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Analysis of Thermal Condition of Classrooms in Suburban Area During Corona Virus Desease using Adaptive Method

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Analysis of Thermal Condition of Classrooms in Suburban Area During Corona Virus Desease using Adaptive Method

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Abstract. This article addresses the influence of a classroom's thermal environment on the thermal comfort of the student when windows and vents are wide open during a pandemic, following Corona Virus Desease regulations. This research was conducted quantitatively by measuring the classrooms' thermal environments from 08:00 to 13:00 at a suburban high school. The findings indicate that the classroom's average air temperature (T_a) was 29.80°C, with an average relative humidity (RH) of 67.71%, an average airflow velocity (V) of 0.05m/s, an average Mean Radiant Temperature (MRT) of 29.67°C, and an average operating temperature (T_{op}) of 29.72°C. An analysis was conducted using the web-based CBE Thermal Comfort Tool with the Adaptive Method, which can analyze the acceptance of thermal conditions based on operative temperature (T_{op}). According to the analysis, it can be concluded that the thermal environment conditions in the morning in a "Comfortable" condition based on the ASHRAE-55 scale with the operative temperature (T_{op}) are 27.37°C, the airflow speed (V) is 0.3m/s, and the prevailing mean outdoor temperature is 29.73°C. However, during the day, the ambient environmental conditions change, and the thermal comfort turns to "Too Warm" due to the operative temperature condition (T_{op}), which is at the highest point of 31.46°C, with a prevailing mean outdoor temperature of 29.73°C, and an airflow speed (V) of 0.3m/s. It can be seen that the condition has not been able to meet the ASHRAE-55 standard, both in the 80% acceptability limit and the 90% acceptability limit range.

1. Introduction

At the end of 2019, Corona Virus Desease was discovered for the first time in China's Wuhan Province, and the pandemic was subsequently declared on January 30, 2020. [1]. Following that, illnesses swiftly arose worldwide, leading to a global health crisis that caused negatively impacted many facets of life and the global economy.

The pandemic of Corona Virus Desease has been ongoing for more than two years. At the onset of the Corona Virus Desease pandemic, classroom learning activities shifted to online learning. With the fall in Corona Virus Desease transmission rates, the government has gradually begun to permit the limited reintroduction of classroom learning under tight health procedures. This condition results in the discontinuation of air cooling devices in the room (air conditioner/AC) and starting of the implementation of natural ventilation in the classroom. However, these conditions can potentially generate problems with the classroom's thermal environment, which could compromise the students' thermal comfort.

Research worldwide has uncovered the importance of combining environmentally conscious practices with adequate educational settings. Several studies of educational buildings have demonstrated that poor environmental conditions within classrooms can have a negative impact on students' learning ability and concentration [2] [3] [4]. This is due to the fact that students spend one-third of their day indoors [5] [6].

According to ASHRAE 55, thermal comfort is a subjective evaluation of a person's mental state that reflects their level of contentment with their surrounding temperature. The level of thermal comfort is the most crucial indicator of Indoor Environmental Quality (IEQ). In addition, the human race is constantly looking for ways to feel more at ease in its current environment. The human body aims to keep its internal temperature at a steady 37°C through constant heat exchange with the environment. There are three primary modes of heat transport between the human body and its external environment: convection, radiation, and continual evaporation [7] [8].

Several extensive studies have been conducted on the conditions of the thermal environment in the room. The whole concept of thermal comfort revolves around two main aspects that affect the well-being of its inhabitants, namely physiological factors and psychological factors. Physiological factors include personal and environmental parameters, and most studies focus on physiological parameters. Mulyadi et al. investigated the adaptive thermal comfort level of elementary school students located along the West Coast of South Sulawesi Province, Indonesia, which is generally high in temperatures. The result shows that most respondents still feel comfortable adapting to indoor thermal conditions [9].

Students' academic performance suffers when the ambient temperature in the classroom is too high to be comfortable [10]. There is a correlation between the student's performance or production and the classroom's thermal environment, independent of the students' ages [11]. Research by Hamzah et al. conducted in Makassar, Indonesia, indicated that 53% of residents complained of heat exhaustion when the mercury hit 24.0°C. Student body temperatures were measured, and they averaged 27.0°C, greater than the classroom environment [12]. Children's metabolisms are unique, as are the clothes they wear and the activities they engage in [13], and they also have fewer opportunities to adjust to their environments than adults do [14] [15] [16]. Adaptive comfort temperatures for children are approximately 2°C lower than those for adults [17] and can be as much as 3° C lower [15], according to a study conducted on children [16]. Researchers Wargocki et al. found that lowering the temperature in Chilean classrooms from 30 to 20°C resulted in a 20% improvement in student performance [10].

Hamzah et al. looked into overheated classrooms in Makassar, Indonesia. They found that lows are about 28.2°C and highs are around 33.6°C. The Thermal Sensation Vote (TSV) and Thermal Comfort Vote (TCV) results show that a sizable minority of students continue to report feeling at ease (between 1 and +1). Even though roughly 80% of the student body is subjected to extreme heat, the vast majority would rather have cooler conditions. Only roughly 23% of respondents are expected to feel at least a little bit warm (+1) in terms of PMV (Predicted Mean Vote). When comparing TSV and TCV, the regression analysis revealed that their respective neutral temperatures were 29.0°C and 28.5°C [18].

In light of the foregoing, how do secondary school classes in natural suburban regions with wide-open windows and vents fare during the Corona Virus Desease pandemic? Is it up to ASHRAE specifications? This research aims to examine suburban classrooms' temperature and humidity levels during the recent Corona Virus Desease epidemic using the Adaptive Method. The adaptive method is the most often used and works better to predict thermal comfort in naturally ventilated enclosures [19] [20].

2. Method

2.1. Data collection

The study was carried out at a high school in a suburban area approximately 18.6 kilometers from the center of Makassar City and 8.8 kilometers from Sungguminasa City, the capital of Gowa Regency. The research object is a high school named SMAN 8 Gowa, located in Bontomarannu District, Gowa Regency. The purpose of the study was to collect data on the thermal environmental conditions of classrooms, such as air temperature (T_a), Relative Humidity (RH, and air velocity (V). The following photograph depicts the atmosphere of the school complex of SMAN 8 Gowa, together with the classroom arrangement and the placement of the measuring devices utilized (Figure 1).

Figure 1. The classroom's layout and atmosphere.

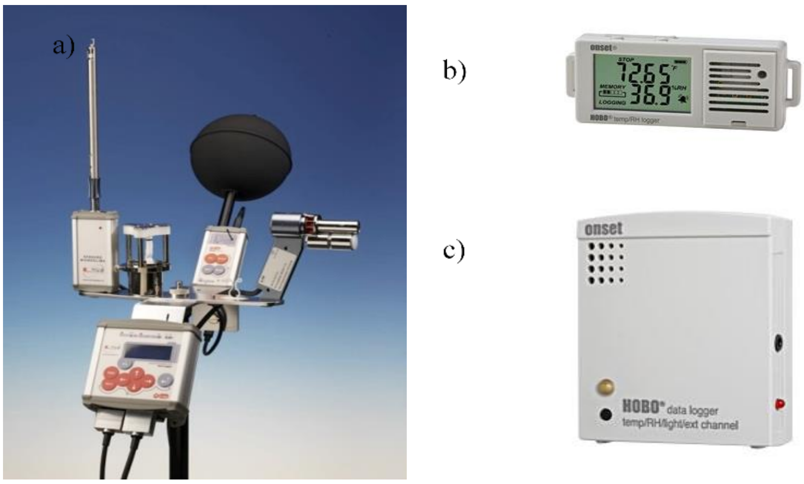


Figure 2. (a) LSI-LASTEM Multi Logger, (b) HOBO data logger, and (c) HOBO data logger with an external sensor.

The measurements were obtained in the classroom at the height of one meter above the floor for a period of five hours, beginning at 08:00 am and continuing until 01:00 pm, with data log intervals occurring every 15 minutes. Figure 1 provides a visual representation of the classroom's plan and the placement of measurement instruments.

The Hobo data logger (Hobo UX100), which measures temperature, humidity, and air flow speed, and the LSI LASTEM Multiloggger, which can measure the air temperature and Globe Temperature, are the tools that are used to obtain data on the thermal environmental conditions. Figure 2 depicts the functions of both of these instruments.

The temperature (Ta), globe temperature (Tg), airspeed (V), and humidity (RH) are measured in the classroom using the Hobo data logger and the LSI-LASTEM measuring instruments, as can be seen in Figure 2. This is done to get an accurate reading of the classroom's thermal environmental conditions.

2.2. Data analysis

The data analysis was carried out based on data on thermal environmental conditions obtained such as Ta, RH, and V and calculated MRT and T_{op}. These data were then juxtaposed with ASHRAE 55 standards using the Adaptive Method available through the CBE Thermal Comfort Tool (https://comfort.cbe.berkeley.edu/).

3. Result and Discussion

The results of measurements of the thermal environment conditions of the room carried out for five days in five different classes on the conditions of wide-open windows and ventilation during the Corona Virus Desease pandemic, as shown in Figure 3, show the profile of air temperature conditions (T_a) in the classroom on average of 29.80°C, with a maximum temperature (T_{max}) of 32.47°C during the day and a minimum (T_{min}) of 26.74°C in the morning. There was an increase of 5.72°C in temperature from 08:00 to 13:00. The average temperature increase in the classroom was 1.14°C per hour or about 0.02°C per minute.

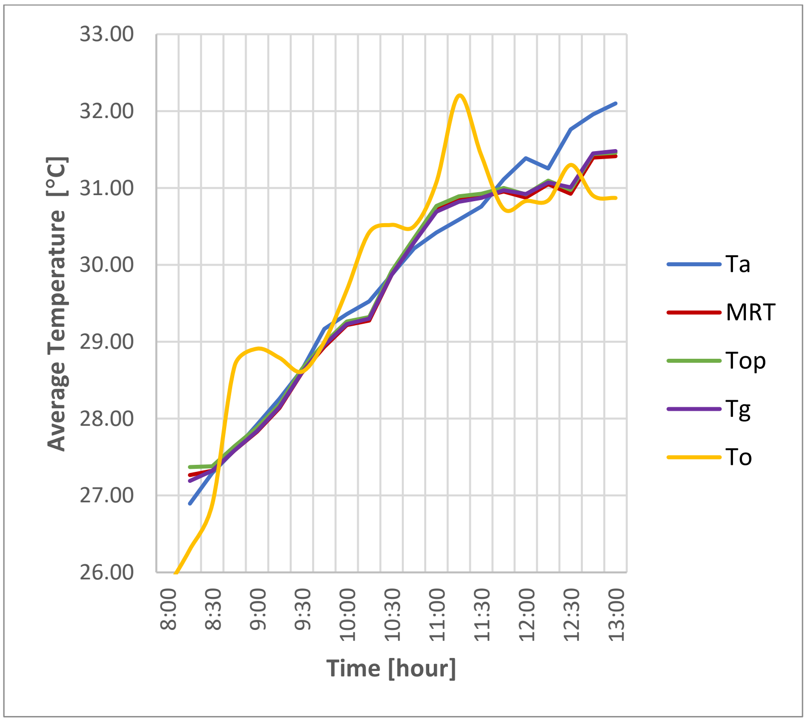


Figure 3. The temperature profile of outdoor (T_o), indoor temperature (T_a), Mean Radiant Temperature (MRT), Operative Temperature (T_{op}), and Globe Temperature (T_g)

Based on the results of the measurement of the thermal environment conditions of the classroom, the average air humidity in the classroom is 67.71%, as shown in Figure 4. The maximum humidity occurs in the morning by 81.27%, and the minimum humidity occurs during the day by 53.51%. The average humidity decreased from morning to noon by 5.55% per hour. Airflow velocity conditions in the classroom are relatively low (Figure 4), with an average speed of 0.05m/s. The minimum airspeed of 0.04m/s occurs at noon. The maximum air speed occurs in the morning at 0.14m/s. With the opening of windows and ventilation, of course, air circulation will occur properly. However, it depends on the condition of the speed of outside airflow into the classroom and the position and dimensions of window openings and ventilation. As shown in Figure 2, window openings and vents allow cross-ventilation to occur to facilitate airflow in and out of the classroom.

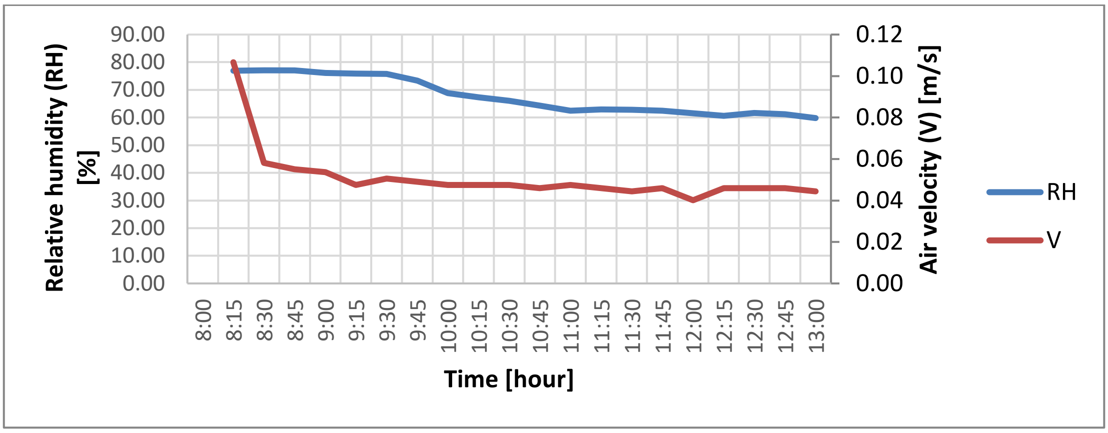


Figure 4. The profile of relative humidity (RH) and air velocity (V)

Using data from measurements of globe temperature (Tg) and airflow speed (V), the value of Mean Radiant Temperature (MRT) can be calculated using the following formula [21] [22]:

$$MRT = T_g + 2.42 \times V \times (T_g - T_a) \quad (1)$$

Where MRT is Mean Radiant Temperature [°C], T_g is the globe temperature [°C], V is air velocity [m/s], and T_a is indoor air temperature [°C].

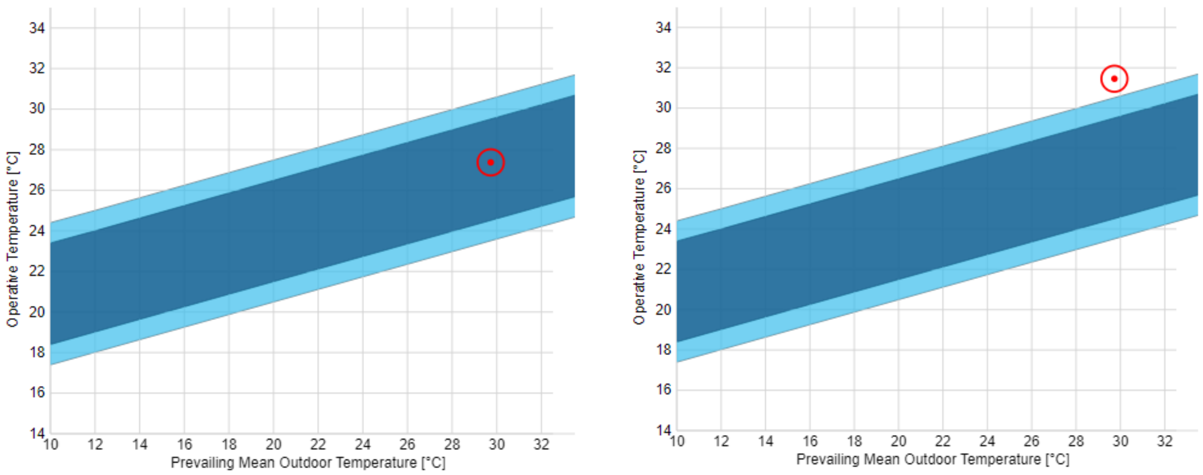
The results of the MRT calculation can be seen in Figure 3. The calculation results show that the average MRT in the classroom is 29.67°C. The lowest MRT value occurred in the morning at 27.27°C and the highest MRT value occurred during the day at 31.41°C. This condition is related to the high value of the globe temperature (T_g). From Figure 3, it can be seen that the average value of globe temperature (T_g) is 29.68°C, with the highest value of 31.48°C during the day and the lowest in the morning at 27.19°C. This causes the MRT value to also be high, in addition to the contribution of the airflow speed (V). The relatively low airflow speed (V) contributes to the high value of the MRT. As shown in Figure 4, the average airflow speed (V) is only 0.05m/s, and the maximum is rated at 0.14m/s; this value is deficient in circulating the hot air in the classroom.

Next, the operative temperature (T_{op}) is calculated using the formula 2. Operative temperature (T_{op}) is the uniform temperature of an imaginary black enclosure/layer/surface where the user of a place will exchange the same amount of heat for radiation plus convection. Mathematically, the operative temperature can be shown as follows [23]:

$$T_{op} = \frac{\{MRT + (T_a \times \sqrt{10V})\}}{1 + \sqrt{10V}} \quad (2)$$

Where T_{op} is operative temperature [°C], MRT is Mean Radiant Temperature [°C], T_a is air temperature [°C], and V is airflow velocity [m/s]. From the calculation of the T_{op}, it can be seen that the average value of the T_{op} is 29.72°C. The T_{op} maximum value is 31.46°C during the day and the T_{op} minimum in the morning is 27.37°C.

Using the CBE Thermal Comfort Tool [24], the thermal environment conditions in the classroom, both in the morning and during the day, can be predicted whether they meet the ASHRAE 55 standard. The tool used the Adaptive Method to predict the user's thermal comfort, as shown in Figures 5 (a) and (b). The adaptive thermal comfort model (temperature-based method) employs more inclusive ranges of thermal comfort temperatures, which may be used to assess the thermal performance of the entire building by measuring the number of hours in which the internal air temperature remains within the thermal comfort range (80% acceptability criteria). In the adaptive approach, the thermal comfort limits for 80% acceptance are 3.5 °C on either side of the optimum thermal comfort temperature, and the 90% acceptability limits are 2.5 °C on either side [25]. The adaptive thermal design allows occupants to interact with their environment to preserve thermal comfort [26]. Also, the method can only be used in naturally cooled spaces controlled by the occupants and meet the following criteria: a) No mechanical cooling system is set up. No heating system is running; (b) metabolic rates between 1.0 and 1.3 met, and (c) occupants are free to adjust their clothing to the indoor and/or outdoor temperatures within a range of at least 0.5 to 1.0 clo [27].



(a) (b)

Figure 5. (a) Adaptive chart of the morning condition with T_{op} = 27.37°C, prevailing mean outdoor temperature = 29.73°C, airspeed = 0.3m/s. (b) adaptive chart of the noon condition with T_{op} = 31.46°C, prevailing mean outdoor temperature = 29.73°C, and airspeed = 0.3m/s.

Based on the results of the analysis in the morning conditions, as shown in Figure 5 (a), where the operative temperature (T_{op}) is 27.37C, the airflow speed (V) is 0.3m/s, and the prevailing mean outdoor temperature is 29.73C, it can be seen that the condition has met the ASHRAE 55 standard. In the 88% acceptability limit range, where the operative temperature (T_{op}) value is between 23.5°C and 30.5°C, the classroom conditions on the study object can meet the ASHRAE-55 standard at a "Comfortable" level. Similarly, in the 90% acceptability limit range where the operative temperature (T_{op}) value is between 24.5°C and 29.5°C, classroom conditions are at a "Comfortable" level based on the ASHRAE-55 scale.

However, the analysis results in the conditions during the day gave different results. The results of the analysis of classroom conditions during the day, as shown in Figure 5 (b) at the operative temperature condition (T_{op}), are at the highest point of 31.46°C, with a prevailing mean outdoor temperature of

29.73°C, and an airflow speed (V) of 0.3m/s it can be seen that the condition has not been able to meet the ASHRAE-55 standard. In this condition, classroom objects are at the "Too Warm" level based on the ASHRAE scale, both in the 80% acceptability limit and the 90% acceptability limit range.

These two conditions, both in the morning and during the day, give an idea that the thermal conditions in the classroom fluctuate based on the conditions of the surrounding environment. Although in the morning, the thermal conditions of the classroom can meet the ASHRAE-55 standard and are at the "Comfortable" level based on the ASHRAE scale, over time, the thermal conditions of the surrounding environment also change to hotter, causing a change in conditions from a "Comfortable" to "Too Warm" scale. This condition will certainly cause students to take adaptative actions in anticipation of these conditions. These conditions can affect student performance in learning. However, further research is needed to know the effects of thermal conditions to the student's performances during the day.

4. Conclusion

Based on the analysis and discussion of the thermal environment conditions in high school classrooms in urban areas during the Corona Virus Desease pandemic, using a web-based CBE Thermal Tool adaptive methods, it can be concluded that in the morning is in a "Comfortable" condition level based on the ASHRAE-55 scale. However, during the day, as the temperature gets high, the humidity is gradually turning down, and also the airspeed decreased; the conditions are different and change to "Too Warm" due to the influence of changes in thermal environmental conditions.

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