International Journal of Applied Chemistry. ISSN 0973-1792 Volume 12, Number 1 (2016) pp. 57-61
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Indoor Air Quality and Sick Building Syndrome (SBS) among Staff in Two Different Private Higher Learning Institution Settings in Kuala Lumpur and Selangor

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Abstract — Purpose of this study is to determine the relationship between Indoor Air Quality (IAQ) and Sick Building Syndrome (SBS) among staff in two different settings of Private Higher Learning Institutions in Kuala Lumpur and Selangor. The differences in building setting which are retrofitting and purposed-built building may have different IAQ levels and ventilation system efficiency as well as different in number of reported SBS. 120 respondents consist of male and female administrative staff from Building A and B were participated in this cross sectional comparative study. SBS symptoms measured using validated questionnaire from modified IAQ and Work Environment Symptom Survey while IAQ parameters measured using IAQ devices. Result shows that symptoms of SBS which is stuffy or irritated nose (OR=2.99, 95% CI=1.14-7.88) and fatigue, unusual tiredness or drowsiness (OR=2.58, 95% CI=1.12-5.97) shows a significant association in Building A and B. Besides, there was no significant association between the reported SBS with level of IAQ in Building A and B, however Building A shows an insignificant OR with increasing risk of developing SBS among staff office. After controlling the confounder, there was no significant association between reported SBS with indoor air pollutant in Building A, however result shows an increase risk with insignificant OR of developing SBS when exposed to CO_2 (OR=1.92, 95%CI=0.49-7.46), temperature (OR=1.54, 95% CI=0.38-6.19), bacteria (OR=1.72, 95% CI=0.46-6.42) and fungi (OR=1.72, 95% CI=0.46-6.42). While for Building B, there is a significant increased risk of developing SBS when exposed to CO_2 (OR=1.67, 95%CI=0.42-5.79), temperature (OR=1.49, 95% CI=0.07-32.36) and bacteria (OR=1.29, 95% CI=0.42-3.99). As a conclusion, purposed-built building is more suitable for the construction of college compared to retrofitting building since retrofitting building showed higher levels of pollutants which exceed the permissible limit. Thus, a proper maintenance of ventilation systems and good housekeeping should be practiced as well as control the source of IAP in the office.

Keywords: *Indoor air quality (IAQ), sick building syndrome (SBS), Indoor air pollutant (IAP), Retrofitting and purposed-built building.*

I. INTRODUCTION

Good IAQ is needed for a healthy indoor environment [4]. According to Environmental Protection Agency (EPA), IAQ is defined as the air quality within and around buildings and structures, especially its influence the human health and comfort. Comfort is important for building occupant to perform their work and it is depends on the quality of the indoor environment. Mostly, people spend more than 80% of their time indoor, whether at work or at home [13]. Perceive IAQ occurred when there is a presence of indoor air pollutants in indoor environment which become a significant problem for people, especially for office building occupants.

Workers who exposed to poor IAQ and subsequently develop symptoms or health conditions called Sick building syndrome (SBS) when they are in the building; and their symptoms often got better when they left the building. SBS is defined by Industrial Code of Practice on Indoor Air Quality (ICOP) as an illness which is experienced by building occupants due to poor IAQ [4]. Common symptoms experienced by building occupants are irritation of the mucosal membrane [4] and upper respiratory tract, headache and fatigue. The problem arises from IAQ may contributed to problem which affects the worker's health, well-being, comfort, and productivity. Other than that, the quality of indoor air in office also contributed to problem with inadequate ventilation [12]. Since private institution building is fully ventilated with centralized air conditioning system, it becomes a threat of having inadequate ventilation and poor IAQ.

Retrofit building is a modification or renovation made in an old building which transform into the new building with a different purpose. A previous study stated that the prevalence of SBS in the old building was significantly higher compared to the new building [14]. Majority of the retrofit building do not meet the standard of retrofitting process required, which is why this study is important to be conducted to determine if the levels of IAQ of these building were in accordance to the standard requirement. Meanwhile, purposed-built building is constructed purposely to fit the college specification. The problem of IAQ in a building can be influenced by many factors, including inadequate ventilation system, presence of indoor air pollutants, overcrowding, radon, high moisture and dampness and presence of contaminant from the use of cleaning and disinfecting material [4].

Another reason for conducting this study was due to there are limited researches about the IAQ in different types of buildings. In identifying the symptoms of SBS, the feedback from building occupant and the level of indoor air pollutants are important, specifically assessing those condition in different types of building where the occupants work at. The main objective of the study is to determine the relationship between IAQ and SBS among office staff in two different types of building in Private Higher Learning Institutions which are purpose-built and retrofitting college building.

II. METHODOLOGY

A. Study Location and Subject Selection

This study involved two private higher learning institution, Building A located at Kuala Lumpur city and Building B located at Kota Damansara. Building A was an old, retrofit building was an old building in the range of 30 to 40 years with an excellent education program. This building was retrofitted from a commercial office building into private learning institution building while Building B was purposely built for educational purpose with age around 5 to 6 years old. Same with the Building A, this building type used a centralized air conditioning system and only depends on the general ventilation which provided sufficient air to all people included office rooms, lecture rooms and laboratories.

Cross sectional comparative study was conducted to assess the association between the IAQ of two different types of private higher learning institution buildings and the reported SBS symptoms. The staffs were selected based on the proximity of their offices to the indoor air pollutants through random sampling method. The study samples were staffs (male and female) with the range ages between 25 and 45. The staffs chosen were based on the closest of them from the IAQ equipment to measure the exposure level from indoor air pollutant.

B. Instrumentation: Questionnaire and IAQ devices

Questionnaire

Validated questionnaire based on modified Indoor Air Quality and Work Environment Symptom Survey, NIOSH Indoor Environment Quality Survey (1991) was used which consists of background information of respondents, workplace information, health status of respondent, symptoms of SBS experienced and workplace condition. Reliability analysis, which is Cronbach Alpha was run before distributed to respondents and the value within the reliable value which is 0.74.

Based on the study by Ooi et al. [9], there were criteria compatible with the WHO definition for SBS case definition. Office worker were classified having SBS if at least twice weekly when they in the building. The score given based on the positive response which was one score given for one symptom appeared nearly every day according to SBS scale and if two symptoms appeared nearly every day, the score given will be two and so on. The data were then analysed using Statistical Package for the Social Sciences Version 20 (SPSS).

Indoor Air Quality Devices

The IAQ measurement devices used were TSI 8386A Velocicalc Plus, TSI 8554 Q-Trak Plus Monitoring, TSI Model 8520 Dust-TrakTM Aerosol TSI Model 8525 P-Trak Ultrafine Particle, MiniRAE 2000, Formaldemeter htV-M, and DUO SAS Super 360. Sampling method was based on Industrial Code of Practice on Indoor Air Quality by DOSH [4]. Collection of data was conducted at four different time slot which includes morning, afternoon, early evening and late evening. The measuring devices were placed between 75 and 120 cm from the floor.

TSI 8386A Velocicalc Plus was used to measure the ventilation rate, temperature and relative humidity. TSI 8554 Q-Trak Plus Monitoring was used to measure carbon dioxide (CO_2) and carbon monoxide (CO). MiniRAE 2000 was used to measure the level of TVOC contained in the indoor air. TSI Model 8520 Dust-TrakTM Aerosol was used to measure the particle concentrations which are PM_{10} (Particulate matter with aerodynamic less than 10 micrometers). TSI Model 8525 P-Trak Ultrafine Particle was used to measure ultrafine particulate level. Formaldemeter htV-M was used to measure the level of formaldehyde. DUO SAS Super 360 High Volume Air Sampler was used to detect microbial air contaminants (bacteria and fungi).

C. Measurement and Sampling Procedure

Levels of indoor air pollutant obtained from this study were compared with standard compliance specified by Industrial Code of Practice on Indoor Air Quality (ICOP IAQ) and ASHRAE standard 62 for ventilation rate. All sampling locations were recorded and the procedure for measurement were according to specific procedures by ICOP IAQ [4] and ventilation measurement were according to guidelines from ASHRAE – 62 [2]. Measurement of all parameter was conducted in four different time slot which are during the morning, afternoon, early evening and late evening. For morning, data was taken between ranges of 8 am to 11 am. For afternoon, the range time for data collection is between 11 am to 1 pm. During the early evening, the data collection was taken between the ranges of 1 pm to 3 pm while the last data collection was conduct between the ranges of 3 pm to 5 pm. All instruments were calibrated as one of the quality control applied to ensure its sensitivity and to prevent the occurrence of error during data collection phase.

D. Ethical Committee Approval

Approval from Universiti Putra Malaysia (UPM) Ethical Committee was obtained as a requirement before conducting study involving human participation.

III. RESULT AND DISCUSSION

A. Socio Demographic Information

In this study, both genders were involved and result shows that female recorded higher in number compared to male in Building A (61.7%) and B (65%). Besides, Malay race in Buildings B has higher number of staff compared to other races; however Malay and Chinese respondent from Building A have same percentage compared to other races. Another study stated that Malay races have higher number of office worker compared to the other races [8]. Degree educational level was higher in number from Building A (65%) and B (53%) compared to other educational level. This shows that mostly staffs have good background education and have aware about symptoms of SBS and changes in environment and shows that the level of education has relationship with reported SBS symptom among staff [3].

B. Reported Sick Building Syndrome (SBS)

Symptoms of SBS were assessed through SBS questionnaire such as dry, itchy eye, nose, and throat and skin irritation, chest tightness, sneezing, wheezing, shortness of breath, cough, headache, nausea or vomit, fatigue, unusual tiredness or drowsiness, difficulty in remembering things or concentrating, dizziness or lightheaded and tension, irritability or nervousness.

Table 1 shows that there was a significant association in stuffy or irritated nose (OR=2.99, 95%CI=1.14-7.88) and fatigue, unusual tiredness or drowsiness (OR=2.58, 95%CI=1.12-5.97) recorded between Building A and Building B which leads to SBS cases. Other symptom such as dry, itchy or irritated eyes, chest tightness, sneezing, shortness of breath, cough, nausea or vomit, difficulty in remembering things or concentrating, dizziness or lightheaded and tension, irritability or nervousness showed an insignificant with OR more than 1 increased risk in developing SBS. According to a previous research [10], they found that the most common symptoms reported by the worker at their targeted population were irritated, stuffy, or runny nose. This study was supported by previous study done by Nur Fadilah and Juliana [8] where they reported that the stuffy nose was one of the significant symptoms associated with SBS that experienced by staffs due to poor IAQ.

After looking at work related-symptom and other symptoms, it was reported that the common symptoms reported by workers were nasal symptoms, fatigue, skin dryness and eye-related symptom, as well as hoarse or dry throat. High cases of sore or dry throat recorded due to exposure from higher level of CO_2 present in indoor environment [1].

C. Reported SBS with Levels of IAQ between Building A and B

The quality of indoor air and ventilation system are related to each other [5]. Level of IAQ is an important indicator to determine the efficiency and adequacy of ventilation system [6]. If the ventilation system did not meet the recommended requirements, health problem could be experienced by workers from poor IAQ including respiratory problem, allergic reaction and others SBS symptoms. The main reason of IAQ problems arise was strongly suggested that it was related to ventilation system used. It was found that there was no significant association between the reported SBS with indoor air quality in Building A and B but Building A shows a significant OR with increased risk of developing SBS among staff office as shown in **Table 2**.This was supported by previous study state that respondents who gave positive result of their experienced on SBS symptoms were working in office that had central ventilation system compared with respondent who did not [6].

Table 1: Comparison of the Reported SBS Symptoms among Respondents between Building A and B

Symptom	Study Sample				p	OR	95% CI
	Building A (N=60)		Building B (N=60)				
	Yes	*No*	*Yes*	*No*			
Dry, itchy or irritated eyes	6 (10.0)	54 (90.0)	3 (5.0)	57 (95.0)	0.491	**2.11**	0.50-8.87
Stuffy or irritated nose	17 28.3)	43 (71.7)	7 (11.7)	53 (88.3)	**0.039**	**2.99***	**1.14-7.88***
Sore or dry throat	8 (13.3)	52 (86.7)	20 (33.3)	40 (66.7)	0.017	0.31	0.12-0.77
Dry or itchy skin	9 (15.0)	51 (85.0)	11 (18.3)	49 (81.7)	0.807	0.79	0.30-2.06
Chest tightness	6 (10.0)	54 (90.0)	4 (6.7)	56 (93.3)	0.743	**1.56**	0.42-5.82
Sneezing	19(31.7)	41 (68.3)	16 (26.7)	44 (73.3)	0.688	**1.27**	0.58-2.81
Wheezing	1 (1.7)	59 (98.3)	3 (5.0)	57 (95.0)	0.619	0.32	0.03-3.18
Shortness of breath	3 (5.0)	57 (95.0)	1 (1.7)	59 (98.3)	0.619	**3.11**	0.31-30.73
Cough	13(21.7)	47 (78.3)	9 (15.0)	51 (85.0)	0.480	**1.57**	0.61-4.00
Headache	12(20.0)	48 (80.0)	13 (21.7)	47 (78.3)	0.822	0.90	0.37-2.18

Nausea/vomit	2 (3.3)	58 (96.7)	1 (1.7)	59 (98.3)	0.559	**2.03**	0.18-23.06
Fatigue, unusual tiredness or drowsiness	22 36.7)	38 (63.3)	11 (18.3)	49 (81.7)	**0.040**	**2.58***	**1.12-5.97***
Difficulty in remembering things or concentrating	8 (13.3)	52 (86.7)	5 (8.3)	55 (91.7)	0.558	**1.69**	0.52-5.51
Dizziness or lightheaded	7 (11.7)	53 (88.3)	5 (8.3)	55 (91.7)	0.762	**1.45**	0.43-4.86
Tension, irritability or nervousness	10 16.7)	50 (83.3)	8 (13.3)	52 (86.7)	0.799	**1.30**	0.48-3.56

*Chi-square test *Significant at p<0.05 *OR insignificant at more than 1. * 95%CI significant at more than 1

Table 2: Association of the Reported SBS with Level of IAQ in Building A and B

Building Type	Variables	Reported SBS		x^2	p	OR/95% CI
		Yes N (%)	No N (%)			
A	High IAQ Level (>15CFM/person)	17 (28.3)	11 (18.3)	0.693	0.446	1.65/ 0.23-1.81
	Low IAQ Level (>15CFM/person)	16 (26.7)	16 (26.7)			
B	High IAQ Level (>15CFM/person)	20 (33.3)	32 (53.3)	2.054	0.241	0.23/ 0.03-1.99
	Low IAQ Level (>15CFM/person)	1 (1.7)	7 (11.7)			

*Significant at p<0.05 *OR insignificant at more than 1 *High and low Level of IAQ classified as High=1 and Low=0

D. Reported SBS with Levels of Indoor Air Pollutant

Levels of indoor air pollutants (CO_2, CO, PM_{10}, UFP, RH, temperature, bacteria and fungi) in this study were assessed according to the categorized value depending on the median value of each pollutant measured; set as 1 for higher than median value and 0 for low than median value. The result from **Table 3A** shows that there is no significant association between reported SBS with indoor air pollutants in Building A. However, there is an increase risk of developing SBS if worker exposed to CO_2, RH, temperature, bacteria and fungi resulted from the OR value more than 1. For Building B, the results showed no significant association between reported SBS with indoor air pollutant measured. However, there is an increase risk with insignificant OR of developing SBS if worker exposed to CO_2, temperature and bacteria

After determine the association, Logistic Regression was done to determine the main factor which associated between reported SBS and the level of indoor air pollutant. It was reported that there was no significant association between reported SBS with indoor air pollutant in Building A after adjusted for confounders. However, there is a risk of developing SBS if worker expose to CO_2, temperature, bacteria and fungi. For Building B, the result from **Table 3B** shows no significant association between reported SBS with indoor air pollutant after adjusted for all confounders. However, there is a risk of developing SBS if staff exposed to CO_2, temperature and bacteria. This study was supported by Sulaiman and Mohamed [11].

Table 3A: Multiple Logistic Regressions on Indoor Air Pollutant and Reported SBS among Respondent in Building A

Parameter	Parameter Category	Reported SBS N=60 (100%)		Adjusted OR (95% CI)	Adjusted p-value
		Yes N(%)	No N(%)		
CO_2	High Low	21 (35.0) 12 (20.0)	15 (25.0) 12 (20.0)	1.92 (0.49-7.46)	0.346
RH	High Low	15 (25.0) 18 (30.0)	9 (15.0) 18 (30.0)	0.73 (0.19-2.86)	0.057
Temperature	High Low	22 (36.7) 11 (18.3)	17 (28.3) 10 (16.7)	1.54 (0.38-6.19)	0.546
Bacteria	High Low	19 (31.7) 14 (23.3)	14(23.3) 13 (21.7)	1.72 (0.46-6.42)	0.420
Fungi	High	19 (31.7)	14 (23.3)	1.72 (0.46-6.42)	0.420

	Low	14 (23.3)	13 (21.7)		

*Adjusted for age, race, educational level, smoking status, smoking family status, chemical sensitivity and history of health problem.

*OR insignificant at more than 1. *Nagelkerke R square = 0.158

Table 3B: Multiple Logistic Regressions on Indoor Air Pollutant and Reported SBS among Respondent in Building B

Parameter	Parameter Category	Reported SBS N=60 (100%)		Adjusted OR (95% CI)	Adjusted p-value
		Yes N(%)	No N(%)		
CO_2	High Low	11 (18.3) 10 (16.7)	20 (33.3) 19 (31.7)	1.67 (0.42-5.79)	0.422
Temperature	High Low	19 (31.7) 2 (3.3)	30 (50.0) 9 (15.0)	1.49 (0.07-32.36)	0.798
Bacteria	High Low	13 (21.7) 8 (13.3)	22 (36.7) 17 (28.3)	1.29 (0.42-3.99)	0.651

*Adjusted for age, race, educational level, smoking status, smoking family status, chemical sensitivity and history of health problem.
*OR insignificant at more than 1. *Nagelkerke R square = 0.290

IV. CONCLUSION

In conclusion, purposed-built building is more suitable for the construction of college as compared to retrofit building. In terms of IAQ and pollutant levels in this study, retrofit building recorded higher levels of certain pollutant where it exceeded the standard level such as CO_2, PM_{10}, bacteria count and temperature. This study can be used as baseline data and also as a control measure of IAP source in the future for both building. Several SBS symptoms were having significant relationship such as stuffy or irritated nose, sore or dry throat and fatigue. It is also concluded that no significant association between reported SBS with indoor air pollutant in Building A and B. However, there is an increased risk of developing SBS if staff exposed to air pollutants. It is recommended that periodic housekeeping such as vacuuming carpet should be maintained in office room to control IAP exposure and ensure working area are free from dust or dirt. Besides, return and supply air diffuser shall be maintained periodically and ensure temperature in office room shall be at comfort level recommended by standard ICOP. In addition, detail inspection of ventilation system should be proposed in order to determine the adequacy of ventilation system since inadequate ventilation cannot remove the pollutant out of the building. A good work environment is important as it could affect worker's psychology in completing their task in their office [7]. It is important to control the exposure since good IAQ can ensure the health and comfort of the office workers and most importantly, their performance and productivity at work will also be better.

ACKNOWLEDGEMENT

Staff and management who involved in this study were very much appreciated by us.

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