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ORIGINAL ARTICLE

RETROFITTING AND PURPOSED-BUILT BUILDINGS: INDOOR AIR QUALITY AND SICK BUILDING SYNDROME AMONG PRIVATE HIGHER LEARNING INSTITUTION STUDENTS IN KUALA LUMPUR AND SELANGOR

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ABSTRACT

This study was done to determine the relationship between indoor air quality and Sick Building Syndrome (SBS) among students in Retrofitting Building (Building A) located in Kuala Lumpur and Purposed-built Building (Building B) located in Selangor. A cross sectional study was conducted among student from selected buildings with the total number of 130 respondents. Modified questionnaire based on Indoor Air Quality and Work Symptoms Survey, NIOSH, Indoor Environmental Quality Survey, 1991 was used to record the number of students experienced SBS. Measurement of indoor air quality was performed using instruments recommended by the IAQ Code of Practice, Department of Occupational Safety and Health, Malaysia. There was a significantly higher number of occupants experienced SBS in Building A (60 of 65 respondents) compared to Building B (50 of 65 respondents) (X^2= 4.127, p = 0.042). It was also found that there is a significant difference between the numbers of respondents having SBS between Building A and Building B (p < 0.045). Building A had higher CO_2, bacteria, fungi, and UFP significantly as compared to Building B. However, only CO was significantly higher in Building B compared to Building A. It is suggested thatregular maintenance of both buildings is compulsory as ventilation played an important role in maintaining good indoor air quality in a building.

***Keywords**: Indoor Air Quality, Sick Building Syndrome, Retrofitting Built Building, Proposed Built Building.*

INTRODUCTION

Previous studies conducted by EPA stated that indoor air pollution is among the top five environmental health risks[1]. SBS is closely related to indoor air quality. SBS is defined as a situation where building occupants experience acute health related to the time spent indoors[2]. Indoor air pollutants might increase the chance of both long and short term health effects among students and staffs, reduce the productivity of lecturers and degrade the students learning environment and comfort[3].

Besides that, exposure to indoor pollutants can lead to a variety of health and cognitive problems, which can affect student's academic performance[4]. Lecture rooms contain a variety of pollution sources such as carbon dioxide, cleaning agents, dust and mold. Overcrowded lecture rooms will cause poor indoor air quality, resulting in adverse health problems[5]. Others indoor air pollutants are dust particles from carpets; volatile chemicals such as formaldehyde and glue from building materials; mold from moisture or dirt in HVAC systems; animal (pets and rodents) and other biological allergens; and other materials used in interior furnishings. Besides, low ventilation rates in buildings and outdoor pollutants, including vehicle exhausts have been identified as primary problems for human health, comfort and productivity[6]. Common symptoms of SBS include chest tightness or shortness of breath, chills, cough, diagnosed infection or clusters of serious health problems, dizziness, eye, nose and throat problems (congestion, swelling, itching or irritation), fatigue, drowsiness, dizziness or lethargy, fever, headache, nausea, sinus congestion, skin irritation and sneezing[1]. However, the symptomoccurrence depends on the sensitivity of the occupant to the indoor environment. Other than that, long term exposure to indoor air pollutants may lead to serious diseases. Occupational studies have noted statistically significant associations between exposure to formaldehyde and increased incidence of lung and nasopharyngeal cancer[7].

METHODS

Subject Recruiting and Selection

Name lists of students were obtained from the Human Resource Department for both buildings. 65 students from Building A were recruited and categorized under Retrofitting Building group. The other 65 students were recruited from Building B who fulfil the stated criteria and matched as a group of Purposed-Built Building. The respondents were sampled by using the simple random method. All respondents were explained about the procedure of the study and consent letter was obtained from all respondents before the study begins. Building A operated at least 35 years while Building B was operated at least 5 - 6 years. These buildings were chosen as both buildings were using centralized air conditioning systems.

Socio-demographic Information and the Number of Students Experienced Sick Building Syndrome

A set of questionnaires wasused to obtain the sociodemographic background of the respondents such as personal information, smoking status and duration of classroom/lecture hall usage. SBS symptom questions were based on the modified questionnaire of Indoor Environmental Quality Survey and Work Symptoms Survey, National Institute Occupational Safety and Health (NIOSH) Indoor Environmental Quality Survey, 1991. The questionnaires asked about students' experience on symptoms of SBS such as dry and itchy eyes, cough, chest tightness, runny nose and shortness of breath.

SBS symptoms experienced by respective respondents on each day of IAQ assessment conducted were recorded by the researcher and the score was given based on the frequency of symptoms experienced. Based on the study by Ooi*et al*.[8], students were defined as having SBS if they had at least one symptom of SBS and it appeared at least once in a week. The building occupants also must have had reported symptom occurrence of at least 1-3 days and the symptoms appear at least once in a week.

Indoor Air Quality Measurements

Indoor Air Quality measurement was conducted in Building A and B according to Malaysia Indoor Air Quality Code of Practice (IAQ, COP), Department of Occupational Safety and Health[9]. The measurements of indoor air parameters were taken using a consecutive method with which data were measured at 9.00am, 1.00pm and 3.00pm. This would give average readings. The students from both buildings were selected based on their proximity to the IAQ air sampler. The students who are closest to the air sampler were selected first and the selection was continued in concentric circles from the air sampler location until the required number of the students is achieved.The Sampler was located in the centre of the location at 75 cm above the ground. All the sampling points were recorded on the layout plan to mark the location of which the measurements were taken. There are 8 sampling points at Building A and 9 sampling points at Building B.

TSI 8554 Q-Trak Plus and TSI 8386 Velocicalc Plus (Velocicalc) were used to measure the indoor air quality of the buildings involved in the study. The TSI 8554 Q-Trak Plus was used to 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 a ventilation indicator of fresh air supply, supply air from the diffuser, return air and outside air. TSI 8386 Velocicalc Plus (Velocicalc) was used to assess air movement, air flow, velocity, volume, pressure different and ventilation rate in both buildings. TVOC was recorded by using MiniRAE 2000. For the particulate matter (PM_{10}), TSI Model 8520 Dust Trak Aerosol was used. Meanwhile, TSI Model 8525 P-Trak® Ultrafine Particle Counter (UFP) was used to capture UFP concentration on selected location in both buildings. On the other hand, FormaldemeterhtV-M was used to measure the formaldehyde concentration in both buildings. For biological pollutants, Air Samplers, Duo SAS Super 360 was used to sample the bacterial and the fungal counts.

Ethical Issues and Quality Control

Ethical approval was obtained from the Ethical Committee of University Putra Malaysia (UPM). A pre-testing questionnaire was distributed to 10% of target population before conducting the research in order to determine the validity and reliability of the questions in the questionnaire. All the equipment was calibrated before each time the equipment was used. The main function of calibration is to maintain the sensitivity of the equipment and to prevent measurement errors from occurring when the readings were taken. Meanwhile, the questionnaires were re-checked after respondents returned it back to prevent the respondents from leaving blank answers to avoid missing data. For bacteria and fungi total count, all the agar plates must be kept at suitable temperatures after the air sampling process.

RESULTS AND DISCUSSION

Socio-Demographic Information

It was found that there were more female respondents in both buildings which were 64.6% and 78.5% from Building A and Building B respectively as shown in Table 1. Meanwhile, there were 35.4% and 21.5% of male respondents from both Building A and Building B respectively.

Indoor Air Quality (IAQ) supplied air assessment

IAQ supplied air into the indoor environment in this study was measured in cubic feet minute per person (cfm/person). According to ASHRAE Standard 62-2007, supplied air equal or more than 17 cfm per person in a space is a good ventilation rate. Mann-Whitney U test was used to determine whether there is a significant difference between the two studies. Table 2shows that there is a significant difference between the IAQ of supply air in Building A and Building B. By comparing to the recommended Standards, Building B was significantly supplied with good Indoor Air Quality as compared to Building A.

Comparison of Indoor Air Pollutants in Both Building

Based on Independent t-test as shown in Table 3, there is asignificant difference for bacteria and fungi between Building A and Building B. Meanwhile, based on Mann-Whitney U test in Table 4, p-value for Humidity, PM_{10} and temperature is >0.05. Hence, there is no significance in indoor air pollutants for humidity, PM_{10} and temperature between Building A and Building B. However, the p-value for CO_2, CO and UFP are <0.05. Hence, there was a significant difference in indoor air pollutants for CO_2, CO and UFP between Building A and Building B.

The higher amount of biological pollutants present in Building A was probably due to the ineffective ventilation system, the leaks of ceilings, and the presence of ill and unwell students in the classroom. The leak in the ceilings allowed water to flow into the classroom. The water which flowed in increased the optimum environment for the fungi to grow as for dampness. The presence of many biological agents indoor is due to dampness and inadequate ventilation[10].
Building A recorded more UFP concentration probably because of the emissions from motor vehicles as Building A is located near the main road. Thus, many vehicles passed by every day and the emission of UFP pollute the indoor air in Building A[11] shows traffic accounting for about 40% of total emissions of UFP in 2007. Both buildings were recorded of having carbon dioxide concentrations exceeding the ceiling limit for carbon dioxide stated under theMalaysian Industrial Code of Practice for Indoor Air Quality which is at C1000 ppm. CO is one of the most significant pollutants that influenced SBS among building occupants. The high levels of CO found in Building B compare to Building A probably due to insufficient supplied air for the high number of students in the classroom during time when measurement was done.

Table 1 - Socio-demographic characteristics of Building A and Building B respondents

Variables	Study Group (%)			
	Building A (n=65)	Building B (n=65)	x^2	p
Sex				
Male	23 (35.4)	14 (21.5)	3.060	0.080
Female	42 (64.6)	51 (78.5)		
Race				
Malay	34 (53.8)	1 (1.5)	90.721	<0.001*
Chinese	7 (10.8)	61 (93.8)		
Indian	20 (30.8)	2 (3.1)		
Others	3 (4.6)	1 (1.5)		
Smoking Status				
Smoker	11 (16.9)	4 (6.2)	6.875	0.032*
Ex-smoker	1 (1.5)	6 (9.2)		
Non Smoker	53 (81.5)	55 (84.6)		

*significant at p < 0.05
N=130

Table 2 - Comparison of IAQ supplied air in both buildings

Parameter	Mean Difference	Standardized Difference	p-value	Parameter		Mean Difference	
				Building A	Building B	lower	Upper
CFM/Person	-5.1839	-2.524	0.015*	16.683	21.867	-9.301	-1.066

*significant at p <0.05
* Mann- Whitney U test
N=130

Table 3 - Comparison the concentration of indoor air pollutants between Building A and Building B based on Independent t-test

Parameter	Mean Difference	Standardized Difference	t- value	p-value	Mean		95% CI	
					Building A	Building B	lower	Upper
TVOC (ppm)	0.0009	0.864	0.864	0.391	0.0009	0.0008	0.001	0.0031
Bacteria (cfu)	112.00	3.470	4.832	< 0.001*	183.88	151.21	13.79	51.54
Fungi (cfu)	31.35	2.705	3.114	0.008*	64.94	55.75	2.37	16.00

*significant at $p < 0.05$

Table 4 - Comparison the concentration of indoor air pollutants between Building A and Building B based on Mann Whitney test

Parameter	Mean rank		p-value	U- value
	Building A	Building B		
Humidity	28.83	28.06	0.862	373.50
PM_{10}	31.39	24.65	0.126	291.50
Temperature	27.91	29.29	0.753	217.00
CO_2	37.95	15.90	<0.001*	81.50
CO	21.78	37.46	<0.001*	169.00
UFP	39.08	14.40	<0.001*	45.50

*significant at $p < 0.05$

Number of students who experienced Sick Building Syndrome (SBS)

The score of SBS was done in relation to the symptoms experienced by the respondents. These symptoms include dry and itchy eyes, headache, sore throat, unusual tiredness, chest tightness, runny nose, cough, tired or stiff eyes, restlessness, lack of focused, dizziness, shortness of breath, nausea and dry or itchy skin. If one of these symptoms was recorded nearly every day, one point was given to the SBS score; while if two symptoms were reported every day, two score will be given and so on. Table 5 shows the number of respondents who has been categorized as experienced SBS. It was found that there was a significant difference (X2 = 4.127, $p < 0.042$) between the number of respondents who experienced SBS in both buildings.

Based on Table 6 and Table 7, it was found that there was an association between the number of respondents having SBS with the levels of indoor air quality in Building A ($p < 0.045$), (Adjusted OR = 1.118, 95% CI = 1.054-9.163). This finding contradicted with Zamaniet al.[12], who reported that there was no significant association between the prevalence of sick building syndrome and the level of indoor air quality. However, for Building B, there was no association between the numbers of respondents having SBS with the level of indoor air quality in Building B after confounders had been adjusted ($p < 0.486$), (Adjusted OR = 2.230, 95% CI = 0.441-11.286). Norhidayahet al.[13] stated that the crucial predictors of sick building syndromes are ventilation and accumulation of possible contaminants within the indoor environment. Thus, the indoor air quality supplied is an important factor that needs to be considered in the indoor air assessment as if the IAQ level in a building does not meet the occupants' requirement as SBS symptoms will occur among the building occupants.

Based on Table 8, it was found that there was no association found between the numbers of respondents having SBS with the level of Indoor Air Pollutant in Building A. However, there was an insignificant increase risk for exposure to CO, UFP, RH, temperature, bacteria and fungi at Building A. Based on Table 9, there was also no association found between the numbers of respondents having SBS with the level of indoor air pollutants in Building B. However, there was an insignificant increase risk for exposure to UFP, RH, temperature, and fungi at Building B. According to Zamaniet al.[12], their study stated that there was a significant association between the prevalence of sick building syndrome and level of indoor air pollutants UFP.

Table 5 - Comparison the number of students having SBS between Building A and Building B

Variables	Number of students experienced SBS (100%)		X^2	P	OR	95% CI
	Yes	No				
Building A	60(92.3)	5(7.7)	4.127	0.042*	0.333	0.111-0.998
Building B	50(77.0)	15(23)				

*significant at p < 0.05
* OR significant if 95% CI >1
N=130

Table 6 - Association numbers of respondents having SBS with the level of Indoor Air Quality in Building A after confounder was adjusted

Variable	Prevalence of SBS N= 65 (100%)		X^2	P	OR (95%CI)	Adjusted OR (95%CI)
	Yes	No				
High IAQ level (>17 CFM/person)	17(28.3)	4(80.0)	5.634	0.045	0.099 (0.010-0.949)	1.118* (1.054-9.163)
Low IAQ level (<17CFM/person)	43(71.7)	1(20.0)				

*significant at p < 0.05
*OR significant if 95% CI >1n
* High and Low CFM categorized based on median value and classified as 1= High and 0 = Low.
N=65

Table 7 - Association numbers of respondents having SBS with the level of Indoor Air Quality in Building B after confounder was adjusted

Variable	Prevalence of SBS N= 65 (100%)		X^2	P	OR (95%CI)	Adjusted OR (95%CI)
	Yes	No				
High IAQ level (>17CFM/person)	37(71.2)	11(84.6)	0.976	0.486	0.448 (0.089-2.270)	2.230 (0.441-11.286)
Low IAQ level (<17CFM/person)	15(28.8)	2(15.4)				

*significant at p < 0.05
*OR significant if 95% CI >1
* High and Low CFM categorized based on median value and classified as 1= High and 0 = Low.
N=65

Table 8 - Logistic Regression for association between the relative humidity, temperature and SBS among students from Building A

Parameters	Parameter Category	Prevalence of SBS N= 65(100%)	Crude OR (95%CI)	Adjusted OR (95%CI)	Parameters
CO	High	47(78.3)	3(60.0)	2.410	0.491
	Low	13(21.7)	2(40.0)	(0.364 – 15.981)	(0.046-5.279)
UFP	High	31(51.7)	2(40.0)	1.603	2.674
	Low	29(48.3)	3(60.0)	(0.250 – 10.295)	(0.158-45.280)
RH	High	33(55.0)	1(20.0)	4.889	0.124
	Low	27(45.0)	4(80.0)	(0.516 - 46.364)	(0.009-1.776)
Temperature	High	33(55.0)	1(20.0)	4.889	0.112
	Low	27(45.0)	4(80.0)	(0.516 - 46.364)	(0.006-1.918)
Bacteria	High	32(53.3)	2(40.0)	1.714	1.389
	Low	28(46.7)	3(60.0)	(0.267 – 11.009)	(0.132-14.633)
Fungi	High	40(66.7)	3(60.0)	1.333	0.987
	Low	20(33.3)	2(40.0)	(0.206 – 8.634)	(0.100-9.711)

*Adjusted OR for age, health status and smoking status
*OR significant if 95% CI >1

Table 9 - Logistic Regression for association between the relative humidity, temperature and SBS among students from Building B

Parameters	Parameter Category	Prevalence of SBS N= 65(100%)		Crude OR (95%CI)	Adjusted OR (95%CI)
UFP	High	28(53.8)	6(46.2)	1.361	0.609
	Low	24(46.2)	7(53.8)	0.402 – 4.606	(0.168-2.204)
RH	High	33(63.5)	7(53.8)	1.489	0.760
	Low	19(36.5)	6(46.2)	0.436 – 5.082	(0.194-2.972)
Temperature	High	30(57.7)	6(46.2)	1.591	0.428
	Low	22(42.3)	7(53.8)	0.469 – 5.396	(0.110-1.661)
Fungi	High	29(55.8)	5(38.5)	2.017	0.382
	Low	23(44.2)	8(61.5)	0.581 – 7.000	(0.089-1.648)

*Adjusted OR for age, health status and smoking status
*OR significant if 95% CI >1

Logistic regression was conducted to determine the main factors contributed to SBS symptoms among the students in both buildings. However, it was found that there was no significant association (after adjusting the age, race, health status and smoking status) for Building A with CO, UFP, Relative Humidity, temperature, bacteria and fungi.It was also reported that there was no significant association (after adjusting the age, race, health status and smoking status) for Building B with UFP, Relative Humidity, temperature and fungi.

CONCLUSION

This study found that sufficient ventilation system plays an important role to reduce the number of students experienced SBS and to dilute the IAP, even though both buildings are meeting the existing ASHRAE ventilation standard. SBS symptoms were significantly associated with the level of Indoor Air Quality in Building A (Retrofitting Building). Exposure to inadequate supplied air and continuous exposure to indoor air pollutants might increase the health problems among the students. It is suggested to Management of both buildings to reduce or solve indoor air quality problems in thebuildings. Regular housekeeping can help to eliminate residues of air pollutants such as particulate matters in the classroom. Recirculation of air containing contaminants must be avoided. In addition, the management should conduct regular maintenance in order to maintain the proper functions of the ventilation systems.

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