Assessment of pulmonary function of cement industry workers from West Bengal, India

Mandal (Majee) A.*, Majumder R.

Department of physiology, Raja Peary Mohan College, Uttarpara, Calcutta University, Hooghly, West Bengal, India

ABSTRACT

Purpose: To evaluate the basic pulmonary function parameters of cement industry workers from West Bengal. This cross-sectional study was carried out in a cement factory at Durgapur, district Burdwan on male cement industry workers and a control group of office workers.

Materials and methods: Ninety workers of different sections of cement industry and a control group of 141 office workers participated in this study. All the dynamic pulmonary function parameters were determined by spirometry. Number of years of exposure to cement dust, respiratory symptoms and smoking history if any were recorded.

Results: Nineteen percent of higher age group and 28% of lower age group workers had restrictive pulmonary diseases but smokers showed higher percentage of restrictive and combined respiratory diseases. Prevalence of chest tightness and chronic bronchitis were highest in packing, loading and storage department workers (OR=5.09 and 6.4 respectively) followed by maintenance workers of the workshop (OR=4.41 and 2.59 respectively) and then the production department workers. Logistic regression analysis of prevalence of respiratory symptoms at the multivariate level indicated that year of smoking and dust concentration were significantly associated with chronic bronchitis but smoking habit was significantly associated with chest tightness. In addition, 46% and 20% of higher and lower age group workers from high dust zone suffered from the liver problems. Multiple regression equations of pulmonary function parameters on the basis of age, body height, year of dust exposure and duration of smoking had been established but the equations were significant for FVC, FEV_1 and FEF $_{75\text{-}85\%}$.

Conclusions: This study demonstrated acute reduction of respiratory functions of cement industry workers from West Bengal. The work signified occupational health hazards of these cement industry workers which indicates an alarming situation if remain unchecked.

Key words: pulmonary function, cement workers, India, multiple regression, adjusted odds ratio

***Corresponding author:**
Anindita Mandal (Majee)
27 Mohanlal Mukherjee street
p.o-Uttarpara, Dist-Hooghly, West Bengal, India
pin-712258
Tel: 033 26636745(r)/26634155(o)/09433910161 (m)
e-mail:anindita11us@rediffmail.com

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INTRODUCTION

Industrial workers are prone to developing respiratory complication [1].This is due to the lung, with its extensive surface area of alveolar epithelium, and high blood flow rate (450ml/s or 12% of the body's total volume).It constitutes an important site of contact with the various materials contained in the enormous liters of air to which it is exposed daily. Hence, inhalation is the commonest route of entry into the body of occupational agents. This is why the lung is considered the most important organ in occupational medicine [2].

Cement is manufactured through a series of processes which include the mining, crushing, grinding of raw material, blending and kiln burning to form clinker, cement milling and packaging, loading etc. Dust is emitted mainly in packaging, loading and storage. The health risk posed by inhaled dust particles are influenced by the deposition pattern of the particles in various regions of the body mainly the respiratory system. Cement dust irritates the skin, the mucous membrane of the eyes and the respiratory system. Its deposition in the respiratory tract causes a basic reaction leading to increased pH values that irritate the exposed mucous membranes. Several researchers have reported that chronic occupational exposure to dust in cement factories leads to a greater prevalence of respiratory symptoms such as chest tightness, cough, sputum and dyspnoea and also reduces pulmonary function indices [3-7].

Exposure to high levels of cement dust irritates the nose and throat and causes difficulty with breathing [8]. Broncho constriction that occurs during the work shift in the cement workers who are exposed to relatively high dust concentration produce changes of pulmonary function. Reduction in FEV1, $FEV_{1\%}$ and FEF in the range of 25-75% has been noticed by Ali et al. [9]. However, contradictory reports had been presented by Vestbo and Rasmussen [10], Yang et al. [11] and Fell et al. [12], which indicated that neither this dusty environment increased the morbidity, nor it was associated with prevalence of respiratory diseases.

Very few studies had so far been conducted on pulmonary function of cement industry workers of India, but no such study has been carried out on cement industry workers from West Bengal. This has prompted us to conduct pulmonary functions of cement industry workers of West Bengal, India.

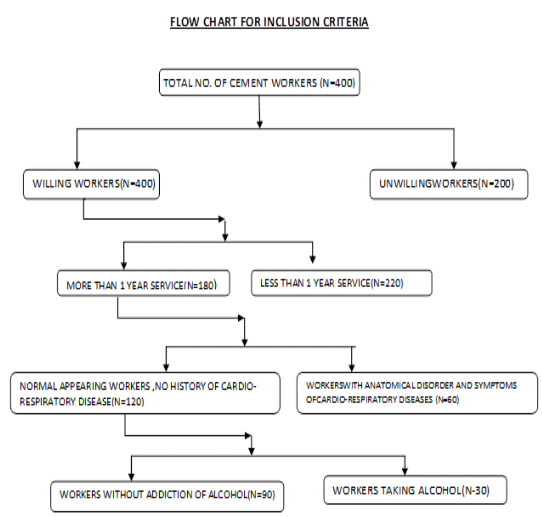
Therefore, the purpose of the present study was a) to evaluate the basic pulmonary function parameters of cement industry workers of West Bengal b) to compare the lung function parameters with the control group.

METHODS AND MATERIALS

Subjects

This cross-sectional study was carried out on 90 cement industry workers of a cement industry at Durgapur area, Burdwan district of West Bengal and they were divided into two age groups-18-35 yrs. and 36- 60 yrs. This study population was selected from a total of 400-450 workers exposed to dusty operation of grinding, rotary kiln, cranes, mills, storage and packing of cement industry. The control group of subjects (n=141) were selected from office workers, school and college employees, having no respiratory diseases. Age was recorded from their office register, smoking habits with particulars regarding year of smoking, duration of cement dust exposure, symptoms of respiratory diseases, family history of diseases were recorded by questionnaire. From questionnaire study it was also known that workers did not use protective equipments regularly.

Exclusion criteria were: unwilling workers, workers less than one year experience, subjects with deformities of the thoracic cage, vertebral column, musculoskeletal system, known cases of neuromuscular diseases, gross anaemia, diabetes mellitus, chronic obstructive pulmonary diseases, malignancy, and drug addicts. The subjects who were taking vigorous exercise regularly or had undergone abdominal, or chest surgery were excluded from the study.



Before starting this experiment individual consent was taken from each subject and approval from employer was also taken. The research design was approved by Institutional Ethical Committee of our institute. This cross-sectional study was conducted during August- September 2009. Myself and a group of experienced research scholars conducted this study and collected data. The subjects were taken from their departments with the assistance of the management, and study was conducted in their medical room within the factory premises. This study population consisted of 90 male workers of cement from a total of 400-450 workers exposed to dusty operation of grinding, rotary kiln, cranes, mills, storage and packing of cement industry.

Environmental Study: This cement production unit where we conducted our study produces cement mainly from grinding the clinker which was made in a closed chamber and it was a machine operated system that required no worker. But in the workshop where testing of cement had been made and the final was stored in silos, bulk or packed the emission as well as exposure to cement dust was maximum and it was a manual process. After that, loading had been done where high cement dust exposure had been found. The extent of concentration of air borne cement dust particles in grinding, coal mill, packing, store building, main gate, laboratory was collected from the factory's recent pollution report (Table I).It was found that Central Pollution Control Board recommendation for cement dust exposure was 150mg/Nm3 (from stag air)but it was 10mg/m3 according to American Conference of Governmental Industrial Hygienist [13].

Pulmonary Function Test: Forced vital capacity (FVC) and Forced Expiratory Volume in 1 sec (FEV_1), FEV_1%, Forced Expiratory Flow in 200-1200ml, $FEF_{25-75\%}$, $FEF_{75-85\%}$ were measured by Spirometer (Spirovit SP1) and Peak Expiratory Flow Rate (PEFR) was measured by Wright's Peak Flow Meter. The measurements were taken on the subject in standing upright position with the nose clip [9]. Three respiratory efforts were recorded and the highest value was used as lung function parameters. All volumes were adjusted to body temperature and pressure saturated with water vapour.

A modified questionnaire [14] was used for the respiratory symptoms. Emphasis was laid on enquiry regarding occurrence of chest tightness, chest compression, wheezing, cough and phlegm appearing in them and the frequency of occurrence, day of occurrence, duration and relationship with work were recorded. Age was recorded from factory record. Body weight was recorded by standard weighing machine without shoes, body height was recorded by standard procedure without shoes to nearest 0.5 cm. BMI was calculated from body weight (kg)/(body height in m)^2.

Statistical analysis

Mean, standard deviation and correlation between parameters were analyzed. Student's *t*- test was performed to compare the mean between two groups. Odds ratio and 95% Confidence interval had been calculated to analyze the risk factors. Mean, standard deviation and Pearson's product moment correlation between parameters were analysed. Student's *t*-test was performed after performing normality test by histogram, b_1 and b_2 method and by Chi square test and Q-Q Plot method to compare the mean between higher/lower age group, smoker and non-smoker, cement workers and control group and so on. Adjusted odds ratio (OR) and 95% confidence interval (CI) were calculated for occurrence of respiratory diseases (dependant variable) among smoker/ non smoker and compared the odds of exposure to cement dust of different level of year of exposure (<10 yrs/19-20 yrs/>20 yrs) [15]. Multiple Regression Equations was made based on age, body height, smoking habit and years of exposure.

RESULTS

Table 1 presents the concentration of air borne dust particles in different sections of a cement industry. The mean dust concentration (SPM) of different sections of cement industry such as Grinding section- cement mill 1,2,3,4, coal mill 1, packing machine 1.2 is 66.25μg/Nm^3 which was much less than recommended standard of our country (150μg/Nm^3). Besides, in store building, laboratory and main gate mean SPM concentration was 275.33 μg/m^3. So, the relative concentration of dust within the production department was high, It was classified as 'High dust Zone' and surrounding the production unit i.e., laboratory, main gate etc. was indicated as 'Low dust zone'.

Table 2 shows mean ± SD values of physical characteristics and pulmonary functions of the cement industry workers as also the control group. Body height, body weight and BMI values of cement industry workers were significantly lower in comparison to the control group. FVC, FEV_1 and FEV_1%, $FEF_{200-1200}$.$FEF_{25-75\%}$,, $FEF_{75-85\%}$ and PEFR values of control group (both the higher and lower age group) were significantly higher than cement industry workers. In case of smoker workers of the lower age group FEV_1%, FEF $_{200-1200}$, $FEF_{25-75\%}$, and in higher age group FVC, FEV_1, FEV_1%, FEF $_{200-1200}$, and PEFR values were significantly lower than control group. Conversely in non-smoker workers of lower age group all the pulmonary function values were significantly (p<0.01-0.001) higher in control group but only FEV_1 and FEV_1%, $FEF_{200-1200}$ and PEFR values of higher age group were significantly lower than control group.

Table 3 presents comparison of the physical and pulmonary function parameters of the high and low dust exposed group. It was found that only FVC,

FEV_1, $FEF_{75\text{-}85\%}$ and PEFR values of the lower age group working in the high dust zone were significantly lower than those working at the low dust zone.

Table 1. Concentration of air borne dust particle in different sections of a cement industry of West Bengal.

Within factory	**Suspended Particulate matters (SPM) μg/Nm^3**	**Standard prescribed by State Pollution Control Board for particulate matter emission (mg/Nm^3)**	
Grinding Mill 1	86	150	
Grinding Mill 2	62	150	
Grinding Mill 3	60	150	
Grinding Mill 4	90	150	
Coal Mill 1	78	150	
Packing Machine 1	46	150	
Packing Machine 2	38	150	
Loading	70	150	
Surrounding the factory	**Suspended Particulate matters (SPM) μg/m^3**	**SO_2 (μg/m3)**	**NO_X (μg/m3)**
Store Building	240	26	34
Laboratory	326	32	38
Main gate	260	28	32

mg/Nm3= amount of particulate matter in mg/m3 at 25^{0}c and 760 mmHg collected from Stag air

Only FVC and PEFR values in smokers of the higher age group working in the high dust zone were significantly higher than smokers working in the low dust zone and $FEF_{75\text{-}85\%}$ value of the higher age group working in high dust zone was significantly higher than low dust zone. Although in the production departments dust concentration was within the permissible limit, the probability of long term mean exposure exceeded the permissible limit.

Table 4 shows the mean ± SD values of pulmonary function parameters with the different level of duration of exposure. It was found that FVC values of 10-20 years, of exposure was significantly ($p<0.05$) lower than < 10-year exposure group but $FEF_{75\text{-}85\%}$ and PEFR values of >20 years of exposure decreased significantly ($p<0.01$) and ($p<0.05$) than <10 yrs. Exposure group.

Table 5 presents the correlation between pulmonary function parameters with year of exposure. It was found that correlation values of respiratory flow rates ($FEF_{25\text{-}75\%}$, $FEF_{75\text{-}85\%}$ and PEFR) were significant but negative when all cement workers were considered (n=90). But in few cases of correlation between FVC, FEV_1 and PEFR showed significant values when the cement workers were divided into higher and lower age group as well as smoker and non-smoker groups. This was probably due to small number of subject in each sub-groups of cement workers.

Table 6 shows correlation between pulmonary function parameters with duration of smoking, cigarette/day and pack-year.

As lower age group cement workers randomly selected were all non-smokers, higher age group smoker workers were considered in this correlation. Significant correlation had been found between FEV_1 and duration of smoking, $FEF_{25\text{-}75\%}$ with Pack-year and cigarette/day in high dust zone workers. Most of the correlation values were negative and insignificant probably due to less no. of subjects in each sub-groups of cement industry. i.e., high dust zone, low dust zone etc.

Table 7 presents the logistic regression equation of prevalence of respiratory symptoms. From the analysis of logistic regression equation and association of age, BMI, dust concentration, smoking habit and year of exposure with prevalence of chest tightness and chronic bronchitis at the multivariate level, it was observed both smoking habit of the workers ($p=0.01$) and dust concentration ($p=0.04$) were significantly associated with chronic bronchitis. Only smoking habit was significantly ($p=0.01$) associated with chest tightness.

Table 8 shows that among higher age group workers 19% had restrictive, 11% had obstructive and 9% had combined pulmonary diseases. While in the lower age group 28%, 8% and 11% had restrictive, obstructive and combined respiratory diseases respectively.

Smokers of both the higher and lower age group indicated more restrictive and combined respiratory diseases than their non-smoking counterparts. When all cement workers and control group were compared, it was found that 22% cement workers had restrictive lung disease in comparison to 10% control group individuals while 10 % obstructive lung disease had been found in cement workers in comparison to 2% in the control group.

Table 2. Mean ± SD values of different physical parameters and pulmonary functions of cement workers and control group from West Bengal.

	Cement worker						**Control**					
	LA			**HA**			**LA**			HA		
	(All) (n=36)	S (n=13)	NS (n=23)	(All) (n=54)	S (n=21)	NS (n=33)	All (n=60)	S (n=21)	NS (n=39)	All (n=81)	S (n=26)	NS (n=55)
Age (yr)	29.42 ±4.62	29.23 ±5.26	29.52 ±4.34 *****	48.02 ±6.25	48.71 ±5.99	47.58 ±6.46	24.9 ±6.06	26.76 ±6.36	23.90 ±5.72	47.83 ±7.30	47.73 ±7.76	47.87 ±7.14
Weight (kg)	57.99 ±9.65 ***	57.85 ±8.46	58.07 ±10.45	60.4 ±10.76 *****	59.05 ±10.75 **	61.30 ±10.83 **	62.7 ±10.76	63.8 ±12.17	62.13 ±10.03	67.1 ±10.58	67.6 ±11.23	66.9 ±10.35
Height (cm)	165.49 ±6.29 ***	164.09 ±6.68	166.29 ±6.07	162.7 ±6.88 ****	162.45 ±5.94 *	162.82 ±7.50 *	168.43 ±5.95	168.4 ±5.97	168.46 ±6.02	166.40 ±7.35	166.5 ±6.89	166.33 ±7.62
BMI (kg/m^2)	21.14 ±3.13 ***	21.44 ±2.30	20.98 ±3.55	22.81 ±3.64 **	22.34 ±3.59 *	23.12 ±3.70	22.10 ±3.65	22.48 ±4.06	21.89 ±3.44	24.21 ±3.18	24.29 ±2.9	24.17 ±3.33
FVC (L)	3.57 ±0.77 *****	3.53 ±0.64	3.59 ±0.84 *****	3.41 ±0.71 **	3.23 ±0.60 **	3.53 ±0.76	4.30 ±0.61	4.19 ±0.45	4.35 ±0.67	3.69 ±0.61	3.7 ±0.61	3.68 ±0.62
FEV_1 (L)	2.96 ±0.78 *****	2.91 ±0.57	2.97 ±0.92 *****	2.78 ±0.68 *****	2.68 ±0.55 **	2.84 ±0.75 **	3.91 ±0.64	3.82 ±0.53	3.96 ±0.70	3.17 ±0.56	3.12 ±0.58	3.2 ±0.56
FEV_1%	82.15 ±12.93 *****	81.8 1±12.2 ****	81.41 ±14.12 *****	79.5 ±14.17 *****	79.08 ±9.39 ***	79.75 ±16.66 ****	90.98 ±6.31	90.96 ±5.45	90.99 ±6.8	86.09 ±6.93	84.33 ±7.8	86.92 ±6.39
$FEF_{200-1200}$ (L/min)	4.53 ±1.97 *****	4.4 ±1.47 *****	4.57 ±2.28 *****	4.63 ±1.92 *****	4.54 ±1.79 *****	4.69 ±2.03 *****	7.44 ±1.98	7.44 ±1.84	7.45 ±2.08	6.94 ±1.89	6.65 ±1.94	7.09 ±1.87
$FEF_{25-75\%}$ (L/min)	3.63 ±1.57 *****	3.51 ±1.38 ****	3.67 ±1.74 *****	3.11 ±1.37 *****	2.87 ±1.51 *	3.27 ±1.28 *	5.04 ±1.34	4.92 ±1.2	5.11 ±1.42	3.80 ±1.27	3.54 ±1.16	3.93 ±1.31
$FEF_{75-85\%}$ (L/min)	1.94 ±0.98 *	2.08 ±0.81	1.85 ±1.09 ***	1.31 ±0.77	1.23 ±0.92	1.36 ±0.66	2.34 ±0.98	2.16 ±1.04	2.43 ±0.95	1.33 ±0.62	1.2 ±0.48	1.39 ±0.67
PEFR (L/min)	487.5 ±72.87 ****	510.77 ±42.71	470.0 ±89.29 ****	452.78 ±74.52 *****	419.05 ±87.92 *****	474.24 ±56.07 *****	530.5 ±59.96	533.33 ±57.13	528.97 ±62.10	517.04 ±59.13	511.15 ±54.14	519.82 ±61.63
Exposure (Yr.)	8.61 ±5.76	6.85 ±6.35	9.61 ±5.28	24.19 ±7.95	25.76 ±7.44	23.16 ±8.22	6.93 ±4.03	6.25 ±4.6	7.02 ±3.97	25.77 ±9.96	24.46 ±9.71	29.81 ±36.29
C/Day	-	6.08 ±3.25	-	-	7.52 ±8.34	-	-	4.50 ±3.15	-	-	10.87 ±7.95	-
Pack-Yr.	-	221.81 ±118.71	-	-	274.60 ±304.34	-	-	164.25 ±114.84	-	-	396.79 ±290.13	-
Duration Smoking	-	22.60 ±9.30	-	-	11.31 ±8.33	-	-	7.72 ±5.87	-	-	22.78 ±9.75	-

*p<0.10, **p<0.02, ***p<0.05, ****p<0.01, *****p<0.001 S=Smokers, NS=Non-Smoker,HA=Higher age group, LA= Lower age group.

Table 9 shows the prevalence of chest tightness and chronic bronchitis of workers of different departments of cement industry with odds ratio and 95% confidence interval. It was found that with respect to others, e.g.; sweeper, security workers etc. occurrence of the above respiratory abnormalities were the highest in packing, loading and storage department workers (OR=5.09) followed by workers working in workshop i.e.; maintenance (electrical and mechanical) workers (OR=4.41) and then the production department workers (OR=1.6) for chest compression. Similarly, in case of chronic bronchitis the highest occurrence was found in packing, loading and storage department workers (OR=6.4) followed by workshop workers (OR=2.59) and then production workers (OR=1) indicating that workers engaged in packing, loading and storage had five times more risk in developing chest tightness and 6 times more risk in occurrence of chronic bronchitis. However, workers engaged in the workshop, i.e.; maintenance workers showed four times and 2.5 times more risk in developing chest compression and chronic bronchitis respectively.

Table 3. Mean ± SD values of different physical parameters and pulmonary functions of cement workers of low and high dust exposure from West Bengal.

	Lower Age Group				**Higher Age Group**					
	High Dust Zone	**Low Dust Zone**			**High Dust Zone**			**Low Dust Zone**		
	All/NS (n=5)	All (n=31)	S (n=13)	NS (n=18)	All (n=13)	S (n=6)	NS (n=7)	All n=41)	S (n=15)	NS (n=26)
Age (yr)	32.4 ±3.21	28.94 ±4.67	29.23 ±5.26	28.72 ±4.34*	49.69 ±5.51	50.33 ±4.84	49.14 ±6.36	47.49 ±6.44	48.07 ±6.43	47.15 ±6.55
Weight (kg)	48.5±11.26	59.52 ±8.62 **	57.85 ±8.46	60.72 ±8.78 **	62.7 ±10.27	64.3 ±7.68	61.36 ±12.53	59.70 ±10.93	56.93 ±11.29	61.29 ±10.61
Height (cm)	158.04±3.93	166.70 ±5.78 ****	164.09 ±6.68	168.58 ±4.29 *****	163.2 ±6.39	164.7 ±6.98	161.86 ±6.07	162.52 ±7.09	161.56 ±5.48	163.08 ±7.92
BMI (kg/m^2)	19.42 ±4.42	21.42 ±2.87	21.44 ±2.30	21.41 ±3.29	23.48 ±3.04	23.69 ±1.96	23.3 ±3.90	22.60 ±3.83	21.80 ±3.99	23.07 ±3.72
FVC (L)	2.59 ±0.88	3.73 ±0.63 *****	3.53 ±0.64	3.88 ±0.59 *****	3.65 ±0.74	3.65 ±0.49	3.65 ±0.95	3.36 ±0.66	3.11 ±0.44 ***	3.50 ±0.72
FEV_1 (L)	2.21 ±0.93	3.08 ±0.69 **	2.91 ±0.57	3.21 ±0.76 ***	2.91 ±0.69	2.89 ±0.47	2.93 ±0.87	2.73 ±0.68	2.60 ±0.57	2.81 ±0.73
FEV_1%	83.66 ±11.51	81.91 ±13.30	81.81 ±12.2	81.98 ±14.39	80.31 ±12.07	79.42 ±9.76	81.07 ±14.52	79.23 ±14.90	78.95 ±9.58	79.39 ±17.43
$FEF_{200-1200}$ (L/min)	3.60 ±2.62	4.68 ±1.85	4.40 ±1.47	4.89 ±2.10	4.14 ±1.66	4.20 ±1.55	4.10 ±1.87	4.79 ±1.99	4.67 ±1.91	4.85 ±2.07
$FEF_{25-75\%}$ (L/min)	2.78 ±1.65	3.77 ±1.54	3.51 ±1.38	3.95 ±1.67	3.38 ±1.29	3.51 ±1.42	3.26 ±1.27	3.03 ±1.41	2.62 ±1.51	3.27 ±1.31
$FEF_{75-85\%}$ (L/min)	1.08 ±0.45	2.08 ±0.97 ***	2.08 ±0.81 *	2.08 ±1.10	1.75 ±1.06	1.66 ±1.19	1.83 ±1.03	1.17 ±0.60 **	1.06 ±0.78	1.23 ±0.48 ***
PEFR (L/min)	428 ±79.81	497.10 ±68.27 ***	510.77 ±42.71	487.22 ±81.80	482.31 ±52.94	480.0 ±60.99	484.29 ±49.95	443.41 ±78.38 *	394.67 ±86.51 ***	471.54 ±58.22
Exposure (yr)	11.8 ±4.71	8.10 ±5.81	6.85 ±6.35	9.0 ±5.39	28.0 ±4.94	30.0 ±2.61	26.86 ±6.15	22.9 ±8.32	24.07 ±8.12	22.0 ±8.52
C/Day			6.08 ±3.25			12.0 ±11.82			5.73 ±6.12	
Pack-Yr.			221.81 ±118.71			437.92 ±431.06			209.27 ±223.50	
Duration of Smoking			22.60 ±9.30			9.60 ±8.20			12.38 ±8.78	

*p<0.10, **p<0.02, ***p<0.05, ****p<0.01, *****p<0.001 S=Smokers, NS=Non-Smokers.

Table 10 shows multiple regression equations of pulmonary function parameters based on age, height, year of dust exposure, cigarette/day, Pack-year and duration of smoking. However, the equations were significant for FVC, FEV1, FEF25-75%, $FEF_{75-85\%}$.

Table 4. Mean ± SD values of different physical parameters and pulmonary functions of cement workers of different duration of exposure.

	Duration of Exposure		
	<10 yrs. (n=24)	**10-20 yrs. (n=32)**	**>20 yrs. (n=34)**
Age	29.20±6.97	36.94±5.49 ****	51.97±3.23 ****
Weight	56.54±9.96	57.36±9.68	63.47±10.22 **
Height	165.23±6.48	162.74±6.35	163.79±7.31
BMI	20.67±3.25	21.62±3.06	23.69±3.62 ***
FVC	3.65±0.78	3.26±0.72 *	3.56±0.68
FEV1	3.00±0.70	2.85±0.72	2.74±0.74
FEV1%	80.78±11.22	83.93±12.94	77.21±15.39
FEF200-1200	4.73±1.91	4.51±1.97	4.57±1.95
FEF25-75%	3.69±1.61	3.42±1.32	2.96±1.47
FEF75-85%	1.91±0.84	1.63±1.00	1.25±0.78 ***
PEFR	486.67±81.28	473.75±75.68	445.88±67.60 *
Exposure	4.38±2.65	16.16±3.15 ****	29.39±3.22 ****

* p<0.05, **p<0.02, ***p<0.01, ****p<0.001

In addition, 28% and 17% of workers from the higher and lower age group respectively complained of pain in knee, ankle, and pelvic region of the body while 43% and 44% of the study participants from the higher and lower age group respectively suffered from liver problems.

Table 5. Correlation between pulmonary function parameters with a year of exposure to air borne cement dust to workers.

Duration of exposure																	
ALL		**Lower Age Group**							**Higher Age Group**								
PARAMETERS	ALL Cement workers N=90	**All**			**High Dust Zone**	**Low Dust Zone**			**All**			**High Dust Zone**			**Low Dust Zone**		
		ALL	S	NS	ALL/ NS	ALL	S	NS	ALL	S	NS	ALL	S	NS	ALL	S	NS
		n=36	n=13	n=23	n=5	n=31	n=13	n=18	n=54	n=21	n=33	n=13	n=6	n=7	n=41	n=15	n=26
FVC	-0.05	-0.40 **	-0.21	-0.54 ***	-0.86	-0.26	-0.21	-0.44	0.27 *	0.47 *	0.25	-0.46	-0.56	-0.47	0.32 *	0.31	0.41 *
FEV_1	-0.14	-0.26	-0.01	-0.43 *	-0.84	-0.10	-0.01	-0.25	0.01	0.03	0.04	-0.70 **	-0.76	-0.73	0.13	-0.01	0.27
$FEV_{1\%}$	-0.11	0.08	0.24	-0.13	-0.55	0.13	0.24	0.06	-0.21	-0.08	-0.25	-0.41	-0.40	-0.42	-0.18	-0.07	-0.21
FEF 2-1.2 lit	-0.03	-0.12	0.02	-0.24	-0.82	0.03	0.02	-0.003	-0.09	0.01	-0.13	-0.23	-0.22	-0.28	-0.01	0.09	-0.04
FEF 25-75%	-0.21 *	-0.21	0.16	-0.46 *	-0.80	-0.09	0.16	-0.32	-0.12	0.07	-0.22	-0.39	-0.02	-0.69	-0.11	-0.04	-0.12
FEF 75-85 %	-0.32 ***	-0.24	0.15	-0.42 *	-0.79	-0.14	0.15	-0.33	-0.05	0.02	-0.07	-0.45	0.46	-0.89 ***	-0.08	-0.22	0.08
PEFR	-0.25 **	-0.37 *	-0.09	-0.50 **	-0.73	-0.27	-0.09	-0.35	-0.01	0.27	-0.15	-0.02	-0.23	0.09	-0.10	0.16	-0.22

* p<0.05, ** p<0.02, *** p< 0.01, **** p<0.001 ALL= All the workers of lower / higher age group. S= Smoker workers. NS= Non-smoker workers

Table 6. Correlation of different pulmonary function parameters with cigarette/day, pack-year and duration of smoking of the cement workers.

	Parameters	Lower Age Group Workers	Higher Age Group Workers		
		All/Low Dust Zone	All	High Dust Zone	Low Dust Zone
		(n=13)	(n=21)	(n=6)	(n=15)
Cigarette/ Day	FVC	-0.63*	0.14	0.51	-0.31
	FEV_1	-0.57*	0.19	0.45	-0.06
	$FEV_{1\%}$	0.20	-0.10	0.01	-0.22
	$FEF_{2\text{-}1.lit}$	0.41	0.22	0.71	0.07
	$FEF_{25\text{-}75\%}$	0.38	0.33	0.89**	-0.11
	$FEF_{75\text{-}85\%}$	0.06	0.42	0.89**	-0.20
	PEFR	-0.47	0.07	-0.06	-0.13
Pack-Year	FVC	-0.63*	0.14	0.51	-0.31
	FEV_1	-0.57*	0.19	0.45	-0.06
	$FEV_{1\%}$	0.20	-0.10	0.01	-0.22
	$FEF_{2\text{-}1.lit}$	0.41	0.22	0.71	0.07
	$FEF_{25\text{-}75\%}$	0.38	0.33	0.89**	-0.11
	$FEF_{75\text{-}85\%}$	0.06	0.42	0.89**	-0.20
	PEFR	-0.47	0.07	-0.06	-0.13
Duration of Smoking	FVC	0.47	-0.16	0.79	-0.39
	FEV_1	0.52	0.18	0.92***	-0.03
	$FEV_{1\%}$	0.15	0.01	0.34	-0.13
	$FEF_{2\text{-}1.lit}$	0.04	0.06	0.65	-0.17
	$FEF_{25\text{-}75\%}$	-0.05	0.04	0.80	-0.08
	$FEF_{75\text{-}85\%}$	-0.13	0.07	-0.44	0.16
	PEFR	0.22	-0.19	-0.06	-0.16

** $p<0.02$, *** $p< 0.01$

Table 7. Logistic Regression Equation for respiratory symptoms.

		Chest Tightnes					Chronic Bronchitis				
		Coefficients	SE	P value	OR	95% CI	Coefficients	SE	P value	OR	95% CI
Age		0.03	0.05	0.57	1.03	0.94-1.12	0.08	0.06	0.16	1.08	0.97-1.21
BMI		0.06	0.08	0.44	1.06	0.91-1.23	0.24	0.09	0.01*	1.27	1.06-1.52
Smoking Habit		1.46	0.52	0.01*	4.29	1.56-11.77	1.01	0.60	0.09	2.74	0.85-8.81
Dust concentration		0.62	0.65	0.34	1.85	0.52-6.64	1.49	0.71	0.04*	4.42	1.09-17.93
Year of Exposure	10-20 yrs.	-0.11	0.76	0.89	0.90	0.20-4.01	-0.35	0.91	0.71	0.71	0.12-4.24
	>20 yrs.	-0.47	1.27	0.71	0.63	0.05-7.58	-1.43	1.45	0.33	0.24	0.01-4.13

OR= Odds ratio, CI= confidence interval SE= standard Error

Table 8. Prevalence of respiratory diseases in cement industry workers and control group from *West Bengal*

	Cement workers														Control n=141	
	Lower Age Group						Higher Age Group						All (n=90)			
	All		Smoker		Non-Smoker		All		Smoker		Non-Smoker					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Normal	19	53	6	46	13	56	33	61	10	48	24	73	52	58	112	79
Restrictive	10	28	4	31	6	26	10	19	5	24	4	12	20	22	26	19
Obstructive	3	8	1	8	2	9	6	11	2	10	4	12	9	10	3	2
Combined	4	11	2	15	2	9	5	9	4	18	1	3	9	10	-	-

Table 9: Prevalence of chest compression, chronic bronchitis among workers exposed to cement dust in different departments of cement mill with Odds ratio and 95% confidence interval.

Departments		No. Examined	Chest compression				Chronic bronchitis			
			No	**(%)**	**OR**	**95%CI**	**No**	**(%)**	**OR**	**95%CI**
HD	**Packing, Loading, cleaning**	18	7	38.89	5.09	0.52-50.01	8	44.44	6.4	0.66-62.40
LD	**Production**	18	3	16.67	1.6	0.14-18.0	2	11.11	1.0	0.08-12.76
	Workshop	45	16	35.56	4.41	0.51-38.53	11	24.44	2.59	0.29-23.06
	Others	9	1	11.11	-	-	1	11.11	-	-

HD=High Dust Zone, LD=Low Dust Zone, Production= Includes all the departments of grinding, Workshop = maintenance departments like electrical , mechanical etc., others= sweeper, security persons etc.

Table 10:Multiple regression equations of pulmonary function parameters on the basis of age, height, year of exposure and duration of smoking.

Parameters	Constant	Age (yrs.)	Height (cm)	Exposure (yrs.)	Duration of Smoking (yrs.)	R	R^2
FVC	-1.84	-0.01	+0.03	+0.003	-0.01	0.34*	0.12
FEV1	-1.44	-0.02	+0.03	+0.02	-0.001	0.38**	0.14
FEV_1%	+87.93	-0.56	+0.05	+0.42	-0.01	0.23	0.05
$FEF_{200-1200}$	-2.08	+0.02	+0.04	-0.02	-0.01	0.15	0.02
$FEF_{25-75\%}$	0.97	-0.03	+0.02	-0.004	-0.02	0.27	0.07
$FEF_{75-85\%}$	2.72	-0.04	+0.002	+0.01	-0.0002	0.39***	0.15
PEFR	+402.86	-1.70	+0.87	-0.41	-0.57	0.30	0.09

* p<0.05, **p<0.02, ***p<0.01

Among them 46% of workers from the higher age group and 20% of workers of lower age group working in the high dust zone reported liver problem (Figures 1, 2, 3, and 4).

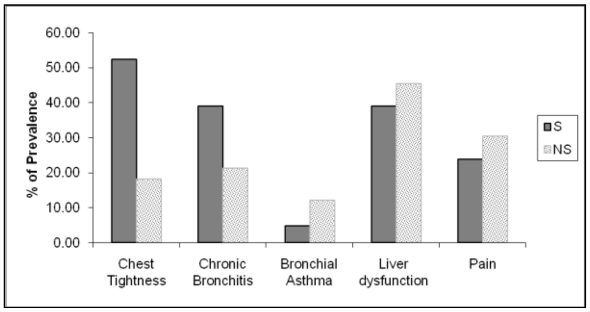


Figure 1. Prevalence of chest compression, cough, pain, liver dysfunction of lower age group of smoker(s) and non-smoker (Ns) of cement workers of West Bengal.

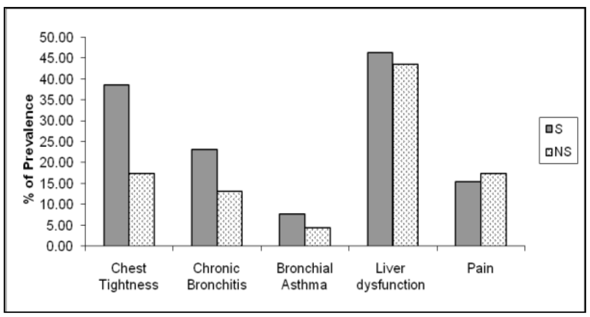


Figure 2. Prevalence of chest compression, cough, pain, liver disfunction problem of higher age group of smoker (s) and non-smoker (Ns) of cement workers of West Bengal.

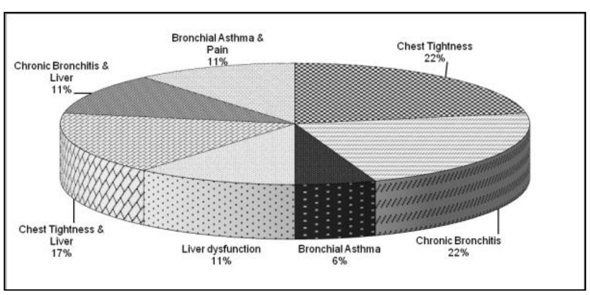


Figure3. Prevalence of chest compression, pain, liver problem and skin problem of cement industry workers of hazardous zone.

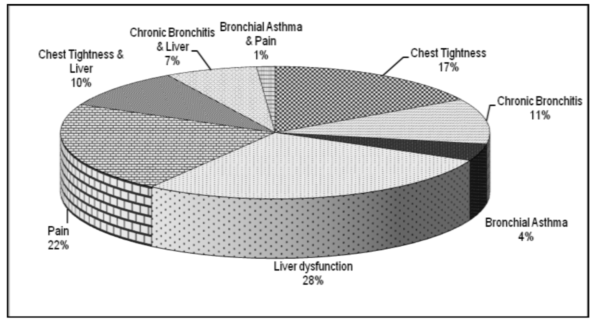


Figure 4. Prevalence of chest compression, pain, liver problem and skin problem of cement industry workers of non-hazardous zone

DISCUSSION

The major finding of this study was having that significant reduction in all pulmonary function parameters in comparison to the control group. This is inconsistent with the findings of Noor et al. [16] for Malaysian cement workers, Alakija et al. [17] for workers of Nigeria and Al Neamini et al. [5] for workers of Arab, but in case of some other studies such effects were absent [12-13, 18] probably due to low dust concentration in case of these factories in comparison to our findings. Mahmood et al. [8] observed significant decrease in Pulmonary function parameters between pre and post shift workings. Although we studied the workers during the shift but significant decrease in pulmonary function might be due to broncho-constriction during work-shift [8]. FEV1/FVC ratio was less in exposed workers than control group ones and this difference was statistically significant in our study which was consistent with the study of Ali et al[9], Yang et al [19], Al Neaimi et al. [5] but this was not in agreement with Badri et al. [20], and Poomajaf et al. [21]. They reported that when FEV1/FVC ratio of exposed workers differ significantly, indicated minor degree of restrictive ventilator impairment, as also suggested by Kumar et al. [22] where demographic pattern of exposed workers and the control group was identical.

The dust concentration in our study was maximum in packing, loading and storage departments suggesting thereby that finished materials were the main sources of dust pollution in the factory followed by maintenance department like electrical and mechanical where workers visited different departments regularly and exposed themselves to high dust concentration. The production department workers were less exposed to dust due to mechanization and close system operation of these departments. In the present study workers of high and low dust zone were compared and in most cases significant reduction in pulmonary function parameters had been found among workers exposed to high dust except $FEV_{1\%}$ of both higher and lower age group and $FEF_{200-1200}$ and $FEF_{25-75\%}$ in case of higher age group. These findings indicated that high dust exposure affected the pulmonary function parameters, although pollution report indicated low dust concentration below permissible limit.

Sewefy et al. [23] stated that pulmonary function reduction was due to irritant effect of cement dust on respiratory apparatus. Kalacic [24] suggested that Pulmonary Function test (PFT) reduction was due to structural restrictive changes of the lung. But these findings differ from Rasmussen et al. [25], Abu Dhaise et al. [26], Yang et al. [19] where they pointed out that dust concentration did not markedly affect lung function of cement workers presumably due to low dust concentration (1240µg/m3) in these factories but consistent with the study of Noor et al. [16] where dust concentration was much higher (10180 µg/m3)

As regards the year of dust exposure when considered it was found that almost all pulmonary function parameters decreases with increase in year of dust exposure except $FEV_{1\%}$ but only FVC and PEFR values showed significant reduction with increase in year of exposure. This result corroborated with the study of Mahmood et al. [8]. However, Mewaiselage et al. [3] reported that thirty years exposure to average total inhalable dust levels of 10mg/m3 would lead to marked deficit in FEV_1 and FVC. Low values for FEV_1 and $FEV_{1\%}$suggested airway obstruction [8]. This study also focused the year of exposure was negatively correlated with pulmonary function parameters but significant correlation had been found in case of flow rates. i.e.; $FEF_{25-75\%}$, FEF $_{75-85\%}$ and PEFR. Moreover, a greater difference was observed between smoker workers and the controls as well as non-smoker workers and the control, suggested that smoking might aggravate the deleterious effect of cement dust. However correlation between smoking habit, cigarette/day and Pack-year and lung function parameters was mostly insignificant except $FEF_{25-75\%}$, $FEF_{75-85\%}$ and PEFR with cigarette/day and Pack-yr. and between years of smoking of high dust zone. It is also in agreement with Noor et al. [16] and Mwaiselage et al. [3] studies. The reason could be the low prevalence of smokers (n=21 for higher age group) [27].

Logistic Regression equation of respiratory symptoms indicated that chronic bronchitis was related to smoking habit and dust concentration but year of smoking was an important predictor for chest tightness among cement workers. However, Ballal et al. [4] reported smoking and duration of exposure as predictors of cough and phlegm and exposure to dust as only predictor of wheezing and shortness of breath and asthma. Abrons et al. [18] pointed out that prevalence of chronic phlegm among cement workers increased with duration of exposure and prevalence of wheezing increased with duration of exposure as well as dust level.

In the present study, the cement workers from higher and lower age groups indicated mainly restrictive impairment (28% and 19% respectively) and all cement workers showed 22% restrictive and 12% obstructive impairment in comparison to the control group (19% restrictive and 2% obstructive) which was supported by Badri and Saeed [20], Meo et al. [28], Oleru [27], Kalacic [24]. They stated that reduction in FVC, FEV_1 and PEFR indicated restrictive pulmonary disease. Again statistically significant difference in $FEV_{1\%}$ indicated obstructive lung disease of cement workers of present study (10%) in comparison to control (2%). These findings might be due to increase in bronchial muscle tone leading to some degree of broncho constriction as a result of irritant effect duly induced by acute exposure to cement dust [9] and this effect was found to be aggravated by smoking [26].

Workers from high dust zone of the present study reported chest compression, chest pain and chest tightness more frequently than those of a low dust zone which confirmed the data of Meo [29].

Besides, in accordance with the findings of Mojiminiyi et al. [30] workers of the present study working at high dust zone were badly affected by liver dysfunction (50% higher age group and 40% lower age group). Prevalence of chest tightness and chronic bronchitis was highest in packing, loading and cleaning workers of the cement mill (OR=5.09 and 6.4) due to high dust exposure among these workers (0.038-0.07 mg/m3) caused by resuspension of dust particles during the shoveling of piled dust that might produce a continuous supply of dust to the breathing zone which was expected to be deposited in the upper part of the airways than in case for the production workers [31]. Prevalence of the above respiratory symptoms were higher in maintenance workers of the workshop (OR=4.41 and 2.59) than production workers (OR= 1.6 and 1) probably due to nature of work of these workers, i.e.; they actually migrated from one departments to another from production to wagon loading and thereby exposed to high cement dust in comparison to production workers.

Although dust concentration in different departments was below the permissible limit (Indian standard-150µg/Nm^3 by Central Pollution Control Board) ,it was much lower than the permissible limit of respirable dust and total dust recommended by ILO, i,e five mg/m^3 and 10 mg/m^3 [32]. But concentration of respirable dust for the exposed group was 3.6 mg/m^3 for Taiwan [19], $3.9 mg/m^3$ for Jordan [26], 1.5 mg/m^3 median value for Denmark [10], 0.9 mg/m^3 (Arithmetic mean) for Norway [12] and $0.57 mg/m^3$ (Geometric mean) for United States [18]. Thus, the current occupational exposure limit of National and International standard used by many countries seems to be too high to prevent the respiratory health effects of dust exposed cement workers. In our study, the decline in pulmonary function of cement workers mainly depends on concentration of respirable dust in the environment. Thus, we recommend dust concentration far below the permissible limit of national and international standard, for example, $0.01 mg/m^3$.

CONCLUSIONS

This study showed acute reduction in respiratory functions and high prevalence of chronic respiratory symptoms of the cement industry workers of West Bengal exposed to the emission of cement dust particles. Therefore, it is an urgent need to control the air quality and reduce the cement dust emission in the working environment. It also transpires from the reply in response to questionnaire and also from the interview of the workers whom the protective measures which should have been adopted to combat such hazards are not adequate. Therefore, we recommend national programs of cement dust exposure assessment and health surveillance that cement factory management should embark on health education of workers and must supply effective protective gadgets and enforce their usage during working condition. Smoking should be prohibited within factory premises. Periodic health check up as also awareness among workers is also essential for monitoring the proper health condition of the cement industry workers.

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Conflicts of interest

The authors declare that they have no competing interests in the publication of the manuscript.

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REFERENCES

1. Arikrah TC. Respiratory symptoms and lung function tests in an African Jute factory workers. West Africa J Med. 1989 Apr-Jun; 8(2):98-105.
2. Obiotnu CN. Some specific occupational diseases. In synopsis of occupational and environmental health. Enugu, Nigeria: Cedar Top Press Ltd. 1999.
3. Mwaiselage J, Bråtveit M, Moen BE, Mashalla Y. Respiratory symptoms and chronic obstructive pulmonary disease among cement factory workers. Scand J Work Environ Health. 2005 Aug; 31(4):316-23.
4. Ballal SG, Ahmed HO, Ali BA, Albar AA, Alhasan AY. Pulmonary effects of occupational exposure to Portland cement: a study from Eastern Saudi Arabia. Int J Occup Environ Health. 2004 Jul-Sep; 10(3):272-7.
5. Al-Neaimi YI, Gomes J, Lloyd OL. Respiratory illnesses and ventilatory function among workers at a cement factory in a rapidly developing country. Occup Med (Lond). 2001 Sep; 51(6):367-73.
6. Zeleke ZK, Bente E, Magne B.Cement dust exposure and acute lung function: a cross shift study. BMC Pulm Med. 2010 Apr; 14; 10:19 -26.
7. Neghab M, Choobineh A. Work related respiratory symptoms and ventilatory disorders among employees of a cement industry in Shiraz, Iran. J Occup Health. 2007 Jul; 49:273-8.
8. Mahmood AM, Wafi NAR, Shaikhani MAR. Spirometric measurements among workers of Tasluja cement factory. J Zankoy Sulamani. 2010; 13(1):9-14.
9. Ali BA, Ballal SG, Albar AA, Ahmed HO. Post-shift changes in pulmonary function in a cement factory in eastern Saudi Arabia. Occup Med (Lond). 1998 Nov; 48(8):519-22
10. Vestbo J, Rasmussen FV. Long term exposure to cement dust and later hospitalization due to respiratory disease. Int Arch Occup Environ Health. 1990; 62(3):217-20.
11. Yang CY, Huang CC, Chang IC, Lee CH, Lsai JT, Ko YC. Pulmonary function and respiratory symptoms of Portland cement workers in Southern Taiwan. Gaoxiong Yi Xue Ke Xue Za Zhi. 1993Apr; 9(4):186-92.
12. Fell AK, Thomassen TR, Kristensen P, Egeland T, Kongerud J. Respiratory symptoms and ventilatory function in workers exposed to Portland cement dust. J Occup Environ Med. 2003Sep; 45(9):1008-14.

13. American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values for chemical substances and physical agents biological exposure indices. ACGIH, Cincinnati. Ohio, 2008.
14. World Health Organization. Technical Report Series. 1983; 684:1-78.
15. Agresti A .Categorical data analysis. 2nd Edition. John Wiely, New York, 2002.
16. Noor H, Yap CL, Zolkepli O, Faridah M. Effect of exposure to dust on lung function of cement factory workers. Med J Malaysia. 2000 Mar; 55(1):51-7.
17. Alakija W, Iyawe VI, Jarikre LN, Chiwuzie JC. Ventilatory function of workers at Okpella cement factory in Nigeria. West Afr J Med. 1990 Jul-Sep; 9(3):187-92.
18. Abrons HL, Petersen MR, Sanderson WT, Engelberg AL, Harber P. Respiratory symptoms, ventilatory function and environmental exposure in Portland cement workers. Br J Ind Med. 1988 Oct; 45(6): 368-75.
19. Yang CY, Huang CC, Chiu HF, Chiu JF, Lan SJ, Ko YC. Effects of occupational dust exposure on the respiratory health of Portland cement workers. J Toxicol Environ Health. 1996 Dec 27; 49(6):581-8.
20. EI Badri OA, Saeed AM. Effect of exposure to cement dust on lung function of workers at Atbara cement factory. Kharoum Med J. 2008; 1(2):81-4.
21. Poornajaf A, Kakooei H, Hosseini M, Ferasati F, Kakaei H . The effect of cement dust on the lung function in a cement factory, Iran. Int J Occup Hygiene. 2010; 2(2): 74-8.
22. Kumar V, Cotran R, Robbins S. Basic Pathology, 5th ed. Philadelphia: WB Saunders Company, 1997.
23. EL-Sewefy AZ, Awad S, Metwally M. Spirometric measurements in an Egyptian Portland Cement factory. J Egypt Med Assoc. 1970; 53:179-86.
24. Kalacic I. Early detection of expiratory airflow obstruction in cement workers. Arch Environ Health. 1974 Sep; 29(3):147-9.
25. Rasmussen FV, Borchsenius I, Holstein B, Solvdteen P. Lung function and long term exposure to cement dust. Scand J Resp Dis. 1977 Oct; 58(5):252-64.
26. AbuDhaise BA, Rabi AZ, al Zwairy MA, el Hader AF, el Qaderi S. Pulmonary manifestations in cement workers in Jordan. Int J Occup Med Environ Health. 1997; 10(4):417-28.
27. Oleru UG. Pulmonary function and symptoms of Nigerian workers exposed to cement dust. Environ Res. 1984 Apr; 33(2):379-85.
28. Meo SA, Azeem MA, Ghori MG, Subnan MMF. Lung function and surface electromyography of intercostals muscles in cement mill workers. International Int J Occup Med Environ Health. 2002; 15(3):279-87.
29. Meo SA. Chest radiological findings in Pakistani cement mill workers. Saudi Med J. 2003 Mar; 24(3):287-90.
30. Mojiminiyi FBO, Merenu LA, Njoku CH, Ibrahim MTO. Regression Formulae for predicting haematologic and liver functions from year of exposure to cement dust in cement factory workers in Sokoto, Nigeria. Afr J Biomed Res. 2007; 10:235-40.
31. Zeleke ZK, Moen BE, Bråtveit M. Lung function reduction in chronic respiratory symptoms among workers in the cement industry: a follow up study. BMC Pulmonary Medicine. 2011Nov 8;11:50-60
32. Fairhurst S, Phillips A, Gilles C, Brown RH. Portland cement dust criteria document for an occupational exposure limit. Health and Safety Executive, London, 1977.