PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 5 No. 1 (2024) 799-807
https://publisher.uthm.edu.my/periodicals/index.php/peat

Thermal Comfort and Occupant Perception at Residential Building in Kedah

Siti Zulaikha Shukeri[1], Amir Haziq Abdul Razak[1]*, Khairullizam Sapari[2]

[1] *Department of Chemical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Hab Pendidikan Tinggi Pagoh, KM1, Jalan Panchor, 84600, Muar, Johor, MALAYSIA*

[2] *Safety and Health Unit, Lumut, Sultan Abdul Halim Mu'adzam Shah International Islamic University 09300 Kuala Ketil, Kedah Darul Aman, MALAYSIA.*

*Corresponding Author: amirhaziq@uthm.edu.my
DOI: https://doi.org/10.30880/peat.2024.05.01.087

Article Info

Received: 28 December 2023
Accepted: 18 January 2024
Available online: 15 June 2024

Keywords

Thermal Comfort, Perception Level , Residential Building

Abstract

This study was conducted to analyze the level and perception of occupants regarding the indoor comfort conditions in residential buildings. This study was conducted by using the questionnaire method to 248 respondents who stayed in residential buildings in Kedah. This questionnaire has measured various types of thermal comfort characteristics, including the current feeling of temperature and comfort in the room, evaluating the effectiveness of the physical conditions in the room, occupants' actions to improve comfort in the room, biological evaluation, health effects from the discomfort of indoor conditions and acceptance of the overall comfort of indoor conditions in residential buildings. The data obtained was analyzed using Statiscal Package for the Social Sciences (SPSS) to measure the level of occupants' perception of the comfort of the interior conditions and to determine the rooms and blocks that were most said to be very uncomfortable. The results of the study show that external factors such as direct sunlight into the room are the main factors of internal discomfort and require improvement in terms of shading ventilation to prevent direct sunlight from entering the room. Finally, the issue of the density of occupants in one room, which should take into account the size of furniture and personal items in determining the number of occupants in one room. This is because residents will feel uncomfortable in crowded spaces because they have less personal space.

1. Introduction

Residential buildings in universities are generally designed as residences for students or staff to ensure a conducive and comfortable living environment. Residential buildings are not only reserved for sleeping and resting. Residential buildings are also a place to socialize, do work such as study and so on. This residential building located in Kedah is a one-story residential building that has eight identical building design structures. This one-story residential building can accommodate up to 896 people at a time. The increase in the number of residents that increases every year can affect the comfort of the residents, therefore affecting the quality of life of the residents during their stay in the residential building. However, this residential building accommodates a maximum of 8 people at a time and there are two types of rooms on each block that are between 38.75 sq.m and 40.20 sq.m.

A better living condition is created through a comfortable quality of life [13]. In improving aspects of the quality of life, thermal comfort should be emphasized to ensure that the occupants feel comfortable with the surrounding conditions. ASHRAE Standard 55-2017 defines thermal comfort as "that condition of mind that expresses satisfaction with the thermal environment." It is a state in which an individual feels neither too hot nor too cold, but rather feels comfortable within the surrounding indoor conditions [2].

2. Methodology

2.1 Research Design

Table 1 shows the research design based on objectives. Data collection will involve questionnaire methods considered to measure occupant's perception and sensation indoor thermal comfort. A questionnaire are involved mixed methods that include quantitative and qualitative methods. A mixed qualitative and quantitative strategy will provide a comprehensive understanding and findings on the researched topic [8].

This survey involves closed-ended and open-ended questionnaire. Google forms were used as a special tool in the survey to be distributed to occupants in residential buildings. Next, the data were analyzed using the Statistical Package for Social Science (SPSS). The results of this analysis will determine occupant's perceptions and sensation also the uncomfortable area.

Next, to achieve the second objective, a qualitative method which were focus group discussion meeting or discussion with the company's Safety and Health Unit to present improvement measure that will improve the comfort of residents in residential buildings.

Table 1 *Research Design*

No.	Objectives	Method	Data
1.	To analyze the level and perception of thermal comfort in residential building.	Quantitative and Qualitative • Closed-ended and Open-ended questionnaire.	The data questionnaire will be analyze using SPSS system.
2.	To suggest measures to improve thermal comfort in residential buildings.	Qualitative • Group discussion or meeting with Safety and Health Unit	Proposed control measure.

2.2 Data Collection Method

2.2.1 Questionnaire

A closed-ended questionnaire is a structured survey tool comprising questions with predetermined response options, simplifying data analysis by offering specific answer choices like multiple-choice options, Likert scales, or binary selections. Designed for efficient and precise data collection, closed-ended questionnaires provide clear guidance to respondents and facilitate the systematic gathering of accurate and meaningful information, making them a valuable instrument for research, customer feedback, and assessment processes. Open-ended questions are inquiries that prompt expansive and unrestricted responses, inviting individuals to express thoughts, opinions, or details without limitations on their answers. There are three different parts in this questionnaire: Part A, Part B, Part C, Part D, Part E, Part F and Part G. Part A is a closed-ended question related to background information that includes multiple choice and checkboxes. Part B is a closed-ended question about the assessment of their conditions in the room which includes Likert scale, multiple choice and checkboxes. Part B contains closed-ended and open-ended questions regarding the assessment of overall acceptance of thermal comfort in their room.

2.2.2 Focus Group Discussion

A focus group discussion is a qualitative research method that involves a small group of participants engaged in a structured conversation to explore their attitudes, perceptions, and experiences related to a specific topic or research question. Therefore, staff from S&H unit Department is the focus group that chosen by researcher to conduct discussion or meeting. It is intended to propose the improvement of indoor thermal comfort at residential buildings. They also can gain the benefits of this study related to effectiveness of the thermal comfort for occupancy.

3. Result and Discussion

The result is built to achieve goals and objectives. This result will also discuss the findings from the questionnaire session on 248 respondents who live in residential buildings. The results of this study will also discuss two analyzes from one questionnaire.

3.1 Descriptive Analysis

Based on the results of the study in the demographics section, there are different age groups where there are students who are still active at the university, post-graduate students, fellows and university employees who stay at the residential college. Based on block number, blocks 1,2 and 3 are male blocks while 4,5,6,7 and 8 are female blocks. Therefore, for gender distribution, block number and room number show that there are more female occupants than male occupants because there are more female occupants staying in residential buildings than males.

In addition, the highest frequency of respondents sharing a room is between 7 to 8 people because the university has maximized only eight people per room. Based on the Guidelines and Regulations for Building Planning Edition 2015, the dormitory system is allowed to accommodate students or trainees and staff. Based on the guideline, the area per person for the dormitory system of 8-12 people per room is 4.75 sq.m. There are two types of rooms on each block that are between 38.75 sq.m and 40.20 sq.m. Based on the room area calculated according to the measurement formula, the room area calculated is 38 s.q.m. However, people will feel it uncomfortable in crowded spaces since they have less personal space [15]. It will feel more uncomfortable when there were increased room density such as furniture or personal things in the rooms. Therefore, the width of furniture and personal items must be considered in accommodating occupants in one room. Next, the highest percentage also shows that most respondents spend time in residential buildings for 7 days a week. This gives more sensations of adaptation to thermal comfort to the occupants. Next, highest respondents often wear clothes such as short sleeves shirts and trousers in residential buildings. Individual thermal comfort levels are greatly influenced by the clothes they choose to wear indoors [11]. Furthermore, wearing loose-fitting garments composed of natural fibers, such as cotton or linen, can help with moisture absorption and encourage heat dissipation in hot and humid environments, improving thermal comfort [9].

Based on the results of the study on the assessment of current feeling related to the thermal comfort in room, it shows that the respondents feel that the current temperature in the room is very hot and the level of satisfied on the current temperature was very unsatisfied. The body's core temperature increases when there is an increase in the combination of temperature and humidity in the room. Body temperature can maintain a stable temperature over time if environmental limits are not critical [12]. Furthermore, thermal sensitivity to skin or operative temperature change is affected by psychological adaptation [18]. Because of this, the results of the study show that the comfortable level being in the room was affected and the comfort only being in the room was only moderate and uncomfortable. There are studies that also state that hot and cold climatic factors have a great impact on achieving comfort in occupied buildings [16]. However, the results from the evaluation of comfortable time and uncomfortable time to rest or study show similarities where the respondents reveal the results which are at night.

Table 2 *Current Feeling and Level of Satisfaction Temperature in Room*

Feeling	Comfort Characteristic Indoor	Frequency	Percentage %
Current Feeling of Temperature	Very Hot (1)	127	51.2
	Hot (2)	76	30.6
	Neutral (3)	40	16.1
	Cold (4)	4	1.6
	Very Cold (5)	1	.4
	Total	**248**	**100**
Level of Satisfied on			

Current Temperature	Very Unsatisfied (1)	90	36.3
	Unsatisfied (2)	78	31.5
	Moderate (3)	57	23.0
	Satisfied (4)	17	6.9
	Very Satisfied (5)	6	2.4
	Total	**248**	**100.0**

The physical assessment in the room showed that the respondents stated that the level of satisfied with the assessment of ventilation in the room was moderate while followed by second highest respondent state very bad. Despite the high percentage show respondents open the window to control the temperature. Furthermore, the highest respondent's state ceiling fan provided is not enough to provide comfort in the room. Evidence from previous studies shows that fans are a common behavior used to achieve terminology where fans are installed to supply cool air to the interior [7]. However, public health organizations state that the use of fans is not recommended if the indoor temperature exceeds 35 [14]. Besides that, the results of the assessment about the outdoor factor affect comfort in the room show the occupants reveal that external factors effect indoor thermal comfort. The indoor temperature to some extent affects the outdoor climate and the outdoor temperature [19]. Most of the external factors found from the results of the study are related to the sunlight and hot weather during the day which causes the temperature in the room to be too hot. The moving sun affects indoor thermal comfort [3]. In addition, daylight also affects the perception of the comfort of a person's situation where lighting conditions should be adjusted and changed according to the operational strategy and building design [6]. Because of this, the evaluation results related to methods implemented to improve comfort in the room showed respondents used self-provided portable fans and opening windows to help improve ventilation.

Table 3 *Physical Assessment of the Ventilation in the Room*

Physical Assessment	**Comfort Characteristics Indoor**	**Frequency**	**Percentage**
Assessment of The Ventilation in The Room	Very Bad (1)	74	29.8
	Bad (2)	73	29.4
	Moderate (3)	77	31.0
	Good (4)	18	7.3
	Very Good (5)	6	2.4
	Total	**248**	**100.0**
Open Window to Control the Temperature	Yes	203	81.9
	No	45	18.1
	Total	**248**	**100.0**
Ceiling Fan can provide a comfort	Yes	20	8.1
	No	228	91.9
	Total	**248**	**100.0**
Arrangement of Furniture and the Location of Your Room Cause Wind Disturbance From Outside	Yes	84	33.9
	No	164	66.1
	Total	**248**	**100.0**

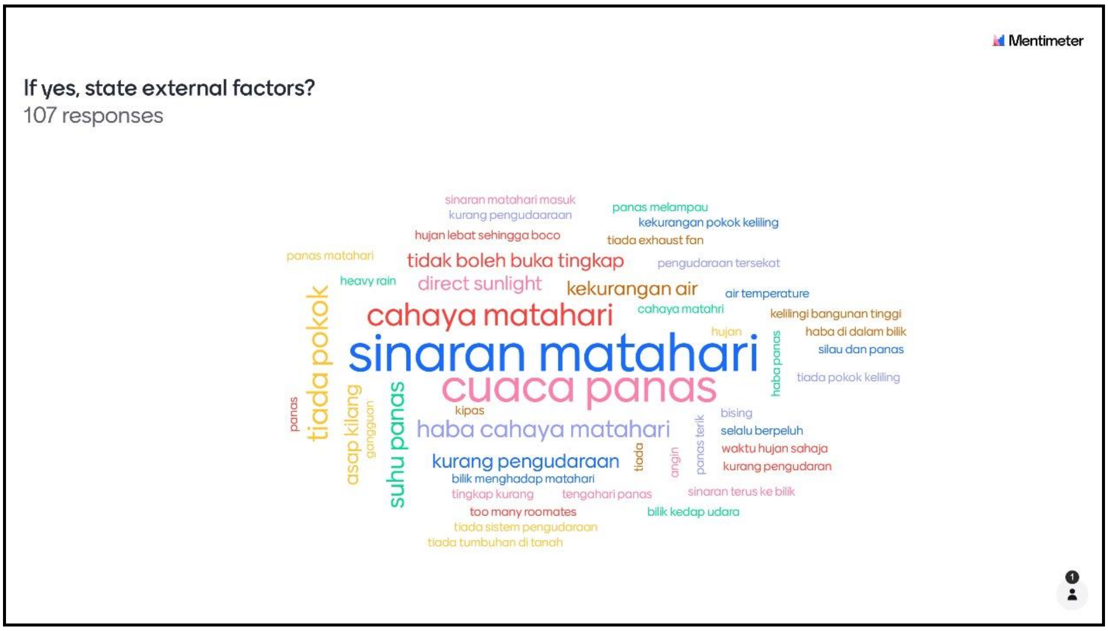

Fig. 1 *Assessment about the External Factor Affected*

Based on the results of type of biological assessment, the highest percentage of all the findings above shows that the respondents feel thirsty very often and the daily estimate is 2 liters per day and reaches more than 3 liters per day. The highest frequency only shown by the respondents to bathe in a day is as much as 2 times. Others, the condition of the hot room greatly very disturbing the respondent's concentration. Some previous research show concentration can affect the employee's well-being and productivity [4]. The learning rate slowed in uncomfortable warm or cold environments or in situations where the temperature changed often [5].

Table 4 *Type of Biological Assessment in the Room*

Type of Biological	Biological Characteristic	Frequency	Percentage %
Often Feel Thirsty	Very Rarely (1)	3	1.2
	Rarely (2)	8	3.2
	Sometime (3)	53	21.4
	Often (4)	90	36.3
	Very Often (5)	94	37.9
	Total	**248**	**100.0**
Estimated Amount of Water Per Day	1 Liter	41	16.5
	2 Liter	106	42.7
	3 Liter	50	20.2
	More than 3 liter	51	20.6
	Total	**248**	**100.0**
Often Take Shower	1 Time per day	1	.4
	2 Time per day	119	48.0
	3 Time per day	86	34.7
	4 Time per day	30	12.1
	More than 4 times per day	12	4.8
	Total	**248**	**100.0**
Assessment about the Hot Temperature in the Room Disturb Concentration	Not Disturbing (1)	1	0.4
	Slightly Disturbing (2)	9	3.6
	Moderate (3)	53	21.4
	Disturbing (4)	64	25.8
	Very Disturbing (5)	121	48.8
	Total	248	100.0

Based on the results of symptoms heat stress while inside residential buildings and experience relief from these complaints shows the highest respondents are exposed to symptoms of heat stress such as headache, severe thirst, dizziness and fatigue or lethargy. Respondents will feel relieved after being at home and after leaving the residential building. Based on Guidelines on Heat Stress Management at Workplace 2016, stress to the body is due to a person being exposed to high temperatures which can cause serious health problems and will become more serious if a person is exposed to high humidity at the same time. Based on previous studies proving that high temperatures in structures can cause thermal discomfort and can cause health problems such as heat stress [1]. Furthermore, Women experience migraines and headaches more often than men, although studies show that an uncomfortable indoor environment can increase the frequency of headaches and migraine diagnoses [17].

Table 5 *Symptoms of Heat Stress While Inside Residential Buildings*

Health Effect	Characteristic	Frequency	Percentage %
Symptoms of Heat Stress	An inability to concentrate	127	17.0
	Heat Rash	84	11.2
	Severe thirst	133	17.8
	Fatigue or Lethargy	110	14.7
	Dizziness	122	16.3
	Headache	158	21.1
	Muscle cramps	14	1.9
	Total	**748**	**100.0**
Experience Relief from These Complaints	After I leave my residential building	85	34.3
	After being at home	132	53.2
	Others	31	12.5
	Total	**248**	**100.0**

Based on the results of assessment on the acceptance of thermal comfort in room show the perception temperature for four period such as morning, mid-day, evening and night. The highest percentage of the findings above shows that respondents reveal that the afternoon is very hot compared to the night and evening. Cold time only in the morning. The relationship between the results of the above study related to sunlight is an external factor at midday that affects indoor discomfort causing the indoor temperature to affect the external climate [18]. Where operational strategies need to be coordinated and used [6]. Finally, although the result of the percentage of respondent's acceptability shows high compared to unacceptability. The results only distinguish only 30 more residents stated. Indoor discomfort needs to be considered because various problems will arise apart from health problems. This will get worse in the future if no action is taken.

Table 6 *Perception Temperature*

Period	Characteristics	Frequency	Percentage %
Morning	Very Hot (1)	8	3.2
	Hot (2)	11	4.4
	Neutral (3)	89	35.9
	Cold (4)	118	47.6
	Very Cold (5)	22	8.9
	Total	**248**	**100**
Mid-Day	Very Hot (1)	167	67.3
	Hot (2)	54	21.8
	Neutral (3)	23	9.3
	Cold (4)	2	0.8
	Very Cold (5)	2	0.8
	Total	**248**	**100%**
Evening	Very Hot (1)	65	26.2
	Hot (2)	83	33.5
	Neutral (3)	91	36.7
	Cold (4)	8	3.2
	Very Cold (5)	1	0.4
	Total	**248**	**100%**

Night	Very Hot (1)	17	6.9
	Hot (2)	39	15.7
	Neutral (3)	124	50.0
	Cold (4)	59	23.8
	Very Cold (5)	9	3.6
	Total	**248**	**100%**

3.2 Cross tabulation Analysis

The correlation analysis reveals a clear association between rooms perceived as "Very Hot" and corresponding blocks where respondents express being "Very Unsatisfied" with the temperature. Room 10, associated with Block E8 in the "Very Hot" category, coincides with respondents from Block E3 expressing high dissatisfaction. Similarly, Room 11 linked with Block E1 for "Very Hot" aligns with respondents from Block E8 indicating significant dissatisfaction. Additionally, Room 4 paired with Block E4 for "Very Hot" corresponds to respondents from Room 12 in Block E1 expressing dissatisfaction, highlighting an interconnectedness between perceived temperature and dissatisfaction across specific rooms and blocks.

Table 7 *Sort by Ascending Highest Frequency of Relationship between Perceptions of Current Temperature in Room and Satisfied with Current Temperature in Room*

Very Hot Room Number	Very Hot Block Number	Very Unsatisfied Room Number	Very Unsatisfied Block Number
1. Room 10	1. Block E8	1. Room 10	1. Block E3
2. Room 11	2. Block E1	2. Room 11	2. Block E8
3. Room 4	3. Block E4	3. Room 12	3. Block E1

4. Conclusion

The proposed recommendations based on this study act as corrective actions to correct the identified issues and emphasize preventive measures on thermal comfort in residential buildings for the long term in improving the indoor environment and promoting the well-being of the occupants.

The first suggestion is to focus on room density, which should consider the size of furniture and personal items in determining the number of occupants in one room. This is because residents will feel uncomfortable in crowded spaces because they have less personal space.

The second suggestion is that management needs to improve the mechanical ventilation system such as upgrading the size and number of existing ceiling fans to increase the movement of air in the room in addition to providing comfort. In addition, other ventilation needs to be added for the long-term well-being of the occupants when in the room such as roof ventilation and indoor ventilation, exhaust fan. By adding this will allow hot air to escape and allow cold air to enter the room. This will help overcome the extreme heat in the indoor environment and help in providing comfort in humid and hot weather.

In addition, the third recommendation is to provide shade ventilation on the exterior windows to prevent direct sunlight from entering the room. In addition, for preventive measure implementation of insulation improvements and the integration of green spaces surrounding the buildings. These measures collectively aim to regulate indoor temperature and alleviate the adverse effects of surroundings heat and give a more favorable indoor comfort for occupants.

Furthermore, management should first focus on rooms that are exposed to be very hot with the current temperature and very dissatisfied with the current temperature. Based on the correlation made in table 4.0 that the rooms and blocks matches that reveal very hot are E8:10, E1:11 and E4:04 while the room and block matches that reveal very unsatisfied with the current temperature are E3:10, E8:11 and E1:12.

In conclusion, the envisioned implementation of these comprehensive control measures holds the potential to effectively mitigate the identified issues, contributing substantially to the creation of an indoor environment that is not just comfortable but also conducive to the well-being of occupants in residential buildings in Kedah. This proactive endeavor towards controlling thermal comfort aspires to elevate the overall quality of life within these living spaces, ensuring sustained comfort and improved living standards for all residents. Finally, the same research recommendations like this should also be made in the rooms of school teachers who only use ceiling fans as the main ventilation to provide comfort in the room.

Acknowledgement

This research was made possible by funding from research provided by the Ministry of Higher Education, Malaysia. The author would like to express the greatest appreciation and utmost gratitude to Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

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

Author Contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

References

[1] Abdel-Ghany, A. M., Al-Helal, I., & Shady, M. (2013). Human thermal comfort and heat stress in an outdoor urban arid environment: a case study. *Advances in Meteorology*, *2013*, 1–7. https://doi.org/10.1155/2013/693541

[2] ASHRAE. (2017). ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[3] Beji, C., Merabtine, A., Mokraoui, S., Kheiri, A., Kauffmann, J., & Bouaziz, N. (2020). Experimental study on the effects of direct sun radiation on the dynamic thermal behavior of a floor-heating system. *Solar Energy*, *204*, 1–12. https://doi.org/10.1016/j.solener.2020.04.055

[4] Bueno, A. M., De Paula Xavier, A. A., & Broday, E. E. (2021a). Evaluating the Connection between Thermal Comfort and Productivity in Buildings: A Systematic Literature Review. Buildings, 11(6), 244. https://doi.org/10.3390/buildings11060244

[5] Cui, W., Cao, G., Park, J. H., Ouyang, Q., & Zhu, Y. (2013). Influence of indoor air temperature on human thermal comfort, motivation and performance. *Building and Environment*, *68*, 114–122. https://doi.org/10.1016/j.buildenv.2013.06.012

[6] Chinazzo, G., Wienold, J., & Andersen, M. (2019). Daylight affects human thermal perception. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-48963-y

[7] Chartier, Y., & Pessoa-Silva, C. L. (n.d.). Natural Ventilation for Infection Control in Health-care Settings. World Health Organization

[8] Creswell, J. W. (2004). Designing a mixed methods study in primary care. Annals of Family Medicine, 2(1), 7–12. https://doi.org/10.1370/afm.104

[9] Gao, C., Li, Y., & Li, Y. (2020). Effects of clothing insulation and air temperature on physiological and subjective responses under the conditions of hot and humid environment. Building and Environment, 168, 106493.

[10] *GUIDELINES ON HEAT STRESS MANAGEMENT AT WORKPLACE 2016* (2016th ed.). (n.d.). Department of Occupational Safety and Health Ministry of Human Resource, Malaysia. 2016.

[11] International Organization for Standardization. (2005). ISO 7730:2005 - 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.

[12] Kenney, W. L., Vecellio, D., Cottle, R., Wolf, S. T., & Us, C. (2022, July 25). *How hot is too hot for the human body?* Scientific American. https://www.scientificamerican.com/article/how-hot-is-too-hot-for-the-human-body1/

[13] Mahir Razali, A., Mohd Ali, K.A., Ab Hamid, M.R. & Mustafa, Z., (2014). Kesihatan dan kualiti hidup masyarakat. Kuantan: Penerbit Universiti Malaysia Pahang

[14] Morris, N. B., Chaseling, G. K., English, T., Gruss, F., Maideen, M. F. B., Capon, A., & Jay, O. (2021). Electric fan use for cooling during hot weather: a biophysical modelling study. *The Lancet Planetary Health*, *5*(6), e368–e377. https://doi.org/10.1016/s2542-5196(21)00136-4

[15] Stamps, A. (2020). Effects of Room Density on Reported Discomfort: Exploring the Role of Personal Space. Journal of Environmental Psychology, 42(3), 215-228.

[16] Shafii, H.B. (2017). Keselesaan terma rumah kediaman dan pengaruhnya terhadap kualiti hidup penduduk (Thermal comfort of house and it's influence on people's quality of life). Geografia: Malaysian journal of society and space, 8.

[17] Tietjen, G. E., Khubchandani, J., Ghosh, S., Bhattacharjee, S., & Kleinfelder, J. (2012). Headache symptoms and indoor environmental parameters: Results from the EPA BASE study. Annals of Indian Academy of Neurology, 15(5), 95. https://doi.org/10.4103/0972-2327.100029

[18] Yan, H., Yang, L., Zheng, W., & Li, D. (2016). Influence of outdoor temperature on the indoor environment and thermal adaptation in Chinese residential buildings during the heating season. *Energy and Buildings*, *116*, 133–140. https://doi.org/10.1016/j.enbuild.2015.12.053

[19] Zhuang, L., Huang, J., Li, F., & Zhong, K. (2022). Psychological adaptation to thermal environments and its effects on thermal sensation. *Physiology & Behavior*, *247*, 113724. https://doi.org/10.1016/j.physbeh.2022.113724