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Comparison of the Respiratory Health Effects of Traditional and Mechanical Brick Factories on the Workers Exposed to Dust

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ABSTRACT

Background: Brick manufacturing produces dust, occupationally exposing workers to hazardous substances (e.g., silica dust). Iran is a ceramic exporter. Few studies have assessed the exposure of workers to silica dust. This study investigated occupational exposure to crystalline silica dust, total respiratory dust, and spirometry performance in traditional and mechanical brick factories.
Methods: This cross-sectional study involved 70 workers in two brick factories (case) and 70 workers in a food industry (control) in 2016, who were monitored for crystalline silica and respirable dust exposure (NIOSH No.7602 and No.600). The exposure of 40 workers in the mechanical brick factory and 30 workers in the traditional brick factory to respirable crystalline silica and dust was compared with the controls. Data were analyzed using SPSS version 19.
Results: The mean respirable crystalline silica and general dust exposure in the mechanical and traditional brick factories was 0.47, 18.43, 0.651, and 28.27 mg/m3, respectively. The cases (brick factory) had lower FEV1%, FVC%, FEV1/FVC%, and PEF% indices compared to the controls.
Conclusion: The mean substance exposure was above the occupational limits. The pulmonary capacities in the traditional and mechanical brick factories had no significant difference. However, the pulmonary function capacities were significantly lower than the controls.

1. Introduction

Dust is produced during the manufacturing process of bricks before becoming mud when the adobe is drying and is transferred into the furnace and loading bricks. The workers of this industry are exposed to these hazardous processes at various stages. The amount of crystalline silica in clay is often within the range of 10-58% depending on the geographical location [1].

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The American Conference of Governmental Industrial Hygiene (ACGIH) has set the 3 mg/m3 as an occupational exposure limit when crystalline silica is less than 1% and there is no asbestos [2]. Ample evidence attests to the carcinogenicity potential of respirable crystalline silica in the workplace. In 1987, the International Agency for Research on Cancer (IARC) has classified silica in the A2 group (potential human carcinogen). Since 1997, this compound has also been categorized as group A1 (definite human carcinogen) [3, 4].

The occupational exposure limit for respirable crystalline silica has been determined to be 0.025 mg/m3 by the ACGIH and Iranian Ministry of Health, while the National Institute for Occupational Safety and Health has recommended the limit of 0.01 mg/m3, and the American Institute of Occupational Safety and Health has set the limit at 0.05 mg/m3 [1, 5, 6].

In the study by Azari et al., the mean occupational exposure was within the range of 0.132-0.343 mg/m3 in 10 industries, including stone cutting, casting, glass, asphalt, sand mining, construction, brick making, cement, and ceramic production. In addition, exposure to crystalline silica has been reported to be 0.169 mg/m3 in the brick industry, which is above the permissible level of occupational exposure in Iran [7]. In a study by Mohammadian et al., the concentration of respirable crystalline silica dust in a brick factory was estimated at 0.19 mg/m3, which is higher than the recommended exposure limit by the ACGIH [5].

On the other hand, Neghab et al. claimed that crystalline silica dust by the X-ray diffraction method was 69% in a ceramic factory in Fars province (Iran) [8], while Dehghan et al. reported that 243 tile factory workers in Yazd (Iran) were exposed to levels above the permissible limits [6].

According to the findings of Asgari Pour, the mean inhalable dust was 7.38±5.5 and 4.19 ± 3.40 mg/m3 in tile and ceramic manufacturing in Semnan (Iran), respectively. An indication of the exposure level is higher than the occupational exposure standards in Iran [9]. In the clay brick industry, dust exposure is considered to be an important risk factor in the work environment [10[].

Exposure to crystalline silica may lead to numerous adverse health effects, with silicosis reported to be the most common event in this regard [11]. However, the role of silicosis in the development of lung cancer associated with silica exposure remains controversial [12]. The disease leads to respiratory failure and death; even after the occupational exposure to crystalline silica has ceased, the condition may further develop in case of no treatment [13].

In another research, Kaushik *et al.* (2012) examined brick manufacturing workers, reporting significant correlations between oxidative parameters and pulmonary dysfunction, which could be due to silica oxidative stress and the subsequent lung damage [14]. Furthermore, Gholami et al. stated that the workers of brick furnaces had complaints of disorders in spirometric indices, which could be indicative of the early stages of silicosis in these individuals [1].

In another research, Neghab *et al.* (2009) observed a significant reduction in some parameters of pulmonary function and disorders in chest radiography [8]. Moreover, Yesar *et al.* (2009) reported the obstruction or limitation of respiratory disorders in workers, stating that the degree of the disorders was directly correlated with the duration of employment [15].

In the past, dust with less than 1% of quartz was assumed to be inert and intrusive, while the recent studies, which have been conducted within the past two decades, have reported higher percentages. Since dust was defined as inert in the past, exposure to high concentrations of dust in the long run would cause chronic obstructive pulmonary diseases or other pulmonary disorders [16]. In a study conducted by Das *et al.* (2014) the pulmonary capacity of 220 workers was investigated, and FVC, FEV1, and FEV1/FVC were reported to significantly decrease compared to the control group [17].

Several methods have been proposed for crystalline silica sampling and analysis by the scientific community, and three methods are more common comparatively, including spectroscopic colorimetry, infrared absorption spectroscopy, and X-ray diffraction. Since the preparation methods of crystalline silica analysis are mainly time-consuming, toxic, hazardous, and costly, the use of preparation methods with higher capability accessibility is essential. In the current research, we applied the optimized method of 7602, which has been validated by Tavakol *et al.* (2016) [18]. Our study was performed conducted considering the key role of Iran in clay brick export, as well as the limitations of the previous studies in assessing the exposure of brick factory workers to total respirable dust and crystalline silica and its association with pulmonary capacity.

The present study aimed to investigate the correlation between pulmonary capacity and occupational exposure to respirable dust and crystalline silica in the workers of two mechanical and traditional brick factories located in the southeast of Tehran, Iran.

2. Materials and Methods

This cross-sectional, analytical study was carried out in a mechanical factory and several traditional brick manufacturing workshops located in Tehran province (Gharchak and Varamin) in 2016. The sample size encompassed all the employees (n=70), including 40 machine workers and 30 traditional workers as the case group considering the inactivity of a large number of workshops in the region due to the current economic conditions in Iran. In addition, 70 workers of a food manufacturing plant without active exposure to dust or gases from similar socioeconomic classes were enrolled in the study as the control group.

The demographic data of the participants were collected using questionnaires. The individual monitoring of respirable dust and crystalline silica was performed in the groups of brick production and furnace packing. The production group consisted of soil transporters, manual pressing, and pressing assistants. In the mechanical factory, the participants were engaged in mechanical molding, lading, furnace cleaning, tram driving, masonry, and soil silo monitoring. The workers engaged in putting bricks in furnaces and packaging after cooking were not involved in brick manufacturing.

Atmospheric conditions (dry temperature, wet temperature, relative humidity, and air pressure) were measured simultaneously through individual sampling on different working days every hour four times per day, and the mean data was determined.

Crystalline silica dust and respirable dust were monitored using the improved method proposed by the National Institute for Occupational Safety and Health (NIOSH) 7602 [18] and NIOSH 0600, respectively. Each set was comprised of a calibrated SKC sampling pump (model: Delux , SKC, UK), equipped with a mixed cellulose ester (MCE) filter (SKC Inc., USA) and a 10-millimeter nylon cyclone (SKC) at the flow rate of 1.7 l/min. The weight of the filters was measured using the Sartorius analytical balance with the precision of 0.00001 gram before and after sampling, and dust concentrations were calculated using an equation [16].

$$C= \frac{(w2-w1)-(B2-B1)}{V} \times 10^{3}$$

For the analysis of the crystalline silica samples by Fourier-transform infrared spectroscopy (FT-IR), a standard curve must be drawn. To this end, the quartz purchased from Merck (Germany) was used for the preparation of the standard samples within the range of 20-340 micrograms per sample. The quartz was powdered into a special mill of the Atomic Energy Organization and prepared after screening with lower particle size than 20 microns. Following that, approximately four milligrams of the prepared silica powder was added to four milliliters of acetone as the solvent and placed in a magnetic stirrer in the suspension mode. Afterwards, the micro-sampler volumes of 20, 40, 60, 80, 140, 160, 200, 240, 270, and 340 microliters containing 20, 40, 60, 80, 140, 160, 200, 240, 270, and 340 micrograms of silica were poured on mixed cellulose ester (MCE) filters, and 200 milligrams of potassium bromide was added to the standard samples, which were placed in an electric furnace at the temperature of 600°C for two hours. The samples were homogeneous after exiting the furnace in the mortar, transferred to 13-millimeter metal molds, and converted into a tablet for two minutes using a press machine at the pressure of 20 MPa. The prepared tablets increased the mass of the crystalline silica and were scanned using the FT-IR spectrometer (model: WQF-510A). The calibration the line formula was calculated based on absorbance within the range of 710-825 wave numbers (cm^{-1}). The absorbance of the working environment samples was also calculated using the FT-IR software (Figure 1).

The pulmonary capacities of the workers in the case group (30 from the traditional and 40 from the mechanical factories) and workers of the food industry in the control group (n=70) were measured after the work shift in accordance with the AST standards. Furthermore, pulmonary function tests were performed using a spirometer (model: Bionet Cardio Touch 3000).

The normality of the data was determined using the Kolmogorov-Smirnov test. The pulmonary capacity of the workers and occupational exposure to total respirable dust and crystalline silica in the brick manufacturing workers were expressed as mean and standard deviation (SD). In addition, the exposure level in the workers of the mechanical and traditional factories and pulmonary capacity of the case and control groups were compared using the Mann-Whitney U test and t-test.

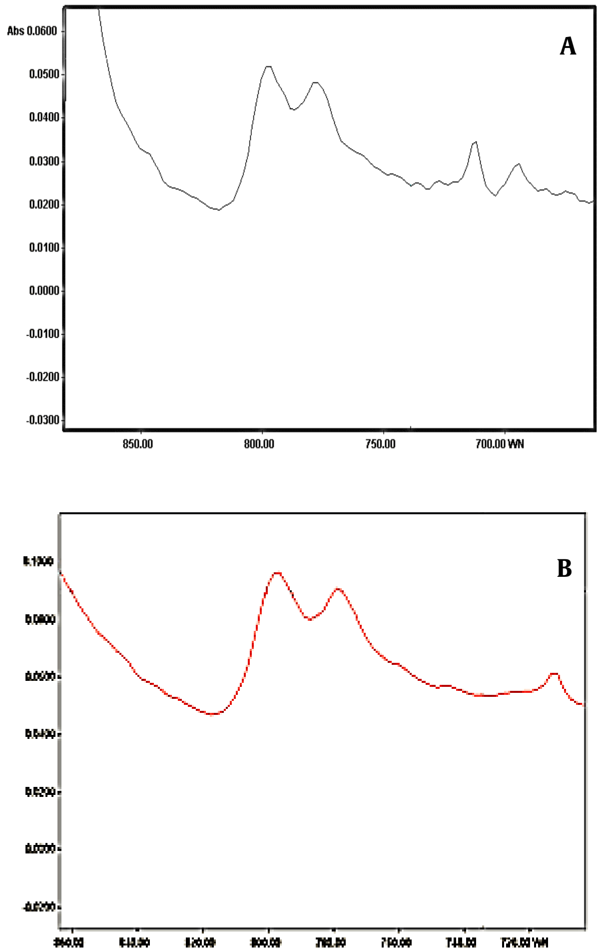

Figure 1: Spectrum Sample of Crystalline Silica Samples of A) Traditional Factories and B) Mechanical Factory Using FT-IR

3. Results and Discussion

The mean age of the workers was 38.82 and 30.47 years in the mechanical and traditional brick factories as the case group and 31.88 years in the control group (Table 1). Significant differences were observed between the demographic characteristics of the workers in the traditional and mechanical brick factories. Since the differences did not interfere in the study procedures, no statistical modulation was required. Table 2 shows the comparison of the demographic characteristics of the case group in both factories and the control group (food industry workers).

Table 3 shows the measured atmospheric parameters, including air temperature, relative humidity, and ambient pressure. According to the findings, the mean crystalline silica concentration was 0.474 mg/m^3 in the brick manufacturing industry (traditional factory: 0.651 mg/m^3, mechanical factory: 29.07 mg/m^3). Table 4 shows the comparison of the mean exposure to respirable dust and crystalline silica with the occupational exposure limits of the ACGIH and Iran (3 and 0.25 mg/m^3).

In the present study, a significant difference was observed in the occupational exposure to respirable dust between the traditional and mechanical brick factories (P= 0.001).

Table 1: Demographic characteristics of workers

Specification	Mechanical Brick factory(40)				*P*value	Traditional Brick factory(30)			
	SD	Mean	Min	Max		SD	Mean	Min	Max
Age	10.56	38.82	23	69	0.004	10.06	30.47	18	47
Height	5.97	173.40	161	188	0.003	5.48	169.23	160	181
Weight	16.46	84.08	59	125	< 0.001	9.26	68.47	56	92
BMI	9.54	29.05	20.19	81.04	< 0.001	3.79	23.77	14.70	30.01
work experience	6.66	11.32	1	25	< 0.001	5.44	6.13	1	20

Table 2: Demographic characteristics of workers

Specification	Case(70)				*P*value	Control(70)			
	SD	Mean	Min	Max		SD	Mean	Min	Max
Age	10.63	34.67	18	69	0.06	6.70	31.80	18	49
Height	6.09	171.61	160	188	0.55	7.97	171.74	157	197
Weight	15.80	77.39	56	125	0.91	15.36	75.83	52	120
BMI	8.02	26.79	14.70	81.04	0.39	4.31	25.65	18.65	41.52
Work experience	6.65	9.1	1	25	0.17	4.94	7.17	1	18

However, no significant difference was denoted in the exposure level of the workers to crystalline silica between the traditional and mechanical brick factories ($P = 0.107$). The pulmonary capacity of the workers of the traditional and mechanical factories was significantly different in terms of the FEF25-75% parameter, and significant differences were also observed in FEV1% and PEF% between the case and control groups (Table 5).

According to the results of the present study, the mean silica concentration in the traditional and mechanical brick factories was 0.474 mg/m^3, which was estimated at 0.651 mg/m^3 in the traditional factory and 0.027 mg/m^3 in the mechanical factory. It was also observed that 100% of the traditional factory workers and 97% of the mechanical factory workers were exposed to higher time-weighted average (TWA) crystalline silica, which is 2.9 times higher than the findings of Azari [7], 2.5 times higher than the findings of Mohammadian [5], and 2.4 times higher than the study by Asgaripour [9]. In the aforementioned studies, exposure to respirable crystalline silica was higher than the ACGIH TWA. In the current research, the mean crystalline silica concentration in the studied industry was 9.49 times higher than the OSHA standards, 18.69 times higher than the Iranian and ACGIH standards, and 47.4 times higher than the NIOSH standards.

The permissible limit of occupational exposure to respirable dust has been set at 3 mg/m^3 by the ACGIH and Occupational Health Committee of the Iranian Ministry of Health, assuming the lack of asbestos and lower crystalline silica content than 1%. Correspondingly, 68.5% of the workers in the present study were exposed to excessive crystalline silica. The mean exposure to total respirable dust in the studied industry was 18.43 mg/m^3 in the current research, which is 4.35 times higher than the value reported by Asgaripour *et al.* (2015) [9]. In the mentioned study, the total exposure to respirable dust was 6.14 times higher than the Iranian and ACGIH standards. According to the comparison of the workers in the traditional and mechanical factories in the present study regarding the total respirable dust exposure, the mechanization of the industry had decreased exposure to respirable dust by 3.2, which was observed in both groups. Compared to the crystalline silica dust, no significant difference was observed in this regard, while exposure in the traditional factories was 2.9 times higher than the mechanical factories, which reflects the impact of the mechanization of the industry on the reduction of exposure.

Considering the exposure of the workers in the brick manufacturing industry to dust and respirable crystalline silica and the subsequent adverse health effects on the respiratory system, the pulmonary parameters of the case and control groups were evaluated. According to the findings, the mean FVC%, FEV1%, FEV1/FVC%, and PEF% were significantly different between the case and control groups. In the present study, the pulmonary function parameters reduced in the case group compared to the control group, which is consistent with the study by Dehghan and Banibrata [6,17]. Accordingly, 12.9% of pulmonary function was restrictive, 8.6% was obstructive, and 4.3% was mixed, and significant differences were observed between the case and control groups in this regard ($P = 0.005$). In line with our findings, Yesar (2009) reported that the workers of brick manufacturing industries commonly had restrictive or obstructive pulmonary disorders compared to the controls [15].

Table 3: Results of measured atmospheric parameters

Atmospheric parameter	Mean (SD)
RH%	50.05 (13.32)
P(mmHg)	684.78(2.181)
Ta(C)	30.64(9.36)

Table 4: Comparison of individual exposure to respiratory and silica dust (mg/m^3)

Dust	Factory	Number	range	Mean ± SD	Times higher than standard	*P*value
Respiratory	Traditional	30	1.12-85.24	28.27± 23.05	9.42	0.001
	Mechanical	40	0.56-74.11	8.60 ± 17.16	2.86	
Silica	Traditional	30	0.015-2.82	0.651 ± 0.69	26.04	0.107
	Mechanical	40	0.054-1.19	0.297± 0.27	11.88	

Table 5: Pulmonary lung function parameters of traditional & mechanical and control groups (Mean ± SD)

Case & Control group		FVC%	FEV1%	FEV1/FVC%	FEF25-75%	PEF%
Case	Traditional	86.59(10.3)	79.76(13.6)	92.38(15.8)	89.62(20.2)	80.97(16.9)
	Mechanical	86.34(9.9)	81.02(15.8)	93.34(15.01)	102.72(22.4)	86.75(14.9)
Control		89.78(8.7)	88.18(9)	98.43(7.9)	97.14(22.5)	89.82(15.7)
*P*value		0.038	0.002	0.035	0.993	0.04

4. Conclusion

According to the results, the implementation of preventive measures is essential to the reduction of exposure to silica. Such examples are the development of efficient control systems and monitoring of the workers, which may prevent the incidence of silicosis and other disorders [19]. Therefore, these measures could be mechanized by the industry.

Authors' Contributions

M.R., created the conception and design of the work. Corresponding author; and F.Z., S.S., H.S., M.R., analyzed the data, drafted the manuscript; and revised the manuscript. All authors approval the final version to be published.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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