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International Journal of Clinical Case Reports and Reviews
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Research Article

A Cross-Sectional Study of Silicosis and Assessment of Spirometry among workers of a Silica Processing Factory in Kurunegala, Sri Lanka

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Received Date: June 12, 2026 | **Accepted Date:** June 19, 2026 | **Published Date:** June 26, 2026

Citation: Kulathunga. K. M. C. N, Mapalagama Y.A, D. G. N.I. Karunarathna, K.M.T.K. Kulathunga, (2026), A Cross-sectional Study of Silicosis and assessment of spirometry among workers of a Silica processing factory in Kurunegala, Sri Lanka, *International Journal of Clinical Case Reports and Reviews*, 36(3); **DOI:**10.31579/2690-4861/1136.

Abstract:

Objectives: A cross-sectional epidemiological study was carried out in February 2025 in a silica processing factory in Kurunegala to study silica dust related lung complications.

Method: All 18 factory workers were studied. An examiner-introduced questionnaire was used. Chest X-rays and Spirometry was assessed.

Results: 5 were diagnosed with silicosis; among them, 3 presented with the accelerated form, 2 with the chronic form of the disease. 66% of the workers with accelerated form of silicosis had a history of two years of exposure. Three workers without silicosis showed probable spirometry evidence of small airway dysfunction.

Conclusions: Exposure to excessive levels of silica dust can result accelerated silicosis after short periods of time. Chest X-rays are essential during the screening of silica related industrial workers. Respiratory function testing should be conducted in accordingly to detect pneumoconiosis early.

Learning Outcomes

1.To screen the workers for silicosis

2.Assessment of spirometry

3.Screen for respiratory symptoms

4.Assess for small airway dysfunction

Key words: silicosis: spirometry; progressive massive fibrosis; pneumoconiosis; silica; surveillance; small airway disease

Introduction

Occupational lung diseases or work-related lung conditions are caused or aggravated by the inhalation of irritants in the workplace [1]. There are surveillance gaps and diagnostic limitations to Occupational lung diseases in resource poor countries. Workplace based and systematic studies on occupational lung diseases including silicosis are scarce in Sri Lanka.

Silicosis is an occupational lung disease, a type of pneumoconiosis due to inhalation of crystalline silica dust [1,2]. Silicosis is of three common types: acute, accelerated and chronic. The usual form, chronic Silicosis is characteristically demonstrated after high level of chronic exposure to crystalline silica, usually over a decade. Chronic Silicosis is asymptomatic and radiography should be demonstrated for diagnosis. Chest radiographs should characteristically reveal nodular lesions located at the upper lobes [2]. Patients with Complicated silicosis are symptomatic and they commonly present with chronic cough and difficulty in breathing. Complicated silicosis is a variant of chronic silicosis [1,2]. Exposure to silica dust over a shorter period could potentially result in the development of accelerated silicosis, a complicated form of silicosis, which develops 5 to 10 years after significant exposure to crystalline silica dust [1,2]. These patients are symptomatic.

Work related interstitial lung disease is an important issue concerning public health, that can potentially be prevented by implementing specific measures. The periodic surveillance of workers exposed to potentially hazardous agents is required to detect adverse respiratory conditions at their early stages.

The present Sri Lankan supply of silica constitutes mostly of crushed and pulverized silica products. The process of production of silica from quartz requires washing, crushing and sieving, a high dust generating mechanical procedure, consequently increasing exposure risk.

In addition, non- occupational exposure to silica dust can occur around industrial sites (quartz crushing, agate grinding, ceramics, use of slate pencils, mining and milling of sand stones, silica flour milling) or from naturally occurring sources such as desert dust or sand. Common occupations which result in silica exposure in Sri Lanka include quartz processing factories, quarrying, tile industry and sandblasting.

Recent evidence shows that the exposure to particulate matter of size less than or equal to 2.5 µm (PM 2.5) is a risk factor for small airway dysfunction (SAD) and the development of chronic obstructive pulmonary disease (COPD). Early changes caused by inhalation of particulate matter and ultra fine particles initiates inflammation in distal and small airways. The interest to utilize spirometry for the assessment and treatment of small airway dysfunction (SAD) and pre-clinical obstructive airway disease, has therefore surged in recent years [4,5].

The objective of this study was to evaluate silicosis and respiratory impairment using radiological and spirometry assessment among workers in a silica processing factory in Kurunegala, Sri Lanka.

2. Methods

Study design and study site

A cross-sectional study was carried out in February 2025 in a silica processing factory in Kurunegala, Sri Lanka

Study population

The entire workforce employed at the time of the study were enrolled. Three main exposure categories were identified based on job tasks. Individuals who worked in the kitchen had mild exposure. The workers involved in grinding of quartz and sieving were identified as having severe exposure due to dust generating activity. No quantitative air sampling was performed and the above levels were identified according to the job task, proximity to the dust generating process and nature of tasks. The workers who had moderate exposure, engaged in washing of quartz.

Sample size

The study population consisted of all workers employed. The total workforce comprised of 18 workers and no sampling was undertaken. Therefore, no formal sample size calculation was performed.

Inclusion and exclusion criteria

All workers employed at the silica processing factory at the time of the study were and occupationally exposed to silica dust were eligible for inclusion. All workers provided voluntary informed consent and were enrolled in the study. Workers with acute respiratory infection and at the time of the assessment or unable to perform acceptable reproducible spirometry despite repeat attempts were planned to be excluded the spirometry analysis. No workers were to be excluded based on smoking or presence of respiratory symptoms. No workers met these exclusion criteria, so all workers were enrolled in the study.

3. Methodology

Ethical clearance was taken from Ethics Review Committee - Department of Health Services, Provincial Council of the North western Province, Sri Lanka.

Data was collected at the workplace using a structured interviewer administered questionnaire. Demographic characteristics, occupational history, job tasks type of exposure, duration of occupational exposure to silica dust respiratory symptoms and smoking status were assessed. Exposure categories were assigned to the workers based on the job roles and nature of work performed. Occupational exposure to silica dust was qualitatively categorized as mild, moderate, or severe based on job task, proximity to dust-generating processes, and duration of time spent in each task. Exposure classification was performed by the study investigators following workplace walkthrough observation and review of job descriptions. Workers involved in crushing, sieving, and belt operations were categorized as having severe exposure; workers engaged in washing of quartz were categorized as having moderate exposure; and workers performing kitchen or administrative tasks were categorized as having mild exposure. Quantitative environmental dust measurements, personal air sampling, and crystalline silica concentration analysis were not performed. Use of personal protective equipment and ventilation characteristics were recorded but not objectively measured.

All participants underwent standardized clinical assessment followed by spirometry and chest radiography as a part of the study protocol. Silicosis was diagnosed based on two key factors, history of the participant being exposed to occupational silica dust and having radiological digital chest X-ray findings or HRCT findings consistent with silicosis. Spirometry was performed in all participants using a calibrated spirometer MIR SPIROLAB-iii, according to the standardized guidelines of the American Thoracic Society (ATS). Measurements included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), the FEV1/FVC ratio, and forced expiratory flow between 25% and 75% of vital capacity (FEF25–75). Participants performed a minimum of three acceptable forced expiratory maneuvers, and the best values were selected according to ATS acceptability and repeatability criteria. Tests that did not meet quality criteria were repeated until acceptable and reproducible results were obtained.

Participants who failed to perform the initial spirometry test or could not produce reliable results, were re-scheduled for other examinations in one-week intervals until reliable results were obtained to achieve the acceptability and repeatability criteria for spirometry [6].

Chest Radiography was performed in all participants and radiological changes were graded using International Labour Organization (ILO) Classification of Radiographs and pneumoconiosis. Participants suspected of accelerated silicosis based on chest radiography underwent further evaluation with high resolution computer tomography (HRCT). Participants who had radiological evidence of silicosis underwent bronchoscopy to exclude infections, including Pulmonary Tuberculosis. All Radiographs were reviewed by a trained Respiratory Physician with experience in occupational lung disease, independent of spirometry findings and clinical symptom status based on Standardized ILO Criteria. SAD was defined as maximum mid-expiratory flow (MMEF) < 65% of predicted value by spirometry [4].

4. Data management and analysis

Data collected from the questionnaire were entered into Microsoft Excel and cross checked for accuracy. Analysis was performed using Statistical Package for Social Sciences (SPSS) software version 31.0.2.0.

Descriptive statistics were used to summarize participant characteristics, exposure categories, radiological findings, and spirometry patterns. Categorical variables were presented as frequencies and percentages.

5. Results

The study population in the silica factory comprised of 18 participants with median age of 49 years and 44.4% of them were between the age of 50-60years.Twelve participants (66.7%) were male.

Demographics of the study population

Tablie1

Past history of respiratory diseases

Table 2

15 participants (83.3%) reported no prior respiratory diseases and three workers (16.7%) were diagnosed of Asthma by physicians prior to starting employment at this workplace. No participants reported chronic obstructive pulmonary disease, Bronchiectasis, interstitial lung disease, or lung malignancy.

Table 3 Smoking status of the Sample

Nine workers (50%) were current smokers; all were male and exclusively cigarette smokers. Among smokers, 77.8%) reported smoking one cigarette per day and two (22.2%) reported smoking three cigarettes per day.

Exposure to indoor air pollutants

Fifteen workers, 83.3%, used a cook stove or hearth for domestic cooking and used firewood as the main source of fuel. Among them eleven workers (73.3%) had installed their cooking stove or hearth inside the house. Additional fuels were kerosene oil (11.1%, n=2) and plastic (5.6%, n=1).

Table 4 Exposure to indoor air pollutants

Table 5 Type of occupational category

Half of the workers (n=9,50%) had severe exposure, 33.33% (n=6) moderate and 16.67% (n=3) had low exposure.

Workers were categorized into three exposure levels based on job tasks and proximity to dust-generating processes. Severe exposure was identified in nine workers (50.0%) who were involved in crushing, sieving, and belt operations. Moderate exposure was identified in six workers (33.3%) engaged in quartz washing. Mild exposure was identified in three workers (16.7%) performing administrative or driving duties. All workers diagnosed with silicosis belonged to moderate or severe exposure categories.

Prevalence of Respiratory symptoms in silica factory workers

Table5 Respiratory symptoms among employees

Most workers were asymptomatic at the time of assessment (77.7%, n=14). Respiratory symptoms were reported in two workers. Cough and shortness of breath were reported by two workers (11.1%), itchy eyes by one worker (5.6%), and headache by one worker (5.6%).

Spirometry findings

Spirometry was successfully performed in all participants. Restrictive ventilatory defects were identified in five workers (27.8%), and all of these workers had radiological evidence consistent with silicosis. Small airway dysfunction was identified in three workers (16.7%) without radiological evidence of silicosis.

Table 6- Spirometry readings

Table 7 Small air way dysfunction

Radiological Findings

Table- 8. International Labour Organization- ILO Classification of chest x-ray

Five workers (27.8%) had chest radiographic findings consistent with pneumoconiosis based on the International Labour Organization classification. Among these workers, three (16.7%) were consistent with accelerated silicosis, two (11.1%) with chronic silicosis, and one (5.6%) had progressive massive fibrosis. Radiological patterns included nodular opacities in two workers, fibrotic nodular disease in two workers, and progressive massive fibrosis in one worker.

Figure 8, HRCT-chest abnormality

2 (11.11%) workers had nodular opacities, 2 (11.11%) symptomatic patients had nodules and fibrosis and one (5.56%) patient had radiological evidence of progressive massive fibrosis

Type of Silicosis according to the working area

Exposure duration among workers with silicosis

Duration of occupational exposure among workers diagnosed with silicosis ranged from 1 to 12 years. Three workers developed silicosis within two years of occupational exposure. One worker developed progressive massive fibrosis after two years of exposure. All affected workers were employed in moderate to severe-exposure job roles.

Variable	Number of workers	Percentage %
Age Category		
30-40	5	27.8
40-50	5	27.8
50-60	8	44.4
Gender		
Female	6	33.33
Male	12	66.67

Table 1: Distribution of socio-demographic characteristics

Variable	Number of workers	Percentage %
None	15	83.3
Asthma	3	16.7
COPD	0	0
Bronchiectasis	0	0
ILD	0	0
Lung Cancer	0	0

Table 2: Past history of respiratory diseases

Variable	Number of workers	Percentage %
Smoking status		
No	9	50
Yes	9	50
No. of Cigarette / Day		
1	7	77.8
3	2	22.2

Table 3: Smoking status of the Sample

Variable	Number of workers	Percentage %
Usage of Cook stoves or hearth for cooking		
No	3	16.7
Yes	15	83.3
Location of Cook stoves or hearth		
Inside the house	11	73.33
Outside the house	4	26.67
Energy source used for the cook stoves/hearth		
Firewood	15	83.33
Kerosene oils	2	11.11
Dung	0	0.00
Wood dust	0	0.00
Plastic	1	5.56
Other indoor exposures		
Mosquito coils	6	33.33
Incense Sticks	11	61.11
Fragrance smoke	0	0.00

Table 4: Exposure to indoor air pollutants

Task	Number	Percentage
Driver	1	5.6%
Supervisor	2	11.1%
Crushing	7	38.9%
washing	6	33.3%
Sieving and belt	2	11.1%

Table 5: Type of occupational category

Respiratory symptoms	Number of workers	Percentage %
Itchy Eyes	1	5.6
Cough and Shortness of breath	2	11.1
Headache	1	5.6
Wheezing	0	5.6
None	14	72.2

Table 6: Respiratory symptoms among employees

ID	FVC(Litres)				FEV1(Litres)				FEV1/FVC(%)				FEF25-75 (Litres/S)			
	LLN	predicted	Best	%Predicted	LLN	Predicted	Best	%predicted	LLN	Predicted	Best	%Predicted	LLN	Predicted	Best	%Predicted
1	1.29	2.08	0.81	39	1.09	1.73	0.7	38	72.2	83.9	81.5	97	0.84	2.24	0.66	29
2	1.6	2.31	1.06	46	1.32	1.95	0.9	47	67.8	78.5	85.6	109	1.59	2.99	1.24	41
3	1.29	2.08	1.4	67	1.09	1.73	1.2	67	72.2	83.9	82.9	99	0.84	2.24	1.16	52
4	2.05	3.1	3.31	107	1.67	2.53	2.5	99	72.2	82.3	75.8	92	1.33	3.11	2.13	68
5	1.35	2.15	1.86	87	1.13	1.77	1.5	85	71.6	83.2	81.2	98	0.87	2.27	1.51	66
6	1.71	2.76	2.65	96	1.42	2.29	2.2	97	73.4	83.6	83.8	100	1.13	2.91	2.35	81
7	1.74	2.79	2.63	94	1.53	2.4	2.3	95	76.4	86.5	86.7	100	1.43	3.22	2.7	84
8	1.34	2.13	1.98	93	1.11	1.76	1.7	95	71.4	83	83.8	101	0.84	2.24	1.84	82
9	2.72	3.78	2.86	76	2.24	3.11	2.4	79	72.6	82.8	85.3	103	2.01	3.79	2.62	69
10	2.69	3.74	3.3	88	2.27	3.13	2.6	82	74.3	84.5	77.6	92	2.14	3.92	2.11	54
11	2.59	3.64	3.78	104	2.18	3.05	3.2	106	74.3	84.5	85.4	101	2.04	3.82	3.68	96
12	2.28	3.33	3.36	101	1.88	2.74	2.7	97	72.8	83	79.5	96	1.61	3.39	2.36	70
13	2.43	3.49	4.53	130	2.03	2.89	3.7	129	73.6	83.7	82.3	98	1.82	3.61	3.65	101
14	2.91	3.96	3.69	93	2.44	3.3	3	91	74	84.1	81.3	97	2.31	4.09	2.97	73
15	2.94	3.99	3.05	76	2.47	3.33	2.5	75	74.1	84.3	81.6	97	2.35	4.13	2.22	54
16	1.82	2.62	2.47	94	1.54	2.19	2	91	71.8	83.5	81	97	1.45	2.85	1.95	68
17	1.43	2.22	1.74	78	1.21	1.86	1.5	78	72.6	84.2	83.3	99	1.02	2.43	1.6	66
18	1.55	2.35	2.64	113	1.3	1.94	1.9	100	71.2	82.9	73.5	89	1.08	2.48	1.38	56

Table 7: Spirometry readings

Small air way disfunction	Number of workers	Percentage %
Present	3	16.66
Absent	15	83.33

Table 8: Small air way dysfunction

ID	Technical quality	Parenchymal abnormalities				Pleural abnormalities					Comments
		Profusion	Shape and Size	Zones	Large opacities	Chest wall: Plaques (localized pleural thickening)	Chest wall: Diffuse pleural thickening	Costophrenic angle obliteration	Diaphragm	Calcification	
1	1	3/3	Primary-u Secondry-p	R L ☑ ☑ ☑ ☑ ☐ ☐	C	No	No	No	No	No	
2	2	3/3	u	R L ☑ ☑ ☑ ☑ ☐ ☐	No	No	No	No	No	No	
3	1	2/2	Primary-t Secondary-p	R L ☑ ☑ ☑ ☑ ☐ ☐	No	No	No	No	No	No	Bilateral Hilar lymph node enlargement seen
4	1	3/3	s	R L ☑ ☑ ☑ ☑ ☑ ☑	No	No	No	No	No	No	
5	1	1/1	Primary-t Secondary-p	R L ☑ ☑ ☑ ☑ ☐ ☐	No	Left In profile, extent = 1	No	No	No	No	

Table 9: International Labour Organisation- ILO Classification of chest x-ray3

Abnormality detected	Number of workers	Percentage %
Nodular opacities only	2	11.11
Fibrosis with nodules	2	11.11
Progressive massive fibrosis	1	5.56
Total	5	27.78

Table 10: HRCT -chest findings

ID	Type of Silicosis	Type of Exposure	Duration of exposure-Years
1	Progressive massive fibrosis	Belt	2
2	Fibrosis with nodules	Crushing	2
3	Fibrosis with nodules	Crushing	12
4	Nodular opacities only	Supervisor	7
5	Nodular opacities only	Crushing	1

Table 11: Type of Silicosis according to the working area

6. Discussion

This study identified a high prevalence of silicosis (27.8%) among workers in a silica processing factory in Sri Lanka. Notably, several workers developed silicosis after relatively short exposure durations of less than two years, and one worker developed progressive massive fibrosis. Most affected workers were asymptomatic at the time of assessment, and all demonstrated restrictive ventilatory defects on spirometry. These findings indicate substantial occupational exposure and early disease development in this workforce.

The prevalence observed in this study is consistent with findings reported in other silica-exposed occupational settings globally, where silicosis prevalence varies depending on exposure intensity, industrial processes, and workplace protective measures. Accelerated silicosis has increasingly been reported in workers exposed to high concentrations of respirable crystalline silica, particularly in industries involving crushing and processing of quartz. The early onset of disease observed in this study supports existing evidence that high-intensity exposure may lead to rapid disease progression.

All workers diagnosed with silicosis were employed in tasks that involve significant generation of respirable silica dust, increasing the risk of inhalation. Personal protective equipment use was limited and primarily consisted of surgical masks, which provide inadequate protection against respirable crystalline silica. These workplace factors may have contributed to the development of silicosis and the occurrence of accelerated forms of the disease in this population.

Most workers diagnosed with silicosis were asymptomatic, highlighting the importance of radiological screening for early detection. Silicosis may remain clinically silent in its early stages, and reliance on symptom-based detection alone may result in underdiagnosis. The restrictive ventilatory defects observed in affected workers are consistent with fibrotic lung disease and reflect physiological impairment associated with silica exposure.

Small airway dysfunction was identified in three asymptomatic workers without radiological evidence of silicosis, suggesting early physiological effects of occupational exposure. Occupational exposure to respirable particulate matter, including crystalline silica, has been associated with early airway dysfunction and may precede overt radiological abnormalities. These findings highlight the importance of periodic lung function monitoring in silica-exposed workers to detect early functional changes.

Smoking and exposure to biomass fuel were assessed as potential confounding factors. Although half of the workers were current smokers, smoking intensity was low, and most workers had no prior respiratory disease. These factors suggest that occupational silica exposure was the primary contributor to the observed radiological and spirometry abnormalities.

7. Conclusion

A previous Sri Lankan study conducted among 250 silica-exposed workers reported a prevalence of silicosis of 5.6%, with most cases demonstrating features of accelerated silicosis and one case of progressive massive fibrosis10. In contrast, the prevalence observed in the present study was substantially higher at 27.8%. This difference may be partly explained by methodological differences, as the previous study screened only symptomatic workers, potentially underestimating the true burden of disease. In the current study, all workers underwent radiological assessment irrespective of symptom status, enabling detection of asymptomatic cases.

Notably, both studies demonstrate a predominance of accelerated silicosis, suggesting high levels of occupational exposure in silica processing industries in Sri Lanka. However, the present study identified cases of silicosis, including progressive massive fibrosis, occurring after relatively short exposure durations of two years or less, which is shorter than that reported in the earlier study. This finding raises concern regarding the intensity of exposure and possible inadequacies in workplace control measures in the studied setting.

In contrast to findings from large-scale studies in other occupational settings, a study conducted among over 14,000 gold miners in South Africa reported a silicosis prevalence of 3.8%, with the majority of affected workers having more than 15 years of exposure11. Although this population differs from silica processing workers in terms of work environment and exposure characteristics, the findings highlight the typical long latency of silicosis in settings with regulated occupational exposure.

Compared to this, the present study demonstrated a markedly higher prevalence of silicosis and a significantly shorter duration of exposure among affected workers, with cases identified within two years of employment. This suggests that workers in silica processing industries may be exposed to higher concentrations of respirable crystalline silica, particularly in the absence of adequate dust control measures. The occurrence of silicosis over such short exposure durations in the present study contrasts with the predominantly long-latency disease observed in gold mining cohorts, emphasizing the potential role of exposure intensity in accelerating disease onset.

This study has several strengths. All workers employed at the factory were included, minimizing selection bias within the workplace. Comprehensive assessment using radiography and spirometry enabled detection of both structural and functional abnormalities. Exposure classification was based on direct workplace assessment and job tasks, allowing appropriate identification of high-risk exposure groups.

This study also has limitations. The small sample size limits generalizability of the findings. Quantitative environmental dust measurements were not performed, preventing precise exposure quantification. The cross-sectional design limits assessment of temporal relationships and disease progression. Additionally, the study was conducted at a single workplace and may not represent all silica processing environments. These findings highlight the importance of occupational health surveillance in silica-exposed workers. Early detection through radiological and spirometry screening may facilitate identification of disease before symptom onset. Effective workplace exposure control measures and appropriate respiratory protective equipment are essential to reduce disease risk.

Acknowledgments:

1. All sources of support relevant to publication- None

2. Specific Author Contributions of every Author,

KMCNK- Conception and design, Interpretation of Spirometry and imaging, Analysis and interpretation of results, Manuscript writing, study supervision, critical manuscript review

YAM-Analysis and interpretation, Manuscript writing, critical revision of manuscript

DGNIK- Data acquisition and collection, data management, manuscript review

MAIP-Data acquisition and collection, data management, manuscript review

KMTKK- Data management, spirometry and equipment calibration, manuscript review

3. Data Availability,

The data that support the findings of this study are not publicly available due to confidentiality and ethical restrictions but are available from the corresponding author upon reasonable request.

4. EQUATOR Network checklist- Not applicable

5. Author(s) thesis information -Not applicable

6. AI detailed, manuscript preparation etc.

Artificial intelligence tools (ChatGPT, OpenAI, Grammarly) were used to assist with language refinement and editing of the manuscript. The authors reviewed and verified all content and take full responsibility for the accuracy and integrity of the work. No AI was utilized at any stage during research development & design, data collection, clinical or radiographical interpretation, data analysis or result interpretation.

7.Ethical Considerations & Disclosure(s) (e.g. IRB Information, consent process, if applicable)

Ethical approval was obtained from the Ethical Review Committee of the Department of Health Services, Provincial Council of North Western Province, Sri Lanka on the 25th March 2025, valid through 25th March 2026 under application number ERC/NWP/2024/24. Informed voluntary consent was obtained from all participants. The study did not deviate from the protocol permitted by the Ethical Review committee.

Funding Sources for All Authors -Non-Declared

Conflict of Interest for All Authors - Non-Declared

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DOI:10.31579/2690-4861/1136