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Original

Exposure to Respirable Dust and Crystalline Silica in a Cement Plant

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Abstract

Background: People working in industrial environments may be exposed to respirable dust. Crystalline silica dust is known as a respiratory risk. The cement industry is among the most important manufacturing industries whose workers are exposed to dust. Therefore, this study was conducted to investigate workers' exposure to respirable dust and crystalline silica in a cement plant. **Methods:** According to a sample size calculation formula, 50 dust samples were collected from workers' respiratory zones in different parts of the plant. Respirable dust concentrations exposed were calculated using NIOSH-0600 method. Concentrations of crystalline silica in dust samples were determined according to NIOSH-7601 method and using visible absorption spectrophotometry. **Results:** The highest time weighted average of respirable dust concentration (6.12 mg/m^3) was obtained in crusher unit. The minimum and maximum concentrations of respirable dust were 1.6 mg/m^3 and 12.1 mg/m^3, respectively. The highest concentration of crystalline silica (0.044 mg/m^3) was obtained in raw material grinding unit. The minimum and maximum concentrations of crystalline silica were obtained in cement grinding unit and packaging and loading unit (0.001 mg/m^3 and 0.16 mg/m^3), respectively. **Conclusion:** The concentrations of respirable crystalline silica and dust in most units are higher than the threshold limit value which has the potential to harm workers in these units.

Key words: Respirable dust; Crystalline silica; Occupational exposure; Cement Industry

Introduction

Dust containing crystalline silica is known as a respiratory risk.[1] The cement industry is one of the most important manufacturing industries whose workers are exposed to dust in various parts and processes of production. The aerodynamic diameter of the cement dust is in the range of respirable dust that has the potential to penetrate to and settle in the pulmonary alveoli.[2] Portland cement is a mixture of calcium oxide, aluminum trioxide, silicon dioxide, ferric oxide, calcium disilicate, magnesium oxide, selenium, thallium, and a small amount of hexavalent chromium. Cement industry workers face numerous health hazards including cement dust, high temperature and noise during cement production. The most important risk factor is cement dust that is released at high concentrations in most cement production processes.[3] In a study conducted by Aminian et al. in a cement plant, the average concentration of total dust

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was 16.55 mg/m^3 in the exposed group and 0.39 mg/m^3 in the control group.[4]

In the study of Mwaiselage et al. in a cement plant, the geometric average of the respirable dust concentration was 2.13-4 mg/m^3 in the workers of case group and 0.7-1 mg/m^3 in those of the control group.[5] The study of Zeleke et al. showed that the highest geometric average of dust concentration was obtained in the crusher unit (38.6 mg/m^3), while the average of dust concentration was 18.5 mg/m^3 in the packaging unit and 0.4 mg/m^3 in the administrative unit.[6] Zarandi et al. conducted a study in one of the cement industries, the results of which showed the highest average exposure of workers to respirable cement dust occurred in the raw material grinding unit and the cement grinding unit. Exposure of workers to respirable dust in the plant production units ranged from 1.77 mg/m^3 to 18.98 mg/m^3.

Workers' exposure to crystalline silica in all production units was 0.011-0.1 mg/m^3. The highest exposure was estimated in the raw material grinding unit and the least exposure in the cement grinding unit.[7] Crystalline silica is another risk factor for developing pulmonary diseases in cement dust. Occupational exposure to silica may lead to diseases such as silicosis, lung cancer, pulmonary tuberculosis, and airways diseases of the lung. The International Agency for Research on Cancer (IARC) introduced crystalline silica as definitely carcinogenic to humans in 1997.[8] Therefore, due to the importance of the effect of cement dust and crystalline silica contained in it on the health of workers in these industries, the present study was conducted to investigate the exposure of cement industry workers to respirable dust and crystalline silica.

Methods

This cross-sectional study was carried out in a cement plant in 2016. The factory was set up in 2011 and produces 10500 tons of cement per day. A total of 600 workers in two work shifts are working in the plant, and the raw materials of the production process include iron ore, silica, limestone clay, limestone and gypsum. The units of the plant are crusher, soil hall, raw material grinding, furnace, cement grinding, and packaging and loading. Because in the present study only the exposure was measured and no experiments were carried out on workers, its protocol did not need to be approved by an institutional or otherwise research ethics committee. However we will not mention the name of the plant throughout the article to ensure observance of ethical considerations.

Assessment of Dust Exposure

A total of 50 dust samples were collected from workers' respiratory zones in different parts of the plant. To determine the respirable dust concentration according to the National Institute of Occupational Safety and Health (NIOSH-0600), sampling was done using the individual sampling pump (DELOCEX, SKC) and cyclone (Hicks, Higgins-Dewell HD) with mixed cellulose esters with a pore size of 0.8 µm, a diameter of 37 mm and a flow rate of 2.2 l/min. In this method, before and after sampling, the filters were placed inside the desiccator for 24 hours to remove moisture and then were weighed. After correcting the final weight obtained from the weight of the control samples, the results were expressed as mg/m^3.[9]

Visible absorption spectrophotometry at 420 and 820 nm was used in order to determine the concentrations of crystalline silica in the dust samples according to the NIOSH-7601 method using spectrophotometer. Based on the amount of light absorbed in each sample, the calibration curve slope and the volume of the sampled air were determined by the concentration of crystalline silica and expressed as mg/m^3.[10] Since the workers' shift length was 12 hours, the threshold limit value (TLV) was adjusted based on working hours per day according to the Brief and Scala model:

Equation 1: $$Adjusted - tlv = \frac{8\times(24-h)\times RF}{16\times h}$$

Adjusted values and TLVs were calculated at 0.5 mg/m^3 for 12-hour daily shift.[11]

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Table 1. Mean concentration of respirable dust in different units (mg/m3)

Variable Sampling units	Samples(n)	Means(SD)	Minimum	maximum
Crusher	8	6.12(3.99)	4.08	12.1
Soil hall	4	2.52(0.85)	1.94	3.5
Cement mill	11	1.77(0.24)	1.6	2.1
Packing and loading	12	3.4(0.84)	2.3	4.3
Raw mill	11	2.92(1.14)	1.8	4.3
filtration	4	2.6(0.58)	2.08	3.2

Table 2. Mean concentration of crystalline silica in different units (mg/m3)

Variable Sampling units	Samples(n)	Means(SD)	Minimum	maximum
Crusher	8	0.035(0.0123)	0.02	0.05
Soil hall	4	0.026(0.005)	0.02	0.03
Cement mill	11	0.039(0.054)	0.001	012
Packing and laoding	12	0.027(0.06)	0.014	016
Raw mill	11	0.44(0.054)	0.01	0.13
Filteration	4	0.036(0.038)	0.013	0.08

The SPSS version 16 software was used to analyze the data and one-way ANOVA was used to analyze the concentration of respirable dust and crystalline silica in different units. The confidence interval in all tests was considered to be 95%.

Results

The results of the comparison of the time-weighted average (TWA) of exposure to respirable cement dust in various working processes for our participants is summarized in Table 1. The minimum and maximum concentrations of respirable dust were 1.6 (cement grinding unit) and 12.1 (crusher unit) mg/m^3, respectively In addition to the respirable dust concentrations in different plant processes, the concentrations of crystalline silica were also determined Table 2. According to the results, the TWA of crystalline silica concentration in all units was higher than the TLV (0.025 mg/m^3) recommended by the ACGIH and NIOSH. The highest individual exposure to crystalline silica was obtained in the raw material grinding unit (0.044 mg/m^3).

The minimum and maximum individual exposures to crystalline silica were obtained in the cement grinding unit and the packaging and loading unit (0.001 and 0.16 mg/m^3), respectively. Individual exposure of workers was obtained 0.035 mg/m^3 in the crusher unit, 0.044 mg/m^3 in the raw material grinding unit, 0.039 mg/m^3 in the cement grinding unit, 0.027 mg/m^3 in the packaging and loading unit, 0.036 mg/m^3 in the filtration unit and 0.026 mg/m^3 in the soil hall unit.

Discussion

Cement dust is one of the most harmful chemical agents that can cause respiratory problems in workers exposed. Silicosis is the most important pulmonary disease due to continuous inhalation of dust containing crystalline silica, in which the lung tissue is damaged and the ability to absorb oxygen is reduced.[12] In this study, we used ACGIH standards to compare the TWA-TLV with the occupational exposure limits. According to the results, the exposure to crystalline silica in all units was higher than the TLV of the ACGIH and NIOSH (0.025 mg/m^3). The highest exposure to crystalline silica was obtained in the raw materials grinding unit (0.044 mg/m^3) and the lowest exposure in the loading and packaging unit (0.027 mg/m^3). In general, the exposure to crystalline silica was lower in the final processes of cement production than the early processes.

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Reduced exposure to crystalline silica in the production process can be due to the application of heat on the raw materials and the release of crystalline silica radicals in this phase, or the addition of plaster to the raw materials and the reduction of the contribution of crystalline silica to the cement production. According to the samples obtained from the respiratory zones of workers in different parts of the plant, the results indicate that the minimum and maximum concentrations of respirable dust were obtained in the cement grinding unit (1.6 mg/m3) and the crusher unit (12.1 mg/m^3), respectively.[13] Smailyte et al. reported the development of gastric cancer in the workers of the cement industry.[14] The authors suggested that control measures should be taken to reduce the exposure of workers to cement dust. The exposure to respirable dust in our study in all units was higher than the TLV (1 mg/m^3). According to the statistical tests, the highest exposure to respirable dust was obtained in the crusher unit and the least exposure in the cement grinding unit.

In a crusher unit, dust is naturally released and because technical-engineering methods such as wet wiping and enclosing are not used, the highest amount of dust released is observed in this unit, but in other units dust emissions are greatly prevented because of the use of the most modern technology of the world in the equipment. Based on the results of a study conducted in a cement plant in Jordan, exposure in the packaging (bag filling) unit was 3.9 mg/m^3, which is very close to the results of the present study.[15] Abrons et al. in a study carried out in a Portland cement plant estimated the exposure to respirable dust at 0.57 mg/m^3.[16] In another study carried out in a cement plant in Mashhad, the average exposure to respirable dust was 23.13 mg/m^3.[16] In the study of Hazrati et al. in Ardabil Cement Plant, the average inhalable and respirable dust concentrations for individual samples were estimated at 13 and 58 mg/m^3, and for environmental samples at 27 and 154 mg/m^3, respectively.

On average, dust concentrations in 90% of environmental samples and in over 80% of individual samples are higher than the standard values of Iran.[17] In the study of Yang et al. in a cement plant in Taiwan, the exposure to respirable dust was obtained to range from 0.22 mg/m^3 to 1.26 mg/m^3,[17] and in the study of Mwaiselage et al., the range of exposure to respirable dust was 4-13.2 mg/m^3.[8] Therefore, it can be inferred that exposure to respirable dust in the studied cement plant is more consistent with the results of studies in other countries where cement plants use modern technology, but dust exposure in our study is much lower compared to other studies conducted in Iran probably because the studied factory has recently been established, its equipment is new, its maintenance is appropriate and appropriate industrial brushes are used to clean its units.

Steenland et al. concluded that exposure to crystalline silica at a concentration of 0.1 mg/m^3 for 5 years increases the risk of renal disease.[18] It is therefore necessary to control the exposure of workers to crystalline silica in all units given that the exposure to crystalline silica in these units was higher than the TLV and that silica has adverse effects on employee health.

Conclusion

The results of this study show that the concentrations of respirable crystalline silica and dust in all units are higher than the TLV and have the potential to damage workers working in these units. It is therefore necessary to take necessary measures by adopting technical-engineering methods and efficiently using appropriate respiratory masks in order to prevent the development of pulmonary and respiratory diseases, especially in the workers of units with high dust concentrations.

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