

Silica exposures in workplaces in the United States between 1980 and 1992

by Caroline S Freeman, MPH,¹ Elizabeth A Grossman, MPH¹

Freeman CS, Grossman EA. Silica exposures in workplaces in the United States between 1980 and 1992. *Scand J Work Environ Health* 1995;21 suppl 2:47–9.

Between 1980 and 1992, compliance officers of the Occupational Safety and Health Administration in the United States measured respirable quartz in 1655 inspections in 255 industries. In 52% of the 255 industries where respirable quartz was measured, the average severity value was less than one, indicating average exposures below the permissible exposure limit, and in 48% the permissible exposure limit for silica was exceeded. Among industries where more than 10 facilities were inspected, the most severe respirable quartz exposures were found in fabricated structural metal; painting and paper hanging; nonresidential construction; shipbuilding and repair; masonry and other stone work; bridge, tunnel and elevated highway construction; metal coating, engraving and allied services; and special trades contractors.

Key terms brick, clay, construction, foundries, glassware, metal fabrication, permissible exposure limit.

As the need for silica materials has increased in diverse industries, sampling procedures for occupational exposure to silica have improved dramatically and therefore allowed for greater accuracy and precision. New sampling methods can rectify deficiencies in the qualitative and quantitative assessment of airborne silica levels (see Lorberau & Abell, this issue), and efforts to standardize exposure units are underway around the world.

The intensity of peak exposures is often associated with acute health outcomes, while the intensity of cumulative exposure is generally more relevant for diseases with long latency. Depending on the exposure scenario, however, peak exposures may also be etiologically relevant in chronic disease induction (1). For this reason, time-weighted average (TWA) exposures, peak exposures, and, ultimately, permissible exposure limit (PEL) values all need to be accurately quantified, and the adverse health effects associated with excessive silica exposures need to be accurately enumerated.

Regulatory agencies such as the Occupational Safety and Health Administration (OSHA) in the United States need to be able to measure occupational exposures to silica accurately, not only to quantify dose-response relationships, but also to determine compliance with existing standards. The silica-related health effects of concern to OSHA include silicosis and lung cancer among stonemasons, sandblasters, construction employees, and other groups of silica-exposed workers (2). This paper updates and expands earlier reports on industrial exposures to respirable quartz (3, 4). It focuses on the levels of respirable crystalline silica measured during OSHA inspections in all industries and recorded on OSHA's Integrated Management Information System (IMIS).

Collected data

Records in IMIS comprise OSHA's enforcement data base, and it was not designed for research. The contents of IMIS include inspection date, inspection type, employment size, the specific contaminant sampled, the measured level of that contaminant, the job title of the sampled worker, the number of workers similarly exposed, code of the Standard Industrial Classification (SIC), and all other applicable data. The SIC system is widely used for classification and allows industries to be categorized on the basis of the principal product, groups of products, or services performed (3). Because OSHA targets high risk industries for inspection, this data base cannot be considered to be representative of the universe of all workplaces in the United States. Furthermore, it excludes mines and farms because OSHA does not have inspection authority over these industries.

From 1980 to 1989, OSHA's permissible exposure limit (PEL) for quartz was measured as a function of the portion of respirable quartz in the sample. The formula used to calculate the PEL was also used to calculate exposures to respirable mixtures. The PEL, expressed in units of milligrams per cubic meter of air ($\text{mg} \cdot \text{m}^{-3}$), was given by:

$$\text{PEL} = (10 \text{ mg} \cdot \text{m}^{-3}) / (\% \text{SiO}_2 + 2),$$

where $\% \text{SiO}_2$ is the percentage of free respirable quartz in dust. By making the PEL a function of the portion of respirable quartz in a sample, the PEL was more restrictive for samples with smaller proportions of respirable quartz.

In 1989, a fixed PEL of $0.1 \text{ mg} \cdot \text{m}^{-3}$ for respirable quartz was incorporated into OSHA's air contaminants standard (29 CFR

¹ US Department of Labor, Occupational Safety and Health Administration, Washington, DC, United States.

Reprint requests to: Ms CS Freeman, US Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Room N-3718, Washington, DC 20210, USA.

1910.1000, tables Z-1, Z-2, and Z-3). The revised PEL not only appeared to be universally understandable to industrial hygienists, but also comparable worldwide. As the result of a federal legal ruling OSHA's PEL for respirable quartz was returned to the pre-1989 adjustable PEL at the end of 1992.

With these changes in the PEL over time, the routine recording of exposure levels measured during inspections has also changed. This change makes it difficult to compare the occupational exposure levels recorded on the IMIS over time. One way around this problem is to convert exposure levels into comparable units. An alternative solution, however, is to use the severity of exposure instead of the measured exposure level as an indicator of exposure intensity. Severity is reported on the IMIS as the ratio of the measured level of respirable quartz to the "current" PEL (ie, exposure level/PEL). A severity measure greater than 1 indicates exposure above the PEL, and a severity measure less than 1 indicates exposure below the PEL. By expressing exposure levels in terms relative to the PEL, severity takes into account the changes in OSHA's PEL over time.

Table 1. Inspections conducted by the Occupational Safety and Health Administration between 1980 and 1992. (SIC = Standard Industrial Classification, NEC = not elsewhere classified)

Industry	Number	Percentage of total
Gray and ductile iron foundries (SIC 3321)	321	19.4
Copper foundries (SIC 3366)	95	5.7
Steel foundries (SIC 3325)	69	4.2
Aluminum foundries (SIC 3365)	48	2.9
Concrete products except block and brick (SIC 3272)	39	2.4
Brick and structural clay tile (SIC 3251)	35	2.1
Malleable iron foundries (SIC 3322)	30	1.8
Heavy construction NEC (SIC 1629)	29	1.8
Pottery products NEC (SIC 3269)	27	1.6
Steel works, blast furnaces and rolling and finishing mills (SIC 3312)	26	1.6
Clay refractories (SIC 3255)	26	1.6
Special trades contractors NEC (SIC 1799)	26	1.6
Ceramic wall and floor tile (SIC 3253)	24	1.5
Pressed and blown glass and glassware NEC (SIC 3229)	23	1.4
Vitreous china plumbing fixtures (SIC 3261)	23	1.4
All Other Industries	814	49.1
Total	1655	100

Several researchers have reported findings of adverse silica-related health effects using relative exposure measures similar to the IMIS severity measure (4, 5). Evaluating exposures in terms of relative measures allows for the comparisons of possible health effects in industries with similar dust levels. Serious hazards can be distinguished from less serious hazards, rapidly identified, and targeted for intervention. For example, foundry workers cannot only be exposed to respirable quartz, but also to polycyclic aromatic compounds, aromatic amines, and other compounds which have been shown to be carcinogenic (2). Since acute high-level exposures may result in a greater risk of illness and death, OSHA is primarily concerned about such exposures. Thus severity is useful for reflecting exposures of greatest concern.

Findings

The analysis presented herein was restricted to samples collected during inspections where some amount of respirable quartz was measured. It was further restricted to those samples measured as personal, 8-h TWA values and recorded in the IMIS in units of milligrams per cubic meter. Results from follow-up inspections were excluded.

Between 1980 and 1992, federal OSHA compliance officers measured some level of respirable quartz in 6779 personal, 8-h TWA samples collected in 1655 inspections in 255 industries. Table 1 presents the number of inspections conducted in the 15 most frequently sampled industries identified by their four-digit SIC codes. This table shows that half of the inspections were conducted in only 15 industries. Overall, among the 15 most frequently inspected industries, 34% of the total inspections were conducted in foundries (SIC codes 3321, 3366, 3325, 3365, and 3322), 12% in the stone, clay, glass, or concrete products manufacturing industry (SIC codes 3272, 3251, 3269, 3255, 3253, 3229, and 3261), 55 inspections in the all construction industries category, and 26 in steel mills.

Table 2 presents the number of personal, 8-h TWA samples collected in each of the 15 industries presented in table 1, as well as the mean, median, and maximum severity. Table 2 shows that, while the greatest number of samples was collected in the most frequently inspected industry, a large number of samples was collected in some industries with far fewer inspections. For example, 261 samples were collected in 30 inspections of malleable

Table 2. Summary statistics on severity measures in the 15 most frequently inspected industries between 1980 and 1992.^a (SIC = Standard Industrial Classification, NEC = not elsewhere classified)

Industry	Samples (N)	Mean	Median	Maximum
Gray and ductile iron foundries (SIC 3321)	2442	1.62	.78	153.00
Copper foundries (SIC 3366)	374	1.04	.52	100.00
Steel foundries (SIC 3325)	346	1.19	.83	16.61
Aluminum foundries (SIC 3365)	137	0.76	.44	10.00
Concrete products except block and brick (SIC 3272)	78	1.36	.74	29.70
Brick and structural clay tile (SIC 3251)	143	2.59	1.19	82.19
Malleable iron foundries (SIC 3322)	261	1.42	.64	54.05
Heavy construction NEC (SIC 1629)	62	2.84	1.12	48.22
Pottery products NEC (SIC 3269)	72	1.97	.83	33.17
Steel works, blast furnaces etc (SIC 3312)	136	0.89	.54	7.66
Clay refractories (SIC 3255)	128	0.94	.63	5.84
Special trades contractors NEC (SIC 1799)	60	8.33	1.73	99.00
Ceramic wall and floor tile (SIC 3253)	124	1.80	1.17	14.49
Pressed and blown glass and glassware NEC (SIC 3229)	45	1.39	.53	10.48
Vitreous china plumbing fixtures (SIC 3261)	96	2.19	1.14	18.58

^a Severity calculated as the measurable level of respirable quartz divided by the permissible exposure limit.

iron foundries, giving an average of 8.7 samples per inspection. By contrast, 95 inspections were conducted in copper foundries, but only 374 samples were collected, giving an average of 3.9 samples per inspection.

The data in table 2 demonstrate that in all but three of the 15 industries (aluminum foundries, steel mills, and clay refractories) the mean measure of severity was greater than one. Therefore the average exposure for 12 of the 15 industries exceeded the PEL. In every case, the mean exceeded the median level, indicating that severity is skewed towards samples in excess of the PEL. Of the 15 most frequently inspected industries, only two (steel works and clay refractories) had maximum levels less than 10 times the PEL. There were silica samples near or above 50 times the OSHA PEL for gray iron foundries, copper foundries, brick and clay tile, malleable iron foundries, heavy construction, and special trades contractors.

Overall, the mean measure of severity was below one for 133 of the 255 industries (52%); however 48% of the industries had average silica exposures exceeding the PEL. Table 3 presents the mean severity for the 10 industries subject to 10 or more inspections which had the most severe exposures to respirable quartz as measured by mean severity. These industries are fabricated structural metal (SIC 3441), painting and paper hanging (SIC 1721), nonresidential construction (SIC 1542), shipbuilding and repair (SIC 3731), masonry and other stone work (SIC 1741), bridge, tunnel and elevated highway construction (SIC 1622), metal coating, engraving and allied services (SIC 3479), special trades contractors (SIC 1799), fabricated plate work (SIC 3443), and heavy construction, not elsewhere classified (SIC 1629). For eight of these ten industries, the mean severity measure indicated average exposure to levels of respirable quartz at least eight times greater than the PEL.

The number of inspections, by year of inspection, is provided in table 4. This table indicates that the number of inspections where samples of respirable quartz were measured has declined over time from 227 in 1980 to 75 in 1992. There are several possible interpretations for the trend observed in table 4. One is that the focus of OSHA inspections has changed during this period. The second is that occupational exposure to respirable quartz has declined over time. Because this study has focused on inspections where respirable quartz was measured and because there is no complete data on the number of times respirable quartz was sampled but not found, it is not possible to determine from these data which interpretation is correct.

Summary

OSHA's IMIS identifies industries that have been inspected for respirable quartz. Information provided on the severity of the exposure can be used, in conjunction with data from other silicosis surveillance data bases, to target industries in which relatively high respirable quartz exposures can be expected. By using different surveillance sources, all gaps in any one system should be

Table 3. Most severe 8-h time-weighted average exposures in industries inspected ≥ 10 times where measurable levels of respirable quartz were found. (SIC = Standard Industrial Classification)

Industry	Mean severity
Fabricated structural metal (SIC 3441)	33.11
Painting and paper hanging (SIC 1721)	16.64
Nonresidential construction (SIC 1542)	15.59
Shipbuilding and repair (SIC 3731)	15.27
Masonry and other stone work (SIC 1741)	13.04
Bridge, tunnel, and elevated highway construction (SIC 1622)	10.84
Metal coating and engraving and allied services (SIC 3479)	8.42
Special trades contractors (SIC 1799)	8.33
Fabricated plate work (SIC 3443)	2.96
Heavy construction NEC (SIC 1629)	2.84

Table 4. Number of inspections where respirable quartz, measured as personal 8-h time-weighted averages, was found by year of inspection.

Year	Number of inspections	Percentage
1980	227	13.7
1981	199	12.0
1982	200	12.1
1983	138	8.3
1984	111	6.7
1985	133	8.0
1986	94	5.7
1987	100	6.0
1988	99	6.0
1989	111	6.7
1990	93	5.6
1991	75	4.5
1992	75	4.5
Total	1655	100

identified. In this way, coverage of silica-exposed workers can be improved.

Disclaimer

The views expressed in this paper represent those of the authors and do not necessarily represent those of the US Occupational Safety and Health Administration.

References

1. Checkoway H, Rice C. Time-weighted averages, peaks, and other indices of exposure in occupational epidemiology. *Am J Ind Med* 1992;21:25-33.
2. International Agency for Research on Cancer (IARC). Silica and some silicates. Lyon: IARC, 1987. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans, vol 43.
3. Oudiz J, Brown JW, Ayer HE, Samuels S. A report on silica exposure levels in United States foundries. *Am Ind Hyg Assoc J* 1983;44:374-6.
4. Valiante DJ, Richards TB, Kinsley HB. Silicosis prevention in New Jersey: targeting workplaces using occupational disease and exposure surveillance data. *Am J Ind Med* 1992;21:517-26.
5. Seaton A, Legge JS, Henderson J, Kerr KM. Accelerated silicosis in Scottish stonemasons. *Lancet* 1991;337:341-4.