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Work Schedule Patterns and Related Respirable Crystalline Silica Exposure among Household Sandstone Workers in Nakhon Ratchasima Province, Thailand

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Abstract

Workers in sandstone production are subject to exposed to respirable crystalline silica (RCS) dust, associated with silicosis, lung cancer, and other health issues. This study investigated the work schedule patterns, task engagements, and related RCS dust exposures among household sandstone workers in Nakhon Ratchasima Province, Thailand. Data analysis of interview questionnaires and self-reported work diaries revealed four distinct work schedule patterns among 106 participants: single task in a day (STD), multiple tasks in a day (MTD), multiple tasks in a week (MTW), and multiple tasks in a month (MTM). The concentrations of RCS dust for stone cutting in mine (CM), at home (CH), chiseling (CL), and carving (CV) were assessed by collecting personal air samples from 81 work sessions, which were then used to estimate the 8-hr TWAs for each participant. The geometric means were as follows: 0.015 ± 3.288, 0.012 ± 1.395, 0.019 ± 1.364, 0.016 ± 1.264, 0.037 ± 1.156, 0.018 ± 1.273, 0.005 ± 1.226, 0.125 ± 1.186, 0.014 ± 1.347, 0.019 ± 1.455, and 0.020 ± 1.435 mg/m³ for the groups of STD, MTD, MTW, MTM, CM, CH, CL, CV, CH + CL, CM + CH, and CM + CH + CL, respectively. The statistically significant differences were attributable to the task engagements rather than work schedule patterns ($p < 0.05$). Establishing a system to record the work activities of household workers would be beneficial for assessing occupational exposure and monitoring local health.

Keywords: Work schedule pattern; Respirable crystalline silica; Exposure; Sandstone; Household worker

1. Introduction

Respirable crystalline silica (RCS) is a type of fine mineral dust composed of crystallized silicon dioxide, typically found as quartz or cristobalite. They are typically present in the air in workplaces where materials such as gravel, sand, and sandstone are processed mechanically. Their diameters are 10 µm or smaller, allowing them to be inhaled and deposited in both the upper and lower respiratory tracts (Thompson and Qi, 2022; Thongtip *et al.,* 2019b).

Exposure to RCS dust, whether acute or chronic, can lead to the development of silicosis, a lung disease that cannot be reversed. Workers who have higher and longer exposure face increased risks (National Toxicology Program, 2021). When individuals are affected by this disease, their lung capacity can significantly decrease, which may hinder their ability to carry out work-related or personal activities. Moreover, the RCS dust exposure has been associated with an increased risk of lung cancer development. It has been classified as IARC Group 1 carcinogen based on substantial evidence from studies involving both humans and animals that demonstrate its carcinogenic potential (Rey-Brandariz *et al.,* 2023; International Agency for Research on Cancer, 2012).

Occupational exposure to RCS dust may occur in a wide range of industries, including quarrying, mining, stone processing, construction, and more. Millions of workers worldwide are at risk of being exposed to harmful levels of RCS (Barnes *et al.,* 2019). Several developing and developed countries have implemented occupational exposure limits (OELs) for RCS as a legislative tool/aid for worker protection. The OELs vary greatly amongst the countries, ranging from 0.025 mg/m^3 to 0.35 mg/m^3, averaged over an 8-h work shift (Hoy *et al.,* 2021). Despite the lack of an international agreement, the American Conference of Governmental Industrial Hygienist (ACIGH) has suggested the OEL for RCS at 0.025 mg/m^3 as the maximum airborne concentration to which a worker can be exposed without incurring injury or developing adverse health effects (Hoy *et al.,* 2022; Kunpeuk *et al.,* 2021).

Evaluating worker exposure to RCS is important for determining whether exposure controls and personal protective equipment are necessary. The formal procedure includes measuring the 8-h exposure, which can be achieved through personal or area air sampling, followed by compliance with the specified occupational exposure limit (OEL) (National Institute for Occupational Safety and Health, 2024). Previous studies conducted in Thailand indicated that the levels of RCS exposure in households or small-scale industries varied significantly depending on the specific tasks and materials involved. Some workers have been exposed to levels exceeding the national OEL of 0.025 mg/m^3, which necessitates the implementation of prevention measures and participation in a medical surveillance program (Chanvirat *et al.,* 2018; Kunpeuk *et al.,* 2021). Since household workers, whether self-employed or subcontracted, may not have a fixed schedule and can adjust their workload as needed, the levels of RCS exposure they experience may vary depending on their work schedule patterns and task engagements (i.e., whether they perform single or multiple tasks within a day, week, or month, and the specific groups of tasks they perform), their work hours (i.e., whether they work more or fewer than eight hours per day), and other related characteristics. Understanding these factors would allow for a more comprehensive assessment of their exposure to RCS dust. However, there is insufficient research on this topic.

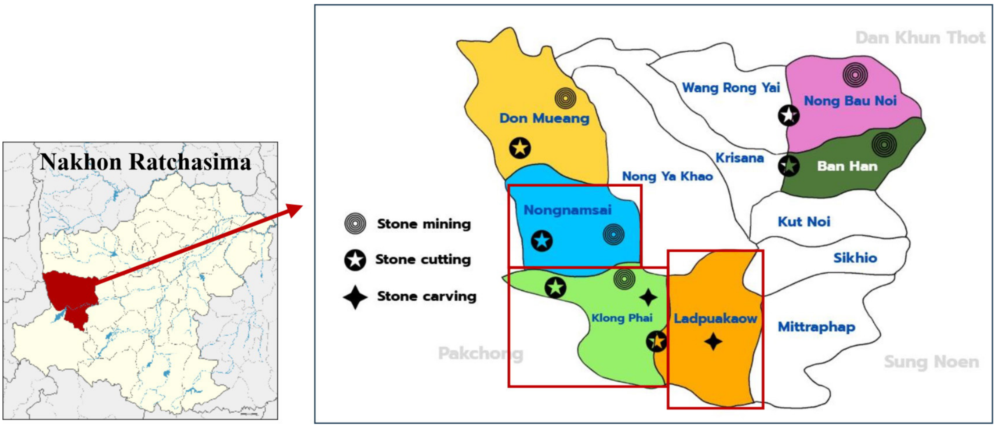
This study aimed to bridge this gap by examining a case study of sandstone workers in Nakhon Ratchasima Province, in northeastern Thailand. Interview questionnaires, self-reported work diaries, and personal air sampling were employed to gather information on the work schedule patterns, task engagements, and other related characteristics of household workers, as well as the associated levels of RCS dust exposure. The findings may offer important insights to aid in risk assessment and health surveillance related to RCS dust exposure among sandstone workers in the informal sector.

2. Methodology

This study was conducted between February and March 2022 in the Nongnamsai, Klong Phai, and Ladpuakaow sub-districts of the Sikhio District, situated in Nakhon Ratchasima Province, recognized as a significant and extensive sandstone industrial region in Northeastern Thailand (Figure 1).

2.1 Study population and sample

The study population was identified as household sandstone workers within the study area. The sample size consisted of 106 workers, determined using Cochran's equation (Cochran, 1977). The margin of error was set at 0.1, with a confidence level of 0.95, and an additional 10% was included to improve representativeness. The criteria for inclusion were as follows: participants must be aged between 20 and 65 years, have had exposure to RCS dust for over one year, have performed four major tasks in sandstone production in Sikhio District (stone cutting in mine [A], stone cutting at home [B], stone chiseling [C], and stone carving [D] as shown in Figure 2), be able to read, write, and communicate in Thai, and provide voluntary consent to participate in the study. The exclusion criteria included individuals with physical or mental health issues that would prevent personal air sampling, as well as those with congenital diseases that could lead to work interruptions, such as asthma, blood disorders, or other similar conditions. A quota sampling method was employed to recruit participants, reflecting the proportion of sandstone workers in each area according to the annual survey data from the Sikhio District. The participants included 82 from Nongnamsai sub-district, 17 from Klong Phai sub-district, and 7 from Ladpuakaow sub-district.



(The study area consists of the districts highlighted in the red boxes)

Source: Sikhio hospital, 2019

Figure 1. Locations of sandstone production in Sikhio District

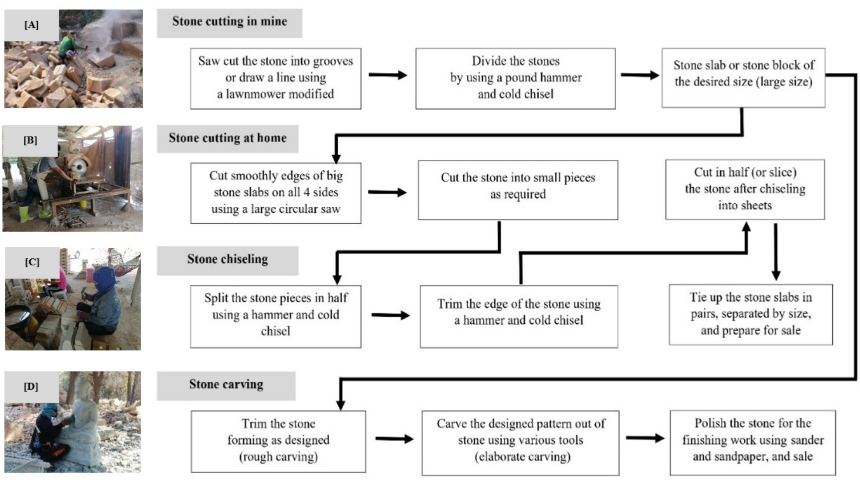


Figure 2. Four major tasks in sandstone production in Sikhio District

2.2 Data collection

2.2.1 Interview questionnaire

This study employed an interview questionnaire to collect demographic information, occupational details, protective behaviors, work environments, and historical illnesses of the participants. It was reviewed by three experts in occupational health and environmental management to ensure its content validity, resulting in an item objective congruence index (IOC) of 0.7. The interviews took place at the workplace of each participant and lasted approximately 20 to 30 minutes.

2.2.2 Self-reported work diary

Participants were asked to self-document their work activities by writing down the task title along with the start and end times for each task they completed every day in a work diary over a period of 30 days. The work diary was modified from Freeman *et al.* (1999) and achieved an IOC of 0.83 according to expert reviews.

2.2.3 Personal air sampling

This study collected air samples over 81 work sessions from a subgroup of 15 participants across five consecutive days based on the principle of similar exposure groups.

The personal air sampling was followed NIOSH Method No. 7601 (National Institute for Occupational Safety and Health, 2003), utilizing the use of a personal sampling pump (SKC Model 224-PCXR8, USA and GilAir Plus, FL33716, USA), a collection device (nylon cyclone, 1.7 L/min), and a 37 mm polyvinyl chloride filter with a 5 µm pore size, housed in a two-piece filter cassette. A consecutive sampling strategy was employed, in which a new filter and filter holder were replaced each time the participant changed tasks during a workday.

Each air sample was subsequently analyzed for the task-specific concentration of RCS dust using visible absorption spectrophotometry (VIS) at the Reference Laboratory and Toxicology Center, Division of Occupational and Environmental Diseases, Department of Disease Control, Thailand.

The study also measured wind speed, temperature, and relative humidity in the work environment using the Climomaster Anemometer - 6501 Series. Additional work-related conditions, such as the use of equipment during tasks, protective measures, and dust control systems, were recorded using an observation form that achieved an IOC of 0.89 based on expert evaluations.

2.3 Exposure assessment

The task-specific concentrations of RCS dust were subsequently combined with data from the self-reported work diary to calculate 8-hour time-weighted averages (8-h TWAs) for each participant's workday, allowing for comparison with the national OEL of 0.025 mg/m³.The equation from the Occupational Safety and Health Administration (2020) was adapted and used to calculate the 8-h TWAs, as shown in Eq. 1.

Eq. 1: $$TWA = \frac{\sum T_n \times C_n}{8}$$

Where; TWA is the 8-h time-weighted concentrations of RCS dust in mg/m³ for all the tasks performed by the participant in a workday (mg/m³); T_n is the duration in hours the participant engaged in the nth task from work diary (hr); and C_n is the corresponding task-specific concentration of RCS dust for the nth task from personal air sampling (mg/m³).

2.4 Data analysis

Descriptive statistics were used to summarize the data collected from the interview questionnaire, self-reported work diary, and personal air sampling. Because the collected data did not follow a normal distribution, the Fisher's exact test was employed to assess associations among work-related characteristics, while the Kruskal-Wallis test and Dunn's test with Bonferroni correction were utilized to evaluate differences in these characteristics across different work schedule patterns. All statistical tests were carried out at a 95% confidence level using R Statistical Software (v4.3.1; R Core Team 2023) with RStudio (v 2023.09.0 Build 463; RStudio Team).

3. Results and Discussion

3.1 Work schedules patterns and related characteristics

This study examined data from interview questionnaires and self-reported work diaries and then identified four distinct work schedule patterns among the 106 participants: single task in a day (STD, n = 78), multiple tasks in a day (MTD, n = 8), multiple tasks in a week (MTW, n = 16), and multiple tasks in a month (MTM, n = 4) (Table 1). The participants with the STD pattern dedicated all their work hours each day to a single task and consistently maintained focus on it throughout the study period. They were likely engaged in stone cutting at home or stone chiseling. Those with the MTD pattern allocated their daily work hours to two or more tasks, maintaining focus on them for most of the study period. They were likely involved in stone cutting at home and stone chiseling. The participants with the MTW or MTM patterns generally focused on one task each day; however, they adjusted their work plans to accommodate one or two other tasks on certain days throughout the weekly or monthly cycles, respectively. They were likely engaged in stone cutting in mine, stone cutting at home, or stone chiseling. Insights from personal discussions indicated that household sandstone workers usually concentrate on tasks where they possess the most skill and experience. Those with the MTD, MTW, or MTM patterns were typically engaged in activities that required similar skills or were interconnected within the sandstone production process. However, they did not participate in stone carving, likely due to its lengthy duration and the need for specialized skills.

The participants had the average daily work hours of 7.1 ± 1.58 and the average monthly workdays of 24.77 ± 3.27. About 25% of them, especially those with STD or MTD patterns who were engaged in stone cutting at home and stone chiseling, exceeded the standard work schedule of eight consecutive hours over five days (Mellemsæther and Eide, 2016). They might be at a higher risk of developing adverse health outcomes due to their prolonged exposure to RCS dust. However, the Kruskal-Wallis test revealed no statistically significant differences in average daily work hours and monthly workdays across the four work schedule patterns ($p > 0.05$).

The participants had flexible working hours according to their workloads and deadlines. Approximately 30% of them started their work each day in the early morning hours (5 - 6 a.m.), while the rest began their work around 7 - 10 a.m. They typically finish their work each day between 4 and 6 p.m. Those engaged in multiple tasks a day had averages work hours of 4.05 ± 1.25, 4.8 ± 1.25, and 2.92 ± 1.05 for stone cutting in mine, stone cutting at home, and stone chiseling, respectively.

3.2 Demographics and health related characteristics

Male participants (n = 69) typically were engaged in tasks that required greater strength, such as cutting stone in mine, cutting stone at home, and carving stone, whereas female workers (n = 37) tended to undertake lighter work or tasks demanding less strength, like chiseling stones (Table 2). This was similarly observed in the earlier study in the same area (Chanvirat *et al.,* 2018). Using the Fisher's exact test, the study found a significant link between work schedule pattern and gender ($p < 0.01$). The MTD, MTW, or MTM patterns were more likely to be found among the male participants.

The participants had the average ages of 41.78 ± 11.90 years old and the average work experience in the sandstone production of 10.67 ± 8.39 years. About 13% of them were over 50 years old and had worked in sandstone production for 10 years or more. The Kruskal-Wallis test showed no significant differences in age and work experience across the four work schedule patterns ($p > 0.05$).

More than 45% of the participants have never had a chest radiograph once. This could be due to the absence of legally required occupational safety and health programs at their workplace, hindering them from taking part in health surveillance (Kongtip et al., 2015). Approximately 20% of the workers who underwent a chest radiograph at least once were found to have abnormalities, specifically diagnosed with silicosis and pulmonary tuberculosis.

Nearly half of the participants were either former or current smokers, which means they have a higher chance of developing adverse health effects like silicosis, lung cancer, and more (Wang *et al.,* 2020).

3.3 Preventive measures and protective behaviors

Almost 75% of the participants had tools equipped with a wetting system, particularly during stone cutting in mine, stone cutting at home, or stone chiseling (Table 3). This system can help reduce the generation of respirable crystalline silica (RCS) dust (Akbar-Khanzadeh *et al.,* 2010). It is important to note that stone carving relies on a dry process instead. About 19% of the participants implemented other preventive measures, such as installing an exhaust fan or a partition wall, either alongside the wetting system or independently. However, approximately 15% of the participants did not implement any preventive measures, especially those with the STD pattern who were engaged in stone chiseling.

Table 1. Summary of work schedules patterns and related characteristics among all participants

Work schedule patterns, n (%):	
Single task in a day (STD)	78 (73.59%)
CM	11 (10.38%)
CH	23 (21.70%)
CL	33 (31.13%)
CV	11 (10.38%)
Multiple tasks in a day (MTD)	8 (7.54%)
CH + CL	7 (6.60%)
CM + CH + CL	1 (0.94%)
Multiple tasks in a week (MTW)	16 (15.09%)
CH + CL	7 (6.60%)
CM + CH	7 (6.60%)
CM + CH + CL	2 (1.89%)
Multiple tasks in a month (MTM)	4 (3.78%)
CH + CL	2 (1.89%)
CM + CH	2 (1.89%)
Work hours in a day, mean ± SD	7.1 ± 1.58
Workdays in a month, mean ± SD	24.77 ± 3.27

Note: CM = stone cutting in mine; CH = stone cutting at home; CL = stone chiseling; and CV = stone carving.

Table 2. Summary of demographics and health related characteristics among all participants

Gender, n (%)	
Male	69 (65.09%)
Female	37 (34.91%)
Age (years), mean ± SD	41.78 ± 11.90
Work experience in the sandstone production (years), mean ± SD	10.67 ± 8.39
Chest radiographic findings to silicosis, n (%)	
Never	49 (46.23%)
Normal	47 (44.34%)
Abnormal	10 (9.43%)
Smoking status, n (%)	
Non-smoker	55 (51.89%)
Former smoker	10 (9.43%)
Current smoker	41 (38.68%)

Almost all participants wore masks as personal protective equipment, particularly medical and cotton masks. With the onset of the COVID-19 pandemic in Thailand, insights from personal discussions revealed that workers were concerned about contracting COVID-19 and had heightened awareness of the risks associated with silicosis. Furthermore, nearly half of the participants maintained a safety routine by cleaning their equipment after each use, particularly those with the STD pattern who were engaged in stone cutting at home or stone chiseling. They typically rinsed the equipment thoroughly with tap water. This practice may help prevent dust from drying on the equipment and becoming airborne (Occupational Safety and Health Administration, 2009).

3.4 Task-specific concentrations of RCS dust

The air samples collected from 81 work sessions were analyzed to assess the concentrations of RCS dust associated with the four major tasks in sandstone production. Figure 3 presents boxplots of task-specific concentrations of RCS dust. The overall distributions were consistent with those reported in the previous study conducted in the same area (Chanvirat *et al.,* 2018). However, the highest average concentrations of RCS dust were observed during the work sessions for stone carving, followed by stone cutting in mine, stone cutting at home, and stone chiseling, respectively (Table 4). This discrepancy may primarily stem from the work methods, equipment, and preventive measures employed, particularly regarding the application of the wetting system. It should be noted that this study observed the use of wetting systems during stone cutting in mine, stone cutting at home, and stone chiseling, whereas Chanvirat *et al.* (2018) reported its application solely during stone cutting at home. Additionally, certain atmospheric factors present during sampling could affect the dispersion of RCS dust and influence the measured concentrations.

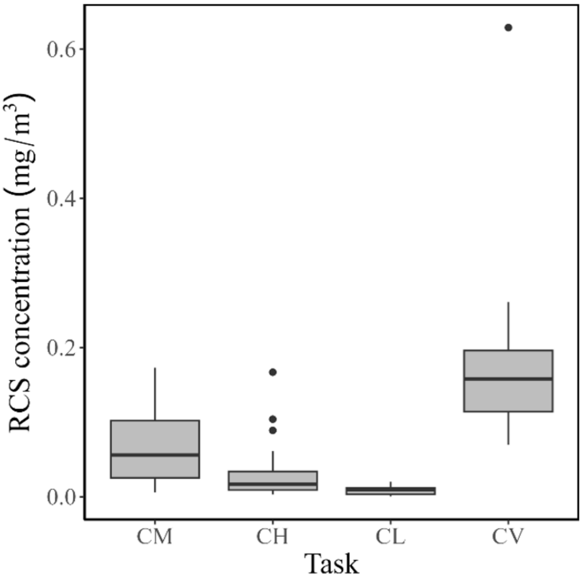
The measured concentrations in this study were also within the same range as those observed in earlier studies conducted among stone processing workers in northern Thailand (Thongtip *et al.,* 2019a; Sayler *et al.,* 2018). However, they were lower when compared to the concentrations reported in previous studies involving stone miners in India (Prajapati *et al.,* 2020) and construction workers in Iran (Normohammadi *et al.,* 2016).

The Kruskal-Wallis test indicated significant differences in RCS concentrations across the four major tasks ($p < 0.0001$), and the Dunn's test with Bonferroni correction revealed significant differences in RCS dust concentrations when comparing stone carving to stone chiseling ($p < 0.0001$), stone carving to stone cutting at home ($p < 0.001$), stone cutting in mine to stone chiseling ($p < 0.001$), and stone cutting at home to stone chiseling ($p < 0.05$).

Table 3. Summary of protective measures and behaviors among all participants

Equipped with a wetting system, n (%)	79 (74.53%)
Installed an exhaust fan or a partition wall, n (%)	20 (18.87%)
Wearing a mask during work, n (%)	104 (98.11%)
Type, n*	
N95 mask/ Half mask respirators	10
Medical mask	47
Cotton mask	41
Silk full face mask	1
Cloth to cover mouth and nose	49
Cleaning the tools after work, n (%)	52 (49.06%)

*Multiple responses



Note: CM = stone cutting in mine; CH = stone cutting at home; CL = stone chiseling; CV = stone carving

Figure 3. Boxplot of task-specific concentrations of RCS dust (mg/m³)

Table 4. Summary of task specific RCS concentrations

Task	Number of air samples (Range of sampling times in hours)	Concentration of RCS dust (mg/m³)	
		GM ± GSD	Range
CM	11 (2.67 – 6.28)	0.043 ± 3.041	0.006 – 0.173
CH	35 (1.27 – 7.80)	0.018 ± 2.600	0.003 – 0.167
CL	26 (2.07 – 6.80)	0.005 ± 3.249	0.001 – 0.020
CV	9 (4.20 – 7.37)	0.165 ± 1.888	0.070 – 0.629

Note: CM = stone cutting in mine; CH = stone cutting at home; CL = stone chiseling; and CV = stone carving. All work sessions were naturally ventilated during the air sampling, with the average wind speed of 0.500 ± 0.410 m/s, the ambient temperature of 31.516 ± 2.808 °C, and the relative humidity of 60.329 ± 10.926 %.

3.5 Exposure concentrations of RCS dust

This study combined the task-specific RCS dust levels with numbers of working hours the participants engaged in each task in self-reported work diaries to estimate 8-h time-weighted averages (8-h TWAs) of RCS dust exposure concentration for each participant during the study period.

The participants with the MTW pattern had the highest geometric mean of the 8-h TWA of RCS dust exposure levels at 0.019 ± 1.364 mg/m³. This was followed by the MTM pattern at 0.016 ± 1.264 mg/m³, the STD pattern at 0.015 ± 3.288 mg/m³, and the MTD pattern at 0.012 ± 1.395 mg/m³ (Table 5). The Kruskal-Wallis test showed no significant differences in 8-h TWA of RCS dust exposure levels across work schedule patterns ($p > 0.05$). Those engaged in stone craving had the highest geometric mean of the 8-h TWA of RCS dust exposure concentrations at 0.037 ± 1.156 mg/m³. This was followed by stone cutting in mine at 0.037 ± 1.156 mg/m³, stone cutting in mine, stone cutting at home, and stone chiseling at 0.020 ± 1.435 mg/m³, stone cutting in mine and stone cutting at home at 0.019 ± 1.455 mg/m³, stone cutting at home at 0.018 ± 1.273 mg/m³, stone cutting at home and stone chiseling at 0.014 ± 1.347 mg/m³,

Table 5. Summary of exposure and risk of RCS across different work schedule patterns

Work schedule pattern/ task engagement groups	Number of participants	8-h TWA of RCS dust (mg/m^3)	
		GM ± GSD	Range
STD	78	0.015 ± 3.288	0.003 – 0.165
MTD	8	0.012 ± 1.395	0.006 – 0.017
MTW	16	0.019 ± 1.364	0.012 – 0.034
MTM	4	0.016 ± 1.264	0.014 – 0.023
CM	11	0.037 ± 1.156	0.030 – 0.045
CH	23	0.018 ± 1.273	0.012 – 0.026
CL	33	0.005 ± 1.226	0.003 – 0.007
CV	11	0.125 ± 1.186	0.095 – 0.165
CH + CL	16	0.014 ± 1.347	0.006 – 0.023
CM + CH	9	0.019 ± 1.455	0.014 – 0.032
CM + CH + CL	3	0.020 ± 1.435	0.012 – 0.034

Note: STD = single task in a day; MTD = Multiple tasks in a day; Multiple tasks in a week (MTW); Multiple tasks in a month; CM = stone cutting in mine; CH = stone cutting at home; CL = stone chiseling; and CV = stone carving.

and stone chiseling at 0.005 ± 1.226 mg/m^3. The Kruskal-Wallis test revealed significant differences in 8-h TWA of RCS dust exposure concentrations across seven task engagement groups ($p < 0.0001$), and the Dunn's test with Bonferroni correction revealed significant differences in RCS dust concentrations when comparing stone cutting at home to stone chiseling ($p < 0.0001$), stone carving to stone cutting at home ($p < 0.05$), stone cutting at home and stone chiseling to stone chiseling ($p < 0.05$), and stone cutting in mine to stone cutting at home and stone chiseling ($p < 0.05$). These results indicated that the varying levels of RCS dust exposure among household sandstone workers were attributable to the specific groups of tasks they performed, rather than their work schedule patterns.

Approximately 25% of participants were exposed to RCS dust levels that exceeded the national OEL of 0.025 mg/m^3 for more than 15 days within a month, particularly those engaged in stone cutting in mine or stone carving for more than 8 hours per day. This indicated that the participants worked in insufficient safety conditions and faced a significant risk of developing adverse health outcomes, like silicosis, lung cancer, and so on, if their situations persist over time (Siriruttanapruk, 2009; Kongtip *et al.,* 2015). The 8-h TWAs of RCS dust exposure were calculated using an indirect method that incorporated task-specific RCS dust levels, and the number of working hours recorded in self-reported work diaries. These findings were consistent with those reported in previous studies based on direct measurements (Thongtip *et al.,* 2019a; Chanvirat *et al.,* 2018; Sayler *et al.,* 2018). However, these estimates may be either underestimated or overestimated if the actual work and environmental conditions differed from those under which the task-specific RCS dust concentrations were determined.

4. Conclusion

This study is the first to investigate how work schedule patterns and task engagements relate to RCS dust exposure levels among household workers, focusing on sandstone workers in Thailand. The participants' work schedule patterns were determined using data from interview questions and self-reported work diaries. The associated RCS dust exposure concentrations for specified tasks were measured through personal air sampling and subsequently used to calculate the 8-hr TWA to ensure compliance with the national OEL. The results indicated that the patterns of work schedules among the participants were significantly linked to gender, but not to daily work hours, monthly workdays, age, or work experience. The household sandstone workers typically organize their work schedules based on the tasks in which they possess the most skill and experience, as well as their workloads and deadlines. This study found significant differences in the 8-h TWAs of RCS dust exposure levels, which were attributable to the specific groups of tasks the participants performed. The findings suggested that governmental agencies, such as the Department of Disease Control, should establish a system for recording the work activities of household workers. Such records would be highly beneficial for assessing occupational exposure and monitoring local health.

This study, however, had limitations that should be recognized. Air samples were collected over 81 work sessions from a subgroup of 15 participants across five consecutive days, due to constraints on resources and accessibility during the COVID-19 outbreak. Further studies should involve a larger subgroup, and a greater number of air samples collected over an extended duration. This may improve the representativeness of task-specific concentrations and result in more accurate exposure assessment.

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Ethical Consideration

This study was reviewed and approved by the Ethics Review Committee for Research Involving Human Research Participants, Health Science Group 1, Chulalongkorn University, COA No. 023/65 dated 28 January 2022.

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