Evaluation of Workers’ Exposure to Total, Respirable and Silica Dust and the Related Health Symptoms in Senjedak Stone Quarry, Iran

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Abstract: The present research was conducted in a stone quarry of marble located in northeast of Iran. Time weighted average of total dust, respirable dust, and crystalline silica (α-quartz) concentration in workers' breathing zone were monitored by using both gravimetric and XRD methods. The results showed that the employees working in hammer drill process had the highest exposure to the total and respirable dust: 107.9 ± 8.0 mg/m³, 11.2 ± 0.77 mg/m³ respectively, while the cutting machine workers had the lowest exposure (9.3 ± 3.0 mg/m³, 1.8 ± 0.82 mg/m³). The maximum concentration of α-quartz in total and respirable dust were detected equal to 0.670 ± 8.49 × 10⁻² and 5.7 × 10⁻² ± 1.6 × 10⁻² mg/m³ respectively, which belonged to the exposure of the workers of hammer drill process. The prevalence of skin and respiratory symptoms were higher in hammer drill workers, however, respiratory symptoms showed no significant prevalence. Regarding the average age of workers (31.6 ± 1.9 yr) and average of their work history (3.8 ± 1.0 yr), these results were predictable.

Key words: Total dust, Respirable dust, Crystalline silica, Stone quarry, Skin and respiratory symptoms

Introduction

When negotiating about crystalline silica, the focus will be on quartz, because it is the most abundant surface minerals amounting to almost 20 percent in the earth’s crust1). At all temperatures below 573°C, quartz has trigonal symmetry and is known as α-quartz or low quartz1, 2). Because α-quartz is the most abundant toxic form of silica, it is the most often addressed in industrial hygiene1). Inhalation of this form of crystalline silica is a well known cause of silicosis3–8) which is a pulmonary disease characterized by fibrosis within the gas exchange region of the lung4). Silica in its crystalline form is intensely fibrogenic, highly toxic and associated with autoimmune disorders such as systemic sclerosis6). It is also shown that an excess of laryngeal cancer occurred for workers potentially exposed to silica dust9).

Dimension stones which are used in buildings have a silica content of different percentages. Hence, the workers of stone quarries are in danger of exposure to silica and there is reason to fear that silicosis will be an increasing problem among them.

There exist 257 marble stone quarries in Iran at which approximately 6,000 workers are exposed to crystalline silica (Primarily quartz) dust each year. Therefore monitoring their exposure is very important. This article focuses on the assessment of workers exposure to α-quartz in Senjedak building stone quarry in Kashmar, in the province of Khorasan, Iran.

Materials and Methods

This research was conducted in Senjedak building marble stone quarry which is a surface mine and located at 90 km west of Kashmar-Iran. According to the analysis done on
the mine stones, the mineral composition consisted of different percentages of Calcite, Quartz, and Wollastonite. In this mine, using the diamond wire method as an advanced exploitation technique causes the least amount of dust dispersion by producing large sizes of the decorative stones. Eighteen male workers were studied in this research. The state data of the workers in term of job categories are shown in Table 1.

This study has been carried out in 2 stages as follows:

1) Determination of workers’ exposure to total, and respirable dust and α-quartz content in the dust samples.
2) Investigation of workers’ respiratory signs and skin disorders history.

Exposure to dust

Five different job activities were selected in the mine. Total and respirable dusts were collected from following sites: horizontal rock drill, vertical rock drill, cutting machine, hammer drill and bulldozer. Total dust samples were collected using a 0.8 µm pore size and 25 mm diameter membrane filter attached to 25 mm close-face cassette at flow rate 2.8 l/min (MSA, model 2G-2867 and SKC, model 224-PCX R3). Respirable dust samples were collected using a 10-mm cyclone at a flow rate of 1.7 l/min. The mass of dust in all samples were weighed to 0.0001 g on a calibrated Sartorious balance before and after sampling. In order to obtain precise results, all filters were allowed to equilibrate in desiccator atmosphere for 24 h prior to weighing. For determination of time weighted average (TWA) concentration, sampling was done each day two 4-hours period of time (2 × 4 = 8 h, full shift). In the next step, dust samples (total and respirable) were analyzed for α-quartz content. Quartz analysis was done by X-ray diffraction (XRD) using a Siemens Model D5000 diffractometer equipped with variable slit in research laboratory of X-ray at the faculty of science, Tehran University. Quantitative measurements of quartz were done on the basis of internal standard method, using wollastonite as a standard. To do this, standards of Quartz and wollastonite (MBH, CO.) were prepared and mixed in different weight ratios. A total of 27 standards were prepared and two standard curves were drawn for two ranges of absolute intensities: 10–100 and 200–800 cps against µg of quartz, respectively. After drawing the standard curves, all filters were placed in diffractometer and intensity of quartz peak in term of cps was obtained at 2θ = 26.686, using specific software.

In addition to air sampling, determination of dust and α-quartz exposures, the workers were asked about respiratory signs and skin disorders via completing a questionnaire. Then statistical tests including one-way variance test and Duncan’s new multiple tests were done.

Results

Exposure of the workers to total and respirable dust according to their job is shown in Table 2. With regard to the findings, the workers who worked in hammer drill process had the highest exposure to total dust and respirable dust: 107.9 ± 8.0 and 11.2 ± 0.77 mg/m³, while the cutting machine workers had the lowest exposure, both in case of total and respirable dust: 9.3 ± 3.0 and 1.8 ± 0.82 mg/m³, respectively. As it was mentioned before, all of workers were exposed to quartz with regard to the angle of index peak (2θ = 26.686), using specific software.

The results of quartz analysis, determination of α-quartz level in total and respirable dust are demonstrated in Table 3. As the results showed, the maximum α-quartz concentration in total and respirable dust were 0.670 ± 8.49 × 10⁻² and 5.7 × 10⁻² ± 1.6 × 10⁻² mg/m³, respectively which belonged to hammer drill process.

One-way variance analysis and also Duncan’s new multiple test which were done between different job activities showed that the mean of quartz concentrations in total and respirable dust samples in hammer drill process was more than the other processes (p<0.05). However on the basis of Duncan
test, there were statistically significant differences between quartz concentration in respirable samples in the following processes:
— hammer drill with the others (vertical rock drill, horizontal rock drill, bulldozer operation, cutting machine),
— Vertical rock drill with the bulldozer and cutting machine,
— Horizontal rock drill with the bulldozer and cutting machine.

In the respirable samples which were taken at the breathing zone of the bulldozer workers, it was found that the concentration of quartz was at its lowest level. The same results were obtained in the case of quartz concentration in total dust samples.

The proportion of quartz to respirable and total dust amounts were calculated, the results are shown in Fig. 1. As expected, in both situations, this proportion is more considerable for operators of hammer drill process.

The effect of inhalation of $\alpha$-quartz on the workers’ health was evaluated by analyzing the complete questionnaires. The prevalence of skin disorders and respiratory signs including cough, phlegm and allergic disorders in the workers at different processes is given in Fig. 2. As the results show, the hammer drill workers had experienced the above mentioned symptoms much more than the other workers. Skin disorders have only been observed in bulldozer workers while the frequencies of allergic disorders are the same for hammer drill and bulldozer workers.

**Discussion**

This research has been carried out in a dimension stone quarry in Kashmar, Iran to assess occupational exposure and potential health hazards to the miners from quartz exposure.

Evaluation of quartz exposure is very important. It may act as a stimulator of pulmonary inflammation and fibrosis. However several chemical factors contribute to the development of chronic inflammation and subsequent silicosis following inhalation of silica particles. Silicosis typically presents as a chronic disease following 10 or more years of exposure to crystalline silica. The existence of a quantitative association between quartz exposure and risk of silicosis is well recognized\((15,16)\). It also may be a human carcinogen. Hence, numerous analytical methods have been developed for the analysis of crystalline silica, however; the most precise method which is XRD has been used here.

This study has been performed for the first time in a stone

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**Table 2. Concentration of total and respirable dust in term of mg/m$^3$ in workers’ breathing zone in different job sites**

<table>
<thead>
<tr>
<th>Process</th>
<th>Respirable dust (mg/m$^3$)</th>
<th>Total dust (mg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>$X$</td>
</tr>
<tr>
<td>Horizontal rock drill</td>
<td>12</td>
<td>6.4</td>
</tr>
<tr>
<td>Vertical Rock drill</td>
<td>12</td>
<td>7.8</td>
</tr>
<tr>
<td>Cutting machine</td>
<td>6</td>
<td>1.8</td>
</tr>
<tr>
<td>Hammer drill</td>
<td>24</td>
<td>11.2</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>6</td>
<td>4.0</td>
</tr>
</tbody>
</table>


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**Table 3. Concentration of quartz in workers’ breathing zone in different job sites**

<table>
<thead>
<tr>
<th>Process</th>
<th>Quartz content of respirable dust (mg/m$^3$)</th>
<th>Quartz content of total dust (mg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>$X$</td>
</tr>
<tr>
<td>Horizontal rock drill</td>
<td>12</td>
<td>$1.79 \times 10^{-2}$</td>
</tr>
<tr>
<td>Vertical Rock drill</td>
<td>12</td>
<td>$1.89 \times 10^{-2}$</td>
</tr>
<tr>
<td>Cutting machine</td>
<td>6</td>
<td>$5.02 \times 10^{-3}$</td>
</tr>
<tr>
<td>Hammer drill</td>
<td>24</td>
<td>$5.7 \times 10^{-2}$</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>6</td>
<td>$7.88 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

$X$: Mean. $S$: Standard deviation.
quarry in Iran. The length of production period is nearly equal to 8 yr. There are 18 workers who are working in five stations as follows: horizontal rock drill, vertical rock drill, cutting machine, hammer drill and bulldozer. As the results show, the workers who work in hammer drill station are exposed to the highest concentration of respirable dust (11.2 ± 0.77 mg/m³) while the cutting machine workers have the lowest exposure (1.8 ± 0.82 mg/m³). Hammer drill process is essentially a dusty process due to use of pneumatic hammer but the cutting machine is a wet process and the humidity reduces the emission rate of dust to the atmosphere. These results are true in the case of total dust and the hammer drill workers had the highest exposure to total dust (107.9 ± 8.0 mg/m³). For this reason, the hammer drill workers are exposed to the highest concentration of quartz (0.670 ± 0.085 mg/m³), however, the cutting machine and bulldozer workers are exposed to the lowest concentration of respirable quartz. It is concluded that the quartz content of dust in cutting machine process is low in comparison to the other processes. It seems that the bulldozer produce a lot of dust when they move and it causes dust concentration which is more than the rate of dust emission in cutting process but the quartz content has no statistical differences.

The mean of quartz ratio to the respirable dust of hammer drill process is much more than the other processes (0.51 ± 0.013%) while there was no statistical differences between horizontal and vertical rock drill processes according to Duncan test. There was not any Statistically significant differences between bulldozer and cutting machine processes in view point of quartz ratio to respirable dust. Personal exposure to respirable quartz dust was below the ACGIH, OSHA and NIOSH TLV in all work areas in the stone mine except for hammer drill process. The only deviation was observed in hammer drill work station, which was more than the NIOSH TLV (0.14 fold of NIOSH TLV). As we know the NIOSH and ACGIH TLV (0.05 mg/m³) for quartz is lower than OSHA. Then; \[ \frac{C}{TLV} = 1.14 \]

while the OSHA and Norwegian TLV for quartz are \[ \frac{10}{\% SiO_2 + 2} \] and 0.3 mg/m³ respectively\(^{4,17}\).

Mean of miners’ age was 31.6 ± 1.8 yr and with regard to their short work history (3.8 ± 1.0 yr), we concluded that the workers are too young to show serious symptoms of silicosis and hence, the probability of cough, phlegm, allergic and dermal disorders are very low in these workers and as the other researches have showed, related high prevalence of symptoms appear after 10 years of work experience while the miners in our research had much less work history and it seems to be too soon for finding any relation between quartz concentration and respiratory and dermal symptoms. Therefore, this research can be considered as a pre-review for future researches. Nevertheless, the results showed that the skin disorders, cough, phlegm and allergic problems in hammer drill workers are higher than other workers. Hence we understand that eventhough the quartz concentration in all of job sites were lower than the TLV, higher concentration of dust and quartz in hammer drill work site might increase prevalence of respiratory and skin disorders in this group of workers in comparison to the other activities.
Acknowledgment

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