Global Journal of Health Science
http://www.ccsenet.org/gjhs
Vol. 1, No. 2
October 2009

Indoor Air Quality and Sick Building Syndrome in Malaysian Buildings

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This project is funded by Universiti Putra Malaysia, Petronas GAS Berhad and Malaysia Energy Center (Sponsoring information)

Abstract

This study was done to investigate the association between sick building syndrome (SBS) and indoor air pollutants in two different buildings (old and new). Hundred and seventy six office workers were randomly selected in this study form April to September 2008. One office from Tower 1, in one private building at Kuala Lumpur City Center (KLCC) categorized as Building A (old building), while another government building, Malaysia Energy Center categorizes as Building B (new building). Modified IAQ and Work Symptoms Survey, NIOSH Indoor Environmental Quality Survey

(1991) was used to measure the SBS occurrence. Measurement of IAQ was performed according to IAQ Code of Practice, Department Occupational Safety and Health, (DOSH, 2005) Malaysia. Building A and B recorded 93 and 83 respondents respectively. Ventilation rate were significantly higher in Building B compared to Building A with median 21.10 cfm/person and 18.60 cfm/person respectively ($z = -11.70$, $p < 0.001$). Higher prevalence of SBS recorded in Building A, compared to Building B ($\chi^2 = 11.9$, $p = 0.001$). Significantly higher of IAP in Building A compare to B for CO_2, CO, TVOC, PM_{10}, $PM_{2.5}$, while Building B showed higher concentration of Ultrafine Particle and Temperature Humidity Index (THI) value. There were significant association between ventilation rate and the prevalence of SBS (OR = 3.13, 95% CI = 1.62 – 6.06). Study result showed that indoor pollutants in old building were high, while new building showed indoor pollutants high for THI value and UFP. The level of THI and CO2 concentration was major factor contribute to SBS complain among office workers.

Keywords: Indoor air quality (IAQ), Sick building syndrome (SBS), Old and new building, Indoor Air Pollutants (IAP), KLCC, PTM

1. Introduction

Energy crisis in year 1970s leading the engineer and building manager to design and maintain indoor environment more efficiently by sealing up the building and thus cause less ventilation rate to safe the electricity (WHO, 1986). The indoor air quality (IAQ) in any building can be compromised by microbial contaminants (mold, bacteria), chemicals (such as carbon monoxide, formaldehyde), allergens, or any mass or energy stressor that can induce health effects (John et al. 2000). The sick building syndrome (SBS) has become common issues in Malaysia recent years due to the construction of buildings designed to be energy-efficient with air conditioning system (Berardil, 1991) but poor maintenance and services of Heating, Ventilation and Air Conditioning (HVAC) system resulting the increasing of indoor air pollutants (IAP) levels.

Studies have demonstrated that SBS is influenced by the type of ventilation system, with the prevalence of SBS being higher in buildings with mechanical ventilation systems compared to normal ventilation system (Burge et al. 1987). Few researches in Tropical Country focus to demonstrate the age of the building and IAP characteristics with the prevalence of SBS and other health effects. New building normally reported to have high concentration of total volatile organic compounds (TVOC) while old building recorded poor ventilation rate with the increasing of Carbon Dioxide (CO_2) level. The inadequate ventilation per occupants and the elevated indoor chemical pollutants concentrations can lead to the SBS prevalence (Michael et al. 2000). SBS symptoms can be on upper respiratory and mucous membrane symptoms for example irritated eyes, nose, sinus, or throat. And the other symptoms are on the lower respiratory for example cough, tight chest, wheeze, or difficulty in breathing (Michael et al. 2000).

The symptoms experienced are non-specific and predominantly upper respiratory in origin (nasal, eye, and throat) but headache and lethargy, potentially more multifactor in origin, are also experienced. This study investigates the different age of the building as the important factor influence SBS with hypothesis if the building is old; the IAP will be increase thus the SBS prevalence will recorded high.

The current study was designed to investigate which etiological factors were still relevant to reported symptoms within state of the art buildings of modern design, where there was expected to be a low prevalence of symptoms associated with SBS. This study was a collaborative project conducted from April to September 2008 in two buildings office in Malaysia with epidemiological study design of the SBS and specialist agency with focus in detailed about occupational hygiene aspects of monitoring indoor environmental conditions and thus provides information of indoor air quality and its associations with the SBS prevalence among office workers in different buildings.

2. Methods and materials

2.1 Subject recruiting and selection

To recruit the study subject, lists of names were obtained from the Human Resource Department in both buildings' office. From the list available, 93 office workers in the first office at Tower 1, KLCC building was recruited and categorized under the old building group named as Building A. The other 83 office workers, who fulfill the stated criteria and matched as a group, were recruited from the Pusat Tenaga Malaysia office building as new building group named Building B. All respondents were explained about the procedure of the study and consent letter was obtained from all respondents before the study begins.

A cross-sectional comparative study was conducted between the Building A (old building) and Building B (new building). Building A was selected as an old building because of its seven years of occupancy after commissioning. However, Building B was considered new due to its occupancy was just three months after commissioning. Both of these buildings were being chosen because these buildings used the same centralized air conditioning unit and the office was completely dependent only on the general ventilation to provide sufficient air for occupants.

2.2 Questionnaires survey

A set of questionnaires were used to get the demographic background and socio-economic of the respondents such as personal information, health status, educational status and income. SBS symptoms questions were based on the Indoor Air Quality and Work Symptoms Survey, NIOSH (National Institute Occupational Safety and Health) Indoor Environmental Quality Survey (1991). The questionnaires include the worker's health status and symptoms of SBS such as chronic cough, cough with phlegm, chest tightness, and shortness of breath. Questionnaires also contain information on the previous workplace, working history, and location of current workstation (near the entrance door, near to photocopied area, etc), and also working background such as overtime, shift work schedule, duration of work per day, duration of work per week and the employment years at the office. Zoning of each worker's workstation then categorized accordingly with the reference of floor plan. Reported SBS symptoms were given to the respective respondents on each day of IAQ assessment conducted and the score given in the analysis of data commence.

The office workers will be defined as having SBS if they had at least one symptom of SBS symptoms and the symptoms appear at least once in a week. The building occupants also must had reported symptoms occurrence of at least 1-3 days per week during four weeks past and the symptoms shown improvement when she/he away from work (Ooi et al. 1998).

2.3 Indoor air quality measurements

Assessment of indoor air quality (IAQ) in Building A and B were conducted according to Malaysia Indoor Air Quality Code of Practice (IAQ, COP), Department Occupational Safety and Health (DOSH), Malaysia 2005. Partial period of consecutive sampling was conducted in three times (morning, afternoon, evening) to represent the IAP status inside the building for the whole day. The office workers from both office buildings were selected based on the proximity of their workstations (according to the zoning area) to the IAQ air sampler. Workers closest to the air sampler were selected first and the selection continued, concentric circles from the air sampler location, until the required number of available office workers was achieved. Sampler was located in the center of the location in the office area 75 cm above the ground.

The indoor air quality was measured using the TSI 8554 Q-Trak Plus. The TSI 8554 Q-Trak Plus measure Temperature (Temp), Relative Humidity (%RH), Carbon Dioxide (CO_2), Carbon Monoxide (CO) and ventilation rate. The concentration of CO_2 in this research was used as the ventilation indicator for the fresh air supply, supply air from diffuser, return air and outside air. TSI 8386 Velocicalc Plus (Velocicalc) was used to assess the air movement, air flow, velocity, volume, pressure different and ventilation rate in both building. The location of all parameter sampling spot was recorded on the layout plan, and then the entire instrument was run simultaneously using specific procedure by IAQ, COP (DOSH, 2005) and ventilation measurement using guideline given by ASHRAE – 62 (2003).

All indoor air pollutants data were downloaded in specific TSI Trak Pro Software for TSI equipment and PROSuite for RAE instruments. There were five important variables in this study. For the CO_2, CO, temperature and humidity detection, the TSI 8554 Q-Trak Plus was used. TVOC were recorded by using the MiniRAE PGM-7600. For the particulate matter (PM_{10} and $PM_{2.5}$), the TSI Model 8520 Dust Trak^{TM} Aerosol Monitor and TSI Side Pack^{TM} (Side Pack) were respectively used in this study. TSI Model 8525 P-Trak® Ultrafine Particle Counter (UFP) was used in this study to collect the UFP concentration on selected location in both building.

2.4 Ethical issues and quality control

Approval from Medical Researcher Ethic Committee, UPM was obtained. Permission from the employer and written consent were gained during data collection period. A set of Pre test was performed on 10% of the sample size before the study begins to ensure the understanding of the questions. The entire instrument was calibrated by the manufacture before air sampling was performed and method of calculation for the indoor air quality was guided by the professional IAQ assessor.

3. Result and discussion

3.1 Socio-demographic information

The descriptive statistics of the respondents show in Table 1. The Malay workers made up the highest number of the office workers in Building A (87.1%) as well as the Building B group (86.7%). The majority of the respondents were married. Table 2 shows respondents were similar in their work duration in a week but significantly different in age, anthropometric data and working history in the building ($p<0.001$).

3.2 Indoor air quality Supplied Air and Ventilation Measurement, Air temperature, humidity, and velocity

Indoor Air Quality Supplied Air and Ventilation Measurement (IAQ-SAVM) was measured by the adequacy of the IAQ supplied air into the indoor environment in cubic feet minute per person (cfm/person). Carbon dioxide (CO_2) gas was used as the main indicator for detect the efficiency of supplied air ventilation. Indoor air quality supplied air and ventilation measurement were conducted and measured according to zoning of the indoor sampling location. The value of 20 cfm per person was determined as the median value of the indoor air quality level (ASHRAE Standard-62, 2003). Table 3 showed the differences between the cfm/person levels in both buildings. The result of Mann Whitney U Test showed the Building B showed significantly higher indoor air quality supplied air compared to Building A. (Table 4).

3.3 Comparison of indoor air pollutant in both building

Building A had 31 sampler spots while 21 sampler spots in the Building B. Normality test were performed and both data were not normally distributed. Building A showed significantly higher parameter of CO_2, CO, TVOC, PM_{10}, and $PM_{2.5}$ compared to Building B. Building B however, showed significantly higher of UFP concentration and THI values compared to Building A (Table 5).

3.4 Prevalence of Sick Building Syndrome

Building A was operated more than 10 years vice versa for Building B (Runeson et al. 2003). The score of the SBS had been done according to the positive response, if one symptoms recorded nearly everyday, the mark given to the SBS scale. If two symptoms reported everyday, two score were given and so on (Ooi et al. 1998). As showed in Table 6, number of respondents that had been categories as having SBS using above criteria given, Building A were recorded 68.8% office workers having SBS compared to 36.1% of office workers in Building B.

Indoor Air Quality (IAQ-SAVM) and ventilation measurement were conducted and found that there were significant association between the level of IAQ and SBS (Table 7). Indoor air pollutants (IAP) (CO_2, CO, TVOC, UFP, PM_{10}, $PM_{2.5}$ and THI values) were categories into high concentration (High) and low concentration (Low) depending on the median value, either above or lower. Based on Table 8, result showed there were significant association between SBS and the IAP concentration namely CO_2, CO, TVOC, and THI value. Logistic Regression was run to obtain adjusted Odd Ratio/ risk (OR) for parameters: CO_2, CO, TVOC, and THI values with the SBS prevalence. The OR was adjusted for age, medical condition, Upper Respiratory Tract Infection (URTI), smoking, having pet at home, and other medical problems. For multiple regression statistics, the factors that significantly influenced the SBS and pollutant concentration were CO_2 and THI values (Table 9).

Carbon Dioxide concentration is a key parameter for assessing indoor air quality and ventilation efficiency (Godish, 2000). IAQ supplied air and ventilation measurement were different in Building A (old building) and B (new building). Low IAQ-SAVM recorded 18.60cfm/person in Building A compare to recommended ASHRAE Standard – 62 (General Ventilation) which suggested office environment require minimum 20 cfm/person IAQ-SAVM (Janssen, 1994). However this IAQ-SAVM in Building A was still acceptable and meets the Code of Practice Indoor Air Quality (COP, IAQ), DOSH Malaysia. Indoor environment recorded lower IAQ-SAVM level of ASHRAE Standard – 62 recommended may introduce thermal comfort issues and improper dilution of IAP that may cause irritating to the eyes, headaches and dizziness if prolonged exposure. Effectiveness of the air handling unit system (HVAC system), its maintenance, cleaning procedures and periodical inspection can improve the ventilation and increase the IAQ-SAVM level in office environment (Irtishad, 2000).

Clear association seen between elevated of indoor CO_2 levels and increases in certain SBS symptoms. Analyses conducted using average and median concentration of indoor CO_2 had similar findings with previous study (Ooi et al. 1998). The reduction of CO_2 could come through large increases in ventilation rates, improved effectiveness in providing fresh air to the occupants' breathing zone (Seppanen et al. 1999), or through identification of the symptom-causing agents in the indoor air and control of their sources. The ventilation that inadequate and insufficient fresh air intake can contribute to high level of CO_2 in certain area in the building (Ooi et al. 1994). The low intake of fresh air will also influence the Temperature Humidity Index (THI) value in the building. Similar conclusion observed in study conducted by Bayer et al. (1990) who stated that the SBS may occur due to inadequate ventilation and high level of humidity and temperature. After adjusting for confounding, we found important and statistically significant associations of SBS symptoms was the increases of CO_2 and THI value.

Building A recorded significantly higher all IAP measured except for UFP concentration and THI values. However all the indoor pollutant measures were below IAQ-COP limit and this indicate that the HVAC maintenances are well in both buildings. Structured of high rise building (Petronas Twin Tower, KLCC) can influence the inadequate of the air exchange in the building (Turiel et al. 1983) thus influence dilution of pollutant by HVAC unit in Building A. Another suspected insufficient fresh air supply from the HVAC systems may due to blockage of humidifier (Godish et al. 1996) by occupants' activities and renovations.

Second parameter which influences the SBS was the Carbon Monoxide (CO). In this study, after adjusted the cofounder it showed that the SBS are not influencing mainly by CO exposure. CO exposure in this study was low and below maximum limits (COP of IAQ, 2005). Carbon monoxide concentration in both areas were recorded slightly similar with the previous study conducted by Berardil et al. (1991) who stated that the concentration of CO was low at the range of 0.01 to 3 ppm. The concentration of CO in previous study conducted by Jonathan et al. (2001) stated that the CO level more than 10 ppm was observed due to outdoor source especially from parking lot. The CO concentration above 10 ppm was significantly associated with SBS symptoms such as dizziness, fatigue and headache (Samet, 1993).

From the result of indoor air pollutants and SBS comparison, the most significant pollutant that influence the SBS was CO_2, CO, TVOC and THI (OR = 4.63, 95% CI =2.45 – 8.76). Indoor air pollutant result from this study showed that, the indoor air pollutant CO_2 mean was lower compared to previous study conducted by Ooi et al. (1998). Increasing the level of CO_2 in each building showed positive association to the occurrences of sick building syndrome thus increases in certain lower respiratory syndrome (Michael et al. 2000). The mechanical floor mechanism was one of the factor influence the higher level of CO_2 in old building. However CO_2 concentration in Buildings B showed in the range of 350.25 – 544.50 ppm. This slightly the same result showed in the study conducted by Berardil et al. (1991) which stated that the concentration of CO_2 in new building work area was at range 400 – 500 ppm.

TVOC showed significant association with the SBS prevalence (OR = 2.25, 95% CI = 1.18 – 4.27). The respondents recorded having SBS for high concentration of TVOC was 43.6%. The similar trend of SBS symptoms such as headache, fatigue and dizziness significantly associated with the TVOC exposure more less than 3 ppm was observed (Runeson et al. 2003). THI values obtained from the calculation of temperature with the humidity level inside the building. High humidity level indoor environment can cause sensation of dryness of office respondents (Fang et al. 2004).

Thermal Humidity Index (THI) value was gathered from temperature and humidity data from this study. Form the result there was a significant difference of THI value in both building that have mean of THI value, 21.55. This result supported by study conducted by Ooi et al. (1998), who showed that the THI index of the mean from the study was 21.22. The higher humidity observed in the Building B which recorded higher range of THI values at 21.78 – 23.84 compared to Building A which THI range at 19.43 – 21.49. High levels of THI when above 23 can create a non comfortable condition of building occupants (Brager et al. 1994). Beside the factor of indoor air pollutants, the there were few studies on health-related selection in relation to the indoor thermal comfort environment or in relation to personality of the respondents (Runeson et al. 2003). Effects of temperature and humidity on the perception of air quality can occur due to insufficient indoor cooling air and slightly raised temperature and humidity (Fang et al. 2004).

4. Conclusion

This study suggested that increases in the ventilation rates per person among typical office buildings will, on average, significantly reduce prevalence of SBS, even when these buildings meet the existing ASHRAE ventilation standards for office buildings. The magnitude of the reduction will depend on the magnitude of the increase in ventilation rates, improvement in ventilation effectiveness, or reduction in sources of SBS causing pollutants.

There is no direct causal link between exposure to CO_2 and SBS symptoms, but rather CO_2 is approximately correlated with other indoor pollutants that may cause symptoms. Behind the study expectation, it found that the temperature and humidity are important indoor factors that can influence prevalence of SBS. UFP also are the common issues that need to be focus on in the new building, because this pollutant can also influence SBS.

Concern about the indoor air quality has been increasing as the public becomes aware that exposure to inadequate supplied air and the exposure to indoor air pollutants may increase the risk of getting health risk. Over the years many types of mitigation (correction) strategies have been implemented to solve indoor air quality problems. Mitigation of indoor air quality problems may require the involvement of building management and staff representing such areas of responsibility as firstly facility operation and maintenance, secondly housekeeping, thirdly policymaking and lastly staff training. All efforts to prevent or correct IAQ problems should include an effort to identify and control pollutant sources. Source control is generally the most cost effective approach to mitigating IAQ problems in which point sources of contaminants can be identified. In the case of a strong source, source control may be the only solutions that will work.

References

ASHRAE. (2003). *Ventilation for Acceptable Indoor Air Quality*, Atlanta GA, American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE Standard 55 – 1992).

Bayer, C. W. (1990). Maintaining optimum indoor air quality, *J. Prop. Manage.* 55: 37 – 39.

Berardil B. M., Leoni E., Marchesini B., Cascella D., and Raffil G.B. (1991). Indoor climate and air quality in new offices: effects of a reduced air-exchange rate. *International Archives of Occupational and Environmental Health* 63, pp. 233 – 239.

Brager, G et al. (1994). Comparison of methods for assessing thermal sensation and acceptability in the field, In Thermal Comfort: Past, *Present and Future*, (eds N. A. Oseland and M. A. Humphreys).

Burge S., Hedge A., Wilson S. (1987). Sick building syndrome: a study of 4373 office workers, *Ann Occup Hyg,* 31, pp. 493 – 504.

Department of Occupational safety and Health (DOSH). (2005). Ministry of Human Resources, Malaysia. *Code of Practice on Indoor Air Quality*.

Fang L., Wyon D.P., Clausen G. and Fanger P.O. (2004). Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance, *Indoor Air* 14 (Suppl 7), pp. 74 – 81.

Godish T, Spengler J.D. (1996). Relationships between ventilation and indoor air quality: a review, *Indoor Air,* 6, pp. 135 – 145.

Godish, Thad. (2000). *Indoor Environmental Quality*. Ventilation. Appleton and Lange. pp: 333.

Irtishad. 2001. "Effectiveness of HVAC duct cleaning procedures in improving indoor air quality", *Environmental Monitoring and Assessment* 72, pp. 265–276.

John D. Spengler, Jonathan M. Samet, John F. Mccarthy. (2000). *Indoor Air Quality Handbook*, McGraw-Hill.

Jonathan M. Horner. (2001). A survey of carbon monoxide in student rented flats in London, UK, *Environmental Management and Health* 12, No. 4.

Michael G. Apte, William J. Fisk, Joan M. Daisey. (2000). Indoor Carbon Dioxide Concentrations and SBS in Office Workers, *Proceedings of Healthy Buildings*, Vol. 1.

Ooi P.L., Goh K.T., Heng B.H. (1994). Epidemiological investigations into an outbreak of building-associated illness in Singapore. *Asia Pac J Public Health* 7, pp. 201 – 205.

Ooi P.L., Goh K.T., Phoon M.H., Foo S.C., Yap H.M. (1998). Epidemiology of sick building syndrome and its associated risk factors in Singapore. *Occup Environ Med*., pp. 188 – 193.

Runeson A.D., Norback H., Stattin. (2003). Symptoms and sense of coherence – a follow-up study of personnel from workplace buildings with indoor air problems. *Int Arch Occup Environ Health* 76, pp. 29 – 38.

Samet J.M. (1993). Indoor air pollution: a public health perspective, Proceedings of the 6th International Conference on Indoor Air Quality. *Helsinki: International Conference on Indoor Air Quality* 1, pp. 3 – 12.

Seppanen O.A., Fisk W.J., and Mendell M.J. (1999). Association of ventilation rates and CO_2 concentrations with health and other responses in commercial and institutional buildings. *Indoor Air* 9, pp. 226 – 252.

Turiel I., Hollowell C.D., Miksch R.R., Rudy J.V., Young R.A. (1983). The effects of reduced ventilation on indoor air quality in an office building. *Atmos Environ.* 17, pp. 51 – 64.

World Health Organization. (1986). *Indoor air pollutants: exposure and health effects*. Copenhagen: WHO Regional Office for Europe. (EURO Reports and Studies No78).

Table 1. Demographic information of respondents

Variables	**Building A**		**Building B**	
	N=93	**%**	**n=83**	**%**
Race				
Malay	81	87.1	72	86.7
Chinese	11	11.8	8	9.6
Indian	1	1.1	2	2.4
Others	0	0.0	1	1.2
Status				
Single	24	25.8	19	22.9
Married	69	74.2	64	77.1

Table 2. Background information of respondents

Variables	Median (IQR) Building A	Median (IQR) Building B	z	p
Age (years)	36 (31.5 – 41.0)	32 (30.0 – 35.0)	-3.64	<0.001**
Height(m)	1.64 (1.58 – 1.69)	1.62 (1.55 – 1.69)	-3.23	0.001*
Weight (kg)	68.00 (62.50 – 70.50)	63.51 (55.0 – 69.00)	-2.04	0.041*
BMI	25.00 (23.8 – 26.4)	24.21 (22.15 – 25.44)	-2.01	0.04*
Working history in building (month)	60.00 (24.00 – 84.00)	4.00 (2.00 – 4.00)	-11.02	<0.001**
Work duration (week)	41.48 (40.00 – 43.00)	40 (40.00 – 45.00)	-1.52	0.13

*significant at $p<0.05$

**significant at $p<0.001$

Table 3. The differences of IAQ Supplied Air in both buildings

Parameter	Building A			Building B		
	Mean (SD)	Median	Range	Mean (SD)	Median	Range
CFM/Person	18.63 (1.96)	18.6	16.20-21.01	22.45 (1.59)	21.10	21.1-24.30

Table 4. Comparison of the IAQ in KLCC and PTM building

Parameter	Median (Inter Quartile Range) Building A (n = 93)	Median (Inter Quartile Range) Building B (n = 83)	z	p
CFM/person	18.60[c] (16.20-21.01)	21.10[c] (21.1-24.30)	-11.70	$p<0.001$*

*significant at $p < 0.05$

[C]Unit in CFM/person

(N = 176)

Table 5. Comparison indoor pollutant concentration between two buildings

Parameter	**Median (Inter Quartile Range)**		**z**	**p**
	Building A n = 93	**Building B n = 83**		
CO_2 (ppm)	643 (412 – 647)	412 (405.5-423)	-11.38	p < 0.001*
CO (ppm)	0.78 (0.14 – 1.43)	0.23 (0.08 – 0.5)	-5.19	p < 0.001*
TVOC (ppm)	0.58 (0.36 – 1.03)	0.33 (0.1 – 0.43)	-6.30	p < 0.001*
UFP (pt/cm^3)	1283 (396.89 – 1378.16)	1964 (1831 – 1983.75)	-11.34	p < 0.001*
PM_{10} (µg/m^3)	61.00 (50 – 72.5)	37.80 (29.3 – 51.00)	-6.96	p < 0.001*
$PM_{2.5}$ (µg/m^3)	61.23 (48.7 – 72.00)	35.8 (35.1 – 45.2)	-8.90	p < 0.001*
THI (N/A)	20.80 (20.62-20.94)	22.28 (22.01 – 22.81)	-11.44	p < 0.001*

*significant at p < 0.001

N = 176

Table 6. Comparison of the prevalence of SBS between two groups

Variables	**Prevalence of SBS N = 176 (100%)**		**χ^2**	**p**
	Yes	**No**		
Building A n= 93	64 (68.8)	29 (31.2)	11.90	0.001*
Building n= 83	30 (36.1)	53 (63.9)		

*significant at p < 0.05

N = 176

Table 7. Association of SBS between two groups of IAQ level

Variables	**Prevalence of SBS N = 176 (100%)**		**OR**	**95%CI**
	Yes n = 94	**No n =82**		
High IAQ level (>20cfm/person)	50 (53.2)	64 (78.0)	3.13*	1.62 – 6.06
Low IAQ level (<20cfm/person)	44 (46.8)	18 (22.0)		

*OR significant at 95% CI > 1

N = 176

Table 8. Association between SBS and pollutant levels

Parameter	**Parameter Category**	**SBS N = 176 (100%)**		**OR**	**95% CI**
		Yes n = 94	**No n =82**		
CO_2	High	62 (66)	30 (36.6)	**3.36***	**1.81 – 6.24**
	Low	32 (34)	52 (63.4)		
CO	High	44 (46.8)	24 (29.3)	**2.13***	**1.14 – 4.00**
	Low	50 (53.2)	58 (70.3)		
TVOC	High	41 (43.6)	21 (25.6)	**2.25***	**1.18 – 4.27**
	Low	53 (56.4)	61 (74.7)		
UFP	High	36 (38.3)	54 (58.7)	0.32	0.17 – 0.60
	Low	58 (61.7)	28 (41.3)		
PM_{10}	High	38 (40.4)	36 (43.9)	0.62	0.22 – 1.76
	Low	56 (59.6)	46 (56.1)		
$PM_{2.5}$	High	44 (46.8)	41 (50)	0.82	0.26 – 2.56
	Low	50 (53.2)	41 (50)		
THI	High	30 (31.9)	53 (64.6)	**4.63***	**2.45 – 8.76**
	Low	64 (68.1)	29 (35.4)		

*OR significant at 95% CI > 1

N = 176

Table 9. Logistic Regression for SBS and Concentration of pollutants after controlling cofounders

Parameter	**Parameter Category**	**SBS N = 176 (100%)**		**OR (95% CI)**	***OR (95% CI)**
		Yes n = 94	**No n =82**		
CO_2 (ppm)	High	62 (66)	30 (36.6)	**3.36**	**2.19[a]**
	Low	32 (34)	52 (63.4)	**(1.81-6.24)**	**(1.32-11.89)**
CO(ppm)	High	44 (46.8)	24 (29.3)	2.13	0.68
	Low	50 (53.2)	58 (70.3)	(1.14-3.97)	(0.26-1.76)
TVOC	High	41 (43.6)	21 (25.6)	2.25	0.63
(ppm)	Low	53 (56.4)	61 (74.7)	(1.18-4.27)	(0.26-1.48)
THI	High	30 (31.9)	53 (64.6)	**4.63**	**11.37[a]**
(^{0}C/RH %)	Low	64 (68.1)	29 (35.4)	**(2.45-8.76)**	**(1.35-16.19)**

* Adjusted OR for age, medical condition, URTI, smoking, having pet at home, other medical problems.

[a]OR significant at 95% CI > 1

N = 176