected as "high" risk and other hazards components were considered in the "medium" and "low" risk level in probability and severity in Table 4. The risk was related to particular activity and evaluated by the estimating with probability and severity in the terms of "Low, medium, high and very high". The risk factors were estimated in accordance with OSHAS 18001 standards [21].

Table 4: Risk matrixes on the basis of risk level.

Probability of Occurrences (P)		Severity of consequences (S)			
		Disaster	**Sever**	**Serious**	**Considers**
		4	3	2	1
Very Likely	4	16 Very high	12 Very high	8 High	4 Medium
Likely	3	12 Very high	9 High	6 Medium	3 Low
Occasional	2	8 High	6 Medium	4 Medium	2 Low
Unlikely	1	4 Medium	3 Low	2 Low	1 Low

Risk colors: Very High = (Red) High = (Orange) Medium = (Yellow) Low = (green)

Compliance of mining law and regulation

According to Pakistan mines safety and health Act, 1996

- Minimum age of employment is 18 years.
- One day of rest per week.
- Limited working hours of employee, 48 in a week.
- In facilities to provide clean water and medical facilities for every worker.
- No unsafe mine.
- Right of inspectors to survey the coal mine regarding health & safety.
- None of workers have not allowed to working in mine, unless the any workplace has been examined and safe declared by mine manager and any other official person. Register report and return including mine plain should be prepared & maintained.

It was observed that maximum provisions were not being complied with in letter and spirit that is why accidents on workplace were becoming more frequent feature of the site [22]. Results of this study substantiate the fact that from contractor to worker there was lack of interest, willingness and arrangements for adherence of life saving and risk mitigation provisions of the laws.

Severity rate and Frequency rate

(A) Lost Time Injury Severity Rate

Formula: $\frac{\text{Number of Work Days Lost* x 200,000}}{\text{Total Hours Worked}}$

Roof fall	18	32.4742268
Side fall	8	14.43298969
Slip	4	7.216494845
Back injury	10	18.04123711
Haulage	3	5.412371134
Eye injury	2	3.608247423

Roof fall	47	84.79381443
Side fall	26	46.90721649
Slip	6	10.82474227
Back injury	17	30.67010309
Haulage	5	9.020618557
Eye injury	5	9.020618557
wooden support	7	12.62886598
Poisonous gases	3	5.412371134

wooden support	4	7.216494845
Poisonous gases	2	3.608247423

Note: 200,000 hours represents the equivalent of 100 employees working 1 full year.

CONCLUSIONS

It was found that the most of coal mine workers were unaware about health and safety protocols. It is revealed that the most of the injuries and fatalities happened because of the roof and side fall accidents and it was also confirmed that diseases were also becoming the source of unhealthy environment. Stakeholders were exercising old mining techniques those are time and resources extensive and it also creates the health and safety issues for the mine workers. Working conditions at coal mines were not as per standard. Workers should not allow coal mining contractors and companies, which are failing to comply with the suggested standards. There was very high risk factor present during mine excavation, coal cutting and transportation process. However, risk assessment is an impartial tool for complete risk management process. Thus, upcoming research efforts should be focused on risk control, implementing, maintaining and control measures.

ETHICAL ISSUES

Ethical issues such as plagiarism was strictly observed while write-up.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest and nothing contrary to facts.

AUTHORS' CONTRIBUTIONS

All authors of this study have a complete and equal contribution for data collection, data analysis and manuscripts writing.

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