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Thermal Comfort in Humid Tropical Climate Areas (Case Study on Open Spaces and Shaded Spaces in Medan City)

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ABSTRACT

Humid tropical climates are areas with high humidity temperature characteristics. This high temperature is partly due to sunlight which is always constant throughout the day, while high humidity is usually associated with relatively high rainfall. Because of this, in general, buildings in this area have a fairly wide canopy or what is often referred to as a shading element in architecture. This will ultimately affect the thermal comfort of buildings in the humid tropics. In this study the authors tried to look at the two main factors that shape thermal comfort, namely the level of temperature and humidity. The author will compare three types of outdoor spaces, namely sheltered outdoor spaces with walls on one side, shaded rooms without walls and outdoor spaces without shade. The research was conducted by measuring temperature and humidity simultaneously at the three locations. Measurements were carried out for two weeks, at five different times with an interval of two hours. The results obtained show that there are significant differences in temperature and humidity between open spaces and shaded spaces. Where the shaded room has lower temperature and humidity. As for other shaded rooms, it is known that shaded rooms without walls have lower temperature and humidity.

Keywords: outdoor space, thermal comfort, tropical.

1. Introduction

Thermal comfort is the human condition for temperature stimuli received from the surrounding environment. The response that is usually shown is the emergence of a feeling of heat or cold. This thermal comfort can also be interpreted as a human perception of the thermal conditions they experience [1].

There are 3 factors that affect thermal comfort [2]: (1) Air temperature, which for Indonesia can be divided into 3 categories: a) comfortable cool with a temperature of 20.5℃ - 22.8℃; b) optimal comfort with a temperature of 22.8℃ - 25.8℃;; c) comfortably warm with a temperature of 25.8℃ - 27.1℃; (2) Air humidity, with a range of 40% -70%; (3) Wind, with a speed range of 0.1 m/sec to 0.5 m/sec.
The above factors can generally be used as a guideline for determining the size of thermal comfort in a room. However, it cannot be used as a standard benchmark for determining thermal comfort in all regions of Indonesia. This is due to the fact that there are other external factors that are quite influential such as environmental parameters and the human body as well as human psychological characteristics [3], gender [4], and cultural and ethnic background [5].

In several further studies it was found that there was a correlation between comfort and human performance at work [6]. Good indoor thermal comfort conditions can apparently increase work productivity [7]. This shows that human comfort in a built environment can also influence the behavior it causes.

The tropical zone is a geographical division terminology that refers to areas located near the equator. The tropical climate area is located between 23½º South Latitude and 23½º North Latitude and almost 40% of the earth's surface receives vertical sunlight. From the division above, the tropical zone is divided into 2 climate areas, namely 1) warm humid/wet tropical zones (Hot/Warm Humid Climate Zones) which are approximately located between 15º LU and 15º LS; 2) Hot-Dry/Arid Climate Zones (Hot-Dry/ Arid Climate Zones) are located between 15º LU - 30º LU and 15º LU - 30º LS. Warm-Humid Zones (Hot/Warm-Humid Zones) are characterized by conditions of high humidity (> 90%) with high rainfall, as well as annual average temperatures above 18ºC. Seasonal differences are almost non-existent and annual temperature fluctuations are very small [8].

If we look into Indonesian vernacular architecture, we can clearly see the efforts of traditional communities to respond to their surroundings, in this case the humid tropical climate, into their buildings. The use of roofs that have long slopes so that the building is not exposed to direct sunlight, stilt-type buildings with wide window openings to maximize air movement to overcome high humidity, and other characteristics. This was later also corroborated by Amos Rapoport who stated that climate and environmental aspects are one of the things that influence architectural products [9].

This is further clarified by further research that has been carried out by experts. Buildings in tropical climates should have a natural ventilation system and have a semi-outdoor room as part of the main building [10], use of balconies as sunshades and passive shading devices on walls facing the sun [11], use of shading and surfaces that reflect light [12], it is necessary to have a cross-ventilation system and the building structure must be shaded from rain and sun heat [13].

Researchers will conduct research on building components that are directly related to the forming factors of thermal comfort, namely temperature, high rainfall which will cause high humidity and the level of air movement. Researchers will compare temperature, humidity and wind speed in three types of space. The first room is in the form of a gazebo with a shaded bamboo structure without walls, the second room is an open space without shade and the third room is the hall of the building which is shaded and has a canopy with a stretch of 1.5 m. The three rooms are located in a straight line and are 10 meters apart from each other.

This research is expected to be able to prove the initial hypothesis regarding thermal comfort in a humid tropical climate, where a shaded room should have a lower temperature or be more comfortable from a thermal standpoint compared to an unshaded room. This research will be a door for researchers to conduct further research, especially research that can provide a way out to obtain optimal thermal comfort for areas with a humid tropical climate.

2. Method

The research method used is a quantitative descriptive research. Descriptive research is defined as research that seeks to describe a symptom, event and event that is happening at the present time [14]. While the quantitative approach can be defined as an approach using numbers, starting from data collection, interpretation of the data and the appearance of the results [15].

2.1. Research sites

The research was conducted in the city of Medan. More precisely, in an open space in front of the Architecture Lecture Building, Universitas Sumatera Utara, Jalan Perpustakaan, Padang Bulan Campus. The research location can be seen in figure 1 and figure 2.

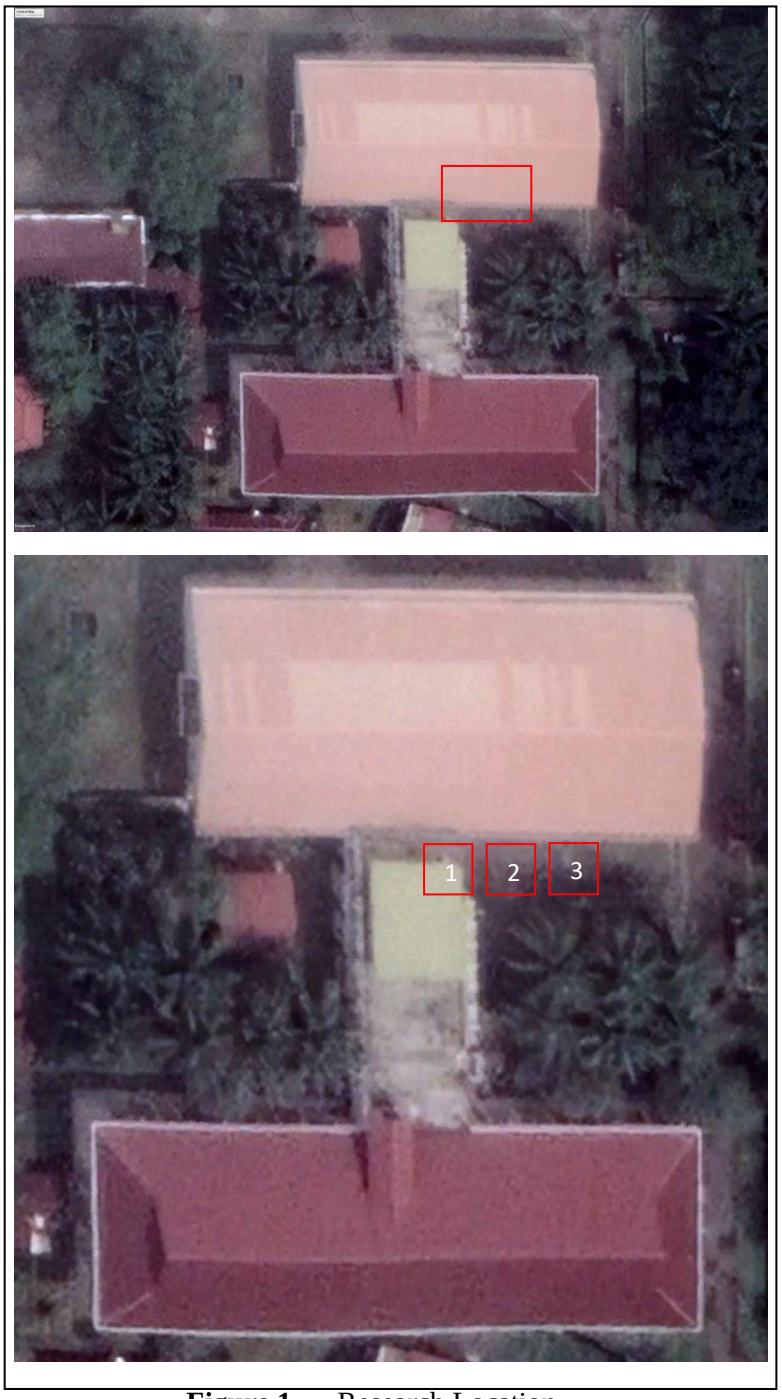

Figure 1 Research Location
Source: Author's image processing results

Figure 2 Location of measurement
Source: Author's image processing results

The measurement points are placed in a straight line and at the same height, which is 2.8 meters from the surface of the paving block.

2.2. Research Stages

The research was conducted at one location with 3 different points. The difference in points is based on the characteristics of the cover (covered or unshaded). Measurement point 1 is placed under the canopy of the building's walkway (shaded but walled on one side); Measurement point 2 is placed in an open space in front of the building (not covered); Measurement point 3 is placed under the gazebo with thatched roof material and a bamboo structure (shade without walls).

Data collection will be carried out on microclimate parameters, including: 1) air temperature; 2) relative humidity; 3) wind speed.

Data collection was carried out 5 times a day, namely at 08.00 WIB, 10.00 WIB, 12.00 WIB, 14.00 WIB and 16.00 WIB. Data collection throughout the active day is carried out to find out the average microclimate data at the same time span as lecture time, so that the results of the research are expected to be able to contribute directly to lecture activities. Data collection was carried out for 10 days, namely on 12,13,14,17,18,26,27,28 April 20203 and 2,3,4,5 May 2023.

The selection of data collection in April-May is also based on the highest average temperature in Medan City, which is around May-June. The determination of this time span is expected to be the highest possible temperature limit to be measured.

Furthermore, the data obtained will be analyzed descriptively based on the parameters that have been collected. The difference between the average air temperature, relative humidity and wind speed at each measuring point will be analyzed using the Correlate Independent T Test statistic. Based on this test, it will be explained how the relationship between conditions of temperature, humidity and wind speed at the research location is shaded with walls, shaded without walls and not shaded.

Besides that, the calculation of thermal comfort will also be carried out at these three points. Many approaches can be used to perform thermal comfort calculations. However, in this study the calculations will be carried out using the effective temperature approach by Houghton and Yaglou [16]. The effective temperature can be obtained by obtaining wet temperature data by connecting dry temperature and humidity on a psychrometric calculator. Furthermore, the wet temperature and wind speed values will be connected in the nomogram chart, so that the effective temperature value will be obtained later.

To determine the criteria for thermal comfort, the thermal comfort standard by Mom and Wiesebron will be used with a range of thermal comfort between 22.9ºC to 24.3ºC [16].

2.3. Equipment

This study uses several measurement tools to calculate some of the data collected as shown in table 1 and figure 3.

Table 1 Data and measurement tools

Data	Measurement Tools
Dry Temperature	ThermoPro TP 65
Humidity	ThermoPro TP 65
Wind Velocity	HoldPeak HP-866B
Wet Temperature	*Psychrometric Calculator*
Effective Temperature	Nomogram
Thermal Comfort Standards	Mom and Wiesebron

Source: Author's data processing results

Figure 3 Location of measurement
Source: Author's image processing results

The thermometer uses 3 outdoor transmitters, so that temperature data can be measured at the same time. The wind speed measurement is carried out at one point only, because the distance between the measurement points is quite close.

3. Result and Discussion

There are 3 data measured in this study namely temperature data, air humidity and wind speed. Measurements were taken 5 times a day, starting at 08.00 WIB and ending at 16.00 WIB with 2 hour intervals.

3.1. Temperature

The research was conducted at one location with 3 different points. The difference in points is based on the characteristics of the

Temperature measurements produce data as shown in table 2:

Table 2 Temperature data measurement results

Date	Times	Temperature ºC		
		Location		
		1	2	3
12 April 2023	08.00	29,9	29,4	26,6
	10.00	35,8	34,9	31,9
	12.00	37,1	37,6	35,2
	14.00	35,6	38,2	36,1
	16.00	34,5	36,8	35,1
13 April 2023	08.00	30,2	30,2	28,6
	10.00	35,6	35,6	32,6
	12.00	37,2	37,2	34,8
	14.00	34,7	34,7	33,4
	16.00	29,8	29,8	29,4
14 April 2023	08.00	28,2	28,2	27,4
	10.00	35,8	35,8	32,6
	12.00	35,9	35,9	34,6
	14.00	35	35	34
	16.00	37,1	37,1	35,4
17 April 2023	08.00	29,5	29,5	28,2
	10.00	34,9	34,9	32,7
	12.00	36,3	36,3	34,2
	14.00	38,9	38,9	36,7
	16.00	35,4	35,4	34,5
18 April 2023	08.00	31,3	31,3	29,5
	10.00	36,6	36,6	33,4
	12.00	38,8	38,8	36
	14.00	39,4	39,4	36,8
	16.00	35,2	35,2	34
26 April 2023	08.00	28,7	28,7	28,3
	10.00	35,6	35,6	32,2
	12.00	37,4	37,4	34,6
	14.00	29,8	29,8	30,4
	16.00	26,5	26,5	26,4
27 April 2023	08.00	27,3	25,9	26,3
	10.00	28,2	27,8	27,4
	12.00	32,9	34,6	32,3
	14.00	32,9	34,3	32,7
	16.00	32,9	34,6	33,3
28 April 2023	08.00	28,6	27,9	26,8
	10.00	32,6	32,9	30,6
	12.00	35,5	37,3	35,2
	14.00	31,9	33,6	31,8
	16.00	32,9	34,6	33,3

Date	Times	Temperature ºC		
		Location		
		1	2	3
2 May 2023	08.00	29,7	29,2	28,5
	10.00	33,2	33,7	31,5
	12.00	36,1	38	35,9
	14.00	35,1	36,9	35,5
	16.00	33	32,5	32,3
3 May 2023	08.00	28,4	28,1	27,9
	10.00	33,3	33,8	30,8
	12.00	34,3	35	33,4
	14.00	33,7	35,2	33,8
	16.00	32,6	33,7	32,4
4 May 2023	08.00	29,6	29,3	28,6
	10.00	36,9	37,3	33,3
	12.00	37,2	40	36,7
	14.00	34,8	35,9	34,1
	16.00	30	29,5	29,1
5 May 2023	08.00	29,6	29,4	28,4
	10.00	33,7	34,3	31,6
	12.00	34,9	36,3	33,8
	14.00	34,6	36,7	33,9
	16.00	31,1	29,8	29,4

Source: Author's image processing results

From the data above, the average daily temperature data at the 3 measurement points at the study location can be displayed as presented in table 3.

Table 3 Daily average temperature data

Date	Temperature		
	Location 1	Location 2	Location 3
12 April 2023	34,58	35,38	32,98
13 April 2023	33,62	33,5	31,76
14 April 2023	34,3	34,4	32,8
17 April 2023	34,8	35	33,26
18 April 2023	34,98	36,26	33,94
26 April 2023	32,02	31,6	30,38
27 April 2023	30,84	31,44	30,4
28 April 2023	32,3	33,26	31,54
2 May 2023	33,42	34,06	32,74
3 May 2023	32,46	33,16	31,66
4 May 2023	33,7	34,4	32,36
5 May 2023	32,78	33,3	31,42

Source: Author's image processing results

If translated into figure 4, it can be seen that location 1 (hallway of a building that is shaded but has walls on one side) has a lower average temperature than location 2 (open space and is not covered). However, on April 13 and April 26, this condition reversed. Whereas for location 3 (under the gazebo with a roof and no walls) the temperature is always the lowest. This shows that the temperature conditions in shaded locations are lower than in unshaded locations, with the lowest temperatures occurring in shaded and non-walled locations.

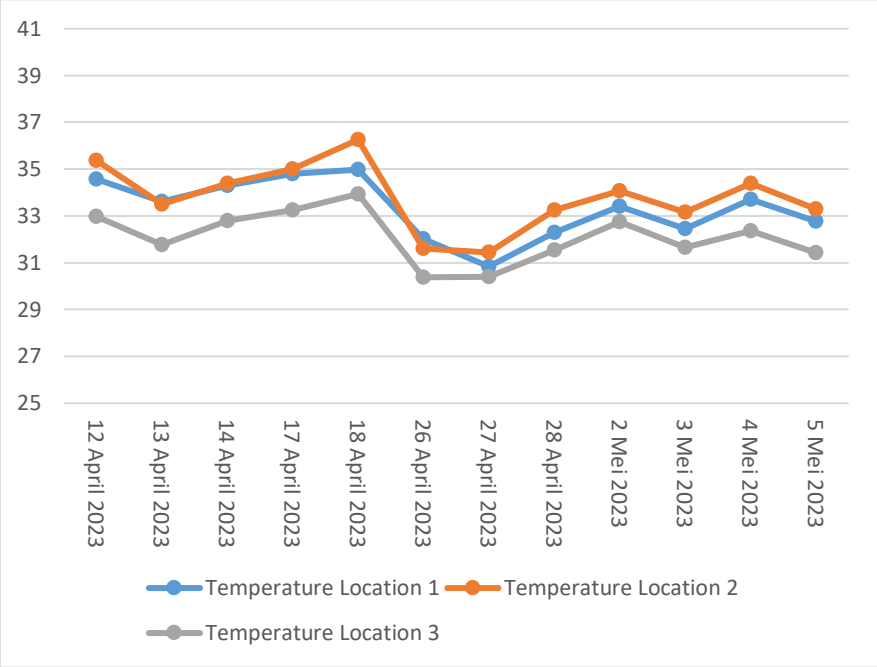

Figure 4 Graph of daily average temperature
Source: Author's data processing results

Next, temperature comparisons were made at 08.00, 10.00, 12.00, 14.00 and 16.00 WIB. This is done to see whether the above trends occur in each time frame when data collection is carried out. The data can be seen in tables 4, 5, 6, 7 and 8.

Table 4 Temperature data at 08.00 WIB

Date	Temperatur		
	Location 1	Location 2	Location 3
12 April 2023	29,9	29,4	26,6
13 April 2023	31,1	30,2	28,6
14 April 2023	30,6	28,2	27,4
17 April 2023	30,1	29,5	28,2
18 April 2023	31,3	31,3	29,5
26 April 2023	29,2	28,7	28,3
27 April 2023	27,3	25,9	26,3
28 April 2023	28,6	27,9	26,8
2 May 2023	29,7	29,2	28,5
3 May 2023	28,4	28,1	27,9
4 May 2023	29,6	29,3	28,6
5 May 2023	29,6	29,4	28,4

Source: Author's data processing results

From the data above, it can be seen that there is a difference from the previous average data. In this time span, the temperature at location 2 turned out to be lower than at location 1. However, the lowest temperature remained at location 3. This can be seen in full in figure 5. This shows that a sheltered location does not necessarily have a lower temperature than the location shaded one.

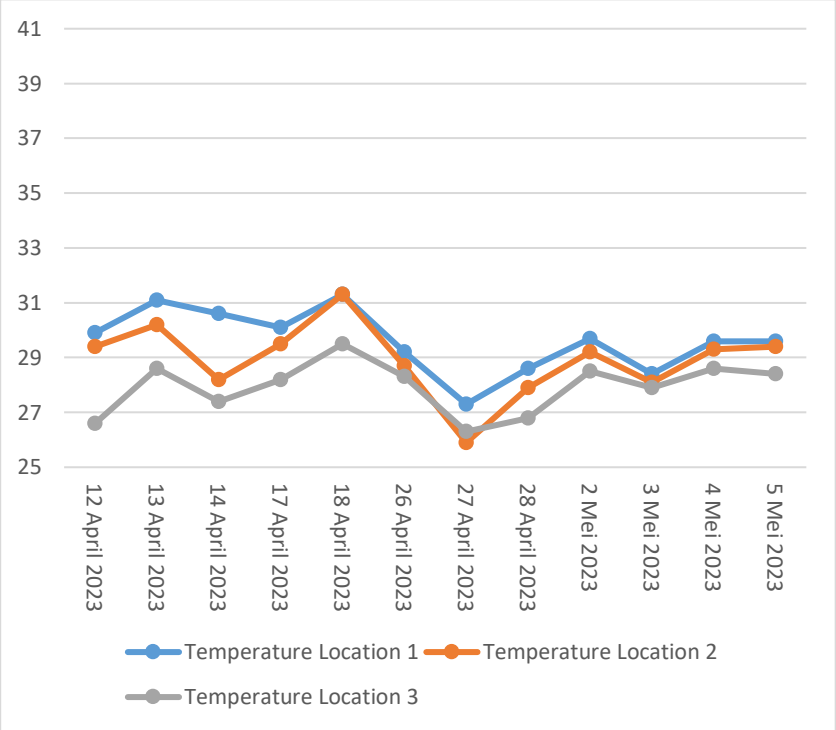

Figure 5 Graph of temperature at 08.00 WIB
Source: Author's data processing results

In table 5 and figure 6, it is known that in the measurement at 10.00 WIB the temperature conditions at locations 1 and 2 tend to be the same, while for location 3 it still shows the lowest temperature conditions.

Table 5 Temperature data at 10.00 WIB

Date	Temperature		
	Location 1	Location 2	Location 3
12 April 2023	35,8	34,9	31,9
13 April 2023	35,6	35,6	32,6
14 April 2023	36	35,8	32,6
17 April 2023	34,9	34,9	32,7
18 April 2023	36,8	36,6	33,4
26 April 2023	35,1	35,6	32,2
27 April 2023	28,2	27,8	27,4
28 April 2023	32,6	32,9	30,6
2 May 2023	33,2	33,7	31,5
3 May 2023	33,3	33,8	30,8
4 May 2023	36,9	37,3	33,3
5 May 2023	33,7	34,3	31,6

Source: Author's data processing results

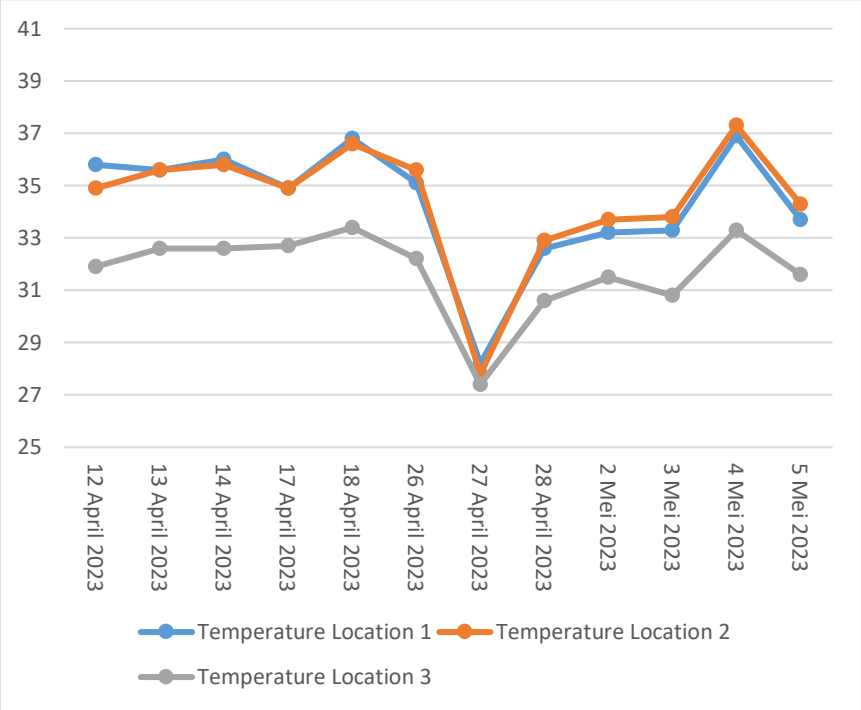

Figure 6 Graph of temperature at 10.00 WIB
Source: Author's data processing results

In table 6 and figure 7, it can be seen from the measurements taken at 12.00 WIB, the temperature condition at location 1 was already lower than the temperature at location 2. The difference was quite significant, where the difference that emerged was not as slight as that which occurred at 10.00 WIB. For temperature conditions at location 3 is still the lowest.

Table 6 Temperature data at 12.00 WIB

Date	Temperature		
	Location 1	Location 2	Location 3
12 April 2023	37,1	37,6	35,2
13 April 2023	36,2	37,2	34,8
14 April 2023	35,9	35,9	34,6
17 April 2023	35,9	36,3	34,2
18 April 2023	36,7	38,8	36
26 April 2023	35,8	37,4	34,6
27 April 2023	32,9	34,6	32,3
28 April 2023	35,5	37,3	35,2
2 May 2023	36,1	38	35,9
3 May 2023	34,3	35	33,4
4 May 2023	37,2	40	36,7
5 May 2023	34,9	36,3	33,8

Source: Author's data processing results

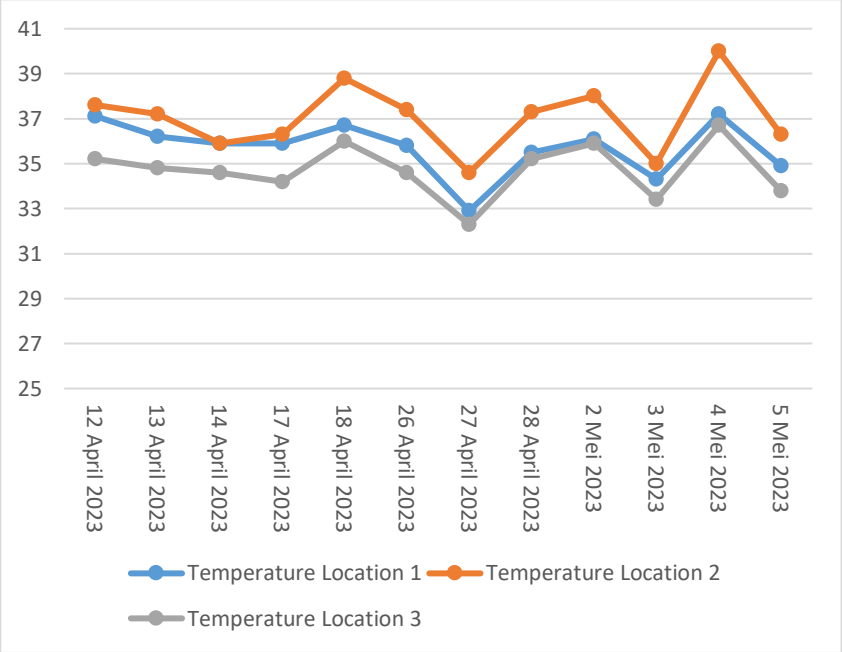

Figure 7 Graph of temperature at 12.00 WIB
Source: Author's data processing results

In table 7 and figure 8, the results of the measurements carried out show that the trend is the same as before. The temperature condition at location 1 is lower than location 2 and for location 3 it still shows the lowest temperature.

Table 7 Temperature data at 14.00 WIB

Date	Temperature		
	Location 1	Lokasi 2	Location 3
12 April 2023	35,6	38,2	36,1
13 April 2023	34,1	34,7	33,4
14 April 2023	34,5	35	34
17 April 2023	36,3	38,9	36,7
18 April 2023	36,2	39,4	36,8
26 April 2023	31,6	29,8	30,4
27 April 2023	32,9	34,3	32,7
28 April 2023	31,9	33,6	31,8
2 May 2023	35,1	36,9	35,5
3 May 2023	33,7	35,2	33,8
4 May 2023	34,8	35,9	34,1
5 May 2023	34,6	36,7	33,9

Source: Author's data processing results

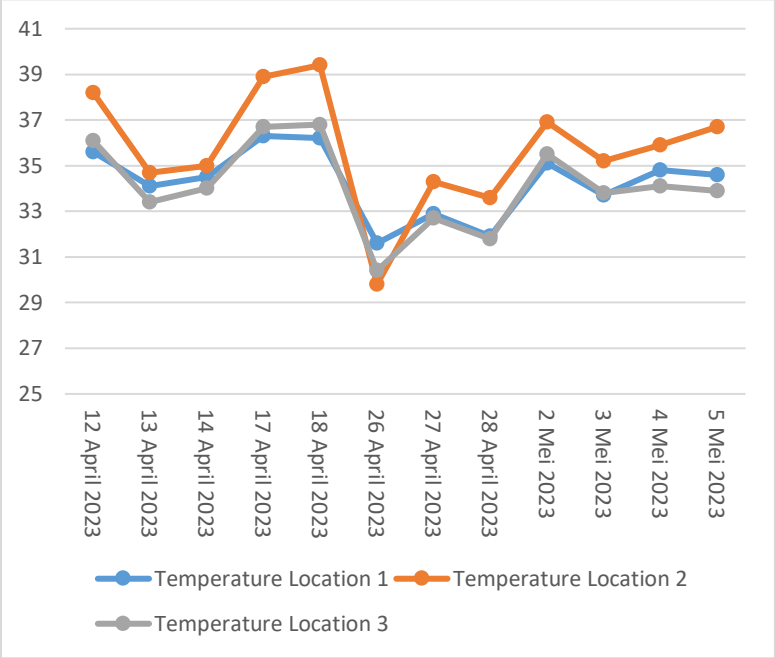

Figure 8 Graph of temperature at 14.00 WIB
Source: Author's data processing results

In table 8 and figure 9, from the results of measurements taken at 16.00 WIB, it was found that the temperature conditions for location 1 were lower than the temperature conditions for location 2. However, the temperature difference was not that large and even tended to be the same. The temperature conditions at location 3 are still the lowest.

Table 8 Temperature data at 16.00 WIB

Date	Temperature		
	Location 1	Lokasi 2	Location 3
12 April 2023	34,5	36,8	35,1
13 April 2023	31,1	29,8	29,4
14 April 2023	34,5	37,1	35,4
17 April 2023	36,8	35,4	34,5
18 April 2023	33,9	35,2	34
26 April 2023	28,4	26,5	26,4
27 April 2023	32,9	34,6	33,3
28 April 2023	32,9	34,6	33,3
2 May 2023	33	32,5	32,3
3 May 2023	32,6	33,7	32,4
4 May 2023	30	29,5	29,1
5 May 2023	31,1	29,8	29,4

Source: Author's data processing results

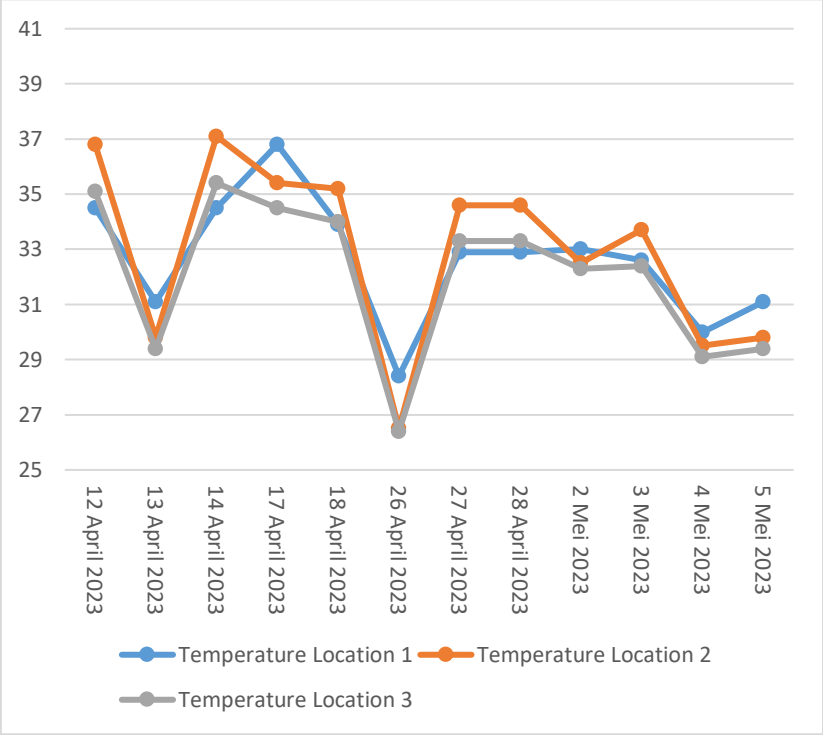

Figure 9 Graph of temperature at 16.00 WIB
Source: Author's data processing results

If you look at the average temperature conditions at the three locations in table 9 and figure 10, it is found that the temperature conditions tend to increase from measurements starting at 08.00 WIB to 12.00 WIB and decreasing again towards 16.00 WIB.

Table 9 Hourly humidity data

Date	Temperature		
	Location 1	Lokasi 2	Location 3
08.00	29,62	28,93	27,93
10.00	34,34	34,43	31,72
12.00	35,71	37,03	34,73
14.00	34,28	35,72	34,10
16.00	32,64	32,96	32,05

Source: Author's data processing results

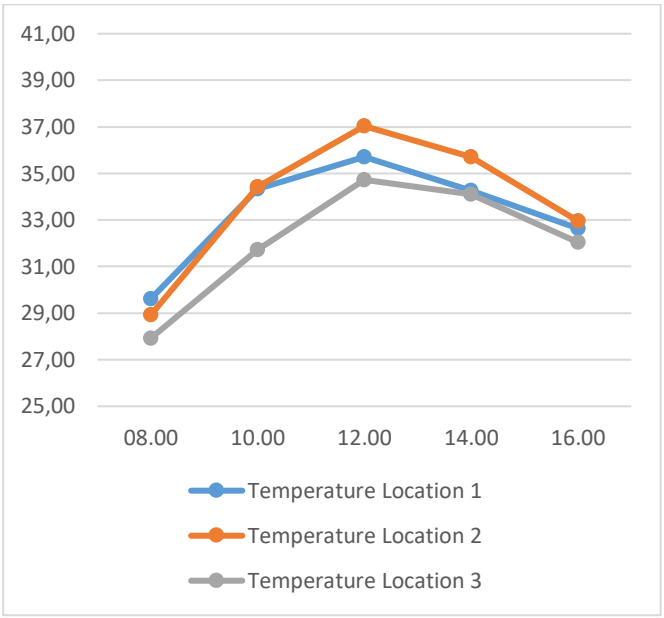

Figure 10 Average Temperature Graph from 08.00-16.00 WIB
Source: Author's data processing results

3.2. Humidity

Humidity level measurement is done at the same time as temperature measurement and using the same tool. Measurements were taken at 08.00, 10.00, 12.00, 14.00 and 16.00. The results of measuring the humidity level can be seen in table 10.

Table 10 Humidity level data

Date	Times	Humidity (%)		
		Location 1	Lokasi 2	Location 3
12 April 2023	08.00	63	64	73
	10.00	50	52	60
	12.00	42	40	46
	14.00	47	41	45
	16.00	45	38	42
13 April 2023	08.00	69	71	75
	10.00	51	53	63
	12.00	49	44	69
	14.00	55	53	58
	16.00	71	78	79
14 April 2023	08.00	66	73	76
	10.00	47	46	54
	12.00	47	45	50
	14.00	51	50	52
	16.00	49	42	49
17 April 2023	08.00	65	67	71
	10.00	53	53	60
	12.00	47	45	51
	14.00	43	37	42
	16.00	45	49	51
18 April 2023	08.00	62	62	65

Date	Times	Humidity (%)		
		Location 1	Lokasi 2	Location 3
	10.00	48	49	57
	12.00	45	39	46
	14.00	47	38	47
	16.00	56	53	55
26 April 2023	08.00	75	76	75
	10.00	56	53	64
	12.00	52	47	53
	14.00	74	87	78
	16.00	87	99	99
27 April 2023	08.00	82	99	82
	10.00	76	84	80
	12.00	58	51	60
	14.00	59	55	59
	16.00	59	55	57
28 April 2023	08.00	78	81	90
	10.00	62	59	67
	12.00	46	42	49
	14.00	58	52	58
	16.00	61	55	60
2 May 2023	08.00	70	70	73
	10.00	59	56	64
	12.00	48	44	50
	14.00	45	51	50
	16.00	60	61	61
3 May 2023	08.00	77	79	77
	10.00	60	59	67
	12.00	56	53	58
	14.00	51	47	51
	16.00	63	60	64
4 May 2023	08.00	74	75	74
	10.00	49	46	59
	12.00	44	37	47
	14.00	52	50	54
	16.00	69	70	70
5 May 2023	08.00	68	69	69
	10.00	56	52	59
	12.00	49	44	52
	14.00	47	43	49
	16.00	71	78	79

Source: Author's data processing results

From this humidity data, average humidity data can be generated from different days as shown in table 11.

Table 11 Humidity level data

Date	Humidity (%)		
	Location 1	Location 2	Location 3
12 April 2023	49,4	47	53,2
13 April 2023	59	59,8	68,8
14 April 2023	52	51,2	56,2
17 April 2023	50,6	50,2	55
18 April 2023	51,6	48,2	54
26 April 2023	68,8	72,4	73,8
27 April 2023	66,8	68,8	67,6
28 April 2023	61	57,8	64,8
2 May 2023	56,4	56,4	59,6
3 May 2023	61,4	59,6	63,4
4 May 2023	57,6	55,6	60,8
5 May 2023	58,2	57,2	61,6

Source: Author's data processing results

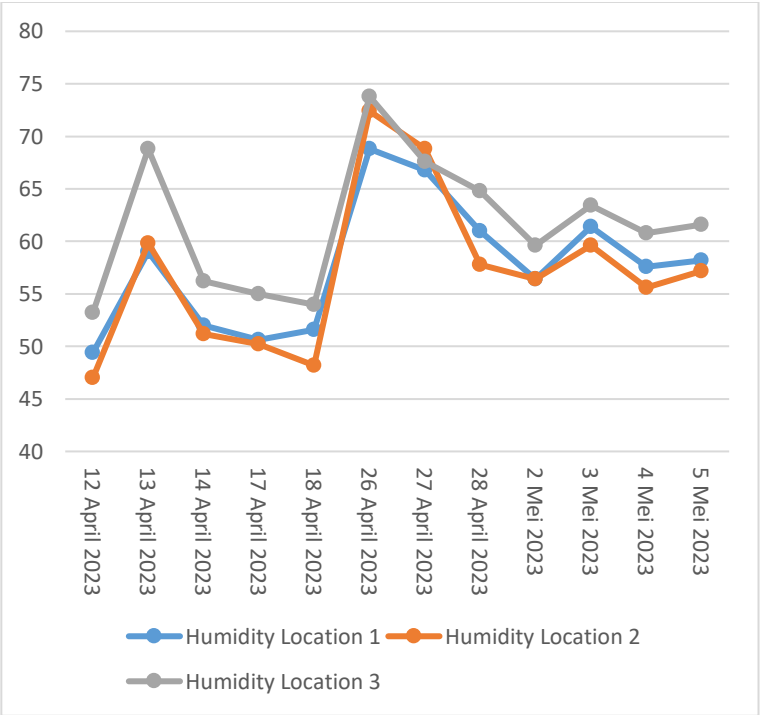

Figure 11 Daily average humidity graph
Source: Author's data processing results

From figure 11, it can be seen that the highest humidity is in location 3 with the highest humidity at 73.8%. Location 1 and location 2 have almost the same average humidity with the lowest humidity being in location 2 at 49.4%.

Table 12 Humidity level data

Times	Humidity (%)		
	Location 1	Lokasi 2	Location 1
08.00	70,75	73,83	75,00
10.00	55,58	55,17	62,83
12.00	48,58	44,25	52,58
14.00	52,42	50,33	53,58
16.00	61,33	61,50	63,83

Source: Author's data processing results

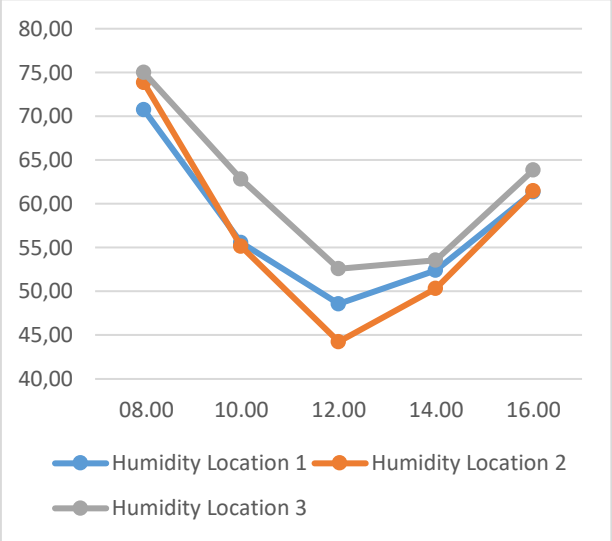

Figure 12 Graph of average humidity from 08.00-16.00 WIB
Source: Author's data processing results

In Table 12 and Figure 12, when viewed from the time of measurement, the lowest humidity is in location 3 with a value of 75% and this occurs at 08.00 WIB. While the lowest humidity is in location 2 with a value of 44.25% and this occurs at 12.00 WIB.

3.3. Wind Velocity

Wind speed measurements were only carried out at location 2. This was done considering the distance between locations which were quite close, so that wind speed conditions did not differ from one location to another. Wind speed data can be seen in Table 13.

Table 13 Wind velocity data

Date	Times	Wind Velocity (m/s)
12 April 2023	08.00	0,2
	10.00	0,2
	12.00	0,1
	14.00	0,2
	16.00	0,1
13 April 2023	08.00	0,1
	10.00	0,3
	12.00	0,2
	14.00	0,2
	16.00	0,1
14 April 2023	08.00	0,1
	10.00	0,1
	12.00	0,1
	14.00	0,1
	16.00	0,1
17 April 2023	08.00	0,1
	10.00	0,0
	12.00	0,1
	14.00	0,1
	16.00	0,3
18 April 2023	08.00	0,2
	10.00	0,2
	12.00	0,4
	14.00	0,3
	16.00	0,6

Date	Times	Wind Velocity (m/s)
26 April 2023	08.00	0,1
	10.00	0,6
	12.00	0,2
	14.00	0,1
	16.00	0,3
27 April 2023	08.00	0,1
	10.00	0,1
	12.00	0,6
	14.00	0,6
	16.00	0,1
28 April 2023	08.00	0,1
	10.00	0,1
	12.00	0,1
	14.00	0,7
	16.00	0,2
02 May 2023	08.00	0,1
	10.00	0,4
	12.00	0,3
	14.00	0,4
	16.00	0,4
03 May 2023	08.00	0,4
	10.00	0,1
	12.00	1,1
	14.00	0,0
	16.00	0,1
04 May 2023	08.00	0,1
	10.00	0,2
	12.00	0,3
	14.00	0,5
	16.00	1,5
05 May 2023	08.00	0,2
	10.00	0,2
	12.00	0,1
	14.00	0,2
	16.00	0,1

Source: Author's data processing results

From this humidity data, average daily wind speed data can be generated as can be seen in table 14.

Table 14 Average daily wind velocity data

Date	Wind Velocity (m/s)
12 April 2023	0,2
13 April 2023	0,2
14 April 2023	0,1
17 April 2023	0,1
18 April 2023	0,3
26 April 2023	0,3
27 April 2023	0,3
28 April 2023	0,2
2 May 2023	0,3
3 May 2023	0,3
4 May 2023	0,5
5 May 2023	0,2
Average	0,3

Source: Author's data processing results

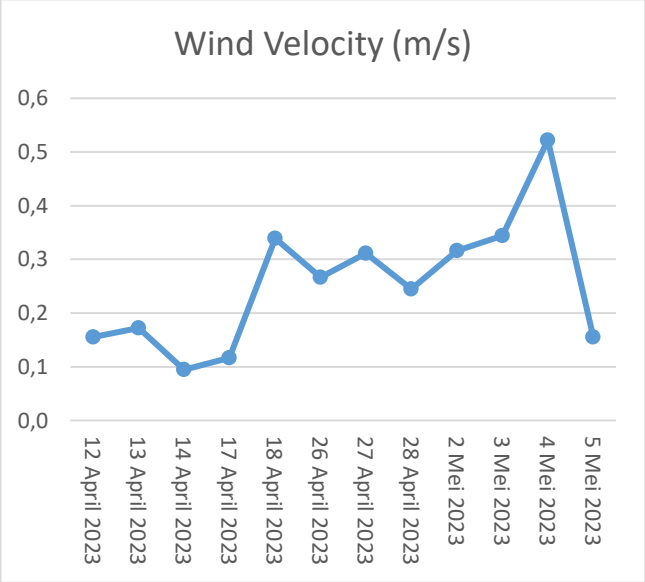

Figure 13 Daily average wind speed graph
Source: Author's data processing results

Figure 13 shows that the wind speed based on the day at the measurement location is still within the wind speed limit in the comfortable category according to SNI, namely 0.1 to 0.5 m/s. There are fluctuations in the daily wind speed, where the wind speed never tends to be the same.

Table 15 Wind velocity data based on the day at the measurement location

Time	Wind Velocity (m/s)
08.00	0,1
10.00	0,2
12.00	0,3
14.00	0,3
16.00	0,3
Average	0,3

Source: Author's data processing results

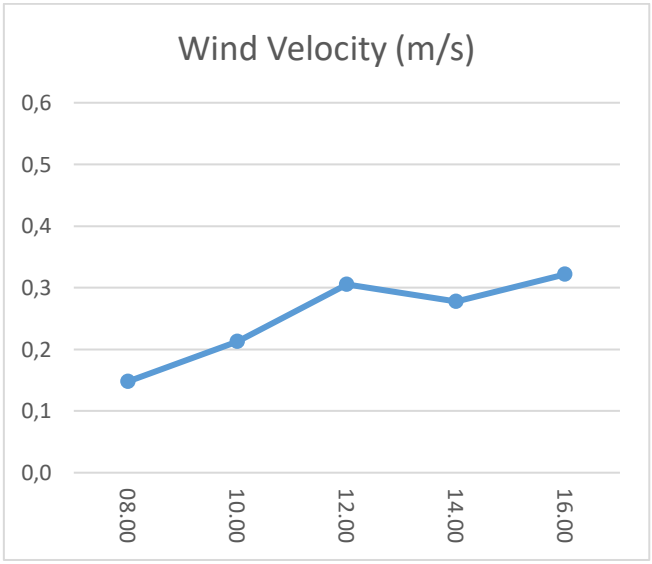

Figure 14 Average wind speed data per measurement time
Source: Author's data processing results

If seen from table 15 and figure 14, it can be seen that the average wind speed based on the time of measurement is still in comfortable conditions. The highest wind speed is at 0.3 m/s and the lowest is at 0.1 m/s.

3.4. Effective Temperature

The effective temperature can be used as an indication for measuring thermal comfort at a single location. According to Mom and Wiesebron the effective temperature range and its relationship to thermal comfort are as follows: (a) Cool - Comfortable 20.5℃ - 22.8℃ ET; (b) Comfortable - Optimal 22.8℃ - 25.8℃ ET; (c) Heat - Comfortable 25.8℃ - 27.1℃ ET.

For conditions of air humidity in the range of 40% -70% and wind speeds in the range of 0.1 - 0.5 m/s. Outside of these conditions, the thermal conditions are considered uncomfortable [17].

To calculate the effective temperature, daily temperature and humidity data are needed which are then entered in the psychrometric calculator to produce a wet temperature value which is then added to wind speed data which is inputted into the nomogram chart. For more details, the calculation method can be seen in Figure 15.

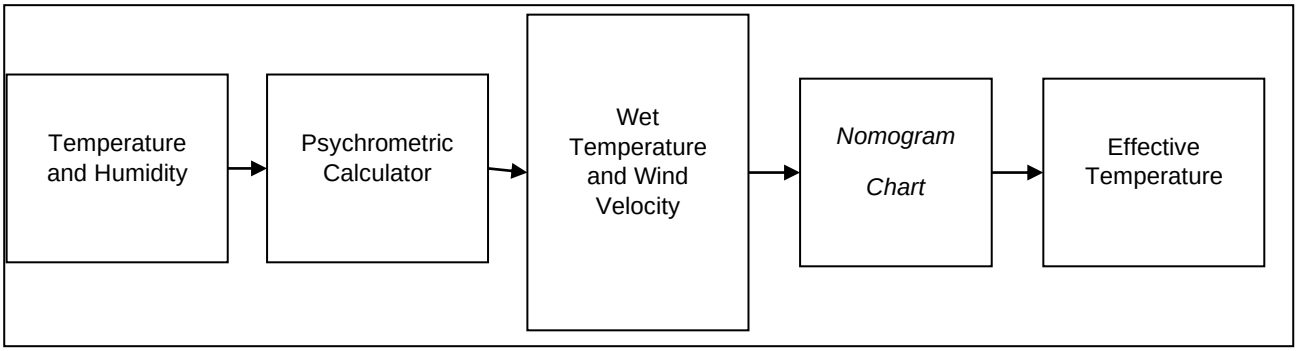

Figure 15 Effective temperature calculation
Source: Author's data processing results

The results of the wet temperature calculation can be seen in Tables 16, 17 and 18. The calculation will be carried out on the temperature per measurement time at each location.

Table 16 Average wet temperature data based on measurement time at location 1

Times	Temperature Location 1	% RH	Wet Temperatur Location 1
08.00	29,62	70,75	25,23
10.00	34,34	55,58	26.64
12.00	35,71	48,58	26.32
14.00	34,28	52,42	25.95
16.00	32,64	61,33	26.29

Source: Author's data processing results

Table 17 Average wet temperature data based on measurement time at location 2

Times	Temperature Location 2	% RH	Wet Temperatur Location 2
08.00	28,93	73,83	25.09
10.00	34,43	55,17	26.64
12.00	37,03	44,25	26.40
14.00	35,72	50,33	26.71
16.00	32,96	61,50	26.60

Source: Author's data processing results

Table 18 Average wet temperature data based on measurement time at location 3

Times	Temperature Location 3	% RH	Wet Temperatur Location 3
08.00	27,93	75,00	24.35
10.00	31,72	62,83	25.75
12.00	34,73	52,58	26.36
14.00	34,10	53,58	26.03
16.00	32,05	63,83	26.22

Source: Author's data processing results

The wet temperature calculation above was carried out using a psychrometric calculator which can be accessed online via the website address: http://people.tamu.edu/~i-choudhury/psych.html which is software development from Texas A&M University. Can be seen in figure 16.

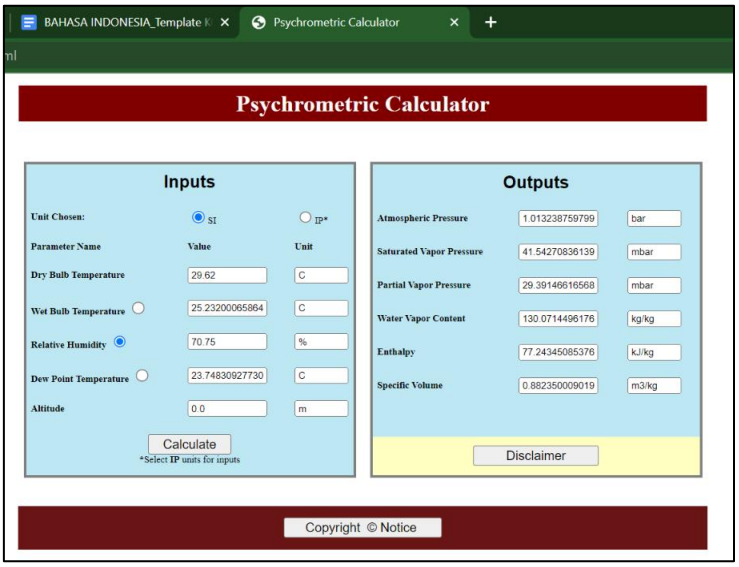

Figure 16 Calculation of wet temperature with a psychrometric calculator
Source: Author's data processing results

The effective temperature calculation can then be carried out by entering the wet temperature and wind speed values on the nomogram chart.

Calculation of the effective temperature is carried out using the nomogram chart [18] in several stages: (1) Draw a straight line between the dry temperature values towards the wet temperature; (2) Draw a curved line according to the magnitude of the wind speed; (3) Draw a diagonal line at the intersection of the three lines earlier. The value printed at the end of the diagonal line is the effective temperature value.

In figure 17, an example of calculating the effective temperature at location 1 at 08.00 WIB is carried out using the nomogram chart. From the calculation results, the effective temperature value is 26.4ºC.

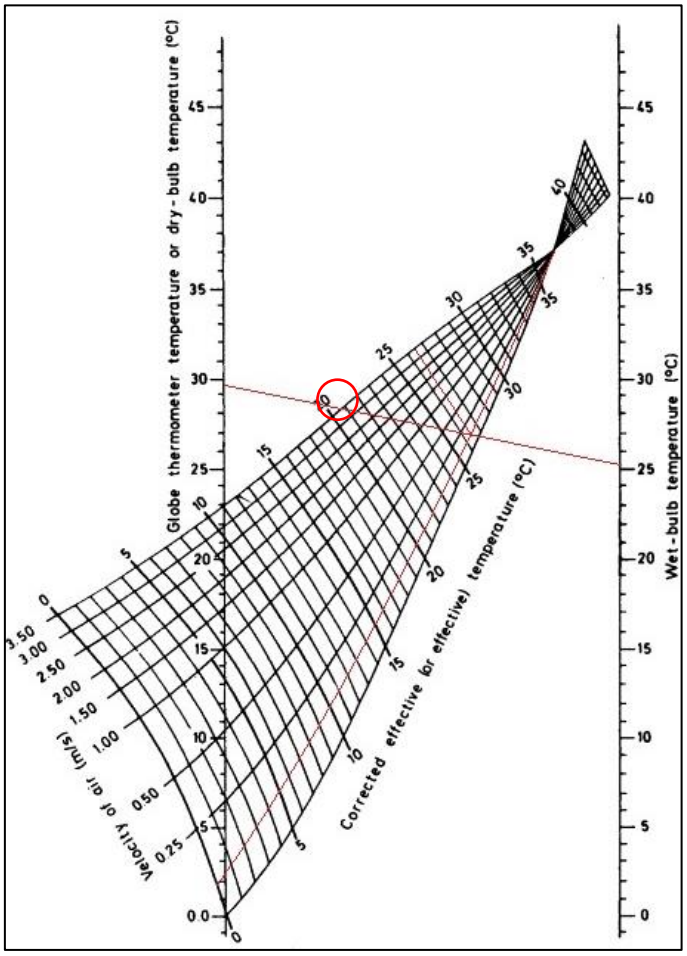

Figure 17 Calculation of the effective temperature at location 1 at 08.00 WIB
Source: Author's data processing results

From the calculation results above for all points, the effective temperature data is obtained which is shown in tables 19, 20 and 21.

Table 19 Effective temperature data based on measurement time at location 1

Time	Wet Temperatur Location 1	Wind Velocity (m/s)	Effective Temperature Location 1
08.00	25,23	0,1	26,4
10.00	26.64	0,2	28,5
12.00	26.32	0,3	28,5
14.00	25.95	0,3	27,7
16.00	26.29	0,3	27,3

Source: Author's data processing results

Table 20 Effective temperature data based on measurement time at location 2

Time	Wet Temperatur Location 2	Wind Velocity (m/s)	Effective Temperature Location 2
08.00	25.09	0,1	26,0
10.00	26.64	0,2	28,3
12.00	26.40	0,3	29,1
14.00	26.71	0,3	28,6
16.00	26.60	0,3	27,6

Source: Author's data processing results

Table 21 Effective temperature data based on measurement time at location 3

Time	Wet Temperatur Location 3	Wind Velocity (m/s)	Effective Temperature Location 3
08.00	24.35	0,1	26,2
10.00	25.75	0,2	27,1
12.00	26.36	0,3	27,6
14.00	26.03	0,3	27,9
16.00	26.22	0,3	27,1

Source: Author's data processing results

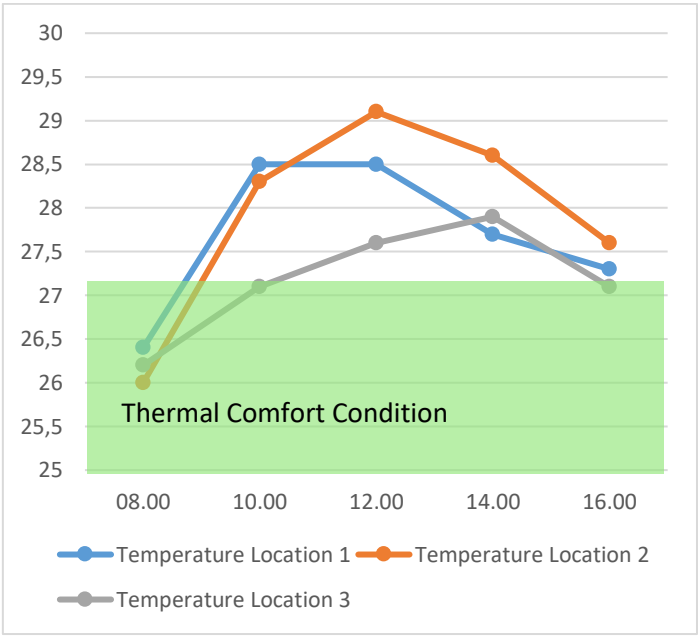

Figure 18 Average effective temperature based on measurement time
Source: Author's data processing results

4. Conclusion

There are several things that can be concluded from the implementation of this research:

1. The temperature in an unshaded room is not necessarily lower than that of a shaded room. This is evident from the results of temperature measurements at 08.00 and 10.00 at the three locations. At 08.00 the temperature at location 1 (shaded but walled on one side) was higher than that at location 2 (open space). However, the temperature at location 3 (covered and free of walls) still has the lowest temperature. This could be due to a number of things, including the orientation of the location to the sun, where the three measurement locations are directly facing the direction of the rising sun (east) and the condition of the walls that can withstand the wind speed at that location and reflect the sun's heat to location 1.
2. The results of temperature measurements at 12.00, 14.00 and 16.00 WIB show the temperature at location 1 is lower than at location 2, with location 3 having the lowest temperature. This proves that the shaded room has a lower temperature than the unshaded room.
3. The average temperature at the three measurement locations can be said to be quite high because it is in the range of 30℃ - 36℃. Even the highest temperature ever recorded was 39.4℃ on April 18, 2023 at location 2 at the time of measurement at 14.00 WIB.
4. The average humidity conditions at these three locations can be said to be still in comfortable conditions, because they are still in the range of 40-70%.
5. The condition of the average wind speed at the measurement location is also said to be comfortable because it is still in the range of 0.1-0.5 m/s.
6. The results of effective temperature measurements at the three measurement locations indicate that

thermal comfort conditions tend not to be achieved. At locations 1 and 2 the thermal comfort condition was only achieved at 08.00 WIB, while at location 3 this condition was reached at 08.00, 10.00 and 16.00.

7. This condition of thermal comfort should still be improved by several efforts such as planting shady vegetation at the research location, creating a water element in the outer space at the research location. By realizing this, if the condition of thermal comfort can be achieved at this location

5. Acknowledgement

We extend our sincere gratitude to all contributors and reviewers for their invaluable dedication to enriching the quality of this scientific journal. Their profound insights, meticulous evaluations, and thoughtful suggestions have significantly elevated the rigor and clarity of the published work. Their commitment to advancing knowledge is truly commendable and has been instrumental in shaping this journal into a reputable source of scholarly excellence. Their collaborative efforts inspire the scientific community and propel us towards further exploration and discovery.

6. Conflict of Interest

The authors affirm that there are no conflicts of interest related to this article. They declare financial interests, or personal connections that could influence the research design, data analysis, or interpretation of results. This study is conducted with complete objectivity and transparency. The authors' dedication to unbiased research underscores the integrity of our findings and ensures the credibility of this contribution to the scientific community.

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