Determination of Exposure to Respirable Quartz in the Stone Crushing Units at Azendarian-West of Iran

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Abstract: The purpose of this study is to describe the personal exposure to respirable dust and quartz and in stone crushing units located at west of Iran. A size of 40 personal samples and 40 stationary samples were obtained and analysis was done by X-ray diffraction (XRD). The results of personal sampling were shown the concentrations of respirable dust exposure level in workers of process, hopper and drivers were 1.90, 2.22, 1.41 times greater than Occupational Safety and Health Administration permissible exposure limit (OSHA PEL). The average value of total dust and respirable dust emission from stationary sources was 9.46 mg/m³, 1.24 mg/m³ respectively, showing that 13.8% of total dust is respirable. The efficiency of local exhaust ventilation (LEV) to control of particles inside of industrial units was greater than 99%. It is concluded from this research the particulate generated from stone crushing activities contain a significant amount of respirable particle. The amount of free silica in stone quartz is 85 to 97 percent that emission of particles effect to health workers. LEV has important effect in the removal of silica particles in stone crushing units. The worker of hoppers still exposed to silica more than standard limits.

Key words: XRD, Stone crushing, Quartz, Respirable dust, LEV

Introduction

Silica is a major component of sand, rock, and mineral ores and is the second most common mineral in the earth’s crust, next to feldspar. The generic term refers to the chemical compound silicon dioxide (SiO₂), which occurs naturally in crystalline, amorphous, and glassy states. The major adverse effects of exposure to crystalline silica include silicosis, chronic bronchitis, certain connective tissue disorders, and lung cancer[1, 2]. Crystalline silica has also been classified as a known human carcinogen and is associated with systemic autoimmune diseases[3].

There are two kinds of stone crusher units in Iran, traditional and modern. The particles emission by traditional units is greater than modern stone crusher factories. There are about 50 traditional stone crusher units in Iran and 29 of them are in Azandarian Area because more than 50% of silica production are in this area. The Azandarian an area, at a distance of 45 km of Hamadan in the west of Islamic Republic of Iran is a center for producing of silica powder. There are 29 stone crushing in this area and

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in each unit five to eight workers are employed, all of workers are men. There are 29 factories that crush quartz stones in two types: the first type is crushes and screened free silica with a purity level of up to 98 percent. In the second type is crushes and screened free silica with a purity level of up to 80 percent. Out of the 29 factories ten of units produce type one silica powder and nineteen produce type two silica powder. On average, each unit produces 6 to ten of silica powder per day. The quartz stone is first put into a jaw crusher where large stone is broken into smaller pieces, which are then taken through a conveyor belt to disintegrator, which makes powder out of these small pieces. It is then separated according to its fineness through a vibrating screen. The quartz powder is also passed through a magnetic separator in order to remove the extraneous ferrous material from the product raw material. Finally the quartz powder was put into bag by Loader from storehouse and transported to various industries.

These processes generate large amounts of free silica dust and thus increase the risk of silicosis and silico-tuberculosis.

This area largely employs rural, migrant, and unskilled workers and often provides only seasonal employment (between agricultural seasons). High turnover, exploitative management and low socio-economic situation have resulted in lack of programs to address worker health and safety in this sector. Since workers also reside close to this units, environmental and occupational exposure to coexit and increase vulnerability community to health impacts. According to Islamic Republic of Iran regulations, the emissions of free silica particles at workplaces and environment should reducing to below permissible limits. We installed the local exhaust ventilation from March 2004 to July 2006. Before installation workers in these industries are exposed to silica, and high rates of pneumoconiosis have been reported in the Azandarian Area. A study by Bahrami et al. shows decrease in LEV1 of workers at in stone crusher units compare to other workers in ceramic and pottery workers in west of Iran. Mohabi et al. observed an association between a progressive decrease in pulmonary function test values and a pneumothorax of workers in Azanderian Area. The occurrence of a pneumothorax was associated with complaints of pleuretic chest pain, resting dyspnea, respiratory distress, paroxysmal nocturnal dyspnea, orthopnea and crackle. In another study Mohabi found a significant association between secondary spontaneous pneumothorax and both emphysema and bullae in acute and accelerated silicosis.

Several investigations have reported about the subjects which exposed to quartz in air in industrialized country. To our knowledge, there are no reports about the determination of free silica from stone crusher in Iran and few study reported respirable dust and quartz exposure from any developing country in Asia. Identifying and characterizing important determinants of respirable dust and quartz exposure may create a platform for determine workers that are in risk of lung disease even after installation of LEV and estimate whether there is a risk of developing pulmonary disease for the workers.

The purpose of this study was to describe the personal exposure to respirable dust and quartz and to identify important determination of exposure in stone crusher units and also evaluate the efficiency of LEV for removing dust particles inside of industrial units.

Materials and Methods

A total of 40 personal samples were obtained to determine respirable dust and quartz from July to September 2006 after installation local exhaust ventilation. The LEV was installed for rotary grinder, hopper, screening I, screening II and conveyer belt. Eight industrial units including four stone crushing type I and four stone crushing type II were selected for total and respirable samples.

A size of 40 stationary samples were obtained to determine of respirable dust and quartz inside of industrial units. Emission sources includes; initial storage, hopper, grinder, screening I and screening II. Total mass of particles inside the industrial units were collected in two periods. March 2004 before the installation LEV and July to September 2006 after installation LEV.

The determination of quartz was carried out according to the NIOSH method number 7500. Personal respirable dust was sampled using a SKC pump (Model - 224-PCXR3) with a flow rate of 1.7 l min\(^{-1}\). A rotameter was used to adjust the flow. The respirable dust samples were collected on 25 mm cellulose acetate filters (pore size 0.8 µm) placed in a 25 mm conductive plastic cyclone. The cyclone was attached to the worker’s overalls as closely as possible to the face in order to determine respirable dust in the breathing zone. Stationary samples of silica particles in the ambient air were taken at a fixed height of 1.5 m above the floor near the emission sources. The filters were conditioned in desiccator environmental chamber for 24 h at 25°C and weighed before and after testing to determine total penetrating weights. Two stock standard were prepared with added 10 and 50 mg of pure quartz to 1 L glass-stoppered. 14 working standard were prepared and filtered through the silver membrane under suction.

The 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. The X-ray diffrac-
tion was run at 0.5 degree per minute from 20 to 26.66 degrees 2θ using specific software. The limit of detection was 0.01 mg m⁻³. Data analysis was performed with SPSS statistical software for windows.

The quotient of the respirable dust exposure and OSHA PEL was determined to establish the degree of compliance with the PEL. The Occupational Safety and Health Administration (OSHA) 8 h time-weighted (TWA) permissible exposure limit (PEL) was calculated based on following equation:\(^\text{12)}\):

\[
    \text{OSHAPEL-PEL} = \frac{10}{(\% \text{SiO}_2 + 2)}
\]

where SiO₂ is the percentage of the respiratory dust mass that is quartz silica.

The data were analysed by using the statistical package for social science (SPSS). Comparison between the mean of respirable dust and quartz concentration in personal samples and different site was performed by One way ANOVA test.

**Results**

Table 1 shows the exposure workers of stone crushing to respirable dust and quartz according to job. Exposure based on job showed that hopper workers had the highest exposure to respirable quartz. Results show significant differences in respirable dust exposure of hopper workers compared to process workers, drivers and offices employee (p<0.05). 78% of the quartz respirable in the personal samples of workers exceeded the TLV. Personal respirable quartz measurement were compared to the 8 h TWA ACGIH TLVs (0.05 mg/m³) and OSHA PELs. The analysis results reveal that the mean of airborne respirable dust free silica content in crusher stones was 85–97% depends to type of stone crushing.

Table 2 shows the mean of total dust before and after of installation of LEV in different sites of stone crushing units. Results show the efficiency of LEV to control of particles is greater than 99%. The average value of total dust emission from sources was 9.46 mg/m³ as compared to 1.24 mg/m³ respirable dust showing that 13.18% of total dust is respirable. No significant difference was observed for emission of particles among stationary sites after installation of LEV.

The results of this study was showed, there is a significant difference between concentration of silica particles in stone crushing type 1 and type 2 before installation of LEV (p<0.001) but no significant difference was observed after installation of LEV (p<0.26).

**Discussion**

The present study was undertaken to evaluate the distribution of respirable dust and quartz in stone crushing units in Iran. The results of personal sampling were shown the concentration of respirable dust exposure level in all of jobs are less than OSHA PELs (5 mg/m³) and ACGIH TLV (3 mg/m³) but the respiratory quartz exposure level in workers of process and hopper were 1.9, 2.22 times greater than the OSHA PEL and 3.80, 8.00 greater than ACGIH TLV (0.05 mg/m³)\(^\text{13)}\) respectively and drivers of loader exposure to quartz more than ACGIH TLV. The office employees was the least exposed with no samples exceeding the TLV. The LEV was installed for all of units but invisible leaking happen from LEV inside of units. The workers in hopper throw the stone quartz inside of hopper manually and exposed to silica more than standard limit. To control emission of dust in this job, changing of process is necessary.

The mean concentration of respirable dust in current

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**Table 1. Exposure of stone crusher workers to respirable dust and quartz according to job**

<table>
<thead>
<tr>
<th>Kind of job</th>
<th>N</th>
<th>Respirable dust</th>
<th>Respirable quartz</th>
<th>OSHA TWA</th>
<th>Ratio to OSHA TWA</th>
<th>Ratio to ACGIH TWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process workers</td>
<td>12</td>
<td>0.21</td>
<td>0.19</td>
<td>0.10</td>
<td>1.90</td>
<td>3.8</td>
</tr>
<tr>
<td>Hopper</td>
<td>8</td>
<td>0.45</td>
<td>0.40</td>
<td>0.18</td>
<td>2.22</td>
<td>8.00</td>
</tr>
<tr>
<td>Drivers</td>
<td>11</td>
<td>0.20</td>
<td>0.17</td>
<td>0.12</td>
<td>1.41</td>
<td>3.40</td>
</tr>
<tr>
<td>Offices Employee</td>
<td>9</td>
<td>0.04</td>
<td>0.03</td>
<td>0.19</td>
<td>0.15</td>
<td>0.60</td>
</tr>
</tbody>
</table>

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**Table 2. The mean of silica concentration before and after of LEV in different sites of grinder stone units**

<table>
<thead>
<tr>
<th>Site of sampling</th>
<th>No LEV</th>
<th>With LEV</th>
<th>ϕ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total dust</td>
<td>Respirable dust</td>
<td>Total dust</td>
</tr>
<tr>
<td>Hopper</td>
<td>1,257.4 ± 72.43</td>
<td>111.12 ± 10.23</td>
<td>8.44 ± 1.37</td>
</tr>
<tr>
<td>Rotary Grinder</td>
<td>2,007.5 ± 567.4</td>
<td>179.23 ± 71.45</td>
<td>11.07 ± 6.96</td>
</tr>
<tr>
<td>Screening I</td>
<td>1,900.1 ± 558.63</td>
<td>170.12 ± 60.24</td>
<td>9.34 ± 5.8</td>
</tr>
<tr>
<td>Screening II</td>
<td>1,787.5 ± 449.77</td>
<td>152.56 ± 58.34</td>
<td>9.00 ± 6.5</td>
</tr>
</tbody>
</table>

ϕ¹ efficiency of LEV.
work practice and dust suppression techniques should be for workers of jaw crusher disintegrator. Proper training controlling dust exposure need to be strengthened especially crushing type II. Humidity and made emission of particles less than stone type 2 have about up to 85% free silica and 2 to 5% a great emission of particles but stones in stone crushing to 98% free silica and during grinding and screening made emission of LEV. The kind of stone in grinder stone has up significant difference between concentration of silica particles in stone crushing type I and type 2 before installation of LEV. The kind of stone in grinding stone has up to 98% free silica and during grinding and screening made a great emission of particles but stones in stone crushing type 2 have about up to 85% free silica and 2 to 5% humidity and made emission of particles less than stone crushing type II.

The engineering and administrative measures for controlling dust exposure need to be strengthened especially for workers of jaw crusher disintegrator. Proper training work practice and dust suppression techniques should be emphasized. The use of a dust suppressant, such as water may also be effective in reducing dust emissions during grinding of stones. Unless immediate measures are initiated to reduce dust levels respiratory protective masks should be used.

Conclusion

It is concluded from this research the particulate generated from stone crushing activities contain a significant amount of respirable particle. The amount of free silica in stone quartz is 85 to 97 percent that emission of particles effect to health workers LEV has important affect to control of silica particles in stone crushing units. The worker of hoppers still exposed to silica more than standard limits.

References

11) National Institute for Occupational Safety and Health...


