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Health implications of exposure to coal mine dust in workers – A Review

Ganesan S, Sangeetha R*

Department of Biochemistry, Vels Institute of Science, Technology and Advanced Studies, Pallavaram, Chennai - 600117, Tamil Nadu, India

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ABSTRACT

Major health problem for workers is prevalent in all nations due to occupational hazards. Coal mining is one of the largest and oldest industries in the world. However, no such information is available in the literature regarding the health status of coal mine workers. Coal is a basic necessity for the production of electricity and steel. Along with machines, humans are the workforce in every coal mine industry. Air pollutants and dust mixed with silica are the two major factors that affect the health of coal mine workers. Coal mine workers run the risk of getting respiratory damage due to high levels of dust and other chemical particulate matters. Some of the disorders caused by coal mines are Chronic Pulmonary Obstructive Disease (COPD), Coal Workers Pneumoconiosis (CWP), Asthma and massive fibrosis. Prolonged exposure to coal mine dust may cause a variety of diseases like Tuberculosis, Chronic Bronchitis, Heart Diseases, Lung Cancer, Pneumonia, liver disease, kidney damage, DM and Reproductive disorders. All these diseases may be induced if mine workers are subjected to prolonged exposure. This review article highlights the outcome of research works done in the past three decades on the health implications of coal mine workers. Further studies are required with respect to the degree of damage to each organ and to prepare a set of guidelines to be followed by coal mine industries to be strictly followed to safeguard the wellbeing of coal mine workers.

* Corresponding Author

Name: Dr. R. Sangeetha
Email: sara_dna@yahoo.co.in

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INTRODUCTION

Coal has been growing rapidly as one of the world's most used resource material for the generation of electricity and steel production. China accounts to around 50% of the world's total coal production followed by the United States of America (USA), Australia and India. The four major coal-producing districts in India are Jharkhand, Odisha, Chhattisgarh and West Bengal. As of the date the number of coal mines operating in India is 430, out of which 175 are open cast, 227 underground and 28 are mixed mines. Along with machines such as Bucket Wheel Excavators, Conveyors and Spreaders, humans are mostly involved in all types of coal mine works and such workers will come across many health implications. It is therefore imperative to study the condition of coal mine workers and to safeguard their health by periodical health check-ups and implementing preventive measures in all type of coal mines (Petsonk *et al*., 1995; Abbas *et al*., 2016).

All workers whether in office or industries always come across health-related risks due to environmental conditions. It is very difficult to select a job which is completely free from health risk. The accuracy of measuring health-related risk starts with hyper airway responsiveness. Workers engaged in coal mines are prone to a variety of health-related risk. Such workers come across with reduced ventilatory lung function followed by an increased rate of ventilation leading to respiratory syndromes. It will be difficult to analyze the effects of dust exposure on workers unless sufficient data are available. Those working in coal-related occupation may show statistically significant univariant self-related prediction, but when analyzed based on potential co-founders it may no longer show the significant prediction. Hence self-related health dose not seems to be related to residential proximity to coal mining facilities or working in the coal mining industry. More studies are required to assess the additional impact of working in coal mines on the health status of workers (Woolley *et al*., 2015).

Coal mine workers are generally involved in extracting rocks, especially aluminium clays which contains kaolins and attapulgite. It is important to pre-treat aluminium clays with cation chealators. This will help to prevent quartz DQ12 induced hemolysis. However, extracts of low Aluminium clays which contains monotmorillonite and hectronite did not prevent quartz DQ12 induced hemolysis, although the hectorite may prevent inflammation. Hence coal mine dust (CMD) and clays rich in aluminium which contains soluble components cations are capable of masking the reactivity of the quartz surface (Stone *et al*., 2004).

Metabolic syndrome

Depression among coal mine workers is a common finding, and higher morbidity and mortality have been observed in such workers due to the induction of Cardio Vascular Disease (CVD). A study conducted in this direction has revealed that 13.61%of miners among 492 were found to have hypertension, MetS and depression. After six months of holistic treatment, a statistically significant reduction in blood pressure (BP), waist circumference (WC), total cholesterol (TC), High-Density Lipoprotein cholesterol (HDL-c), LDL-c, smoking, Beeks scale were observed. All these improvements were followed by total Cardio vascular risk. After six months of combined therapy, respondents showed a further reduction in CV risk with improvements in all factors except Body Mass Index (BMI) and Triglycerides (TGs) (Becarevic *et al*., 2014).

Obesity

Obesity and BP are the two constant findings among coal mine workers which contribute to CVD. There is a need for a CVD monitoring system for the health interventions of coal mining communities (Casey *et al*., 2017). Only observational data are available on public health consequences of mountains top removal (MTR) in coal industries. In order to estimate propensity scores, nine co-variants viz age, sex, current and former smoking, overweight, obesity, high school education, college education and exposure to coal as the home heating source were selected. The results obtained indicated that persons with the MTR group had a significantly elevated prevalence of respiratory symptoms and chronic obstructive lung disease (COLD). Hence impaired respiratory health results from exposure to MTR environments and not from other risk (Hendryx and Luo, 2015).

Generally, coal mine workers are susceptible to dyslipidemia due to risky and stressful job environments as well as unhealthy lifestyles. However, very few studies have been carried out on this aspect. Hence studies are required to investigate epidemiological characteristics of dyslipidemia among coal mine workers. In a study conducted among Chinese coal mine workers, 38% were found to have high TC, 25.8%low HDL-c, 35.1% high LDL-c and 40.5% had high TGs level. The overall prevalence of dyslipidemia was 68.3%. The factors associated for such a high percentage of dyslipidemia were age, sex, marital status, monthly family income, type of work, length of service, smoking status and its index, drinking habits and alcohol consumption per day increased fasting plasma glucose (FPG), increased BP, obesity and abdominal obesity. On the whole, a very high prevalence of dyslipidemia was detected among Chinese coal mine workers, and a battery of risk factors was found to be associated with dyslipidemia (Ye Fan *et al*., 2017).

Respiratory diseases

Coal mine lung disease

Coal mine dust lung diseases (CMDLD) are a spectrum of lung diseases caused by coal mine dust. The diseases under this category are coal workers' pneumoconiosis, silicosis, mixed dust pneumoconiosis, dust-related diffuse fibrosis and Chronic Pulmonary Obstructive Disease (COPD). In the central Appalachian region, CMDLD continues to be a problem in the USA. Treatment of CMDLD is symptomatic, and if people have End Stage Renal Disease (ESRD), lung transplantation is the only choice available as CMDLD could not be cured, and prevention is also critical (Laney and Weissman, 2014).

Chronic pulmonary obstructive disease

In a study to evaluate respiratory-related mortality among coal miners with more than 3 decades of exposure, excess mortality was observed for pneumoconiosis, COPD and lung cancer, confirming that exposure to coal mine dust increased the risk for mortality for pneumoconiosis and COPD. Significant elevation in mortality of COPD was observed among over smokers and former smokers but not current smokers. A positive association exists in models controlling for coal mine dust with mortality from pneumoconiosis and COPD. Further, a significant correlation was observed between coal mine dust exposure and lung cancer mortality but not with respirable silica. A recent follow-up study has revealed that both exposures were positively associated with lung cancer mortality and coal mine dust exposure significance was higher (Graber *et al*., 2014).

Exposure to coal mine dust may develop varieties of pulmonary diseases such as classical pneumoconiosis, and in severe cases, it may lead to progressive massive fibrosis (PMF). Exposure to a coal mine and silica may also lead to pulmonary scarring mimicking Idiopathic Pulmonary Fibrosis as well as COPD, emphysema and chronic bronchitis. Retained dust may cause modular fibrosing pulmonary tissue reactions which can result in a significant respiratory dysfunction insensitive individual (Cohen *et al*., 2008).

Coal worker's pneumoconiosis

It is a common observation that severe impairment of pulmonary function exists in some complicated pneumoconiosis, but the relationship of simple coal worker's pneumoconiosis (CWP) to pulmonary function and respiratory symptoms remains a debatable issue. Miners with CWP had lower values of the pulmonary function and higher prevalence of respiratory symptoms and emphysema than did those without. After adjusting for age, smoking and years in underground, simple CWP were found to be associated with increased risk of respiratory symptoms. As per regression analysis, CWP showed significantly independent effects on parameters of the pulmonary function. Even when pulmonary parameters exhibit its effects, a significant relationship between CWP and decreases in a forced vital capacity as well as diffusing capacity remained. Hence simple CWP is a contributor to significant decrements in pulmonary function which leads to increased risk of respiratory symptoms (Wang *et al*., 1999).

Among coal mine workers, clear differences exist between mean respirable dust and quartz concentration. There were consistent across the different sites but dependent on the day of measurement and the variation between days was not much. Chronic bronchitis frequently was found to be directly related to the year of exposure to dusty jobs outside open cast mining compared to working within the industry. A 5% asthmatic symptoms reported among the workforce was found to be close to the mean frequency found in adult men. No positive associations were found between asthma and occupational exposure. Although the lung function was close to the predicted value but showed no relation to time worked in open cast occupation. Mostly mild chest abnormalities were found in workers in dustier who engage in pre-production job in the industry. Some of these mild abnormalities may be non-occupational due to ageing or smoking, and the association may indicate a small risk of pneumoconiosis, and it is important to monitor high-risk occupational workers (Love *et al*., 1997).

It has been pointed out by earlier studies that coal mining remains a major industry in which workers may face a risk for developing chronic lung disease. Additive habit to smoking may be accelerated by cumulative exposure to coal dust which induces the development of emphysema. A COPD result from increased exposure to coal mine dust and is associated with increased risk for deaths. Within two hours of exposure to coal mines, bronchial symptoms may start with a rapid decline in lung function. For such people, it is essential to do just a radiograph to rule out dyspnoea and computer tomography for emphysema as well as expiratory flow limitation. The above observations have been proved by the latest studies and confirm the association of emphysema and COPD with coal dust exposure. Increased cumulative exposure may also increase death from these diseases (Santo Tomas, 2011).

Coal mine dust or crystalline silica exposure will cause pneumoconiosis, pulmonary fibrosis resulting in lung cell damage as well as the release of lipase and proteases all of which may lead to lung scarring. Further oxidants production by pulmonary phagocytes surpassing antioxidant defences leading to lipid peroxidation, protein nitrosation, cell injury and lung scarring. Pro-inflammatory cytokines and reactive species may also be produced. Growth factors secretion may also happen which will stimulate fibroblast proliferation leading to scarring. These are results obtained in-vitro and animal studies and project the mechanisms for initiation and progression of pneumoconiosis, and this data was supported by exposed workers to these mechanisms (Castranova and Vallyathan, 2000; Huang *et al*., 2002).

In early 1970, coal mine technology and preventive measures for mine workers were very poor in China. After 1970 mechanized and advanced protective equipment were installed for coal mining. Substantial changes for coal mining resulted in the improvement of workers and CWP incidence have come down. This paved the way to identify the characteristics of CWP trends today among coal workers. It is important to do a physical examination for coal workers who are at high risk for CWP to rule out pneumoconiosis every year and for those at low risk at least once in 5years (Shen *et al*., 2013).

Chronic lower respiratory disease

Among mine worker's chronic lower respiratory disease (CLRD) was 13 times more frequent in current smokers and 11 times in ex-smokers compared to nonsmokers. However, CLRD did not increase after 10 years of smoking. CLRD was found to be twice in coal mine smokers compared to non-smokers indicating that some additional factors may promote the development of CLRD (Szymczykiewicz, 1979).

Prevalence of asthma and rhinoconjuctivitis are common in coal mine workers. Children might get rhinoconjuctivitis if their residents from miners were at a distance of 1.72 odds ratio. According to the spatial Bayesian model, closer the residents to the mines more the chances of getting the disease and if it is less than 1.8 KM, the chances of getting the respiratory disease is negligible. These findings of respiratory diseases among coal mine workers are identical to the one found out, and such association in industrial gold or copper mines due to air pollution nearby observed in rural areas of China (Herrera *et al*., 2016).

In a study, significant associations were found between age, educational background, and marital status on alcohol drinking to respiratory disorders. In coal mine workers asthma predominates among the other disease like pneumonia, bronchitis and emphysema. An appropriate health education intervention together with a working environment is critical to improving the overall health of mine workers to prevent respiratory disorders (Ayaaba *et al*., 2017).

Exposure to coal dust can cause interstitial lung disease (ILD), but it is not clear whether it is due to coal or quartz content in coal. Among a total of 9 studies, 6 studies indicated that the non-quartz part showed an independent effect on the development and progression of ILD. Although six out 8 studies have supported the progression to ILD, due to methodological differences, the evidence may be limited warranting further studies (Beer *et al*., 2017).

Many studies have established that working in coal mines is a risk factor for pneumoconiosis and COPD. However doubts remains, and debates are still going on among research communities regarding the risk involved for tuberculosis (TB) and lung cancer among coal mine workers (Montes *et al*., 2004).

An increased standardized mortality ratio (SMR) was observed in non-supervisory underground coal mine workers, transporters and maintenance staff and the highest SMR was noted in maintenance workers compared to with those having the face. Men from Appalachian states tend to have a slightly reduced SMR compared to US men as standard[22]. The overall SMR rate was found to be higher than expected mortality in several categories of non-malignant respiratory disease as well as in accidents (Rockette, 1977).

The life expectancy of CWP patients with pneumoconiosis, TB, lung cancer and pulmonary heart disease were prolonged to an average of 2.1 years. CWP patients without pulmonary TB showed higher than patients with pulmonary TB for survival, and a significant difference was observed in the survival curves between these two groups. Cox regression model for evaluation using risk factors, dust exposure years, an age of onset and first diagnostic stage indicated that prevention and treatment of CWP complication are important for patient survival rates (Han *et al*., 2017).

Cardiac Diseases

Coal miners who work in the underground may come across cardiovascular system abnormalities. Higher risk of cardiovascular abnormalities was noted in those who work long hours in the underground [25]. Particulate matter present in air pollution will increase the risk of Ischemic Heart Disease (IHD) mortality. Studies on the prevalence of IHD mortality risk among coal miners exposed to coal dust showed inconsistent results. Earlier studies may have been biased the effect of healthy workers. Cumulative exposure to coal dust and its quality showed an increased risk of mortality for IHD. Such an effect depends upon the coal mine dust particulate. Air pollution studies have shown an association of the risk of IHD mortality with cumulative exposure (Landen *et al*., 2007). In a study among workers of Donbass coal mine, the occurrence of Coronary Heart Disease (CHD) was found to be 2 times compared to the age-matched population. Working environment and the industrial process were found to be risk factors (Cherkesov *et al*., 1996).

Oral Health

Although the standard of life and living condition are improved by expanding industrial activity, at the other end it has created many occupational health hazards. Coal mines are considered as the major age-old industry in India as well as throughout the world. However, very little literature data are available worldwide as well as in India particularly the oral health status of coal mine workers. About 90% of coal mine workers have the habit of consuming alcohol and chew tobacco. Studies have shown the prevalence of dental caries among such subjects with 48.3% were found to be untreated dental caries and teeth were found to be missing in 20.3%. Periodontal disease was the most prevalent condition accounting for 94.4% with unhealthy periodontium in-terms of gingival bleeding or periodontal pockets. Hence coal mine workers are prone to higher periodontal disease and traumatic injuries all of which requires immediate attention (Abbas *et al*., 2017).

Coal mine workers are prone to get oral health problems and periodontal disease is prominent among such workers. Epidemiological studies indicate that periodontal diseases were found to be 96.2% with 3.8% among the healthy subjects. The significant difference was observed with those brush their teeth daily and visit the dentist every 2 years compared to those do not have this practice. The level of periodontal among coal mine workers was found to be severe, and its distribution and severity are strongly influenced by risk factors are host susceptibility. Priority should be given for a primary prevention program based on population strategy in order to benefit the periodontal health by oral hygiene and by promoting self-care (Cengiz *et al*., 2018).

Studies done in the past have shown increased mortality regarding IHD among miners and industrial sand workers. Smoking habits may not be a contributing factor for IHD mortality. A possible cause may be low-grade inflammation of lungs due to dust exposure. Better dose estimates along with better confounding control are needed to arrive at a relation between silica dust exposure and IHD (Weiner *et al*., 2007).

When evaluating heart disease, SMR'S of 73 miners and 104 non-miners were obtained. In both working and non-working miners, obese smokers had the highest risk of dying of heart disease as the SMR'S found out of these groups were 142 and 144 respectively. Increased SMR'S were observed in underground mine workers, transporters as well in maintenance men. US coal miners have an increased death rate compared to men working in non-coal mine environments (Costello and Ortmeyer, 1975).

Brachial-Ankle pulse wave velocity (BAPWV) is an independent predictor of cardiovascular event and mortality. However, studies on this relationship are lacking in coal miners. Higher BAPWV and its associated risks are prevalent in coal mine workers compared to controls. At age, greater than 60 years, BMI, heart rate and hypertension were associated with increased BAPWV compared to controls. In coal mine worker's silica dust exposure shows increased BAPWV and such increase is associated with traditional cardiovascular risk factors due to long term silica dust exposure. The contributing factors for cardiac strain among coal mine workers are hot climate, overweight and obesity. WHR was found to be higher for coal mine workers compared to controls. The severity of cardiac strain was higher in overweight workers compared with that in normal weight workers. Coal mine companies should select only normal weight personnel as overweight will increase cardiac strain and companies should complement those workers who lose weight during their tenure in coal mine jobs. All mineworkers should be encouraged to do regular physical activities (Zheng *et al*., 2017).

Kidney Diseases

In Appalachian countries among both male and female, the highest level of significance was observed between miners and non-miners for the chronic heart, respiratory and kidney disease but was not higher for an acute form of other illness. Higher rates of acute heart, respiratory and kidney disease mortality may be due to environmental exposure to particulate matter or toxic agents present in coal and released during mining and processing (Hendryx. 2009).

Liver Diseases

Exposure to coal mines may affect the liver and spleen. While the liver and spleen sizes were minimal in non-coal mine workers, there was an increase of 10.4% in liver and 19.5% in spleen size of coal mine workers. No association was found for the extrapulmonary pigment as well as no pathological tissue response. A highly significant correlation was found between the severity of pneumoconiosis and the black pigment scar in both liver and spleen. However, a lower significance was observed between emphysema and pigment scar only for the liver. Such pigment scars showed a significant positive correlation between years spent underground in coal mines, years of retirement and age at death. A negative correlation was also observed between smoking and pigment scars. All these above observations suggest that cumulative lifetime exposure to coal mine dust may be the most important factor in the release of dust into the general population (LeFevre *et al*., 1982).

In a study, coal worker's pneumoconiosis and standard incident ratios showed that gastric, liver, biliary tract, lung and mediastinal cancers were significantly higher in CWP groups than the general population. Multi-variate analysis showed that age greater than 60 years' male gender and liver cirrhosis were significant predictors of cancer developments in CWP patients. Hence patients with CWP especially elderly males were found to be at increased risk of cancers. Along with these observations, liver cirrhosis will accelerate the development of cancers (Hung *et al*., 2014).

Brick manufacturing in Egypt are prone to silica exposure, and all workers engaged in this job showed a significantly higher mean level of liver enzymes, matrix metaloproteinase-9 (MMP-9), IgG and IgE. The mean level of Gamma-Glutamyl Transpeptidase (GGT) level in silicotic subgroups was almost twice the level in the non-silicotic subjects. As per the logistic regression analysis, workers engaged in production showed abnormal GGT and Alanine Transaminase (ALT) level (Zawilla *et al*., 2014).

Endocrine dysfunction

Heavy metals such as Mercury, Aluminium, Selenium as well as air pollutants may affect the functional status of endocrine glands in humans leading to the disruption of hormone production. Research finding shows that prolonged exposure to environmental toxins may be responsible for the dysfunction of the thyroid gland. A significant statistical increase in Thyroid Stimulating Hormone (TSH) was observed in coal mine workers compared to non-coal mine workers. A statistically significant correlation between TSH and creatinine and urea was found. Thus, the measurements of TSH and creatinine in coal mine workers is necessary to assess the toxicity determination among coal mine workers (Tumane *et al*., 2015).

Vitamin D deficiency

In a study among coal mine workers 66.2% were found to have vitamin-D deficiency and 27.8% insufficiency. After adjusting for age, salt intake, physical activity, smoking, alcohol consumption, work type, environmental pollutants, BMI, DM and hyperlipidemia, the odds ratio for hypertension with a normal vitamin-D level are > 50, 25-50, 1.44 and 1.39 respectively (mmol/L). Logistic regression analysis failed to determine a significant association between vitamin-D status and hypertension. More studies are required to establish an association between vitamin-D levels and hypertension (Peng *et al*., 2016).

The relationship may exist between vitamin-D, biochemical bone markers, lumbar spine and femur bone mineral density (BMD). A significant association was found out for lumbar spine, and femur BMD and they were significantly higher in underground workers compared to surface workers. No correlation was found between the duration of underground work, age, vitamin-D levels, smoking and dietary calcium intake with BMD. Hence underground physical working does not seem to be a significant factor for low vitamin-D or low BMD (Sarikaya *et al*., 2006).

Coal mine workers should maintain adequate hydration. In tropical Australia, dehydration is health risk. As per hydration tests, more than half of the miners were found to be dehydrated as per the urine specific gravity >1.020, both before and after their shifts. 54% of the study population was overweight and 37% obese. Miners who enter the shift with poor hydration will leave with 2.6 times dehydrated at the end of the shift compared to those who start the work with good hydration. Dehydration also affects metabolic complications. The 3 simple factors that affect the general health of coal miners are dehydration, being overweight and obesity. In order to maintain good health among miner's good strategies should be followed within the workplace such as good drinking water availability and accessibility, encourage appropriate consumption of water in workplace and at home and to promote good physical activity and better nutrition (Polkinghorne *et al*., 2013).

CONCLUSION

This review article on the health implications of coal mine workers gives a condensed summary of many previous researches done on this field during the last three decades. Almost each organ of the mine workers is affected due to prolonged exposure to coal mine dusts and air pollutants prevailing in this industry. Majority of the studies carried out in the past have given a comparative level of biochemical and infections parameters in comparison with controls. The first organ affected is the lungs leading to the development of lung-related diseases like pneumoconiosis, COPD, CWP, asthma. Other organs affected are liver, cardiac and kidney. The diseases identified are CVD, DM and CKD. The evidence is also available regarding reproductive organ failure. Dehydration-related symptoms have also been pointed out. The contents found in this review article will certainly help the research community to undertake more research on this field and frame a set of useful preventative measures to be taken by the management of the coal mine industry.

CONFLICT OF INTEREST - None

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