Effect of Exposure to Dust on Lung Function of Cement Factory Workers

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Summary

Exposure to Portland cement dust has long been associated with the prevalence of respiratory symptoms and varying degrees of airway obstruction in man. Apart from respiratory diseases, it was also found to be the cause of lung and laryngeal cancer, gastrointestinal tumours and also dermatitis. This study was done to investigate the effect of dust exposure on ventilatory lung function of Portland cement factory workers in Rawang, Selangor. Spirometry tests of 62 male workers (exposed to total dust concentration of 10180µg/m^3 and PM_{10} of 8049µg/m^3) and 70 subjects from UPM (exposed to mean total dust of 192µg/m^3 and PM_{10} of 177µg/m^3 - controls) revealed significant differences in spirometry values between the groups. The workers showed i) significantly lower $FEV_1\%$ and $FEF_{25-75\%}$, and higher FMFT, ii) reduced $FEV_1\%$ with increasing level of dust exposure and iii) higher prevalence of respiratory symptoms. Therefore, we suggest that exposure to dust in the cement factory leads to higher incidence of respiratory symptoms and impaired lung function.

Key Words: Lung function, Cement dust, Occupational hazard

Introduction

Dust has been demonstrated to have adverse effects on human health, particularly chronic obstructive lung disease, COLD. Anyone living or working in a dusty environment is exposed to dust, especially particles less than 10 µm (PM_{10})[1]. Exposure even of healthy persons to the pollutants may result in reductions in pulmonary performance. Chronic pulmonary problems afflict one in every five persons exposed to the pollutants. Such problems include reductions in spirometry values, increased incidence of chest tightness, and also wheezing[2].

The safety of working in a highly dusty environment is of serious concern. Among the populations who are severely exposed to this occupational hazard are workers in cement plants and quarries. Although a previous study for associations between exposure to cement dust and either respiratory symptoms or functional impairment has been inconclusive[3], some other studies are suggestive of a relationship between this occupational exposure and the reduction in ventilatory lung function in workers[4-5].

Exposure to Portland cement of smoking and non-smoking Yugoslavian cement workers had been reported to significantly increase the prevalence of chronic bronchitis and airflow obstruction[3,4]. Moreover, among such workers in Egyptian cement workers, the FEV_1/FVC ratio was significantly lower for the 30 - 49 year old smokers in dusty jobs[5]. After accounting for the effects of smoking and controls, Abron *et al*[3], on the other hand, found no close relationship between exposure to cement dust and respiratory symptoms or ventilatory function in USA cement workers. The workers studied were exposed to 570µg/m^3 respirable dust and 2900µg/m^3 total dust. However, the dust concentration in the Rawang cement plant is much higher, exceeding 3000µg/m^3 and 5000µg/m^3 for fine and total dust, respectively in some areas.

Despite the high concentration of dust in the Malaysian Portland cement plants, no investigation has yet been reported. Therefore, this study was performed to evaluate the impairment of pulmonary function and respiratory symptoms of Malaysian cement factory workers after exposure to dust in their occupational environment.

Materials and Methods

Subjects and locations

A cement factory in Rawang with a production capacity of 1.5 million tonnes per annum was chosen as the study area. Six sampling points were chosen for dust measurements and 62 workers were selected for spirometry studies. The subjects were also required to answer a set of questionnaires. Universiti Putra Malaysia (UPM) with 70 subjects including students and staff, was chosen as the control area.

Dust measurement

Two-stage high volume cascade impactor (130, Shimadzu) was used. It fractionated dust into fine ($<10\mu m$, PM_{10}) and coarse dust ($\geq 10\mu m$). The measurements were run continuously for two hours at 400L/min initial flow rate, and were done in both areas during working hours.

Lung function tests

Lung function tests were conducted during working hours using a spirometer (Vitalograph Ltd.) with the subjects in a standing position. Each subject performed at least three attempts of VC (vital capacity) and FVC (forced vital capacity) with a period of at least 1 minute between attempts. The highest readings plotted on the vitalogram were selected to obtain FEV_1 (forced expiratory volume in 1 second), $FEV_1\%$ (percentage of FEV_1 over FVC or VC, whichever was higher), $FEF_{25-75\%}$ (mid-expiratory flow rate) and FMFT (forced mid-expiratory flow time). The measurements were converted into BTPS unit[6].

Questionnaire

Modified questionnaires based on the American Thoracic Society[7] were distributed during working hours. All subjects were required to answer questions concerning their personal and medical characteristics, respiratory symptoms and history, smoking habits and occupational history with details about their work in the cement factory. The same questionnaire was also forwarded to the control subjects, with exemption of the last part on occupation.

Data analysis

Statistical analysis was performed by Student's t-test, correlation test and Anova in SPSS 8.0. Statistical significance was accepted at $p<0.05$.

Results

Sample Characteristics

The 62 male workers were local labourers and comprised of 57% Indians, 40% Malays and 3% Chinese. In order to match with the controls, only data on 32 non-smoking workers were accepted for analysis. Out of these, 20% were ex-smokers who had smoked between 3 and 12 cigarettes per day. Their tenure of work ranged from 0.5 to 38 years.

Seventy male controls from Universiti Putra Malaysia (UPM) were 50% Malays, 47% Indians and 3% Chinese. None were current-smokers, but 30% were ex-smokers who smoked between 1 and 7 cigarettes per day.

Table I shows the physical characteristics of the subjects. There was no significant difference in the physical characteristics of the control subjects and the non-smoking workers. Therefore, the difference in lung function between the two groups, if any, could be attributed to the occupational environment. Nevertheless, data on the smoking workers were also tabulated for comparison.

Dust Measurement

All sampling points for dust measurements were in the main factory except Quarry 2 which was 0.5km away. The source of dust particles in the factory were raw materials including gypsum, clinker, sand, iron ore, limestone and shale, and finished Portland cement or a mixture of both, depending on the materials used in the

Table I
Spirometry Values (mean ± SE) for Cement Workers and Controls

	Controls (Non-smoking)	Non-smoking Workers	Smoking Workers
No. of subjects	70	32	30
Age range (years)	23 - 52	20 - 54	24 - 52
Mean age (years)	36.63 ± 0.84	35.03 ± 1.26	36.83 ± 0.95
Height (cm)	166.58 ± 1.05	165.62 ± 1.78	164.87 ± 1.41
Ventilatory Function			
VC (L)	3.13 ± 0.09	2.92 ± 0.10	3.03 ± 0.10
FVC (L)	3.23 ± 0.09	3.20 ± 0.10	3.20 ± 0.13
FEV_1 (L)	3.02 ± 0.08	2.69 ± 0.11	2.75 ± 0.13
FEV_1%	92.11 ± 0.73	84.21 ± 2.06*	82.09 ± 2.61*
$FEF_{25-75\%}$ (L/s)	4.57 ± 0.20	3.71 ± 0.27*	3.33 ± 0.22*
FMFT (s)	0.42 ± 0.02	0.50 ± 0.04*	0.53 ± 0.05*
%FVC from predicted#	87.60 ± 1.96	88.04 ± 2.55	89.56 ± 3.90
%FEV from predicted#	102.74 ± 2.24	92.28 ± 3.74	95.74 ± 3.87

**significant differences compared to controls (unpaired t-test, $p \leq 0.05$)*
#formula for predicted values from Singh et al[8]

different sections. However, in this study, the dust particles were only sorted into "fine" and "coarse" fractions according to the size. None of the specific components were identified. The characteristics of these study areas are summarized in Table II.

Table II also shows the dust concentrations measured at the factory. It ranged from as low as 328.10µg/m³ total dust to as high as 10,180.25µg/m³. All measurements exceeded the Malaysian Air Quality Guidelines (MAQG). The highest dust exposure area in the factory in terms of both total and fine dust was Packing Plant 2 followed by Packing Plant 1, while the least exposed was in the Kiln 3 Section. The total and fine dust in UPM was well below the MAQG.

Ventilatory function

Table I shows the mean ventilatory function measurements of the whole study population. Significantly lower values were observed in FEV_1, FEV_1% and $FEF_{25-75\%}$ in the non-smoking workers compared to the control subjects. In addition, the non-smoking workers showed significantly lower values of both the FVC and FEV_1 compared to the predicted values (using formula by Singh *et al*[8]).

The above observations might be confounded by the wide variability in the physical characteristics of the workers, such as the wide range in age. In order to get homogeneous sets of samples, an analysis only on the 30 - 40 year-old workers and controls was carried out (Table III). These groups were homogeneous in terms of age and height. A matched group of smoking workers also did not differ in age and years of employment in the cement factory compared to the non-smoking group. Therefore, it is assumed that they were exposed to cement dust for an equal period throughout their working years.

Since height and age are among the determinants of lung function, it is expected that these groups show almost similar spirometry values with the controls of the same age group. However, significantly lower values of FEV_1% and $FEF_{25-75\%}$ were observed in the workers compared to control subjects. On the other hand, FMFT was found to be higher in the workers. This finding suggests that exposure to cement dust might lower the FEV_1 values, thus reducing the FEV_1% in the workers. As expected, the smoking workers of the same age group showed much lower values of FEV_1% compared to the non-smoking workers. The significantly greater difference between the values measured in the smoking

Table II
Dust Concentration at the Factory and at UPM

	Activities	Dust Particle	Dust Concentration ($\mu g/m^3$) Total	Mean ± SE
Factory				
Packing Plant 2	- packing, loading	Fine	8049.86	
Exp.: High	& checking finish	Coarse	2130.90	
	ed material	Total	10180.25	
		Ratio (F/C)	3.77	
				Exp.: High
Packing Plant 1	- packing, loading	Fine	3440.95	5745 ± 2304
Exp.: High	& checking	Coarse	3424.04	2777 ± 646
	- finished material	Total	6864.99	8523 ± 1657
		Ratio (F/C)	1.00	2.07
Cement Milling 3	-cement milling	Fine	2280.59	
Exp.: Medium	-water pump	Coarse	567.51	
	-clinker conveyor	Total	2848.10	
	-filling of material into hopper	Ratio (F/C)	4.02	Exp.: Medium
Quarry 2	- drilling, blasting,	Fine	2229.44	2255 ± 26
Exp.: Medium	- breaking, loading	Coarse	525.97	547 ± 21
	- haulage	Total	4.24	2802 ± 46
	- crushing	Ratio (F/C)	2755.41	4.12
Kiln 3	-raw meal prepa-	Fine	275.44	
Exp.: Low	..ration	Coarse	52.66	
	-kiln feeding	Total	328.10	
	-preheating	Ratio (F/C)	5.23	
	-cooling			Exp.: Low
Roller Press	-roller press	Fine	666.77	471 ± 196
Exp.: Low	-gravel bed filter	Coarse	181.43	117 ± 64
		Total	848.10	588 ± 260
		Ratio (F/C)	3.67	4.03
UPM		Fine	178	
		Coarse	15	
		Total	192	
		Ratio (F/C)	12.0	

**MAQG = Malaysian Air Quality Guidelines*
TSP (total suspended particulates) = 260µg/m³
PM10 (fine particulate fractions <10µm) = 150µg/m³
Exp. = dust exposure

workers and the control subjects suggests that smoking might have aggravated the effect of cement dust exposure on the workers lung function. The $FEV_1\%$ of the group of more than 40 years of age also exhibited the same trend, with a higher reduction shown by the smoking workers (despite the homogeneity in age, height and years of employment).

Table IV shows the association between spirometry values and the dust exposure status. There was a negative correlation between these parameters. Workers who worked in the lower dust concentration sections had higher spirometry values, particularly in FVC, FEV_1, $FEV_1\%$ and $FEF_{25\text{-}75\%}$. FMFT showed the reverse pattern, it is highest in the high exposure group.

Respiratory symptoms

The prevalence of cough, chest tightness and phlegm was significantly higher in cement workers compared to controls (Table V). One of the smoking workers (who had worked at the high exposure section for 14 years) was suffering from bronchitis after working in the factory. His spirometry measurements of FVC (52.04%), FEV_1 (38.13%) and $FEV_1\%$ (54.07%) were much reduced from the normal predicted values.

Discussion

Physiologically, only particles less than 10µm or PM_{10} (also termed as fine dust) are known to be inhaled into

Table III
Physical Characteristics and Spirometry Values of 30 - 40 Year-Old Workers and Control Subjects

	Control Subjects (non-smoking)	Non-smoking Workers	Smoking Workers
Number of subjects	21	20	36
Mean age (years)	34.33 ± 0.39	34.43 ± 0.57	35.65 ± 0.60
Mean height (cm)	167.33 ± 1.49	164.90 ± 2.47	165.55 ± 1.83
Years of employment	-	11.90 ± 1.02	11.25 ± 1.05
VC (L)	3.07 ± 0.12	2.94 ± 0.11	3.01 ± 0.11
FVC (L)	3.16 ± 0.12	3.20 ± 0.14	3.16 ± 0.16
FEV_1 (L)	3.02 ± 0.10	2.72 ± 0.13*	2.75 ± 0.16*
$FEV_1\%$	92.52 ± 1.08	85.39 ± 1.62*	81.09 ± 3.67*
$FEF_{25\text{-}75\%}$ (L)	4.48 ± 0.29	3.51 ± 0.25*	3.15 ± 0.26*
FMFT (s)	0.42 ± 0.02	0.47 ± 0.03*	0.56 ± 0.07*

**significant differences between the workers and controls (unpaired t-test, $p<0.05$)*

Table IV
Effects of Dust Exposure Status on Mean Spirometry Values of Cement Workers

Spirometry variables	Dust Exposure Categories		
	High	Medium	Low
Age (yrs)	38.61 ± 1.23	37.02 ± 1.13	36.17 ± 2.09
Height (cm)	163.06 ± 2.68	165.26 ± 1.17	166.08 ± 1.71
VC	2.92 ± 0.11	3.03 ± 0.08	2.79 ± 0.16
FVC	2.92 ± 0.13*	3.27 ± 0.10	3.14 ± 0.14
FEV_1	2.35 ± 0.18*	2.71 ± 0.09	2.70 ± 0.15
$FEV_1\%$	81.38 ± 4.40*	83.62 ± 1.58	85.97 ± 2.66
$FEF_{25\text{-}75\%}$	2.79 ± 0.30*	3.55 ± 0.19	4.06 ± 0.53
FMFT	0.61 ± 0.08*	0.49 ± 0.03	0.45 ± 0.06

**significant differences compared to low dust exposure group (t-test, $p<0.05$)*

Table V
Prevalence (%) of Respiratory Symptoms for Workers and Controls

Symptoms	Workers	Controls	
1.Cough (morning)	18 (25.0)	4 (5.7)	*
4 - 6 times/week	13 (18.1)	2 (2.9)	*
At least three months/year	9 (12.5)	4 (5.7)	
2.Phlegm (morning)	17 (23.6)	8 (11.4)	
4 - 6 times/week	11 (15.3)	3 (4.3)	*
At least three months/year	10 (13.9)	2 (2.9)	*
3.Chest tightness	14 (19.4)	4 (5.7)	*

**significant differences (x^2 test, $p<0.05$)*

the smaller bronchioles, thus affecting the ventilatory lung function and also responsible for the prevalence of respiratory symptoms[9]. In the Rawang cement factory, the highest exposure group was usually exposed to 8049.86µg/m^3 of fine dust, almost 54 times higher than the recommended limit set by the country (MAQG=150µg/m^3). Even in the lowest dust exposure area, the fine dust concentration of 275.44µg/m^3 was far beyond the limit.

The dust concentrations measured, particularly in the packing plants, were rather high compared to the same occupational exposure in other countries[3,10,11,12]. The high concentration of dust observed in the packing plants suggests that finished materials are the main sources of dust pollution in the factory. Being exposed to such high dust level, the workers showed significantly lower $FEV_1\%$ and $FEF_{25-75\%}$. Although not statistically significant, VC and FVC were also relatively lower in the workers, indicating adverse effect on their ventilatory function compared to controls. Their FEV_1 and $FEV_1\%$ were also lower compared to predicted values by Singh *et al*[8]. These findings differ from a few observations elsewhere. Rasmussen *et al*[13] found no differences in the spirometric measurements of Danish workers and other blue collar workers. Abu Dhaise *et al*[12] found that inhalation of cement dust did not markedly affect the lung function in Jordan cement workers. The same result was obtained by Yang *et al*[11] on Portland cement workers of Southern Taiwan. However, it must be emphasized that the highest dust exposure to those workers in Taiwan was only 1240µg/m^3 (a concentration categorized as "low" in the current study), whilst in Rawang, the highest was as high as 10 180µg/m^3.

Since two major determinants of lung functions, age and height, showed insignificant differences with the control population (constant variables), these reductions suggest that there is indeed an association between exposure to Portland cement dust and the ventilatory function level of the workers. A significantly reduced $FEV_1\%$ of the workers in the 30 - 40 year-old group compared to the controls in the same age group provided a clearer picture of the possible adverse effect of cement dust exposure on the workers. Moreover, a greater difference observed between the smoking workers and the controls compared to the non-smoking workers and the controls suggests that smoking might aggravate the adverse effect of cement dust on the workers' lung function. However, further studies should be carried out to quantify the effect of smoking alone on these spirometry parameters.

The notion that exposure to cement dust might possibly lower the lung function of the workers is further evidenced by the prominently lower FVC, FEV_1, $FEV_1\%$ and $FEF_{25-75\%}$ observed in the high exposure group, compared to the medium and low exposure groups. It is also in agreement with Yang *et al*[14] who observed significant reductions of ventilatory capacity (FVC, FEV_1, FEF_{50} and FEF_{75}) in dust-exposed Portland cement workers than in the control workers. In addition, Alakija *et al*[15] also observed lower FEV_1 in workers who were in closer contact with cement dust in Nigeria.

This study also failed to show any clear relationship between years of employment (assumed to be the period of exposure) and the lung function of the workers. However, the tenure of work is highly positively correlated with age. Therefore, reduction in spirometry values might not be attributed to exposure to cement dust alone, rather, due to an increase in age which might be a greater confounder. This observation is in agreement with the finding of Abu Dhaise *et al*[12] who stated that there is no tendency for the pulmonary function to decrease with tenure. Their study showed normal indices for all lung functions. However, Alakija *et al*[15] reported decrement in FEV_1, FVC and PEFR with years of service in their subjects.

Besides a decrease in the ventilatory lung functions, the workers also reported higher prevalence of respiratory symptoms, especially cough and phlegm. This is in agreement with the findings of many researchers worldwide, some of whom reported the occurrence of the symptoms even without significant changes in the lung function of the subjects studied[4,12,14,15].

Conclusion

Exposure to high concentration of Portland cement dust in a cement factory in Rawang is associated with decreased ventilatory lung function of the workers. The exposure was also found to be responsible for the increased prevalence of respiratory symptoms in the subjects. The effects are more pronounced in workers exposed to high dust level in packing plants. Therefore, there is an urgent need to improve the ambient air quality in the factories, and to draw up and implement new regulations regarding this occupational hazard in order to protect the workers. Besides the exposure, smoking could aggravate the effect of cement dust on the workers' lung function.

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