Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 53 (2013) 93 – 98

Procedia Engineering

www.elsevier.com/locate/procedia

Malaysian Technical Universities Conference on Engineering & Technology 2012, MUCET 2012
Part 3 - Civil and Chemical Engineering

Indoor Air Quality and Sick Building Syndrome in Three Selected Buildings

A. Norhidayah[a,]*, Lee Chia-Kuang[a], M.K. Azhar[b], S. Nurulwahida[b]

[a]*Faculty of Technology, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang 26300 Kuantan Pahang Darul Makmur, Malaysia*

[b]*Department of Biomedical Science, Kuliyyah of Science, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang Darul Makmur, Malaysia*

Abstract

The respondents presenting with indoor environmentally associated symptoms such as sick building syndrome (SBS) are apt to have been exposed to inadequate indoor air quality (IAQ). The main objective of this study is to determine the association between IAQ parameters and symptoms of SBS in three selected buildings. The criteria of buildings selection is based on long history of occupancy and age of building. The structured questionnaire was distributed to respondents and IAQ parameters were technically measured in the selected buildings. The survey shows that the prevalence of SBS symptoms was similar in the selected buildings. Besides, no association was found between building type and SBS occurrence. IAQ parameters measurement indicated that most of the IAQ parameters were complied with the Malaysia standard of IAQ, excluded air velocity. Significant differences ($p < 0.001$) between the selected buildings were observed among velocity, CO_2 concentration, temperature and relative humidity. However, the CO concentration ($p = 0.18$) and fungal counts ($p = 0.83$) were not significant differences between building. The findings suggested that the important predictors of sick building syndromes are ventilation and accumulation of possible contaminants within the indoor environment.

Selection and peer-review under responsibility of the Research Management & Innovation Centre, Universiti Malaysia Perlis

Keywords: *Indoor air quality, Sick Building Syndrome*.

1. Introduction

Human spend up to 80% of their lifetime either inside their workplace or in their own homes [1]. Indoor air quality of building occupant is a basis determinant of healthy life and people's well being, comfort and productivity of respondents. The interactions between the site, climate, building system, construction techniques, contaminant source and respondents are the factors that affect the quality of indoor air. For example, hazardous compounds emitted from human activities indoors such as combustion of fuels for cooking, emission of toxic gas from construction materials and indoor equipments.

The Industrial Code of Practise on Indoor Air Quality (ICOP) (2010) published by Department of Occupational Safety and Health Malaysia proposed the selected indoor air quality parameters and their acceptable limits [2]. Prior to maintain a good IAQ, the acceptable limit of each IAQ parameter must be complied. The characteristics of good indoor air quality

* Corresponding author. *E-mail address:* hidayahabdull@ump.edu.my

1877-7058
Selection and peer-review under responsibility of the Research Management & Innovation Centre, Universiti Malaysia Perlis
doi:10.1016/j.proeng.2013.02.014

include introduction and distribution of adequate ventilation air, control of airborne contaminants, maintenance of acceptable temperature and relative humidity [3].

The failure to take action immediately and efficiently on the problem of poor IAQ could be have the disastrous consequences on human health. Previous study conducted by EPA states, indoor air pollution is among the top five environmental health risks. In 2009, the World Organization Health (WHO) prepared a report on Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks. This report proposed that indoor air pollution is responsible for 2.7% of the global burden of disease [4]. Higher proportion of individuals presenting with indoor environmentally associated symptoms (such as Sick Building Syndrome [SBS]) are infants, the elderly, person with chronic disease and most urban dwellers of any age.

The International Labour Organization (ILO) defines SBS as a phenomenon that occurs when 20% of the respondents report symptoms associated with their respective place of work with the specific association with air quality [5]. Sick Building Syndrome (SBS) covers the constellation of nonspecific subjective health symptoms such as itchy eyes, skin rashes, and nasal allergy symptoms, to more vague symptoms such as fatigue, aches and pains, sensitivity to odours and difficulty in concentration. The circumstances most suggestive of sick building syndrome are presence of common symptoms amongst a group of respondents that are present when they are in the building and absent when they are not in the building.

Understanding the multifactorial etiology of SBS in buildings has been a crucial challenge since the exact causes of SBS are still idiopathic that can be directly linked to SBS [6]. SBS may potentially affect job satisfaction, work stress, and productivity. Pertaining to these obstacles, the interests in the prevalence of SBS are quite inferior with limited documentation. The aims of this study are to investigate the occurrence of SBS on the selected buildings, to investigate the parameters that define the level of IAQ and to determine the association between IAQ with symptoms of SBS.Problem statement

2. Methodology

2.1 Study design

A cross sectional comparative study was conducted between three selected buildings. These buildings were chosen are Perbadanan Perpustakaan Awam Pahang (PPAP), Perbadanan Kemajuan Bukit Fraser (PKBF) and Pahang Museum of Art (PMA). The criteria of building selection are based on long history of occupancy and age of buildings. The study population comprised the respondents determined with 44 people, 6 people and 13 people who are worked at PPAP, PKBF and PMA, respectively. The PPAP building is occupied by many workers thus, the number of respondents of PPAP building is higher than the respondents in the PKBF and PMA building

2.2 Questionnaire Survey

A structured set of questionnaire was adopted from ICOP 2010 and then, was handed out to study population. The questionnaires include socio – demographic information, respondents' health status and symptoms of SBS, time spent in the building weekly, the job position, the occurrence of SBS and the quality of the air inside buildings. The respondents were defined as having SBS if they had at least one symptom of SBS and the symptoms appeared at least once a week. The respondents also must had reported the occurrence of at least 1 – 3 days per week during the last four weeks and must had reported that the symptoms showed improvement when they were away from the place of work [7].

2.3 Indoor Air Quality Assessment

The assessment of IAQ of the selected three buildings was conducted according to ICOP 2010. The numbers of sampling point were determined based of the estimation of total floor area of each building. The sampling points were considered the position of respondents and source of fresh air intake. The measurement of IAQ was conducted two times in a day, morning and evening. The instruments used to asses IAQ are TSI VelociCalc Air Velocity Meter (to measure temperature, relative humidity, carbon monoxide, carbon dioxide and air velocity). A total fungal count was measured using SAS IAQ (Cat 37657) air sampler. The samples were incubated for 5 days at 25 ^{0}C and then, the colony forming unit was counted.

3. Result and Discussion

3.1 Building Characteristics

The characteristics of each building were investigated. Regarding the age of buildings, the PMA and the PKBF buildings both were built about 100 years ago by colonizing British force as vacation house and club houses. The PPAP building is newer than those buildings with the age of 53 years old. All buildings are located in medium town, near heavy traffic and moderately near industrial area. They were built of concrete or bricks, with slanting tile roof. Fiberglass or rockwool were not presented within the rooms of any building. All buildings are equipped with mechanical ventilation air conditioning systems. A general smoking is not allowed in these buildings. The cleaning procedures included daily mopping with water which contains detergent. The prescribe activities such as major renovation of the PPAP and PKBF buildings were not managed for the latest decades. Nevertheless, the PMA building was recently undergoing a major renovation with upgrading the ventilation systems due to the water leakage problem.

3.2 Respondent characteristics

The survey results that a large proportion of respondents had symptoms compatible with the SBS symptoms. A cross sectional study might has certain shortcomings due to the number of available respondents, which limited the validity of the study. Besides, a selection of bias can be occurred because of inequity in the respondent rates and then, possibly effected to the prevalence of SBS symptoms. A total of 51 respondents were handed out the questionnaires. The respondents rate responded to the questionnaires are PPAP, PKBF and PMA were 84%, 69% and 83%, respectively. The socio demographic information was derived from the questionnaires by the respondents in there selected buildings as tabulated in Table 1. The proportions of male and female respondents were almost equivalent for PPAP and PMA buildings. The mean age of respondents was 39.5 years in PPAP, 35 years in PKBF and 39 years PMA. The mean number of hours per week respondents spent in the buildings was 39.22h, 35h and 39h, respectively.

Table 1. Characteristics of respondents

Building	**PPAP**	**PKBF**	**PMA**
N = 79	44	5	9
Response rate (%)	84	69	83
Sex distribution (%)			
Male	51.35	80.00	55.56
Female	48.86	20.00	44.44
Age of respondent (mean years)	39.5	35	39
Work time per week (hours)	39.22	43.8	44.55

3.3 *Occurrence of SBS*

In the assessment of the SBS, the person with pre-existing medical condition listed in questionnaires such as allergies to dust, mold or pets, sinus infection, asthma, migraine, and eczema. The person is considered as having SBS when they reported the onset of two or more SBS symptoms at least once or twice weekly in the last for week. Person with SBS also demonstrated the improvement of the symptoms after left the buildings. The prevalence of SBS symptoms were shown in Table 2. All three selected buildings had non-uniformity prevalence of the similar SBS symptoms. The SBS symptoms were generally more common in the PPAP and the PMA buildings rather than in the PKBF buildings. It only showed three symptoms of SBS which are “itchy, dry and irritation eyes”, “coughing” and “sneeze” with approximate 20% of each symptom.

Table 2. Percentage prevalence of sbs symptoms of three buildings.

Symptoms	**PPAP**		**PKBF**		**PMA**	
	N = 44		**N = 5**		**N = 9**	
	n	**%**	**N**	**%**	**n**	**%**
Ophtalmic symptoms						
Itchy, dry, irritation to eyes	6	16	1	20	4	44
Headache	6	16	0	0	3	33
Unusual tiredness, lethargy and drowsiness	2	5	0	0	2	22
Strained eyes, tired eyes	9	24	0	0	1	11
Dizziness or lightheadedness	10	27	0	0	2	22

Respiratory symptoms						
Asthma (Wheezing)	2	5	0	0	1	11
Dry and sore throat	4	11	0	0	0	0
Difficulty to breath	0	0	0	0	1	11
Stuff nose, runny nose, sinus congestion	6	16	0	0	3	33
Coughing	3	8	1	20	1	11
Sneeze	8	22	1	20	3	33
Shortness of breath	0	0	0	0	1	11
Psychological symptom						
Tension, irritability and nervousness	6	16	0	0	0	0
Difficulty concentrating or remembering things	5	14	0	0	1	11
Feeling depressed	4	11	0	0	0	0
Dermal symptom						
Dry or itchy skin	5	14	0	0	2	22
Another symptom						
Nausea and upset stomach	1	3	0	0	1	11

Ophthalmic symptoms were more prevalent in the PPAP building than the PMA building: “itchy, dry and irritation eyes” 44% and 16%; “headache” 33% and 16%; “unusual tiredness, and “lethargy and drowsiness” 22% and 5%. On the other hand, these types of symptom were more prevalent in the PMA building than the PPAP building: “strained eyes, tired eyes” 24% and 11%, and “dizziness or lightheadedness” 27% and 22%. There are no prevalence both of the PKBF and the PPAP buildings were observed for respiratory symptoms as well as “difficulty in breath” and “shortness of breath”. However, the PMA building only demonstrated low prevalence for both of these symptoms (11%). Pertaining to psychological symptoms, the PPAP building has the prevalence of “tension, irritability and nervousness” 16%, “difficulty concentration or remembering things” 14% and “feeling depressed” 11%, instead of the PMA building which only has a prevalence of “difficulty concentrating or remembering things” 11%. The PPAP and the PMA buildings depicted the prevalence on “dry or itchy skin” 14% and 22%, and “nausea and upset stomach” 3% and 11%. As indicated in Table 2, both ophthalmic and respiratory irritations are common symptoms in indoor environment [7, 8].

The responses to questionnaires regarding the frequency of such symptoms were used to define and categorize respondents with the SBS symptoms. A frequency of at least 1 to 3 items per week together with reported relief of these symptoms after left the building was the SBS “case definition”. Table 3 showed that a comparison of the prevalence of SBS symptoms between three selected building. The PKBF building pointed out the highest percentage (55.55%) of the respondents reported was confirmed the SBS symptoms and can be designated as a sick building. Second highest was the PPAP building with 35.25% and then followed by the PMA building with 20% of total respondents. The comparison of the prevalence of SBS between three buildings was conducted via Chi-Squared test. A Chi-square test for independence (with Yates Continuity Correction) indicated no significant association between the three buildings and SBS occurrence, (n = 51, χ^2 = 1.997, P = 0.368). It was believed that etiology of SBS probably influenced by the other stressors such psychological, ergonomics of the work, stress level, job satisfaction, position in the hierarchy of the organization and other environmental conditions [9].

Table 3. Comparison of the prevalence of sbs symptomsbetween three buildings.

Variables	**Prevalence of SBS N= 51 (100%)**			
	Yes	**No**	□□	***P***
PPAP	35.15%	64.85%	1.997	0.368
PKBF	55.55%	44.45%		
PMA	20.00%	80.00%		

3.4 Indoor Air Quality Assessment

The result of IAQ parameters assessment indicated in Table 4. Results of the IAQ exposure measurement illustrated

low levels of contaminants or and potential pollutants inside three selected buildings. All IAQ parameters were meet the acceptable limit set by DOSH, Malaysia (ICOP, 2010), excluded air velocity. As can be seen in Table 4, the PKBF building showed a large variation of air velocity with the PPAP and the PMA buildings. Both the temperature and relative humidity of three buildings during the daytime varied from 21.8^0C to 25.2^0C, and 61.5 %RH and 78.8% RH, respectively. The concentrations of CO for three buildings were considered low. It was recommended that outdoor air pollutants become as one of the source of CO due to the location of these building which are located at near heavy traffic and moderately close to industrial area.

The PKBF building presented the highest concentration of CO_2. On the other hands, this building had the lower number of respondents which probably contributed to the lower CO_2 concentration. Since the CO_2 concentration represents the ventilation performance indicator of building, it can be proved that the PKBF building subjected to the poor ventilated indoor air. It was due to imbalance in the ventilation system which allowed the accumulation of possible contaminants with the indoor environment. As a sick building, the PKBF building reached the highest number of total fungi. A higher number of total fungi can be related to higher temperature and percentage of relative humidity. Both of these parameters provided a suitable condition to increase the growth rate of fungi.

Table 4. Comparison of indoor air quality parameter between three selected buildings

Variables	**Acceptable Limit**	**Median (inter Quartile Range**			
	(ICOP 2010)	**PPAP**	**PKBF**	**PMA**	***P***
Velocity (ms^{-1})	0.15 – 0.50	1.86 (0.01-6.21)	0.1 (0.01-0.31)	0.15 (0.04-0.22)	<0.001*
Temperature (^{0}C)	23 - 26	23.2 (17-27.2)	21.8 (23.1-27.2)	25.2 (20.7-24.6)	<0.001*
Relative Humidity (%RH)	40 – 70	62.9 (40.5-84.7)	78.8 (66.7-94.4)	61.5 (52—74.1)	<0.001*
CO_2 (ppm)	C1000	509 (395-884)	717 (445-616)	385 (323-603)	<0.001*
CO (ppm)	10	0.3 (0.1-1.1)	0.5 (0.1-0.8)	0.4 (0.1-0.8)	0.18
Fungi count ($CFUm^{-3}$)	1000	153 (2-905)	206 (38-1138)	144 (2-905)	0.83

*Significant at p<0.05. Values in the bracket show the minimum and maximum value of measurement.

A comparison of IAQ parameters between three selected buildings was carried out by using Kruskall-Wallis. Velocity, CO_2 concentration, temperature, relative humidity showed significant differences between the building (p value < 0.001). CO concentration and fungal count did not demonstrate significance differences between three buildings (p value = 0.18 and 0.83, respectively). Results of the IAQ exposure measurement indicated low levels of contaminants or and potential pollutants inside three selected buildings. All IAQ parameters were meet the acceptable limit set by DOSH, Malaysia (ICOP, 2010), except the velocity of the PKBF building. The results pointed out that any of the IAQ parameters measured to be the only source of SBS in each building. These results were in a good agreement with a research that carried out by Jerry (2002) [6].

4. Conclusion

In conclusion, this study suggested that the PKBF building can be designated as a sick building. The prevalence of SBS was also compared between three buildings and indicated no significant association. Besides, the crucial predictors of sick building syndromes are ventilation and accumulation of possible contaminants within the indoor environment. This study recommended that further research is required to explore the other multifactorial etiologies of SBS such as psychological, ergonomics of the work, stress level, job satisfaction, position in the hierarchy of the organization and other environmental conditions.

Acknowledgment

The authors are grateful to Universiti Malaysia Pahang and International Islamic Universtiy Malaysia for the financial support.

References

[1] Yang, C.H. and Heinsohn, P.A. (2007). "Sampling and analysis of indoor microorganism". 1st edition. Wiley – interscience, A John Wiley and Sons, Inc., Publisher.
[2] Industrial Code of Practise on Indoor Air Quality, 2010. Department of Occupational Safety and Health.
[3] US Environmental Protection Agency (2005). Program Needs for Indoor Environments Research (PNIER).
[4] World Organization Health (WHO) (2009). "Global health risks: Mortality and burden of disease attributable to selected Major Risks".
[5] International Labour Organization (2000). "Encyclopedia of occupational safety and health". 2nd edition. Sick building syndrome.
[6] Jerry, J.T. (2002). "General principle of microbiology and infectious disease". Physical and biological hazards of the workplace. 2nd edition. Page 308.
[7] Hodgson, M. (2002). "Indoor environmental exposure and symptoms". Environmental health perspective 110: 663-667.
[8] Burge, P.S. (2004). "Sick building syndrome". Occupational environmental medicine 14: 108-117.
[9] Hedge, A., Erickson, W.A. and Rubin. G. (1996). "Predicting sick building syndrome at the individual and aggregate leveld" Environmental international 22 (1): 3-19