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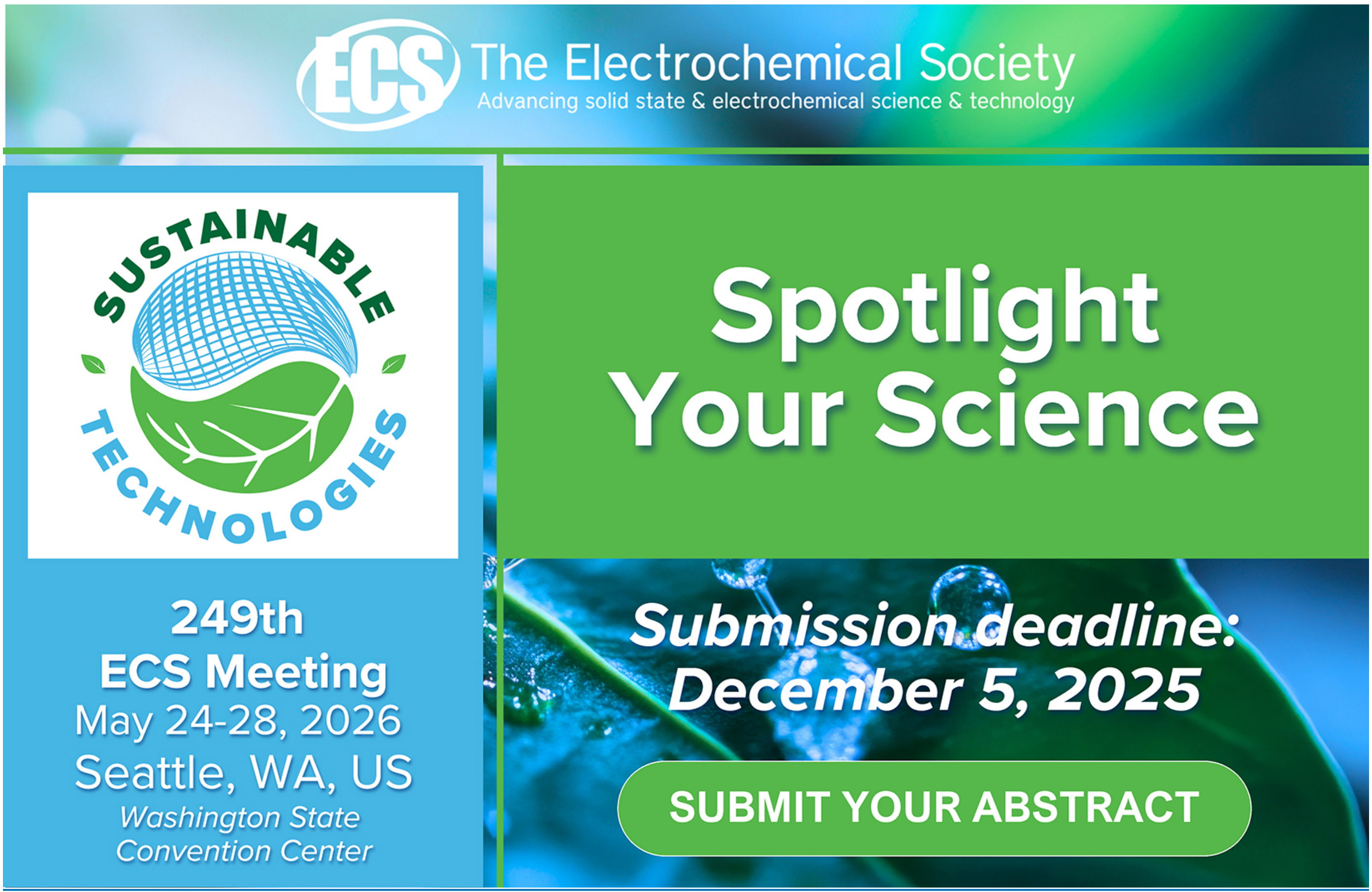

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Improving Indoor Environmental Quality (IEQ) and Comfortability of Lecture Rooms: Case Study – UniCITI Alam Campus, Padang Besar, Malaysia

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Abstract. UniCITI Alam is a mixed development of commercial buildings and medium rise apartments. The whole development was designed based on the integration of student residential community with the combined commercial centre and temporary campus. The lecture rooms are located at the second floor of the triple-storey shop house. To improve the indoor environmental quality and comfortability of the teaching and learning activities, physical measurements of the indoor environment parameters (air temperature, relative humidity and carbon dioxide (CO_2) concentration) and light intensity are the main methods applied in the presented case study. Data collected will be compared with Malaysian Standard MS 1525: 2007 (Code of Practice on Energy Efficiency and Use of Renewable for Non Residential Building) and DOSH. The finding will be used for improving the environmental quality of the lecture rooms and enhancing the ecology circle.

1. Introduction and Background Information

UniCITI Alam is a mixed development of commercial buildings and medium rise apartments. It is located at the coordinate 6°38'58.4"N latitude and 100°15'23.6"E longitude. The whole development was designed based on the integration of student residential community with the combined commercial centre and temporary campus.

The design of lecture rooms in the UniCITI Alam is actually a refurbishment of the commercial building. The lecture rooms are located at the second floor of the triple-storey shop house (refer to Figure 1). There are sixteen (16) lecture rooms and two (2) lecture halls with a slightly different in sizes of the floor areas. One side of each lecture rooms is made of a curtain wall. All curtain walls are tinted with black films and covered by the white boards most of the wall area (refer to Figure 2 and Figure 3). Only four lecture rooms have windows at the corner side. All lecture rooms have been designed by not allowing natural ventilation and natural lighting to enter the rooms.

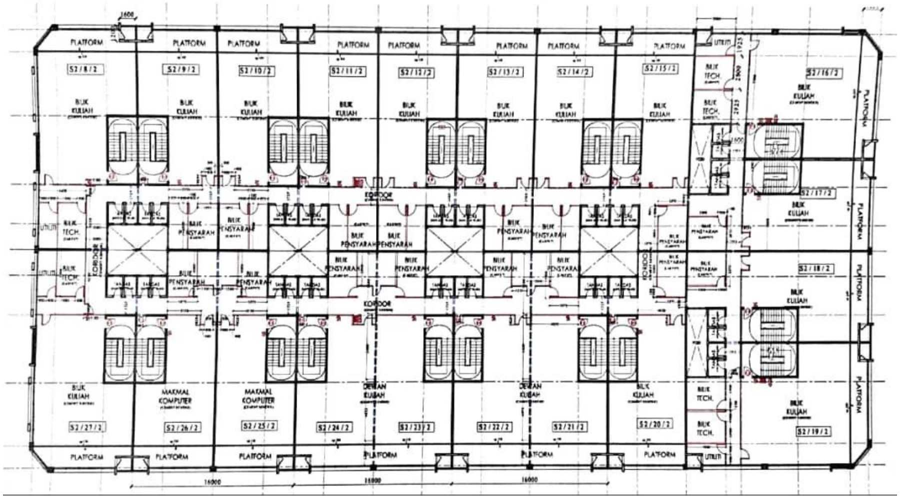

Figure 1. Floor plan of second floor of the triple-storey shop house.

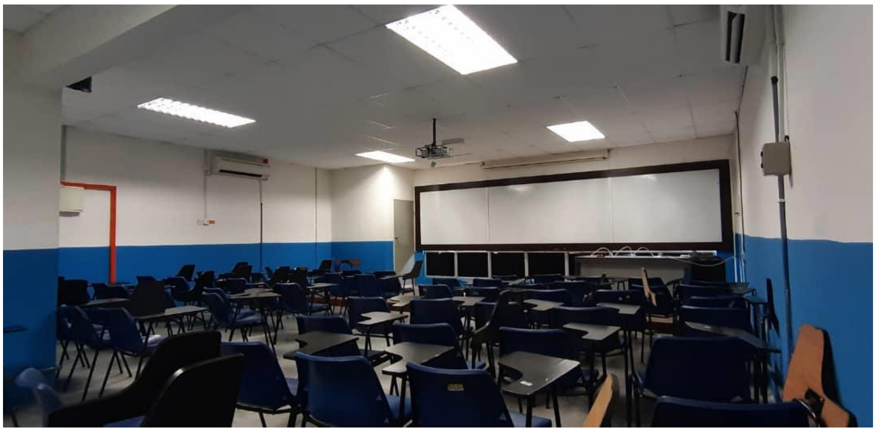

Figure 2. Lecture room with artificial lights without occupants.

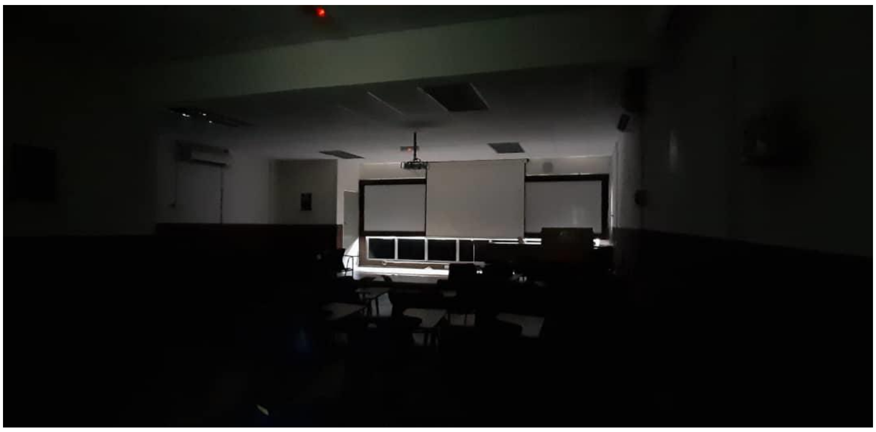

Figure 3. Lecture room with natural lighting without occupants.

2. Problem Statement

Many aspects shall be considered for the improvement of indoor environmental quality (IEQ) and comfortability of the lecture rooms such as indoor temperature, relative humidity, level of carbon dioxide and the light intensity. Stuffy and dark lecture rooms may not be suitable to create a comfort environment for teaching and learning activities. Since all the lecture rooms have been 'sealed', each of the lecture rooms have been equipped with air conditioners as a cooling system and artificial lighting as a source of light. This approaches are not the best solutions and for the long term investment, high expenses of the electricity bills may not return the high profit to the university.

After a certain period of time, if the mechanical cooling technologies like air conditioning system cannot work properly, it will affect the temperature and air quality of the lecture rooms. Poor level of indoor environmental quality in the lecture rooms will create discomfort environment and the students feel difficulty to stay focused during lecture. It may also lead to Sick Building Syndrome (SBS).

3. Literature Review

According to Asere & Blumberga [1], spaces with high occupant density, e.g. in schools, conference rooms, offices, etc., are the main indoor pollutants with CO_2 and volatile organic compounds (VOCs), and air tight building envelopes contribute to a high degree of unacceptable IEQ. Mechanical ventilation systems have to be used to improve indoor environmental quality in buildings where adequate natural ventilation is not available. Such systems increase energy consumption with an assumption improving IEQ and thermal comfort but human productivity are not consistent with energy efficiency [1]. Studies show that the poorer the IEQ, the lower the human productivity (a 15% reduction in performance of schoolwork corresponds to about 1 year of teaching [2]. While Griffiths & Eftekhari [3] mentioned that the increased level of CO_2 has an impact on the students' ability to learn and it decreases this ability by 5%. Apart from IEQ, there have been articles studying a combination of thermal comfort along with the lighting factor [4].

3.1. Air Temperature

Refer to ASHRAE [5] air temperature is the average temperature of the air surrounding an occupant. MS1525:2007 recommended comfort temperature for Malaysia weather is 23ºC - 26ºC. Accordingly, room comfort conditions not only depend on air temperature but also mean radiant temperature, humidity, clothing, metabolic rate and air movement preference of the occupant [6].

3.2. Relative Humidity (RH)

DOSH [7] proposed the ideal comfort goes for relative dampness is 40-60%. While MS1525:2007 recommended RH 55% - 70%. Low humidity can bring about dryness of the eyes, nose and throat and may likewise expand the recurrence of friction based electricity stuns. High humidity, over 80% can be connected with weakness and report of "stuffiness" [7].

3.3. Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is the most widely recognised indoor air contamination discharged by individuals. The levels of CO_2 indoor are reliant upon the quantity of individuals present and level of metabolic movement completed inside the air space. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard suggests greatest level of 1000 ppm for nonstop CO_2 presentation [8]. CO_2 is a key parameter for surveying indoor air quality and ventilation productivity. The ventilation that has deficient outside air admission can contribute to an abnormal state of CO_2 in certain region in the building. A ventilation rate of 10 Ls^{-1} to 20 Ls^{-1} for every individual will diminish the side effects of sick building syndrome (SBS) and achieve a superior air quality [9]. The concentration of carbon dioxide is strongly related with occupant density as well as the type of activity carried out [10]. Common effect of staying in a space with high concentration of carbon monoxide is feeling headache, sleepy and drowsy.

3.4. Light Intensity

Good lighting also creates a pleasant atmosphere and gives occupants a sense of well-being. This can improve their productivity and efficiency. Poor lighting can lead to visual fatigue and discomfort. It can affect the health of people at work causing symptoms like eyestrain, migraine and headaches [7]. According to DOSH [7], lecture hall and interior area for writing, typing, reading, and data processing, lighting must be 500 Lux. They also recommended ceilings and walls should be painted white or in a light colour.

4. Methodology

All experiments were conducted at lecture rooms in building S2-L2 in UniCITI Alam Campus at Padang Besar, Malaysia. There were four (4) experiments conducted; temperature, relative humidity, CO^2 and light intensity. The readings were recorded between 12.00 pm to 7.00 pm by using two instruments which were 5-in-1 Environmental Meter and Indoor Air Quality CO^2 Monitor.

5. Result and Finding

Table 1. Temperature, Relative Humidity, Carbon Dioxide and Light Intensity readings in lecture rooms with and without occupants.

Lecture Room	No of Occupants	Temperature (ºC)		Relative Humidity (%)		Carbon dioxide (ppm)		Light Intensity (Lux)	
		with occupants	without occupants	with occupants	without occupants	with occupants	without occupants	with occupants	without occupants
Lecture Room 1	40	24.93	29.53	57.72	48.53	402.67	1591.67	203.67	269.33
Lecture Room 4	35	24.75	29.87	53.08	47.42	387.00	2707.33	189.00	258.00
Lecture Room 9	40	27.57	29.48	64.40	54.35	440.67	933.00	258.33	275.00
Lecture Room 10	60	26.33	29.37	45.93	48.53	504.67	3004.33	162.33	201.33
Lecture Room 12	60	28.03	31.56	55.32	40.85	500.33	2002.67	270.33	274.67
Lecture Room 14	60	27.20	28.43	56.28	43.22	415.33	2031.00	255.67	280.33
Lecture Hall	65	27.28	28.05	56.40	43.32	384.33	1223.00	130.33	277.67

Table 2. Temperature, Relative Humidity, Carbon Dioxide and Light Intensity readings suggested by DOSH and MS1525:2007.

Suggest by	Temperature (ºC)	Relative Humidity (%)	Carbon dioxide (ppm)	Light Intensity (Lux)
DOSH	20ºC - 26ºC	40-60%	1000 ppm	500 Lux
MS1525:2007	23ºC - 26ºC	55% - 70%	-	300 – 500 Lux

Temperature readings from all lecture rooms show that they did not met the comfort temperature set by DOSH and MS1525:2007 when there were no occupant. Result without occupants temperatures were higher compared to with occupants because the air conditioners were turned off when they were left unoccupied. However, when the occupants more than 40, the temperature readings were not comfort to the occupants. The RH still in the acceptable range when refer to DOSH. All the data taken show that without occupants they were below the range suggested by MS1525:2007. The CO^2 readings taken during no occupant were reliable for all lecture rooms in the range between 384.33 ppm to 504.67 ppm. However, CO^2 readings taken during teaching and learning sessions mostly exceed the acceptable limit. The level of CO^2 depends on the number of occupants and also the activity carried out in that place. CO^2 is key parameter for indoor air quality and ventilation efficiency. Insufficient fresh air contributes to high level of CO^2 in certain rooms (Yau, Chew et. at., 2012). CO^2 cannot be removed by present air cleaning system, that's why ventilation very important for more comfortable indoor environment (Noh, Han, et. al., 2008). Based on the experiments conducted, they showed that there were big difference between CO^2 reading during with and without occupant. This is because the CO^2 produced by human beings. The average readings of light intensity were in the range 200-300 lux. The readings were taken in the conditions of artificial lightings on. The distance of the light sources to the instrument placement were same for all lecture rooms. The distance was in the same level of the ceiling high and the desk used by the students. The types and position of light sources were also same for each lecture room. The presence of occupants may affect the light intensity during teaching and learning sessions compared to without occupant. However, the source of artificial lighting still insufficient for writing, typing, reading, and data processing.

6. Conclusion

A study based on air temperature, relative humidity, level of carbon dioxide and level of light intensity had been made to improve indoor air quality and comfortability in the lecture rooms at UniCITI Alam Campus. Room temperature and RH in the lecture rooms can be improved. Frequent maintenance and services for air conditioners should be done in order to achieve the comfort temperature for the occupants. The level of carbon dioxide were in unacceptable condition and could affect the occupants and contribute the sick building syndrome. The level of light intensity in the lecture rooms were not sufficient and required an improvement for comfortability to the occupants. In conclusion, the lecture rooms at UniCITI Alam Campus need a major improvement in order to achieve good indoor environment quality and increase comfortability to the occupants. Staying long hours in the lecture room can lead to dryness of the eyes, nose and throat, eyestrain, migraine and headaches. Conducive teaching and learning environment can help the students to increase their performance.

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