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Evaluation of Indoor-Outdoor Particle Size Distribution in Tehran's Elementary Schools

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***Abstract*—**A simultaneous study on indoor and outdoor particulate matter concentrations was done in five elementary schools in central parts of Tehran, Iran. Three sizes of particles including PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ were measured in 13 classrooms within this schools during winter (January, February and March) 2009. A laser-based portable aerosol spectrometer Model Grimm-1.108, was used for the continuous measurement of particles. The average indoor concentration of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in studied schools were 274 $\mu g/m^3$, 42 $\mu g/m^3$ and 19 $\mu g/m^3$ respectively; and average outdoor concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ were evaluated to be 22 $\mu g/m^3$, 38 $\mu g/m^3$ and 140 $\mu g/m^3$ respectively.

***Keywords*—**Elementary school, Indoor pollution, Particulate matter, PM_{10}, $PM_{2.5}$, $PM_{1.0}$, Outdoor pollution, Tehran air pollution.

I. Introduction

AMONG the major air pollutants released to the atmosphere, suspended particulate air pollution are considered as one of the major health impact and therefore a large number of related studies have been undertaken in developing countries in the last decade. Several epidemiological studies have been made to revealing the association of PM in air with acute and chronic respiratory disorders, lung cancer, morbidity and mortality. Odds ratio estimated by several studies of the dose-response relationship for PM associated respiratory sickness and premature mortality, increased with rise in PM levels [1] - [6]. Inhalable PM includes both fine and coarse particles. Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions, such as asthma. Fine particles 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 [7], [8].

Particulate matter is considered one of the main sources of air pollution problems in Tehran. The role, size distribution of particulate matter 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 [9], [10].

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 haphazard urbanization, unprecedented vehicular emissions and inadequate infrastructure development are supplementary factors for the fall in air quality. People in Tehran are spending the main part of their time in various indoor environments. For children, schools represent the environment where they pass a substantial portion of the day. A number of studies have revealed that 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 [11] - [14].

The aim of this study was to investigate the mass concentrations of three fractions of particles in some classrooms and its correlation with outdoor concentrations of particulate matter.

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II. Materials and Method

A. Sites Citation and Sampling Program

The study performed in five elementary schools in Tehran. These sites are all located in the central parts of Tehran having averagely 26 students (and the teacher) in each classroom which indicated in Table I. In order to measure the real exposure to the concentration of the particulate matter by children being as close as possible, all samples were collected from 8 AM to 2 PM to cover the period of presence of students in classroom and at the height of 1.1 meter.

In this study, simultaneous measurements of mass concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in the sampling stations were done in the cold season (January, February and March 2009).

The samples were collected once a week, covering each day of the week (without holidays) to be sure that all the days of the week were included. Two or three classrooms in each school were studied and a comprehensive sampling of outdoor PM concentrations from each school was done. Summarily, 13 classrooms in Tehran's elementary schools were studied during this research. Then a comparison between outdoor and indoor PM concentrations was made and discussed for each school.

B. Instrumentation

Portable particle size analyzer-dust monitor Model Grimm-1.108, was used for the continuous measurement of particles. The particles can be reported in their mass concentration as

$\mu g/m^3$. The instrument uses a light-scattering technology for single-particle counts, whereby a semiconductor-laser serves as the light source.

A 47 μm PTFE filter was used for collecting the dust samples. Such a filter was used for instrument calibration that was done according to procedure adopted by Grimm instrumental company, and therefore a correction factor of $C_f = 1.09$ is incorporated into all of the calculations.

A GPS (Global Positioning System) instrument (Model eTrex Vista) was used for geographical position (X and Y in Table I) determination of sampling schools.

TABLE I
SAMPLING SCHOOLS

School Name (Location)	Students in a Classroom	Geographical Position	
		X	Y
Shaheed Pandi (Golha Sq., Mordad St.)	30	E 51° 23' 44"	N 35° 43' 26"
15th Khordad (Palestine St. - Alley 4)	22	E 51° 24' 16"	N 35° 42' 45"
Shaheed Rajaee (East Fatemi St.)	35	E 51° 23' 27"	N 35° 42' 53"
Ostad Shahreyar (West Fatemi St.)	15	E 51° 23' 08"	N 35° 42' 46"
Shaheed Montazari (West Fatemi St.)	30	E 51° 23' 07"	N 35° 42' 44"

III. Results and Discussion

After sampling, average concentrations of three sized fractions of particles were calculated for each sampling school and compared with outdoor concentrations of particles and together.

Indoor and outdoor mean concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ at five sampling schools are illustrated in Figs. 1 to 5.

Fig. 1 shows the compared values of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ between indoor and outdoor concentrations at Shaheed Pandi school.

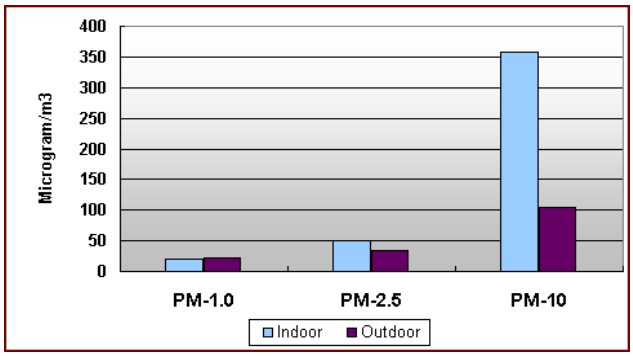

Fig. 1 Mean concentrations of PM at Shaheed Pandi School

Mean indoor concentration of $PM_{1.0}$ in this school was calculated to be 20 $\mu g/m^3$ while outdoor concentration was 22 $\mu g/m^3$. Indoor concentrations of $PM_{2.5}$ and PM_{10} were 50 and 370 $\mu g/m^3$; while outdoor concentrations were 35 and 105 $\mu g/m^3$ respectively.

The data provided in Fig. 1 indicate that indoor concentration of $PM_{1.0}$ in Shaheed Pandi School is relatively lower than its outdoor concentration, while indoor concentrations of $PM_{2.5}$ and specially PM_{10} are higher than outdoor values.

Figs. 2 - 5 represent the results of measurements in other four schools.

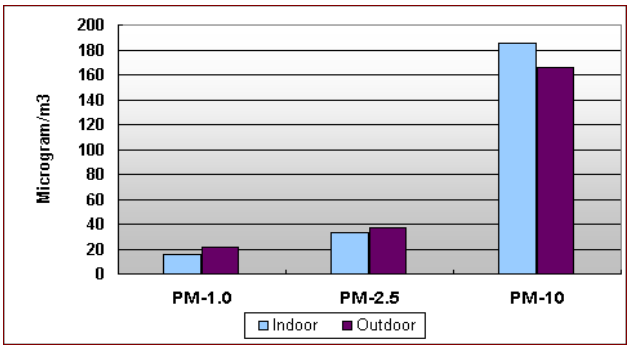

Fig. 2 Mean concentrations of PM at 15th Khordad School

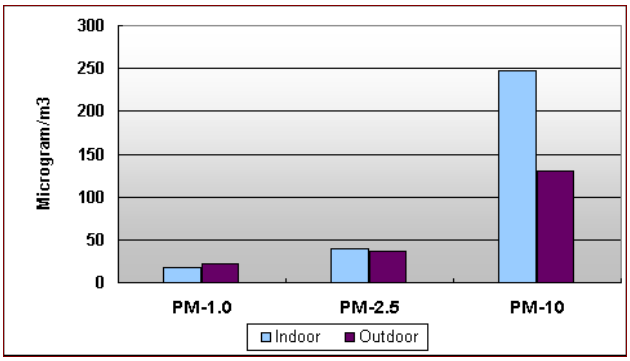

Fig. 3 Mean concentrations of PM at Shaheed Rajaee School

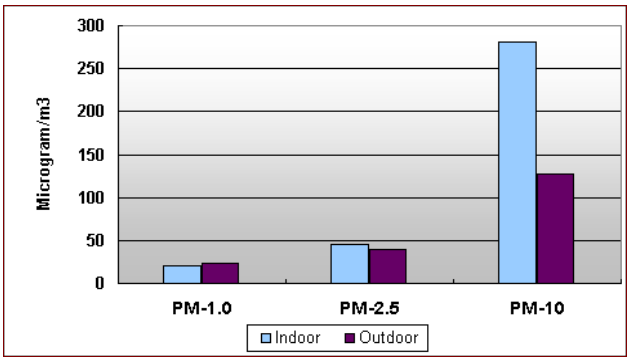

Fig. 4 Mean concentrations of PM at Ostad Shahreyar School

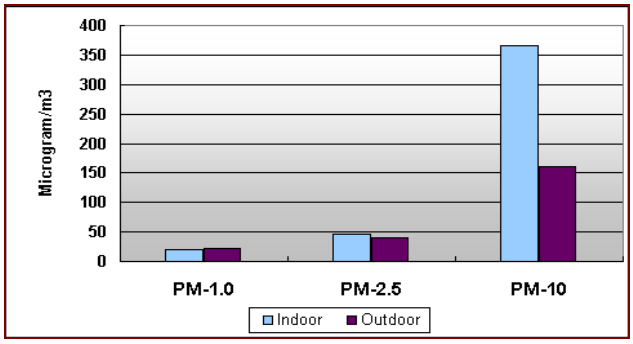

Fig. 5 Mean concentrations of PM at Shaheed Montazeri School

Our results (Figs. 1 - 5) revealed that indoor concentrations of fine particles ($PM_{1.0}$) in all of sampling sites are higher than outdoor values. Concentrations of $PM_{2.5}$ in classrooms and in outdoor air are relatively in same levels. PM_{10}, which can be defined as coarse particles, has much higher values in indoor air up to 2 folds in comparison with outdoor concentrations.

Adverse health effects of particulate matter are mostly attributed to finer particulate matter fractions. However, it has been demonstrated that ambient coarse particles may, under specific conditions, also have negative effects on human health [15], [16]. Coarse particles known to be made up of soil material brought in on shoes, of the blackboard dust, of skin flakes, of cloth and furniture fragments, of viable molds and bacteria, of insect, and of other materials may be significant carriers of allergenic properties. It has also been noted that coarse particles in schools have a high allergenic potential [17], [18].

TABLE II
MEAN CONCENTRATIONS OF INDOOR PARTICULATE MATTER IN SCHOOLS ($\mu g/m^3$)

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

A comparison of mean concentrations of indoor particulate matter in 3 sizes including PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ at five sampling schools could be done in Table II.

Total averages of indoor concentrations of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in this study were calculated to be 274 $\mu g/m^3$, 42 $\mu g/m^3$ and 19 $\mu g/m^3$ respectively. Table III summarizes the average concentrations of indoor and outdoor particulate matters during present study in Tehran's elementary schools.

TABLE III
TOTAL AVERAGE CONCENTRATIONS OF INDOOR AND OUTDOOR PARTICULATE MATTERS ($\mu g/m^3$)

	PM_{10}	$PM_{2.5}$	$PM_{1.0}$
Indoor	274	42	19
Outdoor	140	38	22

In general, indoor concentrations of particles in classrooms derive from outdoor particulate matter concentrations and human activities in classroom. However, more studies are needed to determine the parameters producing these high values of particulate matter concentrations in classrooms.

IV. 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 of schools represent hazardous environments for children. The mean indoor concentration of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in studied schools were 274 $\mu g/m^3$, 42 $\mu g/m^3$ and 19 $\mu g/m^3$ respectively. The average outdoor concentrations of these three sizes of particles were calculated to be 140 $\mu g/m^3$, 38 $\mu g/m^3$ and 22 $\mu g/m^3$ for PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ respectively.

More studies are needed to determine the parameters producing these high values of particulate matter concentrations in classrooms which are potentially affecting health and safety of young students. It is hoped that results of this study aid in regulatory actions of improving air quality in the Tehran and other mega cities in Iran.

ACKNOWLEDGMENT

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