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A Scoping Review on Occupational Exposure of Silica and Asbestos among Industrial Workers in Thailand

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Abstract

Pneumoconiosis is one of the most common occupational lung diseases in Thailand and worldwide. Workplace exposure to asbestos and silica is the main contributor to the prevalence of occupational pneumoconiosis. The aim of this study was to review the prevalence of occupational exposure to asbestos and silica among industrial workers in Thailand. A scoping literature review searched MEDLINE and universities in Thailand. The results from screening 113 were 11 studies selected for further review. Ten studies were cross-sectional and only one study was a retrospective cohort study. Four studies focused on asbestos exposure, whereas seven studies measured silica exposure. From four asbestos exposure studies, three studies showed a higher than standard exposure limit. From seven studies on silica exposure, four studies showed the measured exposure was above the standard level. However, the prevalence of exposure among people working in low-risk areas was not presented. The standard protocol of asbestos and silica exposure measurement was reported. The results showed that the average asbestos and silica exposure exceeded occupational exposure limits stated in either international or national guidelines. The highest level of asbestos exposure was found in a brake pad factory (9.95 fibres/cc). The highest amount of total silica dust was reported in a stone grinding factory (24.3 mg/m^3). Prevention measures and active surveillance programs should be in place for all populations at risk. National surveys on occupational exposure of asbestos and silica are needed to explore current industrial practices and their compliance according to the standard national exposure limit.

Keywords: asbestos, silica, occupational exposure, respiratory, Thailand

Introduction

Pneumoconiosis is one of the most common occupational lung diseases in Thailand and worldwide.[1-3] Exposure to silica asbestos and coal dust can injure lung tissue causing irreversible lung damage.[4,5] Silicosis was the largest specific cause of death from pneumoconiosis, followed by asbestosis and coal workers' pneumoconiosis.[1]

Occupational silica exposure has long been recognized as dangerous to health leading to autoimmune diseases, tuberculosis, lung cancers and other non-malignant respiratory diseases.[6,7] Crystalline silica is considered a human carcinogen by the International Agency for Research on Cancer.[8] Exposure to it has been found in occupations such as construction industries, coal mining, building material industries, glass, and ceramics.[9] It is estimated that silica exposure has been experienced among millions of workers worldwide in a huge number of industries.[9,10] For asbestos, it was widely used in building insulation, roofing shingles, fire blankets, clutches, brake materials and pads for automobiles in many countries during the 19th and 20thcenturies.[11] There are six subtypes of asbestos: chrysotile, crocidolite, amosite, anthophylite, tremolite and actinolite.[12] Asbestos exposure occurs especially from reconstruction and destruction of buildings or materials, with asbestos contamination, and worn vehicle brakes.[13] Asbestos exposure leads to risk of mesothelioma and cancers in different organs including lungs, larynx, and ovaries.[14,15]

Chrysotile imports in Thailand have resulted in massive benefits to the Thai economy.[16] During 1997 to 2010, the value of chrysotile imports was as large as US$ 0.7 billion. Major exporting countries were Russia, China, Brazil, and Kazakhstan.[16] Due to its hazardous effects, the Thai National Health Assembly banned chrysotile asbestos in 2010. In 2018, 134 asbestosis cases were reported in Thailand in 50 provinces.[17] However, diagnosis of asbestos-related disease remains problematic and maybe underestimated in Thailand, because signs and symptoms of asbestosis are similar to other respiratory diseases. Also, owing to its long latent period patients may have recall bias for occupational asbestos exposure.[18] Although the asbestos ban has been adopted in Thailand, implementation has been delayed by unclear information about use of chrysotile, and external pressure from major chrysotile exporting countries.[16]

The Division of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health of Thailand has been a leading authority in tackling asbestosis and silicosis since 2011. A report by the Department of Primary Industries and Mines of Thailand showed that in 2017 there were 436 registered in quarry factories in Thailand.[19,20] In 2018, silicosis cases nationwide numbered about 240 cases in 31 out of 76 provinces, which is about 25% increase from the figure in recent report in 2017 (195 cases in 28 provinces).[17]

Although there is some knowledge on the number of asbestosis and silicosis cases in Thailand, little is known about exposure of asbestos and silica in industrial workers and populations at risk. We therefore aimed to explore evidence about exposure of asbestos and silica among workers in Thailand through a scoping review approach.

Methods

We used a scoping review approach with a special focus on occupational exposure to silica and asbestos that potentially led to pneumoconiosis. Eligibility criteria for screening studies followed the domains of population, exposure, comparator, outcome (PECO),[21] and study type, with a focus on the Thai context, with details as follows. A scoping review is a useful tool to identify the types and gaps of evidence in a given field, and to explore how the research was conducted.[22] It is different from a systematic review as it aims to confirm current practice or address any variation in a particular research question. Also, it is conducted with a rigorous process on critical appraisal and synthesis. However, in this study, there were no limitations about publication years before 2019.

Scope of the Review

Populations

Industrial workers aged 15 years and over working in both formal and informal employment sectors. Unpaid domestic workers were excluded.

Exposures

Asbestos or silica. There was no limitation concerning periods of exposure. Only objective measurements for occupational exposure were included (such as quantitative sample collection of dust and/or fibre using appropriate technologies). Subjective measurements and self-reporting were excluded.

Comparators

The selected papers could be a descriptive study or analytic study with comparator groups (non-exposure samples).

Outcomes

Prevalence of exposure to asbestos and silicosis and the level of asbestos and silica in working environments.

Study types

Only quantitative research was included. All types of study design were eligible. Qualitative studies, case reports and review papers were excluded. The search was limited to only English or Thai articles.

Information Sources

MEDLINE was used as the main source of searched articles with no restrictions of publication years up to 2019. The search strategy was applied from Mandrioli et al,[5] as presented in Table 1. In addition to the electronic search, we sought gray literature from academic institutes and government authorities. These included master-degree dissertations, doctoral theses, reports, and non-peer review publications. Governmental documents provided by the Division of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health were also included. Furthermore, hand searching from Google Scholar was conducted.

Table 1. Exposure, outcomes, and search terms applied in MEDLINE

Domain	Search terms
Silica and silicosis	(((silica) OR ("Silicon Dioxide"[Mesh] OR "Silica Gel"[Mesh] OR "Silicic Acid"[Mesh])) AND (((((silicosis) OR ("Silicosis"[Mesh])) OR ("Lung Diseases"[Mesh])) OR ("Lung Diseases, Interstitial"[Mesh])) OR ("Anthracosis"[Mesh] OR "Pneumoconiosis"[Mesh]))) AND (Thailand) (16 articles as of 2 June 2020)
Asbestos and asbestosis	(("Asbestos"[Mesh] OR "Asbestos, Amosite"[Mesh] OR "Asbestos, Crocidolite"[Mesh] OR "Asbestos, Amphibole"[Mesh] OR "Asbestos, Serpentine"[Mesh]) AND ((("Asbestosis"[Mesh]) OR ("Lung Diseases"[Mesh] OR "Lung Diseases, Interstitial"[Mesh])) OR ("Caplan Syndrome"[Mesh]))) AND (Thailand) (8 articles as of 2 June 2020)

Study Selection Process

All records from online sources were retrieved by ENDNOTE software. Duplicate publications were removed. Title and abstract screening were independently conducted by three authors (ST, JS, MP) before full-text review of potentially relevant records. When any disagreements arose, another author would help to resolve issues. The stage of study selection and reporting followed the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) guideline.[23]

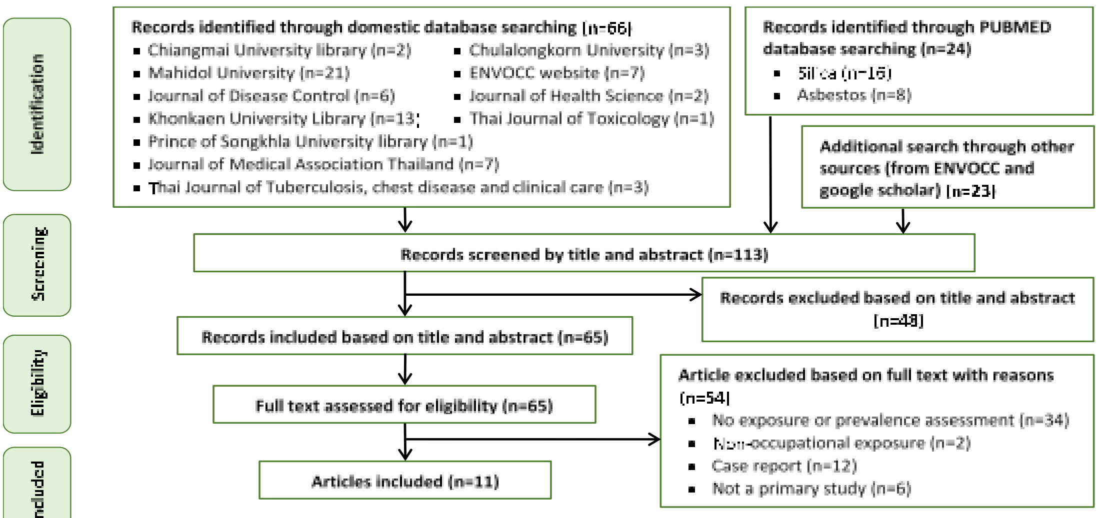
Data Extraction and Analysis

Four authors (SJ, MP, TS, and NR) extracted data from retrieved literature. The extracted data were disaggregated by population characteristics, study design, and industrial or occupation sectors. The proportion of exposed populations to each occupational risk was recorded. Data extraction was conducted using Excel software. We applied framework analysis which was based on the Navigation Guide systematic review methodology.[21] This framework has been applied from the standard Cochrane Collaboration methods for systematic reviews of interventions, and was adapted to the study on occupational and environmental health. The focus of this framework was on hazard identification and risk assessment, which could guide inclusion and exclusion criteria in this study.

Results

Overview of Search Results

A total of 66 articles were selected from domestic websites including Thai universities and government offices, and 24 articles from MEDLINE. Supplementary hand searching identified an additional 23 records. In total, 113 articles were processed for title and abstract screening. Consequently, 48 articles were excluded due to duplication and being non-relevant to the research questions. There were 65 studies eligible for further full-text screening. Finally, we found 11 studies which met inclusion criteria and these entered data extraction process (Figure 1). The excluded data were the articles with no information on asbestos or silica exposure (n=34). Some reported non-occupational exposures (n=2) which were caused by environmental air pollution. Some studies were just a case report (n=12), and were not primary research (n=6). In total, 54 studies were excluded after full-text screening.



Note: ENVOCC: Division of Occupational and Environmental Diseases, Ministry of Public Health of Thailand

Figure 1. Flow diagram of literature search and article selection

Characteristics of Included Studies

Of the eleven studies, year of publication was from 1995 to 2019. Eight studies were peer-review academic articles[24-30] (Table 2 and Supplementary Table 1), one was master-degree thesis,[31] and two were research reports.[32,33] Seven studies focused on silica exposure[19,24,25,29-31,33] while the other four investigated asbestos exposure.[26-28,32]

The central,[28] northern,[32] and southern[27] regions equally had single research about asbestos exposure. Research on silica exposure covered various regions, including two studies in the central region,[24,31] four studies in the northern region,[19,25,30,33] and one in the eastern region.[29] The majority of studies used cross-sectional study design, except Danphaiboon et al,[33] which employed retrospective cohort design.

For asbestos exposure, studies were undertaken in diverse settings (tile factory,[27] cement roof factory,[26] material building factory,[28] and friction material factory).[32] For silica exposure, the majority of studies were conducted in stone mills and stone-related factories,[19,25,30,33] and one study was a sanitary-ware factory.[31] All study participants were identified as 'high risk' as they worked on production sites with direct exposure to asbestos and silica. Mean age of participants varied from 30 to 52 years. The number of participants in most included studies was over 100. Aungkasuvapala et al[24] recruited most participants (n=676). All studies that applied cross-sectional research design presented only descriptive results without analytic findings. Most studies reported 100% high-risk workers exposed to asbestos and silica. It was impossible to estimate asbestos exposure prevalence in a study by Tangtong and Phanprasit[28] as there was no information about participant numbers.

Table 2. Characteristics of the included studies

Author (year)	Type of study record	Study design	Exposure	Location	Characteristics of exposed group	Mean age [years (SD)]	Number of participants (n)	Percentage of exposed workers to total participants involved in the study (%)[40]
Aungkasuvapala et al (1995)[24]	Academic journal	Cross-sectional	Silica in stone grinding factories	Saraburi	High-risk workers at stone-grinding factories	30.7 (9.6)	Exposed=676 Non-exposed =NA	100%
Yingratanasuk et al (2002)[29]	Academic Journal (International)	Cross-sectional	Silica in stone carving company	Eastern region; provinces not specified	Workers at the production site of stone carvers, pestle makers, and mortar makers	33.2 (9.2)	Exposed=97 Non-exposed =NA	100%
Lojananond (2004)[32]	Report	Cross-sectional	Asbestos in break pad (friction materials), tile factory, and cement tube	The lower northern part of Thailand	High risk workers at the production site of break pad (friction materials), tile factory, and cement tube	NA	Exposed=140 Non-exposed =NA	100%
Siriwatananukul (2008)[27]	Academic journal	Cross-sectional	Asbestos in tile factory	Nakhon Si Thammarat	Workers in the tile manufacturing zone and asbestos mixing zone	NA	Exposed=147 Non-exposed =NA	100%
Tangtong and Phanprasit (2008)[28]	Academic journal	Cross-sectional	Asbestos in contained material building	Bangkok	Workers involved in the demolition of building which contained asbestos materials	NA	NA	NA

Table 2. Characteristics of the included studies (Cont.)

Author (year)	Type of study record	Study design	Exposure	Location	Characteristics of exposed group	Mean age [years (SD)]	Number of participants (n)	Percentage of exposed workers to total participants involved in the study (%)[40]
Phanprasit et al.(2009)[26]	Academic journal	Cross sectional	Asbestos in cement roof factory	Four factories; provinces not specified	High risk workers in cement roof factories at the production site	NA	Exposed=19 Non-exposed =NA	100%
Danphaiboon et al. (2012)[25]	Academic journal	Cross-sectional	Silica in stone mill factory	Seven provinces in the northern region of Thailand	Workers at the stone mill production site	NA	Exposed=299 Non-exposed =NA	100%
Danphaiboon (2012)[30]	Academic Journal	Cross-sectional	Silica in stone mill factory	The northern part of Thailand (Chiang Mai, Chiang Rai, Phayao, Phrae, Nan, Lamphun, and Lampang)	Workers in stone mill factory	Overall =40.19 (10.82) Men =40.51 (10.87) Women =35.35 (9.06)	Exposed=272 Non-exposed =NA	100%
Danphaiboon et al (2012)[33]	Report	Retrospective Cohort	Silica in mortar factory	Phayao	Workers in mortar factory	Overall =47.48 (12.08) Men =47.10 (12.10) Women =51.09 (11.84)	Exposed=117 Non-exposed =119	50%
Oopara (2013)[31]	Master's thesis	Cross-sectional	Silica in sanitary ware manufacturer	Saraburi	Workers in the kiln department	36.7 (5.30)	Exposed=168 Non-exposed =NA	100%
Thongtip et al (2019)[19]	Academic journal (International)	Cross-sectional	Silica in stone-mortar factory	Phayao	Stone-mortar workers who had been working there for at least a year	Stone cutters =48 (13) Stone grinders =46 (12) Agricultural workers=47	Exposed=57 Non-exposed =20	74%

NOTE: NA=not described in the paper or not applicable

Exposure Assessment

For asbestos exposure measurement, the standard protocol of the United States National Institute of Occupational Safety and Health (NIOSH), was undertaken to count the number of asbestos fibres. Phanprasit et al[26] and Tangtong and Phanprasit[28] used NIOSH 7400 for reproducible asbestos analysis (Supplementary Table 1). Phanprasit et al[26] conducted both personal and ambient air samplings in wet areas (such as mixing and forming roll areas), and in dusty areas (such as polishing of roof fittings). The number of fibres was counted by a phase contrast microscope. The unit of direct measurement was reported in fibre/cubic centimetre (cc). The unit of cumulative exposure measurement was fibre-years/cc. Tangtong and Phanprasit[28] also used NIOSH 7400 to assess amounts of ambient asbestos from personal and area samples. Siriwatananukul[27] applied NIOSH 7402 for additional analysis by transmission electron microscopy for counting phase contrast microscopy (PCM) visible asbestos fibres. Lojananond[32] did not report the use of standard exposure measurement, only personal pump with 5-micron polyvinyl-chloride (PVC) filter used for air and personnel sampling. Siriwatanakul[27] reported standard exposure time, although other studies did not.

The occupational exposure limits (OELs) from both international and national standards used the same level (0.1 fibre/cc). Lojananond[32] reported the highest asbestos exposure exceeding international and national OELs in a brake pad factory at 6.22-9.95 fibre/cc. Phanprasit et al[26] reported a high level of asbestos exposure at a roof fitting factory at 0.73 fibre/cc. Tangtong and Phanprasit[28] showed that the average asbestos exposure at a ceiling repairing area containing asbestos was at 0.1-0.4 fibre/cc, exceeding the OELs. Only Siriwatananukul's study[27] reported the level of ambient asbestos lower than the OELs, ranged from 0.002 to 0.0068 fibre/cc. Apart from the direct asbestos exposure measurement, Phanprasit et al[6] also calculated the estimated cumulative exposure for high-risk workers which ranged from 90.13 to 115.65 fibre-years/cc.

Measurements of silica dust levels varied by studies (Supplementary Table 2) (for instance, using only ambient air sampling,[25,30,33] using only personnel sampling,[19,29] and a combination of air and personnel samplings).[24] Three studies[19,25,33] applied NIOSH 7601 to determine crystalline silica in respirable or total dust with spectrophotometry to monitor the complex form of silica. However, this method cannot distinguish the difference between three crystalline polymorphs.[34] Danphaiboon et al[30] applied the NIOSH 7500 with X-RAY powder diffraction. This method improved the performance to detect crystalline polymorphs with elimination of silica interferences by phosphoric acid treatment.[35] Oopara[31] measured silica exposure in the production site of sanitary ware with portable devices and use of a universal sample pump (224 PCXR8).

Aungkasuvapala et al[24] used a personal pump with 5-micron polyvinyl-chloride (PVC) pore filter to collect air for area and personnel sampling. Yingratanasuk et al[29] assessed silica exposure in a stone carving company with personal dust sampling. However, there was no report on direct-reading instruments used for respirable silica dust which is less sensitive to detect relatively low-level concentrations of contaminants.[36] Personnel air sampling is more suitable than ambient air sampling for quantifying chemical exposure in studies targeting high-risk workers.[36] However, three studies[25,30,33] did not indicate clear sampling time. Lack of this information limits comparison of results with OELs, which set 8-hour time weighted average exposure level.[37] The study by Oopara[31] applied only four hours for exposure measurement, then adjusted the time to eight hours in order to comply with the time-weighted average.

Findings suggest that the level of silica in all included studies exceeded the exposure limit, in particular the American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH TLV) for respirable fraction of α-quartz and cristobalite, and the Thailand OELs at 0.025 mg/m^3.[38,39] The highest level of silica dust was found in the study by Aungkasuvapala et al.[24] The average amount of total dust was 24.3 mg/cubic metres (m^3)and respirable silica dust was 2.4 mg/m^3.[24]

The level of silica exposure was considered high in Danphaiboon et al's study.[25] The results showed that silica exposure was approximately 15 mg/m^3 in two factories, and average exposure ranged from 1.10 to 15.91 mg/m^3. Another study by Danphaiboon et al[33] reported high levels of average silica dust at 12.11 mg/m^3, with the maximum at 20.41 mg/m^3 in a Phayao mortar factory.

Apart from stone-related factories, Oopara[31] studied silica level in sanitary ware production. Silica exposure before and after the kiln department site was reported at 4.25 and 4.75 mg/m^3, respectively. Yingratanasuk et al[29] measured the severity of exposure and additional three exposure metrics. They were determined by comparing the current quartz exposure to the value indicated by the Thai permissible exposure limit (PEL), and by the ACGIH TLV. The exposure metrics encompassed three measurements. These included, first, years in trade that accounted for the number of years from the time first hired into stone-carving industry until the study year. The second was exposure-years, which was the summation of the overall exposure time (months per year) that a subject has worked in any stone-working jobs. Third was Jahr's cumulative quartz exposure measurement which was an exposure weighing method for quartz. The results showed that exposure levels in carving and pestle production areas ranged from 0.05 to 0.88 mg/m^3. For severity of exposure, only mortar makers exceeded the PEL and ACGIH TLV limits. Moreover, exposure metrics reported in arithmetic means showed that exposure-years was 10.87 years, years in trade was 13.32 years, and Jahr's Quartz Exposure was 19.64 mg/m^3–year.

Discussion

Overall, we found an extremely wide range of silica and asbestosis exposures, when assessing against OELs. For example, Lojananond[32] showed 100% prevalence of exposure among workers in areas with high risk of asbestos. Siriwatananukul[27] reported that all workers operated in areas with low level of asbestosis. For silica exposure, three studies conducted by Danphaiboon et al[25,30,33] demonstrated that all workers in mortar or stone grinding factories had been working in areas where silica levels exceeded the OELs.

The search on occupational risk factors for pneumoconiosis including exposures to asbestos and silica in Thailand was small in number. Almost all studies used only a descriptive cross-sectional approach which is a less rigorous research design. The majority of studies lacked a control group of participants who were not working in areas likely to be exposed to asbestos and silica. With lack of 'control' groups at different levels of exposure, it was difficult to draw conclusions on varying risks of hazard of asbestos and silica to pneumoconiosis, because solid evidence on the exposure of these agents was lacking in this population.

The number of studies on asbestos exposure was smaller than silica exposure, and most studies were conducted in limestone-related factories. This industry type was the largest sector reported in mineral production of Thailand during the fiscal years 2014-2015.[20] Findings suggested that most included studies showed excessive exposure limits indicated by both international and national OELs. For silica exposure, most included NIOSH 7601 as the international standard for silica exposure measurement, and all included studies found excessive levels of silica exposure against OELs. Also, those studies measured exposure level at the production site which revealed critical concern for exposed workers. This situation has been pronounced in low- and middle-income countries[40] where proper control measures have not been regularly monitored, and even in high-income countries where incidence of pneumoconiosis is of critical concern.[41]

The study in Australia examined the proportions of short and thin asbestos fibre during work on asbestos containing materials (ACM). Results showed that both types of asbestos fibre exceeded the World Health Organization fibres exposure limits.[42] A study in Italy showed that many construction workers had exposure levels above the exposure limit set by national legislation (0.01 fibre/cc).[43] Findings suggested excessive levels of asbestos exposure in the US and European countries.[44] A study in New Zealand examined the level of respirable crystalline silica in construction workers. Results showed that about half of the personnel crystalline silica samples exceeded the New Zealand Workplace Exposure Standard, and 56% exceeded the more stringent international recommendation (ACGIH TLV).[45] In low- and middle-income countries, an Indian study showed that respirable crystalline silica dust generated during stone crushing operations in one district exceeded the PEL and REL standards.[46] In China, workers in the asbestos products industry were often exposed to high levels of asbestos which frequently exceeded the Chinese official occupational exposure limit.[47,48] These findings highlight the need for effective prevention measures especially in low- and middle-income countries, where there are high demands from the construction industry as part of national infrastructure development.

Limitations

This review is likely to be one of the first studies to explore the level of occupational asbestos and silica exposure in Thailand. However, some limitations remain. First, the majority of industries reported in the included studies were small (1-49 workers) and medium size (50-199 workers). Therefore, the estimated prevalence in large-scale factories is missing. Second, a larger number of articles were from research reports by universities with few from routine monitoring reports by government agencies. These lacked a long-term follow up, and varying degrees of compliance from factories which created difficulties for monitoring process. Moreover, existing laws on environmental health do not give full authority to the Ministry of Public Health to perform monitoring in all factories at risk. These issues cause challenges to assess the trend of hazard exposure over time. Third, monitoring by officials usually focused on high-risk industries. Hence, evidence included might miss those factories that seemed to be low risk. Forth, as this review aimed to map evidence on the occupational exposure, insights of prevention measures and their implementation on mitigating health risks were lacking in the analysis. Fifth, in methodological terms, some of the included papers seemed to be poor quality. They included flaws with a lack of control group, a small number of participants included, and inexplicit information on exposure assessment. Following the routine approach of a scoping review, quality assessment of the included studies might not be necessary. Moreover, this review did not consider health outcomes of workers. Thus, the causal relationship between pneumoconiosis and its risk factors could not be determined based on this review.

Public Health Recommendations

When considering further public health actions, primary prevention in the workplace should be exercised. Respiratory protective equipment complying with international standards should be strictly and regularly used among workers at risk, and in all factory sizes. All factories should introduce necessary equipment to get rid of the hazards from the beginning, such as installing detectors that can prevent asbestos and silica from contaminating the wider environments. During production activities, preventive measures such as protective equipment for protecting the health of exposed workers in high-risk occupational settings should be in place. In addition, regular monitoring and assessment on the exposure levels to pneumoconiosis risk factors and the health status of the workers at risk should be conducted.

Conclusions

The findings show that most included studies were from the northern region of Thailand with many stone mill factories. A descriptive cross-sectional design was mainly reported, which is considered as less rigorous research design compared with other approaches. The number of participants in most included studies was quite small. More importantly, the lack of information on low levels of silica and asbestos exposure among industrial workers resulted in great difficulties to determine the exact exposure prevalence. NIOSH 7400 and 7402 were the most common methods for assessing asbestos levels. For silica dust, some studies did not present clear methods for exposure assessment. More than half of studies showed that the results of exposure level exceeded OELs, and some studies reported that all high-risk workers functioned in areas where asbestos levels were beyond acceptable standard. Prevention measures and active surveillance programs should be in place for all populations at risk at national level. Current practices of occupational health standards in asbestos- and respirable silica-related factories should be regularly updated. Moreover, analysis of dose-response relationships between asbestos and silica exposure and the effects of respiratory symptoms are of great value and will add academic richness in the field of occupational health in Thailand.

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