Functions of Water Bodies as Mitigation of the Impact of Urban Heat Island in Kampung Luar Batang and Kampung Pulo Geulis

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Abstract: Uncontrolled urban development can cause urban areas to be warmer than the surrounding rural areas, known as the Urban Heat Island. This study aims to determine the microclimate conditions formed in residential areas that have water bodies and to determine the function of these water bodies as an effort to reduce the temperature of the area. A detailed discussion of temperature, humidity and wind speed shows evidence of an increasing trend in temperature in the area (UHI phenomenon) and shows that temperatures in areas far from the sea and close to rivers are lower than the surrounding areas.

Keywords: Urban Heat Island; Microclimate; body of water

1. Introduction

The development of an urban area is characterized by increasing population growth accompanied by increased urban infrastructure development. Physically, the city also has other structural elements or buildings that are not in the form of buildings, namely public facilities, utilities, and other installations. The development led to the transfer of the function of green open space into built-up land such as offices, settlements, recreation areas, shopping centers, and others [1]. In general, urbanization has emerged as a driver of economic, social, demographic, and environmental changes. Urbanization is characterized by the rapid conversion of agricultural land, vegetation, and water bodies into built-up areas [2]. The development of a city can result in changes in land use in urban areas, especially non-built land areas into built-up land. Uncontrolled development of infrastructure and buildings causes a lack of vegetation in urban areas. The rapid development of built-up land can cause an increase in urban surface temperatures. Land cover changes can cause local cooling or heating [3]. Changes in land use that occur can have an impact on changes in climate elements such as temperature, solar radiation, wind speed, and clouds [4]. Cooling in different ways Adsorption is a renewable power system [5].

Changes in the urban surface also produce diverse microclimates which have a gathering effect, reflected by the Urban Heat Island [6]. Green building is an energy efficient building concept that can deal with the issue of buildings a significant impact on environmental sustainability today and in the future [7]. An urban heat island (UHI) or urban heat island is a warming event in an urban area that becomes hotter than the surrounding area as a result of urban development and land burning [8].

Urban Heat Island (UHI) is part of a phenomenon that occurs in urban areas caused by isolated locations (having different conditions) which have higher surface/air temperatures than the surrounding area on direct measurements at the location (in situ). Built-up areas in urban areas have high thermal conductivity, so that they store more thermal energy than rural areas. This can cause urban areas to be warmer than the surrounding rural areas. The basic concept of UHI is the interaction of thermal energy from the sun received by objects on the earth's surface, giving different thermal levels between villages and cities due to differences in their thermal conductivity [9]. According to several studies, there are many factors that lead to the formation of UHI, namely: including the normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), normalized difference water index (NDWI), and population[10][11]. Urban Heat Island can be detected on a scale ranging from a micro-scale area in the form of a shopping center parking lot to a meso-scale urban area. One of the impacts of increasing the pavement area is an increase in air temperature, which results in a decrease in environmental comfort. Urban Heat Island (UHI) can affect aspects of people's lives such as health and comfort, air quality, clean water quality, as well as various human quality of life and can be a cause of concern for city residents [12–15]. Heat insulation seems to play a important role in the installation procedure though it can reduce solar heat transfer through the roof based on indoor thermal conditions and cooling thermal efficiency [16].

Based on the results of previous studies, the UHI phenomenon has become a serious phenomenon so that appropriate steps are needed in an effort to handle and reduce the increase in temperature so that it does not have a greater and serious impact on losses. Six steps to reduce the temperature include[17] adjusting the geometry of the city, using white or bright building materials, saving electricity usage, establishing a good transportation system, increasing water bodies and maintaining green open space (RTH). Other studies also state that water spaces such as creeks, rivers, and lakes specifically have an important role in creating cooling in urban areas, because water spaces have a higher evaporation rate than green open spaces [18,19]. Another step that can be taken is to reduce the carbon emission levels of the village through the arrangement of green areas and additional communal spaces in the area[20,21]. Collecting methane gas from landfills can be used as an alternative energy source so as to reduce a global climate change rate of [22].

To reduce the increase in air temperature, UHI and THI, in addition to increasing green open space, also increase the area of water bodies in the form of ponds, artificial lakes, and ponds/situ. Water bodies have multiple effects, including lowering air temperature, UHI, and THI, as well as acting as a reservoir for excess water during the rainy season, water reserves during the dry season, and potential as a water park[23]. A body of water has the ability to adapt to the microclimate around it. The temperature mitigation capacity of water bodies in urban environments has the potential to reduce energy consumption, increase outdoor thermal comfort and reduce the effect of Urban Heat Island (UHI). According to the layout, cooling temperature performance is improved [24]. Water show no impact on an environment and harmless to life on this planet. Water is not flammable and having a high heat capacity to avoid an exothermic reaction [25].

The air temperature near the water bodies was found to be different from that above the ground due to the difference in the way the water is hot and cold. Water bodies are known to be the best absorbers of radiation, but they show very little thermal response[26,27]. The flat surface of the water body and the large heat capacity make the water body useful for forming "airways" for urban climate regulation and as an important solution for responding to urban climate change and improving the outdoor environment [28]. Studies related to water bodies have been carried out in several cities and countries, such as variations in air temperature and absolute humidity around the two boundaries of the urban water reservoir of So José do Rio Preto[29], simulation of the thermal environment around an artificial pond in Japan [30] and the effect of the cooling effect of water bodies on urban land surface temperature (LST) around Suzhou Bay [31]. As an archipelagic country, Indonesia's territory is dominated by waters with a sea area of 3.25 million km2 (Directorate General of Marine Management, 2020). So it is necessary to study the water bodies owned by urban areas in Indonesia. The urban village area that has elements of water bodies as the shaper of its urban geometry, among others, is Kampung Luar Batang located in North Jakarta and Kampung Pulo Geulis located in Bogor City.

2. Materials and Methods

A. Research Method

This research was conducted by observing the temperature to describe the urban heat island phenomenon in both urban village locations. UHI phenomena can be observed based on air UHI by measuring the temperature directly in the field. Data collection was carried out during the dry season in May. The dry season was chosen as the time to take measurements because it is considered a suitable time to record the temperature because the temperature tends to be stable and not disturbed by rain[32].

The study was conducted at two locations that have water bodies. The first location is in Kampung Luar Batang, North Jakarta. The first location is in Kampung Luar Batang, which has a regional morphology that is formed along the coast of Jakarta Bay, and the second is in Kampung Pulo Geulis, Bogor. Kampung Pulo Geulis has a regional morphology that is formed by the geographical conditions of the village, which is surrounded by a river (the road to the village can only be reached by crossing the bridge). The measurement variables in these two villages include temperature, relative humidity, and air velocity.

B. Study Area

Kampung Luar Batang

Kampung Luar Batang is located on Jalan Gedong Panjang, Penjaringan Subdistrict, Penjaringan Subdistrict, North Jakarta. The boundaries of Kampung Luar Batang are: Pluit Sea View Apartment (North), Sunda Kelapa Harbor (East), Maritime Apartment (South) and Muara Baru Raya Road (West). The population data of Kampung Luar Batang is 3 RW and 37 RT. RW 01 is made up of 11 RTs with 750 families, RW 02 is made up of 12 RTs with 550 families, and RW 03 is made up of 14 RTs with 1220 families.This village is one of the oldest villages in North Jakarta and is estimated to have existed since 1630. This area is located west of the Sunda Kelapa Harbor. To the east of Kampung Luar Batang, which borders the Pakin River, there is an area of Jalan Pasar Ikan which developed along with the development of Kampung Luar Batang.[27] Formalized paraphraseAs the first study location, the measurements in Kampung Luar Batang were divided into 10 measurement points as shown in Fig.1.

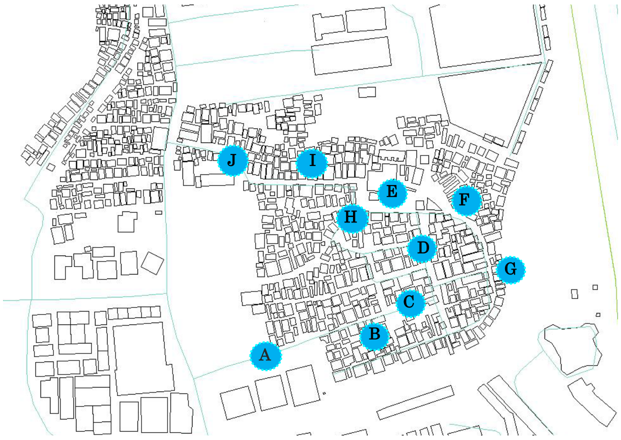

Fig. 1: Measurement location in Kampung Luar Batang

Kampung Pulo Geulis

Kampung Pulo Geulis is located in Babakan Pasar Village, Central Bogor District, is one of the areas located in Central Bogor, Bogor City. Kampung Pulo Geulis is located in the center of Bogor City which is surrounded by the flow of the Ciliwung River with a river area of 2.1 ha which is located at an altitude of 250 meters above sea level so that it looks like an island. Geographically, the area of Kampung Pulo Geulis is 3.5 ha, which is located at 6036'11.21" South Latitude-6036'26.87" South Latitude and 106048'11.14" East Longitude-106048'22.38" East Longitude. For access to Kampung Pulo Geulis, there are four bridges that can be crossed. First, there is a route through the east of Baranangsiang, the second is the route to the north of Bogor Market, the third is the west route, the wheel road, and the fourth is the southbound lane to the Culinary Center, so there are many easy accesses to come to Kampung Pulo Geulis. Not only that, the location of Kampung Pulo Geulis is also strategically close to the Bogor market, close to Baranangsiang Terminal, close to the Bogor Botanical Gardens tourist attractions. With Bogor known as a rainy city, the climate in Kampung Pulo Geulis has good potential for water resources such as rivers, springs, dams/reservoirs/situ. The current geographical condition of Kampung Pulo Geulis can be categorized quite well, with various routes to access the place, it is very easy to visit the place. Based on Kelurahan data, the population of Kampung Pulo Geulis in 2018 was 2,640 people with a total of 773 families (Babakan Pasar Village 2018). Administratively, Kampung Pulo Geulis is an area of RW 04 from Babakan Pasar Village, Central Bogor District.

As the second study location, the measurements in Kampung Pulo Geulis were also divided into 10 measurement points as shown in Fig. 2.

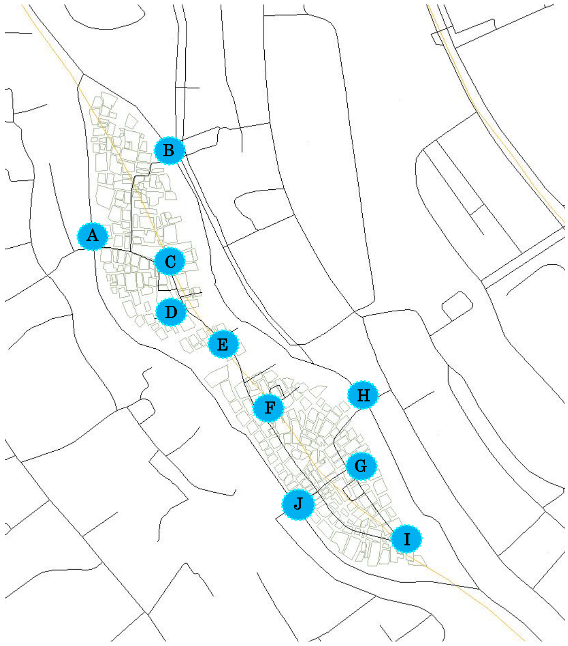

Fig. 2: Measurement location in Kampung Pulo Geulis

C. Data Collection and Measurement

Data collection was carried out by conducting thermal measurements in Kampung Luar Batang and Kampung Pulo Geulis. The thermal measurement data collected is air temperature (C), air velocity (m/s), and relative humidity (%). Measurements were carried out one day with 4 measurement times.

Table 1. Measurement Time

No.	Measurement Time (WIB)	Measuring Point
1	07.00-08.00	
2	10.00-11.00	A, B, C, D, E, F, G, H, I, J
3	13.00-14.00	
4	16.00-17.00	

Measurements for the two villages were carried out using different tools such as the following:

Table 2. Measuring Tool

Location	Tool	
Kampung Luar Batang	Lutron LM-8000	
Kampung Pulo Geulis	Lutron AM-4206, Anemometer	Lutron HT-3006A Humidity/ Temperature Meter

Measurements for both locations were carried out on the same day with the same measurement time.

Table 3. Measurement Results in Kampung Luar Batang

Measurement Time	Measuring Point	Temperature (°C)	Relative Humidity (%)	Air Speed (m/s)
07.00-08.00	A	27.3	74.4	0.53
	B	27.6	74.1	0.0
	C	27.8	73.9	0.0
	D	30.1	68.4	0.0
	E	29.7	69.0	0.0
	F	29.4	68.6	0.03
	G	29.5	70.7	0.0
	H	29.6	68.2	0.0
	I	29.9	69.2	0.0
	J	29.8	68.4	0.0
10.00-11.00	A	32.9	58.4	0.61
	B	33.6	57.3	0.0
	C	33.4	57.5	0.47
	D	34.2	55.4	0.0
	E	33.6	55.5	0.44
	F	34.1	55.2	0.0
	G	33.2	57.7	0.44
	H	34.2	55.4	0.81
	I	34.3	55.5	0.11
	J	33.8	57.5	0.42
13.00-14.00	A	35.2	54.5	0.75
	B	38.4	49.9	0.28
	C	39.5	46.7	0.53
	D	39.4	45.6	1.56
	E	39.9	44.0	0.81
	F	39.6	44.3	0.11
	G	36.6	52.0	1.75
	H	38.1	48.1	0.28
	I	38.0	48.0	0.44
	J	38.4	50.1	0.31
16.00-17.00	A	34.8	61.5	0.67
	B	34.7	61.6	0.0
	C	34.2	62.4	0.0
	D	33.3	63.2	0.64
	E	33.3	64.2	0.72
	F	33.0	65.5	0.0
	G	32.1	61.2	1.17
	H	33.0	61.3	0.36
	I	32.8	62.2	0.42
	J	32.9	61.5	0.5

Table 4. Measurement Results in Kampung Pulo Geulis

Measurement Time	Measuring Point	Temperature (°C)	Relative Humidity (%)	Air Speed (m/s)
07.00-08.00	A	26.4	77.2	0.0
	B	27.7	76.3	0.0
	C	27.0	75.5	0.06
	D	27.2	75.9	0.0
	E	26.8	78.2	0.0
	F	27.5	75.0	0.0
	G	26.2	77.0	0.0
	H	25.6	79.8	0.0
	I	28.4	72.2	0.0
	J	27.0	72.4	0.0
10.00-11.00	A	30.9	66.5	0.0
	B	30.0	69.5	0.03
	C	30.0	70.4	0.0
	D	29.9	70.5	0.0
	E	30.0	70.5	0.06
	F	29.3	71.3	0.0
	G	29.7	71.7	0.0
	H	29.6	70.9	0.08
	I	30.4	69.4	0.0
	J	30.1	68.7	0.0
13.00-14.00	A	34.4	58.9	0.0
	B	33.4	61.3	0.64
	C	34.5	57.1	0.0
	D	33.5	60.6	0.39
	E	34.7	58.1	0.56
	F	33.2	61.3	0.0
	G	33.9	56.2	0.0
	H	33.0	59.1	0.0
	I	33.7	56.0	0.0
	J	32.1	62.0	0.0
16.00-17.00	A	33.5	56.2	0.5
	B	32.1	59.3	0.56
	C	32.3	60.5	0.0
	D	32.1	60.9	0.0
	E	32.2	61.8	0.36
	F	31.3	62.8	0.58
	G	31.6	63.3	0.0
	H	31.4	62.8	1.06
	I	31.3	63.8	0.0
	J	31.0	65.3	0.0

Based on tables 3 and 4, the resulting measurements show differences in temperature, relative humidityand wind speed. The measurement point at one location has several different distances from the water body, starting from the closest to the farthest from the water body.

3. Result

A. Kampung Luar Batang

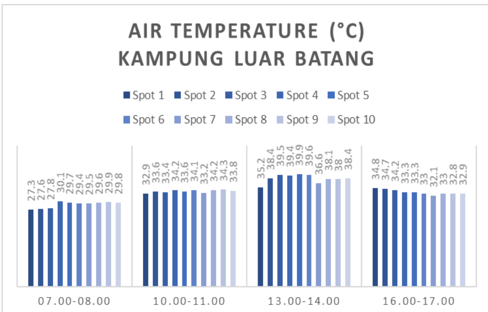

Fig. 3: Air Temperature in Kampung Luar Batang,

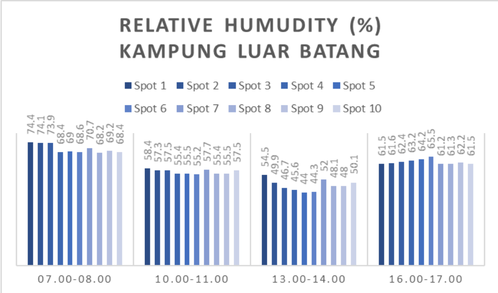

Fig. 4: Relative Humidity in Kampung Luar Batang

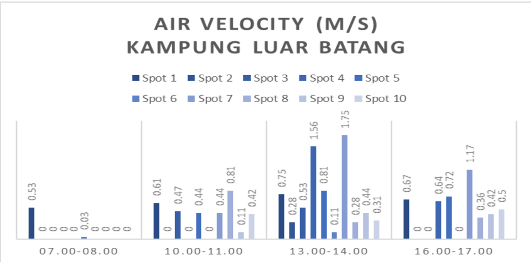

Fig. 5: Air Velocity in Kampung Luar Batang

To determine the characteristics of the maximum and minimum temperatures that occur in Kampung Luar Batang, it is shown in Fig. 3. The maximum temperature occurs at spot E at 13.00-14.00 WIB, at 39.9°C, and the minimum temperature occurs at spot A at 07.00-08.00 WIB, at 27.3°C. Based on the results of these measurements, the average temperature in Kampung Luar Batang is 33.6°C. This shows that the temperature is higher than the average temperature in Jakarta in May, which is 26.5°C. (https://en.climate-data.org/asia/indonesia/jakarta-special-capital-region/jakarta-714756/).

The maximum relative humidity that occurs at this location is 74.4% at spot A, while the minimum relative humidity occurs at spot E is 44%. The maximum wind speed occurs at spot G, which is 1.75 m/s. Based on the description above, it can be seen that there is an urban heat island phenomenon in this area.

B. Kampung Pulo Geulis

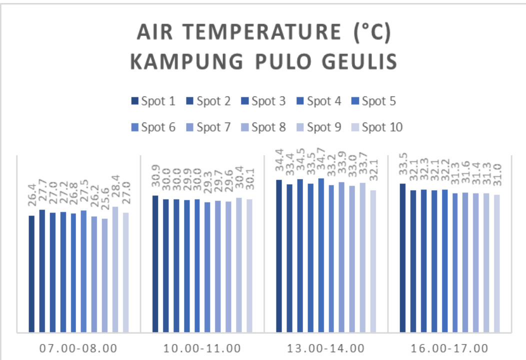

Fig. 6: Air Temperature in Kampung Pulo Geulis

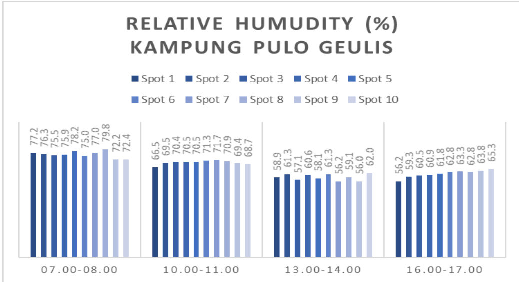

Fig. 7: Relative Humidity in Kampung Pulo Geulis

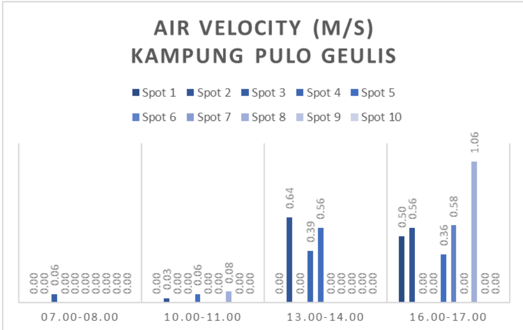

Fig. 8: Air Velocity in Kampung Pulo Geulis

The maximum and minimum temperature characteristics that occur in Kampung Pulo Geulis are shown in Fig. 4. The maximum temperature occurred in spot E at the time of measurement at 13.00-14.00 WIB, at 34.7°C, and the minimum temperature occurred in spot H at the measurement time of 07.00-08.00 WIB, at 25.6°C. Based on the results of these measurements, the average temperature in Kampung Pulo Geulis is 30.6°C. This shows that the temperature is higher than the average temperature of Bogor City in May, which is 24.7°C (https://en.climate-data.org/asia/indonesia/west-java/bogor-3930/). The maximum relative humidity that occurs at this location is 79.8% at spot H, while the minimum relative humidity occurred at spot I at 56%. The maximum wind speed that occurs at spot G is 1.06 m/s. Based on the description above, it can be seen that there is an urban heat island phenomenon in this area. In general, the Kampung Pulo Geulis area also shows the UHI phenomenon.

Based on the results of measurements at both locations, Kampung Pulo Geulis in Bogor has a lower temperature than the temperature in Kampung Luar Batang. Even though the temperature in these two locations is quite high, the humidity is still below 90%, so it can still be said to be in the comfort zone [33].

4. Conclusion

Based on the regional geometry and the formed microclimate, the comparison of the two studies above provides an understanding that geographical location has a significant influence in creating a microclimate. Both locations have high humidity values in the morning need to be investigated more deeply, especially in relation to evapotranspiration and anthropogenic releases of the earth's surface. At the first location, the lowest temperature occurred in spot A at 07.00-08.00 at 27.3°C, at 10.00-11.00 it was 32.9°C and at 13.00-14.00 it was 35.2. Spot A is the main entrance to Kampung Luar Batang and is a measurement spot far from the sea or water bodies. Meanwhile, the lowest temperature in Kampung Pulo Geulis at 07.00-08.00 occurred in spot G at 25.6℃, at 13.00-14.00 at spot J at 32.1℃ and at 16.00-17.00 at spot J at 31℃. Spot A and spot J are measurement points located on the banks of the river. Locations closer to rivers have lower temperatures, while locations farther from the sea have lower temperatures than surrounding areas. A body of water in the form of a river can help lower the temperature compared to a body of water in the form of the sea. In summer, water bodies have a function to cool the ambient temperature based on the type of water. Extreme weather events such as heat waves with high heat levels for urban residents can be overcome by water bodies. [34)]

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