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Influence of Water Features on Outdoor Pedestrian Level Thermal Comfort in a Tropical City Like Dhaka

Jubaida Gulshan Ara [a]*

[a] *Assistant Professor, Department of Architecture, Southeast University, Dhaka, Bangladesh. Email: jubaida.gulshan@seu.edu.bd*

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ABSTRACT

Dhaka is going through rapid urbanization resulting in more hard surfaces. The city is transferring all soft surfaces into hard surfaces which are increasing outdoor temperature and decreases humidity. High temperature is causing UHI(Urban Heat Island) Effect. Several studies have been conducted with different landscape features but most of those were green infrastructure. Limited research has been carried out on water features. Most of those studies were with large water bodies like rivers or canals. This study aims to look into the impact of water features like the fountain at the plaza level for a highly built-up urban area in the tropics like Dhaka city. The site area was located on Gulshan Avenue. Here three adjacent spaces were selected. One had a hard plaza with a prominent pool within it and another was a hard-paved area with some tree cover and the third one was hard-paved without any trees or water features. Temperature and humidity data were collected through a field survey for these three different spaces with the Galaxy Sensor tool. The result showed that temperature is lower (33.6c) under tree-covered areas but humidity is higher (51%) than another two spaces. Surprisingly temperature is 1°c higher around the pool area though the humidity is lower (49.5%) than in the tree-covered area. Air temperature and humidity both are lower in the area where hard paved is neither covered with trees nor water. While analyzing these data with the outdoor comfort level and PET of Dhaka city all the data are within comfort range but the temperature of the microclimate is 1°c higher than the city average temperature. In the third place, though temperature and humidity were lower than in the other two spaces, direct solar radiation made the situation critical for the pedestrian level.

1. Introduction

Housing is characterized as the overall residential area or micro-district, which includes the physical structure, as well as all appropriate amenities, facilities, and infrastructure for an individual's or family's total health and social well-being (Schoenauer, 1981). It is seen as the physical environment in which the family and society's basic units develop and sustain (Rashid, 2019). A domestic unit is a dwelling-place used as a permanent or semi-permanent residence for an individual, family, household or several families in a tribe (Rashid and Khan, 2021). It is often a house, apartment, or other building or any other type of shelter. Homes typically provide areas and facilities for sleeping, preparing food, eating, recreation, social and hygiene for the physical and mental wellbeing of the inhabitants (Rashid, 2020a). Economically, housing represents a major portion of the family budget, yet in the realm of private and public investment, the built environment represents a man's most tangible material asset (Rashid, 2015, 2019, 2020b).

Domesticity is considered as an area, or a mental domain, that extends beyond the house's material, concrete spatial, and bodily boundaries (Rashid, 2013). It is a multifaceted realm concerned with human beings' intimate state and their needs for security, treatment, relaxation, healing, and enjoyment (Mallett, 2004; Bachelard, 2014). The identity of the home is constantly being redefined; it expands and contracts, and increasingly depends not only on a specific physical interior but also on a network of urban

* *Corresponding author: Jubaida Gulshan Ara, Assistant Professor, Department of Architecture, Southeast University, Dhaka, Bangladesh*

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places (Martella and Enia, 2020).

A household is made up of all the people who live in a given housing unit. A household is described as a 'housing unit,' which is a single, spatially delimited physical structure. The household can be seen from both a geographical and a social standpoint. Its design takes into account ecological, demographic, and economic realities that can make it difficult for people to find suitable living arrangements (Schwimmer, 2003).

Many researchers contend that 'housing affordability is a common way of summarizing the complexities of housing issues in many countries, and often illustrates the concepts of 'housing crisis,' 'housing demands,' and 'housing issues' (Haffner and Hulse, 2021). Linneman and Megbolugbe (1992) confirm that housing research had shifted its focus towards housing affordability, homeownership and privatization in the 'middle-class households' (Linneman and Megbolugbe, 1992).

The Global Financial Crisis (GFC) ushered in a new age of housing affordability challenges across a wider spectrum of advanced economies (Haffner and Hulse, 2021). More recent literature on housing affordability has begun to reframe housing affordability as an urban issue (Wetzstein, 2017). This is taking place in the sense of a global urbanization megatrend characterized by an increase in the number of major cities and unending mobility within them. Housing affordability was mainly seen as a social policy concern in the twentieth century, with a focus on the relationships between housing, non-housing spending, and income poverty (United Nations, 2001). Regardless of the scale or extent of industrialization, almost all developed countries are undergoing rapid urbanization as scarce agricultural land and increasing agricultural communities begin to drive families from rural areas to cities and major metropolitan areas (Huth, 1989).

The middle class may simply represent a range along the income continuum (a group that lies between the poor and the rich) and social class (a group lying between the working class and the 'upper' class). To the extent that variables such as consumer spending and education vary monotonically with income, the middle class will possess higher values of these attributes than the poor (but less than the rich). According to Banerjee and Duflo (Banerjee and Duflo, 2008), middle-class people are far more likely than poor people to have salaried employment. Indeed, the most critical distinction between the poor and the middle class is getting a daily, well-paid salaried career. The middle class is, therefore, more likely to migrate to their current place of work and home, to have a smaller family size, to take their children to school (especially private schools), and to seek more costly medical services while they are sick. Another trait of the middle class is geographic concentration. In most nations, the middle class is overwhelmingly metropolitan, as one would assume.

The confusion about the definition of the middle class is not only limited among the common people. Economists and social scientists also struggle to find a common ground when it comes to defining this class. In Bangladesh, the typical middle-class category is a social and cultural construct, but economic features are gradually becoming important in describing the middle-class. People earning under 2 USD per day are considered poor. So, some leading researchers, including Nobel laureates Abhijit Banerjee and Esther Duflo, have used definitions like earning 2 USD - 6 USD per day to be categorized as the lower middle class or 6 USD – 10 USD per day as the upper-middle-class (Banerjee and Duflo, 2008). According to another simple description by Mujeri (2021), people who receive between 2 USD and 20 USD a day are considered middle-class (Mujeri, 2021).

Dhaka, the capital of Bangladesh, is the most crowded city in the world. More than 19.5 million people live in Dhaka. It is the most densely populated city in the country spanning More than 23,234 people per square kilometre, just over half a square mile. It is reported that 2,000 people move to Dhaka every day (Lansat, 2018). At present, 20 per cent of the population belongs to the middle-income category (Khan, 2019).

2. Literature Review

Different types of water bodies have the ability to lower the air's ambient temperature in the summer. Waterbodies reduce the severity of extreme weather conditions like heat waves and the subsequent heat stress they cause for city people. Numerous researches revealed that urban water bodies do have a cooling effect on their surrounds. (e.g. Theeuwes et al, 2013, Xu et al., 2010 and Robitu et al, 2006). In comparison to urban areas close to the locations of reference, all of the works that were analyzed found that temperatures were lower near water bodies. However, compared to studies on vegetation, the number of studies on water bodies will still be far lower (Manteghi et al 2015). By cooling the air and shading the urban surface in the summer, the presence of water ponds and trees enhances the urban thermal environment. The heat transmission between water, vegetation, and air is constantly linked to evaporation and evapotranspiration. The wind is crucial to the process because it replaces the saturated air near water and plant surfaces with dry air (Robitu M et AL 2006).

According to research, a large body of water cannot by itself work in a way that improves thermal comfort because one of its components, namely temperature, is constantly maintained at high levels close to the water bodies. The findings of this study also indicate that water's cooling effect only applies during the day, while warming effects observed at night that is less clear (Manteghi et al 2015). When there is a prevailing wind, water fountains have a cooling effect. It has been discovered that the wind direction significantly affects the thermal environment outside (Lin et al 2007). Areas with warmer temperatures and heat gain from paved floors made of concrete and asphalt are produced by the combination of the simulated southeasterly prevailing breezes, flora, and moisture provided by the dam. The humidified wind's convection mechanism spreads layers up to five meters high over the

built-up area (Masiero, Érico. 2012).

3. Aim and Objective:

Though several studies have been conducted with the impact of trees on outdoor thermal condition especially at the pedestrian level, limited studies have been done with the impact of water features like small water body or fountains. The main objective of this study is to search for the impact of water feature on outdoor thermal condition and comfort. This particular study only dealt with the thermal and humidity condition of the study area to analysis the comfort situation. Though air flow is a vital component to ensure comfort in the humid situation imposed by the water feature but air flow was out of the scope of this research.

4. Methodology

Gulshan Avenue was chosen as the site location. Along the west side of Gulshan Avenue, many tall buildings were having more than 10story. Among them, three towers had a water feature in the front side plaza. But only one had an active water pool fountain at the time of the survey. The geographical location of the site is 23̊47'N and 90̊24'E. The data was collected on 10 October 2022 at 12.54 pm. The water feature was located in the front plaza of Shahjalal Islami Bank Tower which is 15 storied building located on Gulshan Avenue near Gulshan 2 circle, Dhaka, Bangladesh. The unique feature of the site was on the north side it had a hard plaza with tree cover and over the south pedestrian was unshaded and uncovered. Temperature and humidity data were collected with a galaxy sensor tool for these three spaces through a field survey. The quality of climatic data collected through the Smartphone sensor tool has been found acceptable and accurate (Araújo et al. (2017), Mazilu et al (2015). Comparative analysis was done among these data and comfort level was analyzed. Finally, observation was made of the analysis.

5. Data Collection

The three different spaces within the studied site location are marked with A, B, and C (Fig: 1). A location is having tree cover over the pavement, B location is having water fountain beside a pedestrian walkway and C location is having no trees or water feature beside pedestrian walkway(Fig 2,3,4,5). The size of the fountain was 15'X24'.The average temperature of Dhaka city was 32̊c on the day when the study was conducted. But the average air temperature along Gulshan Avenue was higher. Measured air temperature and relative humidity data for three different locations are shown in Table 1. For location A air temperature was 33.6̊c and relative humidity was 51.2%. Whereas for location B Air temperature and relative humidity were 34.7 ̊c and 49.5% respectively and for location C it was 34.4 ̊c and 48.1% respectively. It was observed that due to the stack effect considerable air flow took place along the south side of the Shahjalal Islami Bank Tower. But air speed measurement or air flow direction was not within the scope of this research. At location C temperature and humidity were lower than another two locations but there was strong solar radiation of not having tree shades and the building height did not provide shade at 1 pm. Therefore mean radiant temperature might be an important issue for the pedestrian comfort factor. But mean radiant temperature was also not considered in this study.

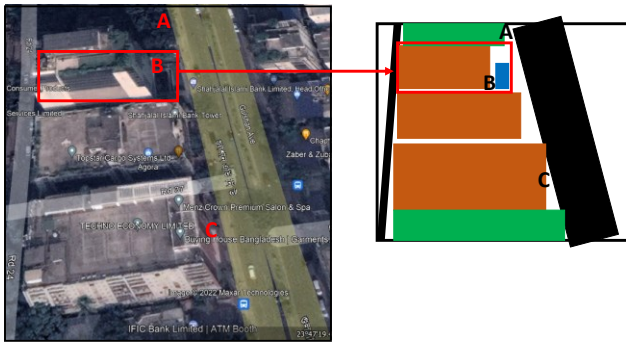

Figure 1: Google map showing the site and three different Locations

Figure 2: Photographs showing the site and three different Locations

Figure 3 : Pavements having tree cover. Location A

Figure 4: Water fountain pool located in Shahjalal Islami Bank Tower plaza. Location B

Figure 6: Pave having neither tree covers nor water feature. Location C

	Location A	Location B	Location C
Temperature	33.6°c	34.7°c	34.4°c
Humidity	51.2%	49.5%	48.1%

Table 2: Temperature and Humidity Data for three different locations

6. Findings and Discussion

This particular study has revealed that manmade hard surfaces in the urban area increase the overall temperature of the city area which is termed as Urban Heat Island (UHI) Effect. Gulshan is developing as the new commercial and business hub of Dhaka city and its average temperature is 1 °c higher than the city average. Along the site, it has been observed that under the tree cover the air temperature is 1 °c lower than the other two locations. But the relative humidity is 3% higher due to evapotranspiration from the trees. This finding is similar to the findings of other studies. It was assumed that humidity will be high near the water feature due to evaporation but the surrounding hard surfaces of the plaza not only elevated the air temperature but also decreased the relative humidity. During the field study, significant airflow was noticed from the south side of the tower due to the stack effect but the wind speed and wind direction were not measured due to limited scope. It is well known that air flow enhances the cooling effect of the water body to the surrounding area where the air temperature is high and relative humidity is low as found in location C. From this research, it is also found that unshaded and uncovered paved area elevates the air temperature and makes the air dry. Moreover, during summer noon mean radiant temperature might make the situation uncomfortable for the direct radiation from the elevated sun. In that case, water features located at location B can add a cooling effect with the prevailing south wind which will have a lower temperature for flow over the water.

The study revealed that the acceptable air temperature range outdoors in Dhaka city is 30-33°C and 33-36 °C will feel slightly warm (Table 2, Sharmin et al 2019). Hence the study area is slightly warm during late summer. Another study has identified the outdoor comfort zone is 28-32 °C if the relative humidity is within 50-73% (Fig 7, Ahmed K S 2003). From the psychrometric chart, it is found that the Effective Temperature is 28 °C for the prevailing air temperature and relative humidity of the study area which is within the neutral temperature range (Fig 6) of Dhaka city according to Ahmed ZN and within comfort zone according to Ahmed K S.

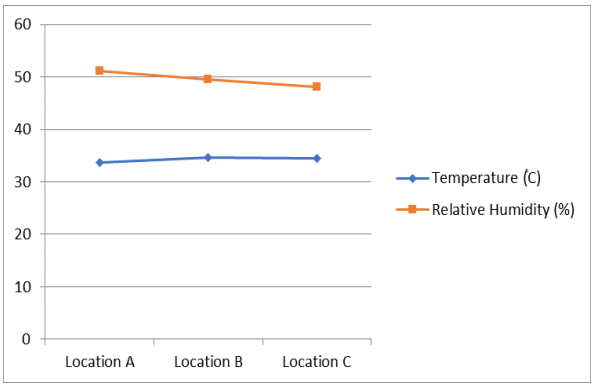

Figure 5: Thermal condition of the site

Thermal sensation	Acceptable PET range for Dhaka (^{0}C PET)	Acceptable air-temperature range for Dhaka (^{0}C)
Cool	23.5 – 26.5	24 – 27
Slightly cool	26.5- 29.5	27 – 30
Neutral	29.5 – 32.5	30 – 33
Slightly warm	32.5 – 35.5	33 – 36
Warm	35.5 – 38.5	36 - 39
Hot	> 38.5	> 39

Table 1 Summer PET classification of Dhaka City (Sharmin et al 2019)

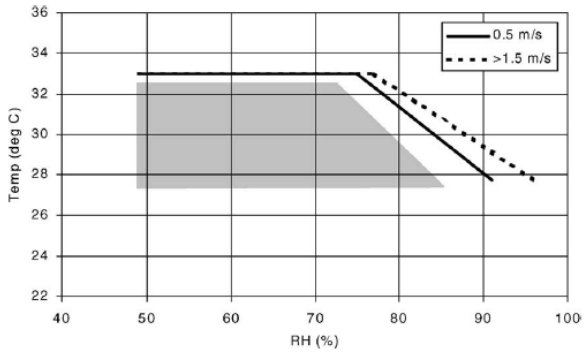

Table 3: Summer outdoor comfort zone for Dhaka City (Ahmed K.S,)

7. Conclusion

The study was carried out during mid-October 2022 which is not a critical weather time for Dhaka city. Even then the air temperature is comparatively higher than in other areas of Dhaka city. Hence further study needs to carry out during critical summer time. Only field study data

were considered in this study, though simulation might bring out more opportunities. This study only dealt with the air temperature and relative humidity whereas thermal comfort is mainly regulated by mean radiant temperature. Therefore mean radiant temperature should be considered in other studies. Again air speed and airflow direction are important issues to ensure thermal comfort around water features in a tropical context like Dhaka city. Hence further studies are needed considering these factors. Finally, it can be summarized that in the changing urban morphology where the air temperature is getting higher than the surrounding context water feature might bring out comfort conditions in the low humid situation need to be further explored.

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