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Silicosis prevalence and related issues in India: a scoping review

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Abstract

Background Silicosis remains a major occupational health challenge in India. This review systematically examines the prevalence, risk factors, regional differences, and diagnostic tools specific to India's high-risk industries. Additionally, it assesses policy gaps and offers insights from diverse clinical and qualitative studies, aiming to inform targeted public health interventions and support the development of effective occupational health policies.

Methods For this review, data were extracted for each study, including author, location, design, study aims, sample size and characteristics, participant age, duration of silica exposure, diagnostic criteria, and primary outcomes. As an add-on analysis included, a random-effects meta-analysis was used to estimate the pooled prevalence of silicosis and assess variability among studies. The review also included qualitative analyses on awareness, diagnostic tools (e.g., CC16 protein), and differences in prevalence across various occupational groups and regions within India.

Results The review initially identified 263 articles, narrowed down to 49 eligible studies on silicosis in India after exclusions and quality assessment. Among these, 11 prevalence studies (total sample size: 2072) showed an average silicosis rate of 31.39%. Specific studies reported high rates, including 52% among Rajasthan mine workers and 69.1% among Khambhat agate workers. Additionally, screening tools, like CC16 protein levels, showed promise for early diagnosis, while qualitative studies highlighted gaps in awareness and regulatory practices. Meta-analysis revealed a significant pooled prevalence (25.98%) and marked variability ($I^2 = 98.86\%$), underscoring the need for targeted interventions and worker protections.

Conclusions This review of current knowledge on silicosis in India finds silicosis highly prevalent among workers in mining and stone industries, with gaps in regulatory enforcement and awareness. Biomarkers like CC16 offer the potential for early diagnosis, underscoring the need for preventive measures. Policy recommendations include stricter dust exposure limits, enhanced workers' education, routine screening, and improved access to protective equipment and health monitoring to reduce the risk of silicosis and health disparities in vulnerable occupational groups.

Keywords Silicosis, Occupational hazard, Stone quarrying, Epidemiology, Review

Introduction

Silicosis is a progressive and irreversible occupational lung disease caused by inhaling crystalline silica dust. This condition, a type of pulmonary fibrosis, arises from breathing in tiny silica particles—a common mineral found in sand, quartz, and diverse rock formations. Silicosis remains a global health concern, mainly in regions with heavy industrial and mining activities. Silica is widely used in various industries, including mining,

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construction, and manufacturing. Workers in these sectors are at a high risk of silica exposure, leading to silicosis development over time. Silicosis is characterised by accumulated lung scar tissue, causing breathlessness, persistent cough, chest pain, and fatigue.

Rationale

In recent years, there has been a growing recognition of the global burden of silicosis [1]. In 2019, global records indicated 2.65 million reported cases of silicosis [2]. During that period, silicosis led to over 12.9 thousand fatalities worldwide, contributing to an estimated 0.65 million disability-adjusted life years (DALYs). While the overall number of fatalities and DALYs related to silicosis decreased between 1990 and 2019, there was an alarming increase in low- and middle-income countries [3]. Around 227 million workers are confronted with the threat of silicosis, notably within the unorganised sector and among migratory workers [4, 5].

With its vast industrial landscape and a large workforce engaged in occupations with potential silica exposure, India represents a significant hotspot for silicosis-related health issues. As of mid-2023, India is on track to become the world's most populous country, surpassing all others with a population exceeding 1.43 billion individuals. Additionally, it is consolidating its position as the third most sought-after manufacturing destination globally [6, 7]. Projections for 2025 indicate that India will house approximately 25% of the global working population (~0.8 billion), with about 92% engaged in the informal sector [8–11]. Most occupations in this informal sector expose workers to silica dust in India.

Globally, both silicosis and tuberculosis are targeted for elimination by 2030 [12–14]. Tuberculosis, referred to as the clinical complication of silicosis or silico-tuberculosis, continues to be a noteworthy public health issue in low and middle-income nations [15]. Mine workers exposed to silica, whether or not they have silicosis, are at an increased risk of tuberculosis. Individuals with silicosis have a much higher likelihood (2.8 to 39 times) of developing tuberculosis compared to those who are healthy [16].

The debilitating impact of silicosis on respiratory health and its association with increased morbidity and mortality highlight the urgency of understanding its prevalence, associated factors, and clinical manifestations.

Objective

Despite a significant body of research on silicosis, comprehensive reviews focusing on India's unique occupational settings, regulatory challenges, and workforce demographics are limited. This review aims to fill this gap by systematically examining the prevalence, risk factors, and regional disparities specific to India's high-risk industries. Additionally, it evaluates current diagnostic tools and policy implications, providing insights for targeted interventions to protect India's large informal workforce. This scoping review contributes to shaping effective occupational health policies by highlighting evidence-based solutions. This review examines silicosis in India, highlighting regional prevalence variations, influencing factors, and challenges in policy implementation. It also addresses innovative screening tools and diverse case studies, emphasising the multidisciplinary approach for improved occupational health outcomes.

Material and methods

We reviewed published studies by various authors to comprehensively evaluate and analyse existing research on silicosis in India. Our focus encompassed the examination of prevalence, associated factors, screening tools, qualitative insights, and diverse clinical presentations. Throughout this iterative review, we adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) – Extension for Scoping Reviews [17]. The PRISMA checklist detailing the steps taken during this review is provided as a supplementary file in the annexure.

Eligibility criteria

Inclusion Criteria: i) Studies must involve a human population; ii) Studies must contain primary data related to silicosis; the case series and case studies were included if they present unique, first-hand observations of individual patient cases. iii) Original research articles or studies, including the qualitative research reporting primary data, are eligible; and iv) Studies conducted in India. *Exclusion Criteria*: i) Studies that do not involve a human population ii) Studies that lack primary data on silicosis iii) Review articles and other non-original articles iv) Studies conducted outside India v) Studies that do not provide sufficient information on silicosis disease. These criteria were applied to select studies for inclusion in our review, ensuring the relevance and quality of the research considered.

Information sources and search strategy

We systematically searched three databases: PubMed, Google Scholar, and Scopus. The search incorporated specific terms and keywords, including 'Silicosis,' 'pneumoconiosis,' 'grinder's asthma,' 'grinder's disease,' 'stonemason's disease,' and 'India.' This review followed an open-frame design, without setting a specific time frame, to maximise the inclusion of pertinent studies in the analysis. In the case of the Google Scholar search, we restricted it to titles only. The keyword 'India' was

systematically included in all combinations of the specified keywords during the search. The results were confined to full articles published in English.

Selection process

The study selection process followed the principles outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) – extension for scoping reviews guidelines. Firstly, duplicate studies across various databases were eliminated. Afterwards, articles were screened based on their titles and abstracts, removing irrelevant ones according to predefined inclusion and exclusion criteria. Further, we assessed the full texts of the remaining articles using exclusion criteria and removed additional studies deemed irrelevant. Both authors independently selected the studies for inclusion. If there is any disagreement between two authors, a senior colleague of the authors (who is not qualified to be an author) acted as an arbiter to resolve these conflicts and ensure a consensus is reached.

Quality evaluation

We rigorously assessed the methodological quality of each included study using JBI's critical appraisal checklists [18]. The appraisal of prevalence and its associated factors studies utilised the checklist designed for prevalence studies, while qualitative articles were assessed using the checklist for qualitative research. Screening tools evaluated the studies based on the checklist tailored for diagnostic test accuracy studies. Additionally, case series and case study studies were appraised using the checklists designated for Case series and Case study, respectively.

Data collection process

After the selection process, data extraction was performed, with two reviewers independently extracting key information such as author (year), study location, study design, the aim of the study, sample size & characteristics, age, duration of exposure, diagnostic criteria and outcomes. The data extraction is done using a PRISMA checklist. Any discrepancies were resolved through consensus or consultation with a third reviewer.

Data synthesis

The selected papers were read thoroughly, and data were extracted and tabulated in detail. The subsequent meta-analysis and data synthesis were carried out using R version 4.3.1. The study employed random-effects modelling and a statistical method utilised in meta-analysis to address inherent variability between studies. Studies reporting the prevalence of silicosis were included in the meta-analysis, and a forest plot was used to visually summarize the prevalence estimates from different studies.

A random-effects model was applied to account for variability in effect sizes across the studies. The between-study variance (τ^2) was estimated to assess the degree of variation among the included studies. Heterogeneity was further examined using the I^2 statistic, which quantifies the percentage of variability due to heterogeneity rather than chance, and H^2, which provides an alternative representation of heterogeneity. The test for heterogeneity, measured by the Q statistic, was significant ($p < 0.0001$), indicating substantial variability in the effect sizes across the studies. The random-effects model was selected to examine the prevalence of silicosis across eleven studies, reflecting the diversity and differences in study findings.

Results

Study selection

On initial searches from three databases, 263 articles were identified. Among them, 75 were found to be duplicates and were subsequently removed. This left us with 188 unique research articles for the first stage of screening, which involved assessing the abstracts. During this stage, 71 articles were excluded based on abstract content. The reasons for exclusion included 27 studies that did not involve a human population, 15 studies lacking primary data, 28 articles categorised as reviews or other non-original articles, and one study conducted outside India. After the initial abstract screening, 117 research articles proceeded to the second stage, which involved a comprehensive full-text review. During this stage, 59 articles were excluded based on the content of their full texts. The reasons for exclusion at this stage included 17 studies that did not involve a human population, six studies lacking primary data, six articles classified as reviews or other non-original articles, 22 studies lacking sufficient information on silicosis disease, and eight studies whose full texts were unavailable.

Subsequently, 58 research articles were considered eligible for inclusion after full-text screening. Following a rigorous quality assessment, nine papers were excluded; six were removed due to insufficient information on silicosis [19–24], and three did not meet the quality JBI's checklist criteria [25–27]. The result of the quality checklist is shown in the annexure. In total, 49 articles were ultimately included in the review. These comprised 11 articles on prevalence, six articles on associated factors, two qualitative studies, two on screening tools, 21 case studies, and 7 case series. The representation of the selection of the papers and their numbers at different steps are illustrated in the form of a PRISMA flow diagram (Fig. 1).

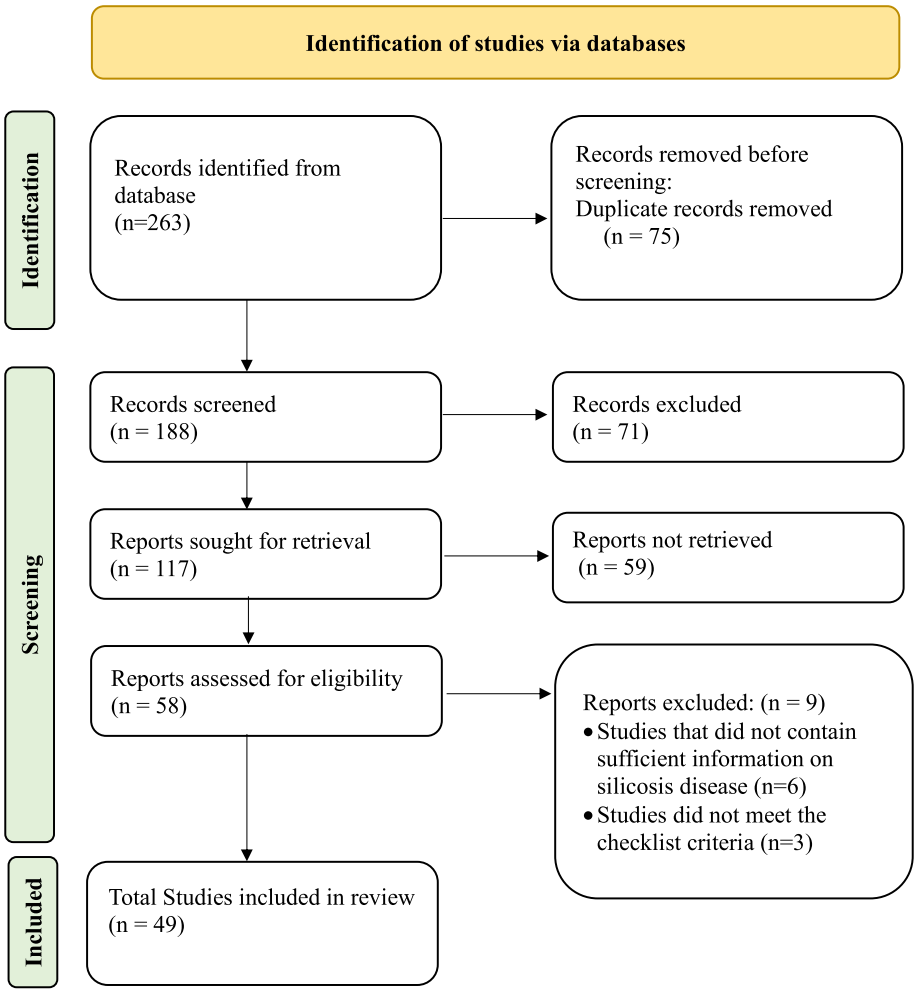

Fig. 1 Flow chart depicting the selection process of articles included in the review

Study characteristics

The data extraction is done using a PRISMA checklist. This checklist encompassed the following information: author (year), study location, study design, the aim of the study, sample size & characteristics, age, duration of exposure, diagnostic criteria and outcomes. The results of data extraction are shown in Table 1. This systematic approach ensured the comprehensive gathering of relevant data points from the selected studies.

Results of the studies

Prevalence of silicosis and associated factors

The prevalence studies of this occupational lung disease were conducted across India. The combined sample size of 2072 individuals across these studies revealed a total of 650 cases of silicosis out of eleven prevalence articles. The overall percentage of silicosis prevalence across the studies is approximately 31.39%. In 1953, an investigation involving 329 miners in Bihar revealed nodular and conglomerate silicosis in 34.1% of cases, demonstrating a direct correlation with both dust exposure and work duration [28]. A study conducted in 1969 observed a 28.3% occurrence of silicosis among 120 stone cutter workers, with a significant seven times increase in pulmonary tuberculosis among those affected [30]. In the year 1984, a specific investigation on 60 stone cutters in Kashmir revealed a 20% prevalence of silicosis [32].

A cross-sectional study conducted in Gujarat involving 134 ex-workers from quartz stone crushing units identified 24 cases of silicosis and 33 cases of silico-tuberculosis. This underscores persistent respiratory health risks associated with exposure to quartz stone dust [36]. Another study in the Godhra region of Gujarat focused on female workers engaged in quartz mill stone-grinding, revealing a high prevalence of silicosis among 85 workers. Chest radiograph findings indicated silicosis in 14% of cases, with 11.6% showing signs of silico tuberculosis and 8.1% having tuberculosis. Abnormal pulmonary function

Table 1 Characteristics of studies included in this review

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
1	Heimann et al. (1953) [28]	Bihar, East India	Prevalence	Investigate the prevalence of silicosis and its correlating factors among workers in the mica mining industry	329 miners	-	-	chest X-ray	Nodular and conglomerate silicosis were identified in 34.1% of the examined miners, and this occurrence was directly correlated with both the level of occupational dust exposure and the duration of time spent working in those occupations
2	Thiruvengadam et al. (1968) [29]	Andhra Pradesh, South India	Case study	A case report of mica-mine worker	One	27 years	> 10 years	-	A 27-year-old man, briefly employed in a mica mine, developed conglomerate silicosis. This progressed to massive fibrosis, ultimately causing respiratory failure ten years after his initial exposure to agate work
3	Gupta et al. (1969) [30]	Not specified	Prevalence	Examine silicosis prevalence and associated factors among stone cutter workers	120 workers	16 to 60 years	1 to 30 years	chest X-ray	The general occurrence of silicosis was identified at 28.3%, and a seven times increase in the occurrence of pulmonary tuberculosis was noted among individuals with silicosis compared to those without silicosis

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
4	Jain et al. (1977) [31]	Mandsaur district, Madhya Pradesh, Central India	Prevalence, Cross-sectional	Study the disease occurrence in employees of small-scale slate-pencil manufacturing industries	151 persons working in slate-pencil manufacturing industries (144 males, 7 females)	-	-	Chest X-ray	Incidence and severity of silicosis proportional to length of exposure
5	Saini et al. (1984) [32]	Kashmir, North India	Prevalence	Examine the incidence of silicosis among workers in the stone-cutting industry	60 stone-cutter	17–65 years	2–45 years	chest X-ray	Among 120 stone cutters, 20% of the workers were diagnosed with silicosis
6	Sharma et al. (1991) [33]	Badarpur, New Delhi, North India	Case series	Evaluate effects of daily prednisolone therapy on alveolitis parameters and lung function	34 male workers with chronic silicosis	37 ± 9.72 years	6 months	Lung function parameters	Pulmonary function tests showed a significant improvement in lung volumes, FEV1, PEFR, SGaw, OLeo, and Pao2; a decrease in total cell count in SAL fluid; no serious side effects encountered
7	Mathur and Dixit (1999) [34]	Jodhpur, West India	Prevalence, Cross-sectional	Assess the relationship between various variables and Forced Vital Capacity in sandstone quarry workers	168 sandstone quarry workers	31.15 years	12.27 years	Radiological opacities suggestive	20% or more deviation in Forced Vital Capacity is significantly associated with radiological opacities, suggesting silicosis

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
8	Chakraborty et al. (2020) [35]	Not specified	Case study	Investigate the link between silica exposure and ventricular tachycardia	One patient, male	45 years	Long-term occupational exposure to silica	ECG, radiological	The case study explores a patient with ventricular tachycardia linked to ventricular myocardial fibrosis due to long-term occupational silica exposure. Emphasises the need for early suspicion and accurate cardiac magnetic resonance imaging diagnosis
9	Tiwari et al. (2003) [36]	Gujarat, West India	Prevalence, Cross-sectional	Assess spirometric measurements	134 ex-workers from quartz stone crushing units	33.18 ± 10.39 years (men); 30.10 ± 9.3 years (women)	Mean duration of exposure: 2.74 ± 1.65 years	Spirometry (measured with Spirovit SP-10)	Among ex-workers, 24 cases of silicosis and 33 cases of silico-tuberculosis were identified through spirometric measurements
10	Parakh et al. (2005) [37]	Not specified	Case study	Present a case of Chronic Necrotising Pulmonary Aspergillosis with aspergilloma complicating silicosis	One male with a long history of silica dust exposure	52 years	-	Clinical, radiological, and microbiological evidence	Diagnosis of Chronic Necrotising Pulmonary Aspergillosis in a patient with silicosis, aspergilloma, PMF, cavitations, productive cough, fever, and hemoptysis
11	Bhagia and Sadhu (2008) [38]	Khambhat, Gujarat, West India	Prevalence	Assess the cost–benefit of installing dust control devices in the agate industry	1927	-	-	-	Installing dust control devices can reduce silicosis and TB prevalence, resulting in significant financial benefits

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
12	Tiwari and Sharma (2008) [39]	Gujarat, West India	Prevalence, Cross-sectional	Study respiratory health effects related to free silica dust exposure	85 female quartz mill stone-grinding workers	28.2 ± 9.2 years	Free silica dust exposure	Chest radiographs, pulmonary function test	Silicosis (14.1%) and silicotuberculosis (11.8%) prevalence in former workers. Respiratory morbidity associated with exposure duration
13	Chaudhury et al. (2010) [40]	Khambhat, Gujarat, West India	Prevalence, Cross-sectional	Assess the prevalence of X-ray positive silicosis among agate workers at Shakarpur	123 clinically suspected cases of silicosis	> = 15 years	-	Chest X-ray	69.1% confirmation of silicosis; Odds of silicosis increased by about 12% for every extra year of exposure
14	Fotedar et al. (2010) [41]	Not specified	Case study	Report a case of bilateral spontaneous pneumothorax in a patient with accelerated silicosis	One male, stone cutting industry worker	24 years	4 years	Radiological features	Bilateral spontaneous pneumothorax, a rare complication of silicosis, potentially linked to the rupture of blebs
15	Tiwari et al. (2010) [42]	Godhara, Gujarat, West India	Prevalence, Cross-sectional	Compare respiratory morbidities among ex-workers and current workers of quartz grinding units	134 ex-workers, 182 current workers of quartz grinding units	31.77 ± 9.99 years (former workers, 26.74 ± 7.12 years (present workers	Ex-workers: 2.74 ± 1.65 years, Present workers: 1.36 ± 2.68 years	Chest radiography, pulmonary function test	17.9% of former workers were diagnosed with silicosis, and 24.7% displayed silicotuberculosis. High respiratory morbidity in ex-workers compared to current workers
16	Tiwari et al. (2010) [43]	Godhara, Gujarat, West India	Prevalence, Cross-sectional	Investigate silica exposure and serum angiotensin-converting enzyme (ACE) activity	134 quartz stone crushing workers (111 men, 14 women)	26.2 ± 6.3 years	1.1 ± 1.9 years	Pulmonary functions	One case of silicosis was identified, and serum ACE levels were elevated

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
17	Yadav et al. (2011) [44]	Jodhpur, West India	Prevalence, Cross-sectional	Assess awareness and practices regarding silicosis among sandstone quarry workers	376 sandstone quarry workers, predominantly males	Varies	-	-	69.9% awareness of silicosis among workers, increasing with literacy. Cough with breathlessness was reported as the most important symptom
18	Chaudhury et al. (2012) [45]	Shakarpur, Khambhat, Gujarat, West India	Case series	Describe comorbidities and their influence on mortality in cases of silicosis	53 chest symptomatic patients	> 15 years	30 months	Chest X-ray, Spirometry, Anthropometry	Over half of male workers had low BMI. Thirteen participants died within three years, with 11 having silicosis and ten also had tuberculosis. Most silicosis cases (81.1%) showed mixed spirometry patterns
19	Aggarwal (2013) [46]	Khambhat, Gujarat, West India	Prevalence, Cross-sectional	Investigate silicosis prevalence and factors among agate workers	82 agate workers	> 20 years	-	-	Explored reasons for high silicosis prevalence and factors affecting noncompliance with preventive methods among agate workers
20	Ganguly et al. (2013) [47]	Not specified	Case study	Report a case of diffuse parenchymal lung disease and systemic sclerosis induced by silicosis	1 participant, a male stone mason worker	26 years	6 years	Clinical, serological, skin biopsy	Silica-induced scleroderma resembles idiopathic systemic sclerosis, showing higher pulmonary involvement and prevalence of anti-Scl-70 antibodies

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
21	Khanna et al. (2013) [48]	Not specified	Case study	Report a case of silicosis with mixed connective tissue disorder (MCTD)	32-year-old stone crusher	-	6 years	Chest X-ray	Development of silicosis progressing to full-blown mixed connective tissue disorder (MCTD) with features of rheumatoid arthritis, scleroderma, and systemic lupus erythematosus
22	Verma and Karmakar (2013) [49]	Not specified	Case study	Report a case of pulmonary tuberculoma with military tuberculosis and silicosis	One male stone cutter-engraver	48 years	-	Radiological, thoracotomy, open lung biopsy	Coexistence of pulmonary tuberculoma with military tuberculosis and silicosis, successfully treated with Antituberculosis Therapy (ATT)
23	Kundu et al. (2014) [50]	East India	Prevalence, Cross-sectional	Examine clinical spectrum of diffuse parenchymal lung diseases (DPLD)	92 patients diagnosed with DPLD	IPF: 56.9 ± 1.12 years, CTD-DPLD: 39.5 ± 1.86 years	-	Spirometry, echocardiography, chest X-ray	Silicosis accounted for 5 cases (5.4%) among patients with Diffuse Parenchymal Lung Diseases (DPLD), comparing Idiopathic Pulmonary Fibrosis (IPF) and Connective tissue Disease Associated DPLD (CTD-DPLD)
24	Mishra et al. (2014) [51]	Not specified	Case study	Report lung biopsy findings and discuss pneumothorax development in a case of chronic silicosis	One participant, a male, bore-well driller	33 years	-	Lung biopsy	This study discussed how pneumothorax developed in a person with chronic silicosis who sadly passed away during the illness

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
25	Srivastava et al. (2014) [52]	Not specified	Case study	Report a case of acute silicosis with bilateral pneumothorax	One patient, a male, stone crusher worker	28 years	1 year	Chest X-ray, bronchoalveolar lavage	This study reported this case because of the rare complications of acute silicosis, such as bilateral pneumothorax
26	Chakrabarti and Pan (2015) [53]	Not specified	Case study	Report a case of Erasmus syndrome	1 male patient	42 years	12 years	Interstitial Lung Disease and pulmonary arterial hypertension	Evidence of Interstitial Lung Disease (ILD) with mediastinal lymphadenopathy and pulmonary arterial hypertension with vascular reactivity
27	Dixit et al. (2015) [54]	Not specified	Case study	Describe a case of acute silicosis complicating spontaneous pneumomediastinum, bilateral pneumothorax, and subcutaneous emphysema	One male stone crusher worker	35 years	-	Clinical and radiological assessment	Unique case with simultaneous occurrence of spontaneous pneumomediastinum, bilateral pneumothorax, and subcutaneous emphysema in acute silicosis
28	Murlidhar (2015) [55]	Central India	Case study	Highlight silicosis due to secondary exposure in the stone-mining industry	One male	11 years	4 years	Sputum examination, chest X-ray	First report of a child with possible silicosis due to secondary exposure to sandstone mining in India
29	Panchadhyayee et al. (2015) [56]	Burdwan, West Bengal, East India	Case series	Determine the course of illness of silicosis patients according to their occupational exposure	19 new and old cases of silicosis (8 from jewellery polishing, 11 from other occupations)	> = 15 years	Jewelry: 3.4 ± 1.7 years, Others: 9.3 ± 4.1 years	Chest radiograph	Jewellery polishing workers developed silicosis within 5 years, while others showed onset after 10 years or more. Higher severity and progression in jewellery polishing workers

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
30	Sivabalasubramaniam et al. (2015) [57]	Not specified	Case study	Present a first case of silicosis in pregnancy with an unusual complication	One pregnant woman worked in a glass industry	37 years	11 years	Chest X-ray, radiological features	An emergency cesarean section was conducted due to inadequate cervical dilation, and subsequently, the patient encountered a burst abdomen with protruding gangrenous bowel loops during the postoperative period
31	Spalgais et al. (2015) [58]	Ladakh, North India	Case study	Study Nonoccupational Anthracosilicosis/ Anthracofibrosis	6 cases, homemakers aged 42–62 years	56 years	4 years on average	Clinical and radiological-pathological features	Anthracosilicosis due to environmental exposure in older women. Obstructive airway disease in 5/6 cases. Progressive massive fibrosis in 4/6 cases. Suspicion of malignancy in 4 cases
32	Bhattacharya et al. (2016) [59]	Not specified	Case study	Present a complicated case of silicosis in the form of progressive massive fibrosis	One male patient, farmer by occupation	52 years	8 years	Radiological images, CT-guided trucut biopsy	A challenging case of progressive massive fibrosis in a male farmer. Radiology-guided trucut biopsy crucial for accurate diagnosis of silicosis

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
33	Rai et al. (2016) [60]	Not specified	Case study	Present an unusual case of silicotuberculosis	One participant, male	43 years	Long-term exposure	Broncho-alveolar lavage fluid analysis, CT scans	Presence of acute silicosis with respiratory failure in the backdrop of long-term silica exposure. Demonstration of crystalline silica particles in bronchial lavage fluid and coexistence of tuberculosis with acute silicosis
34	Shamim and Saraf (2017) [61]	Karauli district, Rajasthan, West India	Qualitative Research	Examine laws and policies on silicosis in the context of sandstone mining and assess challenges faced by mining community in health and safety	217 respondents (184 males, 33 females)	-	-	-	Large-scale illegal mining (95%), understaffed regulatory agencies, complex monitoring system, rights violations, inadequate compensation, and scarce healthcare resources identified in Karauli district. Mining regulations need updating
35	Nandi et al. (2018) [62]	Jodhpur and Nagaur districts, West India	Prevalence, Cross-sectional	Assess silicosis awareness among mine workers	305 stone mine workers	> 30 years	-	Awareness Index	Limited awareness (40%) of silicosis; low knowledge of causes and symptoms (13–26%). Limited awareness of protective measures despite equipment usage. Education correlates with better awareness, indicating increased risk among lower-educated workers

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
36	Sharma et al. (2018) [63]	Not specified	Case study	Study the association of silicosis and systemic sclerosis (Erasmus syndrome)	One patient, a stone cutter	52 years	25 years	Serology, radiological investigations and skin biopsy	Diagnosis of Erasmus syndrome (systemic sclerosis in association with silicosis) made. Patient was advised to stop smoking and further silica exposure
37	Bairwa et al. (2019) [64]	Rajasthan, West India	Case series	Determine the prevalence of bilateral pneumothorax in silicosis and associated predisposing factors	50 patients with silicosis	-	-	Radiological evidence, chest X-ray, sputum	The original report was of silicosis patients presenting simultaneous bilateral spontaneous pneumothoraxes
38	Meena et al. (2020) [65]	Jaipur, West India	Case series	Report secondary spontaneous pneumothorax in critically ill patients with silicosis	50 Patients with silicosis	38.7 years	-	Chest X-ray and sputum for acid-fast bacilli	Increased incidence of secondary pneumothorax in silicosis. Smoking may contribute. Tube thoracostomy is recommended in such cases
39	Naha et al. (2020) [66]	Gujarat and Rajasthan, West India	Screening tools	Evaluate CC16 as a biomarker for early detection of silicosis	121	Varies	-	Serum CC16 levels	Decreased CC16 levels in advanced silicosis patients and moderately exposed workers compared to non-exposed individuals. CC16 ≤ 7.0 ng/ml is suggested as an effective biomarker for early detection of silicosis
40	Rajavel et al. (2020) [67]	Jodhpur, West India	Prevalence, Cross-sectional	Evaluate silicosis prevalence	174	39.13 ± 11.09 years & > = 18 years	Three-fourth (75.3%) have worked > 10 years	Chest X-ray, sputum microscopy, spirometry	Silicosis prevalence observed was 37.3%, with silico-tuberculosis at 7.4%

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
41	Sasi et al. (2020) [68]	Not specified	Case study	Report a unique case of chylothorax in association with silicosis	One patient, a male cement worker	32 years	-	-	Pulmonary silicoproteinosis due to accelerated silicosis along with chylothorax, likely due to extensive lymphatic obstruction
42	Dixit et al. (2021) [69]	Not specified	Case study	Describe a case of silicosis presenting as middle lobe syndrome	One female stone-cutter worker	54 years	12 years	Chest radiographic	Right middle lobe syndrome in silicosis, caused by external compression and bronchostenosis. Rare presentation with endobronchial silicosis and calcified lymph nodes
43	Marwah et al. (2021) [70]	Pune, West India	Case study	Diagnose the patient's condition	One patient, male cement factory worker	54 years	30 years	Chest X-rays, CT of the chest	Diagnosis: Silicosis with systemic sclerosis (Erasmus syndrome). Silicosis as a risk factor for systemic sclerosis. Multi-system connective tissue disease triggered by silicosis
44	Nandi et al. (2021) [71]	Delhi, North India	Screening tools	Develop a rapid and inexpensive screening method for early detection of silicosis	106 serum samples from Delhi's occupational health clinic	-	-	Serum CC16 concentration levels	Developed a lateral-flow assay for semi-quantitative estimation of serum CC16 levels. The assay may be used for periodic screening of silica dust-exposed workers for early detection of silicosis

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
45	Nandi et al. (2021) [72]	Rajasthan, West India	Prevalence, Cross-sectional	Assess the prevalence of silicosis	529 participants	-	-	Chest X-ray	52% showed radiological evidence of silicosis; 12.4% of silicosis subjects had associated pulmonary tuberculosis
46	Chaturvedi et al. (2022) [73]	Jodhpur, West India	Qualitative study	Provide an overview of policy implementation regarding silicosis detection, prevention, and control	35 stakeholders	-	-	-	Low awareness among stakeholders. Unregistered mining activities and migration of workers pose challenges. Misdiagnosis and low notification rates hinder resource access
47	Dixit et al. (2022) [74]	Not specified	Case series	Evaluate renal dysfunction in Indian patients with silicosis and its correlation with exposure duration	52 patients with confirmed silicosis on radiological examination	-	-	Serum creatinine, urinary albumin creatinine ratio	53.84% of patients with albuminuria; a significant association between exposure duration and urinary albumin to creatinine ratio and glomerular filtration rate
48	Dixit et al. (2022) [75]	Not specified	Case series	Evaluate diffusion capacity in patients with simple and complicated silicosis	56 patients with simple and complicated silicosis, without tuberculosis	43.1 ± 10.8 years	-	Tomography	Significant abnormalities in diffusion lung capacity (DLCO) were observed among silicosis patients, correlating with radiological findings. Large opacities on HRCT indicate severe silicosis

Table 1 (continued)

Serail Number	Study	Study Location	Theme/ Type of Study	Aim of the Study	Sample Size and Characteristics	Age	Duration of Exposure	Diagnostic Criteria	Key Findings
49	Jaanakhi et al. (2022) [76]	Not specified	Case study	Report cases of Erasmus syndrome, its diagnosis, and management	5 cases of silicosis and systemic sclerosis	32–39 years	4–33 years	Radiological findings, skin biopsy	Erasmus syndrome, a rare co-occurrence of silicosis and systemic sclerosis, manifests with progressive shortness of breath, skin tightening, and other symptoms. Early diagnosis and intervention are crucial for improved quality of life

was observed in approximately one-third of the workers, emphasising the need for preventive measures in stone-grinding occupations [39]. A study on workers in quartz crushing units in the same region unveiled alarming statistics. Among 134 ex-workers, 17.9% received a diagnosis of silicosis, and 24.7% exhibited silico-tuberculosis, emphasising the occupational health risks associated with prolonged exposure [43]. A related study explored serum angiotensin-converting enzyme (ACE) activity in the same geographical region among 134 participants. Despite the absence of notable associations with demographic or exposure variables, heightened ACE levels were detected in a lone case of silicosis, underscoring the intricate nature of the disease [43]. It reflects the complex role of ACE as a biomarker for lung inflammation and fibrosis. Elevated ACE in some silicosis cases may indicate heightened immune and tissue remodelling responses tied to the renin-angiotensin system. However, individual variations, likely due to genetic and exposure factors, mean ACE isn't elevated in all cases, underscoring the multifaceted progression of silicosis. Addressing the prevalent issue of silicosis among agate workers in Khambhat, Gujarat, X-ray evaluations confirmed silicosis in 69.1% of clinically suspected cases. Workers with over ten years of silica exposure had significantly higher odds of silicosis, emphasising the urgent need for protective measures in this high-risk population [40].

A prospective study in eastern India provided further insights into diffuse parenchymal lung diseases (DPLD). This study diagnosed 92 DPLD patients with idiopathic pulmonary fibrosis (IPF) and connective tissue disease-associated DPLD (CTD-DPLD) identified as prevalent causes [50]. In Rajasthan, particularly in Jodhpur, a cross-sectional study in 2020 assessed the prevalence of silicosis among 174 participants working in mines for over ten years. The study reported a silicosis prevalence of 37.3%, with 7.4% exhibiting silico-tuberculosis, highlighting an elevated risk of silicosis, silicosis tuberculosis, and other respiratory diseases among workers in sandstone mines [67]. In the same state, a separate cross-sectional study in the Karauli and Dholpur districts investigated the prevalence of silicosis among 529 participants, revealing radiological evidence of silicosis in 52% of individuals, with 12.4% having concomitant pulmonary tuberculosis [72]. Other than the prevalence of silicosis, a 1977 cross-sectional investigation in Mandsaur district, Madhya Pradesh, delved into the prevalence of silicosis among workers engaged in slate-pencil manufacturing. The study, encompassing 151 participants, revealed a direct correlation between the incidence and severity of silicosis and the duration of exposure to silica dust [31].

In a 1999 cross-sectional study in Jodhpur, Rajasthan, the focus shifted to assessing the relationship between various factors and Forced Vital Capacity (FVC) in sandstone quarry workers. The study, including 168 participants, identified radiological opacities suggestive of silicosis, establishing a significant association between a deviation of 20% or more in Forced Vital Capacity and radiological opacities indicative of silicosis [34]. A study in 2007–2008 in Jodhpur, Rajasthan, examined the awareness and practices related to silicosis among 376 sandstone quarry workers. Despite two-thirds of the workers being cognizant of the causes of silicosis, a significant proportion remained unaware of preventive measures. This study highlighted the need for heightened awareness among sandstone quarry workers [44].

A study conducted during 2010–2011 in Khambhat, Gujarat, explored the reasons behind the elevated prevalence of silicosis and factors influencing noncompliance with preventive methods among agate workers. The study included 82 agate workers, revealing disparities in awareness and preventive measure utilisation based on educational status [46]. A cross-sectional study conducted in 2018 in the Jodhpur and Nagaur districts of Rajasthan aimed to assess the awareness of silicosis among 305 stone mine workers. The results indicated a limited awareness of silicosis, emphasising the need for targeted educational initiatives to address the alarming lack of awareness and reduce the risk of silica dust exposure among stone mine workers in the region [62]. In Khambhat, Gujarat, a study evaluated the impact of dust control devices on 500 grinding machines in the agate industry [38].

Screening tools

In 2021, a rapid and affordable screening method was developed for early detection of silicosis using a lateral-flow assay in Delhi. The assay provides a semi-quantitative estimation of club cell protein (CC16) levels, making it a viable tool for periodic screening of silica dust-exposed workers for early detection of silicosis [71]. Another study aimed to identify an early marker for silicosis, utilising CC16 as a screening marker. The study developed a lateral-flow assay, offering high sensitivity and specificity and holding potential for early detection, preventing premature deaths, and controlling associated tuberculosis [66]. Thus, CC16 serves as a promising biomarker for silicosis, as decreased levels indicate lung damage from silica exposure, often before significant symptoms or fibrosis develop. Its blood or bronchoalveolar fluid measurement could aid early diagnosis, complementing current imaging and pulmonary function tests, which detect silicosis at more advanced stages. Unlike traditional methods, CC16 offers a non-invasive screening approach, helping identify silicosis risk in

exposed individuals, potentially improving outcomes through earlier intervention and disease monitoring.

Case series and case study

Several case series studies have significantly contributed to understanding silicosis and its multifaceted consequences. A study conducted a clinical trial in Badarpur, New Delhi, evaluating the effects of daily prednisolone therapy on alveolitis parameters and lung function in 34 male workers with chronic silicosis. This study reported a substantial improvement in lung function without serious side effects [33]. In Shakarpur, Khambhat, Gujarat, a case series observational study revealed a notable association between low body mass index (BMI) in male workers and mortality. This study emphasised tuberculosis (TB) and nutritional status as significant factors [45]. A longitudinal study at a medical college hospital explored the course of silicosis based on occupational exposure. This study indicated that jewellery polishing workers experienced more rapid and severe development of silicosis than other occupations [56].

Bairwa et al. [64] conducted a prospective review in Rajasthan to determine the prevalence of bilateral pneumothorax in silicosis, emphasising patients presenting with simultaneous bilateral spontaneous pneumothoraxes. A cross-sectional case series study at a tertiary care hospital in Rajasthan reported on secondary spontaneous pneumothorax in critically ill patients with silicosis. This study highlighted an increased incidence of secondary pneumothorax, with smoking identified as a major contributor [65]. A case series by Dixit et al. [75] investigated 56 silicosis patients, excluding tuberculosis, to assess diffusion capacity. The study revealed notable abnormalities in diffusion lung capacity correlated with radiological findings. Recent observational studies have assessed renal dysfunction and the diffusion capacity of the lung for carbon monoxide in silicosis patients. This study revealed significant associations with exposure duration to silica dust [75].

Results of prevalence data synthesis

The meta-analysis included eleven studies that reported the prevalence of silicosis. The forest plot (Fig. 2) displays the estimated prevalence for each study. Using a random-effects model, the overall prevalence of silicosis was estimated to be 0.2598, with a 95% confidence interval of 0.1361 to 0.3834. A study reported a very low prevalence (0.01) and yielded a very low and negative lower 95% CI of prevalence. The same is reflected in the scale of the forest plot. The analysis showed significant heterogeneity among the studies. The I^2 statistic was 98.86%, indicating that most of the study variability was due to factors other than random chance. The between-study variance (τ^2) was estimated at 0.0427, and the Q statistic for heterogeneity was significant ($Q = 905.1388$, $p < 0.0001$), confirming that substantial variability existed between the studies. This analysis highlights the widespread prevalence of silicosis and the significant differences in prevalence estimates across the included studies.

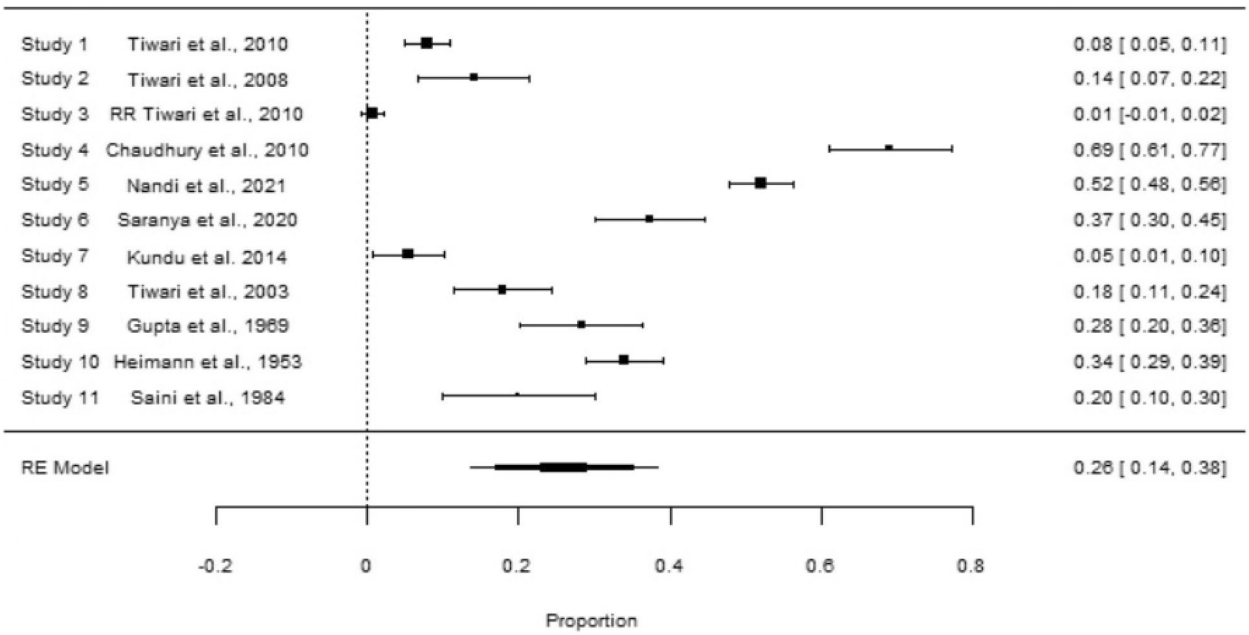

Fig. 2 Forest plot showing the prevalence of silicosis in India

In this review, we included case studies and case series to capture detailed, real-world insights and contextual information that may not be available in other study designs. These sources provide valuable perspectives on various clinical aspects of silicosis relevant to the scope of our review.

Early-onset silicosis development

In 1968, a case study highlighted a 27-year-old mica mine worker in Andhra Pradesh. Despite brief employment, the person developed conglomerate silicosis, leading to massive fibrosis and respiratory failure over ten years [29].

Complications and coexisting conditions

Parakh et al. [37] discuss complications involving chronic necrotising pulmonary aspergillosis complicating silicosis. Fotedar et al. [41] present a case report documenting bilateral spontaneous pneumothorax in accelerated silicosis. Ganguly [47] reports silicosis-induced diffuse parenchymal lung disease and systemic sclerosis in a stone mason worker. Verma et al. [49] discuss pulmonary tuberculoma with military tuberculosis and silicosis, while Khanna et al. [48] report silicosis with mixed connective tissue disorder in a stone crusher.

Diagnostic challenges and unique cases

The study of Mishra et al. [51] explores lung biopsy findings and pneumothorax development in a 33-year-old bore-well driller with chronic silicosis. Another study by Srivastava et al. [52] focuses on a stone crusher worker with acute silicosis and bilateral pneumothorax, highlighting the rarity of this complication and the lack of protective measures.

Secondary exposure

Murlidhar [55] reported the first case of a child possibly developing silicosis due to secondary exposure from sandstone mining in India.

Non-occupational cases and pregnancy

A case series from Ladakh focuses on non-occupational anthracosilicosis/anthracofibrosis in homemakers [58]. In this case report, a 37-year-old pregnant woman with a history of silicosis presented at 42 weeks of gestation with breathlessness and oligohydramnios. She had previously worked in a glass and talc powder factory for 11 years, leading to her diagnosis of silicosis two years prior. Following an emergency cesarean section, she developed a burst abdomen on the third postoperative day, with gangrenous bowel loops protruding. Emergency laparotomy was performed, involving ileal resection and ileostomy. The patient was discharged on postoperative day 14 and remained under follow-up. This case underscores the importance of monitoring for potential complications in pregnant patients with silicosis, as pregnancy may exacerbate the disease's progression. And a report of Sivabalasubramaniam [57] presents the case of a 37-year-old pregnant woman with a history of silicosis presented at 42 weeks of gestation with breathlessness and oligohydramnios. She had previously worked in a glass and talc powder factory for 11 years, leading to her diagnosis of silicosis two years prior. Following an emergency cesarean section, she developed a burst abdomen on the third postoperative day, with gangrenous bowel loops protruding. Emergency laparotomy was performed, involving ileal resection and ileostomy. The patient was discharged on postoperative day 14 and remained under follow-up. This case underscores the importance of monitoring for potential complications in pregnant patients with silicosis, as pregnancy may exacerbate the disease's progression.

Rheumatological complications and long-term effects

Chakrabarti & Pan [53] report a case of a 42-year-old male manual labourer presented with symptoms including joint pain (arthralgia), Raynaud's phenomenon, skin tightening, and reduced mouth opening (microstomia). He also exhibited signs of interstitial lung disease (ILD) and pulmonary arterial hypertension. Diagnostic evaluations confirmed ILD with mediastinal lymphadenopathy and pulmonary arterial hypertension with vascular reactivity. Serological markers for systemic sclerosis were strongly positive. The patient was treated with prednisone, cyclophosphamide, and nifedipine, leading to moderate symptom improvement over six months.

Acute complications and uncommon manifestations

Dixit et al. [54] depict acute silicosis complicating as spontaneous pneumomediastinum, bilateral pneumothorax, and subcutaneous emphysema in a stone crusher worker. A case study by Bhattacharya et al. examines a challenging instance of silicosis, specifically progressive massive fibrosis, emphasising the importance of radiology-guided trucut biopsy as an accurate diagnosis [59]. Rai et al. [60] highlight a unique case of silicotuberculosis, emphasising acute silicosis and respiratory failure coexisting with tuberculosis. The case report of Dixit et al. describes silicosis as middle lobe syndrome [69].

Associations and syndromes

Sharma et al. [63] studied the association of silicosis and systemic sclerosis (Erasmus syndrome) in a stone cutter. A case reported by Marwah et al. highlights silicosis with systemic sclerosis (Erasmus syndrome) in a cement factory worker [70].

Cardiopulmonary complications

Sasi et al. document a case of chylothorax associated with silicosis in a cement worker [68]. A study by Chakraborty et al. discusses ventricular tachycardia linked to ventricular myocardial fibrosis in a patient with silica exposure [35].

Co-occurrence

A case series reports Erasmus syndrome in five cases, demonstrating the co-occurrence of silicosis and systemic sclerosis [76].

Qualitative research

A qualitative study conducted in 2017 examined the laws and policies surrounding silicosis in the context of sandstone mining in Rajasthan's Karauli district. The study revealed a high prevalence of illegal mining, critical issues, and challenges in regulatory agencies and compensation for silicosis victims [61]. Another qualitative study in Jodhpur, Rajasthan, evaluated policy implementation related to detecting, preventing, and controlling silicosis. The study exposed a significant lack of awareness among stakeholders, hindrances in effective silicosis detection, and barriers preventing workers from accessing essential resources [73].

Discussion

The review on silicosis in India provided valuable information on this occupational lung disease's prevalence, associated factors, screening tools, qualitative aspects, and clinical presentations. This scoping review emphasised substantial variations in the prevalence of silicosis across different regions of India, with Gujarat, Rajasthan, and Madhya Pradesh reporting high rates. However, there is no single paper reporting the overall prevalence in India. Hence, this meta-analysis was performed to estimate the pooled prevalence. Eleven studies with a total sample of 2072 reported the prevalence, and based on these data, the pooled prevalence was 25.98%. However, there is considerable heterogeneity among these studies. This heterogeneity may be attributed to the selection of participants from diverse industries, differences in exposure time, age, and different diagnostic criteria. It is imperative to mention that most of the prevalence studies (9 out of 11) were only from Gujarat and Rajasthan states. Thus, there is a gap in the estimation of the prevalence in different industries as well as from other Indian states. Studies, such as those conducted by Tiwari et al. [36] and Chaudhury et al. [40], showed elevated prevalence among workers in quartz stone crushing units and agate industries, highlighting the necessity for targeted interventions in specific occupational settings. The correlation between dust exposure, work duration, and silicosis prevalence was consistently observed in various studies, including investigations by Gupta et al. [30] and Nandi et al. [72]. These results underline the direct occupational risk associated with prolonged exposure to silica dust and emphasise the need for strict safety measures and regulatory oversight in industries with high silica exposure. The National Human Rights Commission of India (NHRC) has directed state and union territory governments to provide comprehensive information on the measures they have taken to prevent and eliminate the issue of silicosis [77].

The association between silicosis and tuberculosis, as highlighted in studies by Farazi [16] and Rajavel et al. [67], presented the interconnectedness of respiratory health issues. This showed that special integrated health programs should be utilised to address both silicosis and tuberculosis among workers in mining and stone-related industries. The study by Bhagia et al. revealed that installing these devices could reduce the prevalence of silicosis and tuberculosis, emphasising the need for collaboration to modernise the industry and safeguard nearby residents from dust exposure [38].

Qualitative studies conducted in Rajasthan, as discussed by Shamim et al. [61] and Chaturvedi et al. [73], shed light on the complex interplay of factors influencing the success of policy initiatives. Recognising the effectiveness of the Rajasthan model, particularly the "Rajasthan Policy on Pneumoconiosis including Silicosis Detection, Prevention, Control and Rehabilitation – 2019," there is a pressing need for a national initiative. Several states, including Haryana, West Bengal, and Jharkhand, have devised their own silicosis relief and rehabilitation policies to confront the silicosis challenge [77]. As discussed in studies by Nandi et al. [71] and Naha et al. [66], the development of screening tools represents a crucial step toward the early detection of silicosis.

The diverse clinical presentations highlighted in case series and studies contribute to a nuanced understanding of silicosis. The association between silicosis and complications such as spontaneous pneumothorax, pulmonary tuberculoma, and systemic sclerosis (Erasmus syndrome) emphasises the need for a comprehensive approach to managing this complex disease. Studies by Chaudhury et al. [45], Dixit et al. [75], and Panchadhyayee et al. [56] provide valuable insights into the impact of silicosis on lung function, mortality, and unique clinical presentations. The stone-mining industry lacks proper preventive measures, posing risks to the respiratory health of workers and the local community. Meanwhile, enforcement of existing protective legislation remains inadequate, highlighting the need for urgent improvements in regulations and enforcement to safeguard the well-being of those in stone-mining areas [55]. Health units addressing silicosis

have been established in districts prone to the condition. These units provide complimentary chest X-rays and pulmonary function tests. Industries utilising silica undergo regular inspections, with non-governmental organisations (NGOs) actively involved to ensure effective monitoring [77]. These diverse case studies collectively enhance our understanding of silicosis, stressing the significance of early diagnosis, preventative measures, and tailored management strategies across different demographics and clinical presentations. These results contribute to evidence guiding clinicians in diagnosing and managing silicosis-related complications. This review aims to provide a comprehensive analysis of existing research on silicosis, with a specific focus on India, where the burden of this disease is substantial.

Limitations of the evidence included in the review

Most studies are conducted in Gujarat and Rajasthan, which restricts their applicability to regions with different environmental and occupational conditions affecting silicosis. Furthermore, most of the studies are cross-sectional; these studies cannot establish causal links between silica exposure and silicosis.

Limitations of the review processes

The review might be influenced by publication bias. Further, the search was conducted across three databases, which might have excluded relevant studies published in lesser-known or regional journals. The exclusion of studies is due to exclusion criteria and quality assessment. It's important to note that this review did not include studies with lower scores. The results of the quality assessment are shown in the annexure. Another limitation is that we could not assess the risk of bias in studies estimating the prevalence of exposure to occupational risk by using tools like RoB-SPEO from the WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury.

Implications of the results for practice, policy, and future research

There is an urgent need for better screening tools for early silicosis detection in high-risk occupations. Regular screenings and interventions are essential for exposed workers. The high rates of silicosis necessitate stricter enforcement of occupational health regulations, improved workplace monitoring, and comprehensive healthcare services for affected workers. Future studies should focus on the longitudinal effects of silica exposure, develop accessible screening methods for low-resource settings, and examine regional differences to inform tailored interventions.

Conclusion

This comprehensive review synthesises current knowledge on silicosis in India, revealing geographic variations in prevalence, challenges in policy implementation, and diverse clinical manifestations. It highlights significant occupational health risks, particularly for workers exposed to silica dust in industries like stone quarrying and mining. The analysis of 49 studies reveals an overall silicosis prevalence of 31.39%, with regions such as Gujarat and Rajasthan reporting alarmingly high rates. For instance, in Gujarat, 69.1% of workers in the agate industry were diagnosed with silicosis, underscoring the severe impact of prolonged exposure. Silicosis is often accompanied by other respiratory diseases like TB, with studies reporting a significant co-occurrence of silico-tuberculosis, which further aggravates the health burden on affected workers. The review also found limited awareness of preventive measures among workers, particularly in regions like Rajasthan and Gujarat, where the risk is highest. Moreover, while early detection tools like the lateral-flow assay for CC16 show promise, their implementation remains limited. The findings call for urgent interventions, including stricter enforcement of preventive measures, enhanced screening for early detection, and stronger national policies to protect vulnerable workers. Addressing these issues is critical to reducing the high burden of silicosis and associated diseases in India's occupational sectors.

Abbreviations

ACE	Angiotensin-converting enzyme
BMI	Body mass index
CTDDPLD	Connective tissue disease-associated diffuse parenchymal lung diseases
DALY	Disability-adjusted life year
DF	Degrees of freedom
DPLD	Diffuse parenchymal lung diseases
FVC	Forced vital capacity
IPF	Idiopathic pulmonary fibrosis
JBI	Joanna Briggs Institute
NHRC	National Human Rights Commission of India
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SE	Standard error
TB	Tuberculosis

Supplementary information

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Supplementary Material 1

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Authors' contributions

M.K. and B.V.B. planned the project and the search strategy. M.K. performed the searches and screened the studies for eligibility. M.K. assessed the quality of eligible studies, extracted data from these studies, and received support

from B.V.B. M.K. and B.V.B. were involved in planning this article. M.K. wrote the initial draft of the manuscript, and B.V.B. provided comments and improved the manuscript, and both approved it before submission.

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Not applicable.

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References

1. Hoy RF, Jeebhay MF, Cavalin C, et al. Current global perspectives on silicosis-Convergence of old and newly emergent hazards. Respirology. 2022;27(6):387–98.
2. Institute for Health Metrics and Evaluation. Global Health Metrics: Silicosis: Level 4cause. https://www.healthdata.org/sites/default/files/disease_and_injury/gbd_2019/topic_pdf/cause/511.pdf. Published 2019.
3. Chen S, Liu M, Xie F. Global and national burden and trends of mortality and disability-adjusted life years for silicosis, from 1990 to 2019: results from the global burden of disease study 2019. BMC Pulm Med. 2022;22:1–10.
4. Lanzafame M, Vento S. Mini-review: Silico-tuberculosis. J Clin Tuberc Other Mycobact Dis. 2021;23:100218.
5. Intergovernmental Forum on Mining Minerals Metals and Sustainable Development (IGF). Global Trends in Artisanal and Small-Scale Mining (ASM): A Review of Key Numbers and Issues. https://www.iisd.org/system/files/publications/igf-asm-global-trends.pdf. Published 2018.
6. United Nations Population Fund. State of World Population Report 2023 [Internet]. United Nations Population Fund. 2023. Available from: https://www.unfpa.org/sites/default/files/swop23/SWOP2023-ENGLISH-230329-web.pdf.
7. India Brand Equity Foundation - an initiative of the Ministry of Commerce and Industry (Government of India). Manufacturing Sector in India: Market Size, FDI, Govt Initiatives [Internet]. 2023. Available from: https://www.ibef.org/industry/manufacturing-sector-india.
8. TeamLease. India Labour Report 2009. Available from: https://www.teamleasegroup.com/sites/default/files/resources/teamlease_labourreport2009.pdf.
9. International Labour Organization (ILO). World employment and social outlook: Trends 2020. Available from: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_734479.pdf.
10. International Labour Organization. Decent Work Country Programme for India (2018–2022). New Delhi: ILO Decent Work Team for South Asia and Country Office for India. ; 2018. Available from: https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---sro-new_delhi/documents/publication/wcms_650119.pdf.
11. Chaturvedi O, et al. Challenges in the Implementation of the Rajasthan Pneumoconiosis Policy. Ann Work Expo Heal. 2022;66:1162–72.
12. World Health Organization. The End TB Strategy. https://apps.who.int/iris/rest/bitstreams/1271371/retrieve (2015).
13. Fedotov IA, Eijkemans GJ. The ILO/WHO Global Programme for the Elimination of Silicosis (GPES). The Global Occupational Health Network (GOHNET) Newsletter (2007).
14. International Labour Organization. Occupational health: Silicosis. https://www.ilo.org/global/topics/safety-and-health-at-work/areasofwork/occupational-health/WCMS_108566/lang--en/index.htm. Accessed on 14 April 2024.
15. Kulkarni G. Prevention and control of silicosis: A national challenge. Indian J Occup Environ Med. 2007;11(3):95.
16. Farazi A, Jabbariasl M. Silico-tuberculosis and associated risk factors in central province of Iran. Pan Afr Med J. 2015;20:333.
17. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MD, Horsley T, Weeks L, Hempel S, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73. https://doi.org/10.7326/M18-0850.
18. Porritt K, Gomersall J, Lockwood C. JBI's Systematic Reviews: Study selection and critical appraisal. Am J Nurs. 2014;114(6):47–52.
19. Srivastava AK, Rastogi SK, Mathur N, Bihari V. Health risk assessment of brick kiln workers Indian. J Occup Environ Med. 2002;6(4):150–5.
20. Bansal N, Lanjewar A, Acharya S, Shukla S. Assessment of pulmonary function test in brick factory workers. J Fam Med Prim Care. 2022;11(11):6916–9.
21 Gera K, Pilaniya V, Shah A. Silicosis: progressive massive fibrosis with eggshell calcification. BMJ Case Rep. 2014;26:bcr2014206376.
22. Tiwari RR, Sharma YK, Saiyed HN. Tuberculosis among workers exposed to free silica dust. Indian J Occup Environ Med. 2007;11(2):61–4.
23. Jain S, Joshi V, Rathore YS, Khippal N. Erasmus Syndrome: Silicosis and Systemic Sclerosis. Indian J Occup Environ Med. 2017;21(2):94–6.
24. Bai M, Dwivedi DP, Babu VM, Warrier LS, Chauhan AS. Splenic Silicosis: A Rare Cause of Splenic Calcifications. Indian J Occup Environ Med. 2021;25(3):185–7.
25. Mathur ML, Choudhary RC. Desert lung syndrome, in rural dwellers of the Thar Desert. India J Arid Environ. 1997;35(3):559–62.
26. Mohammad S. Rehabilitation of silicosis victims of District Karauli, Rajasthan, India. Indian J Community Med. 2019;44(4):347–51.
27. Sivanmani K, Rajathinakar V. Silicosis in Coimbatore district of Tamil Nadu: A passive surveillance study. Indian J Occup Environ Med. 2013;17(1):25–8.
28. Heimann H, Moskowitz S, Iyer CH, Gupta MN, Mankiker NS. Silicosis in mica mining in Bihar, India. Arch Indust Hyg Occup Med. 1953;8(5):420–35.
29. Thiruvengadam KV, Anguli VC, Shetty R, Sambandam S, Kosairam R. Silicosis in a mica-mine worker. J Indian Med Assoc. 1968;51(5):248–50.
30. Gupta SP, Garg AK, Gupta OP. Silicosis amongst stone-cutters (A clinical and radiological study). J Assoc Physicians India. 1969;17(3):163–72.
31. Jain SM, Sepaho GC, Khare KC, Dubey VS. Silicosis in slate pencil workers: a clinicoradiologic study. Chest. 1977;71(3):423–6.
32. Saini RK, Yousuf M, Allaqaband GQ, Kaul SN. Silicosis in stone-cutters in Kashmir. J Indian Med Assoc. 1984;82(6):198–201.
33. Sharma SK, Pande JN, Verma K. Effect of prednisolone treatment in chronic silicosis. Am Rev Respir Dis. 1991;143(4 Pt 1):814–21.
34. Mathur ML, Dixit AK. A study of forced vital capacity and its predictors among the sandstone quarry workers. Indian J Physiol Pharmacol. 1999;43(3):347–54.
35. Chakraborty P, Isser HS, Arava SK, Madan K, Bhatia M, Jahangir A. Ventricular tachycardia: a rare case of myocardial silicosis. Case Reports. 2020;2(14):2256–9.
36. Tiwari RR, Narain R, Patel BD, Makwana IS, Saiyed HN. Spirometric measurements among quartz stone ex-workers of Gujarat. India J Occup Health. 2003;45(2):88–93.
37. Parakh UK, Sinha R, Bhatnagar AK, Singh P. Chronic necrotising pulmonary aspergillosis: a rare complication in a case of silicosis. Indian J Chest Dis Allied Sci. 2005;47(3):199.
38. Bhagia LJ, Sadhu HG. Cost-benefit analysis of installing dust control devices in the agate industry, Khambhat (Gujarat). Indian J Occup Environ Med. 2008;12(3):128–31.
39. Tiwari RR, Sharma YK. Respiratory health of female stone grinders with free silica dust exposure in Gujarat. India Int J Occup Environ Health. 2008;14(4):280–2.

40. Chaudhury N, Phatak A, Paliwal R, Raichaudhari C. Silicosis among agate workers at Shakarpur: an analysis of clinic-based data. Lung India. 2010;27(4):221–4.
41. Fotedar S, Chaudhary D, Singhla V, Narang R. Silicosis with bilateral spontaneous pneumothorax. Lung India. 2010;27(3):173–5.
42. Tiwari RR, Narain R, Sharma YK, Kumar S. Comparison of respiratory morbidity between present and ex-workers of quartz crushing units: Healthy workers' effect. Indian J Occup Environ Med. 2010;14(3):87.
43. Tiwari RR, Karnik AB, Sharma YK. Silica exposure and serum angiotensin converting enzyme activity. Int J Occup Environ Health. 2010;1(1):21–8.
44. Yadav SP, Anand PK, Singh H. Awareness and practices about silicosis among the sandstone quarry workers in desert ecology of Jodhpur, Rajasthan. India J Hum Ecol. 2011;33(3):191–6.
45. Chaudhury N, Paliwal R, Phatak A. Co-morbidities among silicotics at Shakarpur: a follow up study. Lung India. 2012;29(1):6–10.
46. Aggarwal BD. Worker education level is a factor in self-compliance with dust-preventive methods among small-scale agate industrial workers. J Occup Health. 2013;55(4):312–7.
47. Ganguly J, Kumar A, Samanta SK, Mitra R, Kundu S. Erasmus syndrome: a case report of silicosis-induced scleroderma in a 26-year-old male. Oman Med J. 2013;28(5):e058.
48. Khanna A, Suri JC, Ray A, Sharma RK. Silica-associated mixed connective tissue disorder in a stone crusher. Indian J Occup Environ Med. 2013;17(2):76–7.
49. Verma SK, Karmakar S. Pulmonary tuberculoma and miliary tuberculosis in silicosis. J Clin Diagn Res. 2013;7(2):361–3.
50. Kundu S, Mitra S, Ganguly J, Mukherjee S, Ray S, Mitra R. Spectrum of diffuse parenchymal lung diseases with special reference to idiopathic pulmonary fibrosis and connective tissue disease: an eastern India experience. Lung India. 2014;31(4):354–60.
51. Mishra P, Jacob SE, Basu D, Panigrahi MK, Govindaraj V. Bilateral spontaneous pneumothorax in chronic silicosis: a case report. Case Rep Pathol. 2014;16:2014.
52 Srivastava GN, Prasad R, Meena M, Hussain M. Acute silicosis with bilateral pneumothorax. Case Rep. 2014;2014:bcr2013200089.
53 Chakrabarti S, Pan K. Erasmus syndrome in a 42-year-old male: a rare case report. J Clin Diagn Res. 2015;9(5):OD01-03.
54. Dixit R, Meena M, Patil CB. Pneumomediastinum, bilateral pneumothorax and subcutaneous emphysema complicating acute silicosis. Int J Occup Med Environ Health. 2015;28(3):635–8.
55. Murlidhar V. An 11-year-old boy with silico-tuberculosis attributable to secondary exposure to sandstone mining in central India. Case Rep. 2015;2015:bcr2015209315.
56. Panchadhyayee P, Saha K, Saha I, Ta RK, Ghosh S, Saha A, Mitra M. Rapidly fatal silicosis among jewellery workers attending a district medical college of West Bengal, India. Indian J Chest Dis Allied Sci. 2015;57(3):165–71.
57. Sivabalasubramaniam G, Sagili H, Dasari P, Gowda M. Burst abdomen: an unusual complication of silicosis in pregnancy. Case Rep. 2015;2015:bcr2014207132.
58. Spalgais S, Gothi D, Jaiswal A, Gupta K. Nonoccupational anthracofibrosis/ anthracosilicosis from Ladakh in Jammu and Kashmir, India: A case series. Indian J Occup Environ Med. 2015;19(3):159–66.
59. Bhattacharya S, Dey A, Pal A, Kar S, Saha S. Silicosis in the form of progressive massive fibrosis: a diagnostic challenge. Indian J Occup Environ Med. 2016;20(2):114.
60. Rai S, Acharya V, Vahab S, Minal J, Chakraborti S. Bright asteroids in the polar sky—clinic-radio-pathological correlation in an unusual case of silicotuberculosis. Indian J Occup Environ Med. 2016;20(1):60.
61. Shamim M, Saraf A. Examining legal and policy provisions on silicosis in the context of sandstone mining in Karauli, Rajasthan-India. Indian J Public Health Dev. 2017;8(4):407–14.
62. Nandi S, Burnase N, Barapatre A, Gulhane P, Dhatrak S. Assessment of silicosis awareness among stone mine workers of Rajasthan State. Indian J Occup Environ Med. 2018;22(2):97–100.
63. Sharma RK, Sharma AK, Sharma A. Erasmus syndrome: association of silicosis and systemic sclerosis. Indian Dermatol Online J. 2018;9(3):185–7.
64. Bairwa MK, Joshi N, Agnihotri SP. Silicosis with bilateral spontaneous pneumothorax in Rajasthan. Indian J Occup Environ Med. 2019;23(3):112–6.
65. Meena MK, Singh R, Joshi N, Rathore SS, Chadalawada S, Abubakar M, Shah K. Silicosis with secondary spontaneous pneumothorax in the Western Rajasthan. Cureus. 2020;12(11): e11811.
66. Naha N, Muhamed JC, Pagdhune A, Sarkar B, Sarkar K. Club cell protein 16 as a biomarker for early detection of silicosis. Indian J Med Res. 2020;151(4):319.
67. Rajavel S, Raghav P, Gupta MK, Muralidhar V. Silico-tuberculosis, silicosis and other respiratory morbidities among sandstone mine workers in Rajasthan-a cross-sectional study. PLoS ONE. 2020;15(4):e0230574.
68. Sasi A, Ray A, Bhalla AS, Arava S, Agarwal S, Jadon RS, Vikram NK. Chylothorax in a case of accelerated silicosis with pulmonary silicoproteinosis: a unique association. Indian J Occup Environ Med. 2020;24(1):39.
69. Dixit RD, Jalutharia J, Goyal M, Chaudhary P, Kasliwal N. Middle lobe syndrome in silicosis. Indian J Occup Environ Med. 2021;25(3):182–4.
70. Marwah V, Katoch CDS, Hegde A, Choudhary R. Cement factory worker presenting with Raynaud phenomenon, breathlessness, and digital ulcers. Chest. 2021;159(2):e93–6.
71. Nandi SS, Lambe UP, Sarkar K, Sawant S, Deshpande J. A rapid point of care CC16 kit for screening of occupational silica dust exposed workers for early detection of silicosis/silico-tuberculosis. Sci Rep. 2021;11(1):23485.
72. Nandi SS, Dhatrak SV, Sarkar K. Silicosis, progressive massive fibrosis and silico-tuberculosis among workers with occupational exposure to silica dusts in sandstone mines of Rajasthan state: an urgent need for initiating national silicosis control programme in India. J Family Med Prim Care. 2021;10(2):686.
73. Chaturvedi O, Mantri N, Joshi NK, Goel AD, Jain YK, Gupta MK, et al. Challenges in the implementation of the Rajasthan pneumoconiosis policy. Ann Work Exposures Health. 2022;66(9):1162–72.
74. Dixit R, Jalutharia J, Goyal M. Asymptomatic renal function abnormalities in patients having silicosis. J Assoc Physicians India. 2022;70(11):11–2.
75. Dixit R, Jalutharia J, Gupta A, Mathur R, Goyal M, Gupta N, Chaudhary P, Tiwari T. Measurement of diffusion lung capacity (DLCO) in silicosis patients: correlation with radiographic abnormalities on high-resolution CT scan chest. Lung India. 2022;39(4):352–6.
76. Jaanakhi VM, Ram B, Qureshi MJ, Jain M, Sawale S. Erasmus syndrome: A case series of rare co-occurrence of silicosis and systemic sclerosis. Indian J Occup Environ Med. 2022;26(4):285.
77. National Human Rights Commission. Background note. National conference on silicosis, 25 July 2014. New Delhi: National Human Rights Commission; 2014. Available from: http://nhrc.nic.in/Documents/Background%20Note%20on%20Silicosis.pdf.

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