Original Article

# High Prevalence of Silicosis and Progressive Massive Fibrosis Amid Sandstone Engravers in Lopburi Province, Thailand

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## Abstract

**OBJECTIVES:** This study aimed to explore the prevalence of silicosis and chest radiographic features among sandstone engravers in Lopburi province, Thailand.

**MATERIALS AND METHODS:** This retrospective descriptive study was conducted in February 2021 through individuals' medical records and chest radiographs. The diagnosis of silicosis was based on criteria by the Thailand Social Security Office, where chest radiographs with a profusion of at least 1/0 were suggestive of silicosis. All chest radiographs were read by the NIOSH-certified B reader according to the 2011 ILO International Classification of Radiographs of Pneumoconioses (ILO/ICRP).

**RESULTS:** Among thirty-one workers residing in the same village, the prevalence of silicosis was 41.9%. Regarding those with silicosis, 92.3% had a profusion category of 2 or 3, and 30.8% exhibited progressive massive fibrosis. The participants' mean age and mean working year were 51.9 and 19.6 years, respectively. 48.4% of them were male, and 41.4% were ever-smokers. There was no statistically significant difference between silicotic and non-silicotic groups regarding sex, age, years of working, and ever-smoking status.

**CONCLUSION:** This study raises concerns regarding the ongoing burden of silicosis. The high prevalence of silicosis reflects the underreporting of at-risk workers and the prevalence of silicosis in Thailand. The Thailand Occupational and Environmental Diseases Control Act, B.E. 2562 (A.D. 2019) marks a significant milestone in strengthening silicosis surveillance systems. Hopefully, further vigorous support from all functional levels will put the silicosis preventive strategy in place in the near future.

**Keywords:** silicosis, prevalence, pneumoconiosis, occupational diseases

Silicosis, a currently incurable but preventable occupational lung disease, is caused by inhalation of respirable crystalline silica (RCS), which is less than 10 µm in diameter.[1] Exposures to the RCS can be found in work processes applying pressure to silica-containing materials, which include manufacturing of ornamental stone and pottery, mining, and construction.[2] The RCS can deposit in distal airways and alveoli, resulting in inflammation and subsequent fibrosis in lung tissues. However, some patients present deterioration of lung function after such exposure is terminated.[3]

Based on the concentration and exposure time of the RCS, various clinical features have been observed, including simple silicosis, complicated silicosis or progressive massive fibrosis (PMF), and acute silicosis. Chronic simple silicosis is the classic form manifesting asymptomatic nodular disease; and may eventually progress to complicated silicosis exhibiting nodule coalescence, progressive fibrosis and worsening respiratory symptoms.[4]

While extensively recognized for decades, controlling the disease has remained challenging. The prevalence of silicosis

varied among occupational contexts, extending from 14% to 96%.[5] The Global Burden of Disease Study estimated that silicosis caused 12,887 deaths and 655,763 disability-adjusted life years (DALY) between 1990 and 2019.[6] Even though global trends of such burdens decreased, the numbers of workers exposed to silica or of those with silicosis have still been underreported according to public health constraints, especially in economically developing countries.[7] A large number of new cases were recently diagnosed among the world population and in various industrial settings.[6] To eliminate silicosis worldwide by 2030, the International Labour Organization (ILO) and World Health Organization (WHO) have jointly implemented the Global Programme for the Elimination of Silicosis (GPES) since 1995, aiding countries to develop their national action programs.[8]

The first case of silicosis in Thailand, reported from Wolfram mine in 1954, had raised some health concerns. Thailand set up the Silicosis Surveillance Program in 1981 and later developed the National Silicosis Elimination Program in 2001, which was concordant with the GPES framework.[9–11] From 2013 to 2018, the reported prevalence of silicosis among stone-related workers in Thailand varied from 27.3% to 36.1%.[12,13] There were 2,084 silicosis cases reported in the Thailand Health Data Center database between 2013 and 2023.[14] Furthermore, the number of new cases has remained considerable.[12] Recent studies revealed that silicosis in Thailand was still underdiagnosed.[15,16] Accordingly, silicosis management has been lawfully strengthened by the Thailand Occupational and Environmental Diseases Control Act, B.E. 2562 (A.D. 2019); thus, potential silicosis cases must be reported to authorized officers.[17] Abiding by such law, the first-time investigation was conducted in 2021, attentively characterizing medical and work environment aspects for each silicosis case in a small village in Thailand.[18] For an extensive view of such disease burden, this study aimed to explore the prevalence of silicosis and chest radiographic features among sandstone engravers in the same workplace in Lopburi province, Thailand.

## Materials and Methods

This retrospective descriptive study was conducted in one district of Lopburi province in February 2021, which included 31 consecutive individuals previously working as sandstone engravers and residing in the same village as the reported cases. Data was collected through individuals' medical records and chest radiographs. The parameters of the study comprised sex, age, years of working, smoking status, and chest radiographic findings.

Diagnosis of occupational silicosis was based on appearance of at least two of the three criteria including occupational history of continuous silica exposure for at least 2 years; chest radiographic abnormalities compatible with silicosis, regarding a profusion of 1/0 or greater in accordance with 2000 revised version or newer of the ILO International Classification of Radiographs of Pneumoconioses (ILO/ICRP); and silicosis-related evidence on pathologic findings of lung tissue and/or epidemiologic study. Essentially, other diseases manifesting similar chest abnormalities must be excluded.[19,20]

Accordingly, all posteroanterior (PA) chest radiographs in this study were interpreted by a board-certified pulmonologist with an experience of 25 years, who was the B reader certified by the National Institute of Occupational Safety and Health (NIOSH) upon the 2011 ILO/ICRP.[21,22] Regarding diameters, small round opacities were labeled as p (up to 1.5 mm), q (1.5 to 3 mm), and r (3 to 10 mm). Besides, those with small irregular shapes were categorized as s (up to 1.5 mm), t (1.5 to 3 mm), and u (3 to 10 mm). Profusions of the small opacities were classified on a 4-point major category scale (0-3) and three minor features for each major category. This totally provided a 12-point scale for increasing profusion (0/-, 0/0, 0/1, 1/0, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, and 3/+). The extent of large opacities was defined as category A with its combined greatest dimension exceeding 1 cm but less than 5 cm; B with a dimension larger than 5 cm but not exceeding the equivalent area of the right upper lung zone; and C with the extent greater than the category B as a sum of areas exceeding the equivalent area of the right upper lung zone.[22]

Statistical analyses were performed using R statistical software version 4.2.2 (R Foundation). Quantitative data were presented as mean with standard deviation (SD) or median with interquartile range (IQR) as appropriate, while qualitative data were displayed as count and percentage. The statistical significance of quantitative variables was determined by the Chi-square test or Fisher's exact test as proper. In addition, the t-test or Wilcoxon rank sum test was implemented for qualitative variables regarding the distribution of the data. A *p*-value less than 0.05 was considered statistically significant.

## Results

Among a total of 31 participants included in this study, the prevalence of silicosis was 41.9% (13/31). The characteristics of the population are detailed in Table 1. At-risk participants' ages ranged from 31 to 67 years (Mean 51.87, SD 8.67), with 48.4% identified as male; and 41.4% ever-smoking. The mean working year was 19.56 years (SD 11.35). Among the silicosis-confirmed group, the mean age was 54.92 years (SD 5.88); the working year was 22.62 years (SD 9.84), ranging from 5 to 40 years; along with 53.8% female and 30.8% ever-smoking. There was no statistically significant difference between the two groups regarding such parameters.

Upon acceptable image quality, the ILO/ICRP chest radiographic findings of the 13 silicosis cases are shown in Table 2, where the majority (92.3%) were interpreted with a profusion of 2/1 or greater. Shape and size of small opacities were found as p/p (38.5%) and q/q (61.5%). Large opacities were presented in 30.8% of silicosis cases. Among the non-silicotic group, most of them presented with normal chest radiographs (55.6%), while the remaining participants exhibited abnormal findings, which included calcified nodules, atelectasis, bronchiectasis, and fibrosis.


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**Table 1:** Characteristics of the participants

| Variable | All participants n (%) | Silicotic group n (%) | Non-silicotic group n (%) | $p^1$ |
|---|---|---|---|---|
| n | 31 (100) | 13 (41.9) | 18 (58.1) | |
| Sex, n (%) | | | | 0.833 |
| Male | 15 (48.4) | 6 (46.2) | 9 (50.0) | |
| Female | 16 (51.6) | 7 (53.8) | 9 (50.0%) | |
| Age (years) | | | | 0.113 |
| Mean ± SD | 51.87 ± 8.67 | 54.92 ± 5.88 | 49.67 ± 9.80 | |
| Min, Max | 31, 67 | 42, 67 | 31, 63 | |
| Years of working | | | | 0.215 |
| Mean ± SD | 19.56 ± 11.35 | 22.62 ± 9.84 | 16.71 ± 12.26 | |
| Min, Max | 2, 40 | 5, 40 | 2, 40 | |
| Ever-smoking, n (%) | 12 (41.4) | 4 (30.8) | 8 (50.0) | 0.296 |

[1]Pearson's Chi-squared test; Wilcoxon rank sum test

## Discussion

This study furthers disease characterization regarding the first-time investigation of silicosis subject to the Thailand Occupational and Environmental Diseases Control Act, B.E. 2562 (A.D. 2019). Results revealed high silicosis prevalence in the group of sandstone engravers in Lopburi province, which is greater than that found in Chonburi province, ranking second in terms of high-risk areas of silica exposure in Thailand.[12,23] However, such a high prevalence is comparable to a previous study among stone carvers in Brazil.[24] Interestingly, this study found a high proportion of large opacities, or PMF in the pathological term, from chest radiographs, which can subsequently pose deteriorations of pulmonary function and quality of life. Such finding was similar to the proportion among stone-crushing workers in India (31.7%) but higher than that of stone-cutting workers in Hong Kong (24.8%).[25] Explanations for these include critical work environments and inappropriate work practices. Regarding previous studies on stone-related industries in Thailand, the majority were exposed to silica concentration above occupational exposure limits, especially stone grinding factories with the highest exposure level.[26] In addition, participants in this study were informal workers in rural areas where appropriate use of personal protective equipment was probably neglected.

Most of the participants in this study presented with a profusion category of 2 or 3 on their chest radiographs. There was only one person with a profusion category of 1, having large opacities as well. Regarding this, a previous study among coal workers found presence of higher small opacity profusion on chest radiographs to be a critical factor for progression to PMF.[27] However, large opacities later appeared in some category 1 cases without the progression of small opacity profusion.[3] Notably, the PMF consists of multiple small opacities that have coalesced together, likely resulting in a relative decrease in small opacity profusion.

An effect of sex on developing silicosis was not significantly found in this study. This is in line with some previous studies in the ceramic and agate industries.[28,29] However, the present finding contrasts more recent cohort studies exhibiting male predominance for silicosis, where females constituted a very small part of the population studied.[30–32] The nature of mutual support among Thai rural villagers, which comprises both sexes in an equivalent proportion, can explain the insignificant effect in the context of informal workers in this study. Although the influence of sex on silicosis is still arguable, both men and women should be emphasized as the risk is based on a dose-response relationship.[33]

**Table 2:** ILO/ICRP chest radiographic interpretations of silicosis cases

| Chest radiographic findings | Numbers of participants n = 13 |
|---|---|
| 1/1, p/p, large opacity B, eggshell calcification | 1 |
| 2/1, p/p | 1 |
| 2/1, q/q | 1 |
| 2/2, p/p | 1 |
| 2/2, q/q | 1 |
| 2/2, q/q, large opacity A, eggshell calcification | 1 |
| 2/3, p/p | 2 |
| 2/3, q/q | 1 |
| 2/3, q/q, large opacity A | 1 |
| 3/2, q/q | 1 |
| 3/2, q/q, large opacity B, eggshell calcification | 1 |
| 3/3, q/q | 1 |

The mean age of workers with silicosis in this study is parallel to that of a cohort study in the UK reporting the number at 61 years.[30] Regarding exposure duration in this study, silicosis patients had an average working year of more than 20 years, which can display the background of the workers starting the stonework at a young age without appropriate protective measures. Furthermore, all of them had no abnormal symptoms, reflecting that all patients were categorized as having chronic silicosis. In the same manner, a study in Brazil reported a higher risk of silicosis among stone carvers after tenures of 15 years or more.[24] Exceptionally, among Turkish denim sandblasters aged between 25 and 37 years, the prevalence of accelerated silicosis was reported at 96.4%.[34] That the majority of such workers were young with little work experience as well as lacked hazard awareness and used inappropriate protective measures could imply the high cumulative silica exposure. Moreover, a study on sandblasting in small-scale workplaces in Turkey reported critical levels of

respirable silica, exceeding standard limits of approximately 300 folds.[35] In addition, a study in artificial stone-related workers in Australia revealed cases of accelerated silicosis with a median age of 44 years. A dry cutting process created a tremendously high level of RCS compared with that from a wet procedure.[36]

Smoking had long been mentioned as a risk factor of silicosis in many studies; however, this study could not exhibit its significant effect.[37–39] Interestingly, the proportion of ever-smokers in the non-silicotic group was higher than that of the other. Given the heavy smoking habits among Thai rural villagers, an effect of second-hand smoke might underpin this phenomenon.

As aforementioned, a silicosis preventive strategy should be fostered at all functional levels. In addition to silicosis health literacy and safe work practices, law enforcement is a key pillar for the control and elimination of silicosis in a national aspect. Such a strategy should highly scope small workplaces and informal workers in the stonework sector, who are exposed to high silica levels with less protection.[9,23,40] Importantly, chest radiography is widely accessible and remains the primary tool for silicosis surveillance. The guideline under the recent Act has lowered the profusion threshold for silicosis from 1/1 to 1/0, leading to the further identification of cases. This change also provides greater opportunities for medico-legal compensation and facilitates the implementation of workplace controls.

Certain limitations of this study should be acknowledged. Firstly, this study was a descriptive design, making it inappropriate to demonstrate the causal relationship among variables. Additionally, the data were collected from informal workers in a single village where some details of their work might have been somehow missed; thus, generalizing the findings to a broader population should be cautiously considered. However, we believe this study depicts common workplace practices of the stonework industry, particularly in rural Thailand. Further studies with comprehensive assessments regarding occupational and environmental aspects are recommended.

## Conclusion

The high prevalence of silicosis portrays underreported numbers of at-risk workers and the prevalence of silicosis in Thailand despite the preventive strategy by the National Silicosis Elimination Program, being launched for more than 20 years. Moreover, the occurrence of progressive massive fibrosis in sandstone engravers suggests heavy silica exposure. Nonetheless, the enactment of the recent Thailand Occupational and Environmental Diseases Control Act is a milestone in strengthening actionable silicosis surveillance systems, as evident in this study. Ultimately, with continued robust support from all functional levels, it is expected that the silicosis preventive strategy will soon be effectively implemented, improving the health and well-being of all the workers.

## Conflict of interest

The authors declare no conflict of interest.

## Statement of Ethics

This study was approved by the Human Research Ethics Committee of Thammasat University (Medicine) with the approval number MTU-EC-CF-0-163/65. Written informed consent was obtained from all the participants for the publication of their information.

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