Original article

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Occupational exposure to silica dust in Slovenia is grossly underestimated

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As a by-product or material used in various industries crystalline silica contaminates the air many occupational settings. If its fine particles are inhaled, they are deposited in the lungs and may cause the development of silicosis, chronic obstructive pulmonary disease, and lung cancer. The goal of this study was to estimate occupational exposure to respirable crystalline silica (RCS) in Slovenia and the associated health risks. To do that, we ran two cross-sectional studies, one to determine the number of workers at risk of occupational exposure to RCS in Slovene industries and the other to determine and classify changes in the lung radiographs of glass factory workers exposed to RCS, as a means to infer health risks for other RCS exposed workers in Slovenia. However, the first study shows that official public data on occupational exposure to silica in Slovenia are unreliable and incomplete and that company representatives strongly underestimate occupational exposure to silica. Measurements of total and silica dust are made by 8.3 % and 1.8 % of companies working with silica, respectively. The second study shows that about a third of the exposed workers had lung changes associated with silicosis. We have failed to achieve the goal of our study, as the obtained data are grossly underestimated and unreliable, but it has opened our eyes as to what needs to be improved. All companies need to systematically be informed about occupational health risks, field inspections need to be consistent, regular, and intensified, and health surveillance of all exposed workers implemented regularly.

KEY WORDS: construction industry; glass industry; respirable dust; silicon dioxide, quartz

Crystalline silica (SiO_2; aka silicon dioxide, quartz sand, silica sand, or quartz) can be found in nearly all types of rock, sand, clay, shale, and gravel, and workers in the stonecutting, mining, construction, concrete, pottery, and ceramic industries are exposed to it the most (1–3). As it has a high melting point, it is also used in foundries, glass industry, electronics, and production of optical components (3, 4).

Occupational health risk due to exposure to silica arises when workers are exposed to particles of crystalline silica smaller than 5 μm in diameter, that is, to respirable crystalline silica (RSC) (5). Occupational exposure may occur in work operations generating fine dust, such as rock and gravel crushing, stone cutting and grinding, land cultivation, soil excavation, building demolition, aggregate production, and material grinding, polishing, and sandblasting (2).

After RSC is inhaled, it turns into biologically active dust that is deposited in the lungs and increases the risk of silicosis, chronic obstructive pulmonary disease (COPD), and lung cancer (5). The International Agency for Research on Cancer (IARC) classifies crystalline silica in group 1 (i.e., carcinogenic to humans). There is sufficient evidence that exposure to crystalline silica increases the risk of lung cancer (3).

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It is estimated that 5.3 million workers in the European Union are exposed to RCS (6). In the US, over 2 million workers are exposed to it in the construction industry alone (7). The number of exposed workers is even higher in developing countries (8).

Slovenia does not have any data available on the number of workers exposed to RCS, the intensity of their exposure, and the consequences of occupational exposure. Therefore, the main goal of this study was to estimate the magnitude of the health burden (silicosis) caused by occupational exposure to RCS among the exposed workers in Slovenia.

METHODS

To do that, it was first necessary to estimate the extent of occupational exposure to silica sand in the country, after which an interdisciplinary team of specialists (a pulmonary specialist, a radiologist, and an occupational medicine specialist) reviewed all available and regularly monitored radiographs of exposed glass workers from 1985 to 2001 to determine which changes were likely associated with occupational exposure to crystalline silica. Based on the degree of occupational exposure and silicosis in the group of the studied glass workers, we intended to infer the extent of health impact of exposure to RCS (the onset of silicosis) for all exposed workers.

This research consisted of two cross-sectional studies. The first was to determine the number of workers at risk of occupational exposure to RCS in Slovene industries. The second determined and classified changes in the lung radiographs of glass factory workers exposed to RCS.

The first study population included all workers employed in companies headquartered in Slovenia that had more than ten employees and operated in industries at high risk of occupational exposure to RCS. The starting points for collecting data were two official lists: the list of importers and buyers of hazardous chemicals containing silica maintained by the Slovenian Chemicals Office and the list of business entities operating in industries at high risk of exposure to RSC according to the Standard Classification of Activities in the Slovenian Business Register (SBR). We matched both lists and added importers that were not in the SBR list. Of the 29,545 business entities in this extended SBR list, 10,977 had no employees, 10,425 had up to ten employees, and 6,012 had no information on the number of employees. We therefore took a random sample of 665 companies with no such information to establish that only four engaged in a production that uses silica or is associated with exposure to silica dust. Seeing such a low proportion, we decided not to include in the study any entities with no data on the number of employees in the business register. The final list therefore consisted of 2,131 companies ranking among high-risk industries and employing at least ten people. Ten people was taken as minimum because we assumed that the data would be more accurate if a company had more employees. We reasoned that if we obtain reliable data for companies with over ten employees, we would then investigate companies with fewer than ten employees.

To obtain exposure data on company workers we relied on an online questionnaire asking company representatives to estimate the number of employees regularly or occasionally exposed to silica, specify the type of operations their workers performed and for how long, and report environmental measurements of dust and silica concentrations in their work environment. To estimate the intensity of exposure to RCS, each work operation was classified as high, medium, or low exposure, based on the RCS concentration estimates for specific operations/jobs from literature (9–11).

Of the 2,131 listed companies, we invited 1,378 that had an email address and asked them to complete our online questionnaire. Because some of the email addresses were invalid, the final number of recipients was 1,281. The survey was sent out four times and then closed. We received 727 questionnaires in response. After eliminating 75 double submissions, blank questionnaires, and questionnaires with substantial inconsistencies established by content analysis, the analysed sample included data from 277 companies (21.6 % of the invited) operating in high-risk industries. These companies employ a total of 18,064 workers.

The second study included 131 glass cutters employed at a large Slovenian glass factory, who had been examined and regularly monitored at an occupational outpatient clinic from 1985 to 2001. We reviewed their lung radiographs in order to determine any health impairments associated with exposure to RCS.

The mean concentration of total dust at their workplace at that time was 8.9 mg/m^3 and the average concentration of RCS was 0.9 mg/m^3. The mean concentration of respirable dust particles (smaller than 5 μm) was 1,625/cm^3, and of particles larger than 5 μm 510/cm^3. The mean concentration of RCS in the dust was 2.3 %, which corresponds to the concentration of 0.2 mg/m^3 in total dust.

Health impairments were defined as radiological changes in the lungs most likely associated with occupational exposure to silica. Radiographs were reviewed by an interdisciplinary team composed of a pulmonologist, a radiologist, and an occupational medicine specialist with long-standing experience in verifying occupational pneumoconioses. Decisions on the changes were determined by consensus. Based on the presence of lung changes, the radiographs of all 131 workers were classified into three groups. The first group included workers with radiographs showing fibrous changes, tiny calcifications, granulomas, and adhesions; that is, the changes of the lung parenchyma most likely associated with silicosis. The second group included workers with radiographs showing changes that

Table 1 Number of companies and workers exposed to SiO_2 by industry (self-reported estimates by company representatives vs literature-based estimates according to job description)

Industry	Companies (N)	Workers (N)	Workers exposed as estimated by			
			Company representatives		Study authors based on literature data	
			N	%	N	%
Construction and concrete manufacturing	140	6,005	857	14.3	2,716	45.2
Metal production and processing	76	4,749	172	3.6	620	13.1
Mining and natural stone processing	12	530	72	13.6	218	41.1
Ceramics and brick manufacturing	2	70	5	7.1	48	68.6
Glass production	3	1,018	298	29.3	299	29.3
Other	44	5,692	668	11.7	1,106	19.4
Total	**277**	**18,064**	**2,072**	**11.5**	**5,007**	**27.7**

could also be associated with other diseases. The third group included workers with radiographs showing no pathological changes.

Only descriptive statistics were used in the statistical analysis.

RESULTS

Most respondent companies are from the construction industry (50.54 %), followed by those in metal production and processing (27.4 %) and mining and natural stone processing (4.3 %). The construction industry and metal production and processing also employ most workers (33.3 % and 26.3 %, respectively, Table 1).

Only 36.5 % (N=101) of the respondents reported that their workers were regularly or occasionally exposed to silica, 2,072 in total, most of whom come from the construction industry. However, the highest share of exposed workers (as self-reported by respondents) comes from the glass industry (29.3 %; Table 1).

Our analysis based on job descriptions associated with high risk of exposure (number of workers performing specific operations, Table 1, last two columns) according to literature data (9–11), however, suggests a much higher number of exposed workers, namely 5,007, as opposed to the self-reported 2,072. The difference is most notable for workers in the construction industry (Table 1). Nearly half of the 5,007 workers estimated to be exposed to silica based on literature data (N=2,323 or 46 %) carried out operations characterised by high exposure (Figure 1). Among these, 1,513 (65 %) work in the construction industry, followed by those working in metal production and processing (456 or nearly 20 %).

With regard to operations performed in these companies, most workers are exposed to silica when cutting or drilling concrete (764 workers), followed by quarrying, grinding, crushing, and transporting gravel, soil, minerals, or rocks (697 workers), and sandblasting and grinding metal products (662 workers).

Only 23 respondent companies (8.3 %) provided data on dust concentration measurements carried out at 57 work posts. The concentration of silica was measured by only five companies (1.81 %) for at 13 work posts, one of which measured the percentage of RCS. None of these companies is in the construction business. The current exposure limit was exceeded in five silica measurements (locations) (Figure 2).

The reviewed lung radiographs of 131 workers exposed to silica dust in a glass manufacturer suggest that half (N=66; 51 %) had no changes in the lung parenchyma, 24 (18 %) had changes not necessarily associated with silica exposure, and 41 (31 %) had lung changes most likely associated with exposure to silica. The most common lung changes included tiny calcifications (N=18; 43.9 %) and typical fibrous changes (N=11; 26.8 %).

DISCUSSION

Our research – so far the only attempt to systematically collect data on worker exposure to silica in Slovenia – points to several issues. First and foremost, it clearly shows that official public data on occupational exposure to silica in Slovenia are unreliable and incomplete. There are several reasons for this. The Slovenian

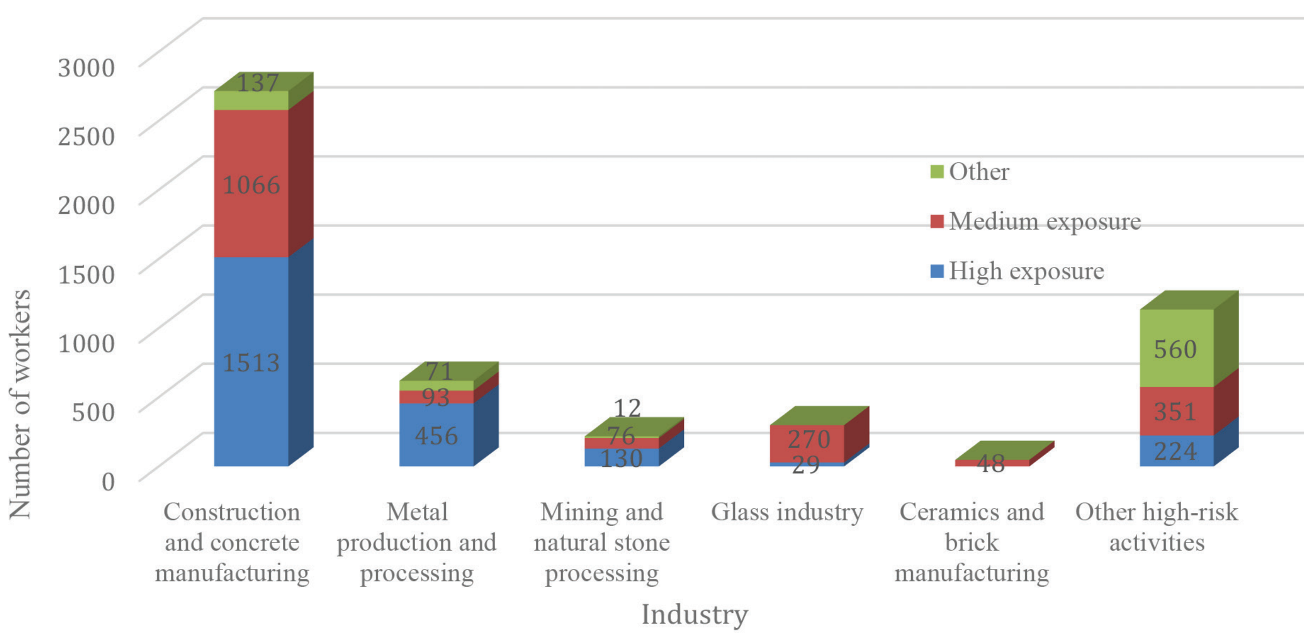

Figure 1 Number of workers according to exposure intensity by industry

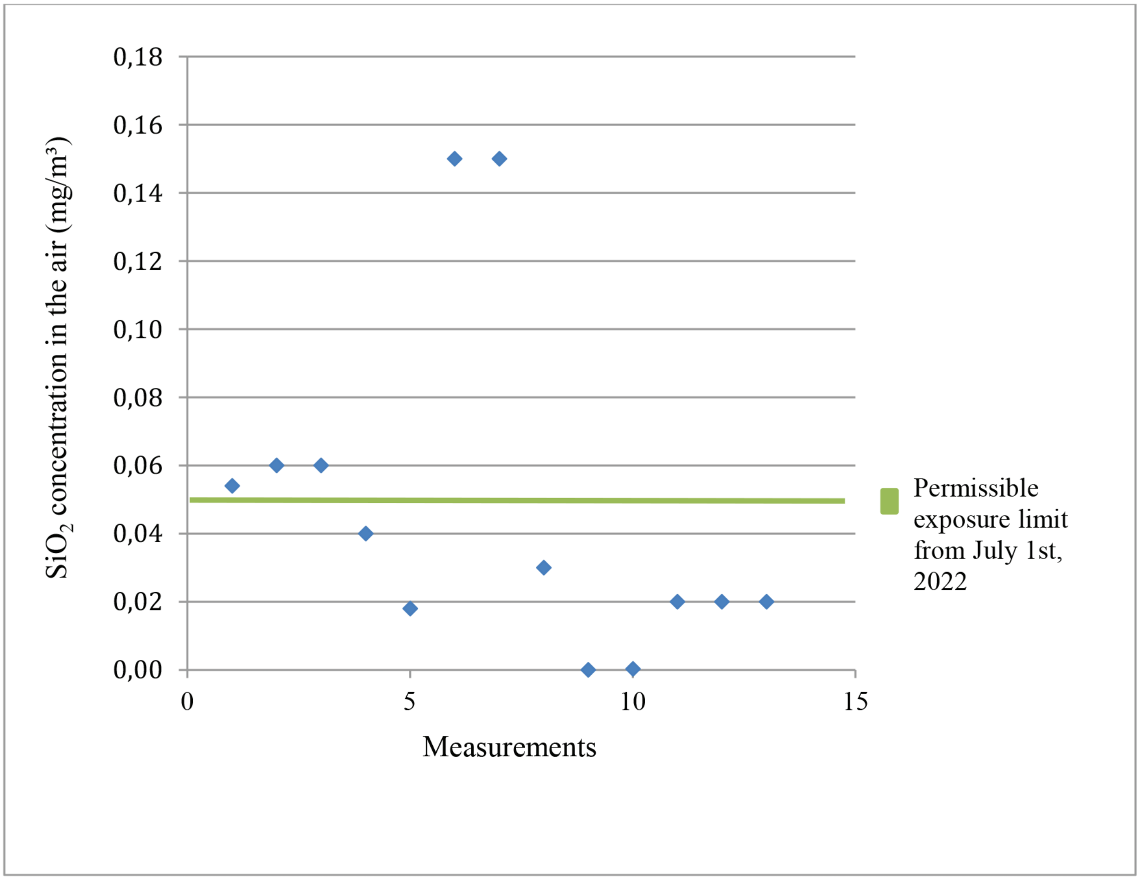

Figure 2 Measured SiO_2 concentrations in the air compared to the current permissible exposure limits

Chemicals Office collects data on importers and buyers of hazardous substances, but most silicon compounds are not classified as hazardous. Data on distributors and retailers as intermediaries between importers and users are deficient, and companies hide certain data behind trade secrets because they are afraid of potential sanctions by occupational health and safety authorities. Furthermore, some high-risk (e.g., construction) companies are registered under low-risk activities (e.g., "project implementation organisation"). In addition, most companies did not respond to the survey, even though a reminder was sent to them three times. Of the 1,281 companies included in the survey, only 652 filled out the questionnaire. One fourth of these (N=164) denied exposure to silica dust in all questions and work operation descriptions, which suggests that they either ignore the problem, are not informed about this issue, or are afraid of sanctions and/or inspection.

Only 277 (of 2,131 listed) companies (13 %), which employ 18,064 people, provided some kind of data, albeit strongly underestimating occupational exposure to silica.

Another issue is the glaring difference between the number of workers exposed to silica as estimated by self-reporting company representatives 2,072 (11.5 %) and the number based on job description in line with literature 5,007 (27.7 %). This discrepancy is most likely owed to a lack of knowledge or awareness. A case in point is glass industry, in which the use of silica sand is widely known and shows practically no difference between the self-reported number of exposed workers and the number based on job description. The greatest difference between these two sets of data are in the construction industry, with the 1:3 ratio between the two. This is an industry in which, according to our own experience, awareness about exposure to silica sand is generally poor.

Furthermore, it is alarming that the concentration of dust in the air is measured by no more than 8.30 % of all participating companies and the concentration of silica by 1.81 % of the companies. It has become clear that such a small amount of measurement data cannot be used in further research.

In contrast, data from the second part, the one studying changes in lung radiographs of occupationally exposed glasscutters between 1985 and 2001 are far more reliable. We chose glass industry, as the questionnaire analysis suggests that these companies are best informed about exposure to silica. They require that their glassworkers take regular medical check-ups, which include lung radiography. The identified exposure-related changes in nearly a third of the reviewed radiographic images and silica concentrations twice the current permissible exposure limit (although glass industry ranks lower in exposure than some other industries) suggest that lung radiographs of construction and concrete production workers in our study would show similar if not even worse findings than those of glass cutters, yet no such data are available.

An obvious weakness of the first part of our research is that the survey data are considerably scarcer than expected in terms of both quantity and quality, which makes our findings unreliable. Nonetheless, or precisely because of this, this study is important because it demonstrates low awareness of the sources of exposure to silica and the associated health risks among all stakeholders.

Another clear weakness of this study is the lack of air silica dust measurements at workplace and the consequent use of semi-quantitative estimates of exposure (i.e., small, medium, and large) based on literature data, which may be misleading. Even so, we find this approach appropriate enough, as it reveals that company representatives grossly underestimate workers' exposure to RSC and its consequences.

The limitations of the second part of our research primarily arise from the fact that many radiographs were too old and hardly intelligible, so that the group of medical experts was not able to apply the ILO classification (12).

Despite all these weaknesses, the main message this study conveys is that permissible silica exposure limits, which have been repeatedly lowered in the last decade, can protect the health of exposed workers only if all the stakeholders are systematically informed, inspections are consistently carried out, and health surveillance of all exposed workers is implemented regularly.

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Conflicts of interest

None to declare.

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Poklicna izpostavljenost kremenčevemu pesku je v Sloveniji podcenjena

Silicijev dioksid v kristalni obliki se uporablja v različnih gospodarskih panogah ali pa je prisoten kot vzporedni produkt. Fini delci se po vdihavanju deponirajo v pljučih in lahko povzročijo nastanek silikoze, kronične obstruktivne bolezni pljuč in pljučnega raka. Cilj študije je bil oceniti poklicno razširjenost izpostavljenosti vdihljivemu silicijevemu dioksidu in stopnjo zdravstvenega bremena zaradi take izpostavljenosti v Sloveniji. Da bi to lahko naredili, smo v prvi raziskavi skušali oceniti število delavcev izpostavljenih vdihljivemu silicijevemu dioksidu v slovenski industriji, v drugi pa smo odčitali in klasificirali spremembe na radiogramih delavcev izpostavljenih vdihljivemu silicijevemu dioksidu. Iz slednje bi lahko posredno sklepali o zdravstvenem tveganju preostalih izpostavljenih delavcev v Sloveniji. Vendar pa je prva študija pokazala, da so javni podatki nezanesljivi in pomanjkljivi in da predstavniki podjetij močno podcenjujejo poklicno izpostavljenost silicijevemu dioksidu. Meritve celokupnega praha je naredilo le 8,3% podjetij, meritve praha silicijevega dioksida pa le 1,8 % sodelujočih podjetih. Druga raziskava je pokazala, da ima ena tretjina izpostavljenih delavcev spremembe na rentgenogramih pljuč, ki bi jih lahko pripisali silikozi. Ker so bili pridobljeni podatki hudo podcenjeni in nezanesljivi, cilj naše študije ni bil dosežen; rezultati pa so pokazali, kaj je potrebno storiti za izboljšanje stanja. Vsa podjetja morajo biti sistematično obveščena o poklicnem tveganju, inšpekcija za delo pa mora vztrajno, redno in dosledno izvajati nadzor izpostavljenosti.

KLJUČNE BESEDE: gradbeništvo; meritve praha; silicijev dioksid; steklarstvo; vdihljiv prah