academicJournals

Vol. 6(5), pp. 57-63, September, 2014
DOI: 10.5897/JGMR14. 0206
Article Number: 99251CC47354
ISSN 2006 – 9766 © 2014

http://www.academicjournals.org/JGMR

Journal of Geology and Mining Research

Full Length Research Paper

Relationship of individual and work related factors with obstructive type lung function disorder of underground coal miners: A spirometry study

Bijay Mihir Kunar[1]*, Ashis Bhattacherjee[2], Biswajit Samanta[2] and Analava Mitra[3]

[1]Department of Mining Engineering, NITK Surathakal, India.
[2]Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India.
[3]School of Medical Science and Technology, Indian Institute of Technology, Kharagpur, India

Received 14 July, 2014; Accepted 9 September, 2014

In this study, an attempt is made to correlate the presence or absence of FEV1 < 80% predicted as measured by spirometry, with a number of individual and work related factors. This is a cross-sectional study involving 341 workers of an underground coal mine situated in the southern part of India. The data used in this investigation were collected from the Periodical Medical Examination (PME) center of the case study mine and through a questionnaire survey. During questionnaire survey, face-to-face interviews were taken so that workers did not face any difficulty in responding to the questionnaire items. Data were analyzed through univariate and multivariate approaches. The univariate analysis includes simple logistic regression modeling for the calculation of crude (unadjusted) odds ratio. The multivariate analysis includes multiple logistic regression modeling as the logistic regression model provides relationship among the dependent and independent variables. Multiple logistic regression analysis confirmed the association of underground exposure (ORa: 1.21, 95% CI: 1.07-1.31), smoking habit (ORa: 8.19, 95% CI: 2.83-23.80), and work location (ORa: 5.19, 1.90-14.16) with obstructive type lung disorder.

Key words: Dust, coal workers pneumoconiosis (CWP), underground mining, smoking habit**,** lung disorder.

INTRODUCTION

Dust is produced by almost all mining operations in underground coal mines and is seen to be deposited all around the mine. Hence, coal miners are exposed to coal dust in the workplace. Significant exposure to coal dust may occur especially during underground coal mining (Donbak et al., 2005). Inhalation of coal mine dust (dust particle size of aerodynamic diameter >10 µm are being denied entry to lungs by body selectors) is associated with the development of pulmonary disease in miners. Different occupational groups in a mine get exposed to different dust levels and in order to minimize the probability of developing coal workers' pneumoconiosis (CWP), it is necessary to investigate the workers' exposure to dust. The CWP is a disease defined in terms of coal dust deposition in lungs. Borm and Tran (2002) in a study had seen that the dust deposition in lungs even

*Corresponding author. E-mail: bkunar@gmail.com, bjaykunar@yahoo.com.

reached up to 30 g in coal miners with accumulation rate of 0.4-1.7 g each year. The concentration of respirable coal dust for the period of exposure and free silica content are important factors associated with pneumoconiosis risks (Mukherjee et al., 2005).A few studies were carried out in India, which addressed the association between coal mining operations and lung function disorder. Kunar et al. (2008) analyzed the flow-volume loop pattern of the workers (pattern analysis) of an underground coal mine situated in the southern part of India. Their study identified various types of lung function disorder. The lung disorder which is caused by pollutant particles present in mine environment can be defined as the occupational lung disorder of the miners (Rao, 2004). Coal dust can be a source of reactive oxygen species, stimulates macrophages to produce cytokines and enhances production of antifibrogenic factors like TNF-α, increases protease activity and increases inactivation of α_1-antitrypsin and leukocyte elastase activity.

It is a general trend that mining companies rarely pay focus attention to address the health risk of mine workers. As a consequence, mine workers suffer from various occupational diseases with increased rate of health risk which cause high absenteeism, low production and productivity, and increased medical costs. This evidence came from extensive and well-planned epidemiologic and laboratory-based investigations by Bhattacherjee et al. (2013). The present study aims to investigate the relationships between the determinant of lung function disorder and the various risk factors which are responsible for lung disorder. The study results would help mine management to react in an appropriate manner in implementing preventive programs. They might seek help from occupational physicians, safety officers, and other related experts to reduce the lung disorder of coal miners to improve overall health status.

BACKGROUND OF THE STUDY

According to Hermanus (2007), most countries do not have comprehensive database to assess occupational health related issues. Most often the available data are fragmented and incomplete. Metz (2002) had stated that, under-reporting is one of the most serious problems in dealing with health issues (disease and illness) in the mining industry. Reliability of the occupational health data is especially questionable in developing countries like India where reporting systems and reporting criteria are not well established. Nevertheless, the NIOSH has carried out some studies in the USA on health-related issues of workers including the miners who were exposed to coal dust, silica dust, diesel particulate matters, asbestos, noise, welding fumes, and skin disorders. Several studies attempted to establish the relation between respiratory symptoms and lung function disorder of coal miners. Rae et al. (1971) analyzed data on 4122 men from 20 collieries who had been working at the coal face and other places during the period of survey. The analysis of the data was carried out after the exclusion of 127 men whose respiratory symptoms were deemed unreliable. The result revealed that there was a significant association between younger ages and the presence of bronchitic symptoms. This study included both smokers and non smokers. Rogan et al. (1973) examined the relation between forced expiratory volume in one second (FEV1) and cumulative dust exposure among 4122 men. It was found that there was a reduction in FEV1 with increased dust exposure in almost all of the age groups. Love and Miller (1982) analyzed changes in FEV1 values of 1677 miners of five collieries who participated in three Pneumoconiosis Field Research (PFR) follow-up survey and who did not have radiological changes of progressive massive fibrosis at any of the three surveys. The follow-up survey was done for a period of approximately 11 years. The collected data were analyzed using statistical methods. With an appropriate adjustment for the effect of height, smoking, and age, FEV1 showed a declining trend with the higher level of dust exposure. Soutar and Hurley (1986) analyzed the relations between lung function and individual cumulative exposure to respirable dust among 1867 men who were working in the coal mining industry and were followed and examined 22 years later. Levels of FEV1, forced vital capacity, and FEV1/FVC ratio at follow up were found to be inversely related to exposure to respirable dust after adjusting for other factors including age, height, weight, and smoking. The relation of dust to FEV1 was clearly significant in smokers, ex-smokers and non-smokers. The associated reduction in lung function was somewhat greater in non-smoker than in smoker. There was, however, evidence of a greater effect of dust among 2192 men who had left the coal industry before the normal retirement age. They had taken up other jobs and reported symptoms of chronic bronchitis at follow up particularly for ex-smokers. The authors concluded from this study that exposure to respirable dust could occasionally cause severe respiratory impairment in the absence of progressive massive fibrosis (PMF).

Research paper published by Soutar et al. (1993) revealed that researchers conducted various research study on respiratory symptoms and lung function disorder of coal miners at the early 1980s at various parts of Australia namely South Wales, Yorkshire and North east. During the period 1981-1986, random sample of men who had been working in these mines were invited to attend a medical survey. A total of 1671 random samples of men, including 604 men who had already left the industry from these mines with certain progressive massive fibrosis (PMF), was invited to attend a medical survey. Predicted values of FEV1 for nonsmokers with zero dust exposures were calculated for each mine using non-linear regression models. This study subsequently used logistic regression to analyze the factors influencing the probability of 942 ml deficit in FEV1. After adjustment for smoking and employment status, they found that cumulative dust exposure caused an increased risk of deficit in FEV1 for South Wales (odds ratio 1.6; 95% CI 1.3-2.0) colliery, but not at the other two mines. However, for the Yorkshire mine, they found a strong correlation between age and life time dust exposure (correlation coefficient=0.80) from non-linear regression model.

Another investigation in South Wales compared the respiratory health of miners from a single mine with that of a control group of telecommunication workers from the same locality. More of the miners (31%) tended to have worst respiratory health. Some 20% miners had a FEV1 less than 80% of their predicted value of FEV1; whereas, 10% control group of workers had a FEV1 less than 80% of their predicted value of FEV1 (Lloyd et al., 1986). In Belgium, Nemery et al. (1987) carried out a cross-sectional study of 32 non smoking coal miners and 34 non smoking steel workers. In this study, they found that the miners had significantly lower FEV1 values and maximum expiratory flow rates and significantly higher residual volumes than the steel workers.

Literature review revealed that several studies were carried out across the globe on the health related issues of coal mine workers including the miners who are exposed to coal dust. Most of the research studies have addressed the role several factors including exposure to coal mine dust on lung disease. However, a very few literature are available in this area on coal miners in India. Moreover, recent trend suggests that there is a growing concern for Indian mining industry towards the health issues of coal miners' related to lung function disorder. The spirometry study becomes a common test as a periodical medical check-up in India. Since the spirometry data are available in all PME centres, there is enough scope to analyze these data for determining the risk factors responsible for lung function disorder.

Spirometry

Spirometry is a physiological test that measures how an individual inhales or exhales volumes of air over time. The primary signal measured in spirometry may be volume or flow rate. Spirometry is invaluable as a screening test of general respiratory health in the same way that blood pressure provides important information about general cardiovascular health. The most important aspect of spirometry is the FEV1 in one second, which is the volume delivered in the first second of a forced vital capacity (FVC) maneuver. Spirometry can be undertaken with many different types of equipment, and requires cooperation between the subject and the examiner, and the results obtained will depend on technical as well as personal factors. If the variability of the results is diminished and the measurement accuracy is improved, the range of normal values for population can be narrowed and the abnormalities can more easily be detected. Spirometer is used in mines for many reasons such as: i) comparing the lung function of the miners and non-miners, and ii) assessing the patterns, symptoms and lung function of the miners. The flow volume loops of spirometry test provide the visual pattern of the normal subjects, restrictive subjects and obstructive subjects. The spirometer gives data including observed FEV1 as a percentage of predicted FEV1, FVC and ratio of FEV1/FVC.

MATERIALS AND METHODS

The study was conducted during the recent two-year period. This is a cross-sectional study of 341 workers randomly selected from a population of 1396 coal miners of an underground coal mine situated in the southern part of India. Out of the 341 workers, 120 workers were face workers and the remaining 221 workers were non-face workers. Half of the workers are illiterate. The work duration of a worker is eight hours per day and six days per week. The mine operates six days a week, three shifts per day for coal production. A total number of 341 subjects of the case study mine workers have undergone periodical medical examination during period of the study. In this study, regular survey to the subjects was done before hand. The medical records of the workers and their visit to attending physicians/ clinics were regularly checked. Spirometry test of the study workers was conducted by the medicos/medical department of the case study mine. The miners were invited to the PME center for medical examination. During the spirometry study, the spirometer was calibrated before and after each day's use without any significant differences being found. Before examination, each subject was given the opportunity to learn the art of the spirometry technique while watching other persons' blow into the spirometer. The subjects were measured sitting with nose-clips fitted, and the spirometric readings were taken by choosing three best acceptable tracings that met the acceptability and reproducibility criteria. The spirometry data of these workers were collected along with their age, experience, and medical history from the PME center of the mine. The workers were also interviewed by questionnaire items to collect health related risk factors namely occupational history, exposure to dusty environment, respiratory problem, and smoking habit. The participants were mainly chosen from workers category which consisted of coal cutters, coal fillers, conveyor operators, general mazdoors, timber men, multi-skilled group, pump operators and others.

Statistical analysis

To study the effect of various factors on FEV1 of workers, FEV1 values were categorized into two groups according to guidelines used for obstructive respiratory impairments: i) the observed FEV1 values that are less than (<) 80% of predicted FEV1 value, and ii) the observed FEV1 values that are greater than or equal to (≥) 80% of predicted FEV1 value. The risk factors considered in this study are: smoking habit, underground exposure, work location, presence of any disease, body mass index, and present age. The mean age of the workers was 45.4 (SD 6.4) years with an average underground exposure of 20.6 (SD 6.0) years. The mean body mass index (weight/height^2) was 22.7 (SD 3.4) (Table 1). The factors, smoking habit (smoker and non-smoker), work location (face and non-face workers), presence of any disease (disease, and no disease), were categorized into two groups (Table 2). Underground exposure, body mass index, and present age were treated as continuous random variables. To assess the effect of

Table 1. Demographic distribution of miners (sample size: 341).

Variables	Mean	S.D. (Standard Deviation)
Age (Years)	45.4	6.4
Underground Exposure (Years)	20.1	6.0
Body Mass Index (kg/m2)	22.7	3.4

Table 2. Characteristics of the categorical variables (sample size: 341).

Variables	% of Predicted FEV1		Comparison between two groups
	<80	≥80	
Any disease			
Yes	12.1	87.9	p<0.05 (S.G.)
No	6.0	94.0	
Smoking habit			
Smoker	12.0	88.0	P<0.01 (S.G.)
Non smoker	4.8	95.2	
Work location			
Face worker	18.3	81.7	P<0.001 (S.G.)
Non-face worker	3.2	96.8	

S.G.: Significant, N.S.: Non-significant.

significant factors on the percentage of predicted FEV1, univariate and multivariate analysis was computed for each variable. The univariate analysis includes the simple logistic regression analysis for the computation of crude odds ratio (*unadjusted*) and multivariate analysis includes multiple logistic regression analysis for the computation of adjusted odds ratio. Logistic regression models were used to investigate potential interaction between the variables. All *p* values reported are from two-sided tests of statistical significance. Statistical significance was determined at the level of significance P≤0.05. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) package (SPSS, 1999).

The logistic model deals directly with the probability function. It treats each individual as a separate observation rather than grouping them to estimate the probabilities. If X_{bmi}, X_{dis}, X_{page}, X_{sm}, X_{ues}, and X_{wl} represent the factors for body mass index, presence of any disease, present age, smoking habit, underground exposure, and work location respectively, Y is the outcome variable with probability of lung function disorder (p), then the multivariate logistic regression model is given as follows (Equation 1):

$$Y = \ln[p/(1-p)] = \beta_0 + \beta_{bmi} X_{bmi} + \beta_{dis}X_{dis} + \beta_{page}X_{page} + \beta_{sm}X_{sm} + \beta_{ues}X_{ues} + \beta_{wl}X_{wl} \quad (1)$$

$\ln[\frac{p}{1-p}]$ is called the logistic transformation and it is used as the dependent variable. The term $[\frac{p}{1-p}]$ is known as odds ratio of risk.

An odds ratio value of 1 means that the odds of a given outcome equal for those who are exposed and who are not exposed to a possible risk factor. An odds ratio value < 1 means that the given outcome is less likely among those who are exposed than among those who are not exposed. An odds ratio value > 1 means that the given outcome is more likely among those who are exposed than among those who are not exposed.

RESULTS

The crude odds ratio and adjusted odds ratio values for various risk factors are shown in Table 3. In the univariable model the crude odds ratio (OR) value reveals that for obstructive type lung disorder, the significant risk factors are: work location (OR=6.86, P<0.001), present age (OR=1.61, P<0.01), underground exposure (OR=1.17, P<0.001), smoking habit (OR=2.69, P<0.05) and presence of any disease (OR=2.17, P<0.05). The effect of the risk factor body mass index, is found to be non significant (OR=1.06, P>0.05). From the multivariable analysis, adjusted odd ratio (ORa) values reveal that out of 6 factors, 3 factors namely smoking habit (ORa:8.19, 95% CI: 2.83 to 23.80; P<0.001), work location (ORa: 5.19, 95% CI: 1.90 to 14.16; p<0.01) and underground exposure (ORa: 1.21, 95% CI: 1.07 to 1.31; P<0.01) have significant association with FEV1 values; whereas, present age (ORa=1.04, 95% CI:0.92 to 1.18), presence of any disease (ORa: 2.36, 95% CI:0.94 to 5.91) and body mass index (ORa:1.05, 95% CI: 0.91 to 1.22) do not contribute significantly for the FEV1 values.

Table 3. Crude odds ratio (OR) and adjusted odds ratio (ORa) for various risk factors for obstructive type disorder (Sample size: 341).

Variables	Crude OR	95% CI	Adjusted OR	95% CI
Body mass index	1.06	0.94-1.19	1.05	0.91-1.22
Any disease	2.17*	1.00-4.71	2.36	0.94-5.91
Work location	6.86‡	2.83-16.60	5.19†	1.90-14.16
Present age	1.61†	1.07-1.25	1.04	0.92-1.18
Smoking habit	2.69*	1.15-6.25	8.19‡	2.83-23.80
Underground exposure	1.17‡	1.09-1.26	1.21†	1.07-1.31

*p<0.05, †p<0.01, ‡p<0.001.

DISCUSSION

Medical science is based on scientific validation of data in different arena by different workers. Populace around the world is heterogeneous. Statistical and other data which are being cited in different experiments involving human volunteers by different workers varies and there are enumerable references in different journals citing works in a particular area involving different cohorts at different conditions thus causing differences in values due to differing genetic, environmental and life style conditions. The present study sheds light on the roles played by a number of individual and occupational factors on the presence or absence of FEV1<80% predicted for coal miners in India. This study was a cross-sectional study of 341 miners. The subjects were randomly selected from the population of a mine located in the southern part of India. The study as a whole was well accepted by the miners, occupational physicians and the company.

Most of the cross-sectional survey conducted by several researchers revealed that loss of FEV1 was only associated with dust exposure. Exposure to coal mine dust is associated with symptoms of chronic bronchitis but bronchitis itself does not appear to cause detectable loss of FEV1. Further, researchers suggested that there is some clue lies in the pattern of lung function deficit associated with dust exposure. There is some indication that the loss of FVC relative to FEV1 is greater from dust than smoking (Marine et al., 1988). Though at present the exact nature of the pathology underlying the loss of lung function is still uncertain; however, most of the research study revealed that the loss FEV1 may give an indication of lung function disorder.

Some researchers have raised issues that the coal mine dust is not the only cause for loss of lung function in the absence of complicated pneumoconiosis. A weakness of all the research studies comparing miners and non-miners is their inability to control completely for possible confounding by non-occupational influences on lung function. In particular the miners examined may have different lung function from their controls even before they entered into the mining industry. Such selection effects are of less concern in the present research studies described above as those have compared lung function within miners according to their exposure to dust. The development of lung disorder is associated with content of free silica in the dust, dispersion, year of exposure, prevention and individual factors. This research study is carefully planned by taking into account that 6 factors are suspected to have association with FEV1 values at the beginning of investigation. These are work location, present age, underground exposure, smoking habit, body mass index and presence of disease of worker. Both the univariate and multivariate logistic regression analysis confirmed that only 3 factors namely work location, underground exposure, and smoking habit are statistically significant. Odds ratios are not found significant for the factors body mass index, presence of any disease and present age. The risk factors present age and presence of disease are significant in univariate analyses; however; they are not significant in multivariate analysis. This may be due to the fact that some of the other factors are related with present age and presence of disease. The multivariate logistic regression analysis provides a more guarded assessment of lung disorder of the workers by controlling for the presence of all the variables with their categories, including the generation of odds ratios. The logistic regression analysis indicates that smoking and work location had a notable high odds ratios of 8.19 (95% CI 2.83-23.80) and 5.19 (95% CI 1.90-14.16) with P < 0.001 for obstructive respiratory symptoms. Smoking is the major risk factor for chronic obstructive pulmonary disease (COPD). However the relevant information from published literature indicates that about 15% of all cases of COPD is work-related (Boschetto, 2006). It is also found from this study that smokers are at 8.19 times higher risk of lung disorder than non-smoker. This study found that presence of respiratory symptoms can represent an early biological response to smoking and occupational exposures. However, current evidence shows that a coal mine worker, even in the absence of CWP and controlling for smoking, is associated with chronic bronchitis, chronic airflow limitation and emphysema. A study of white South African gold miners showed that the FEV1 and the FEV1/FVC ratio, adjusted for age, height, and smoking decreased with increasing cumulative respirable dust exposure in both smokers and non-smokers. The average cumulative respirable dust exposure attributes loss in lung function. Coggon and Newman (1998) from their research study concluded that the combined effects of coal mine dust and smoking on FEV1 appear to be additive. The risk of lung cancer in a coal dust exposed individual greatly enhanced by cigarette smoking. So it can be a risk factor for loss of pulmonary function in the future. The study recommended that adverse respiratory effects due to active smoking necessitate counseling for exposed individuals. The other factors influencing the risk of lung cancer in exposed workers include intensity of exposure and fibre type. The risk for CWP depends on the total dust burden in the lungs and is also related to the coal rank which is based on the carbon content. In higher ranking coal, there may be a greater relative surface area of the coal dust particles, higher surface-free radicals and higher silica content (Attfield et al., 1995). Hence silicosis is more common in mines with high grade coal. An excellent review by Moosman and Chung (1998) summarizes the process whereby silica produces inflammation and fibrogenesis in the lung. Although silicosis continues to be most common disease associated with silica exposure, this study results found that there is a significant association between underground exposure and lung disorder of underground coal miners. Past pathologic studies suggest that emphysema (destruction of the air spaces where gas transfer occurs) severity in coal miners is related to dust exposure. Recent studies on South African and U.S. coal miners confirmed these findings (Naidoo et al., 2005). The odds ratio for underground exposure indicates that for two workers who have difference of underground exposure of one year and are adjusted for all other risk factor, the odds in favour of obstructive type disorder for the worker with the higher underground exposure is 1.21 times as great as for the worker with lower underground exposure. So this study suggests that mine management should pay special attention to the workers having higher underground exposure by frequent health checkup.

The WHO recommends that routine medical evaluation is required in every 2-5 years, ideally life-long for workers exposed to silica dust (Wagner, 1996). Important additional information on this topic, using quantitative estimates of both coal mine dust exposure and smoking habit, has been recently published by Kuempel et al. (2009). These authors found a highly significant relationship between cumulative exposure to respirable coal mine dust and emphysema severity, controlling for effects of smoking, age, and other variables. The effect of dust exposure was similar in magnitude to that of smoking, and was seen in the non-smoking subgroup. In a further analysis, Kuempel et al. (2009) established that exposure to coal mine dust can produce clinically important levels of emphysema and later on COPD in coal miners. The loss of progressive stromal architecture of lung with reduced elastic tissue and increase of fibrous tissue cause reduced compliance of lungs.

This study reveals that face workers have 5.19 times higher risk of lung disorder than non-face workers. So it is recommended that cares should be taken for the workers based on work place location. Face workers should be provided with nose musk so that they can wear it while working. For face workers in workplaces with high dust levels, administrative measures can also be used to reduce exposure of dust by cutting short their working hours or job rotation. Exposure control at worker level includes training and education on work practices and personal protection. Personal protection equipment such as respirators is a good solution for short duration tasks. Respirators can be used in combination with engineering controls. Care should also be taken for non-face workers having smoking habit and underground exposure ≥ 20 years. Regular medical evaluation commonly includes respiratory questionnaire, physical examination, and chest radiography. Spirometry is required to detect the adverse health effects among face and non-face workers before the disease reaches advance stage.

The occurrences of lung function disorder can be reduced to as low as possible if the mine management can take all types of preventive programs. This is only possible if the mine management has the knowledge of all types of risk factors and symptoms of declining lung function. The pattern knowledge and spirometric test value on the occurrences of illness in these conditions can help the mine management to reduce further respiratory problem in workers. Though several studies pointed out that the pattern of CWP occurrence, both collagenous (fibrogenic dust) and non-collagenous (non-fibrogenic dust) types, across the nations is not uniform; hot spots of disease appear to be concentrated in the several developed countries. The knowledge of risk factor responsible for lung disorder of workers would help the mine management in implementing preventive programs in which the occupational physicians, safety officers, and the mine management can work together to reduce the respiratory problem and to improve the worker's health and safety.

Employers, unions, employees and government agencies have a great and growing interest in health and safety issues related to the workplace. There is an increasing trend in work related injuries, illnesses and deaths. In general, the employees' health at the workplace is a major concern in Indian mining industry. Many of the ethical issues are being addressed by legislations/ local regulatory bodies. In Indian Council of Medical Research guideline involving human volunteers, there are specific guidelines. The volunteers and their family are being explained of the spirometry study, risk involved and benefits of the study in vernacular. Further, regular meetings are being held with all citing the risk of coal use including hazards of coal dust. The mine owners have the social responsibility to make the work environment free from any hazards including the health hazards. Moreover, they have to supply clean coal to the users to avoid degradation of environment. The mine owners are also answerable to the regulatory body namely Directorate General of Mines Safety in India for any type of occupation related diseases including lung disorder problems. Technical findings in the paper and other likely papers in this area will call for steps in social media/print and electronic media/ administrative authorities for prevention against coal dust hazards in all directions.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Mr. M. Shahid, Assistant Manager Mining, CMPDIL Head Quarter Ranchi for his contribution in this study. The support from the management, occupational physicians, staff and workers of the case study mines are highly appreciated.

REFERENCES

Attfield MD, Seixas NS (1995). Prevalence of pneumoconiosis and its relationship to dust exposure in a cohort of U.S. bituminous coal miners and ex-miners. Am. J. Ind. Med. 1995;27:137-151. http://dx.doi.org/10.1002/ajim.4700270113

Bhattacherjee A, Kunar BM, Baumann M, Chau N, Lorhandicap G (2013). "The role of occupational activities and work environment in occupational injury and interplay of personal factors in various age groups among Indian and French coal miners". Int. J. Occup. Med. Environ. Health. 26(6):1-20. http://dx.doi.org/10.2478/s13382-013-0165-4

Borm PJA, Tran L (2002). From quartz hazard to quartz risk: the coal mines revisited. Ann Occup. Hyg, 46:25-32. http://dx.doi.org/10.1093/annhyg/mef021

Boschetto P (2006). Chronic obstructive pulmonary disease (COPD) and occupational exposures. J. Occup. Med. Toxicol. 1:11. http://dx.doi.org/10.1186/1745-6673-1-11

Coggon D, Newman Taylor A (1998). Coal mining and chronic obstructive pulmonary disease: a review of the evidence. Thorax 53:398-407. http://dx.doi.org/10.1136/thx.53.5.398

Donbak L, Rencuzogullari E, Yavuz A, Topaktas M (2005). The genotoxic risk of underground coal miners from Tur- key. Mutat Res. 588:82-87. http://dx.doi.org/10.1016/j.mrgentox.2005.08.014

Hermanus MA (2007). "Occupational health and safety in mining-status, new developments, and concerns. J. South Afr. Instit. Min. Metall. 107(8):531-538.

Kunar BM, Shahid M, Bhattacherjee A (2008). A spirometer study of lung disorder for underground coal miners. Indo-Korean Joint International Symposium on Geoscience & Technology, February 12 – 14, IIT Kharagpur, pp. 180-187.

Kuempel ED, Vallyathan V, Green FHY (2009). "Emphysema and pulmonary impairment in coal miners: Quantitative relationship with dust exposure and cigarette smoking". J. Phys. Conf. Series 151:1-8. http://dx.doi.org/10.1088/1742-6596/151/1/012024

Love RG, Miller BG (1982). Longitudinal study of lung function in coal-miners. Thora. 37(3):193–197. http://dx.doi.org/10.1136/thx.37.3.193

Lloyd MH, Gauld SJ, Soutar CA (1986). Respiratory ill health among coal miners and telecommunication workers in South Wales. Br. J. Ind. Med. 43(3):177–181.

Marine WM, Gurr D, Jacobsen M (1988). Clinically important effects of dust exposure and smoking in British coal miners. Am. Rev. Respir. Dis. 137(1):106–112. http://dx.doi.org/10.1164/ajrccm/137.1.106

Metz EA (2002). Occupational ergonomics: Ergonomics issues in the mining Industry, SME Preprint 02-146. SME annual meeting. P.3.

Mossman BT, Churg A (1998). Mechanisms in the pathogenesis of asbestosis and silicosis. Am. J. Respir. Crit. Care Med. 157:1666-1680. http://dx.doi.org/10.1164/ajrccm.157.5.9707141

Mukherjee AK, Bhattacharya SK, Saiyed HN (2005). Assessment of respirable dust and its free silica contents in different Indian coal mines. Ind. Health. 43:277-284. http://dx.doi.org/10.2486/indhealth.43.277

Nemery B, Veriter C, Brasseur L, Frans A (1987). Impairment of entilator function and pulmonary gas exchange in nonsmoking coalminers. Lancet 1427:30.

Naidoo RN, Robins TG, Murray J (2005). Respiratory outcomes among South African coal miners at autopsy. Am. J. Ind. Med. 48:217-224. http://dx.doi.org/10.1002/ajim.20207

Rao KM (2004). Health and safety. Proceedings of the National Seminar on "Future of Indian Mineral Industry". September 17-18, Kolkatta. The Mining Geological and Metallurgical Institute of India, pp. 217-220.

Rae S, Walker DD, Attfield MD (1971). Chronic bronchitis and dust exposure in British coalminers. In: Walton WH, ed. *Inhaled particles III.* Old Woking, Surrey: Unwin, pp. 883-95.

Rogan JM, Attfield MD, Jacobsen M, Rae S, Walker DD, Walton WH (1973). Role of dust in the working environment in development of chronic bronchitis in British coal miners. Br. J. Ind. Med. 30(3):217-226.

Soutar CA, Hurley JF (1986). Relation between dust exposure and lung function in miners and ex-miners. Br. J. Ind. Med. 43(5):307-320.

Soutar C, Campbell S, Gurr D, Lloyd M, Love R, Cowie H, Cowie A, Seaton A (1993). Important deficits of lung function in three modern colliery populations: relations with dust exposure. Am. Rev. Respir. Dis. 147:797-803. http://dx.doi.org/10.1164/ajrccm/147.4.797

Statistical Package for the Social Sciences (SPSS 10). Inc. Chicago IL (1999). SPSS Reference Guide.

Wagner GWS (1996). Screening and surveillance of workers exposed to mineral dust. Geneva: World Health Organization.