Prevalence of Pneumoconiosis in the Construction Industry: A Systematic Review

Gentil A. Andaque, María de las Nieves González-García, Jacqueline Castelo Branco, Elizabete Nunes, Joana C. Guedes, and João Santos Baptista

Abstract Construction workers can be exposed to fibres, dust, and other toxic particles that can cause pneumoconiosis from silica, asbestos, and mixed dust. This systematic review aims to analyse how pneumoconiosis caused by exposure to dust contributed to the rise of occupational diseases in construction workers from 2001 to 2021. Sixteen keywords were combined to perform the search in six databases. Were included 26 articles which fulfilled all the defined inclusion criteria. A global analysis of risk disease distribution shows that exposures to mixed dust (41.1%), silica (37.5%) and asbestos (21.4%) were related to pneumoconiosis. In addition, individual analysis revealed that pneumoconiosis caused by exposure to chemical agents (silica, asbestos, and their dust) in the construction industry are predominantly related to the exposure to silica (Silicosis 38.1%), asbestos (asbestosis 33.3%, lung cancer 33.3%), and mixed dust (lung cancer 21.7%). Mixed dust seems to be the source of the highest incidence of pneumoconiosis, silica associated with silicosis is the most frequent disease.

G. A. Andaque (✉)
Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), University of Licungo, Quelimane, Mozambique
e-mail: gandaque@unilicungo.ac.mz

M. de las Nieves González-García
Departamento Construcciones Arquitectónicas y su Control, Escuela Técnica Superior de Edificación de la Universidad Politécnica de Madrid, Madrid, Spain
e-mail: mariadelasnieves.gonzalez@upm.es

J. C. Branco · J. C. Guedes · J. S. Baptista
Associated Laboratory for Energy, Transports and Aeronautics (PROA/LAETA), Faculty of Engineering of the University of Porto, Porto, Portugal
e-mail: jcb@fe.up.pt

J. C. Guedes
e-mail: jccg@fe.up.pt

J. S. Baptista
e-mail: jsbap@fe.up.pt

E. Nunes
Faculty of Medicine of the University Eduardo Mondlane, Maputo, Moçambique

P. M. Arezes et al. (eds.), *Occupational and Environmental Safety and Health IV*, Studies in Systems, Decision and Control 449,
https://doi.org/10.1007/978-3-031-12547-8_51

Keywords Silica · Asbestos · Mixed dust · Diseases · Exposure limit

1 Introduction

The construction industry is related to the mining industry, i.e., in extracting sand and stones as aggregates and subjecting workers to exposure to mixed dust (Agioutanti et al. 2020; Sauvé 2015). Several authors mention pneumoconiosis originated from occupational exposure to dust and fibres as one of the work-related diseases in the construction industry (Stocks et al. 2011; Sauvé 2015; Cummings et al. 2019; Bell and Mazurek 2020). These dusts, derived from different minerals such as silica and asbestos, are suspended in the air, resulting in diseases such as silicosis and asbestosis (Stocks et al. 2011; Nelson et al. 2011; Sauvé 2015; Nicol et al. 2015; Walters et al. 2018). Also the mineral nanoparticles are very toxic. They enter the body and can affect several vital mechanisms through blood circulation (Ophir et al. 2019; Bajpayee et al. 2004). In a comparative study on pneumoconiosis between China, Australia, and the United States, it was observed that China lags in studying health concerning safety. This lag is due to companies' emphasis on eliminating work accidents with visible consequences rather than invisible causes such as pneumoconiosis diseases (Han et al. 2018). Between 2001 and 2016 in the United Kingdom, in the Birmingham region, Occupational Lung Disease Services (OLDS) conducted a study to assess the prevalence of pneumoconiosis from asbestos in various industries. There were 160 cases found, of which 71 (44%) were from the construction industry (Walters et al. 2018). Due to the long incubation period, patients with asbestosis were detected only after working in construction for 25, 30 or 40 years (Philteos et al. 2004). However, exposure to silica, asbestos, and mixed dust, forces companies to have greater attention to mitigating health effects considered incurable and characteristics suggestive of asbestosis disease that can impair worker performance, such as oxidative stress, fibrotic degeneration of lung tissue, complexation iron, apoptosis, and inflammation (Chong et al. 2006; Perret et al. 2017; Schmajuk et al. 2019). Likewise, asbestos, silica, and mixed dust were considered risk factors for pneumoconiosis in a study about Global Burden diseases (GBD 2016) and Risk Factors Collaborators (RFC 2016). The WHO/ILO (World Health Organization/International Labour Organization) in 2018 presented a systematical review protocol that designed quantitative studies on the prevalence of pneumoconiosis attributed to risk factors. This study was about the chemical agents (asbestos, silica, and mixed dust) from 1960 to 2018 among the working-age population and disaggregated by country, sex, age, and industrial sector occupation, including the construction industry (Mandrioli et al. 2018; Hall et al. 2020; Kurth et al. 2020; Dhatrak and Nandi 2020).

To investigate pneumoconiosis, it is necessary to consider confounding factors in the manifestation of the disease, such as age, sex, biomass, smoking, tuberculosis, socioeconomic status, pathological conditions and type of work (Han et al. 2017). In addition, the permissible exposure limit (PEL) for free silica was established to prevent the development of the disease. Several studies noted significant differences

(Liu et al. 2017). Some of them were set by OSHA and ACGIH (Linch 2002; Dhatrak and Nandi 2020). For identifying pneumoconiosis, an exposure questionnaire (Ben Saad et al. 2013), spirometry tests (Prasad et al. 2020; Quanjer et al. 2012) and chest X-rays were also suggested to check rounded or irregular opacities, especially in the upper and lower lung fields (Han et al. 2018; Baur 2020; Dhatrak and Nandi 2020). Other authors suggest post-mortem pathophysiological diagnoses of lung tissue (Naidoo et al. 2005; Ndlovu et al. 2016).

This review focuses on pneumoconiosis resulting from exposure to workplace chemical agents such as silica, asbestos, and mixed dust. Some studies which have been visited recognise that silica, asbestos, and mixed dust are risk factors for pneumoconiosis in the construction industry. So, the present systematic literature review (SLR) intends to answer the following questions:

To what extent does the prevalence of pneumoconiosis contribute to illness in civil construction between 2001 and 2021?

Which chemical agent has the greatest weight in the prevalence of pneumoconiosis?

2 Materials and Methods

The research used the PRISMA Statement (Page et al. 2021). The information to compose the research was extracted from six electronic academic databases: Scopus; Ovid Medline with Daily Update; OSH update; Web of Science; EMBASE; and PubMed. Cited references were extracted using keywords related to the topic. A checklist was created to facilitate the analysis of the results, considering the following items: the authors' surnames and publication year, prevalence of pneumoconiosis, exposure to chemical agents, i.e., exposure to silica, asbestos and/or mixed dust, and the disease(s) derived from chemical agents. After selecting the articles related to the construction industry, the authors included pneumoconiosis papers related to other sectors, such as mining, to compare data and results.

2.1 Search Strategy

The strategy used in data extraction was based on a 20-year time horizon (2001–2021). "Data were extracted from works published between January 2001 and December 2021," taking into account title contents, abstracts, and keywords of all articles retrieved from the six databases. The following keywords have been considered, using the booleans "OR" and "AND": [(construction AND asbestos); OR (construction AND silica) OR (asbestos AND mixed dust)]; [(concrete AND asbestos) OR (silica AND mixed dust)]; [(occupational lung disease AND construction)]; [(permissible exposure limit AND silica) OR (construction industry AND mixed dust)]; [(pneumoconiosis AND construction)]; [(abrasive blasting AND silicosis) OR (pneumoconiosis AND asbestosis)]; [(pneumoconiosis AND spirometry)]; [(chest r-x AND pneumoconiosis) OR (asbestos AND mixed dust)]; (construction AND accidents); (pneumoconiosis AND accidents). The asterisk symbol was used to ensure that all possible variations of the terms were considered.

Data were extracted using a standard form developed in Excel to organise and compare information from the articles.

To be included/excluded in this review, studies had to meet the following criteria: experimental random or observational analytical studies focused on pneumoconiosis prevalence caused by silica, asbestos, and mixed dust in the construction industry or related activities with measurements (similar tasks of mining has been included). In addition, the articles need to have available full text and be written in English.

2.2 Data Analyses

The absolute frequencies of diseases in the included studies associated with exposure to at least one of the chemical agents (silica, asbestos and mixed dust) as well as the associated risk factor were sought.

The determination of the absolute and relative frequencies and the verification of the level of prevalence, in percentage, was through the following equation:

$$\text{fr} = \text{fi}/\text{N} \times 100\%$$

where:

fi—(absolute frequency) shows how many times the disease appeared for each article reviewed according to its risk factor;
N—refers to the total number of diseases associated with a risk factor;
fr—(relative frequency) shows the impact number converted into a percentage.

3 Results

3.1 Study Selection and Characteristics

A comprehensive selection of studies was carried out in this systematic review, using the six databases and observing the inclusion/exclusion criteria referred to in the methodology. A total of 1823 records were screened, 1357 of which were removed because they were duplicates, incomplete, not peer-reviewed, not published in scientific journals, or off-topic. Were screened 466 articles having these been removed 440 because they did not correspond to the period under study (2001–2021), had contradictory objectives, or were not written in English. There were found 26

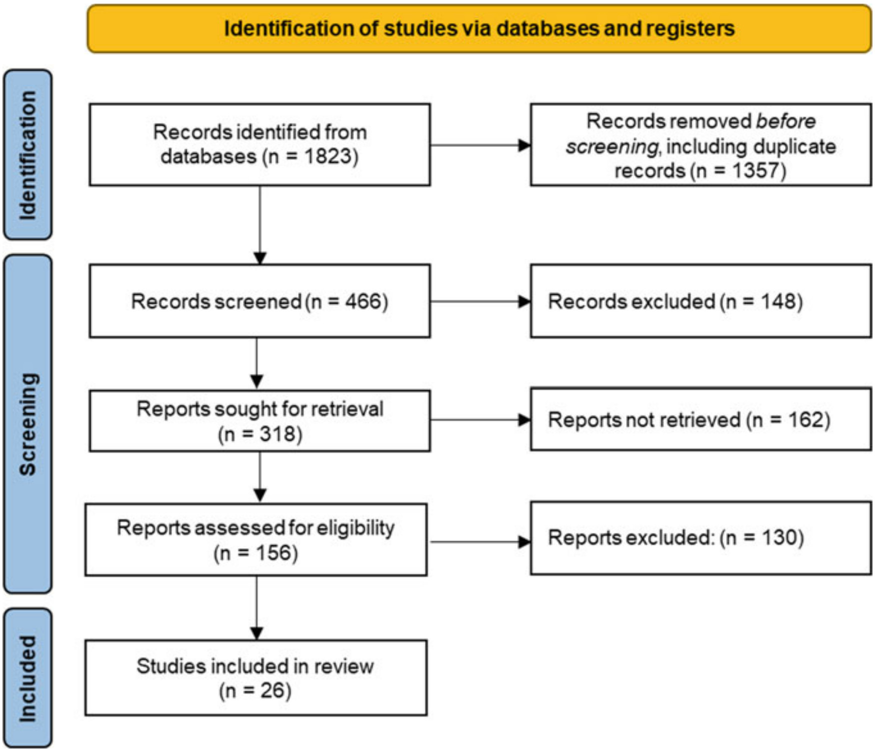

Fig. 1 Study screening diagram (Page et al. 2021)

articles considered eligible (Fig. 1). The extracted information is summarised in Table 1.

3.2 Distribution of Diseases According to Exposure Agent

The construction industry involves a wide range of activities, such as stone-breaking, concrete or brick cutting, pipe cutting, abrasive blasting, and tunnelling (Wang and Meng 2018). Exposure to crystalline silica, asbestos and mixed dust (risk factor) develops silicosis and asbestosis. Mixed dust is a blend of minerals, and it has the potential to cause pneumoconiosis (Nelson et al. 2010). A statistical analysis has been performed with the compiled data from items and characteristics described in Table 2. Moreover, diseases associated with different risk factors can be identified. Note that a disease may be associated with more than one risk factor.

The comparison of prevalence was represented by the absolute and relative frequencies of each type of disease caused by the three chemical agents: silica, asbestos and mixed dust.

Table 1 Characteristics related to pneumoconiosis occurrence from exposure to silica, asbestos, and mixed dust

#	Pneumoconiosis occurrence/detection	Exposure to chemical agents	Occupational Diseases from exposure
Agioutanti et al. (2020)	Respirable rock dust	Dust: from rock and coal	Unknown pneumoconiosis;
Bajpayee et al. (2004)	Of 100,000 workers, 15.3% are in the construction industry	Asbestos	Asbestosis
Baur (2020)	Components of cement and concrete dust in the construction industry	Asbestos and mixed dust	Idiopathic interstitial lung disease
Bell and Mazurek (2020)	In U.S 2738 in 1999 to 1632 in 2018. mortality ratio per million from 12.8 to 5.3	Asbestos, 60.1% of mortality; 820 deaths (25%) occurred in the construction industry; Silica 31.6%; 63 (18.9%); Mixed dust in construction caused 32 deaths (4%)	Asbestosis; Silicosis; Mixed dust pneumoconiosis
Ben Saad et al. (2013)	1992 workers in Tunisia/Africa submitted to a spirometry test: 71.31% lung function disability	Mixed dust	Lung disability
Chong et al. (2006)	Computed tomography (CT) and magnetic tomography studies identified silicosis	Silica	Silicosis and mixed dust; Progressive massive fibrosis; Lung cancer
Cummings et al. (2019)	In 2017, after 50 years, NIOSH used spirometry and X-ray chest	Silica	Silicosis Lung cancer
Dhatrak and Nandi (2020)	12.3% of 1012 X-ray chest performed (PEL) was 0.15 mg/m^3	Silica and mixed dust	Silicosis; Unknown pneumoconiosis
Hall et al. (2020)	109 workers, 1.9%, suffered from pneumoconiosis	Silica and mixed dust	PMF
Han et al. (2017)	495 workers were diagnosed with pneumoconiosis, 95 died	Mix dust	Pneumoconiosis; Chronic pulmonary obstructive (CPOD); Lung cancer; Tuberculosis

(continued)

Table 1 (continued)

#	Pneumoconiosis occurrence/detection	Exposure to chemical agents	Occupational Diseases from exposure
Han et al. (2018)	Increased mortality: 6.02% in China (2001–2011), 0.8% in the UK (1998–2000) and 3.2% in the USA (1998–2000)	Silica, asbestos and mixed dust	Pneumonia; Pulmonary tuberculosis; Lung cancer; Chronic pulmonary obstructive disease (CPOD); Accidents
Kurth et al. (2020)	Health Surveillance Program (CWHSP) found a 7.7% increase in pneumoconiosis severity	Mixed dust	Lung disease
Leonard et al. (2020)	NIOSH findings in the twenty-first century determined the prevalence of pneumoconiosis in young workers	Silica and mixed dust	Silicosis; Deficit lung function; Emphysema
Linch (2002)	NIOSH: 1992 and 1998, exposure to silica in 8 h of (PEL) of 0.05 mg/m^3	Crystalline silica (quartz) coming from the concrete	Silicosis; Unknown pneumoconiosis
Liu et al. (2017)	Low level exposure: 0.05; 0.01 and 0.35 mg/m^3 of silica and mortality	Silica	Silicosis
Mandrioli et al. (2018)	Noted prevalence from1960 to 2018	Asbestos, silica, and mixed dust	Pneumoconiosis from asbestosis, Silicosis; Mixed dust
Miller et al. (2005)	Spirometry standardisation	Silica, asbestos and mixed dust	Disability lung function
Naidoo et al. (2005)	Black miners had 8.3 and 1.2%. White miners had an increased risk of 1.4–5.4% for silicosis	Silica and mixed dust	Silicosis; Moderate to marked emphysema
Ndlovu et al. 2016	Silicosis and pulmonary tuberculosis were 12.0 and 13.0% in black and 20.5 and 2.4% in white miners	Asbestos and mixed dust	Silicosis and pulmonary tuberculosis

(continued)

Table 1 (continued)

#	Pneumoconiosis occurrence/detection	Exposure to chemical agents	Occupational Diseases from exposure
Nicol et al. (2015)	Six cases of eight symptomatic silicoses in six years of study	Silica	Silicosis; (PMF)
Perret et al. (2017)	Of 2257 least one year of experience, 2.0% ($n = 46$) were found CWP, and 0.5% ($n = 12$) had PMF	Mixed dust	Progressive massive fibrosis (PMF)
Philteos et al. (2004)	X-ray chest was performed on a 40-year-long construction worker	Asbestos	Asbestosis; Benign asbestosis lung diseases; Chronic interstitial lung disease
Prasad et al. (2020)	43.91% of workers found asbestos?	Asbestos	Asbestosis
Sauvé (2015)	19% of construction workers were exposed to silica	Silica	Silicosis
Stocks et al. (2011)	18,509 workers were detected 95% of respirable lung diseases and 98% attributed to asbestos	Asbestos and silica	Pneumoconiosis; Lung cancer; Mesothelioma; Non-malignant pleural disease
Waters et al. (2018)	Between 2001 and 2016, found 160 cases of asbestosis in all industries, 71 (44%) were in construction	Asbestos	Asbestosis; Mesothelioma; Bronchial cancer

Regarding the global analysis of the disease distribution in relation to pneumoconiosis, is noted: silica (37.5%), asbestos (21.4%), and mixed dust (41.1%). Obtained through the relative frequencies of the diseases of each agent divided by the total occurrence of the diseases (56%).

Analysing the occurrence of individualised diseases in relation to their risk agent, the following higher frequencies are noted: silica for (Silicosis 38.1%); asbestos for (asbestosis and lung cancer 33.3%), and mix dust for (lung cancer 21.7%) Table 2.

3.3 Permissible Exposure Limit

The literature review shows the need to establish an exposure limit value, given the risk factors for pneumoconiosis in the mining and construction industries (Hall

Table 2 Absolute and relative frequencies of risk factors and diseases

Risk factor	Diseases	fi	Fr (%)
Silica	Silicosis	8	38.1
	Unknown pneumoconiosis	2	9.5
	Lung cancer	4	19.0
	Mesothelioma	1	4.8
	Chronic pulmonary obstructive disease (CPOD)	2	9.5
	Progressive massive fibrosis (PMF)	2	9.5
	Moderate to marked emphysema	2	9.5
Total		21	100.0
Asbestos	Asbestosis	4	33.3
	Lung cancer	4	33.3
	Unknown pneumoconiosis	1	8.3
	Mesothelioma	1	8.3
	Chronic pulmonary obstructive disease (CPOD)	1	8.3
	Pulmonary tuberculosis	1	8.3
Total		12	100.0
Mixed dust	Mixed dust Pneumoconiosis	4	17.4
	Unknown pneumoconiosis	1	4.3
	Silicosis	4	17.4
	Lung cancer	5	21.7
	Chronic pulmonary obstructive disease (CPOD)	3	13.0
	Moderate to marked emphysema	2	8.7
	Pulmonary tuberculosis	2	8.7
	Progressive massive fibrosis (PMF)	2	8.7
Total		23	100.0

fi—absolute frequency; Fr—relative frequency; Unknown pneumoconiosis—diseases that have not been identified with any risk factor in the workplace (silica and asbestos)

et al. 2020). Despite the effort involving several organisations that deal with workers' health, there has been no consensus on standardising exposure values.

Whether due to the continuous exposure to risk factors or too high values of the Permissible Exposure Limit (PEL) (Liu et al. 2017), there are differences in standard levels of silica compared to those recommended by Occupational Safety and Health (OSH) and international organisations in several countries, (Linch 2002; Dhatrak and Nandi 2020) (Fig. 3). The two values corresponding to the United States belong to NIOSH (0.05 mg/m^3) and MSHA (0.10 mg/m^3). China values vary according to the type of ore, from 0.07 to 0.35 mg/m^3. There is currently a difference in exposure values in countries such as India, France, and Portugal, contributing to the prevalence of diseases related to pneumoconiosis, Fig. 2.

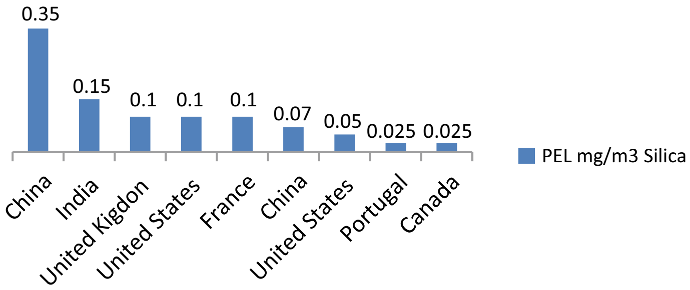

Fig. 2 Permissible exposure limit depending on the country (Linch 2002)

4 Discussion

The prevalence of pneumoconiosis in the construction industry has been studied since the last century (Linch 2002; Higgins et al. 2011; Sauvé 2015; Mandrioli et al. 2018; FCL 2021). In addition, there were studies on asbestos, silica, and mixed dust considered the risk factor for occupational pneumoconiosis, responsible for 100% of this disease (GBD 2016; RFC 2016). Review shows that exposure to chemical agents (silica, asbestos, and mixed dust) are responsible for diseases such as; Silicosis, asbestosis, lung cancer, chronic pulmonary obstructive diseases, moderate to marked emphysema, mixed dust pneumoconiosis, unknown pneumoconiosis, pulmonary tuberculosis, and progressive massive fibrosis (PMF) Tables 1 and 2. These diseases are associated with causes of pneumoconiosis morbidity and mortality in the construction industry due to dust and fibres (Stocks et al. 2011; Agioutanti et al. 2020).

Based on the global review analyse, Table 2, it is noted that mixed dust has a higher frequency of diseases with 41.1%. This can be justified by the presence of two elements together, namely silica and asbestos, forming a compound, joining the diseases of each element (Baur 2020). Then, silica with 37.5% and asbestos with 21.7% caused a long latency fibrotic lung diseases/pneumoconiosis (Stocks et al. 2011; Walters et al. 2018), referenced in Table 2. There is a long latency period for these diseases and a lack of health care for workers in the construction industry. These two factors make employers decline their responsibility (Ndlovu et al. 2016). In pneumoconiosis, workers may have signs of pulmonary dysfunction (pneumoconiosis) 20, 30, 40 or more years after leaving the company. Few studies have shown shorter times (Philteos et al. 2004; Nicol et al. 2015). The individual analysis of the maximum frequencies of diseases related to exposure to the three chemical agents supports the prevalence of pneumoconiosis in the construction industry with the following values: silica (Silicosis 38.1%), asbestos (asbestosis and lung cancer 33.3% both); and mixed dust (lung cancer 21.7%). Although the research shows evidence of pneumoconiosis from silicosis in the mines (Bajpayee et al. 2004; Stocks et al. 2011; Dhatrak and Nandi 2020; Baur 2020), the higher values of silicosis concerning asbestos and mixed dust referred to in Table 2, can support its impact on the construction industry. Knowledge of the risk factors with the most significant impact on the work environment helps identify the causes and, consequently, implement preventive and corrective actions (Bell and Mazurek 2020).

More evidence was seen at the South African Conference on silicosis analysis over 75 years. It was found that silica still affects 19% of construction industry workers (Sauvé 2015). The presence of different levels of exposure in many countries may influence the pneumoconiosis prevalence value (Fig. 2). Exposure Limit Values are not the same in all countries, although there are international organisations that seek to establish a common value for all countries. The existence of different limits influences the value of the prevalence of pneumoconiosis (Linch 2002; Dhatrak and Nandi 2020).

Construction industry workers are subject to the use and handling of products and machines such as explosive pressure vessels, explosives and breakers, machines and loaders, mixed dust, silica and asbestos (Baur 2020; Agioutanti et al. 2020). Proposals to combat pneumoconiosis were suggested, from preventive (work education) and corrective actions, which can be added using diagnosis like exposure questionnaires, spirometry (Prasad et al. 2020), chest X-ray (Dhatrak and Nandi 2020), Computer Tomographic (CT), and Magnetic Tomography Imaging (Ben Saad et al. 2013).

5 Conclusion

After the present literature review, 26 articles were considered eligible. The research shows that the prevalence of pneumoconiosis in the construction industry is due to the raw materials containing chemical elements considered risk factors, namely silica, asbestos and mixed dust. In the global analysis of the risk factors for pneumoconiosis, it was found that mixed dust is responsible for the higher frequency of pneumoconiosis (41.1%), followed by silicosis and asbestosis with 37.5% and 21.7%, respectively. In the individual analysis of the diseases, silicosis is observed more frequently, with 38.1% associated with silica, followed by asbestosis and lung cancer with 33.3% both related to asbestos and mixed dust with lung cancer (21.7%). In conclusion, the three risk factors contribute to diseases that cause pneumoconiosis; mixed dust has the highest number of diseases, while silicosis is the most frequently associated with silica.

Acknowledgements This research was funded by the Doctoral Program in Occupational Safety and Health of the University of Porto, grant number demssogaa541344.

References

Agioutanti, E., Keles, C., Sarver, E.: A thermogravimetric analysis application to determine coal, carbonate, and non-carbonate minerals mass fractions in respirable mine dust. J. Occup. Environ. Hyg. **17**(2–3), 47–58 (2020). https://doi.org/10.1080/15459624.2019.1695057

Bajpayee, T.S., Rehak, T.R., Mowrey, G.L., Ingram, D.K.: Blasting injuries in surface mining with emphasis on flyrock and blast area security. J. Saf. Res. **35**(1), 47–57 (2004). https://doi.org/10.1016/j.jsr.2003.07.003

Baur, X.: Diagnostic challenges of mixed dust silicosis (mixed dust pneumoconiosis)—5 case reports. Pneumologie **74**(3), 159–172 (2020). https://doi.org/10.1055/a-1087-7229

Bell, J.L., Mazurek, J.M.: Trends in pneumoconiosis deaths—United States, 1999–2018. MMWR. Morb. Mortal. Wkly. Rep. **69**(23), 693–698 (2020). https://doi.org/10.15585/mmwr.mm6923a1

Ben Saad, H., El Attar, M.N., Hadj Mabrouk, K., Ben Abdelaziz, A., Abdelghani, A., Bousarssar, M., Limam, K., Maatoug, C., Bouslah, H., Charrada, A., Rouatbi, S.: The recent multi-ethnic global lung initiative 2012 (GLI2012) reference values don't reflect contemporary adult's North African spirometry. Respir. Med. **107**(12), 2000–2008 (2013). https://doi.org/10.1016/j.rmed.2013.10.015

Chong, S., Lee, K.S., Chung, M.J., Han, J., Kwon, O.J., Kim, T.S.: Pneumoconiosis: comparison of imaging and pathologic. Radiographics **26**(1), 59–77 (2006). https://doi.org/10.1148/rg.261055070

Cummings, K.J., Johns, D.O., Mazurek, J.M., Hearl, F.J., Weissman, D.N.: NIOSH's respiratory health division: 50 years of science and service. Arch. Environ. Occup. Health **74**(1–2), 15–29 (2019). https://doi.org/10.1080/19338244.2018.1532387

Dhatrak, S., Nandi, S.: Assessment of silica dust exposure profile in relation to prevalence of Silicosis among Indian sandstone mine workers: need for review of standards. Am. J. Ind. Med. **63**(3), 277–281 (2020). https://doi.org/10.1002/ajim.23077

Fundación Laboral de la Construcción: Trabajos con exposición a SCR: implicaciones asociadas a su consideración como agente cancerígeno en el RD 665/1997, p. 18 (2021). http://www.gotowebinar.com/

GBD 2016 Risk Factors Collaborators: Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet **390**(10100), 1345–1422 (2017).https://doi.org/10.1016/S0140-6736(17)32366-8

Higgins, J.P.T., Green, S., Collaboration, C.: Cochrane Handbook for Systematic Reviews of Interventions. Wiley Online Library (2008)

Higgins, J.P.T., Green, S., (eds.): Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0. 2011 The Cochrane Collaboration (2011). Available from http://handbook.cochrane.org. Updated March 2011

Hall, N.B., Halldin, C.N., Blackley, D.J., Laney, A.S.: Assessment of pneumoconiosis in surface coal miners after implementation of a national radiographic surveillance program, United States, 2014–2019. Am. J. Ind. Med. (2020). https://doi.org/10.1002/ajim.23184

Han, L., Gao, Q., Yang, J., Wu, Q., Zhu, B., Zhang, H., Ding, B., Ni, C.: Survival analysis of coal workers' pneumoconiosis (CWP) patients in a state-owned mine in the east of China from 1963 to 2014. Int. J. Environ. Res. Public Health **14**(5) (2017). https://doi.org/10.3390/ijerph14050489

Han, S., Chen, H., Harvey, M.A., Stemn, E., Cliff, D.: Focusing on coal workers' lung diseases: a comparative analysis of China, Australia, and the United States. Int. J. Environ. Res. Public Health **15**(11) (2018). https://doi.org/10.3390/ijerph15112565

Kurth, L., Laney, A.S., Blackley, D.J., Halldin, C.N.: Prevalence of spirometry-defined airflow obstruction in never-smoking working US coal miners by pneumoconiosis status. Occup. Environ. Med. **77**(4), 265–267 (2020). https://doi.org/10.1136/oemed-2019-106213

Leonard, R., Zulfikar, R., Stansbury, R.: Coal mining and lung disease in the 21st century. Curr. Opin. Pulm. Med. **26**(2), 135–141 (2020). Lippincott Williams and Wilkins, https://doi.org/10.1097/MCP.0000000000000653

Linch, K.D.: Respirable concrete dust-silicosis hazard in the construction industry. Appl. Occup. Environ. Hyg. **17**(3), 209–221 (2002). https://doi.org/10.1080/104732202753438298

Liu, Y., Zhou, Y., Hnizdo, E., Shi, T., Steenland, K., He, X., Chen, W.: Total and cause-specific mortality risk associated with low-level exposure to crystalline silica: a 44-year cohort study from China. Am. J. Epidemiol. **186**(4), 481–490 (2017). https://doi.org/10.1093/aje/kwx124

Mandrioli, D., Schlünssen, V., Ádám, B., Cohen, R.A., Colosio, C., Chen, W., Fischer, A., Godderis, L., Göen, T., Ivanov, I.D., Leppink, N., Mandic-Rajcevic, S., Masci, F., Nemery, B., Pega, F., Prüss-Üstün, A., Sgargi, D., Ujita, Y., van der Mierden, S., Scheepers, P.T.J., et al.: WHO/ILO work-related burden of disease and injury: protocol for systematic reviews of occupational exposure to dusts and/or fibres and of the effect of occupational exposure to dusts and/or fibers on pneumoconiosis. Environ. Int. **119**, 174–185 (2018). Elsevier Ltd., https://doi.org/10.1016/j.envint.2018.06.005

Miller, M.R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., Crapo, R., Enright, P., van der Grinten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., MacIntrye, N., McKay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G., Wagner, J.: Standardisation of spirometry. Eur. Respir. J. **26**(2), 319–338 (2005). https://doi.org/10.1183/09031936.05.00034805

Naidoo, R.N., Robins, T.G., Murray, J.: Respiratory outcomes among South African coal miners at autopsy. Am. J. Ind. Med. **48**(3), 217–224 (2005). https://doi.org/10.1002/ajim.20207

Ndlovu, N., Nelson, G., Vorajee, N., Murray, J.: 38 years of autopsy findings in South African mineworkers. Am. J. Ind. Med. **59**(4), 307–314 (2016). https://doi.org/10.1002/ajim.22574

Nelson, G., Girdler-Brown, B., Ndlovu, N., Murray, J.: Three decades of Silicosis: disease trends at autopsy in South African gold miners. Environ. Health Perspect. **118**(3), 421–426 (2010). https://doi.org/10.1289/ehp.0900918

Nelson, G., Murray, J., Phillips, J.I.: The risk of asbestos exposure in South African diamond mine workers. Ann. Occup. Hyg. **55**(6), 569–577 (2011). https://doi.org/10.1093/annhyg/mer028

Nicol, L.M., McFarlane, P.A., Hirani, N., Reid, P.T.: Six cases of Silicosis: implications for health surveillance of stonemasons. Occup. Med. **65**(3), 220–225 (2015). https://doi.org/10.1093/occmed/kqu209

Ophir, N., Bar Shai, A., Korenstein, R., Kramer, M.R., Fireman, E.: Functional, inflammatory, and interstitial impairment due to artificial stone dust ultrafine particles exposure. Occup. Environ. Med. **76**(12), 875–879 (2019). https://doi.org/10.1136/oemed-2019-105711

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C,. Mulrow, C.D., et al.: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ **372**, n71 (2021). https://doi.org/10.1136/bmj.n71

Perret, J.L., Plush, B., Lachapelle, P., Hinks, T.S.C., Walter, C., Clarke, P., Irving, L., Brady, P., Dharmage, S.C., Stewart, A.: Coal mine dust lung disease in the modern era. Respirology **22**(4), 662–670 (2017). https://doi.org/10.1111/resp.13034

Prasad, S.K., Singh, S., Bose, A., Prasad, B., Banerjee, O., Bhattacharjee, A., Maji, B.K., Samanta, A., Mukherjee, S.: Association between duration of coal dust exposure and respiratory impairment in coal miners of West Bengal, India. Int. J. Occup. Saf. Ergon. (2020). https://doi.org/10.1080/10803548.2020.1742463

Philteos, G.S.R., Coverett, K., Chibbar, R., Ward, H.A., Cockcroft, D.W.: Asbestosis and probable microscopic polyangiitis. Can. Respir. J. **11**(5), 359–362 (2004). https://doi.org/10.1155/2004/341942

Quanjer, P.H., Stanojevic, S., Cole, T.J., Baur, X., Hall, G.L., Culver, B.H., Enright, P.L., Hankinson, J.L., Ip, M.S.M., Zheng, J., Stocks, J., Schindler, C.: Multi-ethnic reference values for spirometry for the 3–95-yr age range: the global lung function 2012 equations. Eur. Respir. J. **40**(6), 1324–1343 (2012). https://doi.org/10.1183/09031936.00080312

Sauvé, J.F.: Historical and emerging workplaces affected by silica exposure since the 1930 Johannesburg conference on silicosis, with special reference to construction. Am. J. Ind. Med. **58**, 67–71 (2015). https://doi.org/10.1002/ajim.22507

Schmajuk, G., Trupin, L., Yelin, E., Blanc, P.D.: Prevalence of arthritis and rheumatoid arthritis in coal mining counties of the United States. Arthritis Care Res. **71**(9), 1209–1215 (2019). https://doi.org/10.1002/acr.23874

Stocks, S.J., Turner, S., Mcnamee, R., Carder, M., Hussey, L., Agius, R.M.: Occupation and work-related ill-health in UK construction workers. Occup. Med. **61**(6), 407–415 (2011). https://doi.org/10.1093/occmed/kqr075

Walters, G.I., Robertson, A.S., Bhomra, P.S., Burge, P.S.: Brief communication asbestosis is prevalent in a variety of construction industry trades. Primary Care Respir. Med. **28**, 11 (2018). https://doi.org/10.1038/s41533-018-0078-6

Wang, X., Meng, F.-B.: Statistical analysis of large accidents in China's coal mines in 2016. Nat. Hazards **92**, 311–325 (2018)