ORIGINAL ARTICLE

Assessment of Indoor Air Quality at Different Sites of Higher Educational Buildings of a University, Shah Alam

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ABSTRACT

Introduction: Indoor air quality is an important aspect in defining Sick Building Syndrome (SBS). SBS triggered by inadequate IAQ may harm occupants. Objective: This study was conducted to establish the relationship between IAQ and SBS in the higher educational building. **Methods:** The research method is divided into three main categories; indoor air chemical and contaminant analysis, microbiological contaminant analysis, and questionnaire. A cross-sectional study was conducted at seven locations in a university in Shah Alam. **Results:** The results were compared to the Department of Occupational Safety and Health standard (DOSH). Significant correlation with temperature ($p<0.05$), relative humidity ($p<0.05$), and particulate matter (PM10) ($p<0.05$) were found.This study suggests that enhancing housekeeping standards and monitoring indoor air quality can enhance the indoor air quality in Malaysian higher education buildings. **Conclusion:** Based on correlation between IAQ and SBS symptoms, poor IAQ and SBS symptoms among occupants may impact teaching and learning process in the university. Conclusion: This study suggests that enhancing housekeeping standards and monitoring indoor air quality can enhance the indoor air quality in Malaysian higher education buildings.
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INTRODUCTION

Indoor Air Quality (IAQ) is defined as the representation of pollutant concentrations and thermal conditions that could have a negative impact on the health, comfort, and efficiency of building occupants (1). IAQ has been a crucial subject from both a social and an economic viewpoint. Most people today usually spend 80-90% of their time indoors, whether at work or elsewhere at home (2,3,4). Factors influence indoor air quality such as site activities, environment, building system, contaminant source and human (5). People's health can be jeopardised by a lack of attention. These issues can be minimised for a safe indoor environment with adequate indoor air quality controls.

Bad IAQ problems can have fatal effects on human health if not addressed frequently and effectively. The standard of indoor air plays a significant role in overall human exposure to air pollution (6). Bad IAQ, including allergic reactions, difficulty breathing, conjunctivitis, sinusitis and bronchitis may cause acute and chronic conditions (7). As a result, this could be related to sick building syndrome (SBS). SBS was a significant issue because it puts many workers in risk and can have an impact on job efficiency, work stress, and productivity. (8).

There have been several reports on the indoor air quality (9). However, there was a lack of data from indoor air quality assessments in Malaysia or other South-East Asian countries with similar climate, heat, and humidity. (8,10). In educational terms, IAQ in educational buildings might have an impact on educators' and students' well-being as well as their teaching and learning output. (11,12,13).

Therefore, the objectives of this study are (i) to determine and compare the level of IAQ parameters (chemical contaminants, biological contaminants, temperature, relative humidity and CO2 level) at different site in educational institution (ii) to evaluate sick building syndrome related signs and symptoms from the occupants in different site of higher educational buildings, (iii) to determine the relationship between IAQ parameter and sick building syndromes at different site of higher educational buildings.

MATERIALS AND METHODS

Participants
A cross-sectional study was conducted among 273 occupants with age range of 18 -55 years old in the higher educational building located in Shah Alam. The occupants were asked to answer standardized questionnaire adapted from Malaysian Industry Code of Practice (ICOP) on Indoor Air Quality 2010. In this study, convenience sampling was used, which meant that the occupants answered the questionnaire when it was convenient for them. Seven locations were selected in this study which were Mosque, Office, Cafeteria, Classroom, Laboratory, Library and Anatomy Dissection Hall.

Instrumentation
Malaysian Industry Code of Practice on Indoor Air Quality (ICOP) by the Department of Occupational Safety and Health, Malaysia (14) is used to collect data on indoor air quality. The sampling points were determined by considering the location of the occupants and the source of the intake of fresh air intake. The sampling points depended on the size of the room in which at least 1 collection period was taken. IAQ meter, EVM7 was utilized for the measurement of temperature, humidity, carbon dioxide (CO^2), and Particulate Matter 10. A standardized questionnaire adapted from the Industry Code of Practice (14) was distributed to the occupants. The questionnaires were collected on socio-demographic history, health status, weekly time spent in the building, SBS symptoms and perceived air quality inside the building.

Biological parameters were calculated alongside physical and chemical parameters, such as total counts of bacteria and fungus. Nutrient agar (NA) was used for microbe testing, and Sabouraud Dextrose Agar (SDA) was used for fungal sampling. Each plate of nutrient agar and Sabouraud Dextrose Agar (SDA) was duplicated, and the counts obtained were combined. The plates were transferred to the laboratory for incubation after sampling.

Data Collection
This study gathered two types of data: measurements of indoor air quality parameters (chemical, physical, and biological pollutants) and a questionnaire on socio-demographics and sick building syndrome (SBS).

The physical parameters studied were respirable particulates (PM10), while the chemical pollutants studied included carbon dioxide (CO_2), relative humidity, and temperature. Real-time monitoring of the IAQ calculation was performed for a week in which readings were taken twice daily where samples were collected twice a day somewhere between 10 a.m. and 11 a.m. and somewhere in the midday between 12 p.m. and 4 p.m. The sampling points were based on the size of the space set to be at least 1 per 500 m^2 (14). The cafeteria and library (< 500 m^2) had three sampling points as both areas were large and open space.

For biological pollutants, microbial analysis is used to assess microbial indoor air quality, duplicate indoor air samples were collected at different point of the location depended on the room size in which minimum 1 time collection to investigate bacterial and fungal counts. Bacterial or fungal counts were measured using the plate count method. The bacterial microorganisms were cultivated at 37 ° C for 48 hours on the nutrient agar, and fungi were cultivated with regular observations at room temperature for 5 days with Sabouraud dextrose agar. The bacterial and fungal colonies were counted after incubation and expressed in colony forming units/ units/ m (CFU/m^3) thus the degree of contamination of different settings from the learning centre can be determined in the light of the reasonable colony counts. Airborne bacterial and fungal colonies obtained were initially separated based on their morphological characteristics (shape, size, colour). Based on their microscopic appearance and results of biochemical tests, they are classified up to the genus level. Gram-straining were then conducted. According to Bergey's Manual of Determinative Bacteriology, colonies are divided into gram-negative and gram-positive groups (15). Sampling method following the standard 1/1/1 schedule (Petri dish and EVM7 were left opened and running to the air for 1 hour,1 metre above the floor,1 metre from the wall) (16).

Besides the biological parameters, the occupants were requested to fill questionnaire at their convenience (14). The questionnaire was designed to accommodate sociodemographic, environmental inquiries and sick building syndrome. There were three alternative responses to each of the SBS questions about their occurrence frequency during the past three months. 'No, never' "Yes, often 'and "Yes, sometimes every week" (14). This SBS section is critical for determining the effect of poor IAQ. If occupants reported experiencing at least one SBS symptom on a weekly basis, they were classified as "having SBS."

Quality Control and Quality Assurance
Prior to data collection, EVM7 was calibrated in accordance with the specifications. Before being used for the assessment, the nutrient agar, and Sabouraud Dextrose Agar (SDA) had been thoroughly inspected for

signs of contamination. Every parameter was measured twice a day at each location, with readings taken every two hours. All measurements were carried out in accordance with the guidelines on indoor air quality specified by ICOP (2010).

Statistical Analysis
The SPSS version 26 statistical package was used to analyse all the data collected. The collected data was entered into an SPSS spreadsheet for analysis. Descriptive analysis was performed for demographics, years of employment, and mean concentrations of indoor air pollutants in the house. The Chi-square test was used to compare occupants' IAQ problems and SBS symptoms in different parts of the building. Lastly, the Pearson Correlation was used to assess the relationship between indoor air quality and SBS symptoms.

Ethical Consideration
Ethical approval to carry out this study was obtained from the University Ethics Committee, Management and Science University. (Ref. No: MSU-RMC-02/FR01/L1/005). A written consent form was filled up by occupants before the study was conducted. The consent form and the questionnaire were made available in English language.

RESULTS

Socio-demography
Questionnaire used in this study to collect socio-demographic information from 7 different locations in higher educational building have been compared. Majority of occupants were females (67%) and aged under 25 years old (80.2 %). In terms of their smoker status, 92.7 % of r occupants reported being non-smokers. Details are shown in Table I.

Table I: Demographic information

Variables		n (%)
Gender	Female	183 (67)
	Male	90 (33)
Age (years old)	<25	219 (80.2)
	25-39	43 (15.8)
	40-55	11 (4)
Smoking	Yes	20 (7.4)
	No	253 (92.7)

*Descriptive Analysis (N=273)

Comparison Indoor Air Physical, Chemical and Biological Contaminants at different site
The results obtained from measuring indoor air quality parameters from seven locations of the higher educational building are shown in Table II. All locations were below the appropriate limit defined by the Malaysian Industry Code of Practice on Indoor Air Quality 2010 for biological pollutants, the acceptable limit value for total bacteria count (500 cfu/m^3) and total fungal count (1000 cfu/m^3). The highest count was in the classroom for both Total Bacteria Count (496) and Total Fungi Count (293). Based on the observation, total fungi count, and total bacteria count report lowest to be in Anatomy Dissection Room. However, in indoor pollutants, Carbon Dioxide concentrations in the office (1730.5) and classroom (1292) exceeded the limit (> 1000ppm), and anatomy dissection hall had a slightly higher temperature (27.3) compared with the rest (23-26°C). The results showed that relative humidity (40-70%) and PM10 (0.15 mg/m^3) did not exceed the limit. The comparison of isolated bacteria and fungi at various locations is shown in Table III. The existence of four types of airborne micro-organism (bacilli, cocci, coccobacilli, mycobacteria) in all locations was further indicated by gram staining. As for fungi, fungal hyphae and fungal spores were the most observed airborne fungal genera in the seven sites monitored. The most studied group of fungi was the fungal hyphae. Using gram staining, bacterial and fungal were further characterized as gram positive and negative. The most influential group of genera was the gram-positive bacilli. Overall, the densest bacterial and fungal occurred in the mosque and classroom, showing more presence of bacteria and

Table II: Comparison Indoor Air Physical, Chemical and Biological Contaminants at different location

Location	Indoor Air Pollutants				Biological Contaminants	
	Temperature (°C)	**Relative Humidity (%)**	**Carbon Dioxide (PPM)**	**PM10 Level (mg/m3)**	**Total Bacteria Count**	**Total Fungi Count**
	Mean (SD)				**CFU/m^3**	
Mosque	23.58 (1.87)	47.05 (3.32)	701.5 (180.3)	0.029 (0.002)	390	168
Office	24.4 (3.11)	44.75 (0.21)	1730.5 (791.3) *	0.01 (0.009)	202	53
Cafeteria	25.95 (0.47)	48.067 (1.74)	651.83 (61.60)	0.0687 (0.03)	282	163
Classroom	23.1 (0.42)	48.65 (0.35)	1292 (63.6) *	0.016 (0.003)	496	293
Laboratory	22.75 (1.067)	40(4.1)	868.5 (142.28)	0.009 (0.007)	324	142
Library	22.6 (0.72)	52.3 (1.4)	637.7 (24)	0.0037 (0.0005)	358	155
Anatomy	27.3 (0.57)*	66.9 (0.99)	474 (2.828)	0.0145 (0.004)	122	33

* Acceptable limit value based on ICOP 2010: Temperature (23-26°C), Relative Humidity (40-70%), Carbon Dioxide (1000ppm), PM10 (0.15 mg/m3),Total Bacteria Count (500 (cfu/m^3)), Total Fungal Count (1000 cfu/m^3)

fungi compared with the rest. Meanwhile, Anatomy Dissection Hall had the least microbe isolated from the agar plates. In addition, Mycobacteria were absence in most locations except classroom.

Table III: Comparison Gram Positive and Negative Between Bacterial and Fungi Isolated at different location

L*	**Bacterial Isolates								**Fungi isolates			
	Bacilli		Cocci		Cocco-bacilli		Myco-bacteria		Fungal hyphae		Fungal Spores	
	G+	G-	G+	G-	G+	G-	G+	G-	G+	G-	G+	G-
1	+	0	0	+	0	0	0	0	+++	0	0	0
2	++	0	0	++	0	0	0	0	0	+	0	0
3	+	0	0	+	0	0	0	0	0	+	0	0
4	+++	+	+	+	++	0	+	0	++	++	+	+
5	+	+	+	+	0	0	0	0	++	+	0	+
6	+	+	+	0	+	+	0	0	+	0	0	0
7	0	0	0	+	0	0	0	0	0	+	0	0

*1 (Office), 2 (Mosque), 3 (Cafeteria), 4 (Classroom),5 (Laboratory), 6 (Library), 7 (Anatomy Dissection Hall);

**G+ (Gram Positive), G- (Gram Negative); += Present, 0=Absent

Sick Building Syndrome (SBS) Symptoms among Occupants at Different Locations

The symptoms of SBS reported by occupants are represented in Figure I. The highest prevalence of SBS symptoms shown in Anatomy Dissection Hall. There was a significant difference in the prevalence of headache, fatigue, strained eyes, wheezing, dry throat, coughing, tension, difficult to concentrate or remember, dry or itchy skin, nausea and upset stomach between location in higher location (p<0.05). Wheezing, difficulty to breath was the least reported in most locations of the building. However, wheezing, dry and sore throat and stuffy, runny nose recorded the highest percentage (97.4) of symptoms in the library.

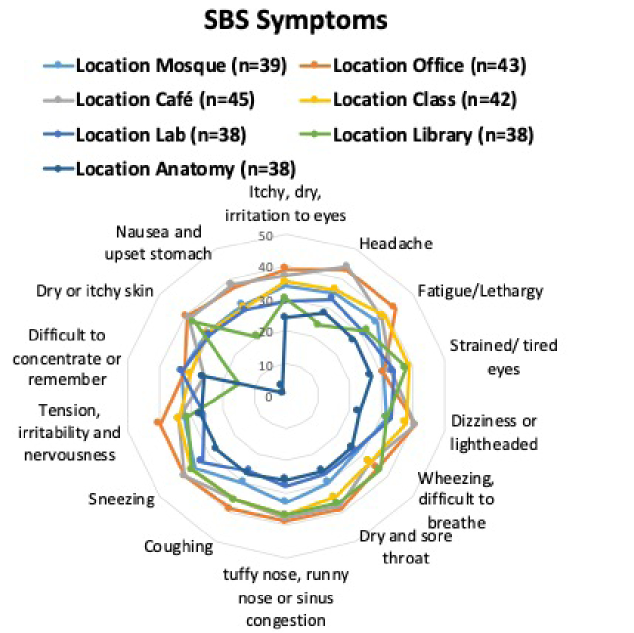

Figure 1: SBS symptoms from selected locations

Association between SBS symptoms and IAQ parameters

Table IV showed the association between the prevalence of sick building syndrome and indoor air quality parameters. There is significant association of temperature on some symptoms like fatigue (p=0.036) and dizziness (p=0.031). Relative humidity was significantly associated with some symptoms such as itchy, dry, irritation to eyes (p = 0.047), headache (p = 0.045), and fatigue (p= 0.040). In addition, PM10 was significantly associated with one symptom only which was itchiness, dryness, and irritation to the eyes (p = 0.006).

Table IV: The association between sick building symptoms (SBS) and indoor air quality parameters (p-value)

INDOOR AIR QUALITY	SICK BUILDING SYNDROME (SBS)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TEMPERATURE	.113	.180	.036*	.066	.031*	.140	.391	.123	.494	.334	.390	.062	.085	.189
RH	.047*	.045*	.040*	.363	.273	.122	.340	.597	.123	.280	.432	.460	.749	.613
CO	.878	.888	.426	.988	.985	.155	.772	.351	.942	.352	.760	.553	.981	.900
PM10	.006**	.443	.759	.910	.700	.889	.377	.810	.746	.394	.155	.168	.920	.863

Pearson Correlation

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

1. Itchy, dry, irritation to eyes,2. Headache,3. Fatigue/Lethargy,4. Strained/ tired eyes, 5. Dizziness or lightheaded,6. Wheezing, difficult to breathe.,7. Dry and sore throat,8. Stuffy nose, runny nose or sinus congestion,9. Coughing,10. Sneezing,11. Tension, irritability and nervousness,12. Difficult to concentrate or remember,13. Dry or itchy skin,14. Nausea and upset stomach

DISCUSSION

Comparison Indoor Air Physical, Chemical and Biological Contaminants at different site

Temperature, relative humidity, and carbon dioxide are the important parameter to measure indoor air quality. It is understood that the temperature is directly proportional to the relative humidity. The development of metabolic heat, heat transfer to the environment, physiological changes, and body temperatures were all found to be associated with a comfort (10). Climate factors such as temperature, humidity, wind speed and direction, personal activities, and clothing have all had an impact on heat transfer from the body to the surrounding environment. (8). Too little humidity will cause static build-up in a room, and people will feel like their skin feels dry, while too much humidity can make the skin feel sticky. Relative humidity has shown a substantial correlation with sneezing, redness of the eyes, and eye pain (17).

The elevated CO_2 levels in the office (1730.5 ppm) and classroom (1292 ppm) could be a result of potential sources of indoor CO_2 contaminants in the room, such as appliances that generate heat during copying and printing processes. The study discovered that electrical appliances contribute to the area's carbon footprint, which causes an increase in CO_2 (18,19). Additionally, the study found a significant correlation between skin symptoms and photocopiers, printers, or fax machines. (5).

Biological pollutants such as viruses, fungi and dust mites may be caused by dust accumulation as evident to the occupants experienced "dust and dirt". Hypersensitivity pneumonitis and allergic reactions also potential diseases from dust exposure (20). Overall, bacteria Gram-positive were the most prevalent. This could be clarified based on their cell wall structure and continuous sources whereas the low level of Gram-negative bacteria detection is due to their air-environment sensitivity (21). The mosque is equipped with taps for washing and ablution. The washing close by may be the primary cause of high moisture content on carpet. Furthermore, a study conducted at a holy mosque in Makkah city discovered the development of indoor microbial growth, concluding that the factors that influence this development typically involve construction, lifestyle, and residential features, as well as the quality of outdoor air (22). The growth of microorganisms such as fungi and bacteria is completely dependent on the presence of moisture, and they can grow quickly in a warm, moist, protein-rich environment that is pH neutral or slightly acidic.

Sick Building Syndrome (SBS) Symptoms among Occupants at Different Locations

Various factors may be mainly responsible for SBS. Firstly, indoor sources such as adhesives, upholstery, carpeting, copying machines, pesticides, cleaning agents may contribute to SBS symptoms (23). Consequently, poor ventilation also contributes towards how the occupants can increase their risk of developing asthma and SBS symptoms. (24). Then, gadgets in the library, office, and classroom, such as phones, laptops, computers emit electromagnetic radiation that ionizes the atmosphere. Pathological symptoms and functional respiratory changes are caused by excessive exposure of occupants to radiation, (25). Lastly, a monotonous work environment is one of the psychosocial variables known to increase in developing SBS (26).

Association between SBS symptoms and IAQ parameters

Indoor temperatures have been found to influence the learning and memory and physiological indices of the brain, with participants performing better at 22°C than at 30°C (27). Another study found that participants complained more at an operating temperature of 33.0°C than at 25.5°C of mental exhaustion, in which they have found that there is a relationship between increases in cerebral blood oxygenation while performing tasks at rising temperatures (11,28). High temperatures and relative humidity (without the use of an air conditioner) are common in Malaysia, which may cause mental exhaustion such as fatigue or dizziness. The higher education building surrounded with carbonaceous particles where it contains PM10. Once the contaminants encounter the eyes, especially if the concentration of the toxins in the air is high, they can cause symptoms in the eyes such as red eye syndrome and dry eye syndrome (29).

CONCLUSION

In conclusion, poor indoor air quality was a significant issue in a temperate climate country and in a setting of higher education. Concerns about problems with outdoor sources and the temperature were widespread. SBS symptoms have been extensively documented in higher educational setting occupants. There is a significant correlation between IAQ and symptoms of SBS. The most frequently reported symptoms are headache and dizziness. Additional research is needed to determine whether a similar pattern of complaints or SBS symptoms exists in other institution. The purpose of this research was to examine perceived symptoms of IAQ and SBS from the perspective of public, environmental, and occupational health and safety programmes in a higher education setting to conduct additional analysis, priorities issues and needs, and ultimately customize future action.

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