Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 8, 2020

EVALUATION OF ENVIRONMENTAL PERFORMANCE IN ACADEMIC BUILDING BY INDOOR ENVIRONMENTAL QUALITY (IEQ)

M.A.A. Rahman*[1], S.F. Ling[2], Mariah Awang[3], M.K. Musa[4], Nuramidah Hamidon[5], M.M. Syafiq Syazwan[6], Fatimah Yusop[7], M.H. Khamidun[8], Faridahanim Ahmad[9]

[*1,2,3,4,5,6,7]Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Muar, Johor, Malaysia
[8]Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Pt. Raja, Bt. Pahat, Johor, Malaysia
[9]Department of Civil Engineering,
Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
E-mail: *ashrafr@uthm.edu.my

Received: 20.05.2020 *Revised: 17.06.2020* *Accepted: 06.07.2020*

Abstract
Most people spend about 90% of their lives indoors, and students spend about 30% of their time in school. Indoor environmental quality (IEQ) is becoming a key aspect considering building envelopes and the health of building occupants. Buildings have to provide a healthy and comfortable environment for humans. However, each building provides different environmental quality results for indoor spaces and occupants. Therefore, the study of indoor environment quality in three different buildings has been carried out in academic building as it acts as important place in performing general activities. The methodologies used to conduct this research are qualitative and quantitative methods. This is to measure the IEQ levels in multipurpose hall, cafeteria and lecture room. This research focuses on the comparison of IEQ in different locations with the national or international standard. Measurement of carbon dioxide (CO_2) concentration, carbon monoxide (CO) con-centration, air temperature (°C), mean radiant temperature (°C), air velocity (m/s), relative humidity (%), lighting (lux), and sound quality (dB) in the three locations were collected. This research found that most of the elements in the three locations were compliance with the standard threshold limit value. However, the indoor air temperature in the multipurpose hall and cafeteria were slightly high with an average air temperature of more than 26 (°C) as set in the standard Threshold Limit Value (TLV). High level of noise in the lecture room also exceeds the guideline. Therefore, some suggestions had made such as improvement of ventilation system in multipurpose hall and maintenance of air-conditioning system in lecture room. The relationship between the IEQ levels and the types of activities carried out in the *buildings is also established.*

Keywords-- Indoor Environmental Quality (IEQ), Academic Building, Parameters, Human Activities

DOI: http://dx.doi.org/10.31838/jcr.07.08.267

INTRODUCTION

Indoor Environmental Quality (IEQ) in buildings is an important factor in sensing the good health and comfort levels of building occupants. However, each building provides different environmental quality results for indoor spaces and occupants. A key factor in achieving a healthy and comfortable built environment is to provide a high level of indoor environmental quality (IEQ) (Zuhaib et. al., 2018).

This is because most people spend about 90% of their lives indoors, and students spend about 30% of their time in school. Human activities and decision-making are probably the most important IEQ issues because it affects other IEQ factors (Asadi, Mahyuddin and Shafigh, 2017).

The IEQ goal is usually focusing on providing a stimulating and comfortable environment for building occupants and minimizing the risk of building-related health problems. The imbalance in IEQ can have a negative impact on facilities, buildings and occupants.

The imbalance in IEQ contributes to Building Syndrome (SBS), which means that occupants of buildings experience serious effects related to health or comfort that seem to be directly related to the time spent on the building (Sulaiman, Yusoff and Kamarudin, 2013).

There are many factors of IEQ that may affect to the student. This is because each building will have different environmental quality that will be perceived by the occupants that would relate to the types of activities carried out in indoor spaces of the building i.e., classroom, laboratories and others (Jamaludin, Mayuddin and Akashah, 2016). Therefore, this research conducted to study the environmental performance of the academic building by using Indoor Environmental Quality (IEQ) parameters.

INDOOR ENVIRONMENTAL QUALITY (IEQ)

According to National Institute of Occupational Safety & Health (NIOSH), Indoor Environmental Quality (IEQ) is de-fined as the environmental quality of the building is related to the health and well-being of the people living in the space (NIOSH, 2013).

Environmental factors such as thermal comfort, visual comfort, acoustics and indoor air quality determine indoor environmental quality. Environmental quality is defined as the harmony of heat, sound and luminescence with breathing air. This should not be a normal health hazard (Tezara et. al., 2014)

Parameters of Indoor Environmental Quality

Indoor environmental quality does not take into account psychological effects, personal and physical causes such as age, disease and degeneration of the body parts, as these are difficult to determine. Indoor environmental quality combines four environmental factors such as thermal comfort, indoor air quality (IAQ), acoustic comfort and visual comfort (Pereira et. al., 2014). Table 1 shows the parameters of Indoor Environmental Quality.

Table 1. Parameters of Indoor Environmental Quality (ISO, 2007; ISO 2005)

Thermal comfort	**Indoor Air Quality**	**Visual comfort**	**Acoustic comfort**
• Air temperature	• Ventilation rate	• Light intensity	• Sound intensity
• Mean radiant temperature	• Carbon dioxide concentration levels	• Color rendering index	
• Predicted Mean Vote	• Ventilation rate	• Glare index	
• Predicted Percentage of Dissatisfied	• (Harmful) pollutants concentration levels		
• Metabolic rate • Clothing • Local thermal			
• Discomfort • Relative humidity • Air velocity • Air temperature			

Indoor Air Quality (IAQ)

According to Department of Occupational Safety and Health Malaysia (DOSH), indoor air quality describes how indoor air affects people's health, comfort and work ability. It can include, but is not limited to, temperature, humidity, mould, bacteria, poor ventilation or exposure to other chemicals. In the past, indoor air pollution has received little attention compared to air pollution in outdoor environments. Now it has become a growing concern of the public, in part because of the emergence of new indoor air pollutants, the isolation of the indoor environment from the natural outdoor environment in a well-sealed office building, and the investigation of sick building syndrome (DOSH, 2016). Table 2 shows the main groups of indoor pollutants of indoor air quality.

Table 2. Main groups of indoor air pollutants (Bluyssen, 2009; Rahman et. al. 2016)

Groups	**Subgroups**
Chemical	Gases and vapours, Particulate matter, Radioactive particles/ gases (radon and its daughters)
Biological	Micro-organisms, mould, fungi, mycotoxins, bio aerosols pollens, mites, spores, allergens, bacteria, airborne infections, droplet nuclei, house dust.

Thermal Comfort

According to Department of According to Standard, ASHRAE Standard 55 (ASHRAE, 2010) and Standard, ISO 7726 (ISO, 2007), thermal comfort is defined as 'the expression of a state of mind that is satisfactory to the thermal environment in which it is located'. Thermal comfort involves physical environmental factors in natural ventilation and conditions. Thermal comfort is the best factor for assessing indoor comfort compared to vision, acoustic comfort and indoor air quality. It has also been found to have an impact on the perception of other IEQ factors (Zuhaib et. al., 2018). Table 3 shows the thermal comfort parameters.

Table 3. The thermal comfort parameters (Pohl,2011)

Parameters	**Definition**
Air temperature	The temperature of the air measured with a thermometer in the shade.
Humidity	The moisture content of the air typically expressed as a percentage in terms of relative humidity.
Air movement	The speed at which air moves across the human body greatly influences thermal comfort.
Mean radiant temperature	The radiation that is received from surrounding surfaces
Rate of work performed	Muscular activity directly impacts the metabolic rate (and therefore the heat production).
Clothing worn	The insulating characteristics of clothing inhibit

Visual Comfort

Lighting quality is a term related to the imaging effect of light and is one of the least understood aspects of architectural lighting. Initially, it was 'a term used to describe all the factors in a lighting device that are not directly related to the amount of illumination' (Kruisselbrink, Dangol and Rosemann, 2018).

According to Department of Occupational Safety and Health (DOSH), illuminance is increasingly recognized as an important factor in visual comfort. Therefore, it is recommended to use the luminance to solve the amount of light.

Illuminance is a measure of the amount of light that falls (illuminating) and spreads over a given surface area. Illuminance is also related to the brightness of the human perception of the illuminated area. The SI unit of illuminance is lux (lx), and the non-SI unit is foot-candle (DOSH, 2018).

Acoustic Comfort

Acoustic comfort is one of the basic prerequisites for a quality indoor environment. Sound is an indispensable part of every-one's life. It is necessary to distinguish between sound and noise. People are often affected by vibration, shock and noise. Sound is the perception of sound waves. Noise is defined as unwanted and invasive sounds. Frequent and excessive noise is one of the important stresses. Unpleasant increases in noise levels can have a negative impact on the quality of the indoor environment (Kraus and Senitkova, 2017).

International and National Standard

The summary of the Threshold Limit Value (TLV) that set by international and national standard is shown in Table 4.

Table 4. Summary of the Threshold Limit Value (TLV) (DOSH, 2018; DOSH 2010, DOE, 2007)

International and national standard	Parameters		Location	Threshold Limit Value (TLV)
Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Indoor Air Quality (IAQ)	Carbon dioxide (CO_2) concentration (ppm)	All locations	1000
		Carbon monoxide (CO) concentration (ppm)		10
	Thermal comfort	Air temperature (°C)	All locations	23 - 26
		Mean radiant temperature (°C)		24 - 27
		Air velocity (m/s)		0.15 – 0.5
		Relative humidity (%)		40 - 70
Guidelines on Occupational Safety and Health for Lighting at Workplace	Lighting quality (lux)		Multipurpose hall	500
			Cafeteria	300
			Lecture room	500
Guideline values for community noise in specific environments, World Health Organization (WHO)	Sound quality (dB)		Multipurpose hall	85
			Cafeteria	65
			Lecture room	35

Effects of the Indoor Environmental Quality (IEQ)

The World Health Organization (WHO) and its regional branches have internationally studied and documented the impact of indoor environmental quality on the health and performance of building occupants. Some of the most powerful evidence from WHO (2015) on the impact of IEQ on building occupants is shown in the table below. The effects of IEQ parameters on building occupants is shown in Table 5.

Table 5. Effects of IEQ Parameters on Building Occupants (WHO, 2015)

hermal comfort	Visual comfort	Acoustic comfort	Indoor Air Quality (IAQ)
Attention distraction Lack of concentration Reduction of manual dexterity Reduction of performance Dizziness Fatigue Headache	Eye irritation Neck and shoulder problems Fatigue Headache Seasonal Affective Disorder (SAD)	Reduction in concentration Temporary hearing loss Acoustic trauma Effects on speech intelligibility Poor performance	Lack of concentration Dizziness Nausea Headache Fatigue Asthma Irritation Lung diseases Cardiovascular diseases Lung cancer Suffocation

Indoor Environmental Quality (IEQ) Control

According to Bluyssen (2009), the control of indoor environmental factors only focuses on preventing or curing different relevant observed physical effects in a largely isolated manner trying to find a separate solution for thermal comfort, lighting quality, sound quality and air quality (DOSH, 2016). The indoor environmental factors, parameters, control and issues of concern are shown in Table 6.

Table 6. Indoor environmental factors, parameters, control and issues of concern (Bluyssen, 2009)

	Thermal Comfort	Lighting quality	Acoustical quality	Air quality
Parameters	Temperature (air and radiant) Relative humidity Air velocity Turbulence intensity Activity and clothing	Luminance and illuminance Reflectance (s) Colour temperature and colour index View and daylight Frequencies	Sound level (s) Frequencies Duration Absorption characteristics Sound insulation Reverberation time	Pollution sources and air concentration Types of pollutants (allergic, irritational, carcinogenic, etc.) Ventilation rate and efficiency
Control	Heating, ventilating and air-conditioning systems Design of building (insulation, façade, etc.)	Luminance distribution Integration Artificial and natural lighting Daylight entrance	Acoustical control Passive noise control Active noise control	Source control Ventilation systems Maintenance Air cleaning Activity control
Issues	Dynamic effects Adaptation Integration systems	Daylight entrance relation to thermal comfort and energy use	Long-term health effects Vibrations and annoyance	Interpretation and detection Secondary pollution

(façade, floor and ceiling) Energy use	Health effects and control	Degree of annoyance with type of noise	(indoor chemistry and micro-organisms) (Fine) dust Energy use

METHODOLOGY

In order to achieve this research, several procedures to conduct the analysis have been selected as shown in the overview of methodology process in Figure 1.

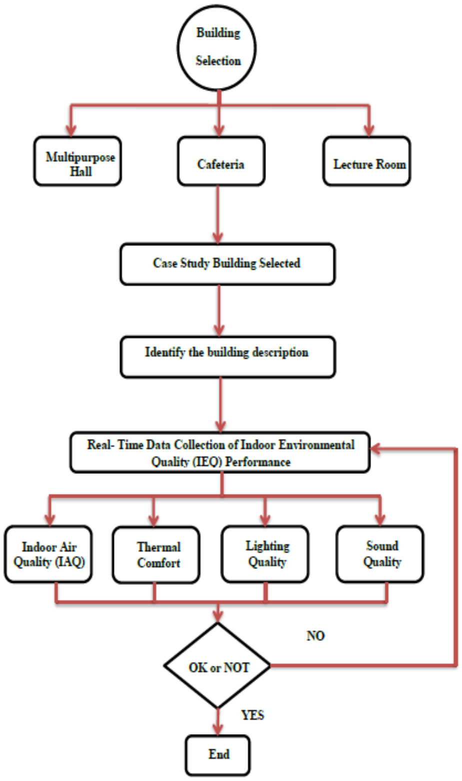

Figure 1. Methodology flow chart

This research was conducted by using quantitative and quantitative analysis applying fieldwork monitoring conducted at three locations where information of indoor environmental quality is measured as listed in Table 7.

Table 7. Project methods and types of data required

Project Method	Types of data required	Sources of data
Qualitative	Building characteristics such as building design	Direct observation
	Types of activities carried out by students	Direct observation
Quantitative	Building characteristics such as building dimension	Manual
	Indoor Environmental Quality (IEQ) levels	Data collection

Building Selection

The selection of locations for measurement is based on the different characteristics of the buildings. Therefore, three locations had been selected as the case study buildings which are lecture hall, cafeteria and multipurpose hall. The buildings characteristics of the locations selected of this case study building are obtained through the direct observation and is shown in Table 8. The attached pictures of the locations selected are shown Figure 2, Figure 3 and Figure 4.

Table 8. Building characteristics of the locations selected

Locations	Building characteristics
 **Figure 2.** Lecture room	Learning area
 **Figure 3.** Multipurpose hall	Closed area

 **Figure 4.** Cafeteria	Opened area

Case Study Building Selected

The summary of buildings description is shown in Table 9. The building description will shown the building characteristics, building size and number of measurement points in the multi-purpose hall, cafeteria and lecture room.

Table 9. Summary of buildings description

No.	Name	Building characteristics	Building size (m2)	Number of measurement points
1	Multipurpose hall	Closed area	67.85 x 34.9 (2,368)	5
2	Cafeteria	Opened area	30 x 18 (540)	2
3	Lecture room	Learning area	13.5 x 9 (121.5)	1

Real-Time Data Collection of Indoor Environmental Quality Levels

The method used for the measurement of Indoor Environmental Quality (IEQ) levels in three different locations is real-time data collection method. Real-time data refers to data that is presented as it is acquired.

Measurement Devices

The equipment's used for the measurements of IEQ levels in the multipurpose hall, cafeteria and lecture room are shown in Table 10.

Table 10. Equipment used for measurement of IEQ levels

IEQ Parameters	Equipment	Range	Parameters	Accuracy
Indoor Air Quality (IAQ)	 **Figure 5.** KANOMAX IAQ monitor	0- 5000 PPM	Carbon dioxide concentration (ppm)	±3% of reading or ±50 PPM whichever is greater
		0 – 500 PPM	Carbon monoxide concentration (ppm)	±3% of reading or ±3 PPM whichever is greater
Thermal comfort	 **Figure 6.** LSI LASTEM S.r.l. Heat shield portable wireless WBGT meter	-20°C - 60°C	Air temperature (°C)	±0.8°C, ±0.4°C (10 – 40°C)
		-20 °C - 60°C	Mean radiant temperature (°C)	±0.3°C
		0 – 100%	Relative humidity (%)	1.8% RH (10 – 90%)
		0.01 – 20m/s	Air velocity (m/s)	±10cm/s (0.5 – 1.5m/s)
Lighting quality	 **Figure 7.** Lux meter	1 lux – 100,000 lux	Illumination level (lux)	<10, ppp lux ±(4% rdg+10 dgt) ≥10, 000 lux ±(5% rdg+10 dgt)

Sound quality	 **Figure 8.** MASTECH Sound level meter	30~80 dB, 40~90 dB, 50~100 dB, 60~110 dB, 70~120 dB, 80~130 dB	Sound level (dB)	±1.5 dB (sound pressure standard, 94 dB @ aKHz)

Measurement Methods

The parameters (air temperature, relative humidity, mean radiant temperature, illumination level, CO_2 concentration, CO concentration, air velocity and sound level) were measured using a Testo-480 portable measuring instrument, where measurement probes were placed 1.0m above the floor near the respondents during normal working hours (8:00–16:00).

The data of indoor air temperature, mean radiant temperature, relative humidity, air velocity, CO_2 concentrations and CO concentrations in the case study locations were recorded every 5 min. The data of sound pressure level every 10 min throughout the school active hours. Illuminance levels were measured within the lighting network. Then, the data of thermal comfort were recorded every 20 min.

Finally, the data of average Indoor Environmental Quality (IEQ) levels obtained in three different locations of this study are recorded and analyzed to establish the relationship between the IEQ levels and the types of activities carried out in the different characteristics of academic buildings.

RESULTS AND DISCUSSION

Indoor Environmental Quality (IEQ) Performance

The real-time data measurements taken in the multipurpose hall, cafeteria and lecture room are to identify the elements of indoor air quality, thermal comfort, lighting quality and sound quality.

Indoor Air Quality

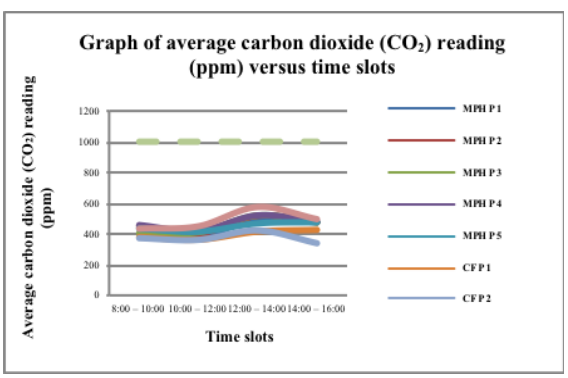

Figure 9. Average CO_2 concentration versus time slots

Based on the Figure 9, the data collected on measurement of concentration of carbon dioxide (CO_2) in the three locations are in the range of 342ppm to 525ppm. It is found that the concentration level of CO_2 in the three locations is within the acceptable standards for the CO_2 that is 1000ppm (dotted lines) which is set by Industry Code of Practice on Indoor Air Quality (DOSH, 2010). This is because the adequate fresh air is being supplied to the space.

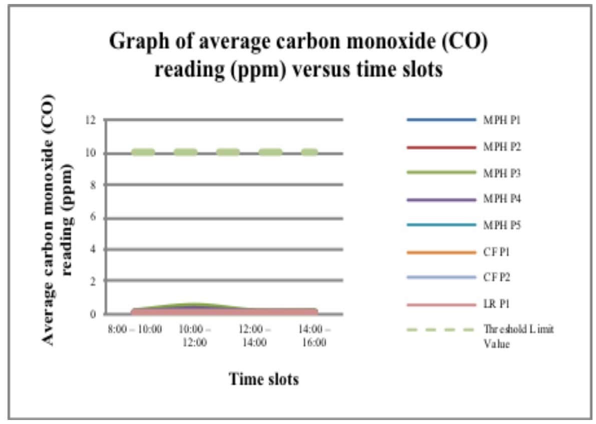

Figure 10. Average CO concentration versus time slots

In addition to CO_2, carbon monoxide (CO) was also measured and it was found that concentration level of CO in the three locations (0.1ppm to 0.4 ppm) is within the acceptable standards for the CO that should be 10ppm (dotted lines) which is set by Industry Code of Practice on Indoor Air Quality (2010) as illustrated in Figure 10 (DOSH, 2010).

Thermal Comfort

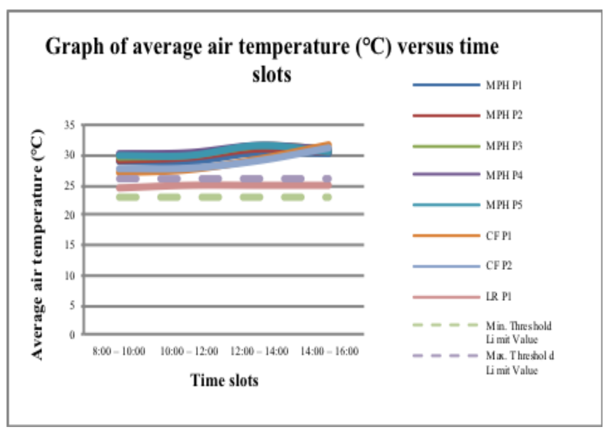

Figure 11. Average air temperature versus time slots

Based on the Figure 11, the average indoor air temperature in the multipurpose hall is in the range of 28.8°C to 31.8°C while 27.3°C to 32.0°C measured in the cafeteria. Next, the average indoor air temperature in the lecture room is in the range of 24.7°C to 25.2°C. The Industry Code of Practice on Indoor Air Quality (2010) provides the suitable temperature for good indoor air quality is within 23°C to 26°C (dotted lines) (DOSH, 2010). It is found that both multipurpose hall and cafeteria failed to achieve the TLV. This may due to poor natural ventilation in the multi-purpose hall where the doors and windows were closed at most of the time when the hall is occupied. Besides that, the lack of mechanical ventilation system (only wall fan) which reduces the ventilation rates of the hall further. However, the indoor air temperature pattern in the cafeteria was observed to be influence by the outdoor air temperature. This is because is an opened area that directly exposed to the outdoor environment with the highest temperature of 36.7°C during the measurement period.

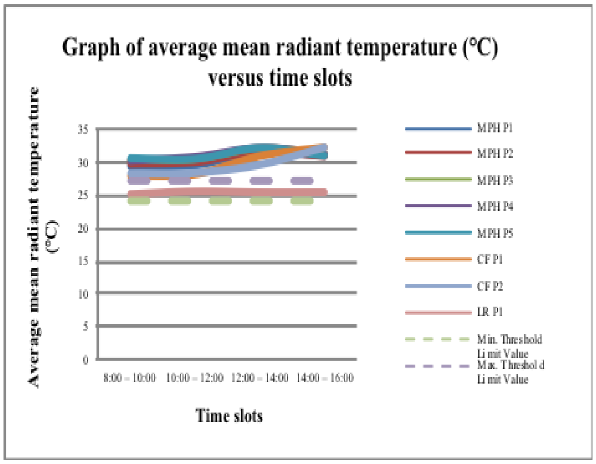

Figure 12. Average mean radiant temperature versus time slots

Based on the Figure 12, the average mean radiant temperature in the three locations is between 25.2°C to 32.2°C. The average mean radiant temperature in multipurpose hall and cafeteria exceeds the standard range set by ASHRAE and Industry Code of Practice on Indoor Air Quality which is between 24°C to 27°C (DOSH, 2010). The reason for this situation is same as the situation of air temperature failed to meet the requirement range.

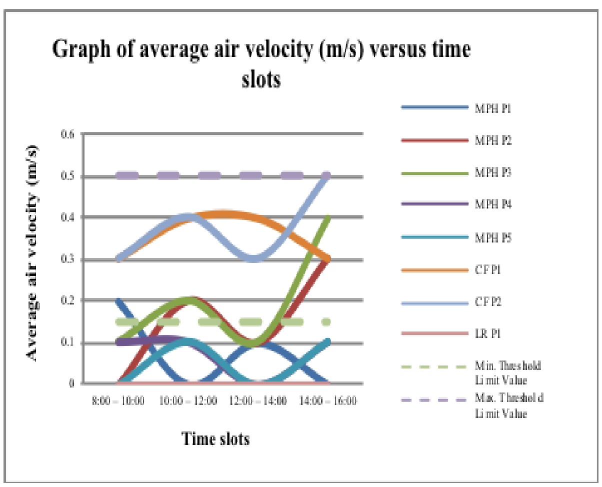

Figure 13. Average air velocity versus time slots

With regards to the air circulation in the multipurpose hall, it was noted that the average reading for air velocity was in the range of 0 m/s to 0.4 m/s as illustrated in Figure 13. Next, the average air velocity in the cafeteria was in the range 0.3 m/s to 0.5 m/s while in the lecture room is in the range of 0 m/s. Those values are in the acceptable range of air movement which is 0.15 to 0.50 m/s (dotted lines) set by Industry Code of Prac-tice on Indoor Air Quality (2010) (DOSH, 2010). Due to this, it can be concluded that the air movement in the three locations are attained satisfaction level.

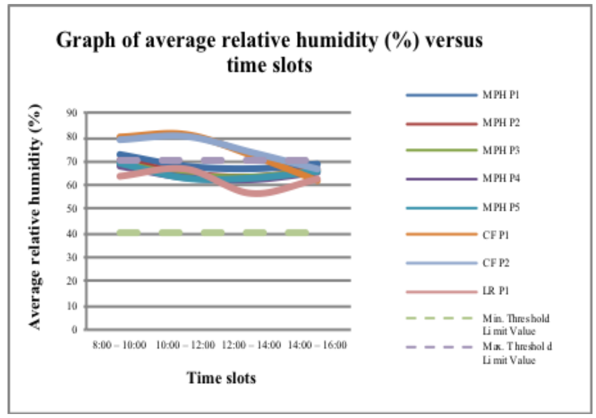

Figure 14. Average relative humidity versus time slots

From the Figure 14, it shows that the relative humidity in the multipurpose is in the range of 62.2 % to 72.3 % while 62.0 % to 81.3 % in the cafeteria. However, at certain time of the day, the RH level was noted to go beyond the TLV (above 70% set by Industry Code of Practice on Indoor Air Quality, 2010) (DOSH, 2010). This may due to the ventilation issues and building envelope problems. Next, the average relative humidity in the lecture room is in the range of 56.8 % to 67.2 %. Those values are in the acceptable range of relative humidity, which is 40 – 70 % (dotted lines) set by Industry Code of Practice on Indoor Air Quality (2010) (DOSH, 2010).

Visual Comfort

Based on the Figure 15, it shown the data collected for the measurement of average lighting quality in the multipurpose hall is 183lux for natural lighting and 318lux for artificial lighting. Overall, most of the areas in the multipurpose hall had lighting intensity above the standard lighting level suitable for multipurpose hall, which is 300lux (dotted lines) (DOSH, 2018).

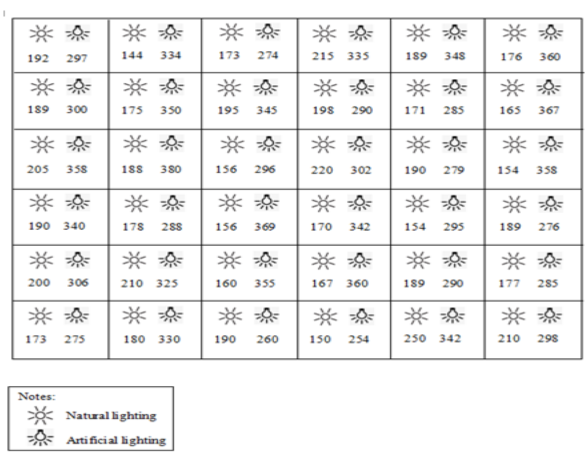

Figure 15. Average lighting performance versus measurement points in multipurpose hall

Further-more, based on the Figure 16, it shown the data collected for the measurement of average lighting quality in the cafeteria is 321lux for natural lighting and 444lux for artificial lighting. Overall, most of the areas in the cafeteria had lighting intensity above the standard lighting level suitable for cafeteria, which is 300lux (dotted lines) (DOSH, 2016). Moreover, based on the Figure 17, it shown the data collected for the measurement of average lighting quality in the lecture room is 47lux for natural lighting and 616lux for artificial lighting. Overall, most of the areas in the lecture room had lighting intensity above the standard lighting level suitable for lecture room, which is 500lux (dotted lines) (DOSH, 2016). Although the lecture room lack of exposure to natural lighting, but the artificial lighting helps to facilitate learning of the students.

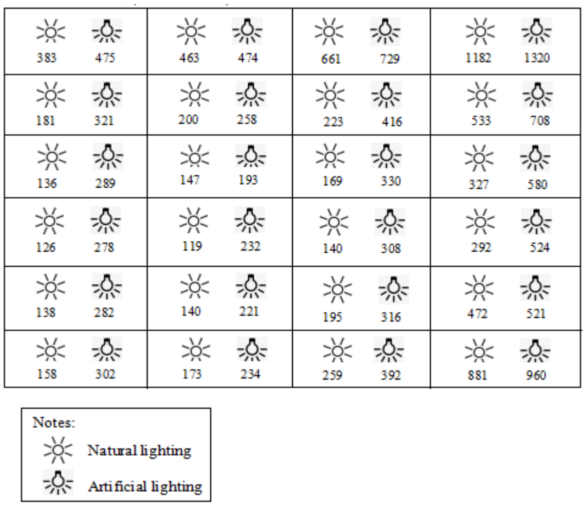

Figure 16. Average lighting performance versus measurement points in cafeteria

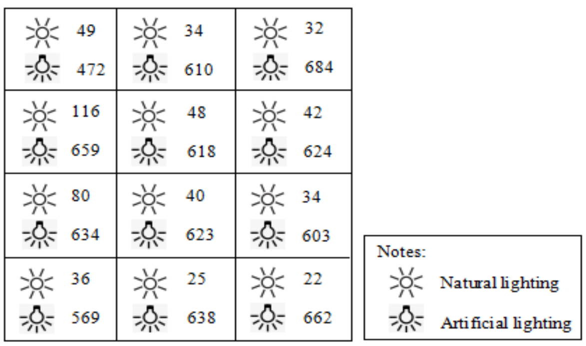

Figure 17. Average lighting performance versus measurement points in lecture room

Acoustic Comfort

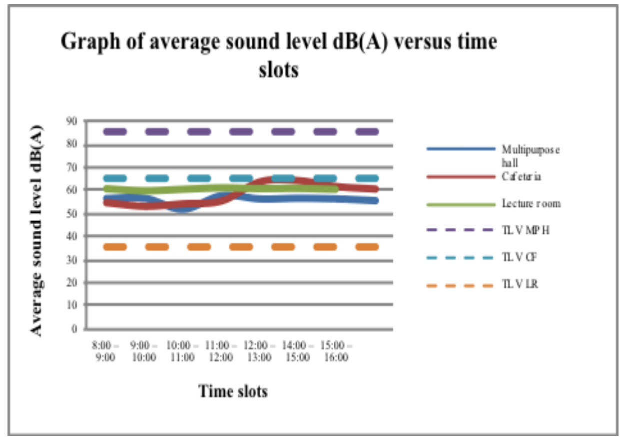

Figure 18. Average sound level versus time slots

Based on the grab sampling taken in the multipurpose hall (Figure 18), the sound level was found below the TLV of the background sound level (85dB) (DOE, 2007). From the data obtained, average readings for sound level were in between 51.8dB to 58dB. Moreover, the average reading for sound level in cafeteria is measured between 52.6dB to 64.2dB. The sound level was found below the TLV of the background sound level (65dB) (DOE, 2007). However, the sound level in the lecture room failed to meet the acceptable value. It is found that the sound level was above the TLV of the back-ground sound level (35dB) (DOE, 2007). From the data obtained, aver-age readings for sound level were in between 58.8dB to 61.3dB. This is probably due to the noise pollution caused by the air-conditioner.

Summary of IEQ Measurements

Table 11 shows the summary for current condition in the multipurpose hall, cafeteria and lecture room. Most of the elements in the three locations were compliance with the standard Threshold Limit Value (TLV). However, the indoor air temperature in the multipurpose hall and cafeteria were slightly high with an average air temperature of more than 26°C as set in the standard TLV. This condition could contribute to dissatisfaction of the building occupant. Next, the sound quality in the lecture room (58.8dB – 61.3dB) was above the standard TLV of 35dB. It could lead to distraction in students learning performance and difficulty in focusing during lecture.

Table 11. Summary of IEQ measurements

Element	Location	Average	Threshold Limit Value		Remarks
Carbon dioxide (CO_2) concentration (ppm)	Multipurpose hall	392 - 525	1000	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Below TLV
	Cafeteria	342 - 435			
	Lecture room	444 - 572			
Carbon monoxide (CO) concentration (ppm)	Multipurpose hall	0.1 – 0.4	10	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Below TLV
	Cafeteria	0.1			
	Lecture room	0.1			
Air temperature (°C)	Multipurpose hall	28.8 – 31.8	23 - 26	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Above TLV
	Cafeteria	27.3 – 32.0			
	Lecture room	24.7 – 25.2			Below TLV
Mean radiant temperature (°C)	Multipurpose hall	29.3 – 32.1	24 - 27	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Above TLV
	Cafeteria	27.9 – 32.2			
	Lecture room	25.2 – 25.8			Below TLV
Air velocity (m/s)	Multipurpose hall	0 – 0.4	0.15 – 0.50	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Below TLV
	Cafeteria	0.3 – 0.5			
	Lecture room	0			

Relative humidity (%)	Multipurpose hall	62.2 – 72.3	40 - 70	Industry Code of Practice on Indoor Air Quality (DOSH 2010)	Below TLV
	Cafeteria	62.0 – 81.3			
	Lecture room	56.8 – 67.2			
Lighting quality (lux)	Multipurpose hall	NL: 183	300	Guidelines on Occupational Safety and Health for Lighting at Workplace (DOSH 2018)	Above TLV
		AL: 318			
	Cafeteria	NL: 321	300		
		AL: 444			
	Lecture room	NL: 47	500		
		AL: 616			
Sound quality dB(A)	Multipurpose hall	51.8 - 58	85	Guideline values for community noise in specific environments, World Health Organization (WHO)	Below TLV
	Cafeteria	52.6 – 64.2	65		
	Lecture room	58.8 – 61.3	35		Above TLV

Notes:
AL: Artificial lighting performance
NL: Natural lighting performance

Relationship Between Indoor Environmental Quality And Human Activities

Table 12 shows there is a relationship between the IEQ levels and the types of activities that carried out in the building. The higher the IEQ levels of the building, the higher the occupant performance and productivity. However, the lower the IEQ levels of the building, the lower the occupant satisfaction and attention during the learning lesson.

Table 12. Summary of the relationship between IEQ level and the types of activities

No.	Name	Building characteristics	Types of activity	IEQ level	Effect
1	Multipurpose hall	Closed area	-Sports activities -Non sport activities	High	-Improve learning performance and productivity -Increase occupant satisfaction
2	Cafeteria	Opened area	-Having meals -Chatting -Discussion	Low	-Improve learning performance and productivity -Increase occupant satisfaction -Lack of attention in the classroom and can lead to health symptoms -Sick Building Syndrome (SBS) -Reduction of work productivity
3	Lecture room	Learning area	-Giving lecture -Attending lecture		

CONCLUSION

General perception and level of IEQ in the multipurpose hall, cafeteria and lecture room of academic building are averagely good. However, there were several parameters in certain place are not achieved the standard of TLV such as:

- High level of indoor air temperature in the multipurpose hall and cafeteria that exceeds the limits.
- High level of noise in the lecture room exceeds the guideline.

Therefore, some improvements have to carry out to increase the IEQ levels in the particular places. Firstly, the indoor air temperature in the multipurpose hall had to improve in order to provide good ventilation system and hence provide satisfaction to the building occupants. Last but not least, operation and maintenance of the air conditioner in the lecture room have to do some operation and maintenance to decrease the sound level during the lecture hours.

Based on the findings, it is recommended that indoor air temperature in the multipurpose hall should be improved to remove heat as well as to increase the level of air velocity. Therefore, the exhaust fan and the air conditioning systems should be fixed and maintained. It is also recommended that questionnaire being conducted to determine occupant's perception and satisfaction towards the current IEQ levels in the three locations of study.

ACKNOWLEDGEMENTS

Highest acknowledgement to Universiti Tun Hussein Onn Malaysia (UTHM), fellow researcher and those who are involve direct or indirectly in the complement of this research.

REFERENCES

1. American Society for Heating, Refrigerating and Air Conditioning Engineers (2010).Thermal EnvironmentalConditions for Human Occupancy. Atlanta, GA: ASHRAE Standard 55.
2. Asadi, I., Mahyuddin, N., Shafigh, P. (2017). The Relation between Indoor Environmental Quality (IEQ) and Energy Consumption in Building Based on Occupant Behavior - A Review. University of Malaya: Degree's Thesis.
3. Bluyssen, P. M. (2009). The Indoor Environment Handbook: How to Make Buildings Healthy and Comfortable. 1st ed. Sterling, London: Earthscan.
4. Department of Environment (2007). The Planning Guidelines for Environmental Noise Limits and Control.
5. Department of Occupational Safety and Health (2018). Guidelines on Occupational Safety and Health for Lighting at Workplace.
6. Department of Occupational Safety and Health Malaysia. (2016). Indoor Air Quality.
7. Department of Occupational Safety and Health. Ministry of Human Resources, Malaysia (2010). Industry Code of Practice on Indoor Air Quality.

8. Ghani, A.B.A., Mahat, N.I., Hussain, A., Mokhtar, S.S.M. (2019). Water Sustainability In Campus: A Framework In Optimizing Social Cost. International Journal of Recent Technology and Engineering, 8 (2 Special Issue 2), pp. 183-186.
9. Hussain, A., Mkpojiogu, E.O.C. (2015). An Application Of The ISO/IEC 25010 Standard In The Quality-In-Use Assessment Of An Online Health Awareness System. Jurnal Teknologi, 77 (5), pp. 9-13.
10. Hussain, A., Mkpojiogu, E.O.C., Kamal, F.M. (2016). The Role Of Requirements In The Success Or Failure Of Software Projects. International Review of Management and Marketing, 6 (7Special Issue), pp. 305-310.
11. International Organization for Standardization (2001). Ergonomics of the Thermal Environment — Instruments for Measuring Physical Quantities. BS EN ISO 7726.
12. International Organization for Standardization (2005). Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. EN ISO 7730.
13. International Organization for Standardization (2007). Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. EN ISO 15251.
14. Jamaludin, N. M., Mahyuddin, N., Akashah, F. W. (2016). Assessment of Indoor Environmental Quality (IEQ): Students Well-Being in University Classroom with the Application of Landscaping. University of Malaya: Degree's Thesis.
15. Kraus, M., Senitkova, I. J. (2017). Indoor Noise Loading in Residential Prefabricated Buildings.
16. Kruisselbrink, T., Dangol, R., Rosemann, A. (2018). Photometric Measurements of Lighting Quality: An Overview, 138, pp. 42–52.
17. M.A Sulaiman, W.Z. Wan Yusoff, W.N. Wan Kamarudin. (2013). Evaluation of Indoor Environmental Quality (IEQ) on dense Academic Building: Case Studies Unversiti Tun Hussein Onn Malaysia. Unversiti Tun Hussein Onn Malaysia: Degree's Thesis.
18. Pereira, L. D. et al. (2014). Assessment of Indoor Air Quality and Thermal Comfort in Portuguese Secondary Classrooms: Methodology and Results, 81, pp. 69-80.
19. Pohl, J. (2011). Building Science Concepts and Application. 1st ed. United Kingdom: Wiley-Blackwell.
20. Rahman, M. A. A., Awang, M., Mustafa, M. S. S., Yusop, F., Sari, K. A. M., Musa, M. K., ... & Hamidon, N. (2019, November). Evaluation and measurement of indoor air quality in the preschool building. In IOP Conference Series: Earth and Environmental Science (Vol. 373, No. 1, p. 012018). IOP Publishing.
21. Tezara, C. et al. (2014). Monitoring of the Indoor Air quality Parameters in the Day Care Centres in Tropical Country, 3(1), pp. 47-52.
22. World Health Organization. (2015). Effects of IEQ Parameters on Building Occupants.
23. Zuhaib, S. et al. (July 2018). An Indoor Environmental Quality (IEQ) Assessment of a Partially-retrofitted University Building, 139, pp. 69-85.