The Journal of Animal & Plant Sciences, 25(3 Supp. 2) 2015 Special Issue Page: 672-676
ISSN: 1018-7081

DETERMINATION OF INDOOR AND OUTDOOR AIR QUALITY UNDER DIFFERENT VENTILATION CONDITIONS IN A RESIDENTIAL AREA OF LAHORE, PAKISTAN

M. Abbas[1*], S. Razzaq[1], R. Shahzadi[1], A. Rahman[1], F. Manzoor[2] and Z. Ali[3]

[1]Department of Environmental Sciences, Lahore College for Women University, Lahore, Pakistan
[2]Department of Zoology, Lahore College for Women University, Lahore, Pakistan
[3]Environmental Health and Wildlife, Department of Zoology, University of the Punjab, Lahore, Pakistan
*Corresponding Author's Email: moneeza.rana@gmail.com

ABSTRACT

Indoor air quality is not only determined by indoor sources but outdoor sources also contribute to it. In this study, a real time aerosol monitor was run parallel in a room and outdoors to measure the mass concentrations of $PM_{2.5}$ with a view to investigate role of ventilation on indoor $PM_{2.5.}$ Under high ventilation conditions, difference in mass concentration of $PM_{2.5}$ of indoor and outdoor air was negligible. The indoor and outdoor 24-h average values of $PM_{2.5}$ were 86.72µg/m3 and 80.42µg/m^3 respectively. However, there was a visible difference in the average concentrations of particulate matter in outdoor air and indoor air under low ventilation available. The 24-hour mean value was recorded to be 172.45µg/m^3 indoors while it was only 108.26µg/m^3 outdoors. This high value indoors was also due to the presence of a smoker in the room. The indoor concentration was strongly correlated with the outdoor air when the available ventilation was high (r = 0.863) and weakly correlated when ventilation was low (r = 0.184). It was concluded that under high ventilation conditions, indoor air is majorly determined by infiltration of the outdoor air, while when ventilation is very low, indoor sources rather than outdoor define the indoor air quality.

Key words: Different ventilations, Indoor air quality, residential areas, Pakistan.

INTRODUCTION

Although majority of people in urban areas spend their maximum time indoors, infiltration of pollutants from the outside can greatly affect the indoor air quality (Hänninen *et al*, 2004). Both the indoor and outdoor air quality is dependent upon each other since pollutants can move in and out through air. Indoor air is often regarded as an extension of the outdoor air (Chan, 2002), but the major factors affecting the indoor-outdoor relationship are the type of building, ventilation and climate (Saksena and Uma, 2008). In buildings with tighter insulation, where there are less chances of infiltration from outdoor, indoor air quality can be affected badly. Indoor sources such as cigarette smoke, particle board, cement, oven exhaust and many others can contribute to very high levels of pollutants indoors and pose serious health risks (Wadden and Scheff, 1983).

Buildings located near high traffic sites generally show a higher concentration of PM, NOx and SOx both indoors and outdoors (Fischer *et al*, 2000). Moreover variations in indoor and outdoor air quality are observed during different seasons. During winter season when doors and windows are mostly kept close, the major source of pollutants is indoors while during the summer season, outdoor air describes the indoor air (El-Batrawy, 2011).

In India a study was carried out to investigate the relationship between indoor and outdoor airborne particles at different sites. The results showed that outdoor PM concentration did indeed effect the indoor PM concentration to varying degrees (Srivastava and Jain, 2003). Another important factor to be noted is that indoor particulate concentration is usually predominated by $PM_{2.5}$ which has a greater association with mortality and morbidity rates than PM_{10} (Geller *et al*, 2002).

Ventilation is an important factor in determining indoor air quality. Improper or poor ventilation can result in increased pollutant level indoors due to insufficient mixing and change of air. On the other hand, increased ventilation results in less pollutant concentration (Wong *et al*, 2005; Li *et al*, 2007; El-Batrawy, 2011). According to many studies, there is a strong relationship between ventilation and health of the occupants. Low air change rate can result in health related problems such as respiratory ailments, growth of moulds and mites and many others (Sundell *et al*, 1995; Berry *et al*, 1996; Wargocki *et al*, 2002; Ucci *et al*, 2004).

The present study was conducted to investigate the relationship between indoor and outdoor air in a residential area with a view to evaluate the role of ventilation on indoor $PM_{2.5}$.

MATERIALS AND METHODS

A three story residential house (N 31^o 32.456`, E 074$^o$ 21.631`) with a floor area of 47 m^2 in Lahore city was selected for the study.The house was located along road side and exposed to vehicular emission.The entire floor area was built with no space for a courtyard or lawn except the top floor which was not fully covered. The ground floor consisted of a covered porch and a room with no windows. The rooms on the first and second floor had large windows that were kept open during most of the time. The top floor consisted of the kitchen only while the rest of the space was open.

An approximate percentage of the available ventilation was calculated in two rooms, one on ground floor and the other on the first floor. Both rooms had the same floor area i.e. 9.29 m^2. The room on the ground floor had only a small ventilator (0.84 m^2), and a door (2.52 m^2) which opened to the outside. The percentage ventilation was calculated to be 36 % approximately. On the other hand the room on the first floor had large windows on two walls which were kept open all the time due to hot weather. The total area for ventilation was measured to be 6.689 m^2. The percentage ventilation was calculated to be 72 % approximately.

DustTrak aerosol monitor (model 8520, TSI Inc.) was used to monitor $PM_{2.5}$ concentrations. The ground floor was selected for monitoring of $PM_{2.5}$ under low ventilation conditions while the first floor was selected for high ventilation conditions. The DustTrak was placed on the top floor for the monitoring of outdoor air. Two instruments were run parallel for the monitoring of indoor and outdoor air.

The instrument was first run under high ventilation conditions for 24 hours with another instrument running in parallel to monitor outdoor air. Then it was placed under low ventilation conditions with the other instrument again monitoring outdoor air in parallel to indoor air for 24 hours. DustTrak was set at data logging interval of one minute and hourly averages were obtained. Correlation was calculated between the indoor and outdoor air using SPSS (version 16). The activities of the occupants were also noted down to determine major sources of fine particulate matter indoors.

RESULTS AND DISCUSSION

The concentration of particulate matter indoors is dependent upon the generation of particulate matter indoors, concentration of particles from the ambient air, air exchange rate and the depositional characteristics of particles (Miguel *et al*, 1995; Thatcher and Layton, 1995; Chao *et al*, 1998). To investigate this, study was conducted about the indoor and outdoor air quality in residential area. It was divided into two parts, first measuring indoor concentration with high ventilation and second with low ventilation.

When concentration of fine particulate matter was measured indoors with high ventilation available, it showed an almost similar pattern as outdoors.Under high ventilation conditions indoors, the 24-h average value of $PM_{2.5}$ was obtained to be 86.72 µg/m³ while the concentration of fine particles in outdoor air was 80.42 µg/m³. The maximum and minimum concentration value observed indoors was 130.41 µg/m³ and 34 µg/m³ respectively. However no large difference was observed in the indoor and outdoor concentrations of $PM_{2.5}$ (Figure 1). It was attributed to adequate ventilation because high ventilation rate raise the indoor-to-outdoor ratio of particulate matter concentration due to the increase in outdoor ingression following reduction in the concentration of indoor generated pollutants (Wong *et al*, 2005). The little variations observed were due to the different indoor activities such as cleaning of the room and movement of people around. In fact the maximum hourly average (130.41µg/m^3) was seen at 6 am when most of the occupants were getting ready for work or schools resuspending the particulate matter into the air. Moreoverhuman activities at the beginning of day such as cleaning of furniture, making a bed, walking around, or even sitting on the furniture re-suspend dust and create a personal dust cloud (Ferro *et al*, 2004) and cause high PM concentration at that hour.

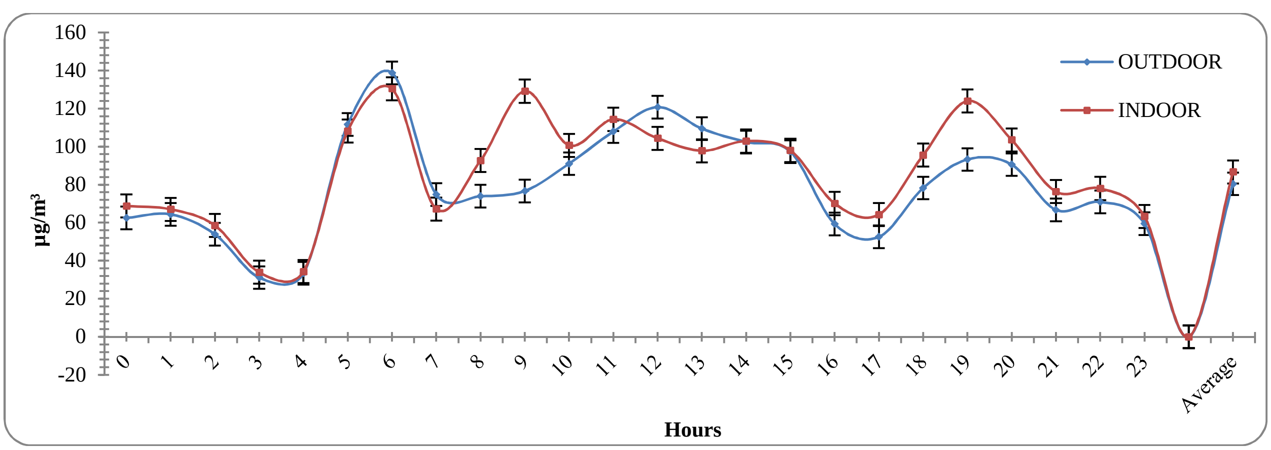

Figure 1: Representative hourly average of indoor and outdoor $PM_{2.5}$ under high ventilation scenario

On the other hand the results for low ventilation were entirely different. There was a comparable difference in the concentration of $PM_{2.5}$ both indoors and outdoors. Since the ventilation was low, there was no significant contribution from outside.When the ventilation was low, the 24-h mean concentration of fine particulate matter indoors was observed to be 172.45 µg/m³ with 108.26 µg/m³ outdoors. The maximum value indoors was 314.56 µg/m³ with the minimum concentration being 76.82 µg/m³. A prominent difference in the concentration of $PM_{2.5}$ was observed in the indoor and outdoor air (Figure 2). The only significant activities identified in the room were cleaning and smoking. Smoking lead to high peaks in the 24-h curve of PM with cleaning contributing to a lesser extent. The highest peak was observed at 7 am (330.45 µg/m³) when the door of the room was open along with smoking and cleaning also being carried out. It was shown in a study that concentration of pollutants increased when the ventilation was reduced (Turiel *et al.*, 1983). Since there was less infiltration of air from outside, the indoor quantity of PM increased.

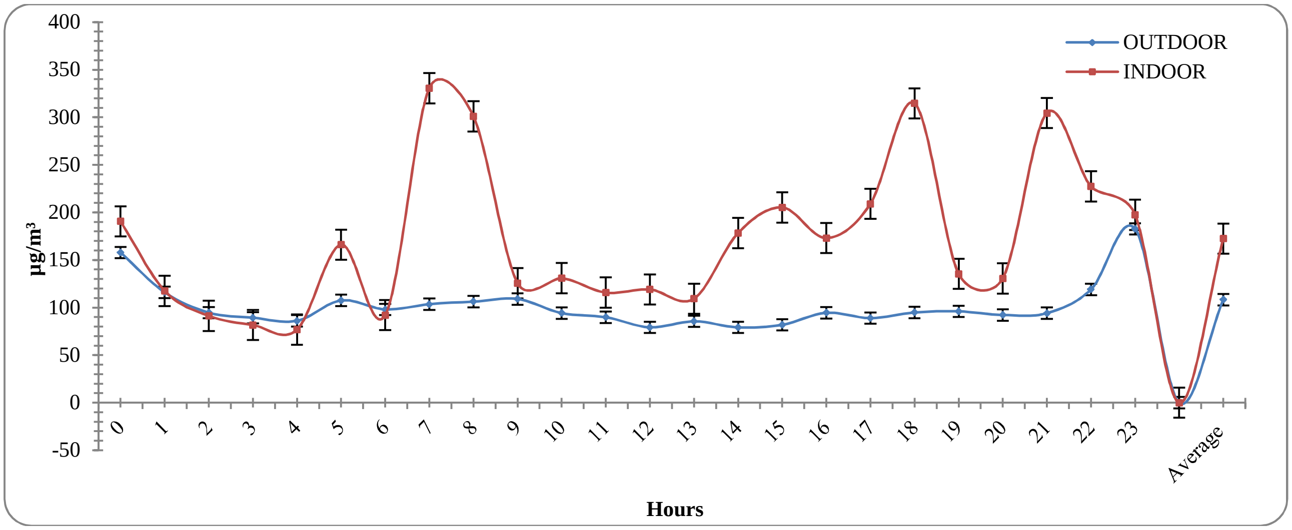

Figure 2: Concentration of fine particles in indoor (low ventilation) and outdoor air

Correlation between outdoor and indoor concentration of fine particles under the high and low ventilation conditions showed visible difference. When ventilation was low indoors, a weak positive correlation was found to exist between indoor and outdoor air (r = 0.184) (Table 1). On the contrary, a strong positive correlation existed between the indoor and outdoor air when ventilation was high (r = 0.863) (Table 2). When correlation was calculated between the concentrations of fine particles indoor under high and low ventilation conditions, it was found to be negative (r = -0.053) (Table 3).

Comparison was made of the indoor air under high and low ventilation conditions and a significant difference was observed. When there was low mixing of air, concentration of $PM_{2.5}$ increased considerably (Figure 3).The overall concentration of indoor fine particles under low ventilation was much higher than the values for high ventilation. Less mixing of air along with indoor sources (smoking and cleaning) in room with low ventilation was the reason for this increased value. These results clearly highlight how ventilation can contribute to indoor air quality. When there are no distinctive sources of pollutant outdoor, the outdoor air contributes to improved air quality indoors under adequate ventilation.

Table 1. Correlation between indoor and outdoor concentrations of $PM_{2.5}$ under high ventilation

Correlations			
		OUTDOOR	INDOOR
OUTDOOR	Pearson Correlation	1	.863**
	Sig. (2-tailed)		.000
	N	25	25
INDOOR	Pearson Correlation	.863**	1
	Sig. (2-tailed)	.000	
	N	25	25

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2. Correlation between indoor and outdoor concentrations of $PM_{2.5}$ under low ventilation

Correlations			
		OUTDOOR	**INDOOR**
OUTDOOR	Pearson Correlation	1	.184
	Sig. (2-tailed)		.379
	N	25	25
INDOOR	Pearson Correlation	.184	1
	Sig. (2-tailed)	.379	
	N	25	25

Table 3. Correlation between indoor and outdoor concentrations of $PM_{2.5}$ under low ventilation

Correlations			
		High Ventilation	**Low Ventilation**
High Ventilation	Pearson Correlation	1	-.053
	Sig. (2-tailed)		.801
	N	25	25
Low Ventilation	Pearson Correlation	-.053	1
	Sig. (2-tailed)	.801	
	N	25	25

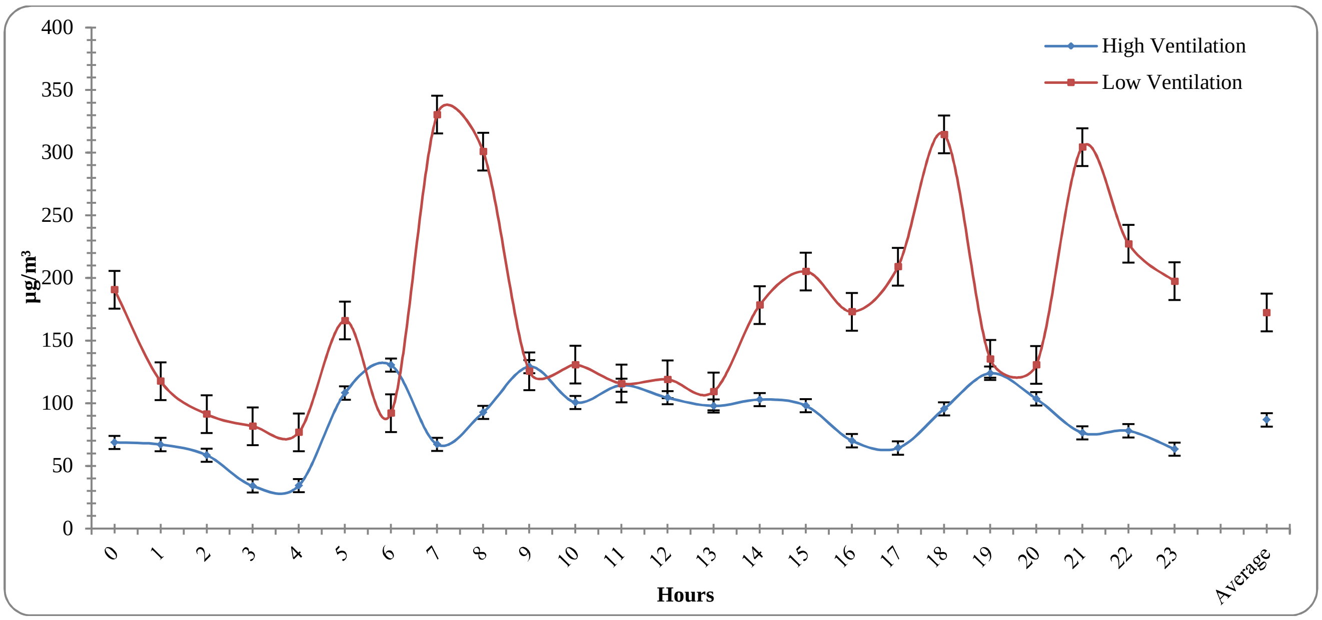

Figure 3: Comparison of Indoor air under high and low ventilation conditions

However an important point to be noted was that the results showed a much higher concentration of $PM_{2.5}$ indoors than the WHO standard of 25 µg/m³ (24-h mean) even in the room with maximum ventilation.

Conclusion: The results of our study lead to the conclusion that outdoor air can contribute significantly to the indoor air quality under high ventilation. Although indoor activities also play a role in increasing the levels of fine particulate matter, ambient air was observed to affect the indoor environment more significantly. However when ventilation was low and there were fewer chances of infiltration from outside, it was the indoor sources that defined the indoor air quality.

REFERENCES

Berry, R.W., V.M Brown, S.K.D. Coward, D.R. Crump, M. Gavin, C.P. Grimes, D.F. Higham, A.V. Hull, C.A. Hunter, I.G. Jeffery, R.G. Lea, J.W. Llewellyn and G.J. Raw (1996). Indoor air quality in homes: part 1. The Building Research Establishment Indoor Environment Study, London, Construction Research Communications.

Chan, A.T. (2002). Indoor-outdoor relationship of particulate matter and nitrogen oxides under different outdoor metrological conditions. Atmospheric Environment,36: 1543-1551.

Chao Y.H., C.W. Tung and J. Burnett (1998). Influence of different indoor activities on the indoor particulate levels in residential buildings, J. Indoor Built Environ. 7: 110–121.

El-Batrawy, O.A. (2011). Traffic Related Air Pollution in Residential Environment, Damietta, Egypt. American-Eurasian J. Agric. and Environ. Sci., 11 (6): 917-928.

Ferro, A. R., R. J. Kopperud and L. M. Hildemann (2004). Elevated personal exposure to particulate matter from human activities in a residence. J. Exposure Analysis and Environmental Epidemiology. 14: S34–S40.

Fischer P.H., G. Hoek, H. van Reeuwijk, D.J. Briggs, E. Lebret, J.H. van Wijnen, S. Kingham and P.E. Elliott (2000). Traffic related differences in outdoor and indoor concentrations of particles and volatile organic compounds in Amsterdam, Atmos. Environ. 34: 3713–3722.

Geller, M.D., M. Chang, C. Sioutas, B.D. Ostro and M.J. Lipsett (2002). Indoor / outdoor relationship and chemical composition of fine and coarse particles in the southern California deserts. Atmospheric Environment,36: 1099-1110.

Hänninen, O.O., E. Lebret, V. Ilacqua, K. Katsouyanni, N. Künzli, R.J. Srám and M. Jantunen (2004). Infiltration of ambient $PM_{2.5}$and levels ofindoorgenerated non-ETS $PM_{2.5}$in residences of four European cities.Atmospheric Environment38 (37): 6411–6423.

Li, Y., G.M. Leung, J.W. Tang, X. Yang, C.Y.H. Chao, J.Z. Lin, J.W. Lu, P.V. Nielsen, J. Niu, H. Qian, A. Sleigh, H.J.J. Su, J. Sundell, T.W. Wong and P.L. Yuen (2007). Role of ventilation in airborne transmission of infectious agents in the built environment – a multidisciplinary systematic review. Indoor Air. 17: 2–18

Miguel A.H., Neto F.R. De A., J.N. Cardoso, P. Vasconcellos De C, A.S. Pereir and K.S.G. Marquez (1995). Characterization of indoor air quality in the cities of Sao Paulo and Rio de Janeiro, Brazil. Environ. Sci. Tech., 1995; 29: 338–345.

Saksena, S. and R. Uma (2008). Longitudinal Study of Indoor Particulate Matter and its Relationship to Outdoor Concentrations in New Delhi, India. Indoor and Built Environment.17 (6):543-551.

Srivastava, A. and V.K. Jain (2003). Relationship of indoor and outdoor air quality in Delhi. Indoor Built Environment,12: 159-165.

Sundell J., M. Wickman, G. Pershagen, S.L. Nordvall (1995), Ventilation in homes infested Ventilation in homes infested by house-dust mites”, Allergy, 50 (2): 106-12.

Thatcher T.L. and D.W. Layton (1995). Deposition, re-suspension and penetration of particles within a residence, Atmos. Environ., 29: 1487–1497.

Turiel,I., C.D. Hollowell, R.R. Miksch, J.V. Rudy and R.A. Young (1983). The effects of reduced ventilation on indoor air quality in an office building. Atmospheric Environment, 17 (1): 51–64.

Ucci, M., I. Ridley, S. Pretlove, M. Davies, D. Mumovic, T. Oreszczyn, M. McCarthy and J. Singh (2004). Ventilation rates and moisture-related allergens in UK dwellings. In: Proceedings of the 2nd WHO International Housing and Health Symposium. WHO, pp. 328-334.

Wadden, R.A. and P.A. Scheff (1983). Indoor air pollution, John Wiley and Sons, Inc., New York, NY, USA.

Wargocki P., J. Sundell and W. Bischof (2002). Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus.

Wong, C.S., D.W.T. Chan and L.K.C. Law (2005). Indoor air pollutant calibration in buildings. Proceeding of 10th International Conference on Indoor Air Quality and Climate.