EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 4(1) (2011) 67-74

Indoor Air Quality and Sick Building Syndrome Study at Two Selected Libraries in Johor Bahru, Malaysia

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Abstract

This study was carried out to investigate the association between sick building syndrome (SBS) and indoor air pollutants in two libraries. 101 workers in both libraries responded to the questionnaire, which was based on Malaysian Industry Code of Practice on Indoor Air Quality 2010 (MCPIAQ) for the measurement of SBS occurrences. Measurements of indoor air quality were also performed according to the MCPIAQ methods. Higher prevalence of SBS recorded in Perpustakaan Sultanah Zanariah (PSZ), Universiti Teknologi Malaysia, compared to Perpustakaan Sultan Ismail (PSI) ($X^2 = 38.81, p = 0.000$), Johor Bahru City. Significantly higher levels of indoor air pollutants were detected in PSZ compare to PSI for CO, CO_2, temperature, bacteria, fungi and Total Volatile Organic Compounds (TVOC), while PSI indicated higher level of relative humidity (RH). The levels of CO_2, temperature, humidity, TVOC and bacteria counts were the possible major factors contributing to SBS complaints among the workers of both libraries.

Keywords: Indoor air quality (IAQ); Sick building syndrome (SBS); Carbon dioxide (CO2)

1. Introduction

Past research indicated that indoor air quality (IAQ) problems and reports of sick building syndrome (SBS) generally were not caused simply by exposure to poor IAQ, but rather the cases occurred due to the combined effects of various physical environment and non-environmental factors ((Ismail *et al*., 2004; Joshi, 2008; Zain-Ahmed *et al*., 2005). IAQ complaints and the SBS are the outcome of complex processes, initiated by a set of stressful multiple risks which create personal strain.

Most studies of IAQ complaints and the SBS have found that there is good evidence that personal, psychological, and occupational variables also affect reports of IAQ complaints and health symptoms (Marmot *et al*., 2006). Gomzi and Bobic (2009) summarize three sets of factors that appear to be common to most SBS such as building factors, specific environmental factors and pollutants, and personal factors.

SBS complaints are influenced by various non-environmental variables, such as personal, occupational, and psychological factors, which can either directly or indirectly alter the stress load on a person, which in turn influences susceptibility and reports of SBS symptoms by individual workers (Pauncu *et al*., 2001). Psychosocial processes may act directly as stressors, causing symptoms, through psycho-physiological mechanisms. Furthermore, they may render the individual more sensitive to normally tolerated physical and chemical factors in the environment (Ooi *et al*., 1998).

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 low prevalence symptoms associated with SBS. This study was collaborative project conducted from March to December 2009 in two libraries in Johor Bahru, Johor, Malaysia with epidemiological study design of the SBS and special agency with focus detailed about occupational hygiene aspects of monitoring indoor environmental conditions and thus provides information of indoor air quality and its association with the SBS prevalence among library workers in two libraries.

2. Materials and Methods

To fulfill the objective of the study, the librarian staff was asked to complete a self administered questionnaire to rate their office environment and report the presence or absence of symptoms. This questionnaire is based on Malaysian Industry Code of Practice on Indoor Air Quality 2010 (MCPIAQ).

MCPIAQ was established in 2010. The purpose of this MCPIAQ is to set minimum standards that will protect the health of employees and other occupants of an indoor or enclosed environment served by a common mechanical ventilation and/or air conditioning system.

This MCPIAQ apply to all non-industrial places of work in industries listed under Schedule 1 of the Occupational Safety and Health Act 1994 (Act 514).

Field measurements at both libraries were conducted in the period between March and December 2009. Samplings were carried out once in a day in the morning (10:30 am - 1:00 pm) and then continued during the afternoon (2:00 pm-4:30 pm).

There were different numbers of sampling location for each library with 23 sampling locations Perpustakaan Sultanah Zanariah (PSZ), Universiti Teknologi Malaysia and 12 sampling locations for Perpustakaan Sultan Ismail (PSI), Jalan Datin Halimah, Johor Bahru. The selections of these sampling locations were based on MCPIAQ.

This study used a combination of "real time" and long term monitoring of the ambient indoor air. Air quality parameters were measured using several real time instruments (CO_2 and CO monitor, particulate counter, velocity meter, and PID). One measurement per site was taken in the designated sample sites within the breathing zone. The results were then recorded on a data sheet. Table 1 shows the indoor variables investigated, types of analytical instruments used, and their detection limits. Indoor air samples were collected from the breathing zone, about 1.4 metre above the floor, at selected locations within the library premises based on approved methods.

The results from questionnaires and indoor variables were analysed by using the Odd Ratio (OR). The OR is one of a range of statistics used to assess the risk of a particular outcome (or disease) if a certain factor (or exposure) is present. An OR is used to compare the odds for two groups, in the same way that the relative risk is used to compare risks.

2. Results and Discussion

2.1. Socio demographic information

Table 2 indicated that 141 individuals or 74.21% responded to the questionnaire. The distribution of the questionnaire for each library shows that 69% and 97% of occupants completed and returned the questionnaire for PSZ and PSI respectively. The result also shows that the distribution base on gender was not consistent.

The characteristics of the respondents are described in Table 3. The occupants of the libraries are 36.7% female and 63.3% male. All libraries mostly occupied by professional, managerial staff, technical and clerical staff. As academic library, PSZ always entertain students during the semesters.

The occupants of the three libraries work for eight hours or more in a day. The occupant's workplace includes a closed office, own cubicle and an open area shared with others. Smoking is prohibited in both libraries.

2.2. Comparison of indoor air pollutants in both buildings

The Indoor air quality (IAQ) results found to be generally satisfactory in all libraries except a few parameters were exceeded the standard limits at some sampling locations.

The concentration of CO_2 varies at different

Table 1. Indoor variables investigated, analytical method used, and their detection limits

Variable	Methods	Instruments	Detection limit
Volatile Organic	Proportional Integral	Directsense™ IAQ	20-20000 ppb
Compounds	Derivative (PID)	Monitor, model IQ-610	0-10000 ppm
Carbon Dioxide		from Garywolf	0-500 ppm
Carbon Monoxide	Non-dispersive		0.1%
Relative Humidity	infrared sensor		-10 +- 70°C
Temperature			
Air movement	AS-201		0.001-100 mg/m^3
Respirable Suspended	Portable laser	DUSTTRACK™	
Particulates	photometer	Aerosol Monitor model	
		8520	0.3 ppm
Formaldehyde	Formaldehyde sensor	PPM Formaldemeter htv	
	type electrochemical		
	manufactured by PPM		
	Technology		1 CFU/m^3
Total bacteria counts	Tryptic soy agar	SKC Biostage single	1 CFU/m^3
Total fungal counts	culture	stage impactor	
	Potato dextrose agar		

Table 2. Distribution of questionnaires at PSZ and PSI

No.	Respondent	PSZ (number)	PSI (number)
1.	Occupants/staff	155	35
	a) Distributed questionnaire	107	34
	b) Completed the form and returned	66	26
	- Male	41	8
	- Female		

Table 3. Some personal characteristics of occupants in both libraries

Characteristics	Occupants of libraries		
	(number)	X^2	Significant
Age (year)		7.68	0.053
Under 20	28		
20-29	33		
30-39	31		
above 40	49		
Marital status		18.44	0.000
Single	45		
Married	96		
Not answered	0		
Job category		56.06	0.000
Managerial	22		
Professional	20		
Secretarial	6		
Clerical	59		
Others	34		
Total year of service		7.511	0.057
Less than one month	28		
1-12 month	33		
1 year-4 years	31		
more than 5 years	49		
Smoking		101.149	0.000
Yes	24		
No	103		
Sometimes	14		
Asthma		210.255	0.000
Yes, on medication	2		
Yes, not on medication	11		
No	128		
Allergy		180.809	0.000
Yes, on medication	4		
Yes, not on medication	15		
No	122		
Migraine		69.511	0.000
Yes, on medication	0		
Yes, not on medication	21		
No	120		

*Significant results emboldened

sampling locations in PSZ and PSI ranged from 321 – 1231 ppm. As a whole, the CO_2 levels were acceptable except at Internet area and the lobby at third floor in PSZ UTM. The values exceeded the MCPIAQ and ASHRAE standard recommended value of 1000 ppm for continuous exposure. This suggests that there was a relatively poor distribution of fresh air over the conditioned air-space or that the ventilation rate is insufficient. The area was also relatively crowded. The complaints of stuffiness maybe due to the lack of fresh air to dilute the CO_2. ASHRAE 62-2007 recommends fresh intake of 20 cfm per person. Unfortunately air change rate or fresh air supply per person are not examined in this study.

CO_2 is a by-product of human respiration. Higher CO_2 is an indicator of the lack of fresh outdoor air. It should be noted that the occurrence of relative high CO_2 level may correlates with areas of stagnant air due to inadequate ventilation i.e. low air change per person or poor ventilation within this area. CO_2 levels above 1000 ppm indicate lack of adequate ventilation which may result in a feeling of "stuffiness" due to built up CO_2. Elevated levels of CO_2 can cause drowsiness and lowered productivity in most individuals. Some symptoms that occupants and visitors may face with are headache, fatigue, dizziness etc.

High concentrations of air-borne bacteria and fungal were found at some sampling locations of PSZ, namely the third floor, the lobby and Bilik Bantuan Penyelidikan (Research Support Room) on level four of PSZ and the administrative office and the binding room in PSI. Microorganisms found in the air are usually originated from soil, water, plants, animals, people or other breathing sources. The nutrients which microbes require to grow are typically found in dust particulates or humid environment which includes human skin flakes and other dead or decaying biological materials.

The ambient temperatures in both libraries ranged from 19.4-32°C with a mean of 24.53°C (median: 24.1°C). Average relative humidity was from 41.6-71.2% with a mean of 62.19 (median: 62.1%). Table 5 lists the concentrations found for the different substances investigated. Respirable Suspended Particulates (RSP) was measured with a mean concentration of 0.04 mg/m^3 and a wide range of values (0.002-0.12 mg/m^3). Concentration measured for Formaldehyde ranged from 0 to 0.19 mg/m^3 with a mean value of 0.04 mg/m^3 (median: 0.04 mg/m^3). Some results at a few locations were above the acceptable indoor concentration of 0.1 ppm (MCPIAQ and ASHRAE). This contaminant is emitted mainly from insulation materials. High

Table 4. Levels of parameters detected in PSZ and PSI (in bracket)

Parameters	Mean	Median	Average	Standard Deviation
Carbon Monoxide	0.66	0.625	0 - 2.4	0.458
(ppm)	(0.61)	(0.550)	(0-1.5)	(0.430)
Carbon Dioxide	685	671	321 – 1231	188
(ppm)	(505)	(490)	(393-887)	(105)
Relative Humidity	62.19	62.1	41.6 - 71.25	5.136
(%)	(66.59)	(67.5)	(52.4-79.9)	(5.29)
Temperature	24.53	24.1	19.4 – 32	1.63
(C)	(24.56)	(24.4)	(21.2-28.9)	(1.58)
Bacteria	338	292	53 – 1431	236
(CFU/m^3)	(399)	(406)	(53-1113)	179
Fungus	243	247	18 – 892	165
(CFU/m^3)	(217)	(194)	(53-512)	(115)
Total Volatile Organic Compound	0.74	0.70	0.08 - 1.9	0.373
(ppm)	(0.77)	(0.75)	(0.25-1.68)	(0.253)
Respirable Suspended Particulates	0.036	0.024	0.002 - 0.12	0.03
(mg/m^3)	(0.030)	(0.020)	(0.011-0.09)	(0.02)
Formaldehyde	0.04	0.04	0 - 0.19	0.029
(mg/m^3)	(0.05)	(0.04)	(0-0.14)	(0.020)
Air movement	0.12	0.08	0.01 - 1.2	0.18
(m/s)	(0.14)	(0.09)	(0.01-0.62)	(0.15)

concentrations of formaldehyde can lead to eye irritation. Total VOCs values indicated concentrations ranging from 0.08 to 1.9 mg/m^3.

2.3. Prevalence of Sick Building Syndrome

The score of the SBS was carried out according to the positive response, if one symptom recorded nearly everyday, the mark given was one, according to the SBS scale. If two symptoms were reported everyday, two points were given and so on (Ooi *et al*., 1998; Syazwan *et al*., 2009). As shown in Table 5, the number of occupants that had been categorized as having SBS using the above criteria, PSZ workers recorded 57.94% of the workers complained of having SBS, compared to 32.35% of the workers in PSI.

Indoor Air Quality (IAQ) measurements were conducted and the results indicated that there were significant association between the levels of IAQ and SBS (Table 6). Indoor air parameters (CO, CO_2, Relative Humidity (RH), Temperature, Bacteria, Fungus, Total Volatile Organic Compounds (TVOC), Respirable Suspended Particulates (RSP), Formaldehyde (HCHO) and air movement) were categorized into high concentrations (High) and low concentrations (Low) depending on the median value, either above or lower. Based on Table 6, the results indicated there were significant associations between SBS and Indoor air parameters namely CO, CO_2, RH, Temperature, Bacteria, Fungus and TVOC. Based on the results, the adjusted Odd Ratio/risk condition (OR) was calculated for same parameters with the SBS prevalence (Table 6). The OR was adjusted for age, medical conditions, the smoking habit and pregnancy. Table 7 indicated that the factors that significantly influenced the SBS and pollutant concentration were CO_2, RH, Temperature and Bacteria.

As be mentioned earlier, CO_2 concentration is a key parameter for assessing IAQ. A clear association is seen between the elevated indoor CO_2 levels and increases in certain SBS symptoms. Analyses conducted using average and median concentrations of indoor CO_2 had similar findings with previous study (Ooi *et al*., 1998; Syazwan *et al*., 2009). The reduction of CO_2 could be done through large increases in ventilation rates, improved effectiveness in providing fresh air to occupant's breathing zone (Seppanen *et al*., 1999), or through identification of the symptom-causing agents in the indoor air and control 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*., 1998; Syazwan *et al*., 2009). The low intake of fresh air will also influence the indoor temperature value in the building. Similar conclusion were observed in the 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.

Both libraries recorded significantly higher all indoor climatic measured except for RSP, HCHO and air movement. However, in general all the indoor pollutant measures were below MCPIAQ limits and this indicate that the mechanical ventilation air-conditioners (MVAC) were well-maintained in both libraries.

Other parameters, which influence SBS were CO, Fungus and TVOC. In this study, after adjusting the confounder it was shown that the SBS was not influencing this parameters. As mentioned earlier CO exposure in this study was low and below maximum limits (MCPIAQ, 2005). CO concentration in both libraries were recorded slightly similar with the previous study conducted by Gul *et al*. (2007) and Syazwan *et al*. (2009), who stated that the concentration of CO was low at the range 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 the outdoor source especially from the parking lot. The CO concentration above 10 ppm was significantly associated with SBS symptoms such as dizziness, fatigue and headache (Samet, 1993).

The results of the indoor air pollutants and SBS comparison indicated that the most significant pollutants that influenced SBS were CO, CO_2, RH, Temperature,

Table 5. Comparison of the prevalence of SBS in the workers of PSZ and PSI libraries

Variables	Prevalence of SBS N = 141(100%)		X^2	*p*
	Yes	No		
PSZ	62 (57.94)	45 (42.06)	37.794	0.000
PSI	11 (32.35)	23 (67.65)		

Significant at *$p < 0.05$, $N = 141$*

Table 6. Association between SBS and pollutant levels (PSZ vs PSI)

Parameter	Parameter Category	SBS N = 141 (100%)				OR In (OR)					95% CI	
		Yes		No								
		n = 73	%	n = 68	%						upper	lower
Co	High	34	46.6	20	29.3	2.1	0.74	0.70	1.43	0.04	4.19	1.01
	Low	39	53.4	48	70.3							
Co_2	High	48	65.8	25	36.6	3.3	1.19	0.69	1.89	0.50	6.59	1.66
	Low	25	34.2	43	63.4							
RH	High	44	60.3	25	36.8	2.6	0.96	0.68	1.64	0.28	5.15	1.32
	Low	29	39.7	43	63.2							
Temperature	High	38	52.1	19	27.9	2.8	1.03	0.70	1.73	0.33	5.64	1.39
	Low	35	47.9	49	72.1							
Bacteria	High	35	47.9	23	33.8	1.8	0.59	0.68	1.27	-0.09	3.56	0.91
	Low	38	52.1	45	66.2							
Fungus	High	40	54.8	22	32.4	2.5	0.93	0.69	1.62	0.24	5.03	1.28
	Low	33	45.2	46	67.6							
TVOC	High	32	30.5	16	23.5	2.5	0.93	0.73	1.66	0.20	5.24	1.23
	Low	41	56.2	52	76.5							
RSP	High	23	31.5	35	51.5	0.4	-0.84	0.69	-0.15	-1.52	0.86	0.22
	Low	50	68.5	33	48.5							
HCHO	High	21	28.8	37	54.4	0.3	-1.08	0.70	-0.39	-1.78	0.68	0.17
	Low	52	71.2	31	45.6							
Air movement	High	19	26.0	19	27.9	0.9	-0.10	0.74	0.65	-0.84	1.91	0.43
	Low	54	74.0	49	72.1							

OR significant at 95% CI > 1, *N = 141*

Bacteria, Fungus and TVOC (OR = 3.3, 95% CI = 1.66-6.59). Increasing the level of CO_2 in each building has shown positive association to the occurrences of SBS thus caused the increase in certain lower respiratory diseases (Michael *et al*., 2000).

TVOC has shown significant association with SBS prevalence (OR = 2.5, 95% CI = 1.23 – 5.24). The respondents recorded having SBS for when the level of TVOC was at 30.5%. There was a trend whereby the workers have SBS symptoms such as headache, fatigue and dizziness associated with the TVOC exposure of more than 3 ppm (Runeson *et al*., 2003). RH also significant association with the SBS prevalence (OR = 2.6, 95% CI = 1.32-5.15). High humidity levels in the indoor environment can cause the sensation of dryness by respondents (Fang *et al*., 2004)

After adjusting for confounding, we found important and statistically significant associations of SBS symptoms was the increases of Bacteria (OR = 1.0, 95% CI = 0.43-2.17). As mentioned earlier, high levels of bacteria exposure will cause allergic reactions and infectious diseases.

Table 7. Association between SBS and pollutant levels (PSZ vs PSI) before and after controlling confounders

Parameter	Parameter Category	SBS before adjust N = 141 (100%)				OR (95% CI)	SBS after adjust N = 101 (100%)				*OR 95% CI
		Yes		No			Yes		No		
		n = 73	%	n = 68	%		n = 63	%	n = 38	%	
Co	High	34	46.6	20	29.3	2.1	22	34.9	18	47.4	0.6
	Low	39	53.4	48	70.3	(1.04-4.19)	41	65.1	20	52.6	(0.26-1.35)
Co_2	High	48	65.8	25	36.6	3.3	39	61.9	16	42.1	2.2
	Low	25	34.2	43	63.4	(1.66-6.59)	24	38.1	22	57.9	(0.98-5.08)
RH	High	44	60.3	25	36.8	2.6	37	58.7	21	55.3	1.2
	Low	29	39.7	43	63.2	(1.32-5.15)	26	41.3	17	44.7	(051-2.60)
Temperature	High	38	52.1	19	27.9	2.8	33	52.4	19	50.0	1.1
	Low	35	47.9	49	72.1	(1.39-5.64)	30	47.6	19	50.0	(0.49-2.46)
Bacteria	High	35	47.9	23	33.8	1.8	31	49.2	19	50.0	1.0
	Low	38	52.1	45	66.2	(0.91-3.56)	32	50.8	19	50.0	(0.43-2.17)
Fungus	High	40	54.8	22	32.4	2.5	32	50.8	22	57.9	0.8
	Low	33	45.2	46	67.6	(1.28-5.03)	31	49.2	16	42.1	(0.33-1.69)
TVOC	High	32	30.5	16	23.5	2.5	22	34.9	16	42.1	0.7
	Low	41	56.2	52	76.5	(1.23-5.24)	41	65.1	22	57.9	(0.32-1.69)
RSP	High	23	31.5	35	51.5	0.4	13	20.6	35	92.1	0.0
	Low	50	68.5	33	48.5	(0.22-0.86)	50	79.4	3	7.9	(0.01-0.08)
HCHO	High	21	28.8	37	54.4	0.3	11	17.5	37	97.4	0.0
	Low	52	71.2	31	45.6	(0.17-0.68)	52	82.5	1	2.6	(0.00-0.05)
Air movement	High	19	26.0	19	27.9	0.9	9	14.3	19	50.0	0.2
	Low	54	74.0	49	72.1	(0.43-1.91)	54	85.7	19	50.0	(0.06-0.43)

OR significant at 95% CI > 1, *N = 141*

4. Conclusion

There is no direct causal link between exposure to CO_2 and SBS symptoms, but rather the levels CO_2 has a strong correlation with other indoor pollutants that may cause SBS symptoms. At the same time, it was found that temperature, humidity, TVOC and Bacteria are important indoor air factors that can influence the prevalence of SBS.

Acknowledgements

The authors are grateful to the Department Occupational Safety and Health Malaysia and the Culture Laboratory, Department of Bioscience, Faculty of Bioscience and Bioengineering, Universiti Teknologi Malaysia for their assistance in the study.

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Received 30 November 2010
Accepted 28 December 2010

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