Environmental Education and Sustainable Development EESd

Available online at www.ap.iauardabil.ac.ir

**Islamic Azad University, Ardabil Branch**

Anthropogenic Pollution Journal, Vol 6 (1), 2022: 75-83

ISSN: 2783-1736- E-ISSN: 2588-4646

I.A.U Islamic Azad University Ardabil Branch

ORIGINAL RESEARCH PAPER

# Multiple Linear Regression Model for Prediction of Pupils Exposure to $PM_{2.5}$

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## ARTICLE INFORMATION

**Received:** 2022.02.01
**Revised:** 2022.02.23
**Accepted:** 2022.02.28
**Published online:** 2022.03.01

**DOI:** 10.22034/AP.2022.1951375.1127

## KEYWORDS

Multiple Linear Regression
$PM_{2.5}$
Preschool
Tehran air quality

## ABSTRACT

Particulate matter, as one of the biggest problems of air pollution in metropolises, is the cause of many respiratory and cardiovascular diseases, adverse effects of which on human health can be reduced through timely awareness and announcement. Therefore, considering that children are more exposed and more sensitive to this pollution, this research was conducted to introduce an evaluated mathematical model to predict $PM_{2.5}$ concentration levels, indoor selected preschools located in one of central districts of Tehran (district 6), using determination of related factors to $PM_{2.5}$ concentration. Classroom environmental information, Meteorological information and urban fixed monitoring stations data were collected through measuring indoor and outdoor classroom $PM_{2.5}$ concentrations using direct-reading instruments, adjusted questionnaire and conducted organizations, simultaneously. Results showed the spring and autumn had the lowest and highest indoor and outdoor concentrations (17.1 and 20.5 µg $m^{-3}$ & 48.7 and 78 µg $m^{-3}$) respectively. Also, multiple linear regression model was introduced by statistical analysis. The results of predicted indoor $PM_{2.5}$ concentration were compared and evaluated to measured data and showed that introduced model, consisting of seven main factors affecting the mean concentrations of indoor $PM_{2.5}$, including outdoor $PM_{2.5}$, the number of pupils, ambient temperature, wind speed, wind direction and open area of the doors and windows has good accuracy ($R^2 = 0.705$) and significantly correlated ($p < 0.001$). The Multiple Linear Regression Model can be used with good accuracy to predict indoor $PM_{2.5}$ concentration of preschool classes in Tehran.

**How to Site:** Baharfar Y., Mohammadyan M., Moattar F., Nassiri P., Behzadi M.H., Multiple Linear Regression Model for Prediction of Pupils Exposure to $PM_{2.5}$, Anthropogenic Pollution Journal, Vol 6 (1), 2022: 75-83, DOI: 10.22034/AP.2022.1951375.1127.

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## 1. Background

Particulate matter (PM) is one of the main air pollutants in urban areas(Mostofie et al., 2014), especially the metropolis of Tehran, as one of the most populous cities in the world with severe air pollution problems, which are mainly produced from various sources (Taghizadeh et al., 2019; Yousefian et al., 2020;Jalilzadeh and Rahmani, 2021;Tabari et al., 2020; Khajeh hoseini et al., 2020a) and affects enclosed spaces, in addition to environmental air, and exposure to them leads to harmful health effects and damage to humans (Mohammadyan and Shabankhani, 2013;Tabari et al., 2021;Khajeh hoseini et al., 2021;Sekhavati and Jalilzadeh, 2021). The researchers concluded that $PM_{2.5}$ is a common airborne contaminant with well-documented health effects (Schraufnagel et al., 2019a), which often affects many organs of the body, including the respiratory system, when it enters the human body through the breath (Schraufnagel et al., 2019b; Khajeh hoseini et al., 2020b;Tabari et al., 2021;Sekhavati and Jalilzadeh, 2021). The results of various studies show that an increase in $PM_{2.5}$ indoors, in addition to the increase in the prevalence of allergies and asthma, can lead to intensification in respiratory disorder, cardiovascular disease, and death; especially premature death in people with cardiorespiratory diseases(Sadigh et al., 2021). According to these studies, long-term exposure to high levels of this pollutant is a major concern, and the elderly, sensitive individuals, and children are more vulnerable (Halek et al., 2009; Mönkkönen, 2011; Rückerl et al., 2011; Chen et al., 2013; Hoek et al., 2013; Park, 2017; Schraufnagel et al., 2019b). One of recent studies have shown that long-term exposure to $PM_{2.5}$ may also play an effective role in having diabetes (Chen and Hoek, 2020). However, current evidence indicates that there is no "safe" level of $PM_{2.5}$ that is not associated with adverse health effects and shows that even low concentrations of $PM_{2.5}$ are a significant health threat (Guo, 2019; Mohammadyan et al., 2017).

Children spend most of their day in small enclosed spaces such as school or home (Cunha-Lopes et al., 2019; Nyarku et al., 2019; Mazaheri et al., 2019). However, several studies have reported high levels of inhalable particulate matter in schools (Diapouli et al., 2017; Goyal and Khare, 2009; Zhang et al., 2018) and children are considered a very sensitive subgroup due to the lack of development of their immune and physiological systems, Which increase their effectiveness at a younger age (Noor et al., 2015). According to the WHO report, acute respiratory infection accounts for 19% of deaths among children under-5, which is the effect of indoor air pollution (Choo et al., 2015). Recent research has explained increasing the concentration of $PM_{2.5}$ particles in schools can increase the absence of students and reduce their performance (Choo et al., 2015; Mendoza et al., 2019). Thus, over the past two decades, attention has been paid to the inhaled pollutants of primary schools in various locations, internationally (Gaffin et al., 2017).

Some studies evaluating the concentrations of particulate and gaseous pollutants in schools have shown that indoor air quality is less suitable than the outdoor and awareness of the extent to which children are exposed to $PM_{2.5}$ particles in environments in which children spend a significant amount of their growth years is very important (Amato et al., 2014; Di Virgilio et al., 2019; Yu et al., 2020). A study conducted in primary schools in Tehran showed that the concentration of respiratory particulates indoor the schools was high, to the extent that even schools were described as a dangerous environment for children and has considered it necessary to conduct further studies to determine the effective parameters in this increase (Halek et al., 2009). Another study abroad also found, finding changes in $PM_{2.5}$ concentrations are very important for evaluating and controlling air pollution in classrooms (Yuhe et al., 2021). Furthermore, the results of a comprehensive review research showed the average $PM_{2.5}$ concentration in most studies conducted in small primary learning environments was higher than the 24-hour limit level recommended by the WHO, and also schools located in the Middle East and Asia had the highest level of indoor concentrations of $PM_{2.5}$ among schools of different continents and it is necessary to study and conduct further research in schools of these areas (Cooper et al., 2020). Of course, studies have been conducted in schools indoor air quality in some countries, nevertheless, little is known about preschool environments (3 to 5 years) (Oliveira et al., 2017). One of the reasons for the lack of studies in schools, especially schools for young children, compared to other studies, is the challenge of deploying sampling equipment in school classrooms compared to closed environments such as adult workplaces (Gaffin et al., 2017).

Mathematical models are widely used to describe the relationships between different types of factors. In the case of air, as one of the environmental components, modeling can be useful for predicting and determining the concentration of pollutants or as a tool to select the best way to improve air quality in the building (Widder and Haselbach, 2017). Statistical and mathematical methods are also used to analyze the effect of some meteorological parameters on the concentration of air pollutants (Załuska et al., 2020). Therefore, it is necessary to provide a valid $PM_{2.5}$ concentration prediction model that can quickly determine the indoor concentration of this pollutant, using publicly available air pollution statistics data.

Thus, according to recemendations of previous researches, arguing the lack of quality statistical analysis, contradictory methods, underlying factors, poor evidence of the relationship between different factors in children's school environments, the need for stronger studies for the indoor environment using monitoring and more comprehensive statistical analysis to present to decision-makers seems crucial (Cooper et al., 2020), and since a suitable and practical model for predicting $PM_{2.5}$ concentration in preschools of the country is not yet presented and based on the mentioned documents, the need to research in this field, due to the sensitivity of this age group of children and its short history in Iran was very much felt, therefore, in addition to being aware of the indoor and outdoor $PM_{2.5}$ concenterations level in selected preschool, this study was conducted to validate the useful Multiple Linear Regression (MLR) model to predict the exposure rate and how $PM_{2.5}$ particles change in preschools in the metropolis of Tehran.

## 2. Materials and methods

### *2.1. Study place*

Tehran, the largest city in the country with a population of 8,429,807 people in 2017 and an area of 730 square kilometers, has 22 regions (www.amar.org.ir). District 6 is the most densely populated urban area of Tehran and is located in the central part of the city, where most of the 6 to 10-storey buildings are located. The main highways of Tehran are located in or on the outskirts of this area, the population and traffic of vehicles in that increase significantly during the day and the most important office-service uses with extra-regional, urban and even national functional scale are located in that. Therefore, this area was selected for the study (Fig1). By examining the student population, considering the dispersion of schools, cooperation of principals, the vicinity of residential/commercial/traffic areas, etc., based on the quasi-cluster statistical method, a total of 5 preschools were selected to measure the concentration of particule matters.

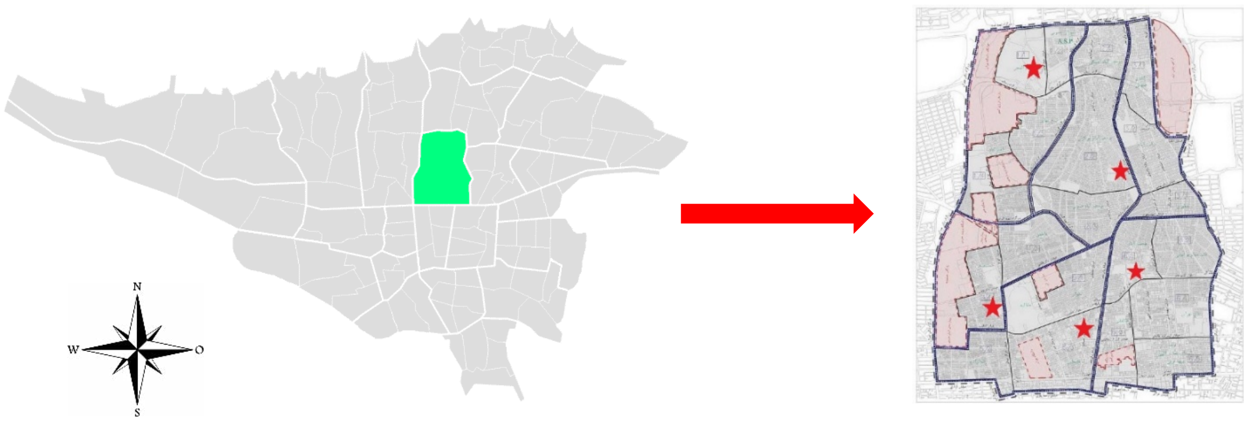


**Figure1.** Location of the study place and the selected preschools

### *2.2. $PM_{2.5}$ Measurement and Environmental Data Collection*

Measurement of indoor and outdoor $PM_{2.5}$ concenterations in preschools was done via two calibrated instrument DUSTTRAK ™ Model 8520, during three academic seasons (autumn (13 days), winter (25 days), spring (15 dsys) and totally 53 days) through the quasi-cluster statistical method and considering the distribution of schools, every day of the week in one of the preschools on a rotating basis and for about 6 hours, by standard methods introduced by relevant organizations (ASTM 2011). Indoor measurement was performed by setting the device in the middle of the classroom, without disturbing the pupils, and outdoor measurement within 1m from the wall and window of classes, and both of them in respiratory levels. During the sampling period, the questionnaire adjusted by the reseracher was completed while observing environmental and classes information. Average of air temperature, wind speed and direction at measurement time was obtained from the Meteorological Organization of Tehran Province, as well as urban air pollutants data recorded by fixed monitoring stations located in the study area, from Tehran Air Quality Control Organization.

### *2.3. Statistical Analysis and Modeling*

Analyzing data and measuring the relationship between them were performed after implementing the values measured by the instruments, on the computer and comparing them with the items in the supplementary questionnaires and data obtained from Tehran's air quality control and meteorological organization by SPSS statistical software (version 20), appropriate statistical methods and Office auxiliary software, etc. Then, the concentration of indoor particulate matters in preschools was predicted using multiple linear regression (MLR), and at the end, the results obtained from the model were compared with the real values resulting from field measurement by the researcher and the introduced model was validated.

In this model, the values of a dependent variable are stimated by the values of two or more other independent variables. This model has been used by many researchers in the field of air quality (Li, 2013; Li and Wang, 2017; Zhao, 2018; Jung, 2020; Cho et al., 2021; Kapić, 2021) and its general formula is as follows; $Y=\beta_0+\beta_1X_1+...+\beta_nX_n+\varepsilon$, where Y is the dependent variable, X is the independent variable, β is the known constant, and ε is the residual value. In the MLR model, the step-by-step method was used and the process was as follows:

Initially, a simple regression analysis was used to analyze the relationship between indoor $PM_{2.5}$ concentrations and each variable, and the variables without significant correlation ($p > 0.05$) were removed. Next, a simple linear regression model was used to evaluate the linearity between the variables. Values with an inflation coefficient of variance> 3 were removed to create a predictive model, and finally, the MLR was used to analyze the relationship between all variables and the indoor $PM_{2.5}$ concentration. This process was repeated until no other variables without statistically significant changes ($p<0.05$) were excluded in the regression model.

## 3. Results

During the study period, 12,055 one-minute measurements of validity for indoor and 10,736 for outdoor $PM_{2.5}$ of classrooms were recorded over 53 days, and based on the analysis of their results, the mean concentrations of classroom indoor and outdoor $PM_{2.5}$ were obtained 32±0.21 $\mu gm^{-3}$ and 43±0.32 $\mu gm^{-3}$ respectively, also the lowest indoor and outdoor concentrations were in spring (17.1 and 20.5 $\mu g\ m^{-3}$ respectively), and the highest concentrations were observed in autumn (48.7 and 78 $\mu g\ m^{-3}$)as the most polluted season, which in Figure 2, their changes can be seen during the measurement period. $PM_{2.5}$ concentration data recorded by fixed urban monitoring stations also showed the highest and lowest concentrations of airborne particulate matter pollution in the study area were concern to December in autumn, and May in spring, respectively, with similar changes of indoor and outdoor concenteration measurement by the researcher.

After ensuring the normal distribution of the measured particulate concentrations data indoor and outdoor the school classrooms ($p=0.062$ and 0.069), using the Kolmogorov–Smirnov test, with Pearson correlation test, determined that there was a highly significant relationship between indoor and outdoor $PM_{2.5}$ concentrations of classes ($r=0.94$, $p<0.001$).

The correlation between indoor $PM_{2.5}$ concentrations and all the assumed effective parameters of meteorology, questionnaires, etc. was investigated that also showed a significant and high correlation (Sig<0.001) between this pollutant and temperature, wind direction, wind speed, number of pupils, urban fixed monitoring $PM_{2.5}$ concentration, door and window status, also, other results of these tests showed that there was a significant correlation ($p<0.05$) between indoor $PM_{2.5}$ concentration of classrooms and other indoor variables including door opening status($r=0.082$), window opening status($r=-0.181$), classroom area ($r = 0.049$), window sealing ($r = 0.053$), heating system ($r=0.296$), floor material ($r=0.047$) and adjacent construction operations ($r=0.041$) and had no significant relationship ($p> 0.05$) with the variable of window material and type of window opening.

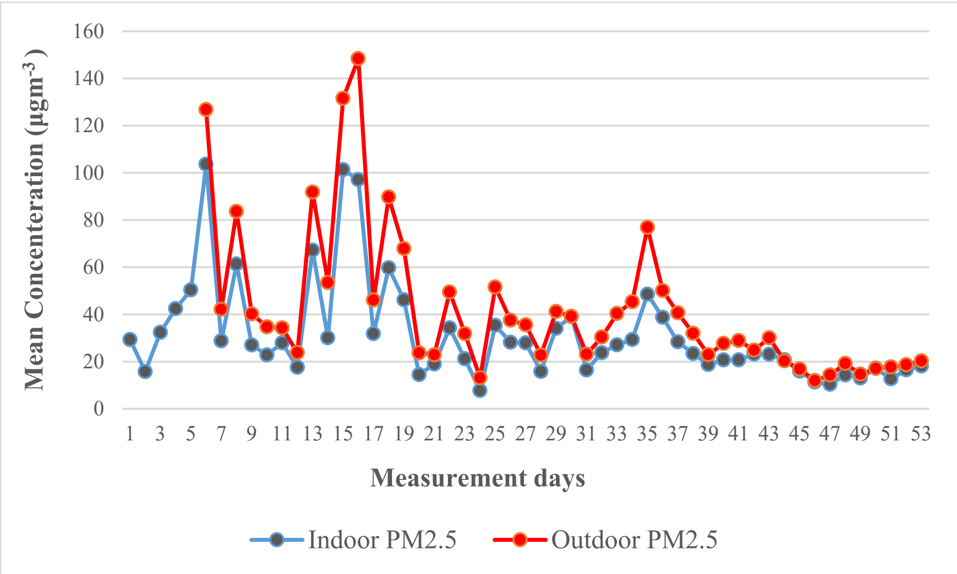


**Figure 2.** Comparison between the 24-h mean indoor and outdoor concentration of PM2.5 of the classrooms during the measurement period

**Table 1.** Result of multiple linear regressin analysis of indoor PM2.5 concentrations and realated factors

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 4560400.705 | 7 | 651485.815 | 4102.114 | .000a |
| Residual | 1910887.473 | 12032 | 158.817 | | |
| Total | 6471288.178 | 12039 | | | |

a. Predictors: (Constant),Temperature, wind direction, wind speed, number of pupils, urban fixed monitoring paticulate concentration, door condition, and window condition

b. Dependent Variable: $PM_{2.5}$ in

### *3.1. Prediction of indoor $PM_{2.5}$ concentration using the proposed MLR model*

Due to the determination of the initial linear relationship between the mean concentrations of indoor $PM_{2.5}$ measured in selected preschool classrooms with a set of hypothetical variables, multiple linear regression was used in the continuation of the process. In this regard, indoor $PM_{2.5}$ concentration of class was defined as the dependent variable and other factors affecting the concentration of this pollutant were defined as the independent variables, which according to the results of analysis of variance test, the linear regression relationship was confirmed (Table 1);

After determining the significant regression results, regression relationships were fitted. Evaluation on regression coefficients of indoor $PM_{2.5}$ concentration equation in classes shows that among all the parameters affecting the concentration of this pollutant, the relationship between indoor $PM_{2.5}$ concentration and the seven independent variables considered in the formula (including, $X_1$=Fixed monitors $PM_{2.5}$ concentration, $X_2$=Class door status, $X_3$=Class window status, $X_4$=Number of pupils, $X_5$=Ambient temperature, $X_6$=Wind direction, and $X_7$=Wind speed) were significant (P <0.001) and The regression relationship is generally presented as follows;

$$Y=-4.33 + 1.176X_1-0.432X_2 + 0.938X_3-$$
$$0.217X_4-0.224X_5-0.025X_6 + 0.483X_7$$

Using this model and the results of the information obtained in the research (Xs), indoor $PM_{2.5}$ concentration, during the months of measurement, was predicted in selected preschools (Y), then was compared with the mean of $PM_{2.5}$ measurement concentration data of the researcher, that the results are given in the following Table 2 and Figure 3.

**Table 2.** Comparison of values obtained from predicting indoor PM2.5 concentrations by MLR model with real values for different seasons

| Time | | Indoor $PM_{2.5}$ Concenterations($\mu gm^{-3}$) | |
|---|---|---|---|
| | | Result of the MRL (Y) | Researcher measurement (X) |
| **Season** | Autumn | 47.08 | 48.69 |
| | Winter | 31.98 | 30.09 |
| | Spring | 16.00 | 17.14 |

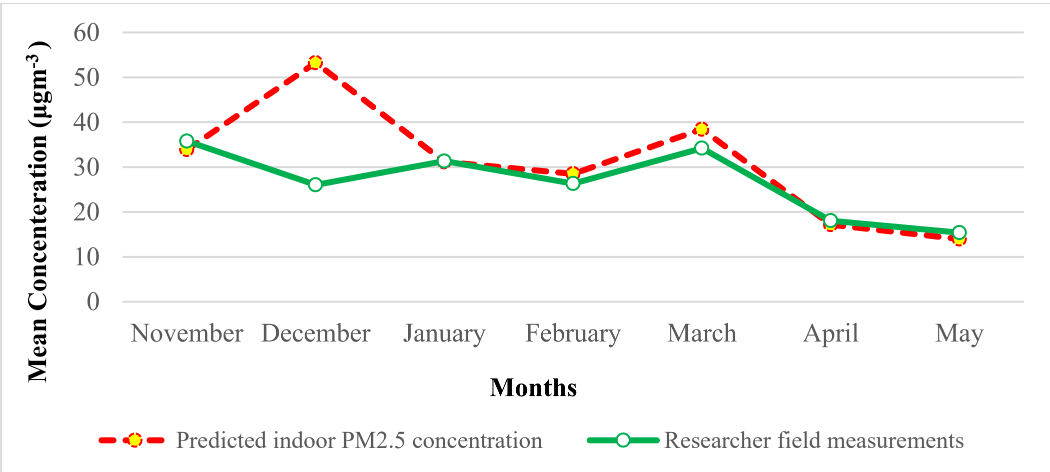


**Figure 3.** Comparison between results predicted concentrations using model and field measurements for different months

## 4. Discussion

In this research, the proposed MRL model was presented and validated by correlating the measurement results and collected information from the factors affecting the concentration of this pollutant for preschools in the center of Tehran. Findings of this study showed that the total mean concentration of measured indoor and outdoor $PM_{2.5}$ in the classrooms was 32 and 43 $\mu gm^{-3}$, respectively, and although is higher than the 24-h standard for mean $PM_{2.5}$ concentration recommended by EPA and Iran's environmental protection organization (25 $\mu gm^{-3}$) and similar to most previous studies conducted in Iran (Mohammadyan et al., 2013, 2017, 2019; Halek et al., 2013) and abroad (Fromme et al., 2008; Peng et al., 2017), but in general, it was lower than the studies of children exposure to particulate matter in small primary school environments in the world between the years 2001-2020, with the mean concentration of indoor $PM_{2.5}$ of 43.83 $\mu gm^{-}$

[3] and the mean concentration of indoor $PM_{2.5}$ of schools in the Middle East and Asia with averages of 78.31 and 71.76 μgm$^{-3}$, respectively (Cooper et al., 2020).

Evaluation with Pearson correlation test in the present research showed that indoor and outdoor $PM_{2.5}$ concentration of the classrooms had a significant linear relationship in the study period with a correlation of 94.2%. This has been confirmed in other similar studies in Spain and the United States (Rivas et al., 2014; Carrion-Matta et al., 2019) and in most other studies conducted at home and abroad (Massey et al., 2012; Halek et al., 2013; Hassanvand et al., 2014; Lv et al., 2017; Mohammadyan et al., 2013, 2019). Of course, in a few reviews, the opposite was reported due to the effect of not considering the indoor sources of pollutants (Stranger et al., 2008), but in addition to the above research, many other studies have proven that ambient air is a definitive and critical source of increasing indoor $PM_{2.5}$ concentrations (Pekey et al., 2010; Han et al., 2015; Gaffin et al., 2017; Jung et al., 2020) and outdoor $PM_{2.5}$ concentration of the classroom can be considered as the main cause of indoor $PM_{2.5}$ concentration changes.

According to the results, there has been a direct and significant relationship between the indoor $PM_{2.5}$ concentration and ambient temperature in center of Tehran, contrary to the other study conducted in Tehran classrooms (Halek et al., 2010). This result is inconsistent with the vast majority of other studies, because of this relationship has been reported inversely in other similar studies conducted in schools (Lin and Peng, 2010; Mohammadyan et al., 2017). The study by Massey et al. (2012) Showed that meteorological parameters are the main factors for forecasting and also confirmed the inverse correlation between ambient temperature and indoor $PM_{2.5}$ during the monitoring period. Some other studies that have drawn similar results (Sidra et al., 2015; Elbayoumi et al., 2015; Li and Wang, 2017), acknowledged that their results are different from most similar results and they provided reasons for this. It seems that the reason for this difference in the present study is the lack of accurate recording of temperature figures momentarily by the researcher thermometer and obtaining average of reports and related information, only for the early and middle hours of the day, from the Meteorological Department of Tehran.

A significant and direct relationship between the studied pollutant and ambient humidity and a significant and inverse relationship with wind speed was confirmed in similar studies (Goyal and Khare, 2009; Lin and Peng, 2010) and even in the analysis performed by Fromme et al. (2008) an increase in the $PM_{2.5}$ concentration by 1.7μgm$^{-3}$ for a 10% increase in ambient relative humidity was clearly concluded. The results of a similar study in Nanjing, China, found that meteorological conditions such as wind speed and relative humidity, along with indoor people activities and outdoor concenterations, had a significant effect and correlation with $PM_{2.5}$ concentration (Xu et al., 2020), but the results of an analysis of the relationship between PM suspension and relative humidity in the laboratory by establishing the characteristics of the primary school classroom environment in one of the studies showed a linear negative correlation between the concentration of this pollutant and increasing humidity (Cho et al., 2021). Therefore, these two parameters can also be expressed as meteorological parameters affecting the changes indoor $PM_{2.5}$ concentration, from the results of this study.

In the schools under measurement, changes in $PM_{2.5}$ concentration were also performed with different conditions of opening doors and windows, and it was found that this pollutant is directly related to the condition of opening the doors and inversely related to windows. Hänninen et al. (2004) showed that ventilation rate was positively correlated with $PM_{2.5}$ penetration rate. Jung et al. (2020) stated in their studies that high ventilation rates may increase the contribution of ambient $PM_{2.5}$ to indoor air at home. In contrast to the present study, a study by Yang et al. (2018) in a student dormitory at Nanjing University on indoor and outdoor $PM_{2.5}$ concentrations with open and close positions of windows in summer showed the mean values of indoor concentrations in the closed window position are generally lower than the the mean for window opening position. However, in this study, the number of present students and the type of their behavioral activities were considered as the determining factor of indoor concentration, which according to the age difference (adolescent and child) of the subjects and their activity and environmental differences (dormitory and school), the obtained result and the resulting difference will be justified.

Temporary increase in mean $PM_{2.5}$ concentrations during the researcher study, which is mainly due to the entry and exit of pupils or the temporary opening of classroom doors and windows, near the measurement instrument, have been similar to the results of some other studies, in which the physical activity of students in the classroom was considered an effective factor in increasing the instantaneous concentration of particulate inside the classrooms (Zhang and Zhu, 2012; Halek et al., 2013; Elbayoumi et al., 2015; Cavaleiro et al., 2016). This was demonstrated in a study of indoor $PM_{2.5}$ concentrations and student activity in the classrooms of a preschool in northern China and children's activity has been an important and influential factor in indoor air quality, causing rapid changes in indoor $PM_{2.5}$ concentrations over short periods (Yuhe et al., 2021). This relationship has been unanimously confirmed in other researches (MacNaughton et al., 2017; Mohammadyan et al., 2017; Peng et al., 2017).

The results of this study showed that there was no correlation (Sig>0.05) between indoor $PM_{2.5}$ concentration and the window material and its type of opening, but its significant relationship with other factors mentioned in this study has been proven. The rate of this relationship was 5.3% for window sealing, 5% for classroom area, 4.7% for floor materials, 4.2% for construction operations, and 29.6% for heating condition. In one of similar study, some of these issues were investigated, but no detailed information was provided on their results (Yushu et al., 2010). Fromme et al. (2008) , attributed changes in the concentration of indoor $PM_{2.5}$ to building materials and other internal sources, in their study and in another article on the chronic absence of children in Massachusetts public schools, the role of building age and building materials has been mentioned as important (MacNaughton et al., 2017).

The results of applying the regression model obtained from the statistical results of the research (MLR), including the main factors influencing the prediction of indoor $PM_{2.5}$ concentration in the preschool classrooms, which are as follows, show that the following variables in the model can explain about 70.5% of the indoor $PM_{2.5}$ concentration variables in the class.

Comparison of the validation of the proposed MRL model with the actual values measured by the researcher showed that there is a strong significant correlation in this regard and this model can predict the concentration of particles in the class with more than 80% accuracy.

The use of MLR model in several studies has been suggested to predict changes in indoors and outdoors $PM_{2.5}$ concentration and the results of its application and validation were confirmed (Li et al., 2013; Li and Wang, 2017; Zhao et al., 2018; Jung et al., 2020; Cho et al., 2021; Kapić, 2021). Elbayoumi et al. (2015) used the MLR model to estimate indoor $PM_{2.5}$ levels in schools. In the study of Cyrys et al. (2004) in Germany, linear regression models were used and showed that more than 75% of the daily indoor changes of $PM_{2.5}$ can be explained by its daily outdoor changes. Multiple regression model to investigate the correlation of $PM_{2.5}$ values with other major air pollutants and some meteorological parameters has been introduced in many studies with high fitting effect ($R^2$> 0.66-0.93) and with value (Li et al., 2013; Li and Wang, 2017; Jung et al., 2020; Cho et al., 2021). Similar to the present study, a study was done on children's room in Taiwan with similar questionnaires, in 4 seasons using a simple linear regression model to select each of the variables and MLR to estimate the final model. Based on this research, a regression model with key influential variables; outdoor $PM_{2.5}$, ventilation, building characteristics, and human activities and with $R^2$>75%, showed significant correlations between predicted and measured indoor $PM_{2.5}$ concentrations in different seasons and regions (Jung et al., 2020).

In several studies, the window opening and closing behavior (time or frequency) caused the error of the indoor $PM_{2.5}$ concentration prediction model, significantly and was considered necessary in future studies, that is considered in the present study and is applied in the final proposed model (Jung et al., 2020; Sun et al., 2019).

In some studies, mixed-effects linear models were used to determine the relationship between indoor and outdoor particulate matter concentrations at school classrooms and to predict exposure to these pollutants, that the output of which was predictable using data measured from central air pollution monitoring stations accurately and its performance has been superior to the models offered for indoor due to the low share of internal resources (Gaffin et al., 2017). A modeling study of air pollution caused by $PM_{2.5}$ in a single-family home in Bialystok by Załuska and Gładyszewska (2020) led to the presentation of a simple linear regression model by examining the concentrations of $PM_{10}$ and $PM_{2.5}$, the temperature and relative humidity of the ambiant air (as independent variables), Which predicts the concentration of this pollutant (dependent variable or response) in a residential building using the concentration of ambient $PM_{10}$. It is stated that this model can be useful for indoor air quality evaluating without the use of indoor measurement tools.

The results of the analysis of the relationship between PM resuspension and relative humidity through the laboratory room with the characteristics of the elementary school classroom environment in the study of Cho et al. (2021), showed that the concentration of this pollutant had a linear negative correlation with increasing humidity and the accuracy of the regression model ($R^2$) used to estimate the suspended concentrations of $PM_{10}$ and $PM_{2.5}$ is 88% and 93%, respectively.

## 5. Conclusion

Finally we found that the total mean concentration of indoor and outdoor $PM_{2.5}$ in the preschools is higher than the EPA and Iran's environmental protection organization 24-h standard (25μgm$^{-3}$), but had a significant linear relationship with a correlation of 94.2% and ambient air is a critical source and the main cause of increasing indoor $PM_{2.5}$ pollutions.

There has been a direct and significant relationship between the indoor $PM_{2.5}$ and ambient temperature and humidity, and activity of pupils in the classroom, but has been a significant and inverse relationship with wind speed. Also, it is directly related to the condition of opening the doors and inversely related to windows. The results showed that there was no correlation between indoor $PM_{2.5}$ and the window material and its type of opening, but its significant relationship with other factors mentioned in this study has been proven.

The results of applying the proposed regression model (MLR), consisting of 7-main factors affecting the mean concentrations of indoor $PM_{2.5}$, mentioned above, showed that it has good accuracy ($R^2$ = 0.705) and significantly correlated ($p < 0.001$). Comparison of the validation of the this MRL model with the actual values, showed that there is a strong significant correlation in this regard and MLR can predict the concentration of particles in the preschool classes with more than 80% accuracy in Tehran.

## Acknowledgements

The authors of the present article express their gratitude and appreciation to the education center of District 6 of Tehran, the principals, teachers, and pupils of the studied schools for their sincere cooperation in conducting the research.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Additional Information and Declarations


### Funding

There was no funding for this study.

### Grant Disclosures

There was no grant funder for this study.


### Competing Interests

The authors declare there is no competing interests, regarding the publication of this manuscript.

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