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ORIGINAL ARTICLE

The Effect of Cement Dust on the Lung Function in a Cement Factory, Iran

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ABSTRACT

The present study aimed at assessing cement dust exposure and its relationship to lung function at a Portland cement factory in Ilam, Iran. Lung function tests were carried out on 112 workers at the cement factory in 2008-09. Simultaneously 85 non exposed workers were used as control. Lung function tests were performed for all subjects. Additionally, total dust level was determined by the gravimetric method. Moreover, X-ray diffraction (XRD) technique was performed to determine the SiO_2 contents of the bulk samples. The arithmetic means (AM) of personal total dust were higher in the crusher (27.49 mg/m^3), packing (16.90 mg/m^3), kiln (15.60 mg/m^3), cement mill (13.07 mg/m^3), raw mill (10.31 mg /m^3) than in the maintenance (3.14 mg /m3), and administration (1.55 mg/m^3). The geometrical mean (GM) concentration was 12.12 mg/m^3, which were considerably higher than occupational exposure limit (OEL) of the American Conference of Governmental Industrial Hygienists (ACGIH), which is 10 mg/m^3. Based on the results, the probability of the long-term mean exposure exceeding to the OEL of 10 mg/m^3 for total dust were higher in the kiln (100%), packing (100%), cement mill (90%), crusher (73%), raw mill (60%) than in the maintenance (0%), and administration (2.3%). Ventiliatory function evaluation, as measured by the function parameters, showed that 35.7% of the exposed workers had abnormality in lung function compared with 5.7% of those unexposed. Statistical analysis of the data indicated that exposed workers compared to the unexposed groups showed significant reductions in Forced Expiratory Volume in one second percent (FEV_1), Forced Vital Capacity (FVC), and FEV_1/FVC (p< 0.05).

Keywords: *Portland cement dust, Total dust, Lung function impairment, Iran*

INTRODUCTION

Hydraulic cement or Portland cement is manufactured from a clay and limestone mixture that is calcined in kiln. Portland cement silicate is a class of hydraulic cements containing tri- and dicalcium silicate ($2CaO.SiO_2$ and $3CaO.SiO_2$) in addition to aluminum, tricalcium aluminate and iron oxide [1]. The final product usually contains silicate compounds (75% calcium silicates), 5-10% calcium aluminates, 5% calcium sulfate, 2-4% magnesium oxide, but little or no quartz. The silicates are minerals in which silicon and oxygen are combined with other elements [2].

The volume of cement production in Iran is very high and the production encountered with dusty operation and process. Annually production at the cement factory, reaches to 600,000 metric tons in 2009.

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Occupational exposure to cement dust is likely to vary in different production operations and process [1, 3].

Workers who work in the dusty production operation such as ore crushing and raw milling have high occupational exposure to total dust (59-95 mg/m^3) and respirable dust (20- 23 mg/m^3) [4, 5]. Kalacic (1973) reported that in the cement production process the aerodynamic diameter range is 0.05- 5.0 µm, which is produced by hearing ground cement rock or other limestone-bearing materials into a fused clinker that, is then ground into a fine powder [6].

Several clinical and epidemiological studies have shown an increased incidence of impairment of respiratory and a prevalence of respiratory symptoms among cement production workers [1, 7, 8]. Regarding potential adverse effects on the respiratory system [9-11], also Portland cement dust is considered to have little potential to induce adverse effects on the lung such as pneumoconiosis or fibrosis [12, 13]. However, Mwaiselage et al. (2005) showed a significant relationship between cumulative cement dust exposure and reduction of FVC and FEV_1 in 126 production workers in Tanzania [14]. Furthermore, the association between developing chronic obstructive pulmonary disease (COPD) and exposure to cement dust for more than 10 years at 10 mg/m^3 is well documented [4, 6, 14]. Although the main hazard in Portland cement production is dust, and respiratory tract disorders are the most important group of occupational diseases in this industry, evidence for associations between exposure to cement dust and either respiratory symptoms or functional impairment has not been conclusive [10, 12].

The main objective of this cross-sectional study was to investigate more thoroughly the relationship between occupational exposure to Portland cement dust and lung function impairment at a local cement-producing factory in Ilam, Iran.

MATERIALS AND METHODS

Study area and production process

This study was carried out in a cement factory that was located in Ilam, Iran. It is the biggest cement company in the west of the country, currently producing about 600,000 tons of Portland cement annually, and it has around 405 workers. The main process consisted of: crushing, raw milling, calcinations in a rotary kiln, cement milling, packing, maintenance and administration. The raw material limestone (60%) and red soil (40%) are crushed before entering the raw mill. The ground materials (fine particles) enter the rotary kiln (with calcining, transition and burning zones) where it is burning at 1300-1450 ºC to form clinker. The clinker is mixing with gypsum (4-5%) and ground in the clinker (cement) mill into Portland cement. The final product is stored in silos, bulk or packed.

Study design and subjects

Data collection in this cross-sectional study was conducted during the year 2008-2009. The studied sample of 129 male workers exposed to Portland cement dust was selected in a group–based strategy, representative measurements that collected on some individuals in the occupational groups (OGs). Similarly, 85 healthy males were control groups from non exposed employees (administration). Both groups were volunteer subjects. All of the participants were signed an informed consent form prior to the commencement of the study. The study was reviewed and approved by Ethics Committee of Tehran University of Medical Science.

Lung function testing

In this study the ventilatory function tests including FEV_1, FVC, PEF, ($FEF_{25-75\%}$), and FEV_1/ FVC were performed with the worker in standing position using a portable calibrated Vitalogrph spirometer (Vitalograph-COMPACT, Buckingham, England) according to the ATS recommendation for acceptability and reproducibility [15]. Three reproducible tracings were obtained and the best of the three spirogram was selected. The spirometer was calibrated in accordance to the standard protocol. The mean percentage of predicted values was based on age, weight, standing height and sex. Lung function tests were performed with the assistance of a trained, skilled technician under supervision.

Exposure assessment

The total dust was analyzed in 197 personal air samples, collected from the OGs dispersed in the factory. Personal air samples were collected on cellulose acetate filter membranes (Millipore type AA; 0.8 µm pore size; 37 mm diameter) using a closed-face filter holder. Air sampling was performed at a flow rate of 2 L/min using a personal sampling pump (model 224-PCX R3; SKC-West, Inc., Fullerton, CA, USA), calibrated by a digital automatic calibrator. The samples of total dust in the breathing zones of the workers were done during the 8-hour morning shift. Gravimetric analysis using a microbalance with a detection limit of 0.01 mg was employed. The results from the occupational exposure monitoring have compared with OEL of the American Conference of Governmental Industrial Hygienists (ACGIH), which is 10 mg/m^3 [6]. The x-ray difraction (XRD) technique was used to determine and estimate the silica phases and the SiO_2 content of the bulk sample.

Statistical Analysis

A database file was created in a personal computer and all statistical analyses were carried out with the Statistical Package for Social Sciences (SPSS) version 13.5 for Windows (SPSS Inc.,Chicago,IL,USA and Microsoft office Excel 2003. Comparison of demographic data among exposed and non exposed groups calculated using Student's t-test, one-way variance analysis for continuous variables. $p< 0.05$ was considered statistically significant.

Table 1. Demographic parameters of study subjects

Parameter	Exposed	Unexposed	*p*- value
Age (yr)	39.3±8.21**	37.4±7.11	0.81*
Weight (kg)	80.5±10.9	79.2±10.31	0.41*
Height (cm)	176±6.28	177±6.73	0.32*
N	112	85	

* There was no statistically significant difference between the means of the two groups. ** Values are given as the mean, with standard deviation

Table 2. Total dust exposure (mg/m^3) for the workers at a Portland cement factory in Iran categorized into seven OGs

	n[b]	Dust concentrations (mg/m^3)				Dust samples Exceeding OEL[a] N (%)
		GM (GSD)	AM	Median	Range	
Crusher	30	20.84 (2.10)	27.49	35.03	39.37-3.48	22 (73)
Raw mill	25	10.44 (2.20)	14.29	17.59	33.25-1.59	15 (60)
Kiln	10	16.78 (1.10)	16.86	17.23	19.45-14.42	10 (100)
Cement mill	10	14.90 (1.60)	16.68	18.25	19.01-2.37	9 (90)
Packing	22	17.29 (1.05)	17.31	17.29	19.28-15.22	22 (100)
Maintenance	15	3.77 (1.80)	4.50	5.19	8.07-1.06	0 (0)
Administration	85	0.88 (4.70)	1.83	1.27	13.78-0.04	2 (2.3)

Am, arithmetic mean; GM, geometric mean; GSD, geometric standard deviation.
[a] Occupational exposure limit (OEL) for total dust (10mg/m^3).
[b]Number of samples

Table 3. Lung function means in exposed and non-exposed subjects

Parameter	Exposed	Non-exposed	*p*-value
FVC	83.61±13.52	77.06±13.56	<0.01*
FEV_1	89.14±14.22	84.22±14.42	<0.01*
$FEF_{25-75\%}$	105.32±29.51	105.32±29.51	0.12
FEV_1/FVC	106.23±7.69	108.86±9.15	<0.03
PEF	89.17±17.72	91.62±15.53	0. 41

* Significantly different from referent value (Student's *t* test, $p< 0.05$).

RESULTS

Demographic parameters

Table 1 shows a summary of the demographic parameters of the exposed and non-exposed subjects. Comparison of the parameters of exposed with the control group was identical.

Exposure to cement dust

The AM, GM and GSD values of total dust in the personal samples are given in Table 2. As summarized in table 2, the crusher, packing, kiln, cement, and raw mill had higher GM total dust exposure than the maintenance and administration. The concentrations in 91 (49%) of the 197 personal samples exceeded the recommended OEL based on the ACGIH for nuisance respirable particles, which is 10 mg/m^3 of air [16]. Based on the finding, the probability of the long-term mean exposure exceeding to the OEL of 10 mg/m^3 for total dust were higher in the kiln (100%), packing (100%), cement mill (90%), crusher (73%), raw mill (60%) than in the maintenance (0%), and administration (2.3%) (Table 2).

Free Silica Content

The percentages of quartz ranged from 21.5 in the limestone to 22.5% in the bauxite. In this category, the percentages of quartz were 21.22% in the clinker and raw cement.

Lung function

The lung function parameters are presented in Table 3. The results indicated that the exposed workers had significantly lower ventilatory indices of FVC, FEV_1, and FEV_1/FVC than the control ($p< 0.05$). Ventiliatory function evaluation, as measured by the function parameters showed that 35.7% of the exposed workers had abnormality in lung function compared with 5.7% of those unexposed

DISCUSSION

Occupational exposure to cement dust is known to be an important factor in the causation of the chronic respiratory health effects [4, 6, 11, 14]. As mentioned above, none of the subjects had past medical or family history of respiratory illnesses or any other chest operations or injuries. Since there were no significant differences in the major confounding variables of age, past history of medical illnesses and family history, the decrements in the parameters of lung function and increased prevalence of respiratory symptoms. The results show that levels of total dust were highest in the crusher, packing, kiln, cement mill, and raw mill process (Table 2). Congruent with previous studies, this study confirms that cement factory workers have a higher occupational exposure to total dust in the crusher and packing processes [3, 13]. Abrons et al., (1988) reported that GM of total dust concentrations in the USA cement factory were 2.9 mg/m^3, which are lower than the amounts were found in the study [12]. In general, in this study, the AM and GM of total dust estimated in the factory (14.13 and 12.12 mg/m^3) was differ from those reported in some of the previous studies [12, 13, 17]. In the current study, 49% of the personal measurements exceeded the OEL of 10 mg/m^3 for total dust, and all of them sampled in the crusher, packing, cement mill, kiln and raw mill processes. This is consistent with the finding of Rappaport et al., (1995) [18] and Van Tongeren (2000) [19] in which the overexposure levels < 10% have indicated as an indicator of acceptable probability of exceedance in the raw mill, maintenance and administration. The major finding of this study is that the lung function parameters FVC, FEV_1, and FEV/FVC were significantly lower in exposed workers compared to control. This is consistent with the finding of [17, 20, 21], in which total dust levels were measured during portland cement manufacture. In contrast, some other studies did not find such effects probably due to low dust exposure among the cement workers [12, 13, 16]. As mentioned above, the FEV_1/FVC ratios were different significantly in the exposed workers compared to the control group. Interestingly enough, occupational inhalation exposure to cement dust is likely to induce minor degree of restrictive ventilatory impairment. This interpretation is in agreement with the finding of Kumar et al., [22] indicating ratio of FEV1/FVC in restrictive pulmonary diseases is close to the normal. Comparison of the demographic parameters of exposed with control group were identical, our results strongly suggest that it is important to match subjects using demographic parameters in lung function. This finding is agreement with the views expressed by Njoku and Anah (1999) [23]. Moreover, the prevalence of chronic respiratory symptoms were sighted to increase with increasing cumulative respirable dust exposure of 20.0 – 99.9 and ≤ 100.0 mg/m^3-year [24]. In general conclusion, the level of cumulative cement dust exposure estimated (11.41-423.98 mg/m^3 - year) is a high risk factor for developing chronic respiratory symptoms when working for many year in adverse condition. Data and information presented in current study might be useful for national programs of health surveillance and retrospective exposure assessment.

CONCLUSION

Occupational exposure to airborne cement dust were generally higher in the Portland cement manufacture process which in constructed in developing country such as Iran than in similar process in the countries with national programs of occupational health and hazard surveillance.

It can be also concluded that our data provide further evidence in favor of the nation that occupational exposure to Portland cement dust is associated with respiratory symptoms and functional impairments. Thus, national programs of cement dust exposure assessment and health surveillance are strongly recommended.

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