Community Research of Epidemiology (CORE)

VOLUME 6 ISSUE 2, JUNE 2026
Page 83-92

p-ISSN: 2774-9703 e-ISSN: 2774-969X
Homepage : http://journal.uin-alauddin.ac.id/index.php/corejournal
10.24252/corejournal.v6i2.65921

Silica dust exposure and silicosis among mine workers: A literature review

Paparan debu silika dan silikosis di kalangan pekerja tambang: Tinjauan pustaka

Fatmawaty Mallappiang*[1], Astrid Amanda Putri[2], Dhini Nackita Majid[3], Nurul Fadhillah[4], Rahmat Ramadhan[5], Rezki Ramdani[6]

[1, 2, 3, 4, 5] Department of Public Health, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, Gowa, Indonesia
[6] Department of Health Administration, Faculty of Faculty of Sport and Health Sciences, Universitas Negeri Makassar, Makassar, Indonesia

Abstract

Although silicosis has long been recognised as a preventable occupational lung disease, recent evidence continues to show persistent risks among mine workers, indicating the need to synthesize current findings on silica dust exposure and disease incidence. This literature review aimed to examine the relationship between respirable silica dust exposure and the incidence of silicosis among mine workers. Articles were searched in PubMed, Google Scholar, and ScienceDirect for studies published between 2015 and 2025 using the keywords silica dust exposure, silicosis, and mine workers. From 100 identified articles, five relevant studies were selected through a stepwise screening process based on predefined inclusion and exclusion criteria. The selected articles were systematically reviewed by comparing study design, exposure assessment methods, worker characteristics, and findings related to silicosis risk. The reviewed evidence consistently showed that exposure to respirable silica dust was associated with an increased risk of silicosis, particularly among workers exposed to higher dust concentrations and longer employment durations. The findings also indicated that the use of personal protective equipment and the implementation of workplace environmental controls were important factors in reducing occupational exposure and disease risk. This review highlights that silicosis prevention among mine workers requires comprehensive exposure control strategies, including dust monitoring, engineering controls, consistent use of protective equipment, health surveillance, and stronger occupational safety policies in mining workplaces.

Abstrak

Meskipun silikosis telah lama diakui sebagai penyakit paru-paru akibat pekerjaan yang dapat dicegah, bukti-bukti terkini terus menunjukkan adanya risiko yang masih ada di kalangan pekerja tambang, yang mengindikasikan perlunya merangkum temuan terkini mengenai paparan debu silika dan insiden penyakit. Tinjauan pustaka ini bertujuan untuk mengkaji hubungan antara paparan debu silika yang dapat terhirup dan insiden silikosis di kalangan pekerja tambang. Artikel-artikel dicari di PubMed, Google Scholar, dan ScienceDirect untuk studi yang diterbitkan antara tahun 2015 dan 2025 dengan menggunakan kata kunci paparan debu silika, silikosis, dan pekerja tambang. Dari 100 artikel yang teridentifikasi, lima studi yang relevan dipilih melalui proses penyaringan bertahap berdasarkan kriteria inklusi dan eksklusi yang telah ditentukan sebelumnya. Artikel-artikel yang dipilih ditinjau secara sistematis dengan membandingkan desain studi, metode penilaian paparan, karakteristik pekerja, dan temuan yang berkaitan dengan risiko silikosis. Bukti-bukti yang ditinjau secara konsisten menunjukkan bahwa paparan debu silika yang dapat terhirup berkaitan dengan peningkatan risiko silikosis, terutama di kalangan pekerja yang terpapar konsentrasi debu lebih tinggi dan masa kerja yang lebih lama. Temuan tersebut juga menunjukkan bahwa penggunaan alat pelindung diri dan penerapan pengendalian lingkungan kerja merupakan faktor penting dalam mengurangi paparan di tempat kerja dan risiko penyakit. Tinjauan ini menekankan bahwa pencegahan silikosis di kalangan pekerja tambang memerlukan strategi pengendalian paparan yang komprehensif, termasuk pemantauan debu, pengendalian teknis, penggunaan alat pelindung diri secara konsisten, pemantauan kesehatan, serta kebijakan keselamatan kerja yang lebih ketat di tempat kerja pertambangan.

Keywords :

silica dust; silicosis; mine workers; occupational health; pneumoconiosis

Correspondence:

✉ fatmawaty.mallapiang@uin-alauddin.ac.id
🏛 Minasa Upa Blok AB9/27, Rappocini, Makassar, Indonesia

Submit (2026/02/19) ; Revised (2026/03/18); Accepted (2026/04/02) ; Available Online (2026/06/29)
©The authors 2026. This is an open access article under the CC BY-NC-SA 4.0 license

INTRODUCTION

A Silicosis is a preventable but irreversible fibrotic occupational lung disease caused by repeated inhalation of respirable crystalline silica (RCS) dust. It remains an important global occupational health concern because silica exposure persists across many work settings, while inadequate surveillance and reporting systems may contribute to the under-recognition of silica-related respiratory disease (World Health Organization [WHO] & International Labour Organization [ILO], 2021; Hoy et al., 2022). Silica is a naturally occurring mineral composed of silicon dioxide (SiO_2) and is commonly found in rocks, sand, and mineral ores. In occupational environments, respirable crystalline silica, particularly quartz and cristobalite, represents the greatest health concern because fine particles can reach the distal airways and alveolar region of the lungs, triggering inflammation, fibrosis, and progressive respiratory impairment (Hoy et al., 2022; Misra et al., 2023).

Mining is one of the occupational sectors with substantial potential for RCS exposure. Activities such as drilling, blasting, crushing, milling, loading, screening, and mineral processing can generate respirable dust containing crystalline silica. Evidence from artisanal gold mining in Tanzania, metal and nonmetal mining in the United States, and lithium mining in Western Australia shows that RCS exposure varies according to mining process, job task, commodity, work location, and workplace control measures (Gottesfeld et al., 2015; Misra et al., 2023; Gbondo et al., 2024). This issue is closely related to the Sustainable Development Goals, particularly SDG 3 on good health and well-being and SDG 8 on decent work and economic growth, because preventing silicosis requires safe workplaces, effective dust-control systems, occupational disease surveillance, and protection of workers from preventable respiratory hazards.

The main research problem is that mine workers continue to experience respirable silica dust exposure and remain at risk of silicosis and related respiratory outcomes, yet the available evidence is fragmented across exposure measurement, clinical diagnosis, tuberculosis complications, and preventive control strategies. Repeated inhalation of RCS can cause pulmonary inflammation and fibrosis, resulting in progressive respiratory impairment, while workers with silicosis have a substantially increased risk of pulmonary tuberculosis (Ehrlich et al., 2021; Hoy et al., 2022). Evidence from artisanal and small-scale mining settings in Zimbabwe and Tanzania has also shown a considerable burden of silicosis, impaired lung function, and tuberculosis among miners, particularly where dust-control measures and occupational health services are limited (Moyo et al., 2022; Mbuya et al., 2024). Therefore, a comprehensive solution requires integrated occupational health prevention, including engineering controls, administrative controls, exposure monitoring, respiratory protection, worker education, periodic medical surveillance, and stronger reporting systems for silica-related respiratory disease (WHO & ILO, 2021; Tsang et al., 2019).

Scientific literature emphasizes that prevention of silicosis should prioritize reducing respirable crystalline silica exposure at the source. Mining activities that generate dust, including drilling, blasting, crushing, and mineral processing, should be controlled through wet methods, water suppression, enclosure of dust-generating processes, local exhaust ventilation, equipment maintenance, and effective worksite ventilation (ILO, 2022; WHO & ILO, 2021). These engineering measures are essential because RCS exposure may persist in specific occupations and operational areas despite existing workplace controls, as shown in studies among metal and nonmetal miners and lithium mine workers (Gbondo et al., 2024; Misra et al., 2023). Exposure reduction should also be supported by administrative controls, including task rotation, restricted access to high-dust areas, routine workplace monitoring, and compliance with occupational exposure limits.

In addition to exposure control, early detection and health surveillance are critical to reduce the burden of silica-related disease among mine workers. Silicosis diagnosis requires consideration of occupational exposure history, clinical assessment, and radiological evaluation. Chest radiography remains an important tool for occupational surveillance and epidemiological assessment, while the International Labour Organization classification system provides a standardized approach for recording radiographic abnormalities associated with pneumoconiosis (ILO, 2022, 2023). Periodic health surveillance should be linked to worker education, appropriate respiratory protective equipment, and referral pathways for workers with suspected respiratory impairment. This approach is especially important because silicosis may progress even after exposure has ceased and is strongly associated with pulmonary tuberculosis (Ehrlich et al., 2021; Hoy et al., 2020; Rajavel et al., 2020).

Previous studies have documented the harmful effects of respirable crystalline silica exposure among mine workers, including silicosis, impaired lung function,

tuberculosis, chronic obstructive pulmonary disease, pulmonary fibrosis, lung cancer, and kidney disease (IARC, 2012; Hoy et al., 2022; Howlett et al., 2023). Studies from different mining contexts have shown that exposure levels and respiratory risks vary according to mining commodity, job task, work location, duration of employment, use of wet methods, ventilation, and respiratory protection practices (Gottesfeld et al., 2015; Misra et al., 2023; Gbondo et al., 2024). However, existing publications often examine workplace dust exposure, clinical outcomes, tuberculosis complications, or mining populations separately. This creates a gap in integrated understanding of how exposure characteristics, worker vulnerability, silica-related respiratory outcomes, and preventive measures interact in mining settings.

The novelty of this literature review lies in its synthesis of published evidence on respirable silica dust exposure, silicosis risk, related respiratory outcomes, and preventive measures among mine workers. Rather than focusing only on exposure levels or disease occurrence, this review brings together evidence from different study approaches to provide a broader interpretation of silica-related occupational health risks in mining. This integrated perspective is important because differences in exposure assessment methods, study populations, and outcome definitions make it difficult to draw a consistent picture of silicosis risk across mining settings. Therefore, this literature review aimed to examine the relationship between respirable silica dust exposure and the incidence of silicosis among mine workers.

METHODS

Search strategy

This study applied a systematic literature review approach to examine the relationship between silica dust exposure and the incidence of silicosis among mine workers. The literature search was conducted in a planned and systematic manner using three online databases: Google Scholar, PubMed, and ScienceDirect. Articles published between January 2015 and January 2025 were included to ensure the use of the most recent and relevant scientific evidence. Literature published in both Indonesian and English was considered in order to obtain a broad and comprehensive range of sources, particularly those relevant to the Asian context.

During the article search process, combinations of keywords were applied using Boolean operators such as AND and OR. The keywords included ("silica dust exposure" OR "silica exposure") AND ("silicosis") AND ("miners" OR "mine workers" OR "mining workers"). In addition, equivalent terms in the Indonesian language were also used to enhance search sensitivity and coverage.

Study selection criteria

Articles were selected based on the PICOS framework: Population—miners exposed to silica dust; Exposure—respirable silica dust in the workplace; Comparison—different levels or durations of exposure, or the presence or absence of exposure control measures; Outcome—the incidence of silicosis or silica exposure–related lung disorders; and Study design—observational studies, case studies, and relevant systematic reviews.

Studies were included if they were national or international journal articles, addressed silica dust exposure and silicosis among mine workers, were available in full text, and were conducted in Asia or within the context of the global mining industry. Studies were excluded if they did not specifically address silicosis, reported exposure without associated health outcomes, were single case reports, editorials, opinion pieces, or had inadequately described methodologies.

Screening and selection process

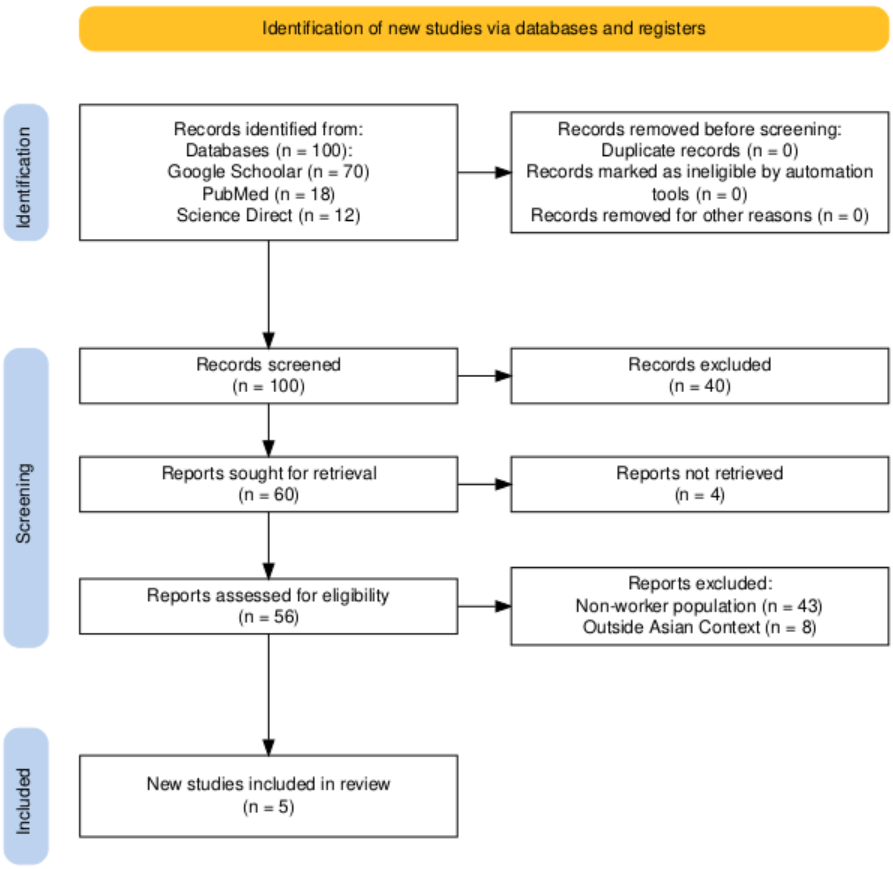
The study selection process was conducted in several stages. The initial search identified 100 records, including 70 records from Google Scholar, 18 from PubMed, and 12 from ScienceDirect. Duplicate records were removed before screening. The first reviewer screened the titles and abstracts of the identified articles based on the predefined inclusion and exclusion criteria. Articles considered potentially relevant were retrieved in full text for further assessment (see Figure 1).

The eligibility of full-text articles was assessed by the first reviewer and checked by a second reviewer. Any differences in judgment regarding article inclusion or exclusion were discussed until consensus was reached. Following title and abstract screening, 60 articles remained. Further relevance screening reduced the number to 56 articles. After full-text eligibility assessment, 13 articles met the worker-population criteria, and five publications were included in the final narrative synthesis.

Data extraction

Data extraction was conducted systematically using a structured synthesis table to summarize key information from each selected study. Extracted data

Figure 1
PRISMA flow diagram



included the authors' names and year of publication, study location or region, research design, characteristics of the study population, type of silica dust exposure, methods used to assess silicosis, and key findings describing the relationship between silica dust exposure and the incidence of silicosis among mine workers.

Data synthesis and analysis

Given the heterogeneity in study designs, participant characteristics, and methods for assessing silicosis, a narrative synthesis was employed as the primary analytical approach. The selected studies were analyzed by comparing research methodologies, study designs, respondent characteristics, instruments used to measure silicosis, and data analysis techniques. The synthesis findings were presented descriptively to illustrate patterns in the relationship between silica dust exposure and the incidence of silicosis among mine workers in Asia.

Methodological quality assessment

The methodological quality of the included publications was appraised according to their study design. The two systematic reviews were assessed using the AMSTAR 2 tool, while the cross-sectional exposure-assessment studies were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies. The document-based case study was assessed using the JBI Critical Appraisal Checklist for Text and Opinion Papers.

The appraisal considered the clarity of the research question, appropriateness of the search or sampling strategy, validity of exposure measurement, adequacy of outcome assessment, management of potential bias, transparency of data analysis, and relevance to the review objective. Two reviewers independently assessed methodological quality, and disagreements were resolved through discussion until consensus was reached. Publications were categorized as having low, moderate, or high methodological quality. The overall quality of the body

of evidence was interpreted by considering the methodological quality, directness to the review objective, consistency of findings, and variation in exposure and outcome assessment across publications.

Protocol registration and reporting

This narrative literature review was not prospectively registered in PROSPERO or another review registry. Although the review objectives, search sources, keywords, and eligibility criteria were specified before article screening, no publicly accessible protocol was available. The study selection process was reported transparently to describe the identification, screening, eligibility assessment, and inclusion of publications.

RESULTS

Five publications were included in the final narrative synthesis, as shown in Table 1. Because the included publications differed in study design, population, exposure-assessment methods, and health outcomes, the findings were not pooled quantitatively. Instead, a narrative thematic synthesis was conducted to identify common patterns and differences across the included publications. Overall, the publications indicated that respirable silica dust is an important occupational hazard among mine workers, although the evidence varied in its focus on exposure measurement, silicosis risk, and related respiratory outcomes.

Methodological quality of included publications

The methodological quality of the included publications varied from low to moderate. The systematic review by Howlett et al. (2023) demonstrated a relatively stronger methodology because it used multiple databases, independent screening by two reviewers, structured data extraction, and a risk-of-bias assessment. However, the authors acknowledged heterogeneity, selection bias, and limitations in the quality of the primary studies included in their review.

The systematic review by Putri et al. (2021) was considered to have lower methodological confidence because reporting of the search strategy, reviewer procedures, and critical appraisal of included references was limited. The document-based case study by Estaurina et al. (2024) provided useful contextual information regarding the vulnerability of female sandstone mine workers; however, its evidence was indirect because it was based on document and literature analysis rather than primary epidemiological data.

Golbabaei et al. (2019) and Prajapati et al. were considered to have moderate methodological quality for exposure assessment because both applied standardized methods to measure respirable dust and crystalline silica. Nevertheless, these studies did not directly assess clinically confirmed silicosis; therefore, their contribution was primarily related to exposure characterization rather than disease occurrence.

Overall, the body of evidence was considered moderate for describing occupational silica-exposure risk patterns and preventive measures among mine workers. However, evidence specifically addressing clinically confirmed silicosis was interpreted cautiously because of indirectness in some publications, heterogeneity of study designs, and variation in exposure and outcome assessment methods

DISCUSSION

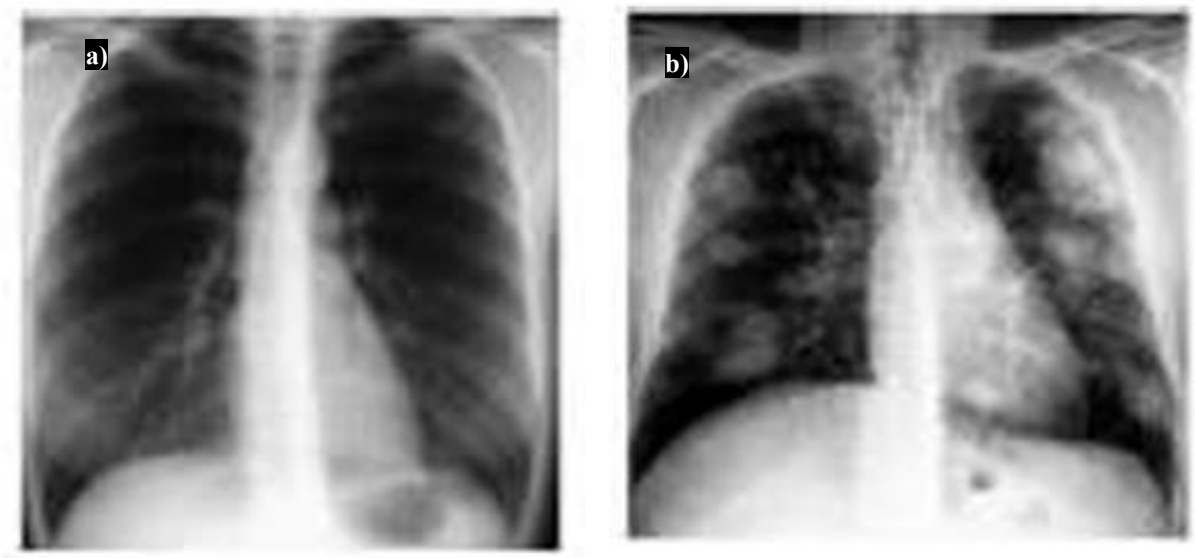
A This narrative literature review synthesized five selected publications addressing respirable silica dust exposure, silicosis risk, related respiratory outcomes, and preventive measures among mine workers. The synthesis indicates that respirable crystalline silica exposure remains an important occupational health hazard in mining settings. However, because the included publications differed in design and scope, the findings should be interpreted as describing consistent risk patterns rather than providing pooled estimates of silicosis incidence. The five publications included in the synthesis table remain the primary evidence base for the findings of this review. Additional references cited in this discussion are used only to compare the findings with wider published literature.

Putri et al. (2021) reported that respirable crystalline silica exposure among mine workers is associated with an increased risk of progressive and irreversible silicosis, particularly under conditions of high dust concentrations and prolonged work duration. This finding is supported by Estaurina et al. (2024), who highlighted the vulnerability of female sandstone mine workers exposed to fine silica dust in settings characterized by long working hours, limited personal protective equipment, and weak occupational health protection. Together, these publications indicate that silica-related risk is influenced not only by dust concentration but also by duration of work, work organization, access to protective measures, and the social vulnerability of specific worker.

Table 1
Synopses of articles

Title (Author)	Objective	Design & Sample	Methods	Results	Conclusion
Systematic Review: Identification of Silica Dust Exposure Hazards among Mine Workers (Putri et al., 2021)	This study aimed to identify the hazards of silica dust exposure among mine workers by conducting a comprehensive literature review of 36 reference sources.	Systematic review; the sample consisted of 15 selected articles discussing mine workers exposed to silica dust, published between 2015 and 2020.	Literature searches were conducted using the ScienceDirect, Google Scholar, PubMed, ProQuest, Elsevier, and Cochrane databases. Inclusion criteria focused on studies addressing silica dust exposure among mine employees. A descriptive, evidence-based analysis was applied.	Exposure to respirable crystalline silica dust among mine workers was strongly associated with an increased risk of silicosis, a progressive and irreversible disease. Higher risks were observed with high exposure concentrations and longer durations of work, particularly in metal mining. Contributing factors included duration of exposure, dust intensity, smoking habits, and low use of personal protective equipment (PPE).	Silicosis is an incurable occupational lung disease caused by silica dust generated during mining activities. Currently, there is no effective treatment; therefore, effective preventive measures are required to reduce risk factors associated with silica dust exposure.
Silicosis: A Case Study of Occupational Lung Disease among Female Sandstone Mine Workers (Estaurina, Pramudit, & Syahir, 2024)	This study aimed to understand silicosis experienced by female sandstone mine workers in Budhpura Village, Rajasthan, India.	Qualitative case study based on a literature review to analyze occupational lung disease (silicosis); the study population consisted of female sandstone mine workers in Budhpura Village, Rajasthan, India.	Literature review of books, journals, scientific articles, and online media; document analysis using a case study approach to identify risk factors, pathophysiology, and intervention strategies.	Silicosis caused by exposure to fine silica dust leads to lung inflammation, fibrosis, and death. Risk factors included long exposure duration (approximately 10 hours/day), lack of personal protective equipment (PPE), and weak enforcement of occupational health regulations. Preventive recommendations included dust control measures, regular health examinations, and occupational health promotion programs.	Silicosis among female workers in the sandstone mining industry exposed to fine silica dust represents a serious occupational health problem. Addressing this issue requires multidisciplinary collaboration and the active participation of female workers to protect their health and labor rights in the workplace.
Evaluation of Occupational Silica Dust Exposure among Mining Workers in Eastern Iran (Golbabaei et al., 2019)	This study aimed to determine total and respirable dust levels, as well as the crystalline silica content in soil within the breathing zones of mining workers in Iran.	Cross-sectional study; all workers across six silica mines in Iran (114 workstations).	Measurement of total and respirable dust concentrations in workers' breathing zones using NIOSH Method No. 0600; analysis of crystalline silica content using NIOSH Method No. 7601 and X-ray diffraction (XRD).	Total and respirable dust concentrations in nearly all mining units exceeded the ACGIH/NIOSH threshold limit values, with the highest exposure observed in crushing units. Crystalline silica content was extremely high (approximately 91%) and, in some units, reached up to 100 times above permissible limits, indicating a very high risk of silicosis.	Crystalline silica exposure among workers in all mining units exceeded recommended standard limits. Immediate implementation of technical, managerial, and personal protective solutions is critically important to reduce silica exposure among workers.
Exposure to Respirable Dust and Crystalline Silica in Various Mining Sectors in India (Prajapati et al., 2021)	To characterize and compare exposure to respirable dust and crystalline silica among limestone, iron ore, and bauxite mine workers in India, and to evaluate exposure levels in relation to applicable occupational exposure limits.	Descriptive observational cross-sectional study; 86 personal dust samples collected from mine workers: limestone (n = 30), iron ore (n = 30), and bauxite (n = 26), collected between March and June 2018.	Personal respirable dust sampling (8-hour time-weighted average) using DGMS-approved dust samplers. Dust concentrations were determined gravimetrically, while crystalline silica content was analyzed using Fourier Transform Infrared Spectroscopy (FTIR) following NIOSH Method 7602. Statistical analysis was performed using ANOVA to compare concentrations across mining sectors.	The geometric mean concentrations of respirable dust were 0.92 mg/m³ for limestone, 1.08 mg/m³ for iron ore, and 1.07 mg/m³ for bauxite. Crystalline silica concentrations were 0.015 mg/m³, 0.012 mg/m³, and 0.008 mg/m³, respectively. Differences in crystalline silica concentrations across mining sectors were statistically significant ($p < 0.05$). Although all samples were below the Indian permissible exposure limits, several exceeded OSHA and ACGIH standards, indicating the need for stricter exposure control to prevent silicosis.	None of the samples exceeded the Indian permissible exposure limit for crystalline silica; however, three samples exceeded OSHA limits and eight exceeded ACGIH limits. The Indian permissible exposure limit is higher than those recommended by international agencies. Although exposure levels were within national limits, lower crystalline silica concentrations should be targeted to minimize the risk of silicosis.
Exposure to Silica, Silicosis, and Tuberculosis among Artisanal and Small-Scale Miners: A Systematic Review and Modelling Study (Howlett P et al., 2023)	This study aimed to examine the relationship between silica and airborne dust exposure and the occurrence of silicosis and tuberculosis among mine workers, and to assess the role of silica exposure as a risk factor for tuberculosis.	Systematic literature review of observational studies, including cohort, case–control, and epidemiological survey studies, involving mine workers and other industrial sectors with high silica dust exposure.	Data were obtained from studies reporting silica exposure levels, silicosis prevalence based on radiological findings or clinical diagnoses, and active tuberculosis incidence. Descriptive and comparative analyses were conducted to assess the relationships between silica exposure, silicosis, and tuberculosis.	The review found that silica dust exposure was associated with an increased risk of both silicosis and tuberculosis. Tuberculosis risk was higher among workers with silicosis; however, an elevated risk was also observed among workers exposed to silica without silicosis, indicating that silica exposure is an independent risk factor for tuberculosis.	The study identified a consistently high burden of silicosis and tuberculosis among artisanal and small-scale miners, despite generally short exposure durations and latency periods. This burden is likely driven by high levels of respirable crystalline silica (RCS) exposure, and reductions in RCS exposure are expected to substantially decrease the prevalence of silicosis and the incidence of tuberculosis.

Figure 2
Normal chest and silicosis



Note: a) Normal Chest X-ray; b) Chest X-ray of a patient with silicosis

The exposure-assessment studies by Golbabaei et al. (2019) and Prajapati et al. (2021) provide quantitative evidence that respirable dust and crystalline silica concentrations may exceed recommended occupational limits in mining activities. Golbabaei et al. reported high exposure in crushing units, while Prajapati et al. found differing crystalline silica concentrations across limestone, iron ore, and bauxite mining. These findings suggest that exposure intensity varies by mining commodity, job task, dust-generating process, and workplace controls. Therefore, compliance with exposure limits should not be assumed to eliminate long-term respiratory risk, particularly after repeated exposure over many years.

Evidence from studies outside the five included publications is consistent with this interpretation. Gottesfeld et al. (2015) identified substantial silica exposure during artisanal and small-scale gold-mining activities in Tanzania. Similarly, Misra et al. (2023) documented persistent hazardous respirable crystalline silica exposure among metal and nonmetal miners in the United States, with variation by mine type, commodity, occupation, and work location. Gbondo et al. (2024) also demonstrated that respirable dust and crystalline silica exposure among lithium mine workers varied across occupational groups and mining processes. These studies support the need for task-specific exposure monitoring rather than relying solely on general workplace measurements.

The relationship between silica exposure and silicosis is also influenced by cumulative exposure. A systematic review and dose-response meta-analysis by Howlett et al. (2024) found that increasing cumulative respirable crystalline silica exposure was associated with a higher risk of silicosis. Long-term follow-up among Vermont granite workers similarly showed that silicosis may still occur after prolonged exposure to relatively low concentrations of respirable crystalline silica (Vacek et al., 2024). In addition, a cohort study by Wang et al. (2025) found that long-term low-level silica exposure was associated with an increased risk of silicosis. These findings reinforce the importance of reducing exposure as far as reasonably achievable and considering cumulative exposure duration in occupational health surveillance.

The health effects of silica exposure are not limited to silicosis alone. Howlett et al. (2023), one of the included publications, reported that silica exposure was associated with increased risks of both silicosis and tuberculosis among artisanal and small-scale miners. This finding is consistent with research among gold miners in South Africa, where the prevalence of silicosis differed across mines and was associated with worker and employment characteristics (Knight et al., 2020). Studies among miners in Tanzania and Zimbabwe have also documented the coexistence of silicosis, impaired lung function, and tuberculosis-related health burdens in small-scale mining populations (Mbuya et

al., 2024; Moyo et al., 2022). Furthermore, a systematic review and meta-analysis by Ehrlich et al. (2021) confirmed that silicosis is strongly associated with pulmonary tuberculosis and that silica exposure may contribute to tuberculosis risk even when radiological silicosis is not confirmed.

Figure 2 is included to provide clinical context and do not constitute evidence derived from the included publications. This Figure illustrates a normal chest radiograph and presents an example of a chest radiograph from a patient with silicosis. The contrast between these images helps illustrate why radiological examination may be relevant in occupational health surveillance for workers with a history of substantial silica exposure. However, chest radiography alone cannot establish the diagnosis or severity of silicosis. Interpretation should consider occupational exposure history, clinical symptoms, standardized radiological assessment, and further examination when clinically indicated. Austin et al. (2021) noted that chest radiography remains widely used for surveillance, whereas computed tomography may provide greater sensitivity for early disease detection in selected cases.

Overall, the findings suggest that prevention of silica-related respiratory disease in mining requires a comprehensive approach. Priority should be given to controlling dust generation at its source through engineering measures, including wet drilling, water suppression, local exhaust ventilation, and enclosed or isolated crushing processes. These measures should be supported by administrative controls, routine exposure monitoring, appropriate respiratory protective equipment, worker training, and periodic health surveillance. Health surveillance should include occupational history, respiratory symptom assessment, pulmonary-function testing when indicated, and radiological evaluation according to applicable occupational health procedures.

The findings of this review should be interpreted with caution. Although the included publications consistently identify silica dust as an important occupational hazard, the evidence varies in methodological quality and directness to clinically confirmed silicosis. Some publications focused on exposure measurement rather than disease diagnosis, while others synthesized evidence from different mining settings. Therefore, this review does not provide pooled estimates of silicosis incidence. Nevertheless, the convergence of findings across exposure-assessment studies, reviews, and contextual mining studies supports the need for strengthened dust control, respiratory protection, and surveillance among mine workers.

This review provides an overview of published evidence on silica dust exposure, silicosis risk, related respiratory health outcomes, and preventive measures among mine workers. A strength of this review is the inclusion of publications with different perspectives, including exposure assessment studies, systematic reviews, and a qualitative case study, which allowed a broader description of occupational silica-related risks in mining settings.

However, several limitations should be considered. First, the included publications varied in study design, study population, exposure assessment methods, and outcome measures, which limited direct comparison across studies. Second, some publications assessed respirable dust or crystalline silica exposure without directly evaluating clinically confirmed silicosis. Therefore, the findings should be interpreted as describing patterns of occupational risk and prevention rather than providing direct estimates of silicosis incidence. Third, the review included a limited number of publications and was restricted to articles available in the selected databases and publication period. This may have resulted in the omission of relevant studies.

In addition, this narrative literature review was not prospectively registered in PROSPERO or another public review registry. Although the search sources, keywords, and eligibility criteria were specified before article screening, the absence of a registered protocol may limit the transparency of the prespecified review procedures. These limitations should be considered when interpreting the findings and recommendations of this review

CONCLUSION

This narrative literature review indicates that respirable silica dust remains an important occupational health hazard among mine workers. The reviewed publications consistently suggest that higher dust exposure, prolonged work duration, inadequate dust-control measures, and inconsistent use of personal protective equipment are associated with increased silica-related respiratory risks, including silicosis risk. However, because the included publications differed in design, exposure assessment methods, and outcome measures, the findings should be interpreted as evidence of occupational risk patterns rather than direct estimates of silicosis incidence or proof of a causal relationship.

This review contributes to occupational health practice by integrating evidence on silica exposure,

respiratory health risks, worker vulnerability, and prevention measures in mining settings. The findings emphasize the importance of reducing respirable silica dust exposure through a hierarchy of controls. Engineering controls, including wet drilling, water suppression, local exhaust ventilation, and enclosure of dust-generating processes, should be prioritized. These measures should be supported by routine exposure monitoring, maintenance of dust-control equipment, worker education, appropriate respiratory protective equipment, and periodic respiratory health surveillance. Government authorities and mining companies should strengthen the implementation and monitoring of occupational safety and health regulations related to silica dust exposure. Health surveillance programmes should consider occupational exposure history, respiratory symptoms, lung-function assessment when indicated, and radiological evaluation according to applicable occupational health procedures. Further research is needed to evaluate the effectiveness of dust-control interventions and long-term respiratory health outcomes, particularly among workers in artisanal, small-scale, and informal mining settings.

ACKNOWLEDGEMENT
The authors would like to express their appreciation to the Department of Public Health, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, and the Department of Health Administration, Faculty of Sport and Health Sciences, Universitas Negeri Makassar, for their academic support in the preparation of this literature review.

FUNDING
The author(s) reported there is no funding associated with the work.

AUTHORS' CONTRIBUTIONS
Fatmawaty Mallappiang contributed to the conceptualisation of the study, study design, supervision, and critical revision of the manuscript. Astrid Amanda Putri contributed to literature searching, article screening, and manuscript drafting. Dhini Nackita Majid contributed to data extraction, synthesis of findings, and manuscript preparation. Nurul Fadhillah contributed to reviewing selected articles, organizing study characteristics, and supporting manuscript development. Rahmat Ramadhan contributed to literature management, data interpretation, and manuscript formatting. Rezki Ramdani contributed to methodological input, manuscript review, and final revision. All authors read and approved the final version of the manuscript.

AUTHORS' INFORMATION
Dr. Fatmawaty Mallappiang, M.Kes is an associate professor in Department of Public Health, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, Gowa, Indonesia. Astrid Amanda Putri, Dhini Nackita Majid, Nurul Fadhillah, and Rahmat Ramadhan are researchers affiliated with the Department of Public Health, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin Makassar, Gowa, Indonesia. Rezki Ramdani, SKM., M.Kes is a lecturer affiliated with the Department of Health Administration, Faculty of Sport and Health Sciences, Universitas Negeri Makassar, Makassar, Indonesia.

COMPETING INTERESTS
The authors affirm that there are no conflicts of interest related to the research, writing, or publication of this article.

REFERENCES

Austin, E. K., James, C., & Tessier, J. (2021). Early detection methods for silicosis in Australia and internationally: A review of the literature. *International Journal of Environmental Research and Public Health, 18*(15), 8123. https://doi.org/10.3390/ijerph18158123

Ehrlich, R., Akugizibwe, P., Siegfried, N., & Rees, D. (2021). The association between silica exposure, silicosis and tuberculosis: A systematic review and meta-analysis. *BMC Public Health, 21*, 953. https://doi.org/10.1186/s12889-021-10711-1

Estaurina, E. L., Pramudit, N. B., & Syahir, R. (2024). Silikosis di kalangan perempuan pekerja tambang batu pasir. *Journal of Evidence-Based Nursing and Public Health, 1*(1), 44–51. https://doi.org/10.61511/jevnah.v1i1.2024.531

Gbondo, D., Zhao, Y., Pham, M., & Rumchev, K. (2024). Trends in exposure to respirable dust and respirable crystalline silica among lithium mine workers in Western Australia. *Safety and Health at Work, 15*(4), 481–490. https://doi.org/10.1016/j.shaw.2024.08.005

Golbabaei, F., Gholami, A., Teimori-Boghsani, G., Yaseri, M., & Kianmehr, M. (2019). Evaluation of occupational exposure to silica dust in mining workers in Eastern Iran. *The Open Environmental Research Journal, 12*(1), 1–6. https://doi.org/10.2174/1874213001912010001

Gottesfeld, P., Andrew, D., & Dalhoff, J. (2015). Silica exposures in artisanal small-scale gold mining in Tanzania and implications for tuberculosis prevention. *Journal of Occupational and Environmental Hygiene, 12*(9), 647–653. https://doi.org/10.1080/15459624.2015.1029617

Howlett, P., Mousa, H., Said, B., Mbuya, A., Kon, O. M., Mpagama, S., & Feary, J. (2023). Silicosis, tuberculosis and silica exposure among artisanal and small-scale miners: A systematic review and modelling paper. *PLOS Global Public Health, 3*(9), e0002085. https://doi.org/10.1371/journal.pgph.0002085

Howlett, P., Gan, J., Lesosky, M., & Feary, J. (2024). Relationship between cumulative silica exposure and silicosis: A systematic review and dose-response meta-analysis. *Thorax, 79*(10), 934–942. https://doi.org/10.1136/thorax-2024-221447

Hoy, R. F., Chambers, D. C., & Glass, D. C. (2020). Silica-related diseases in the modern world. *Allergy, 75*(11), 2805–2817. https://doi.org/10.1111/all.14202

Hoy, R. F., Jeebhay, M. F., Cavalin, C., Chen, W., Cohen, R. A., Fireman, E., Go, L. H. T., León-Jiménez, A., Menéndez-

Navarro, A., Ribeiro, M., & Rosental, P. A. (2022). Current global perspectives on silicosis—Convergence of old and newly emergent hazards. *Respirology, 27*(6), 387–398. https://doi.org/10.1111/resp.14242

International Agency for Research on Cancer [IARC]. (2012). *Arsenic, metals, fibres, and dusts* (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 100C). IARC.

International Labour Organization [ILO]. (2022). *Diagnostic and exposure criteria for occupational diseases: Guidance notes for diagnosis and prevention of the diseases in the ILO list of occupational diseases (revised 2010).* ILO.

International Labour Organization [ILO]. (2023). *Guidelines for the use of the ILO International Classification of Radiographs of Pneumoconioses: Revised edition 2022.* ILO.

Knight, D., Ehrlich, R., Cois, A., Fielding, K., Grant, A. D., & Churchyard, G. (2020). Predictors of silicosis and variation in prevalence across mines among employed gold miners in South Africa. *BMC Public Health, 20*, 829. https://doi.org/10.1186/s12889-020-08876-2

Mbuya, A. W., Mboya, I. B., Semvua, H. H., Mamuya, S. H., Howlett, P. J., & Msuya, S. E. (2024). Prevalence and determinants of evidence of silicosis and impaired lung function among small scale tanzanite miners and the peri-mining community in northern Tanzania. *PLOS Global Public Health, 4*(9), e0002770. https://doi.org/10.1371/journal.pgph.0002770

Misra, S., Sussell, A. L., Wilson, S. E., & Poplin, G. S. (2023). Occupational exposure to respirable crystalline silica among US metal and nonmetal miners, 2000–2019. *American Journal of Industrial Medicine, 66*(3), 199–212. https://doi.org/10.1002/ajim.23451

Moyo, D., Ncube, R., Kavenga, F., Chikwava, L., Mapuranga, T., Chiboyiwa, N., Chimunhu, C., Mudzingwa, F., Muzvidziwa, O., Ncube, P., Mando, T. C., Moyo, F., Chigaraza, B., Masvingo, H., & Timire, C. (2022). The triple burden of tuberculosis, human immunodeficiency virus and silicosis among artisanal and small-scale miners in Zimbabwe. *International Journal of Environmental Research and Public Health, 19*(21), 13822. https://doi.org/10.3390/ijerph192113822

Prajapati, S. S., Mishra, R. A., Jhariya, B., & Dhatrak, S. V. (2021). Respirable dust and crystalline silica exposure among different mining sectors in India. *Archives of Environmental & Occupational Health, 76*(7), 455–461. https://doi.org/10.1080/19338244.2021.1919857

Putri, A. N., Marlia, A., Mar'ah, E. C. F., Suswoyo, F. I. H., Hanief, M. A., & Firdaus, V. A. (2021). Review sistematik: Identifikasi bahaya paparan debu silika pada pekerja tambang. *CoMPHI Journal: Community Medicine and Public Health of Indonesia Journal, 1*(3), 162–169. https://doi.org/10.37148/comphijournal.v1i3.30

Rajavel, S., Raghav, P., Gupta, M. K., & Muralidhar, V. (2020). Silico-tuberculosis, silicosis and other respiratory morbidities among sandstone mine workers in Rajasthan: A cross-sectional study. *PLOS ONE, 15*(4), e0230574. https://doi.org/10.1371/journal.pone.0230574

Tsang, V. W. L., Lockhart, K., Spiegel, S. J., & Yassi, A. (2019). Occupational health programs for artisanal and small-scale gold mining: A systematic review for the WHO global plan of action for workers' health. *Annals of Global Health, 85*(1), 128. https://doi.org/10.5334/aogh.2592

Vacek, P. M., Glenn, R. E., & Parker, J. E. (2024). Low-level respirable crystalline silica and silicosis: long-term follow-up of Vermont granite workers. *International Journal of Environmental Research and Public Health*, *21*(5), 608. https://doi.org/10.3390/ijerph21050608

Wang, D., Li, W., Zhou, M., Ma, J., Guo, Y., & Chen, W. (2025). Long-term exposure to low-level crystalline silica and risk assessment of silicosis: a cohort study. *Thorax*, *80*(7), 451-456. https://doi.org/10.1136/thorax-2024-222660

World Health Organization, & International Labour Organization. (2021). *WHO/ILO joint estimates of the work-related burden of disease and injury, 2000–2016: Global monitoring report.* World Health Organization and International Labour Organization.