A Study on Indoor Air Quality (IAQ) of University Libraries in Malaysia

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Abstract: Indoor Air Quality (IAQ) refers to the level of air quality within and around buildings and structures where it related to the health and comfort of the buildings occupants and recently libraries have also been considered as a sick building syndrome and sick library syndrome has been identified. The goals of research to study field work methods used by previous studies of IAQ on university libraries in Malaysia and analysis perusal of physical parameter (temperature, air speed and relative humidity) and chemical parameters (carbon dioxide and carbon monoxide). The method used was data collection from the journal publication and compared with ICOP 2010, ASHRAE-62.1(2016) and ASHRAE-55 (2017). Based on the results obtained, the correlation studies shows that the outdoor environments do give impacts on the indoor air quality in the libraries as the libraries located in suburban area where background was busy in traffic and industrial factories. The library in suburban area shows the elevated on average temperature, CO_2 concentration approaching maximum level and insufficient humidification. This correlation studies shows that the outdoor environments do give impacts on the indoor air quality in the libraries.

Keywords: Indoor Air Quality, University Libraries, IAQ, Thermal Comfort, Indoor Environment

1. Introduction

A growing number of educational buildings face a complex design challenges as they needed be expertise in any kind of environmental conditions especially on handling periods of high occupancy density. IAQ is an environmental health concern that often gets sidelined among other environmental concerns. Some people take this problem lightly as the poor IAQ does not brings impact to the occupants. Currently, IAQ has taken it place on the top five environmental risks to public health and comfort that ranked by Environmental Protection Agency (EPA). Environmental Protection Agency (EPA) mentioned that indoor air quality refers to the level of air quality within and around buildings and structures where it related to the health and comfort of building occupants [1]. The poor IAQ has been related to health problem including asthma and allergies, specific infectious diseases like legionella pneumonia and several non-specific health complaints, often conceptualized in the terms sick

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building syndrome (SBS), sick house syndrome (SHS), or multiple chemical sensitivity (MCS) [2]. According to Mendell, found that health problems from poor indoor environments give impacts to the performance of the occupants in buildings, with potentially substantial adverse effects on workforce productivity [3].

In year of 2010, The Industrial Code of Practice on Indoor Air Quality (ICOP) published by Department of Occupational Safety and Health (DOSH) Malaysia has proposed the selected indoor air quality parameters and their acceptable limits [4]. Priority to maintain a good IAQ, the acceptable limit of each IAQ parameter must be complied such as levels of contaminants of biological forms (microorganisms or molds), chemicals forms or physical contaminants like dusts.

Recently libraries have also been considered as sick library syndrome has been identified [5]. The factors of university students often spend hours at in the college library because of things that might be helpful for students to do research or assignment such as wi-fi facilities, plug sockets and integration services mode of books collection. Students want the library to fit with the way their work, thus, the most important part when the indoor air quality of library make the students more comfortable. Therefore, this problem can be avoided by improving IAQ in the libraries may also lead the students better in learning and difficult work can be performed. The previous research study, identification on assessment of IAQ in university library, proves that high percentage of accuracy to the pollutants involved in the IAQ of library [6]. In fact, the outrageous level of indoor air pollution inside the buildings is more dangerous for health and comfort of the occupants compared to the outdoor air pollution [7]. This indoor air pollution called as 'silent killer' for the building's occupants health issues. The acceptable indoor air quality in the buildings can reduced the indoor air pollution such as carbon dioxide, carbon monoxide, ozone and others.

This research paper to study the field work methods used by previous studies on IAQ on university libraries in Malaysia. Next, analyzed the perusal of parameter and chemical parameter and compared with the guidelines of ICOP and ASHRAE.

2. Methods

Journal publications were identified through searches using ProQuest and Google Scholar using different combinations of the following search terms: indoor air quality, IAQ, libraries, university libraries. The goal of the search was to study the field work methods used by previous studies on IAQ on university libraries in Malaysia. Next, analyzed the perusal of parameter and chemical parameter and compared with the guidelines of ICOP and ASHRAE. To achieve the objectives of the study, the scope of work has been formulated as following:

i. Field work methods used by previous studies of indoor air quality (IAQ) that obtained through internet
ii. Including college and university level library in Malaysia.
iii. Focus on two parameters where are physical parameter (air temperature, relative humidity (% RH) and air speeds (m/s) and selected chemical parameter (carbon dioxide (CO_2) and carbon monoxide (CO).
iv. The parameter will compare to the guideline given by Industry Code of Practice on Indoor Air Quality 2010 (ICOP 2010) and American Society of Heating, Refrigerating and Air-Conditioning Engineer (ASHRAE 62.1, 2016 and ASHRAE 55, 2017).
v. This research used analysis comparison between parameters value and guidelines chosen only.

Part A

Inclusion criteria for journal selection: (a) indoor air quality were used to represent the perusal parameters in university libraries either collected from real-monitors installed in or around the libraries, or represented by data collected at the nearest monitoring stations (b) study of IAQ that conducted in

Malaysia, (c) studies of perceived IAQ and SBS indicator, (d) thermal comfort in higher education libraries, (e) microbiological of IAQ assessment, (f) different libraries but same library was not consider in the study, (g) published up to 2011. For exclusion criteria: (a) the public university libraries. The characteristics of location, study aim, data collection method (field work monitoring), as well as the type of sensors were compiled and separated based on their findings.

Part B

The data collected from the case studies on ground floor or first floor in libraries of IAQ parameters from previous studies were analyzed and be compared with the IAQ guidelines

IAQ Parameters

This research focus on the IAQ parameters of physical parameters and chemical parameters. The specific physical parameters that stated by ICOP (2010) [4] was consists of air temperature, relative humidity and air movement. Thus, the data collected from the previous study specific physical parameters on college library buildings will be analysed. This research was mainly focus on selected chemical parameters which are carbon dioxide (CO_2) and carbon monoxide (CO).

IAQ Guidelines

The data collected of physical parameters and chemical parameters on college library in Malaysia from past research, the data collected will be compared with the guidelines given by Industry Code of Practice on Indoor Air Quality 2010 (ICOP 2010) for all selected parameters. American Society of Heating, Refrigerating and Air-Conditioning Engineer (ASHRAE 62.1, 2016) for carbon dioxide and carbon monoxide [8] while ASHRAE 55 (2017) for air temperature, air speeds and relative humidity [9].

3. Results

The analysis of selected previous research papers has been divided into two parts: the first one shows the characteristics location of university libraries building and description of field work test methods on IAQ in Malaysia. The second one analysed the data collected for level of physical parameter and chemical parameter of IAQ where in used in situ evaluation strategies to assess comfort levels in the case study. The data collected analysed and compared the physical parameter and chemical parameters with ICOP and ASHRAE standards for evaluating IAQ levels inside the university libraries.

3.1 Studies of IAQ on university libraries in Malaysia

Based on the above journal selection criteria, ten studies were identified that provided data about IAQ on university libraries in Malaysia. The studies shown in Table 1

Table 1: Descriptions of publications about IAQ on university library in Malaysia. Part A

	Descriptions		Field Work Monitoring						
	Legend	Characteristics of Location	Instruments	Parameters					Timeframe
				Temperature	Air Speed	Relative Humidity	Carbon Dioxide	Carbon Monoxide	
[10]	A1	Suburban area	AMI 300 Mulfunction	●	NS	●	●	NS	Less than 12 hours

Ref	Code	Location	Instrument						Duration
[11]	A2	Suburban area	GrayWolf IAQ monitor (Model IQ-610)	●	NS	●	●	●	A weeks
[12]	A3	Suburban area	IAQ Meter	●	●	●	●	NS	Less than 12 hours
	A4	Urban area	IAQ Meter	●	●	●	●	NS	Less than 12 hours
	A5	Rural area	IAQ Meter	●	●	●	●	NS	Less than 12 hours
[13]	A6	Urban area	Portable HAZSCANNER GB-2000	●	●	●	●	NS	Less than 12 hours
[14]	A7	NS	Stated by maintenance	●	NS	●	NS	NS	5 months
	A8	NS	Stated by maintenance	●	NS	●	NS	NS	5 months
	A9	NS	Stated by maintenance	●	NS	●	NS	NS	5 months
[15]	A10	Urban area	GrayWolf IAQ monitor (Model IQ-610)	●	●	●	●	●	10 months
[16]	A11	Urban area	YESAIR devices	●	NS	●	NS	NS	10 months
[17]	A12	Rural area	IAQ Mould Alexeter IAQ-Pro	●	NS	●	NS	NS	NS
[18]	A13	Suburban area	3-in-1 humidity, temperature and Airflow Meter (Model 45160)	●	NS	●	NS	NS	NS
	A14	Suburban area	3-in-1 humidity, temperature and Airflow Meter (Model 45160)	●	NS	●	NS	NS	NS
[19]	A15	Rural area	Large Vane CFM/CMM Thermo-Anemometers	NS	●	NS	NS	NS	24 hours

*NS= Not stated

3.2 Main Findings

Based on the selected previous studies, all the studies concluded the goals to achieve acceptable levels of indoor air environments of university libraries in Malaysia. The percentage of 30.0 % of the studied was conducted for cover the indoor environmental quality of the university libraries [10][18][16] and 70.0 % of the studied was conducted on indoor air quality including physical parameter, chemical parameter and biological parameter [11][12][13][14][15][17][19].

All the identified 15 university libraries from 10 selected paper have been undertaken in Malaysia where hot, humid climates and rainy throughout the year. The differences characteristics of location identified from the studies such as urban area, suburban area and rural area. The percentage of university library was located at suburban are which is 33.0 %, that located in suburban was A1, A2, A3, A13 and A14 [10][11][12][18]. Next, Urban area where was very developed of libraries located area which is 27.0 % of the studied, the studies by [12][13][15][16] were study the IAQ monitoring on libraries of

A4, A6, A10 and A11. While, a rural area of land that has only few homes include agriculture development with the percentage of characteristic on Rural area was 20.0 % [12][17][19]. The rest of previous paper which is 20.0 % was not described any information characteristics of location [14]. This research represented the IAQ studies focused on characteristics of libraries location are important in order to achieve acceptable IAQ. Several of the studies described the energy performance of the buildings [10][18].

The differences measuring instruments for IAQ monitoring from the previous studied were divided into two categories which are expensive instruments and low-cost instruments for the selected paper. Mostly of the studied used expensive instruments which is 60.0 % [10][12][13][16][17][19]. For an efficient investigation on IAQ levels, the IAQ instruments are necessary sensitive with indoor air to monitor from time to time. The effectiveness on uses of expensive instruments was undeniable. Next, the used of low-cost instruments on IAQ monitoring from selected paper was 30.0 % from the studied [11][15][18]. The rest of 10.0 % from the selected paper not stated the using of IAQ monitoring instruments where the studied measuring on IAQ was assisted by the library maintenance [14].

As mentioned in previous chapter, this research paper reviewed on selected parameters such as temperature, air speed, relative humidity, carbon dioxide (CO_2) and carbon monoxide (CO). Many studies parameters by authors were both temperature and relative humidity which are 9 out of 10 were identified [10][11][12][13][14][15][16][17][18]. The study on temperature and relative humidity is important to measure the thermal comfort of the users and visitor of the libraries. The studied on IAQ were carbon dioxide where studied by 5 authors [10][11][12][[13][15]. Carbon monoxide parameter was the least studied by selected papers where only been studied by 2 authors [15] on A10 and [11] on A2. There are 4 authors took place that studied on the air speed parameters [12][13][15][19].

Next, the various of timeframe on IAQ monitoring periods on libraries. For example, some studies were carried out over long-term monitoring on a few university libraries [14][15] while many studies taken short-term periods of IAQ monitoring [10][11][12][13][16][17][18][19]. Table 2 shows a summary of the main findings and recommendations or future work.

Table 2: Summary of main findings

Factor	Practice Observed	Recommendation/Future Work
Characteristics of location	Many of the studies about 33 % focused on suburban area rather than urban area and rural area.	Conduct more IAQ study on urban area as urban area wider of the pollutant
Instrumentation	More than 50 % of the studies used expensive instruments as it more accurate for monitoring. 30 % of the studies used low-cost instruments	The using of low-cost instruments need to investigate deeply to overcome the costs in IAQ monitoring in buildings
IAQ parameters	More than 90 % of the studies on temperature and relative humidity as the important factors of thermal comfort	Further study on IAQ parameters mush be conduct such as ozone, VOCs, formaldehyde and others particulate matters
Timeframe of IAQ monitoring	Various periods of IAQ monitoring depends on parameter from less than 12 hours, a day, a week, 5 months and 10 months.	Identify the minimum timeframe requirements for the IAQ monitoring, so the study would be more relevant

3.3 Studies of IAQ parameters perusal with guidelines on university libraries in Malaysia

Table 3: Perusal of physical parameters and chemical parameter by previous studies on indoor air quality of university library in Malaysia

	University Library	Legend	Physical Parameters		Chemical Parameters			Ventilation System
			T (°C)	AV (m/s)	RH (%)	CO_2 (ppm)	CO (ppm)	
[10]	Information Resource Centre (RCI), Universiti Teknologi Petronas	**A1**	23.04	NS	57.05	580.50	NS	Mechanical
[11]	Engineering Campus Library (USM)	**A2**	23.74	NS	62.26	436.77	0.59	Mechanical
[12]	Universiti Malaysia Pahang (Gambang) Library	**A3**	23.59	0.23	53.78	984.00	NS	Mechanical
	IIUM Kuantan Indera Mahkota Campus Library	**A4**	23.37	0.21	68.57	471.83	NS	Mechanical
	Universiti Malaysia Pahang (Pekan) Library	**A5**	23.28	0.16	68.41	415.33	NS	Mechanical
[13]	Universiti Tenaga Nasional Library	**A6**	22.60	0.12	70.11	694.80	NS	Mechanical
[14]	Library TP	**A7**	21.00	NS	71.70	NS	NS	Mechanical
	Library SA	**A8**	26.3	NS	64.30	NS	NS	Mechanical
	Library TH	**A9**	24.70	NS	74.4	NS	NS	Mechanical
[15]	Sultanah Zanariah Library, Universiti Teknologi Malaysia	**A10**	24.53	0.12	62.19	685.00	0.66	Mechanical
[16]	University of Malaya Main Library	**A11**	22.43	NS	58.33	NS	NS	Mechanical
[17]	Tun Abdul Razak 1 Library, UiTM Shah Alam	**A12**	23.90	NS	69.00	NS	NS	Mechanical
[18]	Hamzah Sendut II Library	**A13**	30.00	NS	50.7	NS	NS	Mechanical

	(Universiti Sains Malaysia)						
	Hamzah Sendut New Library (Universiti Sains Malaysia)	**A14**	26.6	NS	54.80	NS	NS	Mechanical
[19]	University Malaysia Sabah Library	**A15**	NS	0.25	NS	NS	NS	Mechanical

*NS= Not stated, T= Temperature, AV= Ais speed, RH= Relative Humidity, CO₂= Carbon Dioxide, CO= Carbon Monoxide

3.4 Findings of IAQ parameters with guidelines.

3.4.1 Temperature and Relative Humidity

Figure 1 shows data from the reading of average temperature inside the university library building within range of 21.0 to 30.0 °C. According Industry Code of Practice (ICOP) the acceptable range of temperature for a university library range is 23.0 to 26.0 °C. From the graph, all university library has acceptable reading of average temperature except for three libraries which is A8, A13 and A14 that exceeding the maximum range of 26.0 °C [14][18][18]. These libraries exceeding the acceptable range of temperature which is 26.3 to 30 °C recorded. The higher temperature of the library might be effected by hot and humid climate in Malaysia which has high daytime temperatures throughout the year [20]. The reading of average temperature of A13 is highest due to the sunlight radiation where the sunlight consists of heat energy can cause the surface temperature of the building rises [18]. Meanwhile, three libraries were identified has lower average temperature than minimum range of temperature provided by ICOP (2010) which is 23.0 °C, where both A6, A7 and A11 have reading of average temperature was 22.6 °C, 21.0°C and 22.4 °C [13][14][16]. Next, the acceptable range of temperature for educational buildings that proposed by American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE-55, 2017) is 10.0 °C to 40.0 °C. The graph shows all university libraries has acceptable reading of temperature that considered by ASHRAE-55 guidelines.
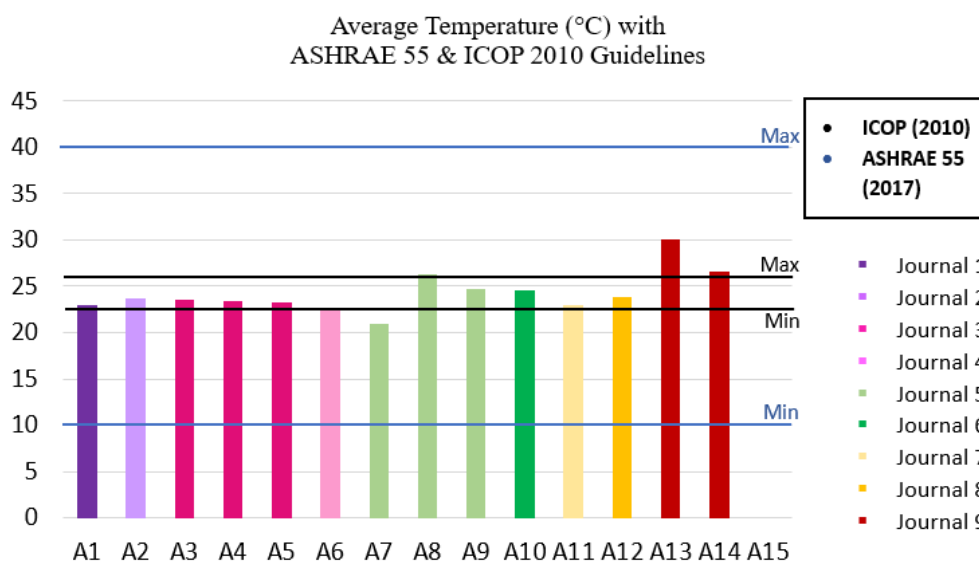

Figure 1: Average temperature for a university library with ASHRAE-55 and ICOP 2010 Guidelines

Figure 2 presented the data of average relative humidity in a university library in the range of 50.7 % to 74.4 %. The ICOP 2010 proposed that acceptable value in range of 40.0 % to 70.0 %. As a results of comparison the value of average relative humidity for a library with ICOP 2010, there are three libraries (A6, A7 and A9) that has value exceeded the range that proposed by ICOP (2010) where 70.1 %, 71.7 % and 74.4 % [13][14][14]. Past studies identified that some occupants found comfort at higher relative humidity (more than 80.0 %) that happened because of acclimatization of occupants to their environmental conditions [21]. However, too high or too low relative humidity can lead to problems of the indoor air quality of the buildings library [10]. Meanwhile, Hamzah Sendut II Library (A13) of Universiti Sains Malaysia have the lowest reading of average relative humidity which is 50.7 % compared to others university library [18]. According to ASHRAE 55 guidelines that considered the acceptable perusal of relative humidity which is in range of 25.0 % to 95.0 %. From the graph, it shows that all university library has acceptable range of relative humidity.
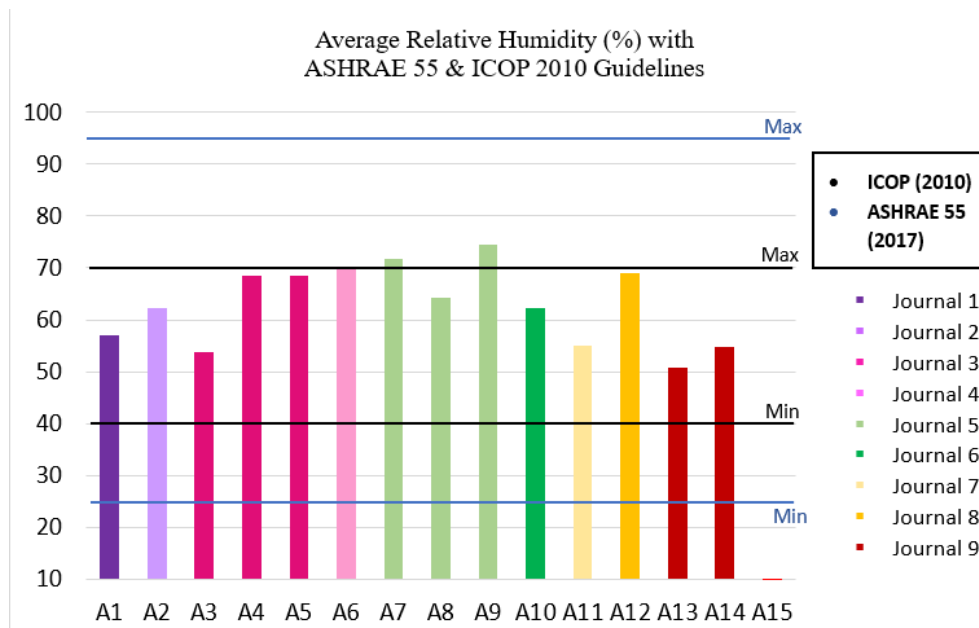

Figure 2: Average relative humidity (%) for a university library with ASHRAE-55 and ICOP 2010 Guidelines

3.4.2 Carbon Dioxide (CO)

Research noted that average perusal for concentration of carbon dioxide (CO_2) was range in 415.33 ppm to 984 ppm shown in Figure 3. This value is below the maximum acceptable limit of ICOP 2010 and ASHRAE 62.1 (2016) guidelines which is 1000ppm. The graph shows highest level concentration of CO_2 among seven university libraries was A3 which is 984 ppm compared to others libraries. Although the level concentration of CO_2 in A3 below the maximum acceptable range of ICOP 2010 and ASHRAE 62.1, it is not possible that the concentration of carbon dioxide can reach the maximum acceptable limit of the guidelines [18]. The value average concentration of CO_2 in A3 was approaching the maximum value proposed by guidelines due to the high occupancy of the users in the library and was located near to actively engaged highway [12]. The higher perusal of CO_2 is a benchmark for the lack of fresh air from outdoor which may result in a feeling of stuffiness [15].
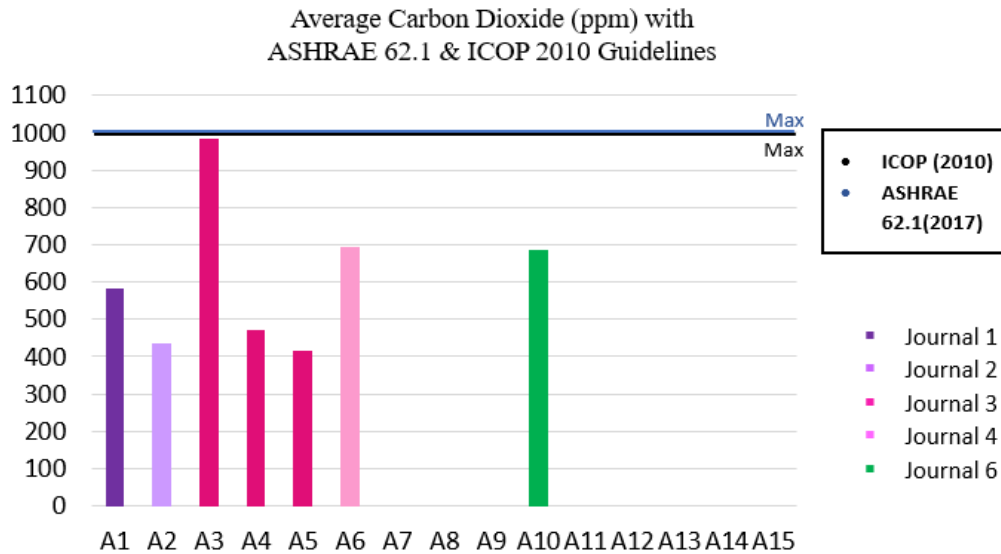
Figure 3: Average carbon dioxide (ppm) for a university library with ASHRAE-62.1 and ICOP 2010 Guidelines

3.5 Correlation data on Findings

The correlation study on this paper were divided three parts correlation collected from previous studies that closely linked to each other. The first correlation data were between characteristics of location and temperature. Second, correlation between relative humidity, temperature and carbon dioxide of the selected libraries

3.5.1 Correlation between Location Characteristics and Temperature

Figure 4 shown the correlation study between characteristics of location and temperature of the eleven libraries where the paper described the location characteristics. All the libraries that involved in characteristics of location were A1, A2, A3, A4, A5, A6, A10, A11, A12, A13 and A14. The maximum acceptable range of temperature that proposed by Industry Code of Practice (ICOP 2010) standards was between 23.0 to 26.0 °C. Based on the bar chart below, Hamzah Sendut II Library (A13) and Hamzah Sendut New Library (A14) were exceeded the maximum acceptable value of temperature where 30.0 and 26.6 °C [18]. Also, both libraries of Hamzah Sendut II Library (A13) and Hamzah Sendut New Library (A14) were located on suburban area. As the suburban area background was busy in traffic and industrial factories, the libraries in suburban area shows the elevated on average temperature [12]. This correlation studies shows that the outdoor environments do give impacts on the indoor air quality in the libraries.
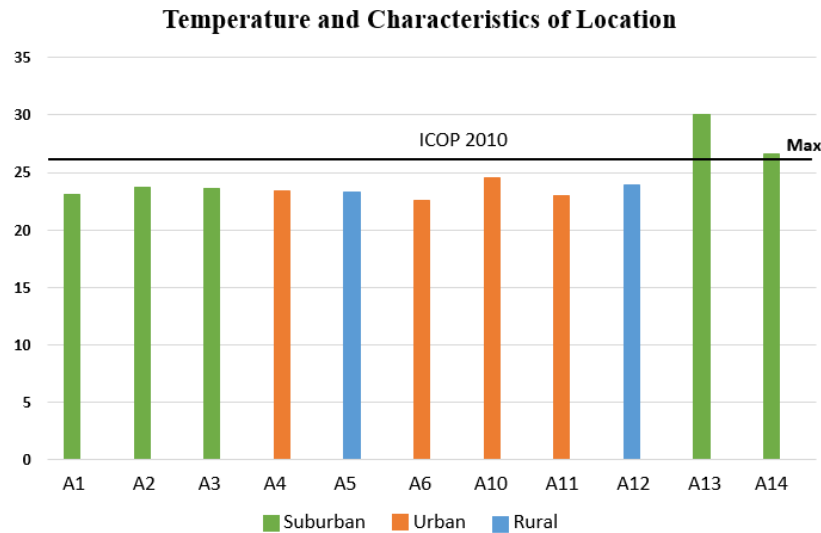
Figure 4: Correlation of temperature and location characteristics

3.5.1 Correlation between Relative Humidity, Temperature and Carbon Dioxide

The correlation study between temperature and relative humidity was closely linked to each other. Figure 5 shows that the correlation value of relative humidity and temperature in fourteen. From the previous data analysed the highest perusal of average temperature amongs the libraries was A13 which is 30.0 °C [18]. The value of temperature in Hamzah Sendut II Library at USM was exceeded the acceptable range between 23.0 to 26.0 °C that proposed by ICOP 2010[4]. The high of temperature in the library due to sunlight radiation where the heat transfers to building walls cause the temperature rises [18]. The relationship between the temperature and relative humidity was when the temperature increases, the relative humidity decreases. This happened when the temperature in library elevated, the air dryness in building also elevated due to the inadequate on humidity in buildings. The hypothesis can be proved as shown the bar chart that the highest value of average temperature on A13, also the lowest value of average relative humidity which is 50.7%. On tropical climates, the elevated of temperature in buildings can cause effect on relative humidity where the excessive on relative humidity or insufficient on relative humidity. The deficiencies of relative humidity was observed can cause the increased of skin and eye dryness [22].
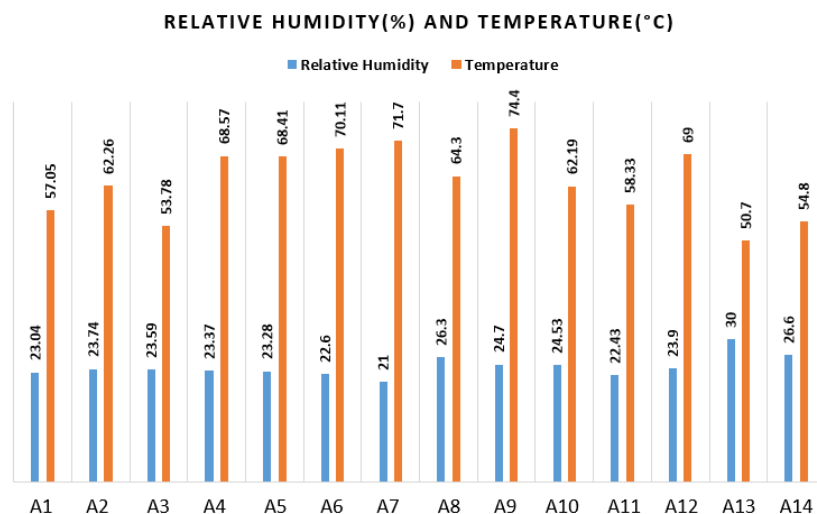

Figure 5: Correlation between relative humidity and temperature

Figure 6 shows the graph of the carbon dioxide (CO_2) concentration versus level of temperature on three libraries where University Malaysia Pahang Library (Gambang), IIUM Kuantan Indera Mahkota Campus Library and University Malaysia Pahang Library (Pekan) were involved [12]. University Malaysia Pahang (Gambang) Library (A3) was the highest concentration in carbon dioxide with 984 ppm. The maximum acceptable range of carbon dioxide concentration by ICOP 2010 and ASHRAE 62.1 was 1000 ppm[4][8]. Although the highest concentration of CO_2 in A3 below the guidelines, the value of CO_2 was approaching the maximum acceptable value that proposed by guidelines. In future, the concentration value of A3 might approached the maximum acceptable value by standards. For the explanation of relationship between carbon dioxide and temperature, the higher the concentration of carbon dioxide, the elevated the temperature in the library spaces. The contribution of higher in carbon dioxide concentration and temperature occurs as the consequences of exhalation by occupation due to windows and door remain closed where all the libraries only used mechanical ventilation [23]. The graph also shows the huge differences on level of carbon dioxide and temperature between A3, A4 and A5. For the explanation of relationship between carbon dioxide and temperature, the higher the concentration of carbon dioxide, the elevated the temperature in the library spaces. The relation between the Hamzah Sendut II Library (A13) [18] cannot be correlate together with carbon dioxide due to the limited of data on carbon dioxide concentration as the author does not required the measurement of CO_2 in the studied.
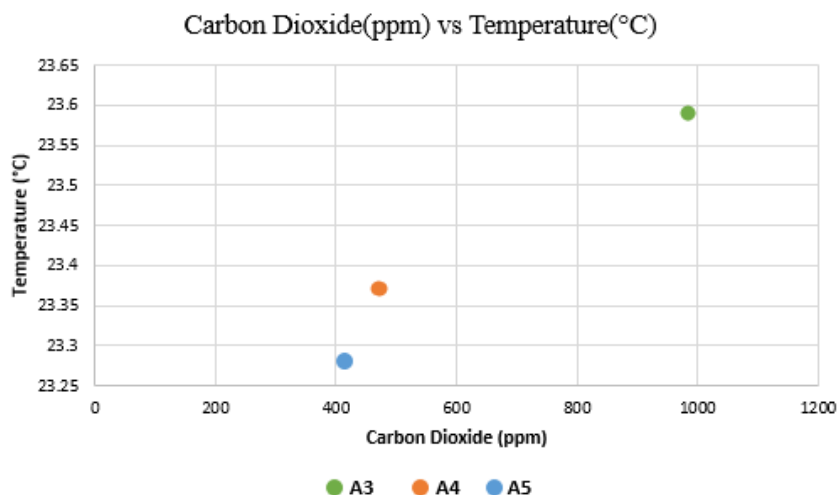

Figure 6: The graph of Carbon Dioxide versus Temperature of three libraries

4. Conclusions

This research has justified the importance of indoor air quality in university libraries buildings by dragging together the relevant correlation between the findings. The problems of the elevated temperature, relative humidity and carbon dioxide in the library spaces and the location characteristics were identified. Since people like students and staff spend most of their time in indoor spaces in university libraries, the acceptable of indoor air quality in educational buildings was important to ensure the health and comfort of occupants. At the end of research, the correlation studies shows that the outdoor environments do give impacts on the indoor air quality in the libraries as the suburban area background was busy in traffic and industrial factories, the libraries in suburban area shows the elevated on average temperature, CO_2 concentration approaching maximum level and insufficient humidification. This correlation studies shows that IAQ in buildings was influenced by the outdoor environments. The evidence from past studies that many researchers run the assessment of indoor air quality every year, proves the IAQ an important topic to be discussed. Besides, a larger sample of previous studies with libraries is required to represent a well-defined study on indoor air quality of educational buildings in Malaysia. Sample size is an important consideration for research such as future

researcher can review on IAQ in university libraries with others chemical parameters such as ozone, volatile organic compounds and microbiological parameters.

Acknowledgement

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