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Exploring Indoor Environmental Comfort in Pagoh Residential College (KKKP)

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Abstract

Indoor environmental quality (IEQ) refers to the overall quality of the indoor environment and its impact on occupant health, comfort, and productivity. In recent years, there has been a growing recognition of the importance of IEQ in buildings, as research has shown that poor indoor environments can lead to various health problems, including respiratory issues, allergies, and even cognitive impairment. The aim of this study is evaluating the Indoor Environmental Quality (IEQ) in the student residential college at UTHM. From the study shows that the student residential college at UTHM, the measurement time taken for each parameter is different but still concentrated at night. The data was obtained with the standard used in Malaysia. For thermal comfort, our country has used ASHRAE Standards. For lighting comfort and sound comfort parameters, it has used Standard MS1525:2014 and standard from the Department of Environment Ministry of Energy, Science and Climate Change (MESTECC) to refer to the level of comfort in a place or a building. One key aspect of IEQ is air quality, as indoor air pollution can be a major concern in buildings that are poorly ventilated or have sources of contamination such as mold, chemicals, or volatile organic compounds (VOCs). Poor indoor air quality can also affect cognitive function and productivity, as research has shown that high levels of CO2. Another important aspect of IEQ is thermal comfort, as the temperature and humidity levels in a building can significantly impact occupant comfort and well-being. Buildings that are too hot or too cold can lead to discomfort, decreased productivity, and even health problems. Lighting is another crucial element of IEQ, as natural and artificial lighting can affect both physical and mental health. Natural light has been shown to improve mood, productivity, and overall well-being, while poor lighting can lead to eyestrain, headaches, and fatigue. Last but not least, sound comfort plays a key role in IEQ, as excessive noise levels can lead to stress, fatigue, and decreased productivity. Buildings that are poorly insulated or located near noisy sources can create a disruptive environment that negatively impacts an occupant's well-being.

1. Introduction

Residential hostels are essential for students who live far away from their homes for a long time. According to [1], a student hostel is a place where students can unwind and sleep after studying for an exam while socializing with other students. The key variables determining how satisfied students are with their hostel are university amenities, room size, safety, security, and amenities [2]. Hostel services also help students enhance their perspectives and understanding of disciplines [3]. Furthermore, students also need a conducive indoor environment to carry out their learning activities. The indoor environment can affect the productivity, concentration, health and comfort of students. This problem is identified as the indoor environment quality (IEQ) that can prevent unwanted mental health issues and promote the overall mental health and well-being of students [4]. This IEQ focuses on four types of parameters, namely Indoor Air Quality (IAQ), thermal comfort, lighting comfort and sound comfort.

In general, Indoor air quality (IAQ) has a bigger impact on human health. Inadequate or less ventilation around the area in the room or the house is categorized as poor air quality. Whereas acceptable air quality is defined as "water in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" [5].

Thermal comfort performance factors are listed as temperature, velocity, and relative humidity. Table 1 below shows the ASHRAE standard readings for the three environmental thermal comfort factors.

Table 1 *Standard ASHRAE for Thermal Comfort*

Thermal Comfort	Standard ASHRAE
Temperature	**Ideal temperature -** 20°C and 25°C (68°F and 77°F)
	Temperature with fan - 27.2ºC and 28.2ºC
Velocity	01 m/s to 2.0 m/s.
Humidity	**Indoors -** 40-70% RH
	Pantry - 45% and 65%
	Bathroom - 30% to 60%

The third element is lighting comfort which includes natural and artificial lighting. Lighting is the most essential aspect of visual comparing user pleasure, comfort, and a pleasing lighting design should offer occupants with a healthy and comfortable visual environment that supports their daily activities [6]. An effective natural lighting system depends on several factors, including the building's location, the surrounding environment, the building's architectural characteristics, and the lighting requirements in certain areas [7]. Table 2 shows the Malaysian Standard, MS 1525:2014 is the standard that is used to compare the lighting levels.

Table 2 *Standard for Lighting Comfort*

Lighting Comfort	Standard MS 1525:2014
Room/Space	300 lux
Bathroom	150 lux
Pantry	150-300 lux

The last parameter is the term "sound comfort" refers to the sense of well-being and happiness acquired from the auditory environment. Sound criteria cover the ambient level of sound, the transmission of sound between areas and rooms, reverberation and specific areas, such as machine noise and auditorium acoustics [8]. A noise problem that often occurs is the sound of vehicle exhaust is so loud that it can cause students to feel disturbed, especially at night. The standards that are used to compare the noise level are the recommended noise level from the Ministry of Energy, Science and Climate Change (MESTECC) as shown in Table 3.

Table 3 *Standard for Sound Comfort*

Sound Comfort	Recommended Standard
During the day	60 dB
At night	55 dB

Thus, this study aims are to identify the Indoor Environment Quality (IEQ) parameter and its importance to the occupant. Next, to measure IEQ level in student residential college, UTHM Pagoh. Besides, to compare the IEQ level with the respective standard. Furthermore, the scope of this study mainly focuses on Indoor Environmental Quality (IEQ) in Pagoh Hostel Residential, UTHM Pagoh. It will be conducted on one house unit with the same orientation on the ground floor and upper floor. Measurements of IEQ will be focused on the evening and at night.

This is because, at that time, the majority of students were in the hostel. The parameters taken in this study are thermal comfort, lighting comfort and sound comfort. The parameter excluded from this study is Indoor Air Quality (IAQ) because it was assumed that the reading was the same in Malaysia. According to [1], for residences, it is acceptable if indoor air pollutants are kept at a minimum level and controlled. It is unacceptable if the amount exceeds the minimum level. Therefore, it is reasonable that students are not possible to store pollutants in the hostel. Normally, these pollutants will be stored in a room provided and separate from the student hostel residential block. Table 4 shows the reading maximum concentration allowed for some indoor air pollutants [9].

Table 4 *Maximum concentration allowed for some indoor air pollutants (Orola, 2020)*

Contaminant	Maximum allowable concentration
Particulate (PM2.5)	35 mg/m3 (24-hr)
Carbon monoxide (CO)	9 ppm (parts per million) (8-hr)
Carbon dioxide (CO2)	1000 ppm (parts per million)

2. Materials and Methods

The observation took place at Block A17, Pagoh Residential College. The data was collected at one unit house on the 1^{st} Floor and 4^{th} Floor. Data observations were conducted since 22 March 2024. The data was recorded manually using an IAQ monitor, 4-in-1 meter, lux meter and sound level meter (SLM). The measurement methods for these instruments are shown in Table 5.

Table 5 *IEQ Measurement Method*

IEQ Element	Instrument	Procedures
Thermal Comfort	4-in-1 Meter 	1. The reading times are 10 a.m., 1 p.m., 4 p.m., 8 p.m., and 10:30 p.m. for all the rooms in the house on the first and fourth levels. 2. 4 in 1 meter is held while standing in the middle of the room and the curtains on the windows and fans are left open. 3. The data has been taken three times for each room to make the data more accurate. 4. Read the measurement value displayed on the meter's screen. 5. Record the result.
Lighting Comfort	Lux Meter 	1. A single reading is taken throughout the data collection process. 2. For the measurement of ceiling lamp lighting levels, the lux meter is placed in 3 different positions within the room and spaces inside the house at 0.8 meters from the floor. 3. Data were recorded in a table for lux meter readings in every room and space. 4. Readings are taken by placing the lux meter on each study desk in every room. 5. Data were recorded in the table of lux meter readings on each table of every room.
Sound Comfort	Sound Level Meter (SLM) 	1. Three readings were taken three times to get the average in a room and spaces. 2. The sound level meter was held in the middle of the room to take the readings. 3. The values displayed on the screen of the tool were read and recorded.

3. Results and Discussion

Data analysis for indoor environmental quality (IEQ) involved an in-depth examination of the collected data of three parameters which were thermal comfort, lighting comfort and sound comfort using graphical representations. The analysis of thermal comfort data was scrutinized to identify the temperature, humidity level and air velocity also using time-series graphs. Other than that, lighting comfort parameters involved the assessment of illumination levels through the use of histograms to determine compliance with recommended standards and sound comfort was evaluated by analysing and identifying the noise level in a hostel and comparing it with a used standard in Malaysia.

3.1 Thermal Comfort

Thermal comfort involves natural ventilation and other physical environmental elements. Malaysia has used ASHRAE standards as a reference as shown in Table 1. Thermal comfort has three factors, which are temperature, velocity and humidity.

3.1.1 Temperature

The temperature reading for a room or space is very important to guarantee the comfort of the occupants in that place. The graph presented in Fig. 1(a) shows the average temperature readings taken in the house on the 1st Floor and 4th Floor. House B107 represents the 1st floor and house B406 represents the 4th floor. The x-axis represents the time taken. The y-axis shows the average temperature. Based on Figure 1(a), the temperature in house B107, in the morning is 30.05ºC, at noon 30.85ºC, and evening 29.4ºC. At night 27.75ºC and midnight 27.8ºC. Next, in the B406 the temperature in the morning 27.32ºC, noon 28.7ºC and evening 28.17ºC. While the temperature at night 27.33ºC and midnight 28.05ºC. From the results, the 4th floor has a lower temperature reading than the 1st floor. Usually, a higher level in a building will make it easier to receive more sun. This is because the level does not have many obstacles for sun to enter the room through the available space. This upper floor also easily gets sun because of the wide windows opened by every room in the house. The temperature reading for the 1st floor shows the highest temperature reading is due to the obstruction of the adjacent building.

In the discussion according to the standard, the graph in Fig. 1(a) will be compared with the standard used in Malaysia which is the ASHRAE Standard in Table 1. For temperature, the ideal temperature range is between 20°C and 25°C (68°F and 77°F). Based on the temperature results, the temperature for both levels is higher than the ideal room temperature. But the temperature range with the fan is between 27.2ºC and 28.2ºC. Referring to the standard temperature range with a fan, at house B107 in the morning, noon, and evening, it does not follow the standard, while at night and midnight, it still follows the standard. Furthermore, for house B406, the readings that do not follow the standard occur in the afternoon and evening. The morning, night, and midnight are still according to the standard. If the temperature does not follow the standard, it can affect the level of comfort of the students living in the house, so it can interfere with daily activities. But at night, the temperature still follows the standard temperature range with a fan. Therefore, it does not have a big impact on students' comfort at night and allows students to sleep more comfortably.

3.1.2 Velocity

The graph in Fig. 1 (b) shows velocity measurements made in each room of house B107. Each room in the house is represented by its x-axis. The y-axis displays the average velocity reading for all rooms. Each room's reading velocity varies, as shown in the graph below. The B107 and B406 show similar patterns of velocity variation throughout the day, with fluctuations occurring at the same times. In this case, the pantry and bathroom in both buildings have no velocity throughout the day. Firstly, the average air velocity at B107 has a slightly higher velocity compared to B406 which is 1.96 m/s > 1.88 m/s. Next, the average air velocity of Room B at B406 is higher than Room B at B107, 1.28 m/s > 1.16 m/s. Moreover, Room C's average air velocity in B406 is higher compared to Room C's average air velocity in B107. Besides, for Room D, at B107, the average air velocity is 1.34 m/s, which is more than the average air velocity at B406, 1.1 m/s. Last but not least, the average air velocity of the pantry and bathroom is maintained at 0 m/s in both houses.

Furthermore, based on Fig. 1(b), velocity is different between levels 1 and 4. This is because level 4's air velocity makes entering the area easier than level 1. Furthermore, the velocity in the afternoon is lower than at night. The optimal velocity range is 0.1–2.0 m/s. The pantry and bathroom have zero velocity at both levels because they are deeply closed spaces, like those found in properly insulated buildings or rooms with closed windows and doors, a lack of ventilation, and no air exchange with the outside environment.

3.1.3 Humidity

The "Average Relative Humidity on Each Room" bar chart shows the average relative humidity percentage (%RH) in various rooms for two different identifiers, B107 and B406 as shown in Fig. 1(c). The bathroom has the maximum relative humidity for B107 and B406, with B107 slightly higher than B406. This space has the highest humidity levels for both B107 and B406, which is typical due to the presence of moisture from activities such as showering. The humidity levels in other rooms are relatively consistent, with differences between B107 and B406 generally ranging between 1.5%RH to 2% RH. The lowest humidity is in room A (B107) which is 60%RH because the room might have increased ventilation, with open windows or exhaust fans bringing in drier air from outside. In addition, room A is the largest room in this house so it might experience lower humidity levels due to the increased volume of air, which dilutes the moisture content. For room A, the average relative humidity is 70.36 % RH in B107, and the average relative humidity is slightly higher at 70.84 % RH in B406. The relative humidity of Room B(B107) is 69.06 % RH, and the relative humidity of room B (B406) is 71.06 %RH. Besides, the relative humidity of Room C for B107 is 69.98 % RH, while the relative humidity of Room C for B406 is 70.84 % RH. The relative humidity of Room D at B406 is higher than room D at B107, which is 70.46 % RH > 70.14 % RH. Other than that, the relative humidity of the pantry at B107 is 70.56 % RH meanwhile at B406 is 72.26 % RH.

Finally, the Health and Safety Executive recommends maintaining relative humidity indoors between 40 and 70%. Furthermore, the recommended humidity for a pantry is between 45% and 65%, whereas the humidity in a bathroom should be between 30% and 60%. Because the bathroom is a place where people shower and wash, the humidity results are provided at the maximum level possible. Based on the data on Fig.1 (c), this data can show how humidity levels change throughout the day in various regions of the house. Low humidity can cause skin, lip, and mucous membrane dryness, which can be both annoying and uncomfortable. Meanwhile, high humidity can encourage the growth of dust mites, germs, and other indoor air pollutants, exacerbating respiratory issues.

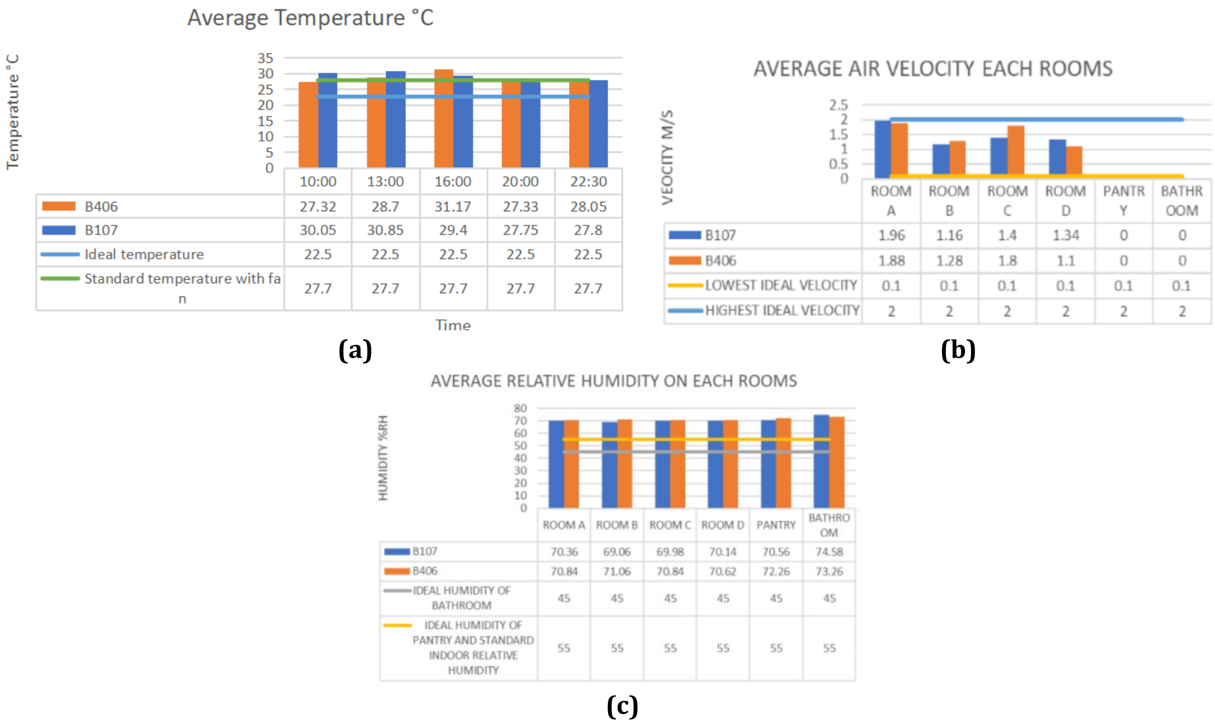


Fig. 1 *Average Thermal Comfort (a) Average Temperature (°C); (b) Average Velocity (m/s); (c) Average humidity (RH)*

3.2 Lighting Comfort

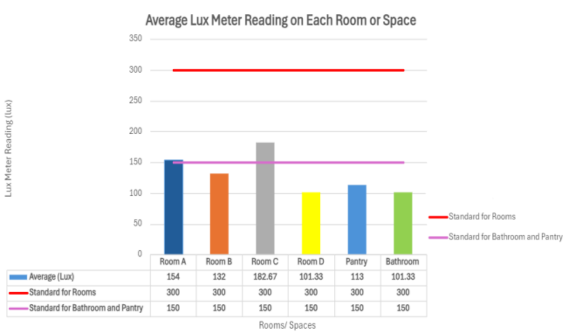
Lighting comfort comprehends natural and artificial lighting that contributes to the occupant's well-being and enjoyment. The standard that Malaysia has been referring to is Malaysian Standard MS 1525:2014 as shown in Table 2. This graph shows the average lux meter readings taken in six different rooms or spaces in a house at block A17. The measurement was taken in two conditions, first is every space in the house (Room A, Room B, Room C, Room D, Pantry, Bathroom). The second measurement is the light measurement on the table. For room measurements, it was recorded under two ceiling lamps in each space. Fig. 2 shows the result of the average lighting levels for both in spaces and on the table. According to the graph in Fig. 2(a), room A has an average lux meter reading of 154 lux. This indicates that room A is relatively well-lit compared to some of the other spaces but the lighting level in this room is not suitable for tasks that require moderate visibility, such as reading or working on a computer. Room B has an average lux meter reading of 132 lux. This is slightly lower than room A. Room C has the highest average of lux meter readings at 182.67 lx. This makes room C the brightest room among all the rooms and spaces listed. Room D has an average lux meter reading of 101.33 lux. The lighting in room D is sufficient for general tasks but not ideal for tasks that require a high level of concentration or detail. Furthermore, the pantry has an average lux meter reading of 113 lux. This level of lighting is adequate for a pantry, where tasks typically involve finding and retrieving items. The lighting ensures that the space is functional without being overly bright. Lastly, the bathroom has an average lux meter reading of 101.33 which is the same as room D. The level of lighting is not enough as it is quite gloomy for a bathroom to provide enough illumination for activities such as showering. This is because the position of both of the lamps was mostly blocked by the partition wall causing the lighting in the bathroom to be gloomy.

Meanwhile, Fig. 2(b) shows the lighting on tables of each room which are table 1, table 2 and table 3. The readings were taken in every room that has a study table that is room A, room B, room C and room D. In room A, the highest lighting is on Table 3 compared to Table 1 and Table 2. It was found that the lux meter reading on Table 1 was lower than Table 2 and Table 3 with a reading of 113 lux. This disparity between Table 1 and the other two tables suggests uneven lighting distribution within room A. This is because the position of the table was not near the study lamp while Table 2 and Table 3 were under the study lamp on the wall. In room B, the graph shows lighting reading on Table 2 is the highest reading at 197 lux while lighting on Table 3 has the lowest reading compared to Table 1 and Table 2. The reading of Table 3 is 170 lux. The lighting levels across the three tables in room B are relatively close, indicating a more even distribution of light compared to room A. In room C which has the highest average lux meter reading. The highest lux meter reading was on table 3 which is 250 lux while the lowest reading was on table 1 at 132 lux compared to table 2 and table 3. The lux meter reading on table 2 was 212 lux. There is significant variation in lighting levels across the tables, with table 3 being almost twice as bright as table 1. This suggests a highly uneven lighting distribution in room C, with table 3 receiving the most light. Last but not least, the graph shows that the highest reading is table in room D which is table 3 at 162 lux. The lowest reading is table 2 with a value of 124 lux. This is because the position of table 2 was not near or under the study lamp because the lighting level on the tables was lower than table 1 and table 3. The lighting levels in room D are relatively low compared to the other rooms, and there is a noticeable difference between table 3 and the other two tables.

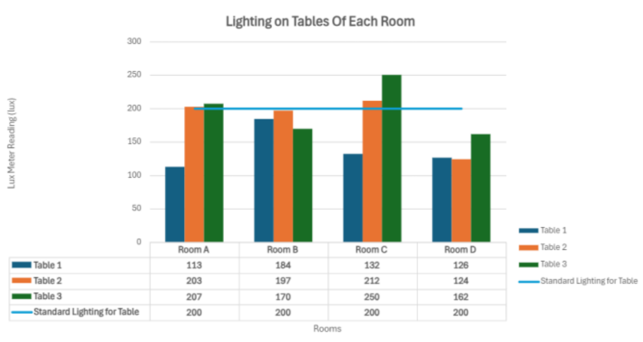
To conclude, the brightest table overall is table 3 in room C with 250 lux and the dimmest table overall is table 2 in room D with 124 lux. Room B has the most even lighting distribution, with the smallest range between the highest and lowest lux readings with 27 lux difference. Room C has the most uneven lighting distribution, with a significant range between the highest and lowest lux readings with a 118 lux difference.

From the data that have been analysed, compared to the standard MS 1525:2014, the minimum average lighting reading that a room should have is 300 lux while the bathroom is 150 lux and the pantry is around 150 - 300 lux. Based on the standard, the average lighting in every room is insufficient as the readings are all under 300 lux in Fig. 2(a). Meanwhile, the average reading of the bathroom and the pantry was also insufficient as the reading shows were below 150 lux. This has shown that the average lighting in every room does not meet the Malaysian standard which leads to showing the rooms do not have good lighting.

Meanwhile based on the analysis of the illuminance level on the tables in Fig. 2(b), according to the Malaysian Standard, MS 1525:2014, the minimum average lighting reading that a table should have is 200 lux. Compared to the standard, the average lighting on the tables of each room is inadequate as most of the readings are all below 200 lux except table 2 and table 3 in room A, table 2 in room B, table 2 and table 3 in room C. This shows that the average lighting reading on tables also does not meet the standard requirement and needs improvement.



(a)



(b)

Fig. 2 *Average Lighting Levels with Compared Standard (a) Average Lighting Level in Each Room;(b) Average Lighting on Tables*

3.3 Sound Comfort

Sound comfort is the sense of well-being and happiness acquired from the auditory environment. The standard that would be compared is from the Guidelines for Environmental Noise Limits and Control. The graph compares the noise levels in two rooms, B107 and B406, at three distinct times of the day: 9 a.m., 7 p.m., and 10 p.m. Noise levels are measured in decibels (dB) as shown in Fig. 3(a). At 9 a.m., both rooms had the same noise level of about 60 decibels. By 7 p.m., the noise levels in both rooms had decreased marginally, with B107 at around 55 dB and B406 just below 55 dB, demonstrating a small drop in noise during this period. However, by 10 p.m., the noise levels in both rooms had returned to around 60 dB, corresponding to those observed in the morning. This trend demonstrates that the noise levels in both rooms are pretty stable throughout the day, with just minor fluctuations between the three time periods. The greatest noise levels were reported between 9 a.m. and 10 p.m., while the lowest was recorded at 7 p.m. Overall, noise levels in B107 and B406 are comparable, with only small differences depending on the room and time of day.

The graph displays the noise levels in two rooms, B107 and B406, during three distinct times of day: 9 a.m., 7 p.m., and 10 p.m., with measurements in decibels (dB) in Fig. 3(b). At 9 a.m., the noise level in B107 is slightly more than 50 decibels, whereas it is somewhat lower in B406, indicating a calmer atmosphere in B406 in the morning. By 7 p.m., noise levels in both rooms have increased significantly, with B107 and B406 reaching over 70 decibels. This peak indicates that activity or external noise increased significantly in the evening compared to the morning. At 10 p.m., the noise levels decline from the evening high, with B107 recording approximately 60 dB and B406 slightly below 60 dB, showing a reduction in noise as the night progresses. Overall, the noise levels in both B107 and B406 follow a consistent pattern throughout the day: they begin moderately in the morning, peak significantly in the evening, and then decline again at night. This trend indicates that both rooms receive greater noise owing to increased activity or external causes throughout the nighttime hours. Despite the changes, the noise levels in B107 and B406 stay relatively constant at each time point, demonstrating consistent noise patterns between the two rooms. The maximum noise levels are recorded around 7 p.m., while the lowest is recorded at 9 a.m., indicating a large difference in noise levels from morning to evening, with a minor decline at night. This analysis provides insight into the daily noise dynamics within these two rooms, emphasizing the evening period as the noisiest time of the day.

To conclude from the data that has been analysed, overall data at 9 a.m. on day 1 in B107 were above the recommended standard which it was 62.2 dB while the noise level at 7 p.m. and 10 p.m. was over the recommended standard which is both in a range of 60.2 dB and 64.6 dB as shown in Fig. 3(a). This indicates that the house noise level was too high due to the position of the house that was on the first level which made the reading affected by the external noise. On the fourth floor, the sound levels are also over the recommended standard with the value of 62.4 dB in the morning. Moreover, at night the noise levels in both houses are also over the recommended standard when it is supposed to be 55 dB and below due to the occupants becoming active after resting in the evening to do their activities and it becoming too loud.

On day 2, the graph also shows that at 9 a.m., noise levels in B107 and B406 are below the recommended permissible noise level which is 60 dB. However, at 7 p.m. and 10 p.m., both houses show noise levels significantly exceeding the night-time standard. This indicates potential issues with noise control, particularly during times when quieter environments might be expected. Furthermore, B406 generally has a slightly higher noise level compared to B107 at all times measured even though the difference is not substantial. Noise levels are highest at 7 p.m. for both houses, suggesting that evening activities could be contributing to the noise increase during this time. Overall, the analysis in Fig. 3(b) highlights the need for addressing elevated noise levels in the monitored locations, with a focus on reducing day and nighttime noise to meet standard guidelines.

(a) (b)

Fig. 3 *Average Noise Level with Compared Standard (a) Average Noise Level on Day 1;(b) Average Noise Level on Day 2*

4. Conclusion

In conclusion, thermal comfort is known as the condition of mind that expresses satisfaction with its thermal environment and will be influenced by temperature, air velocity and relative humidity. Thermal comfort is a critical aspect of ensuring the well-being and productivity of individuals in indoor environments. Moreover, lighting comfort is the most essential aspect of visual comparing user pleasure, comfort, and a pleasing lighting design should offer occupants with a healthy and comfortable visual environment that supports their daily activities. Lastly, sound comforts create an atmosphere in which the acoustic circumstances contribute to the well-being and happiness of the occupants. Indoor environmental quality (IEQ) in Pagoh Residential College (KKKP) has not yet reached a satisfactory level according to the standards set in each parameter. A lot of improvements can be made to achieve a satisfactory level of indoor environmental quality (IEQ) so that the students who live in the college have a comfortable life and good mental health for academic excellence.

The overall recommendation to increase thermal comfort is to ensure the building is properly insulated to prevent heat loss in colder months and heat gain in warmer months. Next, to achieve humidity, it can use dehumidifiers or humidifiers as needed. Finally, good ventilation helps to remove stale air, odors, and pollutants while bringing in fresh air from outside. Other than that, to increase the lighting level is by installing additional ceiling lights, using higher-wattage bulbs or switching to LED bulbs with higher lumens for brighter lighting or rearranging furniture helps to increase the lighting levels by positioning the furniture to avoid blocking the light sources and ensure even distribution of light. Last but not least, for reducing sound comfort can done by by installing sound-absorbing panels on walls and ceilings, house windows can be upgraded by installing double-glazed windows to reduce external noise as it is a contributor to a high noise level. Lastly,use weatherstripping or caulk to seal gaps around windows and doors.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design, data collection, draft manuscript, draft manuscript preparation:*** *Nur Sabrina Dayana, Angelina Jolie, Nurul Syafiqah, Aslila Abd Kadir. All authors reviewed the results and approved the final version of the manuscript.*

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