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Parametric Evaluation of Indoor Particulate Matters in Elementary Schools in the Central Parts of Tehran

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Key Words

Classroom pollution · Elementary schools · Indoor pollution · Particulate matters · Tehran air pollution

Abstract

The objective of this work was to evaluate the indoor-outdoor particle size distribution in elementary schools located in central parts of Tehran and to evaluate those parameters that could be influencing the indoor particles concentrations in the classrooms. Concentrations of particles including PM_{10} , $PM_{2.5}$ and $PM_{1.0}$, as some of the main air pollutants in Tehran, were measured in the schools, during winter 2009. It was found that the average indoor concentrations of PM_{10} , $PM_{2.5}$ and $PM_{1.0}$ were $274 \mu g/m^3$, $42 \mu g/m^3$ and $19 \mu g/m^3$, respectively, while the outdoor concentrations for these particles were $140 \mu g/m^3$, $38 \mu g/m^3$ and $22 \mu g/m^3$, respectively. The main factors influencing indoor particle pollution were found to be the outdoor concentrations of the particles and the physical activity of the students, but other factors such as the differences between indoor and outdoor temperatures, class size dimensions and types of boards in the classrooms had negligible effects.

Introduction

Among the major air pollutants released to the atmosphere, suspended particulate matters (PMs) are considered one of the major pollutants that could have an impact on human health and therefore a large number of related studies have been undertaken in developing countries in the last decade [1–3]. Several epidemiological studies have been made to reveal the association of PMs in the air with acute and chronic respiratory disorders, lung cancer, morbidity and mortality. Odds ratio estimated by several studies of the dose-response relationship for PMs associated respiratory sickness and premature mortality, which increased with a rise in PM levels [4–7]. Inhalable PMs include both fine and coarse particles. Adverse health effects of PMs are mostly attributed to the finer PM fractions. Fine particles (with a diameter <2.5 micro-metres) are most closely associated with such health effects as increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function and even premature death [8–11].

Coarse particles (2.5–10 micro-metres) are known to be made up of soil material which could be related to shoes, chalk dust of the blackboard, skin flakes, cloth and furniture fragments, viable moulds and bacteria, insects,

etc, which could be significant carriers of allergenic pollens. However, it has been demonstrated that ambient coarse particles may, under specific conditions, also have negative effects on human health. Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions, such as asthma [10,12–14].

Tehran is the largest city in Iran, with a population of about 10 million. As in other large cities, Tehran is faced with serious air quality problems. In Tehran, rapid urbanization, unprecedented vehicular emissions and inadequate infrastructure development are supplementary factors for the fall in air quality. PMs are considered to be one of the main types of air pollution problems in Tehran. The role, size distribution of PMs in the city's air pollution and also the effect of motor vehicles and trend of air borne particulate have been the subject of extensive studies [5,15,16]. People in Tehran are spending the main part of their time in various indoor environments. For children, schools represent the environment where they spend a substantial portion of the day.

A number of studies have revealed that the school air may be a source of a wide range of organic and inorganic air pollutants with potential toxic, carcinogenic allergenic and other adverse properties [17–20]. The exposure of children during education activities in the classrooms is of special concern because of their higher sensitivity to air pollutants. Heudorf et al. suggested improving the cleaning and ventilation systems in classrooms for better protection of children during educational activities in the schools [21]. Generally, children suffer from a higher exposure to air pollutants than adults because of their higher physical activity, higher metabolic rate and the resultant increase in minute ventilation [11,22]. The susceptibility of children to health problems as a result of exposure to polluted air has been pointed out several times in the past [10,12,23]. The primary objective of this study was to evaluate concentrations and size distribution of particulate air pollutants in some elementary schools located in the central parts of Tehran and studying the

important parameters influencing the concentrations of the particulate pollution inside the classrooms.

Materials and Methods

Instruments

Portable Particle Size Analyzer-dust monitor model Grimm-1.108 was used for continuous measurement of concentrations of PMs. Simultaneous measurements of the particles were by two analyzers, one of which stationed inside the classrooms and the other was set to collect the outside particles. This instrument uses a light-scattering technology for single-particle counts, whereby a semiconductor-laser serves as the light source. A 47- μ m PTFE filter was used for instrument calibration which was done according to the procedure adopted by Grimm Instrumental Company, and therefore the correction factor of $C_f = 1.09$ is incorporated into all of the indoor calculations and $C_f = 1.08$ into outdoor calculations. The instrument stores the data and transforms it to a computer for further processing. The weight of filters was just used for calibration of the two samplers. Although two separate filters (one for indoor and the other for outdoor measurements) were used in each station, measurements were based on the data stored by the samplers. This is because the average of air samplings from each station was 550 L in each day and the maximum suspended PMs was at most 0.0002 g in each experiment. Microbalance which was used in the experiment was Sartorius-BP211D, with an accuracy of five decimal points. This balance is calibrated yearly and has a current calibration certificate.

A global positioning system (GPS) instrument (model eTrex Vista) was used for geographical position (X and Y in Table 1) to determine the sampling locations in the schools.

Procedure

The study was carried out in five elementary schools in Tehran. All the sites are located in the central parts of

Table 1. Sampling sites in the sixth municipal district

School name (Abb.)	Average of students number in the classrooms	Location	Geographical positions of the sites	
			X	Y
Shaheed Pandi (P)	30	Golha Sq., Gomnam St., Mordad St.	E 51°23'44"	N 35°43'26"
15th Khordad (K)	22	North Palestine St. Alley 4	E 51°24'16"	N 35°42'45"
Shaheed Rajaei (R)	35	East Fatemi St.	E 51°23'27"	N 35°42'53"
Ostad Shahreyar (S)	15	West Fatemi St.	E 51°23'08"	N 35°42'46"
Shaheed Montazari (M)	30	West Fatemi St.	E 51°23'07"	N 35°42'44"

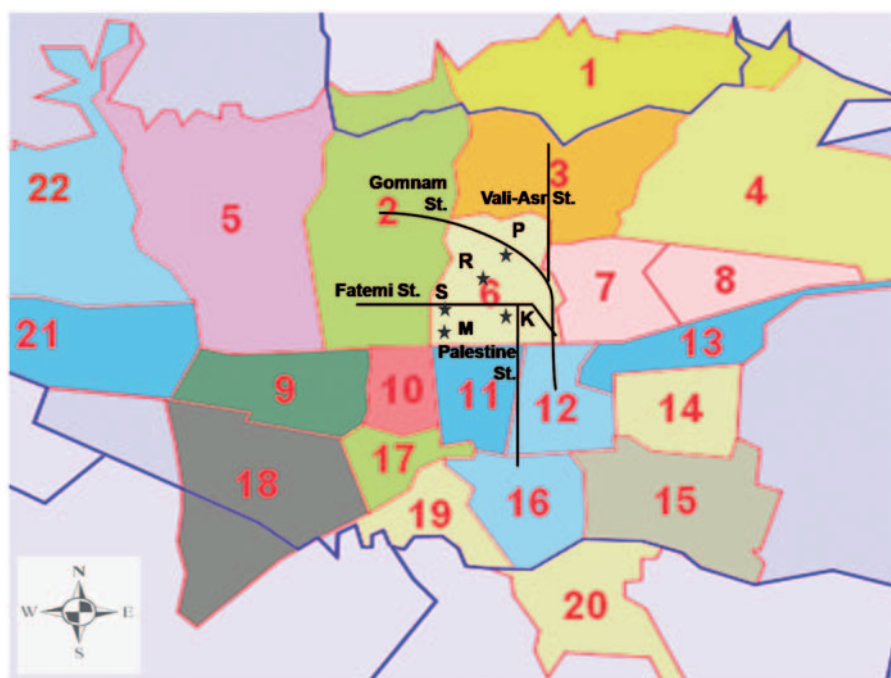


Fig. 1. Map of the sampling sites in the sixth municipal district of Tehran.

Tehran, with an average of 26 students in each classroom (Table 1). Figure 1 shows the map of Tehran's municipal districts in which sampling stations in the sixth region are highlighted. The sampling stations (schools) were selected in the sixth district of this city, which is located almost in the central part of Tehran, where it receives high pollution of the traffic, but is somehow far from the western industrial part of this city where its pollution is mostly caused by the close by industries.

In order to measure the effective exposure of children to the concentrations of the PMs, all of the samples were collected from 8 am to 2 pm, which is the total time period the pupils spend inside the classrooms. Daily air sampling of the particles in the schools was based on rotation of the days in each week to be sure of the equality of the procedure for each school. In general, sampling of the ambient air in this study was planned according to the procedure of standard practice: ASTM-D1357 [24]. The samples were collected at 1.1 m, which was the average height of the pupils. Two or three classrooms in each school (total of 13 classrooms in the schools) were selected as the sampling sites.

Simultaneous measurements of mass concentrations of PM_{10} , $PM_{2.5}$ and $PM_{1.0}$ were carried out in the winter 2009 (January, February and March). Particulate air pollution in Tehran in winter time, when the schools are open, is

generally high [5]. All schools are closed in Iran during the summer time.

Data Analysis

The sampling data were analyzed by Microsoft Excel and SPSS 17.0 software. One result of such analysis demonstrated the concentrations of indoor and outdoor classrooms' PM_{10} , $PM_{2.5}$ and $PM_{1.0}$, respectively, while another one associated with the effect of six different parameters to the indoor concentrations of those particles (Table 2). In the analysis of the data, it was assumed that the indoor particulate concentrations ($(PM_{10})_{in}$, $(PM_{2.5})_{in}$ and $(PM_{1.0})_{in}$) were considered as the variable parameter, then the effect of other parameters on this variable was evaluated. Six parameters were measured (or controlled) during sampling and the effect of these six parameters on indoor PM concentrations was evaluated.

These parameters were: the concentrations of PMs in outdoor air (PM_{out}), presence or absence of pupils in the classrooms during sampling ($X_{presence}$), the kind of activity in the classroom ($X_{activity}$) (such as movement in the classrooms or resting with any movement), type of classroom board (blackboard and chalk for writing or whiteboard and magic marker for writing), volume of the classroom which were simply calculated by measuring their dimensions (m^3) and finally differences between

Table 2. Measured or controlled parameters

Affecting parameter	Parameter	
	Quantitative (unit)	Qualitative (Options)
PM _{outdoor}	µg/m ³	—
Temp _{in} –Temp _{out}	°C	—
Volume of the classroom	m ³	—
Presence of the students	—	1 for presence and 0 for absence
Activity of the students	—	1 for resting and 2 for movement
Classroom board type	—	1 for whiteboard and 2 for blackboard

indoor and outdoor temperatures (Temp_{in}–Temp_{out}) in °C (Table 2). Thereby three different equations were derived in connections with the indoor PM₁₀, PM_{2.5} and PM_{1.0}.

Results and Discussion

Average concentrations of the three sized fractions of particles were calculated for the schools and compared with the outdoor concentrations.

The outdoor and indoor mean concentrations of PM₁₀, PM_{2.5} and PM_{1.0} in the schools are summarized in Tables 3 and 4.

The mean concentrations of the indoor particles are compared together in Table 4. It could be concluded from the data, that in connection with the PM pollution, the most polluted schools are Shaheed Montazari and Shaheed Pandi, while the 15th Khordad should be considered the safest among the other schools. In terms of the indoor concentrations of PM₁₀, PM_{2.5} and PM_{1.0}, the order of abundance of the particles in the classes was as follows: S. Montazari > S. Pandi > O. Shahreyar > S. Rajaei > 15th Khordad.

Our results (Tables 3 and 4) suggest that indoor concentrations of PM_{1.0} in the sampling sites were almost lower than the outdoor values. For example, the mean indoor concentration of PM_{1.0} in “Shaheed Pandi” school was found to be 20 µg/m³, while the outdoor concentration was 22 µg/m³. Indoor concentrations of PM_{2.5} were relatively higher than the outdoor concentrations; and PM₁₀ has much higher values in the indoor air and were almost twice in concentration as compared to the outdoor’s. For example, indoor concentrations of PM_{2.5} and PM₁₀ in “Shaheed Pandi” school were 50 and 357 µg/m³, respectively; while outdoor concentrations were found to be 35 and 105 µg/m³. Total averages of indoor

Table 3. Mean concentrations of outdoor particulate matter in the schools’ area (µg/m³)

	PM ₁₀	PM _{2.5}	PM _{1.0}
Shaheed Pandi	105	35	22
15th Khordad	166	37	21
Shaheed Rajaei	130	37	22
Ostad Shahreyar	128	40	24
Shaheed Montazari	161	41	23

Table 4. Mean Concentrations of indoor particulate matter in the classrooms (µg/m³)

	PM ₁₀	PM _{2.5}	PM _{1.0}
Shaheed Pandi	357	50	20
15 th Khordad	185	33	16
Shaheed Rajaei	274	40	18
Ostad Shahreyar	281	45	20
Shaheed Montazari	366	47	21

concentrations of PM₁₀, PM_{2.5} and PM_{1.0} in this study were found to be 274 µg/m³, 42 µg/m³ and 19 µg/m³, respectively. The average outdoor concentrations of the three sizes of the particles were found to be 140 µg/m³, 38 µg/m³ and 22 µg/m³ for PM₁₀, PM_{2.5} and PM_{1.0}, respectively.

In comparison with other studies on the particulate pollution in the schools, our findings showed high concentrations of these air pollutants. Fromme et al., measured the PM levels at a school located in northern Munich (Germany) during October and November 2005 [25]. Their findings indicated that the outdoor concentrations of PMs were 24.2 µg/m³ (PM₁₀) and 17.0 µg/m³ (PM_{2.5}). The reported indoor concentrations were

118.2 µg/m³ (PM₁₀) and 37.4 µg/m³ (PM_{2.5}). They also analyzed the sampled PMs by scanning electron microscopy (SEM) and energy-dispersive X-ray analysis (EDX) for determination of chemical and morphological properties of sampled (indoor) PM and based on these analyses they reported 24% of indoor PM₁₀ and 43% of indoor PM_{2.5} to be of ambient origin [25].

McCormack and co-workers studied the PM₁₀ and PM_{2.5} concentrations in Baltimore (USA) during September 2001 to December 2003. They reported the mean concentrations of indoor PMs were equal to 40 µg/m³ for PM_{2.5} and 56 µg/m³ for PM₁₀ [26].

Another research work done in Beijing, China, during 2002/2003, reported the mean concentrations of indoor PM₁₀ and PM_{2.5} to be 44 and 133 µg/m³, respectively [27].

Summarily, our results indicate that indoor concentrations of PM_{1.0} in the sampling schools were relatively lower than the relative outdoor concentrations, while the concentrations of PM_{2.5} in the classrooms and in the outdoor air were relatively in same levels and finally PM₁₀ were found to have much higher values in indoor air in comparison with the outdoor concentrations at the sampling sites. In general, it is important to note that indoor PMs concentrations were higher indoors than outdoor.

Evaluation of Parameters Affecting the Indoor PM Concentrations

The sampling data were analyzed by means of SPSS 17.0 software to find out those parameters affecting the indoor air pollution inside the classrooms. The linear regression method was used within software and the so-called "Forward selection process method" was selected for this purpose, considering only those parameters having less than 5% error in the model. In this method, using ANOVA test and by taking 5% error into account, the information, which consist of a set of properly arranged data, incorporated in the model and finally the possible models are proposed in which all of the related parameters are considered. If the indoor particle concentration is considered as the variable parameter, then the effect of other parameters (Table 2) on this variable was evaluated following the proposed equations (Equations (1)–(3)) for PM₁₀, PM_{2.5} and PM_{1.0} concentrations inside the classrooms. Indoor PMs concentrations were evaluated to be in connection with three of these parameters including the outside concentrations of these particles, the presence or absence of pupils in the classroom and kind of activities of the pupils during sampling.

Other three parameters such as volume of classrooms (m³), Temp_{in}–Temp_{out} (the difference of indoor and outdoor temperature – °C) and classroom board were distinguished by the software to have no mentionable effects on indoor PMs concentrations. Equations (1)–(3), as the final output of SPSS software from the evaluation of sampling data, reveal the relationship of the dependent parameter (PM_{in}) to the main three effective parameters.

1. $(PM_{10})_{in} = 118.49 + 0.14 (PM_{10})_{out} + 369.48 (X_{activity}) + 144.95 (X_{presence})$
2. $(PM_{2.5})_{in} = 4.56 + 0.62 (PM_{2.5})_{out} + 24.93 (X_{activity}) + 12.08 (X_{presence})$
3. $(PM_{1.0})_{in} = 5.51 + 0.64 (PM_{1.0})_{out} + 3.42 (X_{activity}) + 2.91 (X_{presence})$

The R^2 were evaluated to be 0.83, 0.79 and 0.81 for equations above, respectively, and N was 154 for all. In these equations, the dependent parameter PM_{in} is the indoor concentration of each size of the particles. PM_{out} denotes the concentration of suspended particles of the outside air at the same time, which is defined as µg/m³ in the equations. $X_{presence}$ denotes the coefficient of presence of the pupils which would equal to either 1 or 0, for the time when the children are in the classrooms and when they are absent, respectively. $X_{activity}$ is the activity coefficient for the time when the pupils are in the classrooms, which would equal to 1 when the pupils are at rest in the classroom with no movements and changes to 2 when they are in movement.

In general, indoor concentrations of particles in the classrooms were mainly derived from the outdoor PM concentrations and also due to the pupils' activities in the classrooms.

Conclusion

It is well known that particulates can accumulate in the lungs after repeated long-term exposure, causing respiratory distress and other health problems, especially in children. Our results revealed that classrooms in the sampling schools represent hazardous environments for children in studied region in the central part of Tehran. The mean indoor concentrations of PM₁₀, PM_{2.5} and PM_{1.0} in the schools were 274 µg/m³, 42 µg/m³ and 19 µg/m³, respectively. The average outdoor concentrations of these three sizes of particles were found to be 140 µg/m³, 38 µg/m³ and 22 µg/m³ for PM₁₀, PM_{2.5} and PM_{1.0}, respectively.

The results of analyzing the data by SPSS software indicated that the concentrations of the three kinds of suspended particles inside the classrooms were mainly in connection with the outside concentrations of these particles, the presence and the physical activity of the pupils. It is also found that the temperature difference between inside of the classrooms and outdoor air, the volume of the classes and the type of the writing boards have negligible effects on the indoor air quality in the

classrooms. It is hoped that results of this study would aid in regulatory actions of improving indoor air quality in the classrooms in Tehran and other polluted cities.

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