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An Experimental Study on Effect of Light Intensity to Indoor Air Temperature and Humidity

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ABSTRACT

It is important to understand the factors influencing thermal responses in relation to human comfort and properly lower energy consumption. Unrelated factors to the thermal environment have been confirmed to influence the thermal responses of occupants. However, there are no detailed studies on these factors especially under different environmental conditions which might be due to insufficient knowledge on the interactions of indoor environmental factors. Therefore, it is imperative to examine the accurate and high-quality data of light intensity. Accordingly, this study focused on the influences of light intensity on temperature, and humidity of the indoor environment under natural and controlled environmental conditions. The main objectives are to investigate and evaluate various parameters affecting the light intensity of indoor air temperature and humidity. The experimental work was implemented by designing a customized room environment prototype of 1 × 1 × 1 m^3 dimensions. This was done by changing the type of lamps and light intensity. The obtained results showed that the light intensity is directly proportional to the indoor air temperature. Thus, the outcomes can be considered as a reinforcement step in emphasizing the actual effect of light intensity whereby the required lighting must be in accordance with the daily duty.

Keywords: Indoor humidity, indoor temperature, light intensity, thermal comfort, environment

1. INTRODUCTION

Humidity and temperature are essential physical factors employed in different human activities and industrial process controls; hence, it is important to accurately detect them [1]. Moreover, light is a phenomenon that has attracted human being since ancient time. Light intensity explains to the amount or strength of light generated through a certain lamp source [2]. Different studies had outlined the effects of daylight on biological and psychological states of human beings [3-4]. Daylight influences human behaviour and psychological. Mood and feelings (psychological state) are affected by the perceived light through the human visual system. The receptor in the visual system discerns light and emanates to the production of melatonin (sleeping hormone) and cortisol (stress hormone) [3],[5-7]. The alteration of day and night can be associated with different human biological rhythms. Using electric lighting had resulted in the mediation of this cycle. Due to this, every human activity is being carried out at any time of the day or night. The work process has been importantly altered through electric lighting, this allows working at any time and three-shift operations (day, morning, evening, and night)[8].

Indoor lighting is developed to visualize necessities based on the regulations and standards; it possesses low energy consumption. Human beings rely on daylight, it is presumed that the light fitting emulate the stream of light in the day can be employed for human bodies and its rhythms;

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the emulation of a sunny day can enhance the mood in humans. The wrong illumination at an inappropriate time can result to the disturbance of circadian rhythm, which can lead to mood disorders, poor sleep, diabetes, depression, and obesity [3],[7], [8-9]. Weather can also affect human's mood [10-13]. Everyone enjoys distinct weather if it is an attractive cloudy, rainy, sunny day, or cold wind. A sunny day is being preferred by many people; due to this, an idea of designing indoor lighting reflecting lighting that looks like the sun was invented by utilizing an appropriate illumination origin. Thus, the real optical factors for sunny daylight were needed to be obtained.

In defining the thermal comfort in a building, the main parameter is an indoor air temperature [14]. Due to elevated heat, sometimes the indoor temperature increased to about 40 °C in northern India during summers [15]. This is an uncomfortable temperature to live with. Thus, it is essential to add a space cooler in the building to achieve a conducive environment. Higher energy is needed in space cooling to achieve a comfortable environment because air condition utilized for space cooling absorb enormous energy [16]. Furthermore, the consumed energy is higher in space cooling [17-18]. Likewise, another study was carried out to provide solutions to these questions, which include: To what limit can the lights that are conventionally refers to as warm and cool generate the actual sensation of heat and cold? What are their effects on the visual and thermal comforts? What is the influence of altering transmitted light's colour on illumination sensation of the occupant? [19]. Additionally, the influences of correlated colour temperatures for a light origin on thermal comfort and thermal sensation were studied; this finding was carried out in a room lighted using a Light Emitting Diode (LED) lighting arrangement with a modifiable correlated colour temperature where relative humidity, air velocity and air temperature remained constant. The correlated colour temperature of the illumination within the test room was modified steadily [20].

Even though, there were several findings carried out in the past, however, a newly discovered diagram for comfortable indoor lighting has not been invented due to the fact that several published articles on preferred or comfortable lighting conditions had depended on subjective determinations that provide outcomes with the large inter-individual differences in subjective functions is not clearly related to lighting zone [21]. Due to this, the re-evaluation of comfortable indoor lighting from psychological points of view in relative to distinct experimental procedures is necessary. In a study, 10 male Japanese were subjected to light emitted from fluorescent. Illuminance from the correlated colour temperature CCT was varied step-wisely. Thereafter, the considered Japanese were directed to show their knowledge of comfort, glare and brightness at the controlled illuminances [22]. Furthermore, electroencephalogram and electrocardiogram data were continuously ceaselessly watched to see the possible tools of boundary illuminances. Therefore, a new illustration of comfortable indoor lighting was postulated depending on the aggregate results [22]. In recent time, there are a prevalence in light-emitting diode (LED) lights as a lighting source. This lighting source has a distinct distribution of spectral power that is different from fluorescent lights.

Based on the resultant highly-localized heat fluxes and miniaturization of electronic components, obtaining effective heat dissipation in a mannered space has constituted daunting problems to the thermal management community. Over 70% of light-emitting diodes (LED) power is used as heat; the evaluated heat might be justified because of the miniaturized size. This noticeably minimized the life span, performance and reliability of LEDs; and ultimately eventually emanate to device failure [15-18]. Higher demands on electronic cooling have resulted to the entrancing investigation of effective cooling techniques. Traditional heat becomes submerged and evacuates the practical heat from its source through conduction [23-25] and convection [26-28]. In addition, the conduction's heat transfer efficiency is inherently bounded through an enormous thermal resistance from heat sink [29-30] and frail thermal coupling between the heat sink and heat source [23-25]. In another way, a reduced heat transfer coefficient can limit the convective heat transports from sink to ambient [26-28]. Out of all the heat transfer modes, the phase-change heat transfer in relation to latent heat transportation is recognized as the main effective technique for high-heat-flux dissolution [31-33]. Hence, it is important to have an optimal balance between the cooling energy and electric lighting used [34].

Regarding the second variable, the humidity benefits of its increase and decrease according to the space used. For example, it is useful in plant growth; there is a benefit in increasing humidity of the air to improve the types of plants and vice versa. The indoor farming system provided with artificial lighting is suggested to significantly decline the natural resources' pressure, with certain capabilities to minimize water for the production of food [35]. The hydroponic has enhanced the efficiency of photosynthetic conditions under constant climatic and lighting condition through the indoor environment, and through dehumidification for transpiration water recovery and indoor cultivation, water use efficiency can also be improved. The water use efficiency can be generally referred to as a gram of fresh biomass created per litre of water used which is more than fifty times higher than recent greenhouse systems [36]. Measuring and controlling the humidity is essential in diverse fields including agriculture, food processing, new material development, and health services[36-37]. Since there is a great interest of understanding and improving the internal environment of the room, it is necessary to study whether there is an effect of the intensity of lighting on the temperature and humidity inside the room.

In this study, the heat resulting from intensity of lighting and the extent of its effect on the internal room temperature and humidity was investigated experimentally. It is essential to introduce an appropriate method in measuring the parameters of light intensity which include a variety of sensors for data collection and a prototype room to measure numbers of important parameters in the indoor environment especially on temperature and relative humidity. The main focus of this study is to investigate and determine the most appropriate light intensity parameters for indoor environments' performance toward a significant understanding of energy used throughout the indoor environmental quality and thermal comfort.

2. METHODOLOGY

In this study, a customized small room was designed and fabricated to simulate the different lighting conditions as shown in Figure 1. The customised small room were fitted up with adjustable and movable lamps. Two types of different lamps were used in this study. Both lamps are easily movable in order to obtain desire effect for this study. The customised small room also was equipped with dimmer switch to control the light intensity. This simple setup enabled the data taken on temperature and humidity of the room based on different conditions. The customized small room simulator provide advantage to the development of comprehensive room environment and lighting testing capabilities to this project. Among the advantages of this customized room simulator is design simplicity, able to simulate room with different lighting conditions, insulated, portable and low cost.

Figure 1 presents the assessment subdivision consisting of the room of equal size in dimensions ($1 \times 1 \times 1$ m^3). Walls of the test section were prepared using aluminium plates with the dimensions of 1 m wide, 1 m length and thickness of 3 mm. All walls were compactly isolated from the external environment with insulation to reduce heat losses to and from the environment.

Aluminium Composite Panel (ACP) sheets also called Aluminium Composite Material (ACM) are made up of a thermoplastic recycled core of the L.D. polyethene sandwich bonded between two thin sheets of aluminium. Its coated side of the aluminium sheet was polyester treated and scratched to prevent the peeling of masking protection film. These panels are strong, frothy and perfect for long-term outdoor signage as well as for multi-purpose. The layers of the room wall construction are displayed in Figure 2.

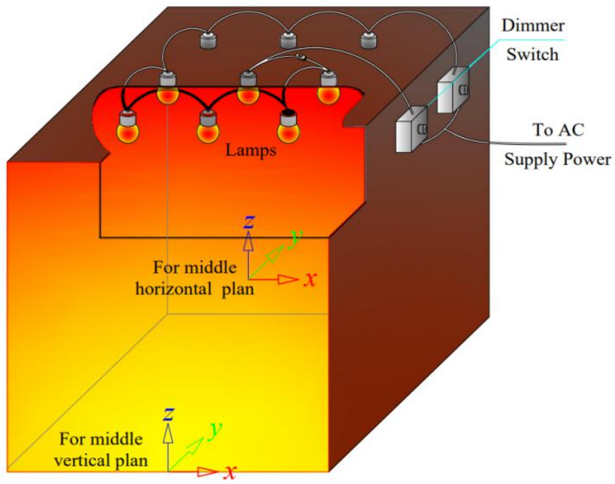

Figure 1. Experimental setup of the room.

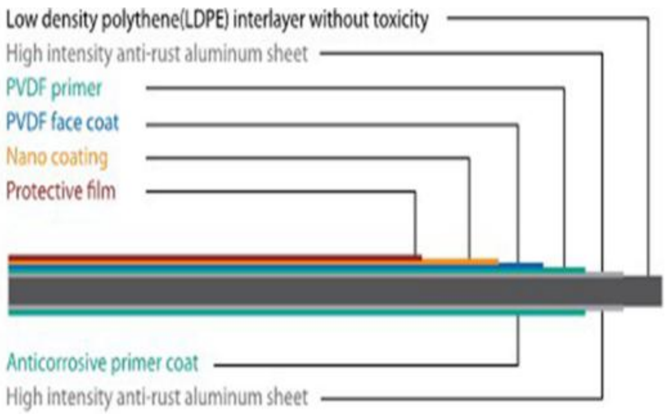

Figure 2. Layers of the room wall [23].

For the purpose of this study, the effect of light intensity on the temperature and humidity of indoor room, two types of lamps were used. The first type is a halogen lamp with 18 W capacity. It is a warm light as shown in Figure 3 (a). The second type of lamp used in the study is the LED lamp as shown in Figure 3 (b) with the same capacity of halogen lamp.

(a) (b)

Figure 3. Halogen lamp (a) and LED lamp (b) [20].

In order to measure the air temperature of the customized room, a constant thermoplastic copper (Type-K with a diameter of 1 mm from the probes) was used. The thermocouples were inserted horizontally and vertically in the middle of the experimental customized room to measure the temperature distribution in test section through the holes, which were drilled with an appropriate diameter on one side of the experiment chamber, as well as the top wall to allow the readings measurement at equal distances from 20, 40, 60, and 80 cm. The lateral and upper sides were arranged horizontally and vertically, respectively. In addition, the thermocouple was located at the centre of the bottom wall of the customized room to measure the temperature at the longest distance. The thermocouples used in this study were calibrated at different temperatures, from the freezing point of distilled water to the boiling point. Furthermore, the relative humidity of indoor air in the was measured by using humidity meter of TSI's Model 8347A.

The effect of lamps on temperature and humidity of the customized room was analysed with proper insulation to avoid any influence of the external environment conditions. Two types of lamps (halogen and LED) were used to study the influence of light intensity and temperature on human comfort. A number of devices were used in this experiment, which was mentioned earlier for the purpose of the experiment that was conducted in the laboratory under appropriate conditions to obtain accurate results. For first stage of experimental work, the customized room was mounted by halogen lamps on its upper surface at equal distance. The experiment was conducted in three cases on all halogen lamps. The first case consists of nine halogen lamps with full throttle of dimmer; the second case was on all the halogen lamps with half throttle of dimmer and third case represent a single halogen lamp at the centre of the customized room. The variables measured in the experimental work were temperature and humidity distribution within the customized room. This process was repeated after replacing the halogen with LEDs in the similar to first and second cases.

3. RESULTS AND DISCUSSION

The effect of lamp temperature on air temperature distribution in the customized room was experimentally studied. A hole was made at the centre of the upper surface to measure the temperature on a vertical line in the customized room and compared the outcome of analysis with the numerical results. In the first experimental case, the surface temperature of nine halogen lamps were measured at 79 °C (352K). The room air temperature was measured in eight different points started from the top surface of customized room. The summary of results obtained from the experimental works are illustrated in Table 1. Table 1 is limited to four cases since the case for three LED lamps was similar to the case of nine halogen lamps and case of one LED lamp was ignored due to the absence of light intensity effect.

Table 1 The room air temperature based on various cases and different distance in z-direction

Distance in Z direction (m)		Nine halogen lamps at 79 ºC (352 K)	Three halogen lamps at 79 °C (352 K)	One halogen lamps at 79 °C (352 K)	Nine LED lamps at 37.6 °C (310.6 K)
Point 1	0	301	301.5	301.4	301
Point 2	0.08	351.5	349.1	348.5	307.6
Point 3	0.1	335	331.3	329.4	303.6
Point 4	0.2	303.6	300	298.9	301.4
Point 5	0.4	303.8	299.5	299.5	301.5
Point 6	0.6	302.9	300.1	299.4	301.6
Point 7	0.8	303.1	300.3	299	301.3
Point 8	1	301.4	299.2	299.9	301.2

For first 3 points, the room air temperature was measured at close distances since the room air temperature in this region was greatly affected by the heat of the lamps. The distance between the points 4 to 8 in Table 1 was equal, and the distance from one point to another was 0.2 m. This is due to the fact that the effect of heat lamps on the air temperature in this region was little. The room air temperature at these points was measured on the vertical line at the centre of the customized room and compared with the air temperature measurements that were drawn from the numerical study. It can be clearly seen from Figure 4 that the experimental measurements of room air temperatures for almost at all points have a good agreement with those of the numerical work.

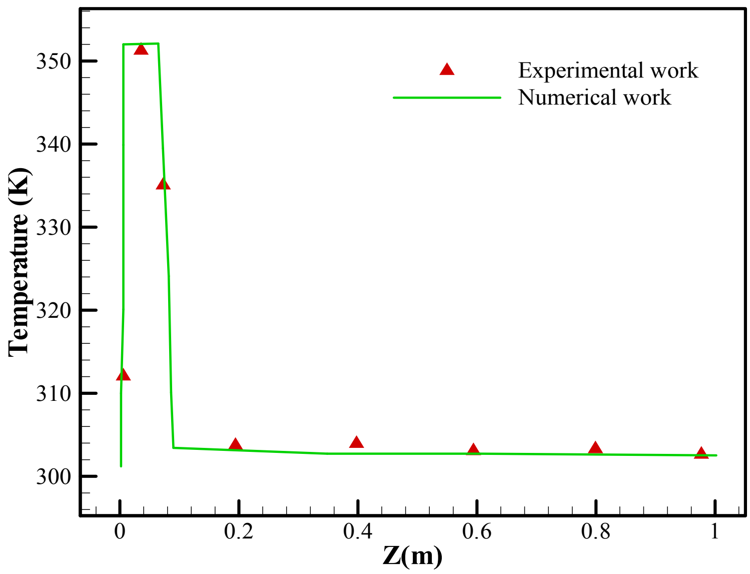

Figure 4. Comparison between the results of numerical and experimental work for 9 lamps.

In the second experiment, the effect of temperature from three lamps on the air temperature in the box was examined as shown in Figure 5. The Experimental results were compared with numerical results; there was a correspondence between the numerical and experimental study measurements.

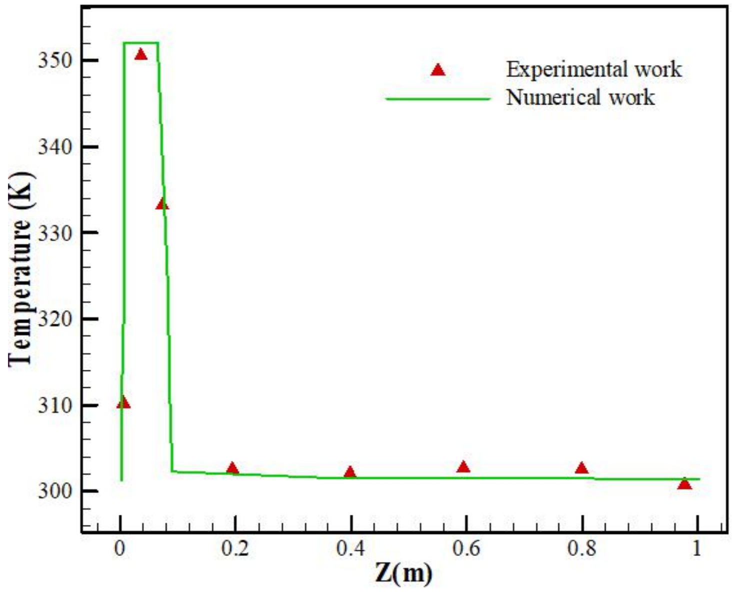

Figure 5. Comparison between the results of numerical and experimental work for 3 lamps.

In addition, the effect of one lamp on the temperature of the box was studied. It is noted from Figure 6 that the results of the practical and theoretical studies are very similar. In order to demonstrate the effect of two different types of lamps depending on the intensity of light temperature, halogen lamps were compared with LED lamps.

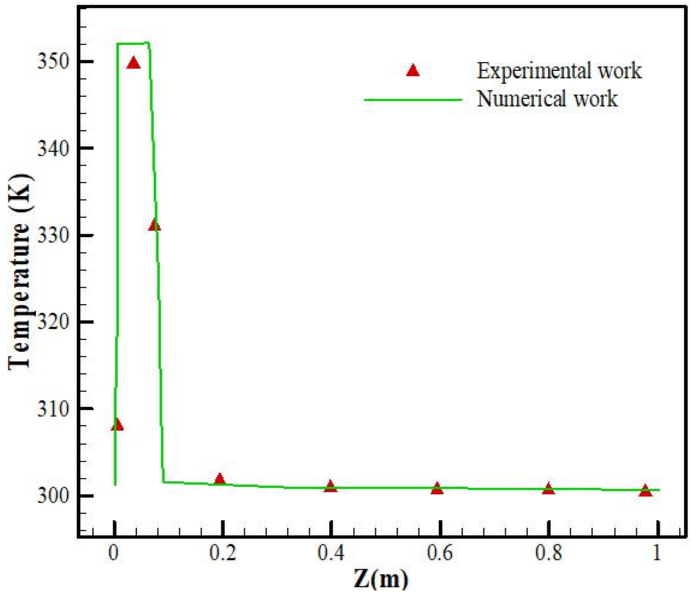

Figure 6. Comparison between the results of numerical and experimental work for 1 lamp.

Figure 7 shows the effect of LED lamps on the temperature of the box, these lamps have almost no effect except for the vicinity of the lamps in contrast to the effect of halogen lamps, which was clearly seen on the temperature of the box, especially in the centre of the box.

Moreover, Figure 8 shows a comparison between the results of practical and theoretical studies. The clear congruence between the two studies can be seen in this figure.

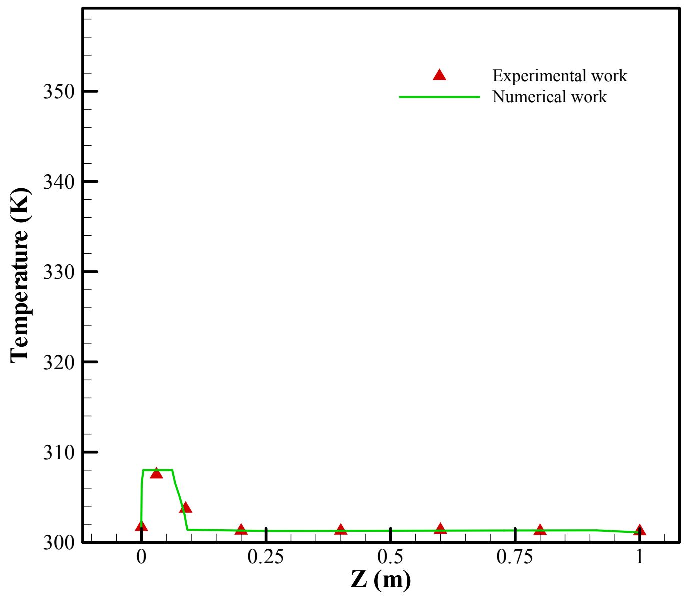

Figure 7. Comparison between the results of numerical and experimental work for 9 LED lamps.

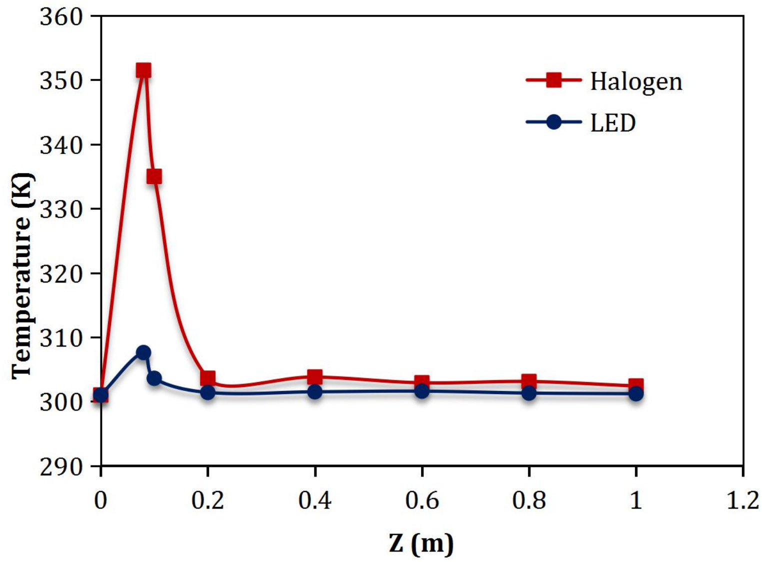

Figure 8. Comparison between the results of the practical study with halogen and LED lamps.

4. CONCLUSION

A significant understanding of the factors influencing thermal functions to human comfort and properly low-energy consumption has been displayed. It has been confirmed that unrelated factors to the thermal environment can influence the thermal functions of occupants. The objectives are to investigate the light intensity parameters on temperature and humidity and evaluate the light intensity requirements. Various parameters affecting the light intensity are temperature and humidity of the indoor environment were considered experimentally using the location of lamps at the top. The results showed that the halogen type has more effect on the temperature. It can be concluded that as the light intensity increased, the indoor temperature increased and the humidity is inversely proportional. It is very important to improve the internal environment of the place according to the usage, taking into account of all the parameters that have a direct or indirect effect such as the comfort of the residents, etc. Thus, more researches are needed in the future.

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REFERENCES

[1] Y. Li, "Temperature and humidity sensors based on luminescent metal-organic frameworks," Polyhedron, **179**, (2020) pp.1-14.
[2] F. Figueiredo, C. Aragão, W. Pinto, M. Teresa, & C. C. V Oliveira, "Optimizing rearing and welfare in Senegalese sole (Solea senegalesensis) broodstock : Effect of ambient light intensity and handling time on stress response," Appl. Anim. Behav. Sci. **222,** (2020) pp.1-9.
[3] M. G. Figueiro *et al.*, "The impact of daytime light exposures on sleep and mood in office workers," Sleep Heal. J. Natl. Sleep Found. **3**, 3 (2017) pp.204–215.
[4] J. Van Hoof, "Technology," (2013) pp.1-13.
[5] L. Sahin & M. G. Figueiro, "Alerting effects of short-wavelength (blue) and long-wavelength (red) lights in the afternoon," Physiol. Behav. **116-117** (2013) pp.1-7.
[6] W. O. Popoola, "Impact of VLC on Light Emission Quality of White LEDs**,"** **34**, 10 (2016) pp.2526–2532.
[7] M. A. Bonmati-carrion *et al.*, "Effect of Single and Combined Monochromatic Light on the Human Pupillary Light Response," **9**, November (2018) pp.1–15.
[8] R. M. Lunn *et al.*, "Science of the Total Environment Health consequences of electric lighting practices in the modern world : A report on the National Toxicology Program's workshop on shift work at night , artificial light at night , and circadian disruption," Sci. Total Environ. **607–608**, (2017) pp.1073–1084.
[9] V. Benard *et al.*, "Sleep and circadian rhythms as possible trait markers of suicide attempt in bipolar disorders : An actigraphy study," J. Affect. Disord. **244**, September (2019) pp.1–8.
[10] M. J. H. Huibers, L. E. De Graaf, F. P. M. L. Peeters, & A. Arntz, "Does the weather make us sad ? Meteorological determinants of mood and depression in the general population," Psychiatry Res. **180**, 2–3 (2010) pp.143–146.
[11] J. J. A. Denissen, L. Penke, & M. A. G. Van Aken, "The Effects of Weather on Daily Mood : A Multilevel Approach," **8**, 5 (2008) pp.662–667.
[12] M. Laudon, "Effect of controlled-release melatonin on sleep quality , mood , and quality of life in subjects with seasonal or weather-associated changes in mood and behaviour," **13,** (2003) pp.137–145.
[13] T. A. Klimstra, H. Berlin, & M. A. G. Van Aken, "Come Rain or Come Shine : Individual Differences in How Weather Affects Mood**,"** **11**, 6 (2011) pp.1495–1499.
[14] B. Yu, Z. Chen, P. Shang, & J. Yang, "Study on the influence of albedo on building heat environment in a year-round," **40**, (2008) pp.945–951.
[15] R. K. Pal, "ANALYSIS OF A HOUSE WITH MUD LAYER IN ROOF FOR," **8,** 1 (2016) pp.31–40.
[16] G. Xing-guo, W. Jia, W. Yue, A. Yu-qiang, & L. Xiang-wei, "Experimental Study of the Thermal Performance of a New Type of Building Reflective Coating in Hot Summer and Cold Winter Zone of China," Procedia Eng., **205**, (2017) pp.603–608.
[17] M. Santamouris, "On the energy impact of urban heat island and global warming on buildings," Energy Build. **82,** (2014) pp.100–113.

[18] F. Ascione, N. Bianco, R. Francesca, D. Masi, M. Santamouris, & G. Peter, "Energy Performance of Cool-Colors and Roofing Coatings in Reducing the Free Solar Gains during the Heating Season : Results of an In-Field Investigation," Procedia Eng., **169**, (2016) pp.375–383.

[19] H. Mohammad, B. M. Reza & G. Zahra, "Investigating the Effect of Changing the Transmitted Light's Color on Thermal and Visual Comfort," Naqshejahan, **6**, 4 (2017) pp.13-25

[20] R. R. Baniya, E. Tetri, & J. Virtanen, "Indoor and Built The effect of correlated colour temperature of lighting on thermal sensation and thermal comfort in a simulated indoor workplace," (2016) pp.1–9.

[21] N. Kakitsuba, "Comfortable indoor lighting conditions for LEDlights evaluated from psychological and physiological responses," Appl. Ergon. **82**, (2019) pp.1-7.

[22] N. Kakitsuba, "Comfortable Indoor Lighting Conditions Evaluated from Psychological and Physiological Responses," (2015) pp.163-172.

[23] Z. Wu, C. Xu, C. Ma, Z. Liu, H. Cheng, & W. Ren, "Synergistic Effect of Aligned Graphene Nanosheets in Graphene Foam for High-Performance Thermally Conductive Composites," (2019) pp.1–8.

[24] Z. Chen, C. Hou, Q. Zhang, Y. Li, & H. Wang, "Reinforced heat dissipation by simple graphene coating for phosphor- in-glass applied in high-power LED," J. Alloys Compd**.** **774,** (2019) pp.954–961.

[25] Y. Zhang, Y. Ren, & S. Bai, "International Journal of Heat and Mass Transfer Vertically aligned graphene film / epoxy composites as heat dissipating materials," Int. J. Heat Mass Transf. **118**, (2018) pp.510–517.

[26] J. Wang, Y. Cai, X. Li, Y. Shi, & Y. Bao, "Electrically-induced ionic wind flow distribution and its application for LED cooling," Appl. Therm. Eng., **138**, March (2018) pp.346–353.

[27] Y. Lai *et al.*, "Liquid cooling of bright LEDs for automotive applications," Appl. Therm. Eng. **29,** 5–6 (2009) pp.1239–1244.

[28] J. Wang, Y. X Cai, Y. C. Bao, J. B. Wang & X. H. LI, "Enhanced ionic wind generation by graphene for LED heat dissipation," International Journal of Energy Research, **43**, 8, (2019) pp.3746-3755.

[29] X. Zhao, Y. Cai, J. Wang, X. Li, & C. Zhang, "Thermal model design and analysis of the high-power LED automotive headlight cooling device," Appl. Therm. Eng., **75,** (2015) pp.248–258.

[30] X. Zhao, E. Jiaqiang, Z. Zhang, J. Chen, and G. Liao, "A review on heat enhancement in thermal energy conversion and management using Field Synergy Principle," Appl. Energy, **257,** (2019) pp.1-25.

[31] W. L. Tong, Y. M. Hung, H. Yu, M. K. Tan, & B. T. Ng, "Ultrafast Water Permeation in Graphene Nanostructures Anomalously Enhances Two-Phase Heat Transfer," (2018) pp.1–12.

[32] W. L. Tong, W. Ong, S. Chai, M. K. Tan, & Y. M. Hung, "Enhanced Evaporation Strength through Fast Water Permeation in Graphene-Oxide Deposition," Nat. Publ. Gr*.*, (2015) pp.1–13.

[33] H. Wang, J. Qu, Y. Peng, & Q. Sun, "Heat transfer performance of a novel tubular oscillating heat pipe with sintered copper particles inside flat-plate evaporator and high-power LED heat sink application," Energy Convers. Manag**.** **189**, January (2019) pp.215–222.

[34] L. Schwartz *et al.*, "Electricity end uses , energy efficiency , and distributed energy resources baseline : Transportation Sector Chapter," (2017) pp.1-370.

[35] L. Graamans, E. Baeza, A. Van Den Dobbelsteen, I. Tsafaras, & C. Stanghellini, "Plant factories versus greenhouses : Comparison of resource use efficiency," **160**, (2018) pp.31–43.

[36] T. Q. Trung, L. T. Duy, S. Ramasundaram, & N. Lee, "Transparent , stretchable , and rapid-response humidity sensor for body-attachable wearable electronics," **4,** (2016) pp.1–13.

[37] Y. Peng, Y. Zhao, M. Chen, and F. Xia, "Research Advances in Microfiber Humidity Sensors," (2018) pp.1-20.