2012 4th International Conference on Chemical, Biological and Environmental Engineering
IPCBEE vol.43 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2012. V43. 21

Investigations of Indoor Air Contaminants in Different Types of Houses and Shopping Centers

Sabah A. Abdul-Wahab[+] and Afshan Saghir

Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 33, Al Khoud 123, Oman

Abstract. This paper aims to assess the exposure of various indoor air contaminants at different residential and commercial places of Muscat (Oman), in order to identify sick building syndrome (SBS) indicators. The investigation procedure is performed by selecting three traditional houses and two different types of shopping centers. Indoor air contaminants selected for the study includes temperature, relative humidity (RH), carbon dioxide (CO_2), organic compounds (i.e., TVOCs), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), ozone (O_3), and particulates matter (PM_{10}). Monitoring of these pollutants is carried out during peak hot summer. Exposure of these pollutants is compared against the standard limit specified by various international agencies of the world. The results indicate that the major pollutants identified are TVOCs, PM_{10}, O_3, temperature and CO_2. These contaminants can be recognized as indicators of SBS because their exposure are found high and above than permissible standards. From this study, various indoor sources are also recognized such as woody products, furniture polish, petrol emission, dusty atmosphere, infiltration of air handling units, and crowdedness etc. Among all places, the food shop is recognized as a major area, representing poor indoor air quality due to presence of many pollutants.

Keywords: houses, shopping centres, indoor air contaminants, sick building syndrome.

1. Introduction

The exposure of indoor air pollutants may pose harmful effects on human health as; the indoor concentrations of many pollutants are often higher than outdoors [1]. People normally spend more than 90% of their time indoors, 60% of which is spent at homes [2]. People also paid visits at shopping centres for their personal needs. The quality of air in such places is important as it plays a vital role in developing a healthy environment [3]. In Muscat, the climate is very hot and temperature often reaches 50 ºC in summer. Due to hot weather, the use of air condition is very common in homes and shopping places. But in these places, the inadequate control of HVAC system can result in poor indoor air quality. Large numbers of field studies demonstrates the association of personal factors with indoor environment exposures [4]. There are substantial numbers of dis-satisfied people in many buildings; among them those suffering from sick building syndrome [5]. On realizing this issue, this study was aimed to assess the strength of indoor variables in developing the SBS in houses and shopping places.

2. Methodology and Procedure

2.1. Field Study

Three different houses and two different shopping centres were selected for the study. The selection of houses was based on the number of years, house been constructed, and its location. A big villa belongs to urban area, and two small old houses belong to rural area were chosen. Urban villa was constructed 5 years back. The monitoring was done in the living area which was found much closed to the kitchen. Some

[+] Corresponding author. Tel.: + 96899453084; fax: +96824141316.
E-mail address: sabah1@squ.edu.om.

cooking was carried out in kitchen and the cooking smell was also observed in the living area. It was observed that occupants of this house used to spray air freshener daily in all rooms. On our discussion, they informed us that it is their habit to use air fragrance inside home to freshen the air. In rural area, there were no proper streets and roads. There were only few houses which were not very closed to each other. These houses were chosen because they were very old, made of clay and their surrounding was covered with dust. Rural house 1 was constructed 200 years back and house 2 was built 17 years back. Measurements were taken in the living area of both houses. The living room of rural house 2 was constructed separately and was found very dirty from inside. Dirty carpet, poor air condition (AC), and some insects were seen in this room. A food stuff shop was targeted due to its location and quick customer entry. This was a small shop, situated adjacent to petrol pump where normally heavy trucks and 4-wheel vehicles comes. A very old furniture showroom situated at main highway was selected. The shop was running since 30 years back. Woody products, use of paints, chemicals adhesives and furniture polish are the main reason for selecting it.

2.2. Pollutants Measurements

For measuring the concentration of each pollutant, the equipment named 'wolf-pack' was used with three probes. Air quality probe was used to detect the level of temperature, RH, CO_2, and TVOCs. Toxic gas probe was used to measure toxicity level of CO, O_3, SO_2, and H_2S. Airborne Particle Counter probe was used for measuring PM_{10}. The measurements were conducted for two hours with an average log interval of 5 minutes at each location. Due to hot weather, the air condition (AC) was operated in all places.

3. Results and Discussion

The average, maximum and minimum exposure of major pollutants identified from all locations is summarized and compared with the standard specified by different agencies in Table 1. The concentration of TVOCs set by Leadership in Energy and Environmental Design (LEED) is 500 $\mu g/m^3$ [6]. Same limit is proposed by National Health Medical Research Council (NHMRC) for one hour period [7]. Average TVOCs obtained from both shopping centres and urban villa is 553 $\mu g/m^3$, 601 $\mu g/m^3$ and 987.4 $\mu g/m^3$ respectively. These values are found above than standard of LEED and NHMRC (Fig. 1). In furniture shop, it is observed that TVOCs level is high because it is dealing with woody furniture where the use of paints, adhesives, and different chemicals is very common. Higher concentration of TVOCs due to furniture and decoration materials is also found from another study [8]. A relation of TVOCs with paint and decoration is found from the study conducted in new apartments [9]. It is observed that food shop is situated adjacent to fuel pump station where heavy trucks come for fuel. The emissions from heavy trucks raised the TVOCs level in shop. Similar result obtained from the study conducted at petrol pump which shows that the emission of diesel engine is a major contributor for TVOCs [10]. Among all places, the highest mean of 987.4 $\mu g/m^3$ is obtained from urban villa. It can be noticed that their occupants used to spray air freshener in rooms daily. So, it is observed that the exposure of TVOCs is high in house due to the use of air freshener. The association of TVOCs with air freshener and aerosols is also found from another study [11].

CO_2 exposure is found normal and below than the standard in all places except the foodstuff shop. In this shop, CO_2 is 1098 ppm that exceeds the ASHRAE standard of 1000 ppm [12]. It was observed that the arrival rate of customers was high and the area of shop was small. So more occupancy resulted in low ventilation and raised the CO_2 level inside shop. Similar results obtained from the study conducted in Hong Kong shopping malls, where CO_2 observed high due to high occupancy and insufficient ventilation [13]. A mean value 846 ppm of CO_2 is found in rural house 2, which can be considered close to ASHRAE standard (Fig. 2). It was observed that the living room of this house was very dirty and the un-filtered AC was in used. Therefore, CO_2 exposure found high due to infiltrations and poor condition of AC.

Exposure of PM_{10} in both rural houses are found high and above than EPA standard which is 150 $\mu g/m^3$ [14]. Mean PM_{10} measured in the rural houses 1 and 2 is 298 $\mu g/m^3$ and 217 $\mu g/m^3$, respectively (Fig. 3). In the rural area, it was observed that the houses were very old, made of clay, and covered with heavy dust. Also the floor of living room in rural house 2 was covered with dirty carpet. Therefore, it is observed that high PM_{10} in both houses are associated with dusty rural atmosphere, and higher infiltrations due to improper cleaning activities. A study conducted in India for PM of different sizes (i.e., 2.5μm, 1.0 μm, 0.5 μm, 0.25

μm) shows higher association of particulates in rural houses as compared to urban due to infiltrations and improper ventilation system [15]

The exposure of O_3 is found high only in rural house 2 (Fig. 4). Average value obtained from this house is 0.127 ppm that exceeds the EPA standard which is 0.12 ppm for 1-hr [14].

The level of temperature in the foodstuff shop and urban villa is 29.3 ºC and 27.84 ºC, respectively (Fig. 5), which is higher than ASHRAE standard [12]. In foodstuff shop, it was observed that the opening of entrance door frequently for customer arrival raised the temperature level. In urban villa we have observed that the living room was much close to the kitchen in which some cooking activities were executed. Therefore, the temperature in the living area was influenced with the impact of heating done in the kitchen. The RH, SO_2, CO, and H_2S are found normal at all places.

Table 1: Maximum, mean and minimum concentrations of major pollutants identified during the study.

Parameters	Exposure of indoor parameters in homes and shopping centers						Standard by Agencies
		Urban Villa	Rural H-1	Rural H- 2	Furniture shop	Food shop	
TVOCs (μg/m^3)	Max.	2057	208	484.4	577.8	855	500 (LEED) 500-1hr (NHMRC)
	Avg.	987.4	150.7	421.6	553	601	
	Min.	300.4	115.5	369.8	439.1	416	
CO_2 (ppm)	Max.	694	855	980	981	1183	1000 (ASHRAE)
	Avg.	604	760.2	846	728	1098	
	Min.	564	685	740	623	1066	
PM_{10} (μg/m^3)	Max.	48	300	225	98	104.6	100 (WHO) 150 (EPA)
	Avg.	35.4	298	217	96.5	103.2	
	Min.	25	150	100	80	100	
O_3 (ppm)	Max.	0.12	0.05	0.15	0.08	0.09	0.07-1hr (WHO) 0.08 (EPA)
	Avg.	0.11	0.045	0.127	0.07	0.082	
	Min.	0.09	0.04	0.09	0.05	0.08	
Temperature (ºC)	Max.	30.1	30.7	28.9	28	29.5	(23 -26) ºC in summer (ASHRAE)
	Avg.	27.84	25.2	25.4	25.9	29.3	
	Min.	26.8	24.3	23.8	23.6	29.1	

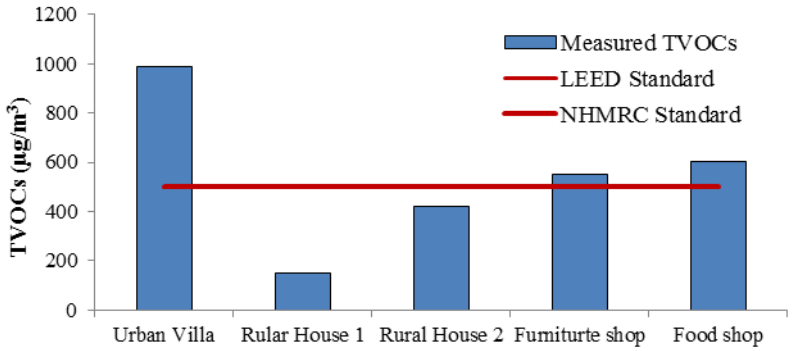

Fig. 1: Comparison of mean concentration TVOCs measured in houses and shopping centres.

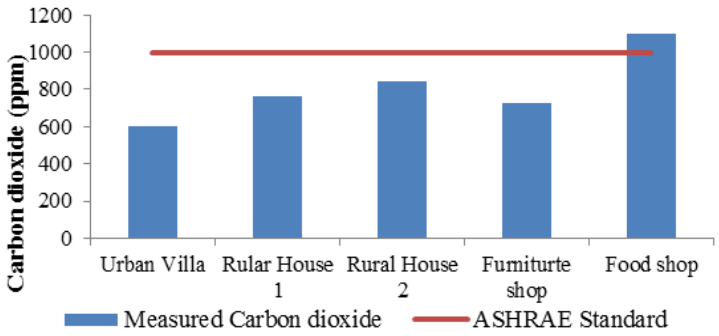

Fig. 2: Comparison of mean concentration CO_2 measured in houses and shopping centres.

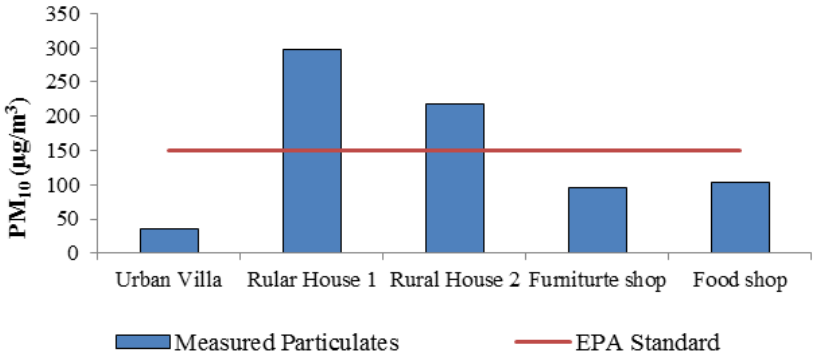

Fig. 3: Comparison of mean concentration PM_{10} measured in houses and shopping centres.

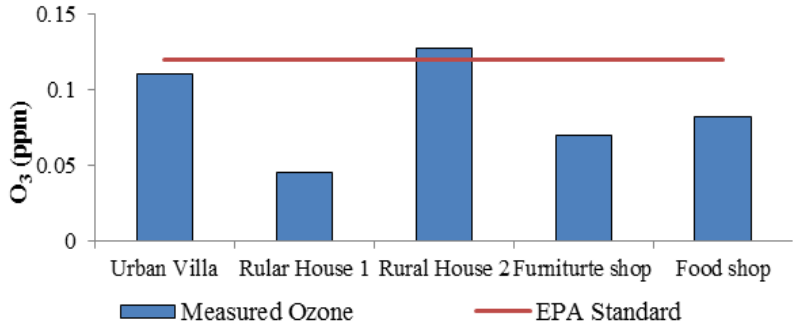

Fig. 4: Comparison of mean concentration O_3 measured in houses and shopping centres.

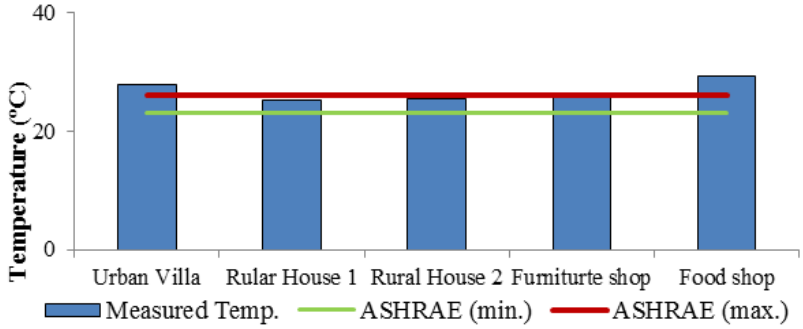

Fig. 5: Comparison of mean concentration temperature measured in houses and shopping centres.

4. Conclusions

The investigations of indoor air quality made in different types of houses and shopping centres revealed higher exposure of various indoor parameters which includes; PM_{10}, TVOCs, O_3, CO_2 and temperature. Average values of these parameters are found above the permissible level recommended by various international agencies. The TVOCs level in shopping centres and urban villa are found high. This is attributed due to association of woody products, paints, chemicals, furnishing polish, adhesives, emission from fuel pump and air freshener spray. Mean PM_{10} concentration in rural houses are higher than urban due to presence of dusty atmosphere in surrounding area, and higher infiltrations. Ozone concentrations are found within the range in all places except rural house 2. Higher temperature and CO_2 level is obtained from the food shop, due to less space, more occupancy rate, low ventilation, quick arrival of customers, frequent opening of doors and emission of heavy motor vehicles from petrol station. Urban villa also displayed high temperature which was influenced due to combustion process of the kitchen. From this study, various indoor sources of pollutants are also identified such as woody products, chemicals, furnishing polish, emission of motor vehicles, petrol, infiltrations due to improper maintenance of air handling unit, crowdedness, dirty carpet, dusty atmosphere, and combustion processes etc.

5. Acknowledgements

The funding provided by Sultan Qaboos University (project IG/ENG/MIED/11/04) is gratefully acknowledged.

6. References

[1] A.P. Jones. Indoor air quality and health. *Atmospheric Environment*. 1999, **33**: 4535-4564.

[2] A.A. Ahmed, S.A. Rahman, S. Shahrani. CO and CO_2, Concentrations In Naturally-Ventilated Houses in Malaysia. The 21st Conference on Passive and Low Energy Architecture. Eindhoven, Netherlands, 2004. pp. 19-22.

[3] S.M. Vural. Indoor Air Quality. In: S.A. Abdul- Wahab (ed). *Sick Building Syndrome in Public Buildings and Work Places*. Springer. 2011, pp. 59-74.

[4] D. Norback, and K. Nordstrom. Sick building syndrome in relation to air exchange rate, CO_2, room temperature and relative air humidity in university computer classrooms. *Int. Arch. Occup. Environ. Health*. 2008, **82**: 21-30.

[5] P.O. Fanger. Human requirements in future air-conditioned environments. *Int. J. Refrigeration*. 2001, **24**: 148-153.

[6] LEED's Indoor Environment Quality. 1Source Safety and Health. http://www.1ssh.com/indoor-air-quality-management-consultation/leeds_indoor_environment_quality.aspx.

[7] *Air Toxics and Indoor Air Quality in Australia*. State of Knowledge Report. Environment Australia, 2001.

[8] C. Wang, H. Zhang, R. Jiang, Q. Jiang, W. Song. Study on the indoor air levels of formaldehyde and total volatile organic compounds after decoration. *Huanjing Yu Jiankang Zazhi*. 2005, **22** (5): 356-358.

[9] X. Gao, Z. Bai, Y. You, J. Miao, B. Liu. Investigation of human exposure level of volatile organic compounds and effects on health. *Huanjing Yu Jiankang Zazhi.* 2006, **23** (4): 300-303.

[10] A. Srivastava, B. Sengupta, S.A. Dutta. Source apportionment of ambient VOCs in Delhi city. *Science of Total Environment.* 2005, **343**: 207-220.

[11] A. Farrow, H.Taylor, K. Northstone, J. Golding. Symptoms of mother and infants related to total volatile organic compounds in household products. *Archives of Environ. Health*. 2003, **58** (10): 633-641.

[12] Illinios Department of Public Health. *Guidelines for Indoor Air Quality*. Division of Environment Health. Springfield illinios.

[13] W.M. Li, S.C. Lee, L.Y. Chan. IAQ at nine shopping malls in Hong Kong. *Science of Total Environment*. 2001, **273**: 27-40.

[14] K. Charles, R.J. Magee, D. Won, E. Lusztyk. Indoor air quality guidelines and standards. Consortium for Material Emissions and Indoor Air Quality Modelling II Report 5.1, 2005. http://irc.nrc-cnrc.gc.ca

[15] D. Massey, J. Masih, A. Kulshrestha, M. Habil, A. Taneja. Indoor/outdoor relationship of fine particles less than 2.5 μm ($PM_{2.5}$) in residential homes locations in central India region. *Building and Environ*. 2009, **44**: 2037-2045.