International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:7, No:6, 2013

Indoor and Outdoor Concentration of Particulate Matter at Domestic Homes

B. Karakas, S. Lakestani, C. Guler, B. Guciz Dogan, S. Acar Vaizoglu, A. Taner, B. Sekerel, R. Tıpırdamaz, and G. Gullu

***Abstract*—**Particulate matter (PM) in ambient air is responsible for adverse health effects in adults and children. Relatively little is known about the concentrations, sources and health effects of PM in indoor air. A monitoring study was conducted in Ankara by three campaigns in order to measure PM levels in indoor and outdoor environments to identify and quantify associations between sources and concentrations. Approximately 82 homes (1st campaign for 42, 2nd campaign for 12, and 3rd campaign for 28), three rooms (living room, baby's room and living room used as a baby's room) and outdoor ambient at each home were sampled with Grimm Environmental Dust Monitoring (EDM) 107, during different seasonal periods of 2011 and 2012. In this study, the relationship between indoor and outdoor PM levels for particulate matter less than 10 micrometer (µm) (PM_{10}), particulate matter less than 2.5µm ($PM_{2.5}$) and particulate matter less than 1.0µm (PM_1) were investigated. The mean concentration of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ at living room used as baby's room is higher than living and baby's room (or bedroom) for three sampling campaigns. It is concluded that the household activities and environmental conditions are very important for PM concentrations in the indoor environments during the sampling periods. The amount of smokers, being near a main street and/or construction activities increased the PM concentration. This study is based on the assessment the relationship between indoor and outdoor PM levels and the household activities and environmental conditions.

***Keywords*—**Indoor air quality, particulate matter (PM), PM_{10}, $PM_{2.5}$, $PM_{1.0}$.

I. Introduction

THE indoor air quality (IAQ) as assessed by particulate matter (PM) has become one of the most important topics of air pollution research. This is because most people spend most of their time in various indoor environments (homes, schools, offices, shopping mall, restaurants etc.). Usually, in health studied, particulate matter (PM) has been measured as the mass of particle smaller than 10 µm, PM_{10} or smaller than 2.5µm, $PM_{2.5}$ [6]. These findings were especially pronounced for inhalable thoracic particles (particles of aerodynamic diameter less than 10µm, PM_{10}) and fine particles (particles smaller than 2.5µm, $PM_{2.5}$ [2], [3], [5], [13], [16], [17].

Many studies have found that the concentrations of suspended particulate matter were higher indoors than outdoors when there were sources of indoor particulate in domestic homes [4], [8], [7], [19], [21]. Incremental concentrations of fine particles were attributed to tobacco smoking and operation of gas stoves for cooking. Reference [19] found that concentrations of fine particle were as high as 300µg/m^3 when a smoker kept smoking for up to 30min until the cigarette had burnt out, also the 24h average concentrations of fine particles could be elevated by 20µg/m^3.

As most time is spent at indoors, information on the indoor/outdoor (I/O) relationship of particulate concentrations is important. Indoor levels can be influenced by outdoor levels and by particle generation indoors [22]. Not only emission sources, but also human activities (e.g. cleaning, working, cooking etc.) and even the mere presence of people at home lead to increases in particulate levels indoors [19].

A variety of studies on I/O relationships have been conducted in the USA. Overall, the I/O ratios ranged from 0.5 to 2 and greater [9]-[11], [18]. In homes with indoor sources (e.g. gas-cooking, smoking) I/O ratios were generally found to be greater than 1, showing that the exposure of subjects to particulates can be greater than outdoors.

A dose-concentration relationship was found for fine particulates with the number of cigarettes smoked at home [14]. Reference [15] investigated I/O relationships in Finland, where the ratios were less than 1 in homes without any indoor sources but greater than 1 in homes with smokers. For fine particulates, Reference [12] found I/O ratios between 0.6 and 2. Without indoor sources, an almost linear indoor/outdoor relationship was observed. In all homes no air conditioning is used and ventilation is conducted mechanically by opening windows.

In this study, approximately 82 homes (1st campaign for 42, 2nd campaign for 12 and 3rd campaign for 28), three rooms (living room, baby's room and living room used as a baby's room) and outdoor ambient at each home were sampled with Grimm Environmental Dust Monitoring (EDM) 107, during different seasonal periods of 2011 and 2012. The relationship between indoor and outdoor PM levels for particulate matter less than 10µm (PM_{10}), particulate matter less than 2.5µm

B. Karakas, S. Lakestani, G. Gullu are with the Hacettepe University, Faculty of Engineering, Environmental Engineering Department, 06800 Beytepe, Ankara-Turkey (e-mail: bilgekarakas@hacettepe.edu.tr, sanaz@ hacettepe.edu.tr, ggullu@hacettepe.edu.tr).

C. Guler, B. Guciz Dogan, S. Acar Vaizoglu are with the Hacettepe University, Faculty of Medicine, Department of Public Health, 06100 Sihhiye, Ankara-Turkey (e-mail: cguler@hacettepe.edu.tr, bdogan@ hacettepe.edu.tr, sacar@hacettepe.edu.tr).

A. Taner is with the TOBB ETÜ Hospital, Microbiology and Clinical Microbiology; Yasam Caddesi No: 5 06510 Sögütözü, Ankara-Turkey (e-mail: ataner@tobbetuhastanesi.edu.tr).

B. Sekerel is with the Hacettepe University, Faculty of Medicine, Pediatric Allergy and Asthma Unit, 06100 Sihhiye, Ankara-Turkey (e-mail: bsekerel@yahoo.com).

R. Tipirdamaz is with the Hacettepe University, Faculty of Science, Department of Biology, 06800 Beytepe, Ankara-Turkey (e-mail: tuz@hacettepe.edu.tr).

($PM_{2.5}$) and particulate matter less than 1.0µm (PM_1) were investigated. Also, the study demonstrates a few representative cases of I/O investigations with the emphasis on reference conditions (homes without indoor source and activity), indoor sources (e.g. smoking, heating type, nearby construction) and elevated human indoor activity in the absence of indoor sources. The objectives of this study were to: (i) compare fine and course PM exposure for the measurement environment (living room, baby's room, outdoor) and the measurement champagnes, and (ii) discuss possible sources that influence indoor and outdoor PM concentrations for the homes.

II. Material and Methods

A. Sampling Site and Data Collection

Ankara is the capital of Turkey and the country's second largest city after Istanbul. In this study, the sampling locations located in different neighborhoods of Ankara district. The locations of the sampling sites are shown in Fig. 1.

Fig. 1 Sampling locations

Within the scope of this study, three measurements campaigns were performed on different time periods. The first measurements campaign carried out between April 20, 2011 to July 26, 2011, second campaign between October 24, 2011 to December 28, 2011 and the third campaign between April 19, 2012 to July 02, 2012.

Approximately 82 homes (1st campaign for 42, 2nd campaign for 12, and 3rd campaign for 28), two rooms (living room and baby room) and outdoor ambient were sampled.

Indoor air samples were collected both in living and baby's rooms (or bedroom). In some homes, the living room is used as a baby room. In situations such as this, the only one measurement was performed for indoor ambient sampling. For the outdoor measurements, samples were taken at balconies, in front of the windows or near to the front of the homes. During the sampling studies, PM monitoring device was placed in the middle of the sampled rooms in the 50cm above the floor on a horizontal surface.

B. Monitoring Equipment and Analysis

In this study, Grimm Series 1.107 Aerosol Spectrometer (Grimm Technologies, Inc., Douglasville, GA, USA), a portable optical counter, was utilized to measure particle mass concentrations and size distributions since this kind of monitor is lightweight, easy to operate, and effective for time resolution.

The Grimm Aerosol Spectrometer measures the number of particles per unit volume of air using light-scattering technology. The number concentration of aerosol particles detected by the spectrometer is converted into a mass concentration via mathematical extrapolation with a correction factor. The relationship between the mass concentration and number concentration can be expressed as

$$m(d_{pi})=C_F(\pi/6)d^3_{pi}n(d_{pi}) \quad (1)$$

where i is channel number of the optical particle counter; d_{pi} is the arithmetic mean diameter of the upper and lower boundaries for channel i; $m(d_{pi})$ is the mass concentration in channel i; $n(d_{pi})$is the number concentration in channel i; and C_F is a correction factor. In this study, measurement raw data are reported based on the default correction factor of 1.0 [23].

This instrument provides four operational modes: environmental, occupational health, mass distribution and count distribution. The instrument measures particle concentrations in an optical size of 0.25–32µm in 31 channels with differently sizes with a concentration range of 1–2,000,000 particles/L (for count distribution mode) or a mass concentration range of 0.1 to 1.500µg/m^3 (for mass distribution and environmental and occupational health modes).

The Grimm EDM107 dust monitor takes a continuous air sample with a flow controlled pump. The particles are measured by the physical principle of orthogonal light scattering. Here particles are illuminated by a laser light and the scattered signal from the particle passing through the laser beam is collected at approximately 90° by a mirror and transferred to a recipient diode. Each signal of the diode is fed, after a corresponding reinforcement, to a pulse height analyzer then classified to size and transmitted in each size channel. These counts are converted each 6 seconds to a mass distribution from which the different PM values derive.

The data is also stored and retrieved for PC display with our software for mass distribution in µg/m^3 for PM_{10}, $PM_{2.5}$, and PM_1. Remote data access is also possible.

In this study, the spectrometer was operated in mass distribution mode to produce mass concentrations versus time. The measured real-time mass concentration data are transferred at 6 seconds intervals to a data storage card. Measurement data were then downloaded from the storage card via the Grimm 1.177 program on mass distribution mode and environmental mode, respectively. The particle mass concentrations in 31 different sizes can be produced at mass distribution mode. Additionally, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ levels can be generated directly when environmental mode was selected.

During the sampling period, carbon dioxide (CO_2), relative humidity (RH) and temperature (T) levels also recorded. The Indoor air IQ-410 quality probe was used to measure CO_2, CO, T and RH parameters. These parameters and concentrations of PM_{10}, $PM_{2.5}$, $PM_{1.0}$, were measured at each environment for a period of 15min interval. The measurements were performed non-simultaneously in indoors and outdoors.

Addition to air quality parameter records, the questionnaire study also have been carried out. The questionnaire containing 30 questions about building conditions, residential life-style and indoor situations was completed by the participants during the sampling period. The questionnaire also asked about the distance of the residence from a main street, amount of smoker at household, smoking places at homes, distance to the construction works etc.

III. Results and Discussion

A. The Results of Carbon Dioxide (CO_2), Relative Humidity (RH) and Temperature (T) Measurements

For the 1st campaign of sampling studies, the average CO_2 concentration in living rooms ranged from 459 to 1118ppm with an average of 742ppm. In the baby's rooms, the mean CO_2 concentrations ranged from 488 to 1176ppm with an average of 741ppm. During the 1st sampling campaign, 40 percent of indoor measurement was carried out at rooms which are same using of both living and baby's room. In the case of the common used areas, the mean CO_2 concentrations ranged from 455 to 1473ppm with an average of 947ppm.

The average temperature (T) level in outdoor ranged from 10 to 23°C with an average of 16°C. Table I shows the indoor and outdoor levels of CO_2 and the results of outdoor temperature measurement obtained in the living rooms, baby's rooms, the living room used as a baby's rooms of residence.

TABLE I
INDOOR AND OUTDOOR CONCENTRATIONS OF CARBON DIOXIDE (CO_2), TEMPERATURE (T), AND RELATIVE HUMIDITY (RH) FOR 1ST SAMPLING CAMPAIGN

1st Sampling Campaign	n	CO_2 (ppm)	n	T (°C)	n	RH (%)
Living Room		742±208		-		-
Minimum	35	459	-	-	-	-
Maximum		1118		-		-
Baby's Room		741±187		-		-
Minimum	35	488	-	-	-	-
Maximum		1176		-		-
Outdoor		455±107		16±4		-
Minimum	43	304	45	10	-	-
Maximum		1115		23		-
Living room & Baby's room	8	947±374	-	-	-	-
Minimum		455		-		-
Maximum		1473		-		-

For the 2nd campaign of sampling studies, the average CO_2 concentration in living rooms ranged from 708 to 1370ppm with an average of 968ppm. The mean CO_2 concentrations in the baby's rooms ranged from 436 to 1567ppm with an average of 1075ppm. In the case of the common used areas, the mean CO_2 concentrations ranged from 530 to 828ppm with an average of 746ppm.

The average temperature (T) level in living room ranged from 18 to 23°C with an average of 21°C.

Average RH measurements level and standard deviation (SD) in indoor (living room, baby's room, the room living and baby's room is the same) and outdoor were 66±9 and 63±8, 51±5 and 58±17 (%) respectively.

Table II shows the indoor and outdoor levels of CO_2, temperature and relative humidity measurement results obtained in the living rooms, baby's rooms, the rooms that living and baby's room is the same and outdoor of residence.

TABLE II
INDOOR AND OUTDOOR CONCENTRATIONS OF CARBON DIOXIDE (CO_2), TEMPERATURE (T), AND RELATIVE HUMIDITY (RH) FOR 2ND SAMPLING CAMPAIGN

2nd Sampling Campaign	n	CO_2 (ppm)	n	T (°C)	n	RH (%)
Living Room		968±228		21±2	8	66±9
Minimum	10	708	9	18		56
Maximum		1370		23		79
Baby's Room		1075±319		21±2		63±8
Minimum	10	436	9	18	9	46
Maximum		1567		26		74
Outdoor		487±144		16±5		58±17
Minimum	14	358	13	8	13	36
Maximum		931		29		93
Living room & Baby's room	4	746±144	4	22±2	4	51±5
Minimum		530		21		46
Maximum		828		26		56

For the 3rd campaign of sampling studies, the average CO_2 concentration in living rooms ranged from 429 to 975ppm with an average of 618ppm. The mean CO_2 concentrations in the baby's rooms ranged from 410 to 1575ppm with an average of 591ppm. The average temperature (T) level in living room ranged from 23 to 33°C with an average of 27°C.

Average RH measurements level and standard deviation (SD) in indoor (living room, baby's room) and outdoor were 31±7 and 30±8 and 25±7 (%) respectively. Table III shown the indoor and outdoor levels of CO_2, temperature and relative humidity measurement results obtained in the living rooms, baby's rooms and outdoor of residence.

TABLE III
INDOOR AND OUTDOOR CONCENTRATIONS OF CARBON DIOXIDE (CO_2), TEMPERATURE (T), AND RELATIVE HUMIDITY (RH) FOR 3RD SAMPLING CAMPAIGN

3rd Sampling Campaign	n	CO_2 (ppm)	n	T (°C)	n	RH (%)
Living Room	27	618±148	27	27±2	27	31±7
Minimum		429		23		17
Maximum		975		33		53
Baby's Room	27	591±235	27	28±3	27	30±8
Minimum		410		24		12
Maximum		1575		43		53
Outdoor	27	443±36	27	28±4	27	25±7
Minimum		392		20		10
Maximum		548		35		40

According to the CO_2 results, the CO_2 levels belong to the 1st sampling period performed at common use room and the levels of living room and baby's room belong 2nd sampling periods did exceed the Level of Guide on Air Quality Certification Scheme for Offices and Public Places of excellent class 800ppmy, as shown in Table IV.

The commonly accepted the average ideal room temperature is between 20 to 25.5°C. In the period of 3rd sampling, the levels of room temperature in living room and baby's room did exceed the average room temperature levels (Table III, IV).

Although Ankara does not have a sea cost, the relative humidity plays a large role in determining people comfort level. The relative humidity results show that the relative humidity levels did exceed the level of excellent class of Indoor Air Quality guideline value for Japan (Law of Maintenance of Sanitation in Building) and South Korea (Public Sanitary Law) on the period of 3rd sampling [1].

TABLE IV
A GUIDE ON INDOOR AIR QUALITY CERTIFICATION SCHEME FOR OFFICES AND PUBLIC PLACES, 2003

Air Parameter	Unit	8-hour average [a]	
		Excellent Class	Good Class
Carbon dioxide (CO_2)	ppmv	<800[b]	<1000[c]
Room Temperature	°C	20 to <25.5[d]	<25.5[d]
Relative Humidity	%	40 to <70[e]	<70
Respirable suspended particulate (PM_{10})	μg/m³	<20[f]	<180[g]

a In some cases, it may not be practicable to take 8-hour continuous measurement. In these circumstances, surrogate measurement (i.e. an intermittent measurement strategy based on the average of half-an-hour measurements conducted at four time-slots) is also accepted.
b US EPA (1996), Facilities Manual: Architecture, Engineering, and Planning Guidelines. Maximum Indoor Air Concentration Standards.
c Indoor Air Quality guideline value for Australia (Interim National Indoor Air Quality Goals), Canada (Indoor Air Quality in Buildings: A Technical Guide), Japan (Law of Maintenance of Sanitation in Building), South Korea (Public Sanitary Law), Singapore (Guidelines for Good Indoor Air Quality in Office Premises/building), Sweden (Ventilation Code of Practice) and Norway (Recommended Guidelines for Indoor Air Quality).
d EMSD (1998), Guidelines on Energy Efficiency of Air Conditioning Installations
e Indoor Air Quality guideline value for Japan (Law of Maintenance of Sanitation in Building) and South Korea (Public Sanitary Law).
f Finnish Society of Indoor Air Quality and Climate (2001), Classification of Indoor Climate 2000: Target Values, Design Guidance and Product Requirements.
g EPD (1987), Hong Kong Air Quality Objectives under the Air Pollution Control Ordinance (Cap. 311)

B. PM Mass Concentration Results

Statistical calculations were performed using the Stat graphics Centurion Statistical Software. The continuous particle concentration data and other environmental parameters were initially investigated by descriptive statistics (mean and standard deviation).

All measurements were conducted for the approximately 3 weeks in Ankara. Table V to VII showed the average concentrations of particulates indoors and outdoors at homes in PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ size fractions respectively for three measurement periods. For the 1st and 2nd sampling periods, it is observed that the mean concentration of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ at the common use rooms is higher than living and baby's room (or bedroom). In the 3rd sampling period, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ concentration measured on the living room is higher than the baby's room PM concentrations. During the 1st sampling period, average PM_{10} concentration and standard deviation (SD) in indoor (living room, baby's room and common use rooms) were 116.4 ± 40μg/m³, 96±38μg/m³, and 167, ± 74μg/m³ respectively. In the first sampling period, the outdoor measurements were not carried out.

TABLE V
THE SUMMARY OF INDOOR AND OUTDOOR PM_{10}, $PM_{2.5}$ AND $PM_{1.0}$ MEASUREMENTS FOR 1ST CAMPAIGN (μG/M³)

1st Sampling Campaign	n	PM_{10}	n	$PM_{2.5}$	n	$PM_{1.0}$
Living Room		116±40		31±11		18±8
Minimum	41	52	41	15	41	5
Maximum		224		63		47
Baby Room		96±38		30±12		18±7
Minimum	40	43	40	13	39	5
Maximum		215		72		40
Outdoor		-		-		-
Minimum	-	-	-	-	-	-
Maximum		-		-		-
Living room & Baby's room		167±74		66±57		47±57
Minimum	7	65	7	24	7	18
Maximum		289		192		178

In the 2nd sampling period, average PM_{10} concentration and standard deviation (SD) in indoor (living room, baby's room and common use rooms) and outdoor were 133 ± 57μg/m³, 104±49μg/m³, 133±70μg/m³, and 107±32μg/m³ respectively (Table VI). The 2nd sampling was carried out during the fall season. It could be conclude that the highest PM values were observed during this period due to general ventilation is not enough in most of the home hence the general point of view of parents was to protect the babies from the cold weather conditions.

TABLE VI
THE SUMMARY OF INDOOR AND OUTDOOR PM_{10}, $PM_{2.5}$ AND $PM_{1.0}$ MEASUREMENTS FOR 2ND CAMPAIGN (μG/M³)

2nd Sampling Campaign	n	PM_{10}	n	$PM_{2.5}$	n	$PM_{1.0}$
Living Room		133±57		40±20		27±15
Minimum	12	63	12	16	12	9
Maximum		243		88		66
Baby Room		104±49		39±22		29±18
Minimum	10	44	10	18	10	9
Maximum		193		91		74
Outdoor		107±32		23±5		17±8
Minimum	3	82	3	18	3	10
Maximum		144		28		26
Living room & Baby's room		133±70		32±22		21±17
Minimum	2	63	2	16	2	9
Maximum		163		48		33

In the 3rd sampling period carried out on the spring-summer period, average PM_{10} concentration and standard deviation (SD) in indoor (living room and baby's room) and outdoor were 93±58μg/m³, 67±26μg/m³, and 59±33μg/m³ respectively (Table VII).

TABLE VII
THE SUMMARY OF INDOOR AND OUTDOOR PM_{10}, $PM_{2.5}$ AND $PM_{1.0}$ MEASUREMENTS FOR 3RD CAMPAIGN (μG/M³)

3rd Sampling Campaign	n	PM_{10}	n	$PM_{2.5}$	n	$PM_{1.0}$
Living Room	28	93±58	28	24±15	28	16±12
Minimum		43		7		3
Maximum		354		76		62
Baby's Room	28	67±26	28	22±14	28	16±13
Minimum		26		8		3
Maximum		152		67		63
Outdoor	28	59±33	28	16±8	28	11±6
Minimum		17		4		2
Maximum		139		39		23

Following the searches, PM_{10} levels except the results of the common use room during the 1st sampling period did not exceed the limit value of National Ambient Air Quality Standards (NAAQS) for particulate matter: 24 hour concentration standard of 150µg/m^3, as shown in Fig. 2 (Table VIII).

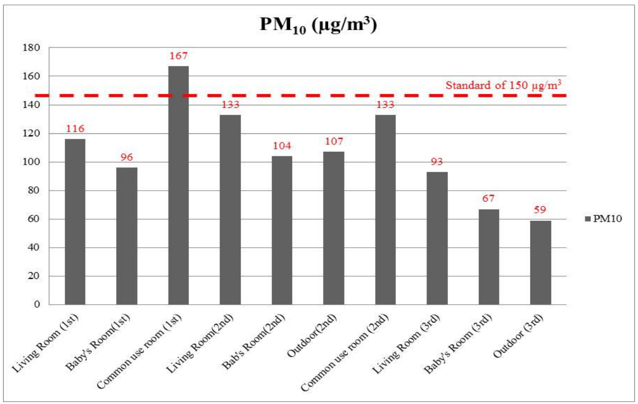

Fig. 2 Concentrations and the limit value of PM_{10} in the measurement environment

When it is considered 2nd sampling period carried out during the fall season, it is clear that $PM_{2.5}$ levels on living and baby's room did exceed the limit value of National Ambient Air Quality Standards (NAAQS) for particulate matter: 24 hour concentration standard of 35, as shown in Fig. 3 (Table VIII) [20].

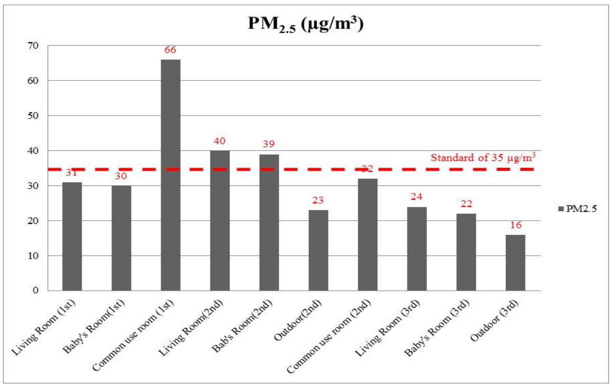

Fig. 3 Concentrations and the limit value of $PM_{2.5}$ in the measurement environment

TABLE VIII
NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) FOR PARTICULATE MATTER FOR 2012 (µG/M^3)

Indicator	Primary/ Secondary	Averaging Time	Level (µg/m^3)	Form
$PM_{2.5}$	Primary	Annual	12	Annual arithmetic mean, averaged over 3 years (1), (2)
	Secondary	Annual	15	Annual arithmetic mean, averaged over 3 years(1), (2)
	Primary and Secondary	24-hour	35	98th percentile, averaged over 3 years (3)
PM_{10}	Primary and Secondary	24-hour (4)	150	Not to be exceeded more than once per year on average over a 3-year period

(1) TSP = total suspended particles.
(2) The EPA tightened the constraints on the spatial averaging criteria by further limiting the conditions under which some areas may average measurements from multiple community-oriented monitors to determine compliance.
(3) The level of the 24-hour standard is defined as an integer (zero decimal places) as determined by rounding. For example, a 3-year average 98th percentile concentration of 35.49µg/m^3 would round to 35µg/m^3 and thus meet the 24-hour standard and a 3-year average of 35.50µg/m^3 would round to 36 and, hence, violate the 24-hour standard.
(4) The EPA revoked the annual PM_{10} NAAQS in 2006.

C. Relationship between Indoor Environment PM Levels and Outdoor Ambient PM Levels

The I/O relationships depend on the type of ventilation and the outdoor climate. Local climatic conditions influence ventilation habits. The ratio of indoor-to-outdoor concentrations (I/O) may give an insight on the relative contribution of indoor and outdoor sources to the indoor concentration levels. As most time is spent at indoors, information on the indoor/outdoor (I/O) relationship of particulate concentrations is important. Indoor levels can be influenced by outdoor levels and by particle generation indoors [22]. Not only emission sources, but also human activities (e.g. cleaning, working, cooking etc.) and even the mere presence of people at home lead to increases in particulate levels indoors

For the 2nd sampling campaign, the calculated I/O ratios at the under study residence were equal to 1.2 for PM_{10}, 1.7 for $PM_{2.5}$ and 1.5 for $PM_{1.0}$. For the 3rd sampling campaign, the calculated I/O ratios at the under study residence were equal to 1.5 for PM_{10}, 1.5 for $PM_{2.5}$ and 1.4 for $PM_{1.0}$. When the I/O ratio is over 1, the presence of indoor sources is considered to be significant. The results showed that the ventilation is not enough during the day at homes (Table IX).

TABLE IX
THE INDOOR/OUTDOOR RATIOS OF PM_{10}, $PM_{2.5}$ AND $PM_{1.0}$ MEASUREMENTS FOR 2ND AND 3RD CAMPAIGN

Measurement Environment	PM_{10}	I/O Ratio	$PM_{2.5}$	I/O Ratio	$PM_{1.0}$	I/O Ratio
Living Room (2nd Campaign)	133±57	1.2	40±20	1.7	27±15	1.5
Outdoor (2nd Campaign)	107±32		23±5		17±8	
Living Room (3rd Campaign)	93±58	1.5	24±15	1.5	16±12	1.4
Outdoor (3rd Campaign)	59±33		16±8		11±6	

D. The Relationship of Indoor Particulate Matter Concentrations with Questionnaires' Results

The parents of the infants were asked to complete a questionnaire about activities in the house during the sampling periods and about specified household characteristics with a potential effect on the indoor and outdoor air PM concentration. In this section, it is observed that the relationship of 1st sampling period of PM_{10} measured on living room with the case of floor of the houses, amount of smokers, and 3rd sampling period of PM_{10} measured on outdoor with the case of the situation of being close to the construction works.

1. The Floor of Houses – PM_{10} Concentration (1st Sampling Period-Living Room)

The levels of houses' floor was specified in three case as (i) ground floor, (ii) 1st, 2nd, and 3rd floor and (iii) more than three floor houses'.

The table given below shows various statistics for PM_{10} for each of the all cases of Houses' Floor. The one-way analysis of variance is primarily intended to compare the means of the different levels, listed here under the average column (Table X).

TABLE X
HOUSES' FLOOR – PM_{10} CONCENTRATION LEVELS (μG/M^3)

Houses' Floor	n	Average	Standard Deviation	Min.	Max.
Ground Floor	21	110.8	35.7	66.1	195.6
1st, 2nd and 3rd Floor	15	137.7	42.3	55.2	224.7
More than 3 Floor	4	78.3	22.0	52.4	100.4

The results show that the houses place in 1st, 2nd, and 3rd floor have higher PM_{10} results than placed in ground floor houses and more than three floor houses and there is a statistically significant difference at the 95,0% confidence level between the houses place in (i) 1st, 2nd and 3rd Floor and (ii) ground level and more than three floor houses'. The box and whisker plots are shown on Fig. 4.

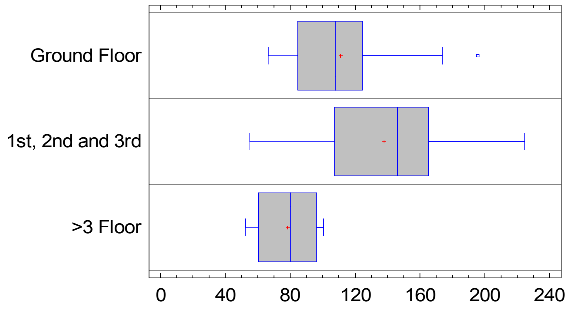

Fig. 4 The box and Whisker Plot of Houses' Floor and PM_{10} Concentration Levels ($\mu g/m^3$)

2. The Amount of Smokers – PM_{10} Concentration (1st Sampling Period-Living Room)

The levels of amount of smokers from the household was specified in three case as (i) non-smoker, (ii) only one smoker and (iii) more than one smoker at homes.

The table given below shows various statistics for PM_{10} for each of the all cases of the amount of smokers from the household. The one-way analysis of variance is primarily intended to compare the means of the different levels, listed here under the average column (Table XI).

TABLE XI
THE AMOUNT OF SMOKERS FROM HOUSEHOLD – PM_{10} CONCENTRATION LEVELS (μG/M^3)

The amount of smokers	n	Average	Standard Deviation	Min.	Max.
Nonsmoker	21	107.7	38.7	52.4	170
1 smoker	14	119.4	37.7	69.5	195.6
More than 1 Smoker	5	154.5	44.1	08.6	224.7

The results show that the houses have more than one smoker from the household have higher PM_{10} results than non-smoking and only one smoking houses. There is a statistically significant difference at the 95.0% confidence level between having more than one smoker houses and non-smoker. The box and whisker plots are shown on Fig. 5.

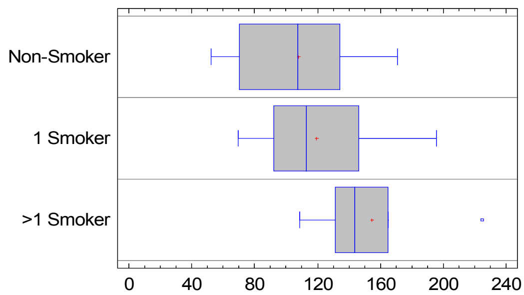

Fig. 5 The box and Whisker Plot of amount of smoker and PM_{10} Concentration Levels ($\mu g/m^3$)

3. The Distance to Construction Works – PM_{10} Concentration (3rd Sampling Period-Outdoor)

In this part, the relationship is examined between distance of construction works to the homes and the outdoor PM_{10} concentrations of 3rd Sampling period.

The levels of distance to construction works of the household was specified in two cases as (i) close to the construction work, and (ii) not close to the construction work.

The table given below shows various statistics for PM_{10} for both case of close to the construction works or not. The one-way analysis of variance is primarily intended to compare the means of the different levels, listed here under the average column (Table XII).

TABLE XII
THE CASE OF BEING TO THE CONSTRUCTION WORKS – PM_{10} CONCENTRATION LEVELS (μG/M^3)

Distance of Construction	n	Average	Standard Deviation	Min.	Max.
YES*	14	76.8	36.0	35.9	139.6
NO**	13	43.5	19.5	17.2	94.3

*YES: There is construction works close to the household.
**NO: There is no construction works close to the household.

The results show that the situation of being close to the construction works were concluded a very effective result. There is a statistically significant difference at the 95.0% confidence level between the case of (i) close to the construction works, and (ii) not close to the construction works. The box and whisker plots are shown on Fig. 6.

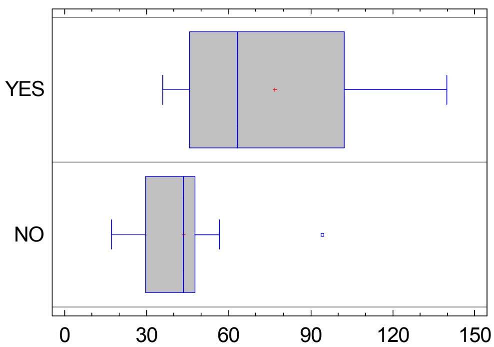

Fig. 6 The box and Whisker Plot of the situation of distance to the construction works and PM_{10} Concentration Levels (μg/m^3)

ACKNOWLEDGMENT

This project was funded by the Scientific and Technological Research Council of Turkey (TUBITAK, Project No: 110Y082).We would like to thank all the volunteers who participated in this project and who allowed us to intrude into their homes and lives whereas sampling took place.

REFERENCES

[1] The Government of the Hong Kong Special Administrative Region Indoor Air Quality Management Group, *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places*, 2003
[2] Ackermann-Liebrich, U, Leuenberger, P, Schwartz, J, Schindler, C, Monn, C & SAPALDIA, T 1997, 'Lung function and long term exposure to air pollutants in Switzerland', *Am J Respir Crit Care Med*, vol 155, pp. 122-129.
[3] Braun, C, Ackermann, U, Schwartz, J, Gnehm, H, Rutishauser, M & Wanner, H 1992, 'Air pollution and respiratory symptoms in preschool children', *Am Rev Respir*, vol 145, pp. 42-47.
[4] Chao, YH, Tung, CW & Burnett, J 1998, 'Influence of different indoor activities on the indoor particulate levels in residential buildings', *Indoor Built Environment*, vol 7, pp. 110-121.
[5] Dockery, D, Pope, C, Xu, X & et, A 1993, 'An association between air pollution and mortality in six US cities', *N Engl J Med*, vol 329, pp. 1753-1759.
[6] IEH, UMIFEAH 2000, 'IEH Airborne particles: exposure in the home and health effects'.
[7] Jones, NC, Thornton, CA, Mark, D & Harrison, RM 2000, 'Indoor/outdoor relationships of particulate matter domestic homes with roadside, urban and rural locations', *Atmospheric Environment*, vol 34, p. 2603–2612.
[8] Kamens, R, Lee, CT, Weiner, R & Leith, D 1991, 'A study to characterize indoor particulates in three non-smoking homes', *Atmospheric Environment*, vol 25, pp. 939-948.
[9] Kim, Y & Stock, T 1986, 'House-specific characterisation of indoor and outdoor aerosols', *Environ Int*, vol 12, pp. 75-92.
[10] Li, C-S 1994, 'Relationships of indoor/outdoor inhalable and respirable particles in domestic environments', *Sci Total Environ*, vol 151, pp. 205-211.
[11] Lioy, P, Waldman, J, Buckley, T, Butler, J & Pietarinen, C 1990, 'The personal indoor and outdoor concentration of PM-10 measured in an industrial community during winter', *Atmos Environ*, vol 24B, pp. 57-66.
[12] Monn, C & Schaeppi, G 1993, 'Concentration of total suspended particles and fine particles and their anionic compounds in ambient air and in indoor air', *Environ Technol*, vol 14, pp. 869-875.
[13] Pope, A & Dockery, D 1992, 'Acute health effects of PM_{10} pollution on symptomatic and asymptomatic children', *Am Rev Respir Dis* , vol 145, pp. 1123-1128.
[14] Quackenboss, J, Lebowitz, M & Crutchfield, C 1989, 'Indoor-outdoor relationship for particulate matter: exposure classification and health effects', *Environ Int*, vol 15, pp. 213-219.
[15] Raunemmaa, T, Kulmala, M, Saari, H, Olin, M & Kulmala, M 1989, 'Indoor air aerosol model: transport indoor and deposition of fine particles', *Aerosol Sci Technol*, vol 11, pp. 11-25.
[16] Schwartz, J 1993, 'Particulate air pollution and chronic respiratory disease', *Environ Res*, vol 62, pp. 7-13.
[17] Seaton, A, MacNee, W, Donaldson, K & Godden, D 1995, 'Particulate air pollution and acute health effects', *Lancet*, vol 345, pp. 176-178.
[18] Sexton, K, Spengler, J & Treitman, R 1984, 'Personal exposure for respirable particles: a case study in Water bury', *Vermont Atmos Environ*, vol 218, pp. 1385-1398.
[19] Spengler, JD, Dockery, DW, Turner, WA, Wolfson, JM & Ferris, BG 1981, 'Long-term measurements of respirable sulphates and particles inside and outside homes', *Atmospheric Environment*, vol 15, pp. 23-30.
[20] U.S Environmental Protection Agency, National Ambient Air Quality Standards (NAAQS) for Particulate Matter for the year of 2012
[21] Wallace, LA 1996, 'Indoor particles: a review', *Journal of Air and Waste Management Association*, vol 46, p. 98–126.
[22] Yocom, J 1982, 'Indoor-outdoor air quality relationships', *A critical review. J Air Poll Control Assoc (JAPCA)*, vol 32, pp. 500-520.
[23] Yu-Hsiang Cheng, Yi-Lun Lin 2010, "*Measurement of Particle Mass Concentrations and Size Distributions in an Underground Station",* Aerosol and Air Quality Research, vol 10: p: 22–29.

B. Karakas comes from Gemerek, Sivas and born in October, 1985. She has got her Bs degree in the department of Environmental Engineering in 2008 from Ondokuz Mayis University, Samsun-TURKEY. She is a candidate M.Sc. Student in Hacettepe University, Department of Environmental Engineering, Ankara-TURKEY. She currently studies under the supervision of Prof. Dr. Gulen Gullu on the indoor and outdoor air quality. She is also working on a project under Prof. Dr. Gulen Gullu investigating of relationship between lower respiratory and allergic symptoms and indoor air pollution in children from prenatal period to two years of age.

She is working as a project specialist at AECOM Turkey-is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental, energy, water and government. Ms. Karakas has been a member of the chamber of TMMB Environmental Engineers.

Sanaz LAKESTANI was born in Iran, on September, 1975. LAKESTANI received a Bs degree in Chemistry in 1997 from Shahid Beheshti University, Tehran-IRAN. In 2001 received a master's degree in Marine Chemistry from Islamic Azad University North Tehran, Tehran-IRAN. Since 2008 she is as a PhD student in Department of Environmental Engineering at Hacettepe University, Ankara-TURKEY. She currently studies under the supervision of Prof. Dr. Gulen Gullu on the indoor and outdoor air quality.

She is PhD student and works as a project assistant in Hacettepe University, department of environmental engineering, Ankara- Turkey. She worked as researcher and development manager at laboratory of chemical factory between 2001- 2007. Now she works in project named “Investigation of relationship between lower respiratory and allergic symptoms and indoor air pollution in children from prenatal period to two years of age”. In this project she has measured VOCs (TD-GC-MS/MS) of indoor and outdoor environments where infants live.

G. Gullu was born in Turkey on July; 1965.Gullu received a Bs degree in 1987 and a master’s degree in 1989 and a PhD degree in1996 from Middle East Technical University, Department of Environmental Engineering, Ankara-TURKEY.

She worked as Associate Professors, in 1999 at Hacettepe University, in Environmental Engineering Department. She became a Professor in 2006. She currently is the head of the Department of Environmental Engineering at Hacettepe University, Ankara- TURKEY. She works on indoor and outdoor air quality control.