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**SUSTAINABLE BUILT
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A STUDY OF THERMAL COMFORT IMPLICATION TOWARDS HUMAN PRODUCTIVITY IN GOVERNMENT OFFICE

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ABSTRACT

This research investigates the impact of thermal comfort on human productivity in a government office. Pejabat Tanah Daerah Hilir Perak is the study location, where both objective measurements and subjective survey responses are used to assess working conditions and employees' perceptions. The study focuses on environmental factors for example temperature, relative humidity, air movement, sound intensity, and lighting levels. The findings reveal that comfortable temperatures within the recommended range and a mechanical ventilation system contributed to effective temperature regulations. The survey findings indicated that employees' perceptions of thermal comfort, lighting, cleanliness, and ergonomic features influenced their performance. On the other hand, airflow velocity and environmental controls can enhance their productivity in government offices. The significance of these research findings is they serve as the foundation for future improvements in thermal comfort and enhance the overall organization's performance.

Keywords: *Thermal comfort, productivity, performance*

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INTRODUCTION

Thermal comfort is defined as a state of mind where that reflects a person's happiness with the thermal environment and is evaluated subjectively (Mora & Bean, n.d.) y. The physical of a human being may be thought as the heat exchanger, with food intake as a source of energy input. A human body will expel surplus heat into the environment so that it may continue to function normally. The heat transfer coefficient is related to the temperature differential. However, the physical of human body will function to lose more heat in the cold environment compared to the heat lost in a hot environment and both situations naturally will lead to discomfort in the physical of humans (Yunus A Çengel & Michael A Boles, 2015). Due to that, HVAC (heating, ventilation, and air conditioning) was created by the design engineers to maintain the standard of thermal comfort for the occupants in the buildings. Basically, thermal neutrality is achieved when the heat generated by human metabolism is supposed to be allowed to disperse, allowing thermal balance with the environment to be maintained. The primary parameters influencing thermal comfort are those that determine heat uptake and loss, such as metabolic rate, garment insulation, air temperature, mean radiant temperature, air speed, and relative humidity. Furthermore, thermal comfort is also influenced by psychological factors for instance individual expectations (Richard de Dear et al., 1997). The temperature of thermal comfort varies significantly depending on each individual and factors for example the intensity of the activities level, the selection of clothing, and the humidity of environments.

LITERATURE REVIEW

Indoor Environment Quality

The concept of Indoor Environmental Quality (IEQ) pertains to the various factors that influence the conditions within a building. Various strategies can be employed to effectively address Indoor Environmental Quality (IEQ), with the overarching goals of safeguarding human health, enhancing quality of life, and mitigating stress and potential injuries. Enhancing the indoor environmental quality, it has the potential to improve the well-being of individuals residing within a building, augment the market value of the property, and mitigate legal responsibilities for the owners of the building (LEED, 2014). However, there were many people out there who had an awareness of the importance of not having a good indoor environment quality in the building. The primary factor contributing to the limited recognition of these issues stems from the predominantly chronic and long-term nature of the consequences associated with indoor air pollution, which do not pose immediate and direct threats to human life (Singh, 1996).

Thermal Comfort

Thermal comfort is widely regarded as a crucial and readily quantifiable aspect of indoor environmental quality (IEQ). For individuals to achieve optimal productivity, it is imperative that their working environment provides them with thermal comfort. Thermal comfort is defined as contingent upon the thermal adaptation of individual occupants, which is influenced by various factors including geographic location, climate, time of year, gender, race, and age (Quang et al., 2014). The human body endeavours to maintain a thermoregulatory set point of approximately 37°C. The maintenance of temperature occurs via heat transfer mechanisms, specifically convection, radiation, and evaporation, which facilitate the exchange of thermal energy between the human body and the surrounding environment. (ASHRAE STANDARD, 2010a). Thermal comfort is determined by six factors four of which can be categorized as environmental parameters. These parameters encompass air temperature, mean radiant temperature, air relative humidity, and air velocity. The remaining two factors can be characterized as personal factors, encompassing human metabolic rates and the influence of clothing insulation (M.C Katafygiotou & D.K. Serghides, 2014).

Factors Affecting Thermal Comfort

There are a few factors that affect thermal comfort. The factors are divided into two which are environmental factors and personal factors. The environmental factors include factors such as air temperature, air velocity, radiant temperature, and relative humidity. The personal factors on the other hand, include factors such as clothing, metabolic heat, and wellbeing. These factors are identified by the AHSRAE 55 Standard. The goal of this standard is to define the combinations of indoor thermal environmental elements and personal factors that will result in thermal environmental circumstances that are acceptable to the majority of the space's inhabitants (ASHRAE STANDARD, 2010), Malaysia. Kementerian Sumber Manusia. Jabatan Keselamatan dan Kesihatan Pekerjaan., 1996) (Koh et al., 2018) (DOSH, 2023).

Table 1: Standard Benchmark for Thermal Comfort Elements for Offices in Malaysia

No.	Temperature (°C)	Relative Humidity (%)	Air Movement (m/s)	Sound Intensity (dB)	Lighting (Lux)
1.	23 – 26	60 – 70	0.15 – 0.80	50 – 85	300 – 500

RESEARCH METHODOLOGY

The respondents in this study are the workers and staffs in the government office of Pejabat Tanah Daerah Hilir Perak. They help to gain an important information that will close the research gap.

Research Design and Strategy

Both the qualitative approach and quantitative approach were implemented as research strategy to gain data and to seek for the relevant information. A set of questionnaires via Google Form and scientific measures using specific tools which are 4 in 1 meter and Sound Level metre for gaining a precise information that will help to answer the objective of this research.

Sampling and Case Study

There are 20 respondents for each level in Pejabat Tanah Daerah Hilir Perak building. The respondents are among the workers and staff on selected building levels which are from level 2 and level 3. The respondents include male and female workers and staff from age 18 and above.

Research Instrument

The research instrument that has been distributed for gathering the information from the respondents was self-administrated questionnaires via Google Forms. A comprehensive survey which consists of 19 questions was conducted to assess the level of satisfaction among the respondents regarding various thermal conditions. These conditions encompassed physical activities, clothing choices, workplace temperature, lighting conditions, and sound conditions. The questionnaires included a Likert scale that ranged from 1 to 5 which signifies completely dissatisfied to completely satisfied. Moreover, the research instruments used to gather the data are by using specific tools which are 4 in 1 metre and sound level metre.

ANALYSIS AND DISCUSSION

The questionnaires with 19 questions including the demographic section have been analyzed and distributed to the workers and staff at Pejabat Tanah Daerah Hilir,

Perak. In addition, the scientific measurement was also conducted by using 4 in 1 metre and Sound Level metre, and the findings have also been analyzed. In this research, the variables involved are temperature (°C), relative humidity (%), air velocity (m/s), light intensity (lux) and sound intensity (dB).

Two levels of employment if the office were chosen. Two-day measuring period is in effect. The first reading took place between 8.00 a.m. – 10.00 a.m. The second reading was conducted between 12.00 p.m. – 1.00 p.m. and the third reading was conducted before employees finished their office hour which was between 2.00 p.m. – 3.30 p.m. The outcome measurement from specific tools in Pejabat Tanah Daerah Hilir Perak is summarized in the table below. These results are based on the average of the reading for both levels 2 and 3 of the office.

Table 2: Summary of Scientific Measurement Results

NO.	Floor Level	Temperature (°C)	Relative Humidity (%)	Air Movement (m/s)	Sound Intensity (dB)	Lighting (Lux)
Standard Benchmark		23-26	60-70	0.15-0.80	50-85	300-500
1.	Level 3	25	51	0.10	55	494
2.	Level 2	24	44	0.20	68	471

Reading below the standard benchmark.

The research findings presented in Table 1 for Pejabat Tanah Daerah Hilir Perak indicate that the temperature on both levels falls within the standard benchmark range of 23 – 26 (°C), with level 2 slightly cooler at 24 (°C) and level 3 slightly warmer at 25 (°C). The relative humidity readings for both levels fall below the established benchmarks of 60 – 70 %, but they remain within a tolerable range, with the lowest record humidity being 30%. The sound intensity levels are satisfactory, ranging from 50 – 85 dB, providing a conducive auditory atmosphere. Lighting intensity in both levels complies with the recommended range of 300 – 500 Lux, ensuring adequate illumination for the occupants. The air velocity at level 3 is below the established benchmark range, recording an average of 0.10 m/s, while level 2 adheres to the benchmark with an average of 0.20 m/s. Adequate air velocity is crucial for achieving desired thermal comfort and promoting occupants' overall well-being.

Discussion from the Survey Findings

The surveys which have been conducted revealed that majority of the respondents believed that environmental factors such as temperature, lighting, cleanliness and ergonomic features had a noticeable impact on their performance and productivity in their workplace. Many of the respondents expressed their satisfaction with the lighting and cleanliness of the environment, but some of them urged for improvement. This includes the upgrading of the air-conditioning system and maximising the utilization of windows. The gathered data provides valuable insights into the prevailing working conditions and employees' perceptions in Pejabat Tanah Daerah Hilir Perak. The findings served as guidance for future endeavours to enhance the comfort, well-being and productivity of the workers and staff. By addressing the identified areas of concern, the organizations can create a more conducive working environment. Therefore, these findings can lead to an increase in the employees' satisfaction and improve the overall performance of the organization.

CONCLUSION

It can be concluded that this research provides a comprehensive overview of the empirical evidence findings. These research findings are vital support to the achievement the research aims, and research objectives and to answer the research questions. They also offer recommendations for future research, specifically focusing on the impact of thermal comfort on workers' and staff's productivity as well as their performance in Pejabat Tanah Daerah Hilir Perak.

Achievement of Objective

This research successfully achieved its objective of identifying the factors influencing thermal comfort and the comfort level of people in the building, thus contributing to valuable insights for enhancing the employees' workplace in terms of productivity and their satisfaction in Pejabat Tanah Daerah Hilir Perak. The objective measurements confirmed that optimal thermal comfort through the mechanical ventilation system is crucial. On the other hand, the findings of the surveys discovered that the employees' perceptions on environmental factors do affect their performance. This study provides information to the organization the valuable guidance for improvements in airflow, and lighting balance, and takes into consideration the employees' feedback in order to create a more conducive working environment. By leveraging these findings, organizations can foster a contented and productive workforce, ultimately improving the organization's performance.

Recommendation for Future Research

This research suggests several recommendations for further study on optimizing thermal comfort in working environments. One of the main suggestions is to conduct a long-term monitoring study to gather data over extended periods, enabling a comprehensive understanding of how factors influencing thermal comfort fluctuate throughout different seasons. This data can aid in developing strategies to maintain optimal conditions year-round. Additionally, the development of predictive models integrates various environmental factors, including temperature, humidity, and airflow. These findings could offer personalized and adaptive comfort solutions. Comparative studies between different office designs and architectural features can be used to determine the best practices for creating comfortable and productive working environments. Lastly, investigating the relationship between thermal comfort, employee health, and well-being outcomes can provide deeper insights into physiological and psychological responses to thermal conditions.

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Tarikh : 20 Januari 2023

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