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Particulate Matter ($PM_{2.5}$) Assessment in the Indoor Air of Preliminary Schools' Classroom, Investigative Results from Rural District of Sari, Iran

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Abstract: A variety of environmental studies have revealed the relationship between the indoor concentrations of particulate matters ($PM_{2.5}$). Though, there is a lake of data about indoor $PM_{2.5}$ concentrations in rural area schools (especially in classrooms), since preliminary children are assumed to be more defenseless to health hazards and spend a large part of their time in classrooms. The objective of this study was indoor $PM_{2.5}$ concentration quality assessment. Fifteen preliminary schools by time-series sampling were selected to evaluate the indoor air quality in the rural district of Sari city, Iran. Data on indoor air climate parameters (temperature, relative humidity and wind speed) were measure by a hygrometer and thermometer. Particulate matters ($PM_{2.5}$) were collected and assessed by Real Time Dust Monitor, (MicroDust Pro, Casella, UK). The mean indoor $PM_{2.5}$ concentration in the studied classrooms was 135μg/m^3 in average. The multiple linear regression revealed that a correlation between $PM_{2.5}$ concentration and relative humidity, distance from city center and classroom size. Classroom size yields reasonable negative relationship, the $PM_{2.5}$ concentration was ranged from 65 to 540μg/m^3 and statistically significant at 0.05 level and the relative humidity was ranged from 70 to 85% and dry bulb temperature ranged from 28 to 29°C were statistically significant at 0.035 and 0.05 level, respectively. A statistical predictive model was obtained from multiple regressions modeling for $PM_{2.5}$ and indoor psychrometric parameters.

Key words: Particulate Matters · Classrooms · Regression · Concentration · Humidity

INTRODUCTION

Many epidemiological researches have been carried out during the current century which illustrated the correlation between the living in a rural district with some air pollutants and the occurrence of health related problems and/or diseases [1-5]. Nowadays, researchers focus of their research has clearly shifted in the direction of particulate matter with diameters less than 2.5 microns (EPA (US-Environmental Protection Agency and WHO (World Health Organization) [6-7, 19, 24]. Subjects living close to an airborne pollution sources were found to have a significantly increased risk of death due to cardio respiratory causes in a study [9-10]. A survey was done in England and Wales revealed high risk of mortality from heart disease when exposed with airborne dusts [11-14]. Some researches pointed on children's health situation; children living near freeways had increased incidence of respiratory disease symptoms [11, 14, 15-19]. Indoor particle matters (PM) concentration is a frequently used as marker of PM exposure in great epidemiologic studies and has been reported to be associated with exposed people health risks. In the indoor environment, in which people spend most of their living, working or studying time, both indoor and outdoor foundations contribute to PM exposure. Personal exposure to PM occurs in various environments, where particles may originate from a wide variety of causes.Main sources of indoor PM are dust re-suspension mechanisms, dust penetration factors, airborne dust concentration, air exchange rates and deposition. In the enclosed places such as a home, classroom, kitchen and workplace, some activities such as cooking, cleaning, walking and particularly smoking are reason the configuration of PM in indoor air [21-22]. While only few data on indoor air pollution are available but numerous measurements of PM in the outside air have been carried out. Currently, only limited personal exposure researches support

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reliability of these markers of long-term exposure to traffic-related air pollution [22-24]. A study conducted in a developedcountry found a difference of 8.2 mg/m^3 (46%) [21]. Compare to the same group of children, researchers reported the increasing rate in school outdoor NO2 was 41%, while the increase in home outdoor NO2 concentration was 28% [24-28]. Thirty percent of day time spend for school-aged children of their daytime in school and may be related to particularly vulnerable to potential health hazards [22-25]. However, no long-term studies have involved personal monitoring of $PM_{2.5}$ (particulate matter with a 50% cut off of 2.5 mm in aerodynamic particle size) and particulate components such as soot [25-28]. Recently, several epidemiological studies have examined respiratory health in children (lung function, respiratory symptoms, bronchial hyperresponsiveness, sensitization to common allergens) and evaluate indoor air pollutant concentrations using a school-based measurement design [23-30]. Then, school children were selected as participants in this study to monitor personal exposure to the particulate matters with 2.5 microns diameter or $PM_{2.5}$.Consequently, the objective of the current study was to determine the indoor $PM_{2.5}$ concentration in a large number of schools in Iran. Besides, the comparison of PM concentrations finding to EPA standards is the second aim of the present study.

MATERIAL AND METHODS

Airborne particles matters with size = 2.5 microns was measured at 15 preliminary schools, located in rural district of a big city within 1000 m from motorways. Weekly averaged measurements were conducted for $PM_{2.5}$, indoor sampling was done during school-hours only (8.00-13.00). Each school was assessed 10 times in the period October 2012-May 2013. Every measuring week, on average 15 schools was measured. In the classrooms measurement were carried out during one school day (about 5 h), all selected school was monitored each day. The sampling and measuring station in the classroom was close to the black board, about one meter above floor level. Indoor $PM_{2.5}$ was measured using Real Time Dust Monitor (MicroDust Pro, Casella, UK) via a near forward angle light scattering technique. Detection limit of MicroDust pro was 1 μg/m^3. This sampler was equipped with a small personal sampling pump (MP2N, SIBATA, Japan) to prepare a suitable airflow (2.2 L/min, stabilized) by a film soap flow meter. As a quality control measurement, zero and span calibration of the monitor was performed before each survey trip. As confirm the factory calibration point an optical calibration filter was used for the instrument.

For data analysis Statistical analysis (Pearson correlation and linear regression) was done using the SPSS V.20 software. Furthermore, a linear regression model was performed to find the impacts of relative factors on personal exposure in the current study. To determine the sample numbers the following statistical formula was used.

$$n = \frac{N Z^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2(N-1) + Z^2_{1-\frac{\alpha}{2}} p(1-p)}$$

where is,
d = 0.17,
p = 0.3,
N = 105¡Z1-á/2 = 1.96

To find the relation between air pollution concentrations and psychrometric parameters as relative humidity, dry bulb temperature and air flow or indoor wind speed, a SIBATA hygrometer and a thermometer were used simultaneously with dust monitoring the selected classrooms [20, 25, 25].

RESULTS

Table 1 indicates the maximum, minimum and mean values of indoor air independent variables with respect to $PM_{2.5}$ concentration in the studied school's classrooms. The lowest minimum $PM_{2.5}$ concentration in all the classrooms was 65 μg/m^3 and also the highest of the maximum PM2.5 concentration was 540 μg/m^3. These values can be considered as high value, compare to EPA exposure limit of 12 μg/m^3. The mean $PM_{2.5}$ concentration was 135 μg/m^3, the mean indoor relative humidity was 75% and the mean dry bulb temperature was 28.5°C. The average size of classrooms for the studied schools ranged from 40 to 60 m^2 and distance from city was from 800 to 1200m.

It has been summarized and stated in Table 1 that several sampling station show variable concentration of $PM_{2.5}$, with respect to dependent variables of each school. The highest value $PM_{2.5}$ concentration was 540μg/m^3 which corresponds to the highest relative humidity (RH) of 85 % for studied classrooms.The gathered datarelated topsychrometric parameters (such as indoor relative humidity, dry bulb temperature and wind speed) and

Table 1: Values of indoor air parameters$PM_{2.5}$ for classrooms

Variables	Concentration(µg/m³)
$PM_{2.5}$, Max	540
Min	65
Mean	135
Relative Humidity (%) or RH, Max	85
Min	70
Mean	75
Dry bulb temperature (C°) or Td, Max	29
Min	28
Mean	28.5
Mean Dimension or D (m^2)	45
Mean Air flowor Af(m/s)	3

EPA Threshold Limit Value (TLV): 12µg/m^3 [12]

Table 2. Regression model summary for $PM_{2.5}$

Model	r	R²	Adjusted R²
	0.922	0.85	0.857

Predictors: (Constant), Air flow (m/s), Dimension of classroom (m³), Dry bulb temperature (ºC) and Relative humidity (%)

classroom dimension (D) in this study were collected and used to predict $PM_{2.5}$ pollution level. Correlation analysis was carried out after checking the normality assumptions for both variables, the result shows that all parameters are strongly correlated with $PM_{2.5}$ concentration where $P< 0.05$. The calculated R^2 values for RH, Td, D and air flow is 0.7566, 0.6822, 0.8948 and 0.684, respectively. Since all parameters are strongly correlated, all of them are put in the regression model. Table 2 showed the regression model summary where it can be seen that 85% of the $PM_{2.5}$ concentration can be attributed to any or all the independent variables (relative humidity, dry bulb temperature, dimension and air flow) ($R^2 = 0.85$).

The results of the summary imply that all or some of parameters (altitude, dimension of factory, relative humidity and dry bulb temperature) can be significant predictors of PM2.5 concentration in the studied classrooms. It can be extracted from the regression model the independent variables have straight correlation with PM concentration which is significant at $P< 0.05$. Since the results of regression model test in illustrate that the independent variables are significant predictors of $PM_{2.5}$ concentration. Based on obtained regression model, classrooms dimension and air flow are not significant ($P>0.05$) but relative humidity and dry bulb temperature can be seen to be significant predictors of $PM_{2.5}$ pollution ($P< 0.05$). This means the size of classrooms and indoor air flow are not significant where the $PM_{2.5}$ pollution is concerned and are therefore taken out from the regression model. The independent variables (relative humidity and dry bulb temperature) were reproduced for the model to find the regression coefficients for $PM_{2.5}$ pollution in the studied schools. Mutually indoor air relative humidity and dry bulb temperature are significantly contributing to the variability of the $PM_{2.5}$ concentration ($R^2 = 0.85$) and both factors also show a straight positive relationship with the $PM_{2.5}$ concentration. This means that as the indoor relative humidity or the dry bulb temperature increases, the $PM_{2.5}$ concentration also increases. The statistical regression model suggests that the average background $PM_{2.5}$ concentration was 135µg/m³ as indicated by the value of the constant in the regression equation. The knowledge is also essential for reliable assessment of the impact of building materials on indoor air quality.

DISCUSSION

Obtained regression model of the current study is closed to the regression models which are used by researchers for indoor dust concentration correlation with educational progress among exposed students. Few of indoor known risk factors as effective factors in the classrooms are slightly close to the similar study were conducted in US [6]. Indoor air pollutant as $PM_{2.5}$pollution in the studied classrooms revealed that there is a high risk of exposure to dust, it implies that not only this risk effect on children health situation but also will decrease the duty or homework attentiveness level during learning in class [8-12]. A study was done by researchers explained that there is a strong relationship between high concentration of dust and low activity and failing of duty among a big company staffs. Also it can expect for low quality of teachers duty with emphasis on learning in the class [7]. The effect of relative humidity and indoor temperature was assessed and reported in the many literatures, [17] they have reported that effectiveness of relative humidity (RH) on indoor air situation in the studied classrooms is a perceptible effect. Comparable to the related studies, the range of RH was in the range of 70 to 85% in this study. The standardized beta coefficient in the $PM_{2.5}$ regression for relative humidity was 0.348 which is lower than that of the coefficient for temperature (1.557). The evaluated range for RH in this study is lower than that reported by surveyors for noticeable effects, hence the effect of RH is expected to be not as significant as to the effects of temperature [17, 19, 25, 31] The finding of the current study is comparable with another study was carried out in the schools for dust evaluation and children exposure.

Investigators reported that the influence of $PM_{2.5}$ on children's health condition and absents rate from class; they found that there is a challenge of PM concentration and manipulate and reactions on health level of exposed people. The outside contamination is a main source of indoor air pollution in the current study schools. This hypothesis already reported from other researches with shown that concentrations of air pollutants in and outside schools near motorways aresignificantly associated with distance [18-19, 22-23], traffic density and composition and percentage of time downwind and the reported results are similar to the obtained finding from the current study [23, 27]. The influence of indoor air on the contamination in the classrooms was investigated via indoor air assessment. The effect of indoor air temperature ranging from 28 to 29C° on indoor air pollution was studied. The results indicate that the rate of dust concentration in the schools classes is slightly related to decrease or increasing of indoor air temperature. In the current study the mean $PM_{2.5}$ concentration was 135µg/m^3. This is comparable to other studies which reported a high concentration of $PM_{2.5}$ in the assessed schools classrooms [31-34, 36].

CONCLUSION

The results of indoor air monitoring in all the schools showed that all studied $PM_{2.5}$concentration values in the classrooms can be considered high in comparison with EPA exposure limit of 12µg/m^3. The $PM_{2.5}$concentration was ranged from 65 to 540µg/m^3 and the mean concentration of $PM_{2.5}$was 135µg/m^3. Both indoor air relative humidity and indoor air temperature have significantly contributed to the variability of the $PM_{2.5}$ concentration ($R^2 = 0.85$) and both factors also showed a straight relationship with the $PM_{2.5}$ concentration increasing level in the classrooms.

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