CALCULATION AND TEMPORAL VARIABILITY OF VENTILATION COEFFICIENT DEPENDING ON LOCATION AND CHARACTERISTICS OF HOUSES IN BALIKESIR CITY CENTER

Nadir Ilten[1,]*, Lokman Hakan Tecer[2], Ayse Tülay Selici[3]

[1]Department of Mechanical Engineering, Balıkesir University, Balıkesir, Turkey
[2]Department of Environmental Engineering, Namık Kemal University,Çorlu/Tekirdağ,Turkey
[3]Balıkesir Municipality, Balıkesir, Turkey

ABSTRACT

In recent years, there has been much research on indoor air quality, owing to a growing interest in improvement of air quality in residential buildings. People spend most of their time indoors, where air quality is affected by many factors such as location and structure of housing, ventilation systems, and comfort parameters. CO_2 and other indoor gas concentrations are important indicators of indoor air quality. The aim of this study is to determine the effects of various factors such as location and characteristics of housing and smoking status on carbon dioxide (CO_2) concentrations and air exchange rates in 29 representative buildings in Balıkesir, Turkey. CO_2 concentrations were measured using a non-dispersive infrared method, air changes per hour (ACH) were estimated using a CO_2 balance method, and other parameters were recorded. Mean CO_2 concentrations were 667 and 1011 ppm in summer and winter, respectively. Estimated mean air exchange rates were 1.04 and 0.70 ACH in summer and winter, respectively. The analysis showed that CO_2 concentrations and ACH were affected by the area of houses, season, ventilation systems and ventilation duration. CO_2 concentrations in winter were higher in all buildings relative to summer in the residential area. Air exchange rates were primarily affected by duration of ventilation, house area, distances to main roads, and smoking status.

KEYWORDS:
air change rate, carbon dioxide, indoor air quality, residential building, Balıkesir, Turkey

INTRODUCTION

People spend about 90% of their time indoors and it is known that air quality of the indoor environment is affected by outdoor air pollution [1]. Ventilation systems and the location of houses affect indoor air pollutant levels [2].

Industrial operations and heavy motor vehicle traffic negatively affect outdoor air quality, thereby readily affecting indoor air media. Ventilation type, ventilation rate and pollutant composition in the indoor environment are parameters used to determine the contribution of outdoor pollutants to indoor pollution [3]. These factors are used to determine conditions called closed building syndrome, sick building syndrome and building-related illness. These conditions might lead to health problems [4].

Indoor pollutant sources and concentrations, building materials, human activities and ventilation systems represent a combination of various complex conditions that determine indoor air quality [5]. Indoor air pollutants were measured very high in different indoor areas of massive public congregations such as bars, schools, exhibition centers and churches [6]. Air transport from leakage, ventilation, and change of location mechanisms between indoors and outdoors affect indoor pollution emission [7, 8, 9, 10]. Under normal conditions, CO_2 makes up about 0.03% of air in the atmosphere. CO_2 concentration varies between 330 and 500 ppm, depending on environmental factors [11].

A human body performing normal daily activities produces 20 liters (L; 0.02 m^3) of CO_2 per hour [4].

Levels of CO_2 emissions that depend on human activity (mobility) are listed in Table 1 [12].

Amounts of breathing, oxygen consumption and CO_2 production based on mobility are shown in Figure 1 [13].

TABLE 1
CO_2 levels emitted depending on human activities.

Position	Activity Degree	CO_2 Emission Amount (liter/hour)
Sitting	I	15
Light activity	II	23
Medium activity or slow walking	III	30
Heavy activity or fast walking	IV	30

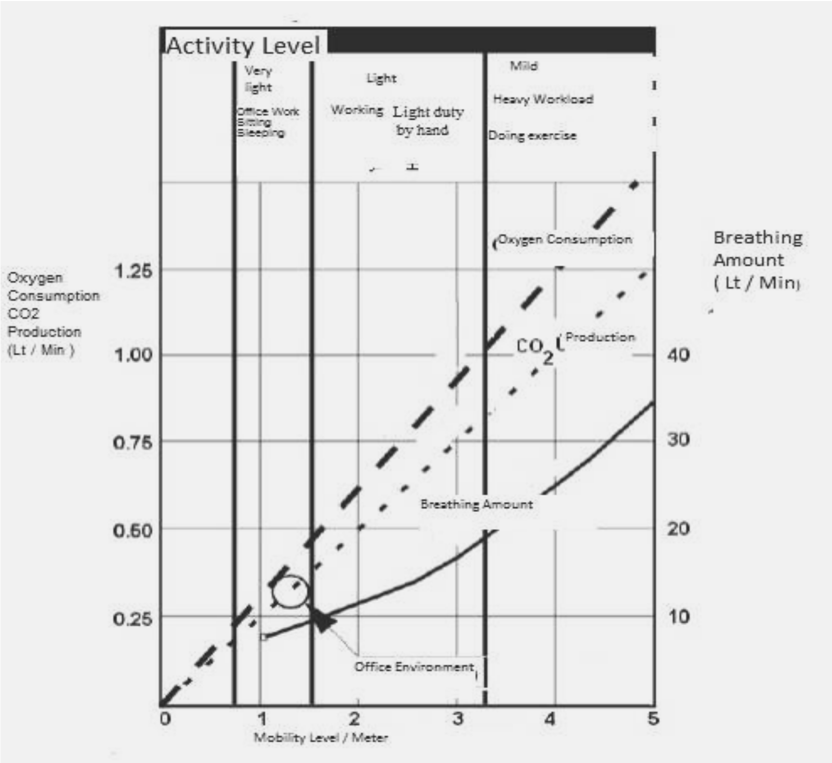


FIGURE 1
Oxygen Consumption and CO_2 Production Depending on Physical Activities [13].

Air change rate (ACR) is accepted as a personal air pollution exposure for indoor environments [14]. In addition, pollutants originating outdoors that enter houses via filtration, open doors and windows, natural ventilation and mechanical ventilation characterize indoor pollution [15]. ACR is also used to evaluate energy consumption of mechanical heating and ventilation equipment [16].

There are many studies that analyze ACR and change of indoor CO_2 concentration [13, 17].

In this study, indoor ACR and air quality were calculated in 29 houses in the city center of Balıkesir, Turkey.

MATERIALS AND METHODS

The city of Balıkesir extends to within the Marmara and Aegean regions, with most of its area in the former. The total area of Balıkesir is 14,456 km^2, about 1.9 % that of Turkey. The central district population of Balıkesir is 259,157 according to a 2009 census [18].

Balıkesir in winter is under the influence of very cold air masses from the north and relatively warm masses from the Mediterranean Sea. A high pressure system in winter reduces the probability of rain and causes strong air pollution [19].

Annual average temperature in Balıkesir is 14.5°C. Average temperature in winter (October–March) is 8.97°C. Wind speeds decrease in winter and spring and increase in summer and fall. Fog occurs province-wide during winter in Balıkesir, generating 95% to 100% humidity. High fossil fuel consumption because of cold temperatures combined with fog in winter causes air pollution [20].

The main reason for the winter air pollution in Balıkesir is the consumption of fossil fuels for energy and heating. Industrial activity and traffic also affects the air quality. The population, topography and winter meteorological conditions increase pollution. The bowl-shaped topography of the city center and weakening winds in winter, as well as the high pressure and decreasing air temperature are all factors that increase air pollution [21].

According to a study in Balıkesir between 1999 and 2005 during winter, statistical relationships between meteorological factors (temperature, wind speed, humidity and pressure) and air pollution were investigated. A high level of air pollution was identified under light wind speeds, low temperature, high pressure and high humidity in winter [22].

In the city center of Balıkesir, 33.5% of houses are heated with stoves, 24.5% with central heating systems, and 42% with combi boilers. General domestic coal is used for heating with stoves. High heat-value coal imported from other countries or natural gas is used for central heating and natural gas for combi boilers. For heating houses, it has been found that natural gas usage accounts for 43% of fuel, domestic coal 30%, and imported coal 22% [23].

Data Collection. In this study, CO_2 level and comfort parameters such as temperature and humidity were measured continually for 24 hours over 5 days, in 29 houses in the Balıkesir city center. Measurements of indoor and outdoor air quality levels were taken simultaneously. The studies were performed by two measurement companies in summer (July–September 2009) and winter (January–March 2010).

Sampling points chosen according to three different socio-demographic characteristics to be able to distinguish and compare the source of pollutants is shown in Figure 2. According to the evaluations, 1st region poor, 2nd middle and 3rd have been identified as high socio-economic groups. These are as follows. According to socioeconomic status, in the first region, there are 11 districts with total population 62,661. In the second region, representing low economic status, there are 24 districts with a total of 120,239 people. In the third region of high economic status, there are five districts and a total of 58,501 people.

The distribution of buildings in these regions is as follows. Measurements were performed in eight buildings in the first region, 15 in the second and seven in the third. We considered the location of the micro-environment in the regions (distance from the street and traffic), smoking in houses and offices, fuel type (natural gas, fuel oil, coal) for heating, equipment for heating, and systems used in the kitchen (LPG, natural gas, electricity).

Indoor CO_2 measurement devices are located in the kitchen of the house and approximately 1.5-2 m in height. They are installed away from the balcony doors and windows and also 1 m away in distance from the furnace type incineration system. Information given to the family members about the activities that may directly affect measures and it is requested to comply specified measurement procedure. Daily life was continued where the measurement were obtained and continuous measurements were taken.

Telair 7001 CO_2 / Temperature Monitor, which uses "NDIR-Automatic Measurement Method with Infrared Rays, is used to determine indoor CO_2 concentration, temperature and humidity values to. The device consists of display unit and a data storage unit (data logger) (Figure 3).

The measurement accuracy of the device is 1 ppm for CO_2 concentration, of 0.01 °C for temperature, and 0.01% for relative humidity (Telaire 7001). Device is adjusted before the measurements were made. In the adjustments; start and end time of the measurement and measurement point information are entered to the data storage unit via a computer. After the measurements completed, data in the data storage unit is transferred to the computer using the software called HOBO ware (version 2.1.1_18). Then these data were converted to Excel format for later use in analysis. The measurement range is in the 0-10,000 ppm and measurement accuracy is ± 1 ppm.

An ASTM E741 test method was used for ACR calculation. In this method, the ventilation coefficient can be identified under certain conditions, from tracking CO_2 gas concentration in the indoor environment.

FIGURE 2
Indoor Air Quality Sampling Points.

(a) **(b)**

FIGURE 3
CO_2/Temperature Monitor (a) and Data Logger (b).

The outdoor air flow equation of the method is [24]:

$$Q_p = 10^6 x G_p / (C_{in,eq} - C_{out}), \text{ where} \quad \textbf{(1)}$$

Q_p = outdoor airflow rate per person into the zone, L/s per person,

G_p = CO_2 production rate in indoor environment per person (L/s),
$C_{in,eq}$ = steady-state CO_2 concentration in indoor environment (ppm),
C_{out} = outdoor environment CO_2 concentration (ppm).
ACR of the room can be calculated per hour [25].

$$ACR = Q_p / V_{room}, \text{ where} \quad (2)$$

V_{room} is volume (m^3) of the room.

Analyses of ventilation and indoor air quality were dependent on indoor and outdoor CO_2 amount measured inside and outside of buildings in Balıkesir.

RESULTS AND DISCUSSION

In 29 houses in Balıkesir city center, averages and standard deviations (SD) of CO_2 levels in summer and winter were 667 ppm (127 ppm) and 1011 ppm (398 ppm), respectively. Outdoor CO_2 measurements were 405 ppm (99 ppm) in summer and 443 ppm (120 ppm) in winter.

We found average and SD of ACR in winter and summer of 1.04 h^{-1}(0.64) and 0.70 h^{-1}(0.67) respectively. Average air leakage rates (and SD) were 78.34 L/sec (45.15) in summer and 48.80 L/sec (40.69) in winter. Descriptive statistics of measured parameters are given in Table 2.

TABLE 2
Statistical data of pollution, ventilation and physical features in the houses.

		N	Minimum	Maximum	Mean	Std. Deviation
CO_2(Indoor environment-Summer)	ppm	29	419	874	627	127
CO_2(Indoor environment-Winter)	ppm	29	538	2062	1011	398
Houses – Square	m^2	29	50	175	107,10	27,15
Q_P(summer)	lt/sec	29	21	220	78,34	45,15
ACR (summer)	h^{-1}	29	0,23	2,98	1,05	0,64
Q_P(winter)	lt/sec	29	7,57	145,78	48,80	40,69
ACR (winter)	h^{-1}	29	0,09	2,18	0,70	0,67

In this study, outdoor air leakage was detected above the 50 L/s limit [14] in most houses during summer, but below this limit in winter (Figure 4).

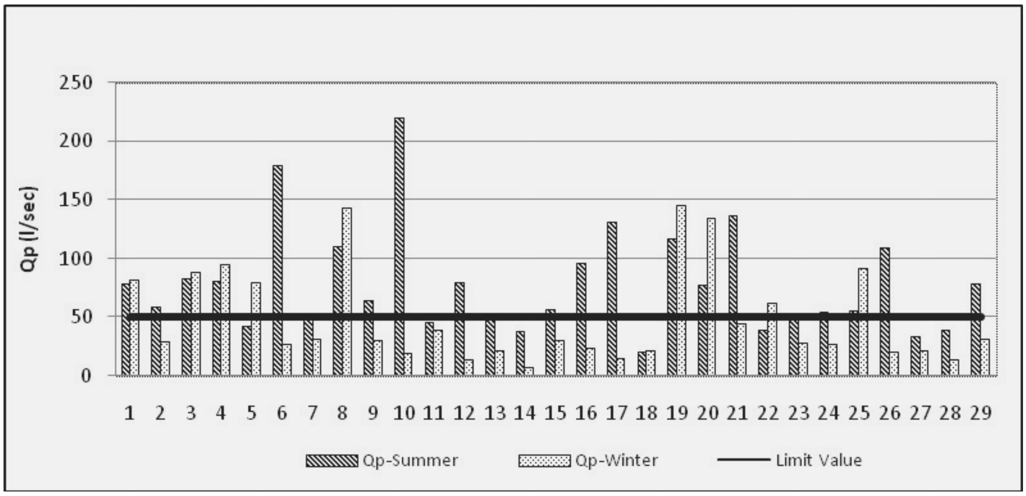
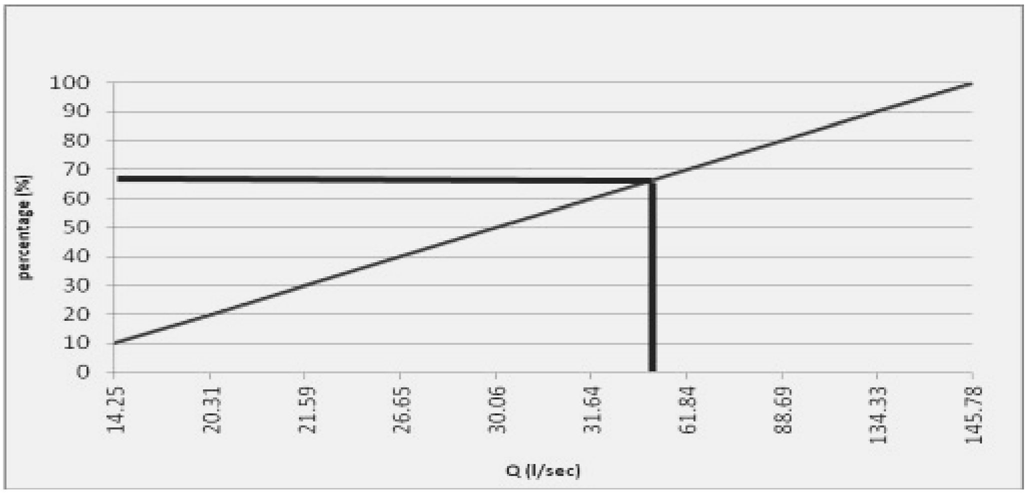
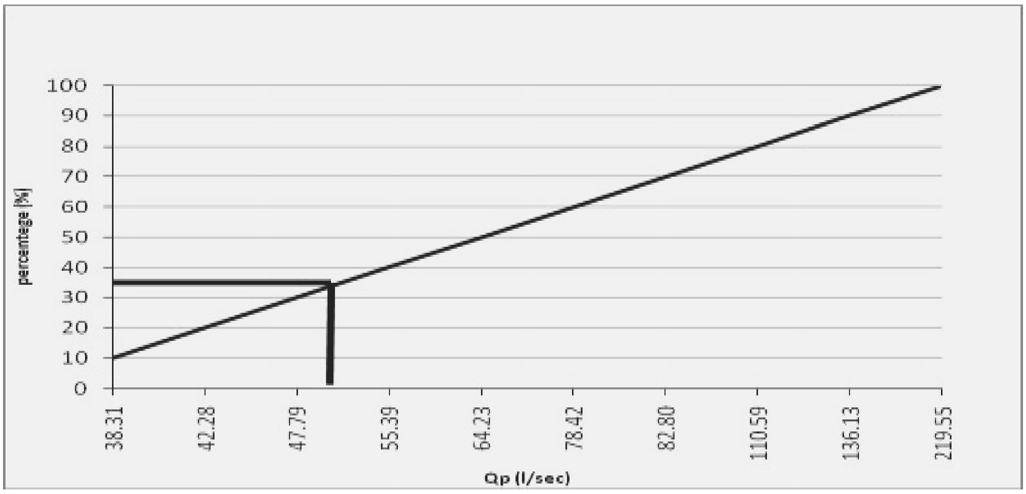


FIGURE 4
Air Leakage Rates Measured in Houses [27].



(a)



(b)

FIGURE 5
Outdoor Air Leakage in the Summer (a) and Winter (b) Season [27].

Cumulative percentage changes of Qp are given in Figure 5**.**

Figure 6 shows that the amount of air coming from outdoors into the indoor environment was less than the limit value in 33% of houses during summer and in 66% during winter**.** Open doors and windows in summer increased air leakage into the indoor environment.

Average ACR (h^{-1}) of the dwellings in winter and summer is summarized in Figure 6. Minimum ACR in most houses was greater than 0.35 h^{-1} in summer. However, in winter, lower ACR values were found. A study in Denmark indicated that ventilation rates in 57% of houses where children aged 3–5 years were living was below 0.5 h^{-1} [26].

According to an ACR cumulative percentage graphic (Figure 7), ACR in almost all the houses exceeded the limit value in summer. In winter, the value in 47% of the houses was below the limit [27].

Qp in all regions of the city was found to exceed the limit value (50 L/s) in summer. In the second and third regions, Qp was below this limit in winter (Figure 8).

The distribution of the outdoor air leakage values by region in summer time were 85.09 L / s (± 44.02) in first region, 83.83 L / s (± 52.79) in 2nd region, and 59.65 L / s (± 25.97) in 3rd region, while in the winter, 71.81 L / s (± 40.58) in region 1, 43.45 L / s (± 43.26) in 2, and Region, 33.20 L / s (± 26.34) in 3rd region. Differences in Qp among the three regions are mainly due to different proximities to the city center and temporal variability.

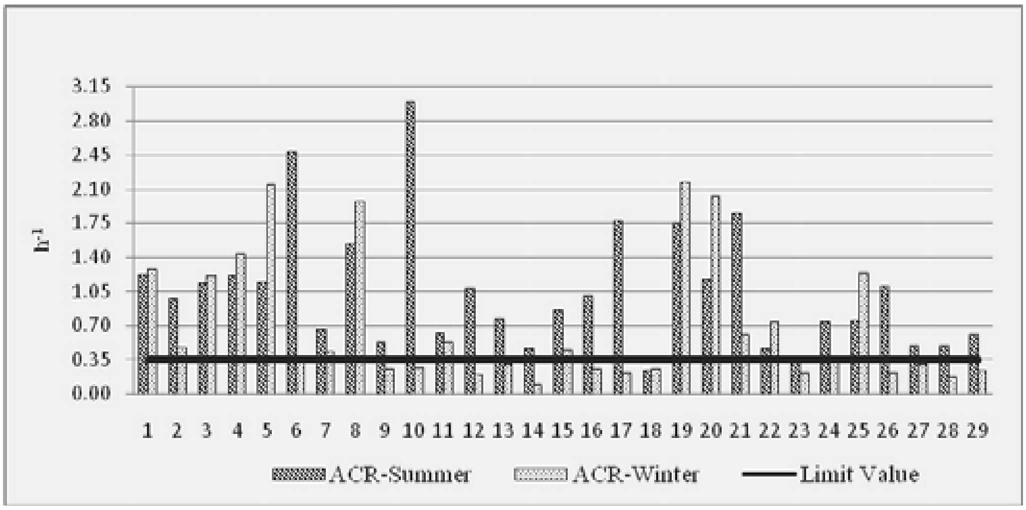
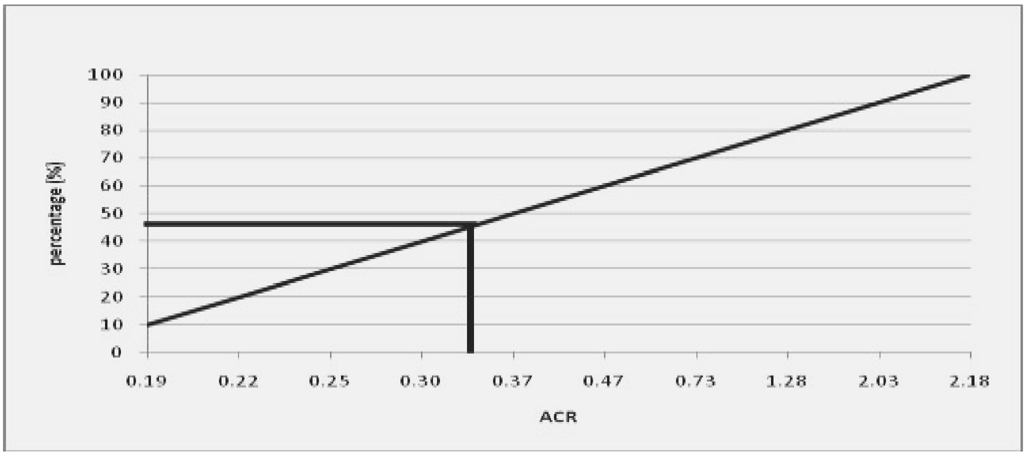
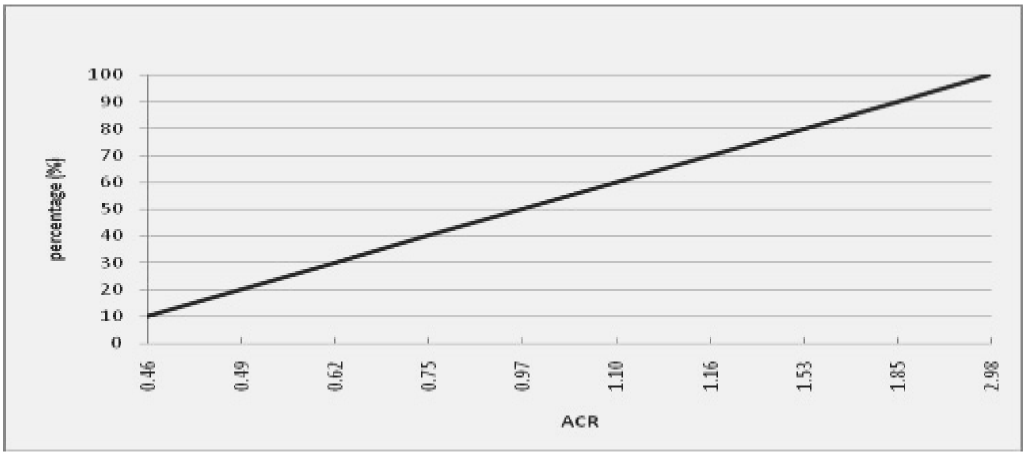


FIGURE 6
Air Change Rate During Winter and Summers (h^{-1}) [27].



(a)



(b)

FIGURE 7
Seasonal Cumulative Distributions of Air Change Rate in the Houses in the Summer (a) and Winter (b) Seasons (%) [27].

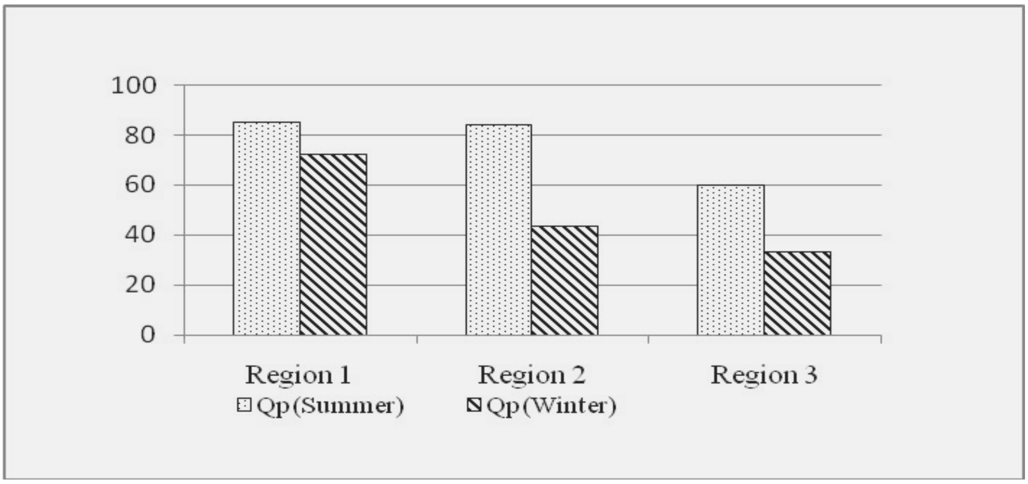


FIGURE 8
Outdoor Air Leakage Values Depending on the Different Socia Economic Region Summer and Winter Season (lt/sec).

Indoor CO_2 rates were less than the limit of 1000 ppm in the houses during summer, but above this limit during winter (Figures 9, 10 and 11). Figure 11 shows that in winter, 43% of houses exceeded the 1000 ppm limit.

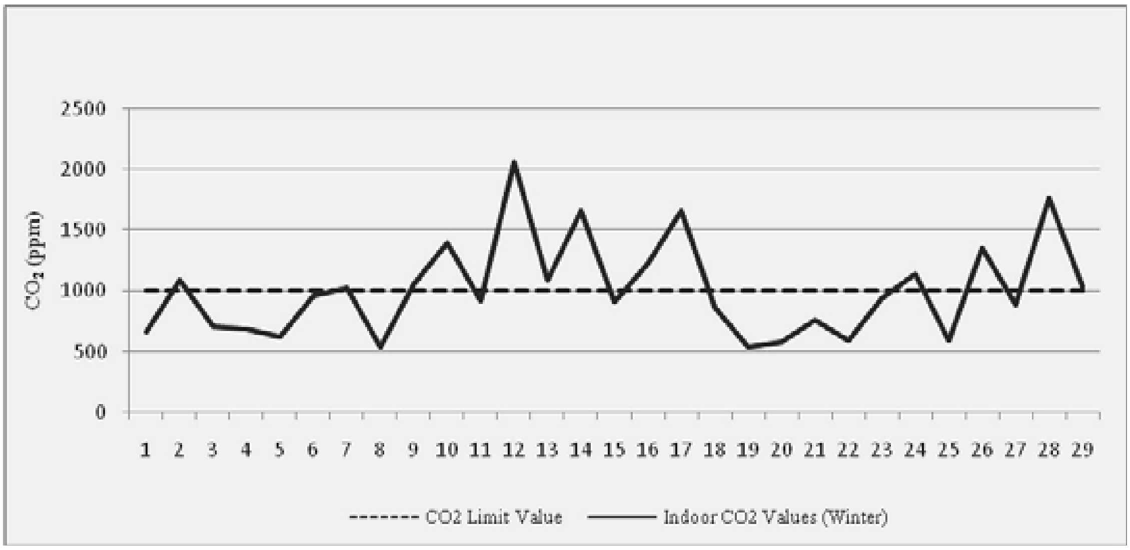


FIGURE 9
Indoor CO_2 Levels in the Winter Season [27].

We analyzed parameters that affect pollution and ACR such as cigarette consumption, ventilation period, area of the houses, distances to main roads, and indoor environment, in 29 houses.

In houses where people smoked, average Q_p was 45.91 L/s (± 37.24) in winter. In non-smoking houses, this was 52.36 L/s (± 45.83). In houses with smokers, ventilation was low, below the standard rate.

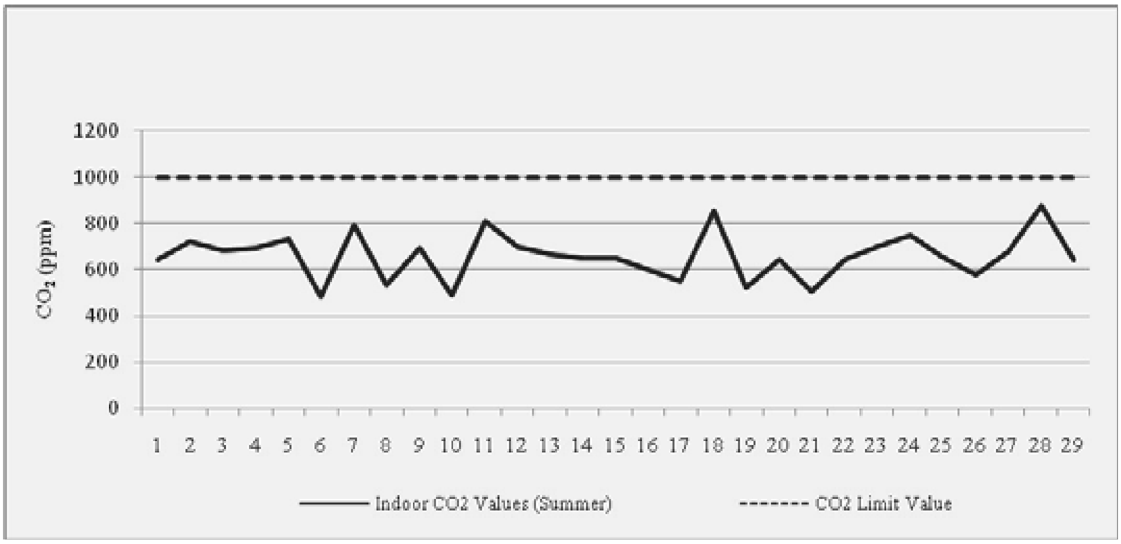


FIGURE 10
Indoor CO_2 levels in the Summer Season [27].

It was also found that Q_p was 84.65 L/s (±51.98) (smoking houses) and 70.59 L/s (±31.90) (non-smoking houses) in summer, which are above the limit value. In winter, ACR was 0.69 h^{-1}(±0.68) (smoking houses) and 0.72 h^{-1}(±0.68) (non-smoking houses), whereas in summer, this rate was 1.15 h^{-1}(±0.76) (smoking houses) and 0.93 h^{-1}(±0.45) (non-smoking houses). ACR in winter was less than in summer.

Statistical data for comfort parameters such as temperature, relative humidity and ACR measured in indoor environments are found in Table 3. Relative humidity measured in summer was below the limit of 60% and, in winter, it exceeded this value in some houses.

Table 4 lists ACR measured in the houses according to cigarette consumption, ventilation duration, house area, indoor comfort parameters, and distances to main roads. This table reveals that human activities and physical conditions in naturally ventilated indoor environments affect ACR and that the standard ACR of 0.35 is not usually met in winter.

TABLE 3
Statistical data of comfort parameters.

	N	Minimum	Maximum	Mean	Std. Deviation
R. Humidity-Summer	29	33,12	53,63	44,36	4,82
Temperature -Summer	29	25,07	30,81	27,67	1,49
R. Humidity-Winter	29	31,11	73,04	53,39	12,09
Temperature -Winter	29	4,62	25,41	17,29	5,67
ACR-Summer	29	0,23	2,98	1,05	0,64
ACR-Winter	29	0,09	2,18	0,70	0,67

Change of ACR in comfort parameters was also determined in summer and winter according to average humidity and temperature. ACR (and SD) corresponding to above and below average humidity values measured in summer were 1.09 h^{-1}(±0.56) and 1.01 h^{-1}(±0.71), respectively. Corresponding values in winter were 1.02 h^{-1}(±0.82) and 0.51 h^{-1}(±0.48). ACR (and SD) corresponding to above and below average temperature values measured in summer were 0.84 h^{-1}(±0.48) and 1.19 h^{-1}(±0.71), respectively. Analogous values in winter were 0.35 h^{-1}(±0.27) and 1.20 h^{-1}(±0.75).

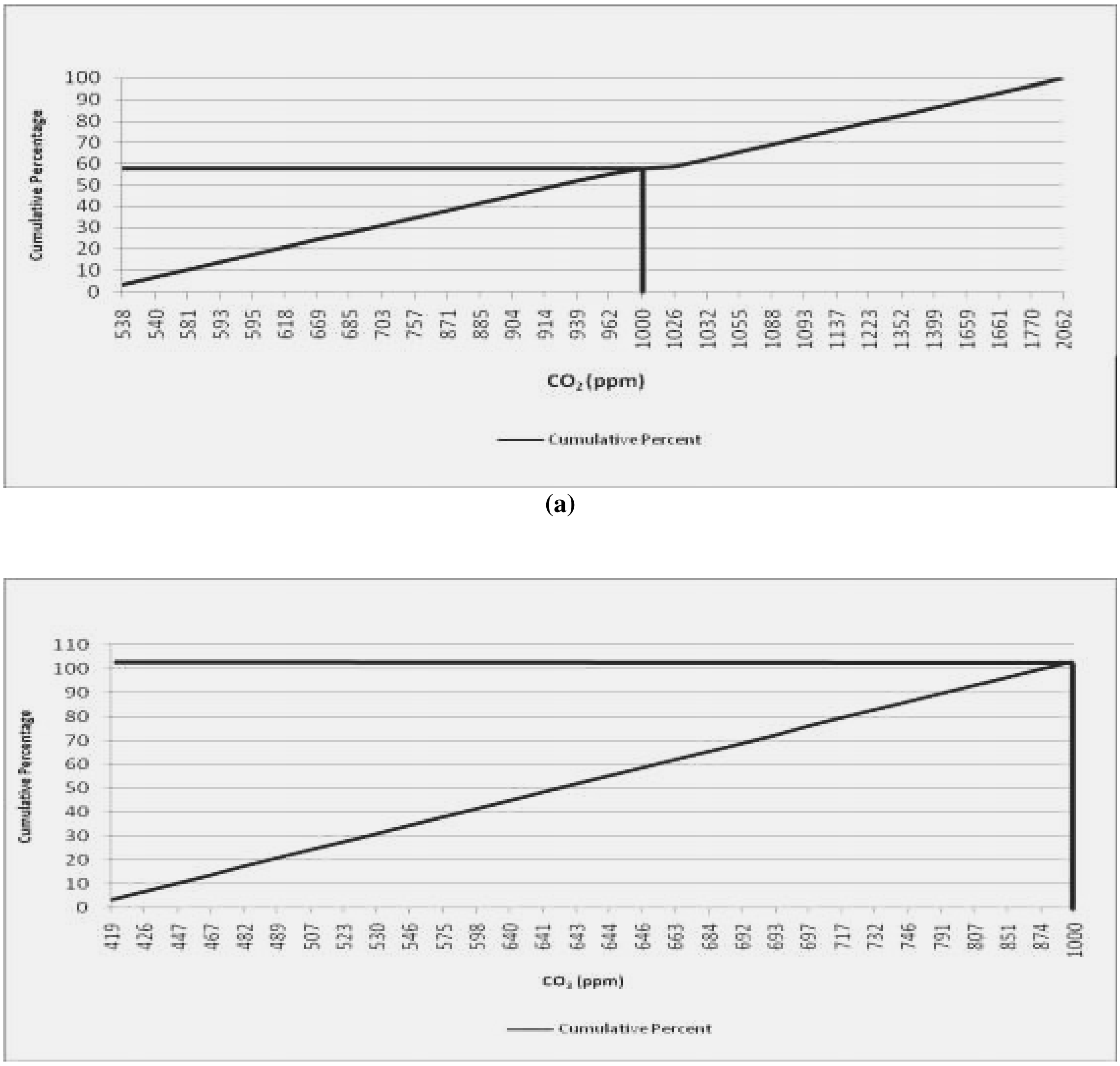


FIGURE 11
Seasonal Cumulative Distributions of CO_2 Concentration in the Houses in the Summer (a) and Winter (b) Seasons (%) [27].

TABLE 4
Air Change Rate in the Houses.

		Summer (h^{-1})	Winter (h^{-1})
General Average		1,04 (± 0,64)	0.70 (± 0,67)
Cigarette Consumption	Yes	1,15 (± 0,76)	0,69 (± 0,68)
	No	0,93 (± 0,45)	0,72 (± 0,68)
Square Meter (m^2)	>107	0,58 (± 0,29)	0,27 (± 0.18)
	<107	1,26 (± 0,64)	0,90 (± 0,72)
Distance to Main Road	Far	1,12 (± 0,62)	0,85 (± 0,71)
	Close	0,94 (± 0,68)	0,47 (± 0,54)
Ventilation Duration (hour)	<2	1,18 (± 0,89)	0,48 (± 0,42)
	>2	0,98 (± 0,47)	0,82 (± 0,75)

Relative to area of the houses above and below 107 m^2, ACR (and SD) was respectively 0.58 h^{-1}(±0.29) and 1.26 h^{-1}(±0.64) in summer, and 0.27 h^{-1}(±0.18) and 0.90 h^{-1}(±0.72) in winter. There was a relationship between house area and ACR. It was less and below the limit value in houses with large area in winter. In summer, there was low ACR in such houses compared with those with small area (Figure 12).

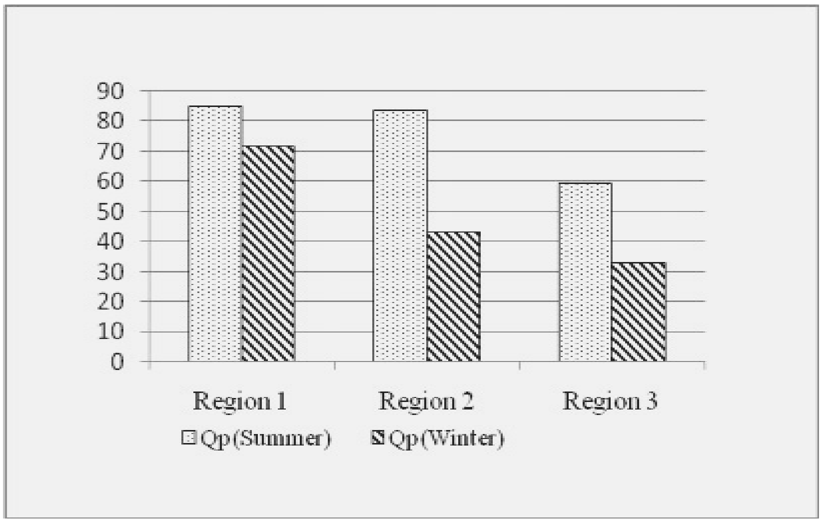


FIGURE 12
Air Change Rate Depending on the Areas of the Houses.

Upon evaluating distance and proximity of ACR to main roads, values in summer were 1.12 h^{-1}(±0.62) and 0.94 h^{-1}(±0.68), respectively, and 0.85 h^{-1}(±0.71) and 0.47 h^{-1}(±0.54) in winter. ACR was lower in houses close to main roads in both seasons.

Data related to ventilation duration in the houses were from surveys, which were found to be around 2 hours. According to the relationship between ventilation duration and ACR in the 29 houses for duration less or greater than 2 hours, the respective rates were 1.18 h^{-1}(±0.89) and 0.98 h^{-1}(±0.47) in summer, and 0.48 h^{-1}(±0.42) and 0.82 h^{-1}(±0.75) in winter. ACR was usually higher because of open windows in summer and lower in winter since houses are less ventilated.

Table 5 shows the comparison of the results of other studies and current study results. The results found by this study are comparable with other studies results. For example, indoor CO_2 concentration was reported at 1603 ppm in winter and 405 ppm in summer at 64 schools. It was also reported that in winter, CO_2 concentration increased because of insufficient ventilation, which is important in determining indoor environment quality [28]. In South Korea in 10 houses, it was found that CO_2 concentrations gradually increased after cooking was begun, but decreased whenever residents used natural or mechanical ventilation [29].

According to another study determining ACR carried out [30], winter ACRs were 2.2–3.3 h^{-1} and 5.3–19.7 h^{-1} in summer. In Northern Europe, It was reported that the median ACR was 0.42 h^{-1} (average 0.55 h^{-1}) in winter according to data collected from 2844 houses [31]. In Sweden, 60% of 390 multifamily houses and 80% of single-family houses did not meet the 0.5 h^{-1} ACR specified in the building code [32].

CONCLUSION

It is determined that carbon dioxide concentrations in 29 houses along with ACR and outdoor air leakage in summer and winter. ACR was higher in summer than in winter. The reason for this is typically open doors and windows, which enhances air circulation.

There is a similar relationship between outdoor air leakage and ACR, with the latter higher in summer than in winter. It was found that this leakage was above the standard of 50 L/s in 77% of houses in summer, and 34% in winter. Insufficient ventilation in the houses during winters might be the reason for this difference.

TABLE 5
Comparison of CO2 concentrations and ACR values.

Parameters	Unit	N	Mean	explain	Ref
CO_2	ppm	29 house	627	summer	this study
			1011	winter	
			<1000	with a mechanical ventilation system	Griffiths and Eftechari, 2008
			1400	windows are closed	
		64 school	405	summer	Fromme et al., 2007
			1603	winter	
ACR	h^{-1}	29 house	1,05	summer	this study
			0,7	winter	
			5,3-19,7	summer	Loupa et al., 2006
			2,2-3,3	winter	
			0,55	winter	Andersan et al., 1997
			1,6	summer	Fromme et al., 2007
			0,61	winter	

Most of the houses met the 0.35 h^{-1} limit for ACR in summer, but only 53% did so in winter.

Indoor CO_2 pollution levels in the houses were measured in winter and summer. CO_2 concentration was found to exceed the 1000 ppm limit in winter, but was less than this value in summer. In winter, 57% of houses exceeded the limit, but none during summer. It is believed that factors such as outdoor air pollution and leakage into the indoor environment, insufficient ventilation, cigarette consumption, and cooking are important in winter.

There was low ACR in houses with smokers relative to houses without them. It is thought that increasing CO_2 from cigarette consumption impacts the ACR.

Higher ACR was found indoors with higher humidity in both summer and winter. ACR was lower in indoor environments with higher temperatures. ACR was higher in houses with smaller areas.

There were smaller ACR values in houses close to main roads. It is believed that in such houses, pollution from traffic affects their indoor environment.

It appeared that ventilation duration influenced ACR more strongly in winter. It is thought that ACR is lower in houses with short ventilation duration in winter, and that indoor pollution reduces ACR owing to insufficient ventilation.

ACKNOWLEDGEMENT

This study was financially supported by the Scientific and Technological Research Council of Turkey (Project No. 108Y166).

REFERENCES

[1] USEPA (1991) Indoor air quality: Sick building syndrome (EPA/402-F-94-004), Indoor Air Group, Resarch Triangle Park, North Cardina.

[2] World Health Organization (WHO) (2003-2004) Health risk assesment of indoor air quality (Mog/HSE/4.3/001,AC.01.03.01.Aw), Ulan boatar Mongalia.

[3] Jones, A.P. (1999) Indoor air quality and health. Atmospheric Environment, 33, 4535–4564.

[4] Schramek, E. (1999) Recknagel-Sprenger Schramek- Heating and Air Conditioning Technology Handbook, TTMD, Ankara, Turkey.

[5] Li, Y., Chen, Z. (2003). A balance-point method for assessing the effect of natural ventilation on indoor particle concentrations. Atmospheric Environment, 37, 4277-4285.

[6] G. Gaidajis, and K. Angelakoglou (2012) Indoor air quality in terms of mass concentrations of particulate matter in areas of massive public

congregation. Fresen. Environ. Bull., Issue 1/8/2012.
[7] Thatcher, T.L. and Laytol, D.W. (1995) Deposition, re-suspension and penetration of particles within a residence. Atmospheric Environment, 29, 1487–1497.
[8] Moriske, H.J., Drews, M., Ebert, G., Menk, G., Scheller, C., Schondube, M. and Konieczny, L. (1996) Indoor air pollution by different heating systems: coal burning, open fire place and central heating. Toxicology Letters, 88, 349-354.
[9] Quackenboss, J.J., Lebowitz, M.D. and Crutchfield, C.D. (1989) Indoor-outdoor relationships for particulate matter: exposure classifications and health effects. Environment International, 15, 353-360.
[10] Polodori A., Fine PM., White V. and Kuran PS. (2013) Pilot study of high performance air filtration for classroom applications. Indoor Air, 23, 185-195.
[11] ASHRAE, (2003) ASHRAE Handbook CD, 2001 Fundamentals, Chapter 9: Indoor Environmental Health. Atlanta, USA.
[12] Doğan, H. (2002) Applied Ventilation and Air Conditioning Technology, Seçkin Publishing, Ankara, Turkey.
[13] Schell, M. B., Turner, S. C. and Omar, S. (1998) Application of CO2-Based Demand-Controlled Ventilation Using ASHRAE Standard 62: Optimizing Energy Use and Ventilation, ASHRAE Transactions, 104(2), 1213-1225.
[14] Pandian, M.D., Ott, W.R. and Behar J.V. (1993) Residential air change rates for use in indoor air and exposure modeling studies. Journal of Exposure Analysis and Environmental Epidemiology, 3, 407-416.
[15] Chao, C.Y.H. and Tung, T.C. (2001) An emperial model for outdoor contaminant transmission into residential buildings and experimental verification. Atmospheric Environment, 35, 1585-1596.
[16] ASHRAE, (2010) Standard 62.2-2010 - Ventilation and Acceptable Indoor Air Quality in Low- Rise Residential Buildings.
[17] Griffiths M. and Eftekhari M. (2008) Control of CO_2 in a naturally ventilated classroom. Energy and Building, 40, 556-560.
[18] TSA, (2013) Turkey Statistical Agency, www.tuik.gov.tr.
[19] BG, (2013) Balıkesir Government, www.balikesir.gov.tr.
[20] BMO, (2013) Balıkesir Meteorology Office, Daily Climatological Data, Balıkesir, Turkey.
[21] BGOPHD, (2013). Balıkesir Governor's Office Public Health Directorate, www.balikesir.saglik.gov.tr.
[22] İlten N. and Selici A.T. (2008) Investigating the impact of some meteorological parameters on air pollution in Balıkesir, Turkey. *Environmental Monitoring and Assesment*, 140, 347-277.
[23] İlten, N., Tecer, L.H. and Selici A.T. (2011) Calculation of Pollutant Emissions are Related to Energy Consumption in Residential, 18. National Thermal Science and Technology Congress. 165-170.
[24] Persily, A.K. (1997). Evaluating Building IAQ and Ventilation with Indoor Carbon Dioxide.http://fire.nist.gov/bfrlpubs/build97/PDF/b97044.pdf.
[25] Bas, E. (2004) Indoor Air Quality-A Guide for Facility Managers, The Fairmont Pres, Lilburn,Georgia.
[26] Bekö, G., Lund, T., Nors, F., Toftum, J. and Clausen, G. (2010) Ventilation rates in the bedrooms of 500 Danish children. Building and Environment, 45, 2289-2295.
[27] Selici, A. T. (2014) Investigation of indoor air quality based on sources of pollutant and comfort parameters and energy consumption, Phd Thesis, Balıkesir Üniversity Institue of Science, 80-82-83, Balıkesir.
[28] Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl R., Liebl, B. And Rüden, H. (2007) Particulate matter in the indoor air of classrooms-exploratory results from Munich and surrounding area, Atmospheric Environment, 41, 854-866.
[29] Lee, H. Lee, Y.J., Park, Y.S., Kim, W.Y., Lee, Y. (2012) The Improvement of ventilation behaviours in kitchen of residential buildings. Indoor and Built Environment, 21(1), 48-61.
[30] Loupa, G., Charpantidou, E., Kioutsioukis, S. and Rapsomanikis, S. (2006) Indoor microclimate, ozone and nitrogen oxides in two medieval churches in Cyprus, Atmospheric Environment, 40, 7457-7466.
[31] Andersen, C.E., Bergsoe, N.C., Majborn, B. and Ulbak K. (1997) Radon and natural ventilation in newer Danish single-family houses. Indoor Air Qual Clim, 7(4):278-86.
[32] Bornehag, C.G., Sundell, J., Hagerhed-Engman, L. and Sigsgaard, T. (2005) Association between ventilation rates in 390 Swedish homes and allergic symptoms in children. Indoor Air, 15(4), 275-280.

Received: 14.08.2015
Accepted: 11.12.2015

CORRESPONDING AUTHOR

Nadir Ilten
Balikesir University
Faculty of Engineering
Department of Mechanical Engineering
10145 Balikesir – TURKEY

e-mail: nilten@balikesir.edu.tr