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Particulate Matter Associated Lung Function Decline in Brick Kiln Workers of Jalalpur Jattan, Pakistan

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Abstract.- Among air pollutants, particulate matter (PM) is one of the most common causes of respiratory diseases in humans all over the world and has become a major problem in developing countries of South Asia such as Pakistan, India and Nepal. A survey based research was conducted to find out respiratory health effects of PM on brick kiln workers in Jalalpur-Jattan, Gujrat, Pakistan. Lung functions of brick kilns workers (n=156) were examined by using spirometery, and by recording forced vital capacity (FVC), forced expiratory volume (FEV1) and FEV1/FVC (FEV1%) during working hours. FVC and FEV1 were found to be significantly lower than predicted for brick workers thereby suggesting restrictive or obstructive pattern of disease. Average concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) in ambient air of each section of brick kilns were found to be above the National Environmental Quality Standards (NEQS) values which can cause pulmonary diseases. These findings of lung function decline in brick workers may suggest prevalence of occupational lung diseases.

Key words: Spirometer, particular matter, lung function, brick kiln workers.

INTRODUCTION

Air pollution in urban and industrial areas has been considered dangerous to human health for centuries. It contributes to the development of pulmonary diseases (asthma, bronchitis, emphysema etc.) and nonpulmonary diseases including myocardial infarction (MI), stroke and cancer (cervical cancer and brain cancer) (Raaschou-Nielsen *et al.*, 2011). Inflammation induced by exposure to air pollution significantly contributes to adverse health effects (Ayyagari *et al.*, 2007; Cho *et al.*, 2007). Among air pollutants**,** particulate matter (PM) is one of the well known causes of respiratory illnesses in humans all over the world and has become a major problem of the developing countries of South Asia (Liu and Diamond, 2005) such as Pakistan, India and Nepal (Aslam *et al.*, 1994; Joshi and Dudani, 2008). Most epidemiological and toxicological studies have focused on the inhalation of ambient particulate matter because of a stronger correlation of mortality and adverse respiratory health effects with fine respirable particles than with other atmospheric gas pollutants. In recent years, epidemiological research has found consistent and coherent associations between both short-term and long-term PM exposure and various health outcomes (Vineis *et al.*, 2004; Gallus *et al.*, 2008). The short term adverse health effects caused by PM include respiratory problems like wheezing, coughing, sputum production, shortness of breath and chest tightness or pain (Kittle, 2000; Roohi and Nazir, 2010) and long term adverse effects include reduced lung function, chronic bronchitis (Kuschner *et al.*, 2009), allergic alveolitis, pneumoconiosis, relative increase of lung cancer risk (Elci *et al.*, 2003), and cardiovascular and respiratory mortality (Pelucchi *et al.*, 2009).

Based on diameter in micrometer (µm), particles are usually classified into three categories: coarse (PM_{10}), fine ($PM_{2.5}$) and ultrafine particles (UFPs; aerodynamic diameter <0.1 µm). The notation PM_X refers to PM comprising particles' size less than X µm in diameter; most often, X is 10, 2.5 or 1 µm (Seinfeld and Pandis, 1998). Inhalation of particles with an aerodynamic diameter less than or equal to a 2.5µm ($PM_{2.5}$), has been associated

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with systemic inflammation and the clinical presentation of various cardiopulmonary heath events (Yeates and Mauderly, 2001). Excess of particle concentration in ambient air may overload the lungs and causes inflammation in adjacent tissues, leading to oxidative stress. Persistent lung inflammation following exposure to UFP may lead to exacerbation of a pre-existing lung disease or even lead to the development of asthma, chronic bronchitis, silicosis, lung fibrosis or cancer (Weinchenthal *et al.*, 2000; Helland, 2004).

Among small scale industries, the brick kiln industry is progressing due to increased urbanization and expansion of cities which created demands of building materials (Bhanarkar *et al.*, 2002).

Clay bricks are most commonly used out of various building materials used in Pakistan. Clay bricks are commonly made from various materials including soil, clay or river sediments rich in silt particles. Primarily, slack coal is used as a fuel in almost all brick kilns in the country except in certain areas where low grade carbonaceous materials such as rice husk and wood/saw dust are also used. All the kiln operations right from digging of earth to unloading of fired bricks from the kiln go along with the discharge of dust which makes the whole workplace dusty. Brick kilns' emission mainly consists of coal particles, dust particles, organic matters, and small amount of gases like sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrogen sulfide (H_2S) and carbon monoxide (CO) etc. On an average 160 kg coal is required for firing 1000 bricks (Bradsher and Barboza, 2006; Joshi and Dudani, 2008). The quantity of the dust evolved in different brick kilns sections is very high. This fugitive dust in working area contributes to the highly dusty conditions in and around the brick kilns which not only cause occupational health hazards but also adversely affect the surrounding environment (Aslam *et al.*, 1994).

The aim of current research was to measure the size and concentration of particulate matter in the ambient air of brick kilns and to investigate their effects on the respiratory health of the workers associated with brick kilns. Therefore, a survey based research was conducted on brick kilns in Jalalpur-Jattan (district Gujrat) Pakistan during Fall-2009 to Spring-2010.

MATERIALS AND METHODS

Data collection tool

Data was taken from 156 workers associated with brick kilns during their working time with the help of a questionnaire. The questionnaire was designed according to prerequisite of study that contained questions about their demographic information including age group, working area, nature of job and duration of working hours. It also included questions about symptoms of respiratory diseases (difficult breathing, chest pain, cough with sputum, chronic cough etc.) they experienced during working hours or at home along. Question were asked about cigarette smoking and other diseases, workers experience during working hours like eye irritation, nasal congestion, head ache, fatigue and skin allergy. BMI was calculated as weight (kg)/length^2 (cm) ×100. Based on their BMI, patients were assigned to three groups: the underweight group (BMI < 18.5), the normal weight group (18.5 ≤ BMI < 24), overweight group (BMI ≥ 24) (Ting *et al.*, 2009) and the obese group (BMI ≥ 30).

Concentration of particulate matter

Concentration of PM (size $PM_{2.5}$ and PM_{10}) in ambient air of brick kiln was measured using the dust monitor, DUST TRAK PRO II model 8530. The PM measured at the different region of brick kilns included average concentration of $PM_{2.5}$ and PM_{10} which were supposed to represent the spatial distribution of PM pollution levels in a study area within area of 1m^3. The concentration of PM was monitored at modulation and loading (locally named, Thapai and Bhrai), burning (locally named, Keri and Jalai) and unloading (locally termed, Nakasi) sections within the brick kilns irrespective of wind velocity.

The average concentrations and maximum and minimum values of $PM_{2.5}$ and PM_{10} were evaluated at modulation and loading (Thapai and Bhrai), burning (Keri and Jalai) and unloading (Nakasi) sections in monitoring.

Spirometery

Pulmonary function test was performed using a portable digital spirometer (Spirolab III, SN A23-

053, MIR, Italy). Forced expiratory volume in one second (FEV1), forced vital capacity (FVC) and FEV1% (FEV1/FVC) were recorded. We considered lung function to be impaired if FEV1 < 80% or FVC < 80% (of the predicted value/ (Schikowski *et al.*, 2008) and FEV1% < 70%.

Statistical analysis

All the data collected from the workers was analyzed statistically by using software, SPSS ver. 16.0 (Wang, 2010) to calculate the appropriate statistical techniques.

Descriptive statistics

Quantitative variables like spirometric values (FVC, FEV1 and FEV1%) and daily duration of exposure to PM (working hours) were presented with mean ± standard deviation (SD). In order to obtain comprehensible presentation of the data, the data were presented in frequency tables. Frequency distribution of different variables like age, nature of job, duration of job (experience), smoking habit, intensity of smoking habit and respiratory disease symptoms (breathlessness, chest, pain and coughing etc.) was interpreted directly using statistical package mentioned above. Information about related diseases other than respiratory disease such as eye irritation, nasal congestion, headache, and fatigue and skin allergy was also investigated and interpreted.

Inferential statistics

Firstly chi-square test of association was applied on the categorical variables to observe the association. But in those cases where expected count was less than five Fisher Exact test was used.

To see the correlation between quantitative variables (spirometric values with age, working experience and working hours) Pearson correlation and Spearman correlation were used. Pearson correlation was used in the situation where normality assumption of the data was not violated. For variables which were measured on ranking scale Spearman rank correlation was applied.

Independent-samples t-test (two-sample t-test) was also used to compare the means of these variables (FVC, FEV1 and FEV1%) with respect to two groups of smoking habit (smokers and non-smokers).

One way analysis of variance (ANOVA) was used to see the equality of means of quantitative variables in several groups. One-way ANOVA was applied in this study to check the means equality of spirometric values (which were assumed to be normally distributed) for factors like job nature and intensity of smoking. Before ANOVA, test of homogeneity of variances was applied. Assumption of homogeneity of variance was also assessed; otherwise we had to apply Welch ANOVA. In case of rejection the equality of means hypothesis, Post Hoc tests (least significant difference (LSD) were applied to see that which group was different from the other.

In all these statistical testing level of significance was set at $p<0.05$.

RESULTS

Concentration of $PM_{2.5}$ and PM_{10}

The average concentrations of $PM_{2.5}$ in ambient air of three main sections of brick kilns were recorded. In the modulation and loading (Thapai and Bhrai) section, the average concentration of $PM_{2.5}$ was 0.301 mg/m^3, in the burning (Keri and Jalai) section was 0.307 mg/m^3 and in the unloading (Nakasi) section, average concentration of $PM_{2.5}$ was 0.628 mg/m^3 (Table I). These concentrations were much higher than National Environmental Quality Standards (NEQS) for $PM_{2.5}$.

Table I. - Concentrations of particulate matter.

	Max. – Min. (mg/m^3)	Avg. value (mg/m^3)
Conc. of $PM_{2.5}$		
Modulation and loading	0.310-0.296	0.301
Burning	0.352-0.296	0.307
Unloading	2.680-0.296	0.628
Conc. of PM_{10}		
Modulation and loading	2.890-0.346	0.888
Burning	6.140-0.354	1.830
Unloading	3.820-0.170	0.861

PM_{10} average concentrations in ambient air of three main sections of brick kilns were recorded. In the modulation and loading (Thapai and Bhrai) section the average concentration of PM_{10} was 0.888 mg/m^3,in the burning (Keri and Jalai) section 1.830 mg/m^3 and in unloading (Nakasi) section, the average concentration of PM_{10} was 0.861 mg/m^3 (Table I). These concentrations were also to much higher than National Environmental Quality Standards (NEQS).

Spirometric values

Forced vital capacity (FVC) was 69.2±12.8, forced expiratory volume in one sec (FEV1) was 78.9±12.7 and FVC (forced vital capacity) ratio (FEV1%) was 114.7±11.2% (Table II).

Working hours

Result shows that mean daily working hours were 10.6; maximum working hours were 15 and minimum were 5 (Table II). Significant negative correlation was found between working hours and FEV1% at p=.049. With the increase in the working hours or daily time of exposure to PM the FEV1% decreased significantly. But we did not find significant relationship between working hours and FVC or FEV1 decline.

Age

Results showed that 35% of brick kiln workers were 11-25 years old, 30.8% were between 26 and 40 years of age, 26.9% belonged to 41-55 years group, while 6.4% were 56-70 years old (Table II). Age depicted significant correlation between FEV1% at p=.003. We found no significant correlation between age and FVC and FEV1 values demonstrating that the increase in age had no negative effect on these values.

Nature (Category) of the job

Regarding the nature of job in brick kilns, results demonstrated that among brick kilns workers, 60.9% were associated with Thapai, 14.7% with Bhrai (modulation and loading), 7.1% with Keri, 9% with Jalai (burning) and 8.3% were associated with the Nakasi (unloading) sections (Table II). We have found that 69.2% are smokers of which about 51.85% belong to Thapai, 17.5 belong Bhrai region, 10.1% belong to Keri region, 11.1% belong to Jalai region and 9.2% people were from Nakasi. There was significant positive association found between smoking habit (regular,

Table II. - Frequency and percentage of age, nature of job, working experience, smoking habit, category of smoking and body mass index of brick kiln workers.

	No.	Percentage
Age		
11-25	56	35.9
26-40	48	30.8
41-55	42	26.9
56-70	10	6.4
Total	156	100.0
Nature of jobs		
Thapai	95	60.9
Bhrai	23	14.7
Keri	11	7.1
Jalai	14	9.0
Nakasi	13	8.3
Total	156	100.0
Working experience (Years)		
1-5	16	10.3
6-10	45	28.8
10-15	36	23.1
16-20	20	12.8
More than 20 years	39	25.0
Total	156	100.0
Smoking habit		
No	48	30.8
Yes	108	69.2
Total	156	100.0
Category of smoking		
Regular Smoker	64	41.0
Irregular Smoker	18	11.5
Chain Smoker	26	16.7
Total	108	69.2
Body Mass Index		
Under Weight	7	4.5
Normal	122	78.2
Over Weight	20	12.8
Obese	7	4.5
Total	156	100.0
Spirometric values*		
FVC	69.2±12.8	
FEV1	78.9±12.7	
FEV1%	114.7±11.2	
Working hours	10.6±1.8	

*FEV1, forced expiratory volume in one second; FVC, forced vital capacity.

irregular and chain smoker) and nature of job at p=0.008. One-way ANOVA demonstrated that there was no significant difference between means of categories of job and spirometric values, all categories of job effect equally on the spirometric values (FVC, FEV1, FEV1%) showing no difference among them because all p-values *i.e.* 0.67, 0.48, 0.39 are greater than α=0.05, respectively.

Working experience

Results demonstrated that 10.3% workers were working since 1 to 5 years, 25.8% since 6 to10 years, 23.1% since 10 to 15 years, 12.8% since 16 to 20 years and 25% workers were associated with brick kilns for more than 20 years (Table II). Significant correlation was found between working hours and FEV1% because p= .013. This showed that there would be a significant decline in worker's FEV1% with chronic exposure to PM. However results didn't demonstrate a significant correlation between working experience and FVC or FEV1 decline.

Smoking habit and intensity of smoking

Among workers in brick kilns we found that, 69.2% were smokers and 30.8% were non smokers. Regarding to intensity of smoking, 41% were regular smokers, 16% chain smokers and 11% were irregular smokers (Table II).

T-test applied for checking relation between smoking habit and spirometric values, showed that p-values for FVC (0.032) were significant. These results showed that value of FVC is significantly affected by smoking habit. On the other hand significance between smoking habit, FEV1% and FEV1 was not found ($p=0.30 > \alpha$.).

Our results did not demonstrate significant value of FEV1% *i.e.* 0.138 showing that all smoking categories equally effect the FEV1%. However, ANOVA demonstrated significant values and rejected H_o for FVC and FEV1 as p-values were 0.023 and 0.010 respectively $<\alpha=0.05$. We later applied least significant difference (LSD) as Post Hoc test which showed that only regular and irregular smoking equally affects spirometric values. But chain smokers values were not equal to other group's values. So it could be assumed that chain smokers were more susceptible group per PM related lung function decline.

Body mass index

Among workers, 78.2% had normal BMI, 12.8% were overweight, 4.5% were under weight and 4.5% were obese indicating a majority of brick kiln workers with normal BMI (Table II). Results of homogeneity of variance demonstrated p= 0.372, 0.277 and 0.560 for FVC, FEV and FEV1% showing these spirometric values are equally affected by BMI. Also there was no significant effect of BMI on spirometric values because p=0.315, 0.381 and 0.414 for FVC, FEV and FEV1% > α (0.05).

DISCUSSION

Occupational sources of PM are associated with acute as well as chronic lung diseases like acute respiratory infections (ARIs) (Romieu *et al.*, 2008), pneumonia, chronic obstructive lung disease, asthma (Schwartz, 1996; Donaldson *et al.*, 2001) lung cancer (Gallus *et al.*, 2008; Vineis *et al.*, 2004) and various restrictive lung diseases such as pulmonary fibrosis, silicosis, coal-worker's pneumoconiosis, asbestosis (Abbey *et al.*, 1998; Zeka *et al.*, 2006) and Interstitial lung diseases (hypersensitivity, pneumonitis etc.) (Weinchenthal *et al.*, 2000; Helland, 2004). These PM sources may also cause oxidative stress and DNA damage (Kaushik *et al.*, 2012). The average concentrations of $PM_{2.5}$ and PM_{10} according to National Environmental Quality Standards (NEQS) are considered as the values above which the particulate matter causes such pulmonary diseases. According to NEQS, the average concentrations for $PM_{2.5}$ are 0.025mg/m^3 (25µg/m^3) for one hour, 0.035mg/m^3 *i.e.*, 35µg/m^3 for 24 hour and 0.015mg/m^3 (15µg/m^3) for annual average monitoring. The NEQS average concentrations for PM_{10} are 0.015mg/m^3 *i.e.* 150µg/m^3 for 24 hours and 0.05mg/m^3 (50 µg/m3) for annual average monitoring. The focus of our study was to estimate the effect of $PM_{2.5}$ and PM_{10} on respiratory health of brick kiln workers.

The average concentrations of $PM_{2.5}$ monitored by DUST TRAK II (model 8530) at different working sections of brick kilns were

$0.301 mg/m^3$, $0.307 mg/m^3$ and $0.628 mg/m^3$ for modulation and loading sections, burning sections and unloading sections respectively. Similarly, the average concentrations of PM_{10} at these three sections were $0.888 mg/m^3$, $1.830 mg/m^3$ and $0.861 mg/m^3$, respectively. These concentrations were far higher than cited by NEQS and enough to cause the pulmonary diseases in people who are exposed to PM on daily bases (Dockery, 2001).

Our results showed that maximum values of FVC, FEV1, and FEV1% were 98, 109 and 138 respectively. The minimum values of FVC, FEV1, and FEV1% were 29, 35 and 61 respectively. There was a decline in the mean spirometric values (FVC, FEV1) of workers associated with brick kilns *i.e.* FVC = 69.2±12.8 and FEV1 = 78.9±12.7. Another thing which have been observed that subjects with restrictive lung diseases had lower values of FEV1 and FVC, but normal FEV1% (Al-Shamma *et al.*, 2006) values without these illnesses (Akgun *et al.*, 2008). We observed that a reduction in lung functions (FEV1 and FVC < 80% of predicted value) was significantly associated with exposure to high levels of PM. Regarding the risk factors, we found the significant correlation between FVC decline and smoking habit at $p=0.04$ in contrast to Zuskin *et al.* (1998), other spirometric values (FEV1, FEV1%) were not significantly correlated with smoking habit.

We found significant *inverse* correlation between FEV1% and daily duration of exposure (working hours) to PM indicating that increase in working hours or exposure to PM there may because decline in FEV1%. Age is considered as a factor for decline in lung function especially FEV1%. It was also found a significant correlation of FEV1% with age (Zuskin *et al.*, 1998). We found that working experience and nature of job was not significantly associated with decline in FVC and FEV1. Our results showed significant correlation between working hours and FEV1% because $p=0.013$ which is less than α. This showed that there would be a significant decline in worker's FEV1% with chronic exposure to PM. So it demonstrates that the decline in FVC and FEV1 was truly due to exposure to concentrated PM. A significantly high prevalence of diseases (breathlessness, chest pain, and cough with sputum) along with other diseases and their manifestations (irritation in eyes, nasal congestion, fatigue and skin allergies) (Kittle, 2000) were recorded in the study group. Regarding BMI as independent risk factor for lung function decline (Ting *et al.*, 2009) we did not find any significant relationship of BMI with spirometric values. As suggested by the respiratory symptoms, a bronchitis component may also be present among workers \

The results of environmental and biological monitoring demonstrated that in area with concentrated PM, a residual risk exists for the respiratory health of the brick kiln workers. Previously research had been conducted on the general relation of the PM with the respiratory problems but very little research was done specifically on the PM of brick kilns and its relationship with the respiratory health of workers in Pakistan.

CONCLUSIONS

It is concluded that among workers in brick kilns, PM causes significant decline in spirometric values (FCV and FEV1) but not in FEV1/FVC (FEV1%) indicating the likely prevalence of restrictive lung diseases like pulmonary fibrosis, silicosis, and interstitial lung diseases (ILDs) (hypersensitivity pneumonitis etc.). In future, respiratory health of the workers could be examined along with the surveys including large population to minimize errors.

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