Analyzing the Impacts of Soapstone Dust on Respiratory System of Mine Workers Through Structural Equation Modelling Technique: A Case Study of Sherwan Soapstone Mines, Abbottabad, Pakistan

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Dust produced in mining has a substantial impact on worker's health resulting in severe respiratory diseases. Researchers mainly focused on the dust problems faced in surface mining whereas the dust produced in underground soapstone mines has received comparatively less attention. This study evaluates self-reported respiratory symptoms and medical examinations of underground mine workers in soapstone mines. It establishes a relationship between the respiratory illness factors and its symptoms, providing new insight into the analysis. Demographic and other respiratory symptoms-related data is collected through questionnaires from underground soapstone mine workers, located in the Abbottabad area, with medical data from 60 of these workers obtained through medical examinations. The collected data is subsequently analyzed using Structural Equation Modelling and regression analysis to investigate the relationship between the evaluated factors in the dust analysis. The dust assessment shows that it is primarily composed of silica, with small particle sizes that are smaller than the threshold limit value and pose a risk of silicosis. The questionnaire data indicates that about 75% of workers exhibit symptoms of respiratory diseases, the majority of them are laborers and old age workers whereas the medical examinations revealed that 80% of workers are affected by lung infections. The Structural Equation Modelling demonstrates that dust inhalation has a stronger effect on symptom occurrence ($\beta = 0.485$, $p < 0.001$) compared to dust severity ($\beta = 0.207$, $p < 0.05$). These results are concerning and underscore the need for interventions, and the adoption of adequate respiratory protection measures for safeguarding the health of workers.

Keywords: Dust Inhalation, Severity, Respiratory Symptoms, Medical Examination, and Structural Equation Modelling.

Introduction:

Soapstone is one of the most important industrial minerals used in rubber, paper, pharmaceutical, and cosmetic industries. Sherwan, located in the district of Abbottabad, Pakistan, holds an estimated 20,000 tons of soapstone reserves. Initially, surface mining was used to extract the soapstone. However, as the mines became deeper and surface mining was no longer feasible, underground mining methods were adopted [1]. In addition to being a valuable industrial mineral, soapstone mining, like other mining sectors, is fraught with numerous hazards. It is estimated that approximately 12,000 workers globally lose their lives each year due to fatal accidents and occupational diseases related to mining activities [2].

According to the Pakistan Coal Mine Labor Federation (PCMLF), more than 100,000 laborers are working in coal mines in Pakistan [3], majority of them are unaware of the hazards in mining. Consequently, hundreds of laborers die in the coal mines of the country every year. Besides other hazards, dust is also one of the major problems associated with the mining industry, causing severe lung diseases in the workers. Inhalation of dust produced in mines causes' respiratory diseases like Coal Worker's Pneumoconiosis (CWP), Silicosis, Fibrosis, Asbestosis, and Talcosis [4]. There is a strong relationship between respiratory diseases in mine workers and dust exposure. Research reveals that about 11% of asthma and 13% of total Chronic Obstructive Pulmonary Disease (COPD) are caused by inhalation of dust produced in mines by workers [5].

Soapstone is a silicate family mineral having the chemical formula $\mathbf{Mg_3Si_4O_{10}(OH)_2}$ but its chemical and physical properties are quite different from other silicate family minerals [6]. The variation in properties is primarily attributed to differences in crystalline structure. The structure of talc is two dimensional in which magnesium ion is sandwiched between two silica sheets held together by weak forces. Metals like nickel and iron present in talc are bound with other particles that cannot be exerted by any biological action [7][8]. The composition and physical properties of talc dust are directly related to the source of talc and other minerals found in the ore body. Sulfide, quartz (free silica), iron oxide, and other silicate minerals are associated with talc. As serpentine is derived from soapstone, therefore it may also be an associated mineral, and traces of serpentine may be available in talc dust as well, Tremolite, a member of the amphibole group, and chrysotile a member of the serpentine group, are most common particles in industrial dust. Industrial talc is selected for different industries based on desired properties and composition, which does not contain pure talc, but a variety of minerals are available in its composition [9].

It is noted that major research work is carried out in underground coal mining and surface mining, but the problems associated with soapstone dust especially in the Sherwan area, are rarely addressed properly. However, pulmonary diseases in soapstone mine workers at Sherwan are increasing at a high rate. Also, the value of dust produced at soapstone mines Sherwan is much higher than their Maximum Allowable Concentration (MAC) value w which includes some harmful ingredients like silica and magnesium oxide [10]. Therefore, it is essential to thoroughly investigate the dust generated at soapstone mines and assess its impact on workers' health. For this study, the Sherwan area located in Abbottabad, Pakistan, was selected. In this research work, the soapstone mine dust samples were analyzed thoroughly, the workers were medically tested for possible symptoms of any lung disease caused by the dust produced at different dust-producing locations in the mines. The data was collected through a questionnaire, mainly addressing the dust and associated issues due to dust inhalation. The data is carefully analyzed, and the results are compared with the standard conditions of the mine.

Methodology:

This research is accomplished by collecting data from labor, medical examination of labor, collection of dust samples, analyzing the dust for possible health impacts on the workers, and then comparing the dust analysis results with the medical examinations of the labor. The data from the labor was collected through the following steps (Figure 1):

- Dust samples analysis
- Data was collected from labor through a questionnaire.
- Medical Examination of the workers.
- Analysis with SEM technique

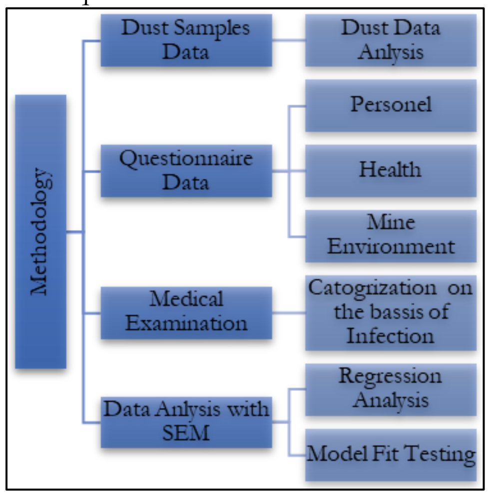

Figure 1: Data Collection Flow Chart.

Dust Sample Analysis:

In this research, dust samples were collected using an IOM dust sampler, and qualitative analyses were conducted, including chemical analysis, elemental analysis, and particle size and shape analysis through X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDS), and scanning electron microscopy (SEM). According to Jaleel & Raza, XRD results revealed that soapstone dust from Sherwan mines consists of 57.53% Silica, 29.35% Magnesium Oxide, 3.37% Aluminum Oxide, 2.90% Calcium Oxide, 1.74% Iron Oxide, and 5.11% moisture [10]. This composition suggests a higher risk of silicosis, a severe and potentially dangerous disease. Further, the authors [10] reported that the Elemental analysis gave a predominant concentration of Silicon in the samples, as the EDX test revealed that soapstone dust is composed of elements like Carbon 8.52 %, Oxygen 51.8 %, Magnesium 16.07%, Aluminium 0.52%, Silicon 23.23%, Calcium 0.17% and Iron 0.41%, while morphological study of the soapstone dust indicates that the particle size of soapstone dust is in the range of 1.273 µm and 2.909 µm and have platy shape with irregular edges. According to Davda (2023), typical inhalable dust particle size is less than 100 µm, whereas less than 10 µm sized dust particles are respirable and penetrate deep into the respiratory systems and lungs causing serious lung issues such as silicosis and lung cancer [11]. From this, it can be concluded that the dust produced in the soapstone mines of Abbottabad is inhalable and respirable. The sharp edges of the particles also cause severe damage to the lung tissue and may cause serious health consequences to the workers. Therefore, to assess the influence of dust on the soapstone workers, this section demonstrates and thoroughly discusses questionnaire data on self-reported respiratory symptoms as well as the results of medical examinations of workers. Further, the Structural Equation Modelling technique is applied to find the relationship between the factors.

Questionnaire Data Collection:

As discussed earlier, besides analyzing dust, the workers' data is collected through a questionnaire (Appendix A). The questionnaire is divided into four parts. In the first part, the worker's biographic data such as name, address, age, nature of work, and exposure to soapstone dust, was collected whereas in the second part, the data regarding their health conditions and any possible symptom/s of pneumoconiosis is analyzed. In the third part of the questionnaire, the workers were asked about the mine working environment such as dust production, preventive measures taken, and impact of dust. The final and fourth part of the questionnaire is about their family background to find any genetically transferred medical issue.

In this way, approximately 200 workers, each with over 3 years of work experience and aged between 18 and 60 years, were surveyed using the questionnaire. The data is then correlated with the medical examinations of the workers. A detailed analysis of both sets of results is presented in the Results and Discussion section of the research.

Medical Examination of Workers:

To detect any infections resulting from soapstone inhalation in mine workers, medical examinations were performed, including chest X-rays and physical check-ups conducted by a qualified medical practitioner. About 60 workers were selected from those whose data was collected through questionnaires. They were selected randomly based on the severity of the lung's disease symptoms i.e., some of them had severe symptoms whereas the others had mild and or no symptoms of pneumoconiosis. The medical officer thoroughly examined the workers and their chest X-rays and categorized their health conditions into severe, moderate, mild, or with no infection.

The data obtained from the questionnaire, personal observations, and medical examinations, is thoroughly analyzed with SPSS v25. The structural equation modeling technique is applied to examine the relationship among the factors analyzed in the dust analysis, which in turn aids in suggesting preventive measures, as detailed in the following sections.

Results and Discussions:

Analysis of the Questionnaire Data:

As mentioned earlier data was collected through a questionnaire also, in which the information was obtained from the workers and concerned officials. The questionnaire was divided into four parts. The results obtained from the questionnaire are analyzed in the following sections.

Health Conditions of the Workers:

In the questionnaire, the workers were asked about any symptoms of pneumoconiosis-like cough, shortness of breath, chest pain, sneezing, and fever. The symptoms were categorized based on severity i.e., very severe (>75%), severe (50-75%), slightly severe (25-50%), and no symptoms (0%). The data revealed that 18.5% of the workers were suffering from cough problems, 10.5% from chest pain, 18% from shortness of breath, 15.5% had sneezing and 22.5 % of the workers faced fever symptoms frequently (Table 1).

Table 1: Respiratory symptoms in workers

S. No	Symptoms	Percentage
1	Cough	18.5
2	Chest pain	10.5
3	Shortness of Breath	18
4	Sneezing	15.5
5	Fever	22.5
6	No symptoms	15

The data further revealed that the percentages mentioned above come under the slightly severe symptoms category i.e., the majority of the workers have slightly severe or no symptoms. Therefore, all workers, including those who currently have no respiratory complaints, should not be overlooked. They may have early-stage chest issues that are not yet noticeable. Figure 2 shows respiratory symptoms in the mine workers with severe lung problems symptoms which are very rare in mine workers. According to the collected data, 4.5% of workers have a severe cough, 1.5% severe chest pain, 2% shortness of breath, 0.5% sneezing, and 1% are suffering from severe fever conditions. It can be concluded that the majority of the workers complain about slightly severe symptoms, whereas severe and very severe symptoms are very rare. A possible reason for this could be that younger workers (aged 18-30) may not experience symptoms at an early age. However, after several years of working, particularly once they are over 30, they might begin to develop lung issues. As the condition worsens, they may eventually stop working in the mines. Hence, workers with severe health conditions already quit their jobs. Similarly, among the interviewed workers, persons with chest pain complaints are more than those with fever symptoms.

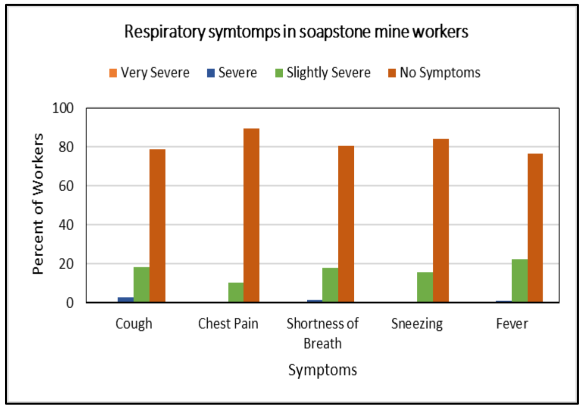

Figure 2: Respiratory Symptoms in Mine Workers

Medical examination in the following section will yield the exact information about the respiratory problems of the mine workers.

Work Nature VS Respiratory Symptoms:

Based on the worker's occupations, they were divided into eight categories i.e., general labor, and workers involved in screening, loading, drilling, installing support, blasting, cutting, and transportation. The general labor involved in all operations inside the mine includes drilling, blasting, loading, and transportation therefore they are affected mostly by inhalation of the dust. Due to the confined and limited space inside the mine, where air movement is minimal, workers are exposed to high levels of dust for prolonged periods. The second most affected occupation is screening, which involves extensive material handling and is performed for a significant portion of the shift (80%). Drilling, while being the most dust-producing operation, has the least reported chest issues, affecting only 2.5% of workers. This is likely due to its shorter duration (12.5% of the shift) and the use of protective masks during the process. Additionally, managerial staff are less affected by dust compared to laborers, as they are not directly involved in the mining operations.

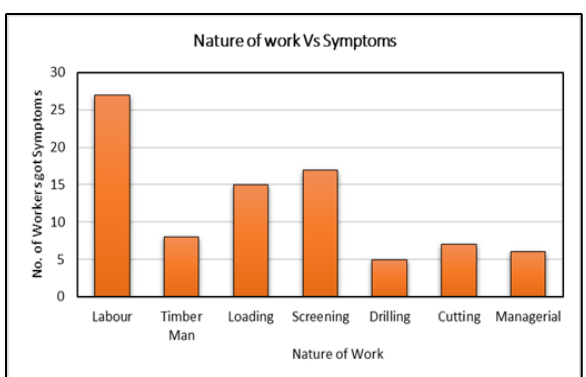

Figure 3: Work Nature Vs Symptoms.

Dust Exposure Duration Vs Respiratory Symptoms:

The data analysis revealed that there is a direct relationship between the duration of dust exposure and respiratory symptoms shown in the graph, which is obvious (Figure 4). A crucial observation is that respiratory disease symptoms typically begin after approximately four years of work experience, escalating to a severe stage—affecting nearly 100% of workers—by around

22 years of employment. Beyond this point, the prevalence of severe symptoms tends to decrease. It can be seen from Figure 4, that no symptoms are reported from 26 to 29 years experienced workers. This observation supports the earlier statement that workers often leave their jobs after approximately 22 years due to deteriorating health. Additionally, workers with over 29 years of experience show an increase in lung-related symptoms, which reach a severe level (nearly 100%) by the time their work history extends to 32 years. The possible reason for this decline could be the discontinuity of jobs by the affected workers and continuity of least or unaffected workers which are saved from the dust hazards so far. However, with continued work and prolonged exposure to dust, their health begins to deteriorate significantly once they reach 32 years of work experience.

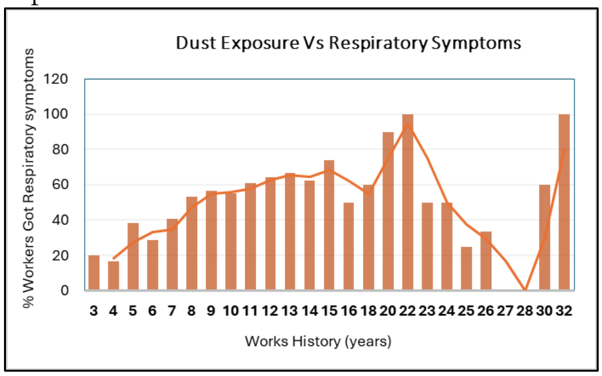

Figure 4: Dust Exposure Vs Respiratory Symptoms.

Age Vs Respiratory Symptoms:

Figure 5 shows the relationship between age of the workers and respiratory symptoms. It can be observed from the graph that workers start working at 18 years of age. Most of the symptoms start in the workers as they reach their ages ranging from 21 years. There is a slight increase from 33 to 48 and reaches to maximum value at ages 51 to 60 years. From the data, it can be concluded that slightly severe symptoms appear at a young age, which becomes severe at mid-age and gets complicated in old age. If the age of the worker is correlated with work experience, then it can be seen that at 21 years of age, workers have 3 years of experience and symptoms appear at this age. At mid-age they have 10 to 15 years' experience and severe symptoms and at old age 20-to-25-year experience and complicated stage of respiratory symptoms. From this, it can be concluded that respiratory problems are associated with the work in the mines. Hence, special care should be taken to work in the mines, which will be suggested at the end of the paper.

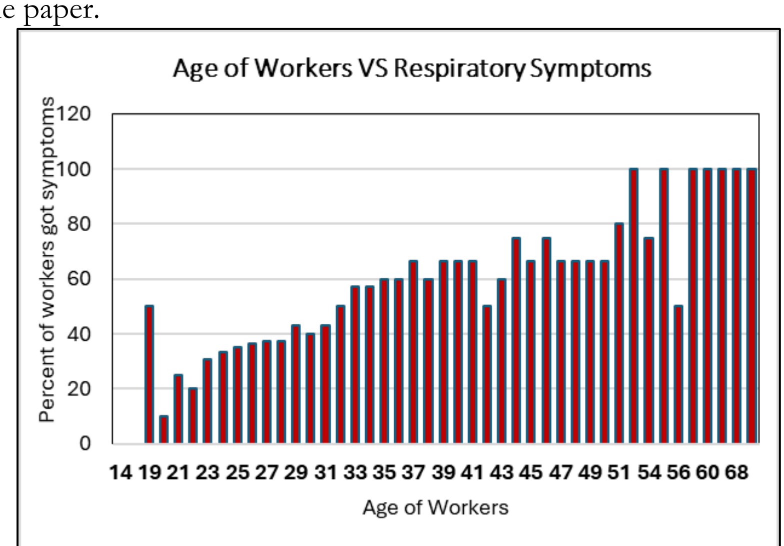

Figure 5: Age of workers vs. respiratory Symptoms.

Mine Environment Investigation:

Mine workers were asked about the mine environment, working conditions, dust production sources, and severity of dust. Based on their experience, their answers are summarized in Table 2. According to 39% of workers, drilling and blasting, 31 % of workers only drilling, 10 % of workers only blasting, 10% of workers screening, 9% of workers loading, and 1% of workers timbering is the main cause of dust production in mines. It can be concluded from this data that drilling is the major source of dust creation which confirms the dust samples quantification analysis already discussed.

Table 2: Sources of Dust Production.

S. No	Operation	% Sources of Dust
1	Drilling & Blasting	39
2	Drilling only	31
3	Blasting only	10
4	Screening	10
5	Loading	9
6	Timbering	1

Table 3 depicts data collected by asking questions regarding the severity of the dust in their duty times. Among these 3% replied that there is no dust (0%), 80% replied there is slightly severe dust in the soapstone mine (<50% of the air), 17% replied dust is severe (>50% of the air) and no worker replied as very severe (100% of the air) dust produced inside the mines (Table 3). This confirms that most of the workers are complaining about dust in their workplaces effects of which need to be reduced properly.

Table 3: Severity of Dust

S. No	Dust	% Workers
1	No Dust	3
2	Slightly Severe	80
3	Severe	17
4	Very Severe	0

The data revealed that 4% of workers wear protective dust masks full time (100% of the shift), 41% of workers wear them maximum time (>50% of the Shift), 28% wear them some time (<50% of the shift) while 27% did not wear protective (Table 4). It was observed that most workers often neglected to wear their masks properly. Although only 27% of workers admitted to not wearing masks during work, this number likely underrepresents the actual rate of non-compliance.

Table 4: Use of Dust Mask.

S. No	Use of Dust Mask	% Workers
1	Full time	4
2	Maximum time	41
3	Sometime	28
4	Not Wears	27

Workers were asked about the availability of PPEs, which revealed that safety helmets are available to 80% of workers, safety shoes to 46% of workers, and dust masks and gloves to 58% of the workers. In response to questions about dust suppression mechanisms in the questionnaire, 59% of workers reported using water spraying, 24% indicated that no dust suppression methods were applied, and 17% provided unclear or incomplete answers.

Personal / Family Investigations:

- The final section of the questionnaire focused on personal and family health, covering topics such as respiratory diseases within their families, other health issues, current medications, and smoking habits. The collected data is summarized below. About 4% of workers have other diseases than respiratory disease.

- 3 % of workers have lung diseases in their families.
- 4% of workers are smoking.

From the data, it can be concluded that respiratory diseases in the families of the soapstone mine workers are very less so the infection from the families is very less. Hence majority of the chest/lung issues faced by the soapstone workers in the area are due to the inhalation of the soapstone dust.

Medical Examination of Mine Workers:

Among the interviewed workers, around 60 persons were selected for medical examinations. Their chest X-rays were taken which were examined by a medical practitioner to find any infection caused by inhalation of soapstone dust. The medical officer physically examined the workers as well. Based on infection in their chest X-rays: the dust impacts were categorized into severe, moderate, mild, and no infections. According to the medical practitioner out of 60 X-rays, 4 had severe infections, 19 had moderate, 25 had mild and 12 had no infection in their lungs.

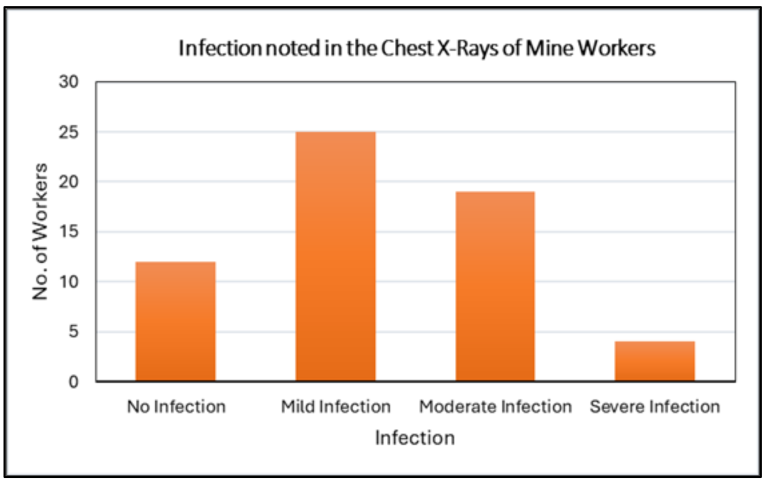

Figure 6: Chest Infection in Mine Workers.

From the examination of chest X-rays, it can be concluded that the majority of workers (80%) have infections in their lungs varying from mild to severe infection. An interesting observation during the medical examinations was that some workers had mild to moderate infections but reported no respiratory symptoms. This indicates that the disease is asymptomatic in its early stages, with symptoms only emerging as the infection progresses and becomes more severe. The graph in Figure 6 reveals that most workers had mild infections while few have severe infections which indicates that initially, every worker gets a mild infection, but when the symptoms appear they get treatment or quit a job, that's why a smaller number of workers get severe infection. Based on these results, it can be concluded that almost every worker gets an infection, but it is not noticeable by the worker at the initial stage and the infections get severe and their symptoms appear then they start treatment. Hence, it is recommended the workers take proper measures and they should regularly examine their health conditions so that the disease can be properly treated on time. From the physical examinations and chest X-ray analysis, the infections were divided into the following categories.

Severe Infection:

In severe infection, 50-75% part of the worker's lungs are damaged, especially the upper and middle lubes of their lungs (Figure 7). The data collected through the questionnaire indicated that severe infection was found in those workers whose ages are above 40 years and whose work experiences are more than 17 years.

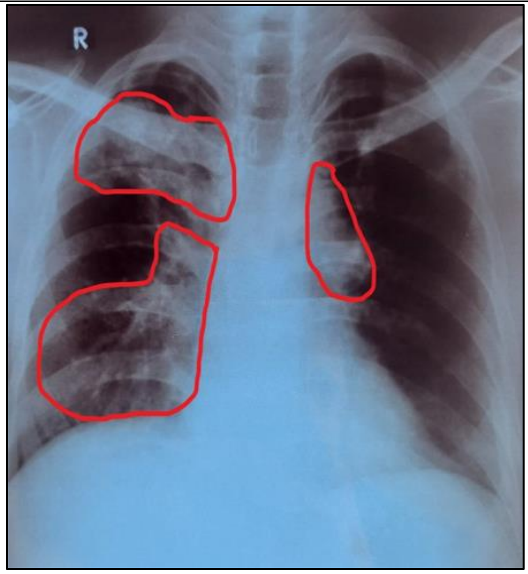

Figure 7: Severe lung Infection in Mine Workers.

Moderate Infection:

In moderate infection about 25-50% part of a worker's lungs is affected by infection (Figure 8). Moderate infection is found in workers who have work experience from 6-15 years and ages from 25-50 years. In moderate infection the white dots on the X-ray got enlarged and from a lengthy node. According to the questionnaire data, the highest occurrence of symptoms appears after 22 years of work experience.

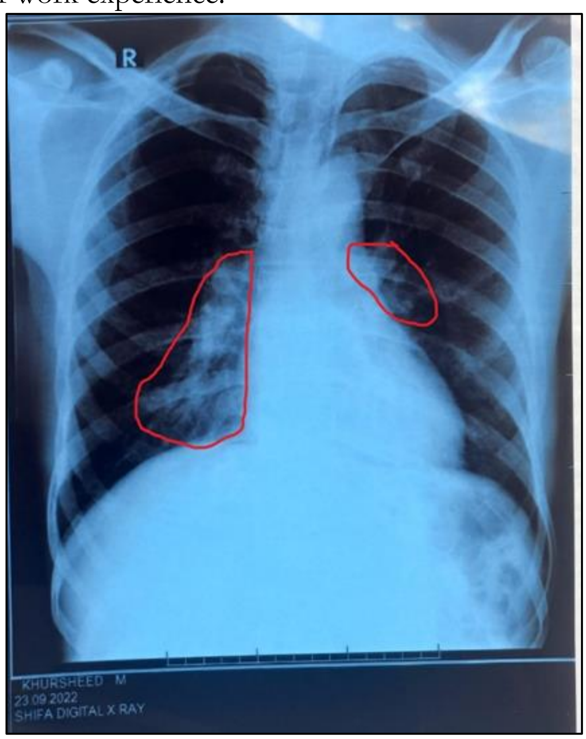

Figure 8: Moderate Infection in Mine Workers Lungs.

Mild Infection:

In mild infection up to 25% part of workers,s lungs are affected by infection caused by soapstone (Figure 9). Mild infections were found in workers with more than 4 years of work experience, particularly those aged between 20 and 40 years. Initially, it can be seen as white dots in X-ray but with time, the white dots enlarge and become a moderate infection. The majority of the workers have mild infections in their lungs also found in the chest X-rays of those workers who don't have respiratory symptoms at all, which indicates that the mild infection is asymptomatic.

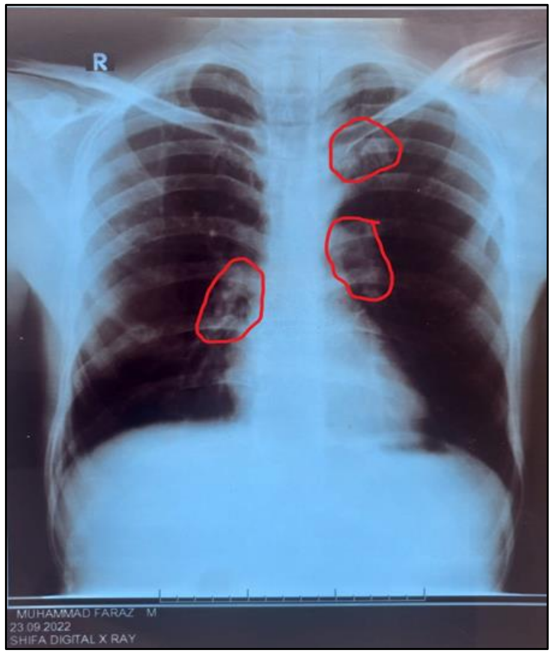

Figure 9: Mild Infection in Mine Workers Lungs.

Analysis with Structural Equation Modelling Technique:

Structural Equation Modelling (SEM) is used to understand the relation among the factors. SEM encompasses both latent and observed variables, where observed variables are directly measurable, while latent variables are inferred from the observed ones, often through confirmatory factor analysis (CFA) [12]. In this study, SEM is utilized in two modeling stages: the measurement model, also known as CFA, and the structural model [13]. In CFA, we determine the number of factors in the dataset and measure variables related to latent factors [14]. Each indicator variable in the model's CFA is associated with its specific latent variable.

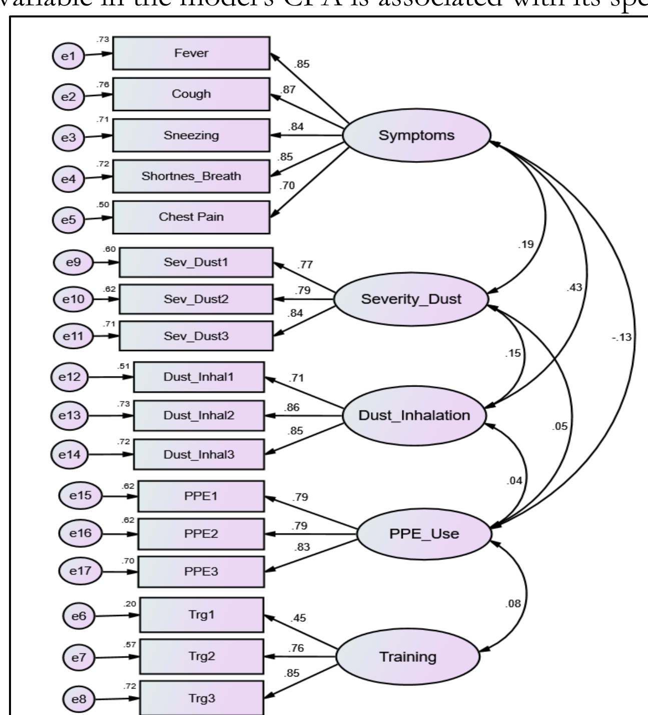

Figure 10: Measurement Model

The findings of the measurement model indicate that all potential causes of respiratory disease-related health issues, including the severity of dust in mines, dust inhalation, the use of PPE, and worker training, were investigated to assess their relationship with symptoms of illness due to dust exposure. These symptoms include coughing, sneezing, fever, shortness of breath, and chest pain among mine workers. All the factors showed significant connections with each other, demonstrating how they interact within the context of a mining environment except training in this case. The utilization of PPE demonstrates an inverse relationship with symptom factors, suggesting that as the use of PPE increases, symptoms of illness decrease. Conversely, as dust inhalation and the severity of dust increase, symptoms of illness also escalate [15]. The structural regression model represents the path diagram for the estimated model of symptoms of illness due to dust in mines [16]. This path diagram includes the variables from the measurement model and the exogenous variables namely age and nature of work [17].

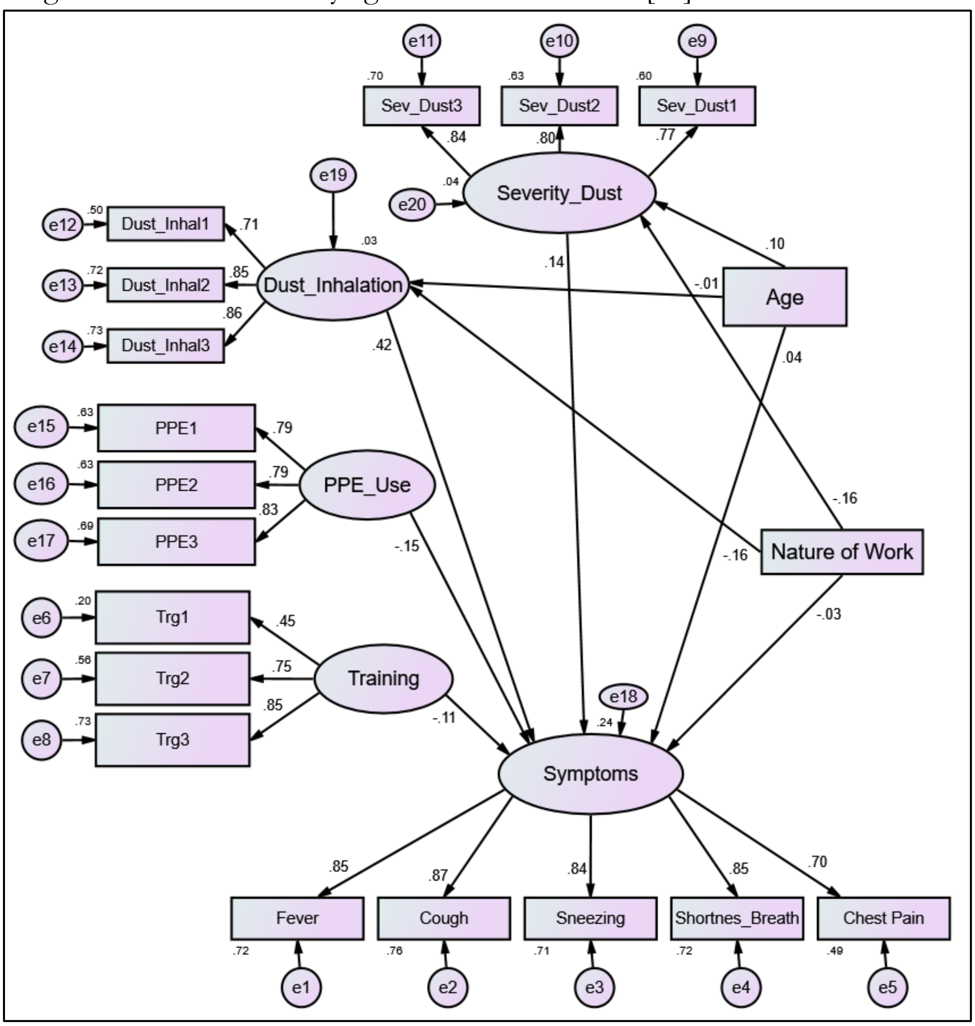

Figure 11: Structural Regression Model

In the structural regression model, the exogenous variables' age and nature of work have either positive or negative non-significant effects on the other variables. This indicates that the sample sizes for each category (age group and nature of work) are randomly distributed, thereby lacking a direct impact on the results. The negative coefficient of -0.12 indicates that as the level of training increases, the level of symptoms decreases. However, since the p-value associated with this coefficient is 0.139, it is not statistically significant at conventional thresholds (e.g., $p < 0.05$). In other words, the observed relationship between training and symptoms could probably be due to sampling variability.

The variable dust inhalation has a significant effect on the variable symptoms, as indicated by the unstandardized coefficient (regression weight) of $\beta = 0.485$ with a significance level of $p < 0.001$ while keeping all other variables constant. This suggests that for every one-unit increase in dust inhalation, there is an associated increase of 0.485 units in symptoms. Similarly, the variable "severity of dust" also has a significant effect on the variable "symptoms," as indicated by the unstandardized coefficient of $\beta = 0.207$ with a significance level of $p < 0.05$. This suggests that for every one-unit increase in the severity of dust, there is an associated increase of 0.207 units in symptoms. The results reveal that dust inhalation and the severity of dust have significant positive effects on symptoms, with dust inhalation having a stronger impact compared to the severity of dust.

Further, the use of PPE shows an unstandardized coefficient of $\beta = -0.158$, significant at the $p < 0.05$ level. The unstandardized regression weight (β) of -0.158 signifies the alteration in the dependent variable symptoms for each one-unit reduction in the independent variable PPE use while holding all other variables constant. This implies that decreasing the utilization of PPE is associated with an increase in symptoms and vice versa. Additionally, the significance level of $p < 0.05$ suggests that this relationship is statistically reliable.

Table 5 presents fit indices for both the Measurement Model and the Structural Regression Model, along with recommended cutoff values for each index. Absolute fit indices assess how well the model fits the observed data. The chi-square to the degree of freedom (X^2/df) ratio, Root Mean Square Residual (RMR), Goodness of Fit Index (GFI), and Adjusted Goodness of Fit Index (AGFI) are provided. For both models, the X^2/df ratio is within the acceptable range (1.27 for the Measurement Model and 1.23 for the Structural Regression Model), indicating excellent fit [18]. The RMR values are both below the cutoff of 0.05, suggesting a good fit. Similarly, the GFI and AGFI values are both above 0.9, indicating an excellent fit for both models. Comparative fit indices compare the fit of the model to a baseline model. The indices include the Normed Fit Index (NFI) and the Comparative Fit Index (CFI). For both models, the NFI and CFI values exceed 0.9, indicating excellent fit. While Parsimonious fit indices evaluate the balance between model fit and complexity. The Root Mean Square Error of Approximation (RMSEA) is provided, with values below 0.08 indicating a good fit. Both models have RMSEA values below this cutoff, suggesting a good fit [18].

Table 5: Model Fit Indices [18][19]

Fit Index	Measurement Model	Structural Regression Model	Recommended cut-off value
Absolute Fit Indices			
X^2/df	1.27	1.23	≤ 3.0 excellent; ≤ 5.0 good
RMR	0.050	0.051	≤ 0.05 good
GFI	0.923	0.917	≥ 0.9 excellent; ≥ 0.8 good
AGFI	0.895	0.890	≥ 0.9 excellent; ≥ 0.8 good
Comparative fit indices			
NFI	0.918	0.901	≥ 0.9 excellent; ≥ 0.8 good
CFI	0.981	0.980	≥ 0.9 excellent; ≥ 0.8 good
Parsimonious fit Indices			
RMSEA	0.037	0.034	≤ 0.08 good
PCFI	0.808	0.825	The higher, the better
PNFI	0.756	0.759	The higher, the better

Additionally, Parsimonious Comparative Fit Index (PCFI) and Parsimonious Normed Fit Index (PNFI) values are provided, with higher values indicating better fit [20]. Overall, the fit indices suggest that both the Measurement Model and the Structural Regression Model have good to excellent fit to the data. The models provide a satisfactory representation of the relationships among the variables under study.

Conclusion:

In this study, dust generated in soapstone mines was collected and analyzed both qualitatively and quantitatively to assess its severity and adverse effects on mine workers. To evaluate the impact of dust on the workers, data was collected through two primary methods. First, health and work-related information was gathered using a questionnaire from 200 workers. The information was composed of worker's personal, work, and health-related issues. In the second phase of data collection, about 60 miners were selected from the interviewed workers for medical examinations including chest X-rays and physical examinations by a medical practitioner. Based on the questionnaire responses, medical examinations, and dust analysis, the following conclusions are drawn:

- Dust is generated at every stage of mining, but the highest concentration is produced during the drilling operations, which are typically conducted in confined underground spaces, significantly increasing the likelihood of dust inhalation compared to other mining activities.
- The questionnaire data reveals that the majority of the workers (85%) are experiencing symptoms of lung diseases, including cough, chest pain, shortness of breath, sneezing, and fever.
- The data also reveals that most workers exhibit slightly severe respiratory symptoms. While severe symptoms are uncommon. Initial infections affect nearly all allied workers. Over time, however, workers either receive treatment or transfer to other occupations.
- General laborers are the most affected workers due to their involvement in various within the mines, such as drilling, blasting, loading, and transportation. In contrast, managerial staff experience fewer effects, as they typically spend less time in these high-risk areas and often take precautionary measures.
- Soapstone mine workers in Sherwan develop mild respiratory symptoms after 3 years of exposure duration and severe symptoms emerge after 16 years of continuous work.
- Chest infections in older workers are more severe than in younger workers, primarily due to their prolonged exposure to dust.
- Medical examinations confirm the questionnaire analysis showing about 80% of the workers have lung infections. Of these, 6.7% have severe infections, 31.7% have moderate, 41.7% have mild infections, and 19.9% show no infection lung infections.
- The Structural equation modeling (SEM) findings establish the significant impact of both dust inhalation and the severity of dust on symptom occurrence with dust inhalation having a stronger impact ($\beta = 0.485$, $p < 0.001$) compared to the severity of dust ($\beta = 0.207$, $p < 0.05$), which tends to increase with these factors.
- Hence, the worker's exposure to dust should be minimized by designing proper mining and ventilation systems, using appropriate equipment, implementing robust dust control measures, and conducting further research to understand the specific health impacts of soapstone dust.
- Additionally, the use of Personal Protective Equipment (PPE) emerges as critical for lessening the effects of dust exposure on symptoms, essentially mitigating their deterioration ($\beta = -0.158$, $p < 0.05$), indicating a statistically reliable relationship.
- Awareness of the health consequences of dust needs to be increased through consistent training programs for workers.

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Conflict of Interest:

The authors declare that there are no conflicts of interest regarding the publication of this paper. All authors equally contributed to the paper.

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(Annex-A):

Data Collection Performa of Labor
(Soapstone Mines)
Name______________________________S/O__________________________________
CNIC_______________________________Age________________________________
Address ____
Total Work Duration in Soapstone Mines __________________________________
Nature of Work__________________________ Daily Working Time (hrs)_______
Name & Address of Lease holder ____
____

Medical Investigations:

	Symptoms	Very severe (1)	Severe (2)	Slightly Severe (3)	No Problem (4)
1	Cough				
2	Chest Pain				
3	Shortness of Breath				
4	Sneezing				
5	Fever				

Mine Envirement Investigation:

- Main causes of dust production _______________________________
- Severity of dust (tick one):

Very severe (Fulltime and 100% of air) (1)	Severe (>50%of shift and of air) (2)	Slightly Severe (<50% of shift and of air (3)	No Dust (4)

- What is the effect of dust inhalation on your respiration? (tick one)

Very Severe (1)	**Severe (2)**	**Slight Problem (3)**	**No Effect (4)**

- Are you using any protective mask from dust during work? (Tick one)

All the Time (1)	**>50% Time of Shift (2)**	**<50% of Shift (3)**	**Not at All (4)**

- If not, what is the reason for not wearing a protective mask?
- Do you know the consequences of not wearing a face mask?
- Is your manager or mine in-charge enforcing you for wearing a Mask?

- Is there any PPE available at the mine site? What are they:
- Is a mining engineer or safety officer available at the mine?
- Did you get proper training on safety? What kind of training?
- Do you know the consequences of not wearing a face mask?
- What kind of dust suppression mechanisms are available on site?
- Is there any regular mechanism for dust removal?
- Are there any dust detectors/monitors on-site?
- Are there any gas detectors on the mine site? What are they:
- How the dust production could be reduced/stopped?
- How to avoid the severe consequences of dust inhalation?

Personal/ Family Investigation:

- Do you go to the doctor for routine check-ups?

Once a Year (1)	Once a Month (2)	Weekly (3)	Never (4)

- Is there lung disease in your family?
- Do you have any other health problem?
- Do you use any medicine?
- What is the effect of these medicine?
- Are you smoking?
- Would you like your kids to come to this field? Why
- Are you available for a free medical check-up?