Mortality in the UK industrial silica sand industry: 1. Assessment of exposure to respirable crystalline silica

T P Brown and L Rushton

doi:10.1136/oem.2004.017715

Updated information and services can be found at:
http://oem.bmj.com/cgi/content/full/62/7/442

**References**
This article cites 13 articles, 8 of which can be accessed free at:
http://oem.bmj.com/cgi/content/full/62/7/442#BIBL

2 online articles that cite this article can be accessed at:
http://oem.bmj.com/cgi/content/full/62/7/442#otherarticles

**Rapid responses**
You can respond to this article at:
http://oem.bmj.com/cgi/eletter-submit/62/7/442

**Email alerting service**
Receive free email alerts when new articles cite this article - sign up in the box at the top right corner of the article

**Topic collections**
Articles on similar topics can be found in the following collections

- Occupational Health (1279 articles)
- Other respiratory medicine (1056 articles)

**Notes**

To order reprints of this article go to:
http://www.bmjournals.com/cgi/reprintform

To subscribe to *Occupational and Environmental Medicine* go to:
http://www.bmjournals.com/subscriptions/
Mortality in the UK industrial silica sand industry: 1. Assessment of exposure to respirable crystalline silica

T P Brown, L Rushton

Aims: To develop a job-exposure matrix (JEM) from personal and static respirable crystalline silica (RCS) measurements in UK industrial silica sand workers.

Methods: A total of 2429 personal and 583 static RCS dust samples were collected using cyclone samplers at seven UK quarries between 1978 and 2000. These data were combined, and analysis of variance using general linear models was used to evaluate the effect of quarry, job, and year on RCS concentrations, and facilitate the creation of five quarry and three time categories with similar exposure levels by comparing the least-square GM RCS concentrations.

Results: The overall geometric mean (GM) RCS concentration was 0.09 mg/m³ (geometric standard deviation 3.9). Silica flour and dry job categories tended to have the highest RCS exposure and 13.3% of all samples exceeded the UK maximum exposure level of 0.3 mg/m³. RCS levels generally decreased over time.

Conclusions: Data have been collected and used to develop a JEM for UK industrial silica sand workers between 1978 and 2000. Although there were some limitations in the data and certain assumptions were made, the use of available data to estimate exposure quantitatively is an improvement over the use of qualitative and surrogate measures of exposure. The continual collection of dust measurements in the industry is essential to facilitate the exploration of exposure-response relations that may exist between silica and silicosis, lung cancer, and other diseases.
Main messages

- A job-exposure matrix was developed for the study of mortality among UK industrial silica sand workers.
- There were some data limitations and assumptions that had to be made about the exposures of some job categories. These assumptions and the developed matrix should be explored by sensitivity analysis of any dose-response relations.
- The continual collection of dust measurements is essential to facilitate the exploration of dose-response relations between silica exposure and the incidence/mortality of silicosis, lung cancer, and other diseases.

Policy implications

- A job-exposure matrix was developed to study the relation between crystalline silica exposure and mortality among UK industrial silica sand workers. The study will add to the literature on the relation between respirable crystalline silica exposure, silicosis, lung cancer, and other diseases.
- The uncertainties in the matrix exposure estimates will hinder the establishment of occupational exposure limits on the basis of exposure-response relations, if any, identified through use of this matrix.

RESULTS

Table 1 presents means and standard deviations of the log transformed RCS measurements for each quarry, job category, and year grouping. Those jobs with the highest exposure to RCS (dry areas and silica flour) were monitored more than the others (for example, wet process, sand winners, drivers, maintenance, management), and 15% of the samples from these job categories exceeded the UK maximum exposure level (MEL) of 0.3 mg/m³. 88% of the samples that exceeded the MEL were from these job categories. A total of 1235 (41.0%) samples were less than 0.05 mg/m³, with 483 (14.4%) 0.01 mg/m³ or less. The overall geometric mean RCS concentration was 0.09 mg/m³ (GSD 3.9), and the highest concentration was 13.97 mg/m³.

The number of samples collected, GMS, and maximum RCS concentrations varied considerably across all quarries. A significant proportion of the samples from quarries 4, 6, and 7 exceeded the current maximum exposure limit (MEL) of 0.3 mg/m³.

Figure 1 shows the change in GM RCS measurements and number of samples taken by year; there is a steady decline over the years. Between 1978 and 1985 just under 20% of samples were not in compliance with the current MEL standard. However, the proportion of samples exceeding the MEL has reduced to below 10%.

DISCUSSION

The historical RCS exposure in the UK industrial sand industry from 1978 to 2000 showed a large quarry effect. These differences, to some extent, reflect how the sand is deposited, extracted, and processed at each quarry. In other studies of industrial sand workers' similar variations between quarries and plants have been observed. Unadjusted geometric means in US sand workers were observed to be between 0.026 mg/m³ and 0.042 mg/m³, of samples taken between 1974–96 and 1974–98, respectively. Although exposure levels in this study (0.09 mg/m³) are higher than in other studies of sand workers over approximately the same time period, they are much lower than in other industries where workers are exposed to silica.

Measurements also showed a clear job effect. The highest exposed jobs tended to be those that were in dustier environments—that is, those exposed to silica flour and the dry job categories (dry/dryer, dry/bagger, dry/other). Other categories that experienced minimal exposure (HGV drivers, workshop, other drivers, site maintenance, and management). For these, the overall quarry mean was multiplied by the overall time period mean and the result divided by the overall mean for the job. Four of the job/quarry/time cells were created from static measurements only and 120 from personal measurements only. Static measurements were not carried out on HGV drivers and site maintenance workers.
studies of sand workers have also shown a wide variation in exposures between different jobs,78 similar jobs receiving similar levels of RCS exposure.

Levels generally decreased over time (fig 1), a pattern seen in the sand industry worldwide,7811 although the decrease was not linear and varied between quarry and job category, probably reflecting the introduction of dust control measures at each quarry. Current exposure levels are slightly higher although generally below the regulatory exposure limit.

Combining the static and personal measurements into a single dataset may have introduced bias to the estimates of exposure in the JEM. Personal samples have been found to be generally higher in concentration than static (area or stationary) samples because of people being closer to the source of exposure and spending more time within the source location, or in the emission pathway.1213 However, when static samples are taken at the source location or in the emission pathway they are similar to the values reported for personal samples,1415 and in some incidents may measure a higher concentration.1216 In the majority of other studies static measurements have usually been dust counts, which have then been converted to respirable mass concentrations, using a variety of conversion factors derived from parallel count/respirable mass measurements.8 In this study the same sampling methodology was used for both static and personal samples—that is, using cyclone samplers, over long

![Figure 1](image-url)  
**Figure 1** Geometric mean respirable crystalline silica measurements (mg/m³) and number of sample measurements by year.

<table>
<thead>
<tr>
<th>Job category</th>
<th>Number of samples (%)</th>
<th>Adjusted GM (mg/m³) (GSD)</th>
<th>Unadjusted GM (mg/m³) (GSD)</th>
<th>Maximum (mg/m³)</th>
<th>% &gt; MEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand winner</td>
<td>207 (6.9)</td>
<td>0.09 (3.8)</td>
<td>0.06 (5.0)</td>
<td>1.17</td>
<td>10.6</td>
</tr>
<tr>
<td>Wet process</td>
<td>141 (4.7)</td>
<td>0.05 (3.6)</td>
<td>0.04 (4.2)</td>
<td>0.73</td>
<td>3.5</td>
</tr>
<tr>
<td>Dry, dryer</td>
<td>572 (19.0)</td>
<td>0.08 (4.0)</td>
<td>0.09 (3.6)</td>
<td>4.10</td>
<td>15.0</td>
</tr>
<tr>
<td>Dry, bagger</td>
<td>461 (15.3)</td>
<td>0.11 (4.0)</td>
<td>0.10 (3.4)</td>
<td>13.97</td>
<td>16.5</td>
</tr>
<tr>
<td>Dry, other</td>
<td>513 (17.0)</td>
<td>0.11 (4.4)</td>
<td>0.11 (4.0)</td>
<td>9.05</td>
<td>12.5</td>
</tr>
<tr>
<td>Laboratory technician</td>
<td>234 (7.8)</td>
<td>0.07 (3.6)</td>
<td>0.06 (3.6)</td>
<td>0.96</td>
<td>6.0</td>
</tr>
<tr>
<td>Driver, HGV</td>
<td>11 (0.4)</td>
<td>0.04 (3.4)</td>
<td>0.08 (2.4)</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>Driver, other</td>
<td>19 (0.6)</td>
<td>0.04 (3.4)</td>
<td>0.04 (6.4)</td>
<td>1.68</td>
<td>5.3</td>
</tr>
<tr>
<td>Site maintenance</td>
<td>55 (1.8)</td>
<td>0.03 (3.5)</td>
<td>0.04 (4.3)</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>Workshop</td>
<td>4 (0.1)</td>
<td>0.03 (3.3)</td>
<td>0.02 (3.7)</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Site management</td>
<td>30 (1.0)</td>
<td>0.03 (3.4)</td>
<td>0.02 (3.2)</td>
<td>0.30</td>
<td>3.3</td>
</tr>
<tr>
<td>Silica flour</td>
<td>765 (25.4)</td>
<td>0.10 (5.9)</td>
<td>0.13 (3.1)</td>
<td>12.01</td>
<td>16.6</td>
</tr>
<tr>
<td>Quarry (group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (A)</td>
<td>159 (5.3)</td>
<td>0.05 (4.1)</td>
<td>0.05 (4.7)</td>
<td>1.87</td>
<td>3.1</td>
</tr>
<tr>
<td>2 (B)</td>
<td>70 (2.3)</td>
<td>0.05 (3.8)</td>
<td>0.03 (4.1)</td>
<td>1.17</td>
<td>5.7</td>
</tr>
<tr>
<td>3 (B)</td>
<td>347 (11.5)</td>
<td>0.05 (6.2)</td>
<td>0.06 (4.3)</td>
<td>13.97</td>
<td>8.1</td>
</tr>
<tr>
<td>4 (C)</td>
<td>415 (13.8)</td>
<td>0.06 (7.0)</td>
<td>0.08 (4.5)</td>
<td>9.05</td>
<td>11.1</td>
</tr>
<tr>
<td>5 (D)</td>
<td>308 (10.2)</td>
<td>0.07 (5.7)</td>
<td>0.07 (3.7)</td>
<td>2.98</td>
<td>9.1</td>
</tr>
<tr>
<td>6 (D)</td>
<td>1045 (34.7)</td>
<td>0.06 (14.4)</td>
<td>0.10 (3.2)</td>
<td>8.84</td>
<td>13.2</td>
</tr>
<tr>
<td>7 (E)</td>
<td>666 (22.2)</td>
<td>0.10 (9.0)</td>
<td>0.14 (3.7)</td>
<td>12.01</td>
<td>22.6</td>
</tr>
<tr>
<td>Year group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978–1985</td>
<td>1240 (41.2)</td>
<td>0.08 (17.9)</td>
<td>0.13 (3.2)</td>
<td>7.29</td>
<td>19.4</td>
</tr>
<tr>
<td>1986–1994</td>
<td>1388 (46.1)</td>
<td>0.05 (19.0)</td>
<td>0.08 (4.3)</td>
<td>12.01</td>
<td>8.8</td>
</tr>
<tr>
<td>1995–2000</td>
<td>384 (12.7)</td>
<td>0.04 (6.0)</td>
<td>0.06 (4.0)</td>
<td>13.97</td>
<td>9.9</td>
</tr>
<tr>
<td>Total</td>
<td>3012 (100.0)</td>
<td>0.09 (3.9)</td>
<td>0.09 (3.9)</td>
<td>13.97</td>
<td>13.3</td>
</tr>
</tbody>
</table>

GM, geometric mean; GSD, geometric standard deviation; MEL, maximum exposure limit 0.30 mg/m³.

Brickworks/wet, brickworks/dry, brickworks/drivers, and office workers assumed to have similar exposures to wet process, dry/dryers, dry/others, and site management.
time periods during a normal working shift period. These practices and the fact that static dust levels were similar to levels obtained from personal measurements, led us to combine personal and static measurements into a single dataset.

Analyses of the samples were mainly undertaken by the company’s own laboratories using FTIS until 1996 and XRD thereafter. This change could possibly have affected the detection of RCS in the samples, and partly explain why levels in the last time period (1995–2000) were greater than the previous period (1986–94). However, a recent study of the performance of laboratories by the UK Health and Safety Laboratory under the UK Workplace Analysis Scheme for Proficiency (WASP) showed a good correlation between the two methods.17

Various engineering control measures to reduce dust exposure have been introduced by the company over the years. However, it was not clear when these measures were introduced at each quarry, although their effect on dust levels would be reflected in the JEM. However, the exposure assessment does not take into account the use of respiratory protective equipment (RPE), for example, dust masks. Data are not available on the use of RPE, either the type or effectiveness, or working practices, especially historically and at all quarries. RPE do not provide 100% protection against exposure to dust, but depending on the protection factor can substantially reduce the amount of respirable dust reaching the lungs. Therefore, if used regularly RPE could have impacted on the exposure assessment and hence the values within the JEM, but only on those dustier jobs requiring its use for long periods, for example, baggers.

The JEM has been developed from measurements of total RCS. It does not take into account particle numbers and surface area per microgram of silica, surface chemistry, or presence of other minerals, factors that vary widely in dusts produced from different industrial processes using different source materials, and affect biological activity.18–20

Summary

In this study we obtained a large quantity of measurements of respirable crystalline silica from seven quarries in the UK industrial silica sand industry. These data have been used to develop a job-exposure matrix for the years 1978 to 2000. There are limitations in the data and a number of assumptions were made, but these are common to those encountered in any attempt to estimate historical exposures. The use of available data to estimate exposure quantitatively and develop a job/quarry/time exposure matrix, however, is a considerable improvement over the use of qualitative and surrogate measures of cumulative exposure, for example, duration of exposure. There are few other published studies on silica measurements of sand quarrying in Europe and these results thus are an important addition to those published from the USA.7–9 The continual collection of dust measurements in the industry is essential to facilitate the exploration of exposure-response relations that may exist between silica and silicosis, lung cancer, and other diseases.

ACKNOWLEDGEMENTS

The authors would like to thank the European Association of Industrial Silica Producers (EUROSIL) for funding this study. We would like to thank the Health and Safety Executive for providing the cohort data and staff at the company involved for their assistance locating dust measurement information and commenting on the technical aspects of silica sand production.

Authors’ affiliations

T P Brown, L Rushston, Medical Research Council Institute for Environment and Health, Leicester, UK

Competing interests: none declared

REFERENCES

15 Lange JH. A statistical evaluation of asbestos air concentrations. Indoor and Built Environment 1999;8:293–303.