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Research Article

OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA AND ITS PULMONARY EFFECTS AMONG WORKERS OF A CEMENT FACTORY IN SAVEH, IRAN

Ali Faghihi-Zarandi[1], Pedram Ebrahimnejad[1], Eghbal Sekhavati[2], Mohamad Reza Baneshi[3]and*Farideh Golbabaei[4]

[1]*Department of Occupational Health, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran*
[2]*Larestan School of medical Sciences, Larestan, Iran*
[3]*Research Center for Modeling in Health, Kerman University of Medical Sciences, Kerman, Iran*
[4]*Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*
**Author for Correspondence*

ABSTRACT

Objectives: This study aimed to assess exposure to crystalline silica and its relation with risk of pulmonary functional disorders among workers of a cement industry in Saveh, Iran.**Methods**: In this cross-sectional study, 62 samples of respirable dust were collected from breathing zone of workers in different sections of a 4-years-old cement factory in 2011. Determination ofrespirable dust concentrations carried out using gravimetric method according to the "National Institute for Occupational Safety and Health"(NIOSH) method no. 0600. Visible absorption spectrophotometry was used according to the NIOSH method no. 7601 to measure crystalline silica content of reparable dust samples.Spirometry test was also applied to assess workers' pulmonary function parameters.**Results**: Range of site workers' exposure to respirable fraction of cement dust was1.77 to 18.89 mg/m^3, and their exposure to crystalline silica was at the range of 0.011 to 0.104 mg/m^3. The highest levels of exposure to respirable dust and crystalline silica were observed in "raw mill". Occupational exposure to crystalline silica in 57% of site samples exceeded theNIOSH REL (0.05 mg/m^3).The partial correlation test showed a significant relationship between workers' exposure to crystalline silica and reduction in parameters such as FVC% and FEV$_1$% (p-value<0.05).**Conclusion**: Exposure to crystalline silica can reduce the value of some pulmonary function parameters such as FVC% and FEV$_1$% and cause restrictive pulmonary disorders. Therefore, control of workers' exposure to crystalline silica, especially in units with highest level of crystalline silica concentration should primarily be considered.

Keywords*: Cement, Crystalline Silica, Pulmonary Function, RespirableDust*

INTRODUCTION

Silica is one of the most abundant elements in the soil and nature(NIOSH 2002)thatis found in three forms: crystalline (polymorphs), cryptocrystalline and non-crystalline (amorphous) (Maciejewska 2008). Crystalline silica, which is the most important form of silica, is a toxic, carcinogenic(Calvert et al 2003)and very dangerous chemical; and occupational exposure results in diseases such assilicosis(Labour Action China 2006), lung, bronchial, throat and stomach cancers(Maciejewska 2008; Labour Action China 2006)
chronic pulmonary effects (Hnizdoet al 2003), autoimmune(NIOSH 2002,Mancino et al 1983) and kidney complications(Calvert et al 2003, Parks et al 1999). The American Conference of Governmental Industrial Hygienists(ACGIH) classified the crystalline silica in the Group A$_2$ of carcinogens (suspected human carcinogen) (NIOSH 2002),whereas the International Agency for Research on Cancer (IARC) classified it as carcinogens Group1 by earning sufficient evidenceson carcinogenicity of crystalline silica (quartz and cristobalite) in humans(Calvert et al 2003). In United State from 1968 to 1994, 14824 workers died due to silicosis, an occupational disease(NIOSH 1992).

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Exposure to silica is a common problem in many industrial environments, including mining, construction, glass, cement, ceramic, iron and steel (Maciejewska 2008). Process of cement production releases particles of crystalline silica into the environment in various stages of production including mining, milling, production, loading and transportation. So the cement industry can be a good option for the study.

Several studies have been conducted about determination of crystalline silica levels in workplace. There are 28712 workers potentially exposed to high risk of crystalline silica in Italy(Scarselli et al 2008).Khorramzade *et al*(2002) estimated that the concentration of free crystalline silica in a modern cement factory in Iranwas more than the occupational exposure limit according to the standard of Iran. Azari*et al*(2009)applied two approaches including breathing air monitoring using visible spectrophotometry and biological monitoring to assess occupational exposure to crystalline silica in sandblasting workers; they estimated that the concentration of crystalline silica was at the range of 0.016 to 0.41 mg/m^3. Also there was a correlation between biological monitoring and air monitoring results in his study. Golbabaei *et al*(2004) used X-ray diffraction technique (XRD) in order to evaluate a quarry workers' exposure to crystalline silica in Kashmar, Iran; they observed the highest level of crystalline silica in the hammer drilling unit (0.057mg/m^3).

In several studies, changes in pulmonary function of workers in the cement industry have been reported. Yang notified chronic respiratory symptoms(Health and Safety Executive 2006)and reduction in lung capacity(Yang et al 1996) and Neghab *et al*(2007) reported irritation in mucous membrane of lung airway and acute reduction of variables including PEF and FEV$_1$. Also in other studies, a significant decrease in pulmonary parameters including FEV$_1$%(Noor et al 2000,Health and Safety Executive 2006,Meo et al 2002), FVC%(Health and Safety Executive 2006,Meo et al 2002), FEV$_1$/FVC%(Health and Safety Executive 2006), FEF$_{25-75\%}$(Noor et al 2000) and PEF(Meo et al 2002)has been reported among cement workers.

Moreover, in other studies, the effect of exposure to crystalline silica on lung function of workers has been studied. Neukirch*et al*(1994) reported chronic restrictive pulmonary disease in pottery workers exposed to crystalline silica. Leigh *et al*(1994) confirmed the relationship between exposure to crystalline silica dust and pulmonary emphysema. Calvert *et al*(2003)claimed that exposure to crystalline silica increases the risk of Chronic Obstructive Pulmonary Disease (COPD). Hertzberg *et al*(2002) reported reduction of FVC, FEV$_1$ and FEV$_1$/FVC in workers exposed to silica. Theyalso notified that as per mg/m^{3}crystalline silica exposure, the FVC and FEV$_1$values will be reduce by 1.6 and 1.1ml/years, respectively. Moreover in other studies (Malmberg et al 1993, Liou et al 1996, Chia et al 1992,Brinkman et al 1972) decreases in pulmonary function parameters in workers exposed to crystalline silica has been reported.

Given the above, it seems that crystalline silica can cause lung function disorders in workers employed in the cement industry, but there is no absolute evidence on this theory and more studies are needed. Unfortunately, on the other hand, so far not many researches carried out on thehealth effects of exposure to crystalline silica in the cement industry in Iran. Therefore the results of the study can provide useful information in term of risk assessment of related diseases to crystalline silica especially in the cement industry.

Based on above mentioned, this study was designed and aimed to assess exposure of cement factory workers to respirable dust and crystalline silica content and its relation with pulmonary function disorders.

MATERIAL AND METHODS

Profile of Factory

This cross-sectional study carried out in a cement factory in the city of Saveh, Iran in 2011. The factory was established in 2007 with a production capacity of 7500 tons cement per day. In this factory, 120 workers were employed in two shifts in different departments. Raw materials include pozzolan, clay,

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Marley, silica, iron ore, limestone, gypsum, and kaolin ore. The main production units of the factory include crusher, raw mill, kiln, cement mill and loading. The first step to prepare the materials was done in crusher. In this section, the input raw materials converted from the large size to smaller (0-100mm) by crushing process and the small materials were transferred to the mill feed silos. After weighing and setting,thematerialswere transferred to the raw mill for the grinding process. At the next phase, the materials were converted to melt and formed the clinker in the kiln. In cement mill, amount of gypsum was added to clinker.

After milling process, the product was transferred to the loading/packing unit, and finally delivered to the customer. It should be mentioned that the silica content of produced cement and clinker is 22.2% and 21.92% respectively

Assessment of Exposure to Respirable Dust and its Crystalline Silica Content

In this study, 50 samples were defined as the minimum number of samples required, according to the pre-test results taking thetypeI statistical error of 5% and power of 80%, and using the formula of sample size estimation for amean. In order to more accurate evaluation and to enhance the test power, 62 samples were collected from different parts of the factory and concentrations were determined.

From five main manufacturing processes include crusher, raw mill, kilns, cement mill, and loading workers were selected as exposed workers group. Also, due to restrictions on access to the groups without occupational exposure, the staff of "operations control and administrative "department which expected to have the lowest occupational exposure to crystalline silica were selected as non-exposed group. Finally, a total of 62 samples were distributed between the selected processes using statistical method of "proportion to size". The standard method no.0600 published by NIOSH(1998) was used for sampling and analysis of cement reparable dust. Three common methods to assess workers' exposure to crystalline silica in the workplace include X-ray diffraction (XRD), infrared spectrophotometry, and visible absorption spectrophotometry (Maciejewska 2008).The method of XRD spectroscopy is expensive; on the other hand, the method is not normally available for comprehensive monitoring of workers' occupational exposure in Iran. Also, the infrared spectrophotometry method is less sensitive than the visible spectrophotometry (Azari et al 2009).Therefore, the visible spectrophotometry method is more applicable for the measurement of workplace air samples at the range oflatest limits recommended forexposure to crystalline silica. Therefore, given the circumstances of this study, the visible absorption spectrophotometry was used as optimum method according to the NIOSH method no.7601(NIOSH 2003).

According to the method used for sampling(NIOSH 2003),the sampling pump Deluxe model made by British company SKC, 10-mm nylon cyclone, and mixed cellulose ester (MCE) filter with a diameter of 37 mm and pore size of 0.8 am(made by SKC Co.) were used. Sampling pumps were calibrated at flow rate of 1.7 liter per minute. Determination of reparable dust concentration was carried out based on gravimetric technique using Sartorius digital scale with a precision of 0.001 mg according to the NIOSH method no.0600(NIOSH 1998).Since the MCE filters are moisture absorbent and this can cause errors in the gravimetric analysis method, so filters were placed in a desiccator containing silica gel for 24 hours before and after sampling(Hazrati et al 2009).After sampling, they were placed in an appropriate filter holder and then transferred to occupational Health Laboratory Tehran University of Medical Sciences to analysis. The samples, after weighing in the laboratory, were analyzed at wavelengths of 420 and 820 nm using visible absorption spectrometry technique according to the NIOSH method no.7601 (NIOSH 2003).

It should be noted that all the information are listed without the employee's name; privacy information and medical examination results was confidential. Also the sampling results are reported correctly and avoided from the exaggeration.

Evaluation of Workers' Pulmonary Function

In order to evaluate the pulmonary function status and lung capacities of workers, the workers in both groups were initially trained; then, the pulmonary function tests including "forced vital capacity"(FVC),

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"forced expiratory volume at the end of the first second"(FEV_1), FEV_1/FVC ratio, and "forced expiratory flow over the middle half of the FVC"($FEF_{25-75\%}$) were carried out at the end of work shift, by occupational medicine physician using calibrated portable spirometer (model SPIROLAB II made by Italian company MIR S.R.L)according to the American Thoracic Society(ATS)recommendation(ATS 1979). Also, the mean of predicted percentage of each pulmonary function parameter was estimated by the spirometer based on age, weight, height, sex and race.
After spirometry test being done, the results were interpreted by the occupational medicine physician to define pulmonary function of the workers. In addition, the mentioned parameters and their percentages (test value divided intopredicted value) were extracted from the Spirometrysheets.

Data Analysis

The statistical software SPSS version 15.0 was used to analysis the results. The tests included the "one sample t test" to compare the levels of exposure to respirable dust and crystalline silica with occupational exposure limits, Analysis of variance and "Tukey" tests to compare the exposure levels and lung function parameters between different units, and "Partial Correlation" test to study the relationship between lung function variables and levels of cement respirable dust and its crystalline silica content while interferences (such as smoking, age, etc.) were eliminated. Confidence level for all tests was set at95%. The "normality test" confirmed normality of the data, so the results were expressed as arithmetic mean and standard deviation.
Concentration of respirable dust was determined by means of gravimetric method based on the difference in filter weights over the sampling and taking corrections to the blank filter(NIOSH 1998).Whereas crystalline silica concentration was determined based on the amount of light absorbed in the sample and blank, slope of the calibration curve, and the volume of air sampled(NIOSH 2003).
Time-weighted average (TWA) of pollutant concentration in workplace air was calculated to determine personal exposure to respirable dust and crystalline silica; and exposure limit was adjusted and calculated using the "Brief &Scala" model based on 9 or 12-hour work shifts in various sections of the factory(OSHS 2002).
Also occupational limits for exposure to respirable cement dust were determined based on its silica content according to the (OSHA)recommendation(OSHA 2012).

RESULTS AND DISCUSSION

Results

From the total of 62 selected subjects, 49 people were working in the production sites and 13 others in the administrative department. Demographic characteristics including age and work history and smoking rateare presented in Table 1. There were no significant differences onmean values ofage, smoking status and work history between the workers as exposed and administrative staff as non-exposed groups (p-value>0.05).Considering that there was no significant difference in work history of workers that being the basis of their exposure and smoking status which affecting pulmonary function of the workers, the administrative group confirmed as non-exposed group.
The result of the time-weighted average of workers' exposure concentration of cement respirable dust in various working processes and crystalline silica content of respirable dust, are summarized in Table 2. The means of workers' exposure to respirable dust exceeded the Threshold Limit Value (TLV) recommended by the ACGIH (1mg/m^3) in all production units including crusher, raw mill, kiln, cement mill, and packing &loading($p<0.05$). Only in operation control and administrative departments the exposure of personnel was lower than the TLV ($p=0.05$).In addition, the range of all production workers' exposure to respirable dust was1.77 to 18.89 mg/m^3 and exposure of all of them (100%) was higher than the TLV.
The percentage of crystalline silica in respirable dust samples in production processes ranged from 1.7% to 0.49% with the mean of 1.17%. The highest proportion of crystalline silica was observed in the kiln and crusher units (1.7% and 1.53% respectively), and the lowest in the cement mill unit (0.49%).

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After calculating the percentage of crystalline silica content of respirable dust in various working processes, the PEL (Permitted Exposure Limit) of respirable dust were determined according to the standard of OSHA.

ThePELswere calculated as follow: crusher 2.83, raw mill 3.39, kiln 2.7, cement mill 4.02, and packing & loading 3.34 mg/m^3. Considering the calculated limits, workers' exposure to respirable dust in raw mill, cement mill and packing/loading units were higher than the PEL ($p<0.05$).

The time-weighted average of workers’ exposure to crystalline silica has been summarized in Table 2. The mean of workers' exposure to crystalline silica exceeded theNIOSH REL (Recommended Exposure Limit)(0.05 mg/m^3) only in raw mill and kiln units ($p<0.05$). In addition, in administrative workers group the mean ofexposure was lower than the REL ($p<0.001$). 57% of production workers’ exposure was higher than the REL.

There was a significant correlation between the levels of personal exposure to respirable dust and crystalline silica ($p<0.001$) with the Pearson correlation coefficient of 0.455.The regression equation was determined as eq. (1).

$$Si = 0.003\ RD + 0.022 \quad (1)$$

Where Si is the level of exposure to crystalline silica, mg/m^3; and RD is the level of exposure to reparable dust, mg/m^3.

The mean of the pulmonary function parameters including FVC%, FEV_1%, FEV_1/FVC%, and $FEF_{25-75\%}$are given in Table 3.There was no significant differences between the exposed group (site workers) and on-exposed group (staff of administrative and operation control departments)in term of these parameters (p-value>0.05).

Moreover, the statues of non-normal values in pulmonary parameters such as FVC%, FEV_1%, FEV_1/FVC%, and $FEF_{25-75\%}$, and pulmonary function stat us of all workers (including administrative and production workers) are showed in Figure (1). The most non-normal values of pulmonary parameters were related to FVC% and FEV_1%. Restrictive statues were observed in some workers.However,none of the workers was afflicted to airway obstructive disorder.

The relationship between lung function parameters and workers' exposure to crystalline silica was assessed using partial correlation model with elimination the interference such as age, height, weight, smoking status and work history (table 4).The modeling showed that the main cause of reducing in lung function capacities can be the workers’ exposure to crystalline silica.

Discussion

In this study, we considered the standards of the NIOSH, OSHA, and ACGIH to compare the time-weighted average values with Occupational Exposure Limits(ACGIH 2012). We determined the overall content of crystalline silica, whereas the standard of ACGIH submitted the OEL for exposure to various forms of crystalline silica separately, so we could not use the TLV recommended by the ACGIH in this study. Alsothe OSHA has not specified limits for exposure to crystalline silica. Therefore, we compared the time-weighted average values with the OEL based on the standards of the NIOSH(2003). Whereas related to exposure to cement respirable dust, since the NIOSH does not have specified exposure limit, the standards of the ACGIH (2012) was used to compare the time-weighted average values with theTLV.Besides, we used the OSHA recommendation to determine the PEL for exposure to respirable dust based on its crystalline silica content(OSHA2012).

The results showed that the concentration of cement respirable dust in all parts of the production site was higher than the TLV recommended by the ACGIH (1mg/m^3).The highest levels of exposure were recorded in raw milland cement mill units.The main exposure of the workers in these sections occurred when cleaning conveyors and other equipments which diffuse a lot of dust intothe environment. Khorramzadeh *et al* (2002)estimated that the mean of respirable dust concentration was 24.65 mg/m^3in the cement mill unit of a modern cement plant, which had the highest value in comparison with other processes. In the other study which was conducted in Jordan cement industry, this value was 3.9 mg/m^3 for the cement mill workers(Yang et al 1996).

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The lowest level of exposure to respirable dust was observed in the kiln, because the process is completely sealed inthis unit.

Levels of the site workers' exposure to respirable dust were at the range of1.77 to 18.89 mg/m^3.In a study, Abrons*et al*(1988) estimated the mean of 0.57 mg/m^3 for exposure to respirable cement dust that is about 8.5 times lower than the mean which were calculated in our study. In addition, in a Research conducted in Taiwan(Health and Safety Executive 2006),the mean of exposure to cement dust was 1.24 mg/m^3.Therefore,it can be pointed that the level of exposure to respirable dust in our study is higher than abroad cases, and this may be because of differences in equipment and devices used, the ability to use and maintenance the control systems, and cleaning mechanisms.

Hazrati *et al*(2009) estimated the value of 13 mg/m^3 for cement respirable dust concentrations in Ardabil Cement Factory. Also in the Khorramzadeh's (2002) study in a cement factory, the cement respirable dust concentration was 13.75 mg/m^3. In other study by Neghab & Choubineh(2007), this value was 26 mg/m^3. In all studies mentioned above, which was conducted in cement industries in Iran, the mean of respirable dust concentration is higher than its level in our study, so we can claim that level of exposure to respirable dust in our studied cement industry is lower than the domestic similar industries, and it may because of thestudied industry is recently stablised, as less wear and tear occurred in the equipment in comparison with other domestic similar industries. Also, the dust concentration in domestic industries exceeds the expected value in comparison with similar industries in other countries; it may because of premature aging of domestic industries due to lack of timely maintenance and technical inspections.

Levels of site workers' exposure to crystalline silica were at the range of 0.011 to 0.104 mg/m^3 that 57% of which were higher than the NIOSH REL (0.05 mg/m^3). The time-weighted average of exposure to crystalline silica was higher than REL only in the raw mill ($p= 0.031$) and kiln ($p<0.001$). However, in other processes, this difference was not statistically significant, and mean of workers' exposure in these units was at the permissible range. Generally, in the processes which are after kiln unit and baking phase, the levels of exposure to crystalline silica were lower than those of earlier stages of the production process.Because as the highest levels of exposure were occurred in the raw mill, crusher and kiln units. The similar result was obtained in Ardabil Cement Factory(Hazrati et al 2009). Reduction in levels of exposure to crystalline silica in processes, which are after the kiln, may be due to heating the raw materials and releasing free radicals of crystalline silica in this phase, or adding amount of gypsum to the materials that result in a reduction in amount of crystalline silica in produced cement.

Golbabaei *et al*(2004)claimed that exposure of the workers of hammer drilling to crystalline silica in the Kashmar Quarry was 0.057 mg/m^3. Mean of crystalline silica concentration in a glass industry was 9.5 times higher than the TLV recommended by the ACGIH(Aliabadi M et al 2007).Aliabadi*et al*(2007) said the mean of crystalline silica concentration was over 0.1 mg/m^{3}in the Hamadan stamping plants. Azari *et al* (2009)estimated that occupational exposure of sandblasting workers to crystalline silicawas at the range of0.016 to 0.41 mg/m^3.Thus, it can be pointed that the level of crystalline silica concentration in industries such as mining, glass, and stone, is higher than its level in the cement industry.

In several studies(Yang et al 1996,Neghab et al 2007, Noor et al 2000,Meo et al 2002,Hertzberg et al 2002,Malmberg et al 1993,Liou et al 1996, Chia et al 1992, Brinkman et al 1972), the effects of exposure to respirable dust, cement dust and crystalline silica on workers' pulmonary function have been reported.Our findings also showed that 34% and 24% of the employees hadnon-normal statues of FEV_1% and FVC% respectively. Herein, Noor *et al*(2000) and Dehghan HS*et al*(1996).have reported decrease in FEV_1% and FVC% and Neghab *et al*(2007) reported acute decrease in FEV_1 among cement factory workers. In the study of Meo *et al* (2002)it was observed that the pulmonary function parameters including FVC and FEV_1 decreased significantly(Meo et al 2002).

However, in other studies, different findings have been earned. Abrons *et al* (1988)claimed that exposure to cement dust could not cause changes in pulmonary function. Dehghan HSet al(1996) did not find a significant relationship between the levels of exposure to cement dust and spirometry test results among workers of a cement industry.

Although in the present study the non-normal values of FEV_1/FVC% and $FEF_{25-75\%}$ were observed in only 1.6% of the workers, decrease in FEV_1/FVC and $FEF_{25-75\%}$ have been reported respectively in the studies of Dehghan HS *et al*(1996) and Noor *et al*(2000)in cement industries. It may be because of the young studied industry and the workers with short term work history, while Noor and Megnesha studied workers with long-term work history.

In our study, no significant differences were found in pulmonary function parameters between the exposed and non-exposed groups. Nonetheless, the results of partial correlation test showed a significant relationship between exposure to crystalline silica and decrease in the values of FVC% and FEV_1%. Therefore, in this study, workers' exposure to crystalline silica caused a decrease in pulmonary function parameters such as FEV_1% and FVC%. In several studies (Malmberg *et al* 1993, Liou et al 1996, Chia et al 1992) the effects of occupational exposure to crystalline silica on pulmonary function parameters have been reported. Brnkman *et al*(1972)claimed that exposure to silica dust reduces the values of FVC and FEV_1. Hertzberg *et al*(2002) reported a decrease in percentages of FVC, FEV_1 and FEV_1/FVC resulted in exposure to silica. In addition, they estimated that odds ratio for the occurrence of non-normal FVC and FEV_1 in 40-yearsexposure to0.1 mg/m^3 crystalline silica (PEL of OSHA) are1.49 and 1.68 respectively.

They also expressed that per 1 mg/m^3 exposure to crystalline silica, the values of FVC and FEV_1 reduce at the rates of 1.6 and 1.1 ml/years, respectively. Like other researchers studies, the present study confirms the effects of exposure to crystalline silica on a fall in values of pulmonary function parameters including FVC% and FEV_1%.

Table 1: Demographic characteristics of the study population in terms of work units

Demographic characteristics		**Exposed groups (production units)**					**Non-exposed group**
		Crusher N=5	**Raw mill N=11**	**Kiln N=14**	**Cement mill N=7**	**Packing & loading N=12**	**Administrative & operation control N=13**
Age (years)	X±SD	30±4.5	29.1±4.3	28.9±3.4	28.6±5.4	27.6	34.1±5.1
	p-value*	0.746	0.264	0.162	0.303	0.051	-
Work history (years)	X±SD	4.2±0.4	4.4±1.4	4.3±0.7	4.5±1.4	3.2±1.8	4.8±1.4
	p-value*	0.983	0.989	0.967	0.997	0.114	-
Smoking (number of smokers)	Smokers	1	3	5	4	6	5
	Non-smokers	4	8	9	3	6	8
	p-value**	0.457	0.562	0.883	0.423	0.337	-

X: mean SD: Standard Deviation
** To comparison between exposed and non-exposed worker groups (two-sample t test)*
*** To comparison between exposed and non-exposed worker groups (Chi-square test)*

Table 2: Time- Weighted Average (TWA) of exposure to cement respirable dust and its crystalline silica content in the study population

process	**Number of samples**	**cement respirable dust**	**crystalline silica**	**Share of crystalline silica content of respirable dust (percent)**

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		X±SD mg/m^3	**Range of concentration mg/m^3**	**Number (percent) of samples exceeded the adjusted TLV ***	**X±SD mg/m^3**	**Range of concentration mg/m^3**	**Number (percent) of samples exceeded the adjusted TLV ***	
Crusher	5	2.73±0.74	2.15-3.69	5 (100%)	0.045±0.03	0.023-0.087	3(60%)	1.53
Raw mill	11	7.8±6.05	2.75-18.89	11 (100%)	0.052±0.035	0.011-0.104	8(73%)	0.95
Kiln	14	2.68±0.9	1.77-4.59	14 (100%)	0.041±0.014	0.02-0.063	12(86%)	1.7
Cement mill	7	7.39±3.73	2.26-12.79	7 (100%)	0.024±0.008	0.013-0.035	2(29%)	0.49
Packing and loading	12	4.06±0.91	3.04-5.9	12 (100%)	0.039±0.02	0.019-0.083	3(25%)	0.99
Administrative and operation control	13	0.53±0.14	0.33-0.7	0	0.008±0.008	0.0005-0.026	0	1.38

* *According to ACGIH recommendation(*ACGIH 2012*), the TLV of exposure to respirable dust is 1 mg/m^3 for 8 hours exposure in the day, which is adjusted based on Brief &Scala model(*OSHS 2002*), and this value earned 0.5 and 0.8 mg/m^3 for 12-hrs and 9-hrs work shifts, respectively. Also based on NIOSH recommendation*(NIOSH 2003)*, the REL of exposure to crystalline silica is 0.05 mg/m^3 for 8 hours exposure in the day, which is earned 0.025 and 0.042 mg/m^3 for 12-hrs and 9-hrs work shifts, respectively. Should be mentioned that work shift is 9-hrs in "Loading" and "Administrative" departments and 12-hrs in other units.*

Table 3: Mean of pulmonary functional parameters include FVC%, FEV$_1$%, FEV$_1$/FVC%, and FEF$_{25-75\%}$ among the workers of cement factory

	process	**Number of workers**	**FVC% X±SD**	**FEV$_1$% X±SD**	**FEV$_1$/FVC% X±SD**	**FEF$_{25-75\%}$ X±SD**
Exposed groups	Crusher	5	88.2±14.3	84.5±10.2	81±6.6	68.1±8.1
	Raw mill	11	82.6±8.5	81.4±8.5	83.3±3.4	83.8±17.2
	Kiln	14	85.8±4.6	84.8±7.2	84.2±4.9	91.9±20.6
	Cement mill	7	81.9±7.7	78.1±5	78.6±4.5	67.5±11.1
	Packing and loading	12	88±6.7	89.8±12.1	86.3±8.3	86.1±23.2
Administrative and operation control (non-exposed group)		13	85.7±8.8	84.9±11.8	83.6±8.4	79.8±21.5
total		62	85.4±8	84.4±9.9	83.4±6.6	82.2±20.3

Table 4: Results of assessing the relationship between workers' exposure to crystalline silica and changes in pulmonary function capacities using the partial correlation test

Parameter (%)	**Level of workers exposure to crystalline silica 0.034±0.025 (mean±SD)**	
	R	**p-value**
FVC	- 0.333	0.01
FEV$_1$	-0.308	0.018
FEV$_1$/FVC	0.055	0.68
FEF$_{25-75}$	0.015	0.912

Adjusted for age, work history and smoking

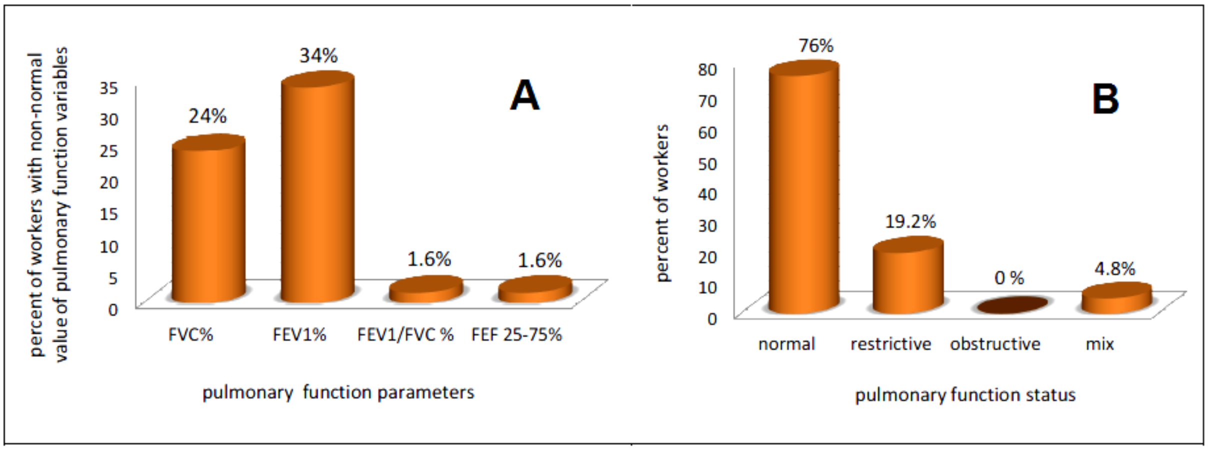

Figure1: A: non-normal status in values of the workers pulmonary function parameters; B: Pulmonary function status of the cement industry workers

Note: The non-normal value of FVC% and FEV_1% is less than 80%, whereas, the non-normal values of FEV_1/FVC% and $FEF_{25\text{-}75\%}$ are less than 70% and 50% respectively.

In the present study, spirometry results indicate that the pulmonary disorder is of the restrictive complications and none of the employees has been afflicted to obstructive airway disorder. In pulmonary restrictive disease, FVC value is reduced, whereas the value of FEV_1 is normal or decrease as much as FVC value, so the value of FEV_1/FVC % will be at normal range(Abrons HL et al 1988,Robbins S et al 1997). Reduction of FVC may be due to decrease in lung compliance ability(Robbins S et al 1997). It seems that incidence of lung restrictive signs in some of the site workers, could be on account of high rates of smoking among them. However, exposure to crystalline silica can also be an important factor in the incidence of respiratory restrictive complications. As Neukirch*et* al(1994) reported chronic restrictive pulmonary disease among workers exposed to crystalline silica.

The findings are consistent with other studies(Hertzberg VSet al 2002, Malmberg P et al 1993, Liou SH et al 1996,Chia KS et al 1992,Brinkman GL et al 1997). Nonetheless, in order to determine the effects of being employed in cement industries on lung function of workers, there is a need for further studies with larger sample sizes, workers with longer work history, and taking consideration to various technologies of cement production and age of industry.

Conclusion

The findings of this study have provided an evidence to confirm the hypothesis that exposure to crystalline silica can cause complication in lung function of cement industry workers. So in order to prevent the development of pulmonary disease and the incidence of respiratory disorders in new workers ofthe industry, it is necessary to prevent workers' exposure to crystalline silica using engineering control methods and protective equipment, especially in units with high levels of crystalline silica concentration (raw mill, crusher and kilns).

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REFERENCES

National Institute for Occupational Safety and Health. Hazard review: Health effects of occupational exposure to respirable crystalline silica. [Online]. 2002 [cited 2007 May 2]; Available from: URL: http://www.cdc.gov/niosh/docs/2002-129/pdfs/2002-129.pdf

Maciejewska A. Occupational exposure assessment for crystalline silica dust: approach in Poland and worldwide. Int J Occup Med Environ Health 2008; 21: 1-23.

Calvert GM, Rice FL, Boiano JM, Sheehy JW, Sanderson WT. Occupational silica exposure and risk of various diseases: an analysis using death certificates from 27 states of the United States. Occup Environ Med 2003; 60: 122-29.

Labour Action China. A short paper on the problem of silicosis in gemstone-processing industry and the legal loopholes in the implementation of the prevention of occupational disease law.[Online]. 2006; available from: URL: http://www.docstoc.com/docs/59634173/Business-Legal-Loopholes.doc

Hnizdo E, Vallyathan V. Chronic obstructive pulmonary disease due to occupational exposure to silica dust: a review of epidemiological and pathological evidence. Occup Environ Med 2003; 60: 237-43.

Mancino D, Buono G, Cusano M, Minucci M. Adjuvant effects of crystalline silica on IgE and IgG1 antibody production in mice and their prevention by the macrophage stabilizer poly-2-vinylpyridine N-oxide. Int Arch Allergy ApplImmunol 1983; 71: 279-81.

Parks CG, Conrad K, and Cooper GS. Occupational exposure to crystalline silica and autoimmune disease. Environ Health Perspect
99; 107: 793-802.

National Institute for Occupational Safety and Health. Hazard review: Health effects of occupational exposure to respirable crystalline silica, determination of airborne crystalline silica. [Online]. 2002. [cited 2003 Mar 3]; Available from: URL: http://www. cdc.gov/niosh/docs/2003-154/pdfs/chapter-r.pdf.

National Institute for Occupational Safety and Health. Request for assistance in preventing silicosis and deaths from sandblasting.[Online]. 1992; available from: URL: http://www.cdc.gov/niosh/docs/92-102.html

Scarselli A, Binazzi A, Marinaccio A. Occupational exposure to crystalline silica: estimating the number of workers potentially at high risk in Italy. Am J Ind Med 2008; 51: 941-9.

Khoramzade M, Gholamnia R, Azari RM, Hazrati S, Zareh M. Evaluation of workplace dusts and its effects on pulmonary function of workers in a modern cement factory. National Conference on Ergonomics in Industry and Production, Tehran, Iran 2002 October 29; 445-56 (in Persian).

Azari MR, Rokni M, Salehpour S, et al. Risk assessment of workers exposed to crystalline silica aerosols in the east zone of Tehran. Tanaffos 2009; 8: 43-50.

Golbabaei F, Barghi M, Sakhaei M. Evaluation of workers' exposure to total, respirable and silica dust and the related health symptoms in Senjedak Stone Quarry, Iran. Industrial Health 2004; 42: 29–33.

Health and Safety Executive. Portland cement dust, Hazard Assessment Document, EH75/7.[Online]. 2006; available from: URL: www.hse.gov.uk/pubns/web/portlandcement.pdf.

Yang CY, Huang CC, Jeng FC, Shou FC, Lan J, Ko YC. Effect of occupational dust exposure on the respiratory health of Portland cement workers. Journal of Toxicology and Environmental Health1996; 49: 581 – 588.

Neghab M, Choobineh A. Work-related respiratory symptoms and ventilatory disorders among employees of a cement industry in Shiraz, Iran. J occup Health 2007; 49: 273-278.

Noor H, Yap C, Zolkepli O, Farideh M. Effect of exposure to dust on lung function of cement factory workers. Med J Malaysia 2000; 55: 51-57.

Meo SA, Azeem MA, Ghori MG, Subhan MMF. Lung function and surface electromyography of intercostals muscles in cement mill workers. International Journal of Occupational Medicine and Environmental Health 2002; 15: 279-287.

Neukirch F, Cooreman J, Korobaeff M, et al. Silica exposure and chronic airflow limitation in pottery workers. Arch Environ Health 1994; 49: 459–64.

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Leigh J, Driscoll TR, Cole BD, Beck RW, Hull BP, Yang J. Quantitative relation between emphysema and lung mineral content in coal workers. Occup Environ Med 1994; 51: 400–7.
Calvert GM, Rice FL, Boiano JM, Sheehy JW, Sanderson WT. Occupational silica exposure and risk of various diseases: an analysis using death certificates from 27 states of the United States. Occup Environ Med 2003; 60: 122-9.
Hertzberg VS, Rosenman KD, Reilly MJ, Rice CH. Effect of occupational silica exposure on pulmonary function. Chest 2002; 122: 721-8.
Malmberg P, Hedenstrom H, Sundblad BM. Changes in lung function of granite crushers exposed to moderately high silica concentrations: a 12 years follow up. Br J Ind Med 1993; 50: 726-731.
Liou SH, Chen YP, Shih WY, et al. Pneumoconiosis and pulmonary function defects in silica-exposed fire brick workers. Arch Environ Health 1996; 51: 227-233.
Chia KS, Ng TP, Jeyaratnam J. Small airways function of silica-exposed workers. Am J Ind Med 1992; 22: 155-162.
Brinkman GL, Block DL. Chronic Bronchitis in a working population.Journal of Occupational and Environmental Medicine 1972; 14: 610-620.
National Institute for Occupational Safety and Health. Manual of Analytical Methods: Silica, Crystalline, by VIS, Method No.7601. 4th ed. Cincinnati: U.S. Department of Health and Human Services: NIOSH; 2003.
National Institute for Occupational Safety and Health. Manual of Analytical Methods: Particulated not otherwise regulated Respirable, Method No.0600. 4th ed. Cincinnati: U.S. Department of Health and Human Services: NIOSH; 1998.
Hazrati S. RezazadehAM, Sadeghi H, Rahimzadeh S, Mostaed N. Dust concentrations in an Ardabil portland cement industry. Journal of Ardabil University of Medical Sciences 2009; 9: 292-298 (in Persian).
American thoracic society (ATS). Statement snowbird workshop on standardization of spirometry Am Rev Respir Dis 1979; 119: 831-838.
Occupational Safety and Health Service. Workplace exposure standards for atmospheric contaminants.Newzeland: Department of Labour: OSHS; 2002. p.10-12.
American Conference of Governmental Industrial Hygienists. Guide to Occupational Exposure Values. ISBN: 9784607260493. Cincinnati, Ohio: ACGIH; 2012.
Yang CY, Huang CC. Effects of occupational dust exposure on the respiratory health of portland cement workers. J Toxical Environ Health 1996; 49: 581-588.
Abrons HL, Petersen MR, Sanderson WT, Engelberg AL, Harber P. Symptoms, ventilatory function, and environmental exposures in Portland cement workers. Br J Ind Med 1988; 45: 368-375.
Neghab M, Chobine AR. The relationship between occupational exposure to cement dust and prevalence of respiratory symptoms and disorders.Behbood Journal 2007; 11: 215-226 (in Persian).
Dehghan HS, Razavizadeh N. Determination and evaluation of free silica in the respirable zone of glassworkers with X-Ray Diffraction Method. Iranian J Public Health 1996; 28: 121-132 (in Persian).
Aliabadi M, Bahrami A, Mahjub H, Ghorbani F, Barghi M, Golbabaei F. Evaluation of release of free silica in the stamping plant's air in Aznadrian area, Hamadan, using X-ray diffraction method. Journal of Hamadan University of Medical Sciences and Health Services 2007; 14: 67-73 (in Persian).
Robbins S. Basic Pathology.In: Kumar V, Cortan R, editors. 5th ed. Philadelphia: Saundres; 1997. p.393-425.
Occupational Safety & Health Administration. Permissible Exposure Limits for silica. U.S. Department of Labor; 2012

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