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A Small Note on Silicosis

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Abstracts: Silicosis is one of the many occupational health anomalies that impair the pulmonary function of the mineworkers directly and people living in the surroundings of the mines indirectly. A continuous inhaling of silica dust and particles for a long period leads to this health hazard among the mineworkers and other people residing near mines. Silica dust is released from silica mines, gold mines, granite, tin, agate mines, and some chemical industries and affects the workers of these mines. This oldest form of pneumoconiosis has become a serious challenge to the scientific world due to its untreatable nature, however, this occupational fibrotic lung disease can be prevented with certain measures and precautions. The present paper discusses various studies conducted on the workers affected by silicosis.

Keywords: Silica dust; pneumoconiosis; Mineworkers; Airway Physiology; Immune System Disorder; Respiratory System Disease; Silicosis.

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Introduction

Occupation is a prerequisite for an individual to earn his/her bread and survive comfortably. The selection of a specific occupation rests on the socio-economic conditions and available opportunities to the individual. The purpose and outcome of the occupation regulate the health of the person involved in it. Therefore, occupation and health are inseparable and this relationship is broad and holistic that had been overlooked by the previous scholars for a long time[1]. The significance of occupational health has been envisaged in various WHO charters and declarations. The Ottawa Charter (1986), Adelaide Declaration (1988), Sundsvall Declaration (1991), and Bangkok Declaration (2005) have mentioned the significance of occupational health in promoting and achieving good health. These initiatives had enhanced research in occupational health that covers various areas like environmental health, lifestyle health, industrial health, etc. The possible health consequences of these

various areas include physical, ergonomic, chemical, and biological health problems. Mining comes under the industrial health problem. Several harmful & toxic materials exposed to mining affect the health of the mineworkers.

Mining, a process or industry to extract the mineral, involves several workers who are exposed to several toxic or harmful materials like fuels, fumes, reagents, chemicals, dust, noise, and particulate matter. Most of these toxic materials are harmful to the health of the workers who are constantly exposed to these toxins. Mining health issues are defined as "any disease or illness employees contact while employed as miners and which could be caused by mining activities."[2] In mine, the process of developing disease or illness is slow and it may take several months or years to manifest. Therefore the workers may constantly get exposed to the toxic or harmful agents for several years being asymptomatic. Many times they face health problems but due to ignorance or job insecurity, they do not mention their illness. This attitude of the workers kept them vulnerable to health hazards which may lead to fatality. Moreover, this attitude also emerges as a limitation to having substantial knowledge about health problems related to the mining workers and affects the research study.

Silica, a combination of silicon and oxygen, is the most abundant crystalline particle found on the earth's surface; which when inhaled by human breath causes a pulmonary health problem known as silicosis. Silica is primarily produced during mining.

Types of Silica

Commonly two types of silica are present in the environment, free silica, and combined silica. Combined silica (SiO2) is chemically combined with some other molecules or atoms, while free silica may occur as amorphous free silica, crystalline free silica, and fused free silica. Fused silica is produced by heating either the amorphous or crystalline forms of silica. The following diagram suggests the different types of silica present in the environment, especially in the mining environment.

An amorphous form of silica is found in a microscopic organism that lives in water, the skeleton of diatoms, and diatomaceous earth (rock/mineral formed from the shells of diatoms). The atoms of silicon and oxygen are not arranged in any particular pattern in amorphous silica, but these atoms are arranged in a repeating, three-dimensional pattern in crystalline silica.[3]

The present article reviews the studies done on silicosis to find out the prevalence of the disease in the national and international context. This review of the literature

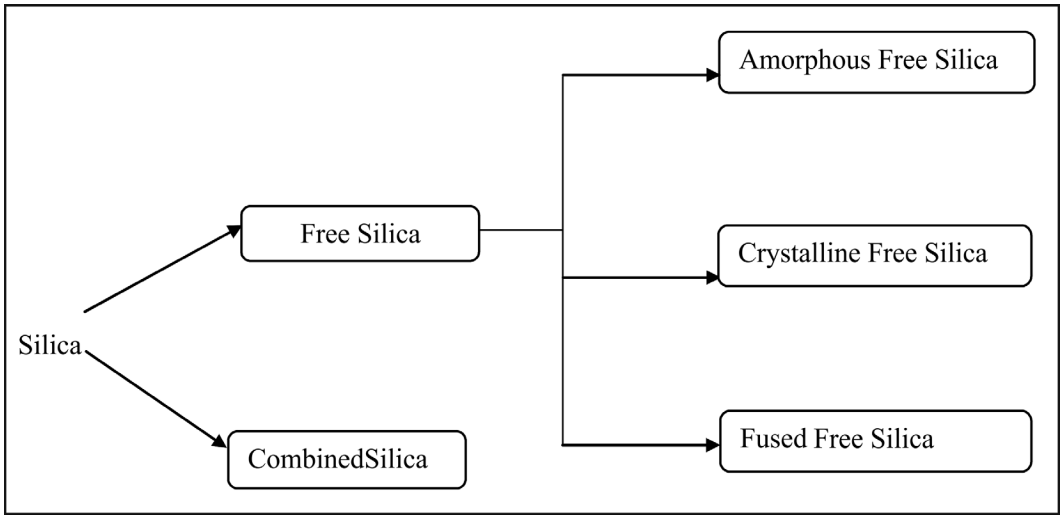

Figure 1: Types of silica present in the environment

will provide an understanding of the current situation of research on silicosis among mine workers. The following text discusses the meaning of silicosis, its physiology, the methodology of collection of data, and its impact on the workers.

Silicosis

Silicosis is the oldest form of pneumoconiosis that is an untreatable but preventable occupational fibrotic lung disease.[4] it is defined as 'pneumoconiosis caused by the deposition of silica particles in the lungs, exclusively from occupational exposures'.[5] the disease is a result of respiration, deposition, and retention of respired free crystalline silicon dioxide or silica dust. Continuous inhalations of crystalline silica (CS) for a longer time progressively evolve into lung impairment that leads to respiratory failure and death, even after the exposure has stopped. The development of silicosis is a chronic process that takes up to 10 years to develop, although acute or accelerated silicosis also occurs less frequently.

Silicosis becomes more hazardous to those workers who are exposed for a considerable time to silica while engaged in mining, quarrying, sandblasting, rock drilling and crushing, construction, demolition, repair, etc.[6,40] Other findings suggest that silicosis is also caused by hydro-fracking of gas and oil or exposure to quartz surfacing during construction and installation of stone in buildings.[7,8] The disease lacks effective treatment and patients rely on supportive care to improve their quality of life. In extreme cases, replacement of lungs remains the only choice

which is again very costly and beyond the budget of mineworkers and they suffer a painful death.

Historical Evidences of Silicosis

The history of respiratory diseases due to industrial exposures can be traced back to the ancient Roman era when Hippocrates first mentioned the case of breathlessness among the miners. Lohneiss (1960) mentioned that lung diseases among miners were caused by dust and stone particles. The disease caused by these dust particles was named "miners' phthisis" by Bernardo Ramazzini. Other names of the dust-related afflictions were 'mason's diseases', 'grinders asthma', 'stonecutter's disease' etc.[9] It was Visconti who used the term 'silicosis' in the 1870s for a disease caused by the inhalation of silica particles. However, the Hawk's Nest Tunnel disaster of the 1930s first signified the importance of silicosis in the public health domain. Since then a large number of occupations have been identified that cause silicosis.

The National Institute for Occupational Safety and Health (NIOSH) reported that between 1990 till 1999, about one-third of all patients with silicosis were employed in the construction and mining industries.[10]

Cause of Silicosis

During inhalation, different sizes of silica particles get settled in different parts of the respiratory system. 5-10μm size silica particles reach the upper respiratory tract, which leads to rhinitis and laryngitis. The 3-5μm size silica particles reach the middle respiratory system and can cause tracheitis, bronchitis, and bronchiolitis. 1-3μm size silica particles are stored directly in the alveoli, which cause other interstitial diseases, including asthma, Chronic Obstructive Pulmonary Disease (COPD), and silicosis.

The pathophysiology of chronic silicosis comprises chronic inflammation arising due to the accumulation of various inflammatory mediators and fibrogenic factors, pulmonary silicoproteinosis(acute silicosis) grows as eosinophilic proteinaceous substances that fill the pulmonary alveolar spaces.[11] the progression of the silicosis disease depends upon the rate of silica deposition and its retention in the lung. Silicosis may be associated with the development of some other diseases such as tuberculosis, cancer, or autoimmune disease. In silicosis, scars formed in the lung tissue decrease the ability to filter and extract oxygen from the air inhaled.[12]

Silicosis has been identified in various clinical and pathological categories including simple or nodular silicosis, silicoproteinosis (acute silicosis), complicated

silicosis (progressive massive fibrosis), and interstitial fibrosis. Silicosis is categorized into the following three major categories:

1. **Acute Silicosis:** Acute silicosis (AS) develops over a long period by inhaling large amounts of silica dust. Generally, people with acute silicosis may have stable health, although sometimes it may lead to a quick death.[13] Acute silicosis led to hypertrophic type II pneumocytes lining alveoli that produce commensurate proteinaceous material and surfactant protein in the alveoli.[14] The free radicals contained in silica generate an inflammatory response.[15] This type of silicosis is predominantly present among the miners working in sandblasting and rock-drilling.
2. **Chronic Silicosis:** This type of silicosis is the most common and occurs due to longer exposure to low levels of silica dust in the air. The inflammatory change in alveoli is due to prolonged exposure to CS results in the genesis of pulmonary fibrosis. The exact mechanism for this has not been explained, yet it is believed that it develops in the lungs when the alveolar macrophages' phagocyte silica particles clean the lungs. The phagocyting phenomena increase when a fresh silica particle enters the lung. Many a time these macrophages damage in the process of cleaning the lung. When a macrophage containing silica dies, the silica particles are released and they are re-engulfed by other alveolar macrophages, thus including a vicious cycle of injury and resultant inflammatory changes.[16] Chronic silicosis is further subdivided into simple chronic and complicated chronic.
    a) **Simple chronic silicosis:** In this type of silicosis, as the chest x-ray reveals, nuclear nodules are found in the lung, however, individuals are asymptomatic (the person is a carrier of a disease or infection). Long term exposure to silica dust can cause complicated silicosis.[13]
    b) **Complicated chronic silicosis:** This type of silicosis is also called progressive massive fibrosis (PMF). In this type of silicosis on a chest x-ray large nodules can be detected. Some individuals may still be asymptomatic or early symptoms that may include shortness of breath, exercise, wheezing, or sputum, which causes cough.
3. **Accelerated Silicosis:** This type of silicosis is caused by the large amounts of silica dust exposed for a shorter period and can progress quickly. In it, after the first five-year exposure to silica dust, the scars of the lung can be detected sooner and nodules appear on chest x-ray.[13]

Proper preventive practices and management at the workplace have helped to reduce both the morbidity and mortality of silicosis in the last few decades but these

cure and prevention are not very promising due to the lack of adequate information on silicosis-related health problems at the level of scientific communities and policymakers.[4] Health surveillance or survey of the mineworkers provide significant information about the prevalence of disease and its possible prevention and cure to the workers by identifying the patients at an early stage. The patients can be brought under health surveillance as World Health Organisation (WHO) suggests that the workers exposed to CS should undergo lifelong health surveillance.

Mining is considered to be one of the most fatal occupations that cause silicosis. From 1968-to 2002 silicosis claimed approximately 74 million lives in the U.S. alone. There is an unavailability of worldwide data on the morbidity and mortality caused by silicosis. Occupational Safety and Health Administration (OSHA) estimated that more than 2 million employees are exposed to silicosis in general industries, construction, and maritime activities. However, it does not specify the number of patients in different sectors. Moreover, the U.S. Bureau of Mines claimed that almost all mining operations involve the production of silica particles.[17] Therefore, the highest mortality due to silicosis is documented in the miners or the areas associated with mining. This review incorporates a few relevant studies that took account of the cases of silicosis related to mining. There are different types of mines in the world, such as gold mines, granite mines, tin mines, agate mines, silica mines, etc. Most mines and chemical industries release silica in the air which is inhaled by the mine or industrial workers. Due to long exposure to silica particles, the workers suffer from silicosis. The following review gives a glimpse of the types of mines associated with the development of silicosis and their findings:

Gold Mines

Hnizdo *et al.*[18] in 1990conducted along term exposure study at White Gold mines in South Africa. In which a combined effect of the gold mining dust with high content of free silica and tobacco smoking were studied. In this study, they analysed the physiological parameters like forced expiratory volume in 1 second (FEV1), vital capacity (VC), and forced expiratory flow between 25 and 75 percent of FVC (FEF25-75%) and the spirogram pattern. The subjects were grouped based on their respiratory function as having normal, minimal, moderate, or marked obstruction with restriction, and pure restriction based on their lung function profiles. Each profile group was compared with the normal group for exposure prevalence. They found that approximately in 94% of the cases the miners became infected with

silicosis, and the severity of respiratory dysfunction would increase in case of additional smoking.

In another study, Water Naude *et al.*[19] in 2005 found that the longer exposure to silica dust had resulted in pulmonary tuberculosis (PTB). The drillers and winch operators had the highest PTB prevalence and the highest silica dust exposures in comparison to other mine workers. A cross-sectional study was conducted on 520 South African miners over 37 ages of years in Cape Town, where analysis of chest radiographs of the workers was done.

In another study, conducted by Ehrlich *et al.*[20] in 2011 in Cape Town where they estimated exposure-response relationships between respirable clouds of dust, respirable quartz, and lung function loss in black South African miners. Using the same physiological parameters in addition to observation on Chest radiographs, they found that the longer exposure to silica dust resulted in reduced forced vital capacity (FVC), accompanied by diseases like Tuberculosis and Silicosis among the gold miners.

Recently Milne *et al.*[21] in 2013 found that the amount of silica dust retained in the lung is related to the presence and severity of silicosis. The study aimed to investigate the quantity of silica in the affected lung of the gold mine workers in Johannesburg. Microscopic observation of the affected lung revealed that 70% of the studied miners suffered from silicosis.

Granite Mines

Granite is intrusive igneous rock. It is high in quartz (about 25%) feldspar, and mica. Ng and Chan[22,]1992 conducted a study at a granite mine in Singapore. Based on a group of granite quarry workers, this study was undertaken to determine whether simple silicosis was linked to the destruction of lung function. They used the same physiological parameter in addition to personal interviews, and radiographic examination of the chest X-ray also. It was found that chronic simple silicosis is not a benign disease, although silica exposure is the primary cause, lung function in silicosis is directly responsible for fibrotic lung disease.

In another study Malmberg, *et al.*[23] in 1993 conducted a 12-year follow-up (from 1976 to 1988) study on changes in lung function of granite crushers exposed to moderately high silica concentrations. They had studied 63 granite crushers who were more than 52 years old and had worked in these fields' for22 years in granite mines in Sweden. In addition to the parameter mentioned in the above paragraph, they measured total lung capacity (TLC), residual volume (RV), maximal voluntary

ventilation (MVV), and vital capacity (VC). They found that exposure to silica at concentrations of about twice the normal was associated with airway obstruction and loss of elastic recoil rather than fibrosis and a restrictive function loss as seen in silicosis.

A similar study was conducted by Vacek, *et al.*[24] in 2011 in the US (Vermont). After analyzing the mortality data of granite workers from the hospitals, it was found that exposure to crystalline silica among the Vermont granite workers, morbidity increased with silicosis and other non-lethal respiratory diseases. But, there was no evidence of an increase in the mortality rate of lung cancer in the cohort due to exposure. Mortality from malignant and non-malignant kidney disease was not found to be increased or associated significantly with silica exposure.

Another study was done by Rice *et al.*[25] in 2001 on Quartz mining, in California. They tested the same physiological parameters as measured by Hnizdo *et al.*[18]in 1990. They found that the risk factors for lung cancer are significantly associated with silicosis.

In India Chaudhary *et al.*[26] in 2010 conducted a cross-sectional study among 123 clinically suspected cases over six months on Agate stone polishing industries in Gujarat. For many decades several small agate stone polishing units were operated by the individual houses in the Shakarpur area of Khambhat city of Gujarat (Census of India, 1960). They measured the same parameters used by Hnizdo *et al.* (1990) and in addition to that X-rays plate of the patients involved were also examined and analyzed. It was found that nearly 70% of miners were affected by silicosis without any discrimination in gender. This study also claimed that for every extra year of exposure, the odds of getting silicosis increased by about 12%. In conclusion, they said that agate stone workers contacted diseases like Silicosis and tuberculosis.

Chemical Industry

Choudat *et al.*[27]in 1990 conducted a study on the Chemical industry located in Paris, France. They tested the same physiological parameters along with chest radiographs and blood gas concentration. Respiratory problem was found not to be significantly associated with exposure index but smoking was found to be a worsening factor for silicosis and pulmonary fibrosis.

A similar study was taken up by Yassin *et al.*[12] in 2005 on US Industrial and Mining Plant. They analyzed airborne silica dust exposure levels and frequency of silicosis among U.S. workers by using the Occupational Safety and Health Administration (OSHA) database. OSHA has estimated that more than two million workers are

exposed to crystalline silica dust in the general, maritime, and construction industries.[28] Though the respiratory problem was not significantly associated with exposure index but smoking was found to be a worsening factor for silicosis.

Tin Mines

Chen *et al.*[29] in 2001conducted a study on the Tin miners, in China.It was a cohort study of 3010 miners. The work history of each worker was abstracted from the complete employment records of their files. They found that 33.7% of miners were identified with silicosis having a mean age of 48.3 years and a mean age of 21.3 years after first exposure. Among those who had silicosis most of them (67% of miners), developed silicosis after exposure ended. In this study, a clear exposure-response relationship was found for silicosis.

Adopting a different approach Calvert *et al.*[30] in 2003 conducted a study using death certificates from 27 states of the United States (Columbia Parkway). Using secondary data from the UN National Occupational Mortality Surveillance (NOMS) system, they examined the incidence of diseases like silicosis, lung cancer, stomach cancer, Oesophageal cancer, pulmonary tuberculosis, rheumatoid arthritis, and various type of renal disease, etc. over fourteen years (1982 to 1955). They also investigated whether silicosis had a higher risk of disease compared to others. They analyzed 4839231 (68%) out of 7153468 death certificates in the NOMS database. The study reasserted that the greatest crystalline silica exposure had a significantly increased risk for silicosis, lung cancer, COPD, and pulmonary tuberculosis.

Status of Silicosis in India:

Large numbers of mining industries are found in India. These mines are located in Chhattisgarh, Jharkhand, Orissa, West Bengal, Madhya Pradesh, Rajasthan, Gujarat, etc. In 1999, the Indian Council of Medical Research (ICMR) reported that around 3.0 million workers are at high risk of exposure to silica; of which 1.7 million workers are in mining or quarrying activities, 0.6 million in the manufacture of the non-metallic product (such as refractory product, structural clay, glass, and mica) and 0.7 million in the metals industry. There are also around 5.3 million construction workers at risk of silica exposure. Due to variations and duration of exposure to silica concentration in the working environment the prevalence of silicosis in India ranges widely from 3.5% among 1977 workers in an ordnance factory to 54.6% among 593 workers in the slate-pencil industry[31]. The following paragraphs review studies conducted on silicosis in India.

Tiwari *et al.*[32] in 2010 conducted a study on quartz at the crushing site of Gujarat. They used chest radiography tests and pulmonary function tests as physiological parameters. In the study, 24.7% of workers were detected with silico-tuberculosis while 18% were detected with silicosis only. They found retired workers had higher respiratory morbidity than the present workers due to the longer exposure among the former.

Athavale *et al.*[33] in 2011 conducted a study on the flour mill worker. A detailed clinical and occupational history, chest x-ray, and high-resolution computed tomography (HRCT) were used to evaluate the health status of the flour mill worker. The study shows that the incidence of silicosis in flour mill workers working with silica-containing grinding stones was 30.4%. They had high respiratory morbidity (93%) cough and dyspnoea was the predominant symptom. Duration of exposure correlates with radiological findings and increased incidence of silicosis. Sometimes, negligence to the safety measures and unawareness about the development of silicosis by the mining works are found to be a major hindrance to preventing silicosis.

Yadav *et al.*[34] in 2011 conducted a study on stone quarry in Rajasthan to understand the knowledge and attitude of the miners on silicosis. They found nearly 40% of miners were aware of the silicosis and its impact but due to the absence of safety measures they were helpless. They found that most long exposure workers suffer from silicosis disease.

Sivanmani *et al.*[35] in 2013 based their study on hospital data in Coimbatore, Tamil Nadu. They found that most of the patients with silicosis were from different sectors. The absence of awareness and preventive measures was found to be a major cause of the development of disease. In 59% of the patients, spirometry showed a restrictive pattern.

Ahmad *et al.*[36] in 2014 survey for four years on the health status of the workers of mines and quarries at Jodhpur, Rajasthan. They found that nearly 73% of workers have claimed that they had silicosis and tuberculosis.

Panchadhyayee *et al.*[37] in 2015 conducted a study on gold jewelers of West Bengal. They analyzed of health reports of jewelers and reported that silicosis was more severe among the jewelry workers as compared to other occupational workers. Jewelry workers developed silicosis after an exposure of 10 years or more.

A recent case was undertaken by Gobindaraj *et al.*[38] in 2016 in Pondicherry on a forty-five-year-old stone quarry worker who had worked for twenty years in a mine. He had no co-morbid illness (two or more illnesses occurring in the same person), chronic dry cough, and breathlessness on exertion of six months duration. The diagnosis was established by occupational history and radiological features

[chest HRCT (High resolution computed tomography)]. Avoidance of further exposure, using personal protective measures, periodic medical check-ups, and strict legislation to protect employees and a system to check compliance should have ensued.

A recent study was conducted by Shamim *et al.*[39]in 2017 in Karauli, a district located in the eastern part of Rajasthan. This study was an epidemiological cross-sectional survey. This study was conducted by the NIMH (National Institute of miners Health). They found that 74% of the miners were suffering from silicosis. According to PCBs (Pneumoconiosis Medical Board) Medical & Health Services, the Government of Rajasthan numbers of silicosis cases (total of 3344) were found in Bharatpur during the year of 2015-2016.

Conclusion

This review reveals that silicosis is a major health concern among mine workers. Some mines produce silica as their main product like in silica, granite, and cement mine, and others as a by-product like in gold, tin, and agate mines. The severity of the diseases depends on the duration of exposure to silica dust. Longer the duration more severe the problem. It was also found that silicosis has developed in other pulmonary problems like tuberculosis, COPD, and cancer. There is a lack of holistic understanding of the prevalence of silicosis among the workers. The above-mentioned studies ignored the socio-economic factors and were limited to documentation only. There is a need for studies that takes a broader and holistic approach to understanding the aetiology of the disease and its preventive mechanism. Since 1995, WHO and the International Labour Organisation (ILO) have initiated an awareness campaign to eradicate silicosis in its all form by 2030. Many nations namely Brazil, China, Indonesia, Malaysia, Poland, Mexico, South Africa, Thailand, Turkey, Chile, Bolivia, and Venezuela, have implemented policies to eradicate silicosis, while others like India are yet to adequately implement such policies[31].

In India silicosis is a large problem that has not been handled well. Most of the research is based on the hospital record. The studies suggest that poor preventive measures and socio-economic status are other challenges to handle silicosis. In India, most of the silicosis patients are from unorganized industries where no preventive measures are taken thus leading to a higher rate of silicosis. Moreover, very few studies incorporate spirometry data to analyze the prevalence and severity of silicosis among miners. There is a dire need to do a study on miners to document

the silicosis among them and to draft occupational health policy accordingly. This initiative needs more research and studies on silicosis to find out the right approach to meet the target.

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