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Relevance of Waterbody in Inducing Low Temperature in Residential Neighborhood: A Case of Dhanmondi, Dhaka

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Urbanization leads to increased thermal stress in city's climate due to increased surface and air temperatures and reduced wind speed. As urban areas develop, changes occur in the landscape. Buildings, roads, and other infrastructure replace open land, vegetation and water bodies. Surfaces that were once permeable and moist generally become impermeable and dry. Cities which are covered with large heat capacity structure such as concrete and asphalt are easier to get heated by the sun than the suburbs.

Urban water bodies have immense impact on urban climate and as well peoples' life. Water body beside residential areas can help to reduce this high urban temperature. There are two kinds of cooling mechanism in urban water bodies: cool water surface and wind path. The former cool water is due to the large heat storage in the water body rather than the evaporation at the water surface. The later wind path mechanism activates vertical ventilation and introduces cool breeze into the building. The wind path effect is more efficient than that of the cool water for the air temperature at the river side area.

This paper describes a climatic analysis of efficiency of water bodies for cooling effect in residential buildings during the warm humid season in Dhanmondi, Dhaka. Temperature, humidity and wind speed regimes observed inside two residential buildings, one beside road and the other beside water body, are compared and analyzed. The observation system is then presented, followed by a comparison of the data obtained from the two different situations. The effects attributed to the water body are then analyzed and finally the significance of the findings is discussed and their implications summarized. The findings indicate that inclusion of water bodies in urban areas would reduce the indoor air temperature of nearby residential buildings during the daytime hours under warm humid weather conditions.

Keywords: Urbanization**,** Water Body, Evaporative Cooling, Heat Balance.

Field of Research: Architectural Engineering

1. Introduction

Like other developing countries, urbanization in Bangladesh is a growing phenomenon. As urban areas develop, changes occur in the landscape leading to increased thermal stress in city's climate due to increased surface and air temperatures and reduced wind speed. This in turn affects the indoor temperature of buildings, causes thermal discomfort to the dwellers and calls for higher demand for mechanical and electrical energy.

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Urban water bodies not only serve as places of recreation and leisure activities but also contribute immensely to urban climate. They cool hot wind, minimize back radiation, maintain soil moisture and keep surface cool. This paper attempts to analyze the efficiency of water bodies for cooling nearby residential buildings by observing temperature, humidity and wind speed regimes inside two residential buildings, situated in Dhanmondi, Dhaka, during the warm humid season. The findings indicate that water bodies in urban areas can substantially reduce the indoor air temperature of nearby residential buildings during the daytime hours under warm humid weather conditions.

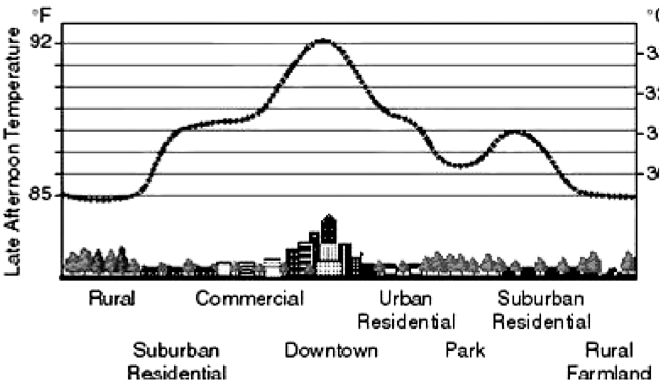
The growing concern for the impact of urbanization on climate, especially the diminishing volume of water mass in urban areas leading to higher temperature and thermal discomforts to the dwellers of the urban buildings demands the urgency to analyze the efficiency of urban water bodies for cooling nearby residential buildings. In doing so the paper is basically divided into three major parts: literature review, observation system and analysis leading to concluding remarks.

2. Literature Review

In the vicinity of water bodies two main processes take place. One is related to evaporation, and is expressed in both an increase in humidity and a reduction in temperature due to latent heat absorption. The second is related to sensible heat transport between the air and the underlying water (Saaroni & Ziv 2003). If the water is cooler than the air, as is the case during the daytime, especially under hot climatic conditions, the effect is expressed in a temperature drop. If the moisture content of the air remains unchanged, the decrease in temperature implies an increase in relative humidity. The net relieving effect of water bodies on humans under hot conditions depends on the balance between two contradictory contributions to heat stress: cooling, which reduces heat stress, and moisturizing, which increases it.

Urbanization has caused many problems for city inhabitants. One of the most prominent problems is increase ambient air temperature in urban areas compared to the rural areas. The development activities of the city adversely affect human thermal comfort. Increased vertical surfaces and reduced areas of green and water result in high temperature and high humidity, reducing both convective and evaporative cooling in urban areas, particularly during summer (Fig. 1).

Figure 1: High Temperature Profile of Cities



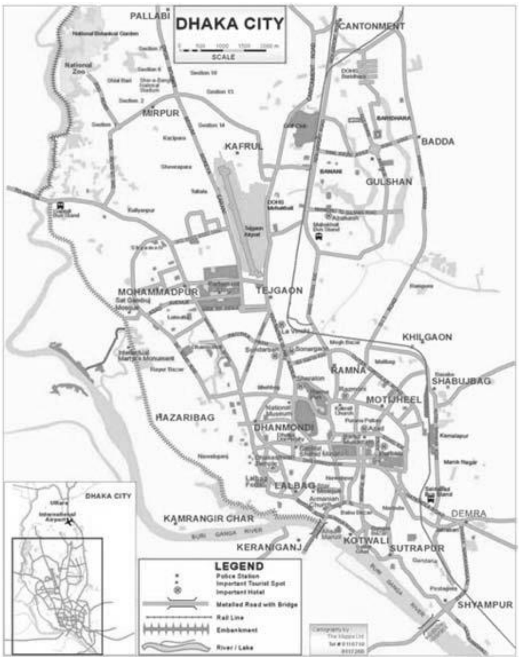
As shown in Figure 1, temperature is about 2^o~5^o higher in the city than its surrounding area. This effect is typically present both during day and night, but tends to be strongest during the day when the sun is shining. On average, the difference in daytime surface temperatures between developed and rural areas is high compared to the difference in nighttime surface temperatures, which is typically smaller. These results in warmer air in urban areas compared to cooler air in nearby rural surroundings. Therefore, buildings located in the city need an increasing energy for cooling. A study (Santamouris 2001) verified that 10^o rise in the temperature causes the cooling energy to be doubled.

The resistance to airflow presented by the solid volumes of buildings slows down the wind; as a result, wind velocities in cities are generally low at ground level. The result is a reduced rate of heat dissipation by convective cooling. The rapid unplanned development activity of the City results in much reduced areas of green and water compared to the rural area and thus reduced levels of humidity and lesser contribution from evaporative cooling is noticed. This modification also results in higher air temperatures in the urban environment (Oke 1987). Properties of urban materials, in particular solar reflectance, thermal emissivity, and heat capacity, also influence increased urban temperature, as they determine how the sun’s energy is reflected, emitted, and absorbed.

2.1. Dhaka and Its Water Bodies

Bangladesh is in the world’s largest delta system and has the greatest flow of river water to the sea compared to any other country on earth (Novak 1993). The country is surrounded through an intricate system of waterways and tidal channels. Dhaka, the mega city, being its capital, is located on the central part of Bangladesh. The city lies between 98 ^{o} 20´ and 90 ^{o} 30´ east longitude and 23^o40´ and 23^o 55´ north latitude. It is situated on the Northern bank of the river Buriganga. The city is on the higher ground – the southern edge of an alluvial old terrace – a low-lying region and at a strategic position regarding the water- routes of the country (Hossain, Zahir and Apurba 2009). The city is bounded by the Balu River in the East, Tongi Khal in the North and Turag River in the West (Fig 2). These rivers are connected to the Ganges-Brahmaputra River system and also include the Old Brahmaputra River flowing towards southeast from the all sides of the bigger neighboring region. The bigger area is closely dissected by number of rivers and Khals which are hydro-logically connected to these major rivers. Moreover there are a large number of ponds and few retention basins to maintain the hydrological balance of the area. The edges of the high lands are flanked by marshes and old river beds.

Figure 2: Topography and River Network of Dhaka City Source: Dhaka City Corporation



2.2. Impact of Urbanization on Climate

Like other developing countries, urbanization in Bangladesh is a growing phenomenon, which is steady in nature but affects urban climate fretfully. Bangladesh, being one of the densely populated countries of the world, is perhaps the worst victim of environmental degradation. Bangladesh has a composite climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations.

Dhaka is the eighth largest city in the world, with a population of about 12 million people enlisted in the Dhaka Statistical Metropolitan Area (DSMA) (DCC), accounting for about one third of Bangladesh's urban population. Uncontrollable and unpredictable rural to urban migration is largely responsible for rapid urbanization of the city and development of both planned and unplanned residential neighborhoods. The expansion of the city is occurring both horizontally and vertically due to the development of formal and informal housing settlements. High urban growth rates and high urban densities have already made Dhaka more susceptible to human-induced environmental disasters. The interaction between society and climate is ongoing.

Intergovernmental Panel for Climate Change (IPCC) in their publication of Fourth Assessment has listed the climate-related problems in Bangladesh that include:

- In Bangladesh, average temperature has registered an increasing trend of about 1°C in May and 0.5°C in November during the 14 year period from 1985 to 1998.

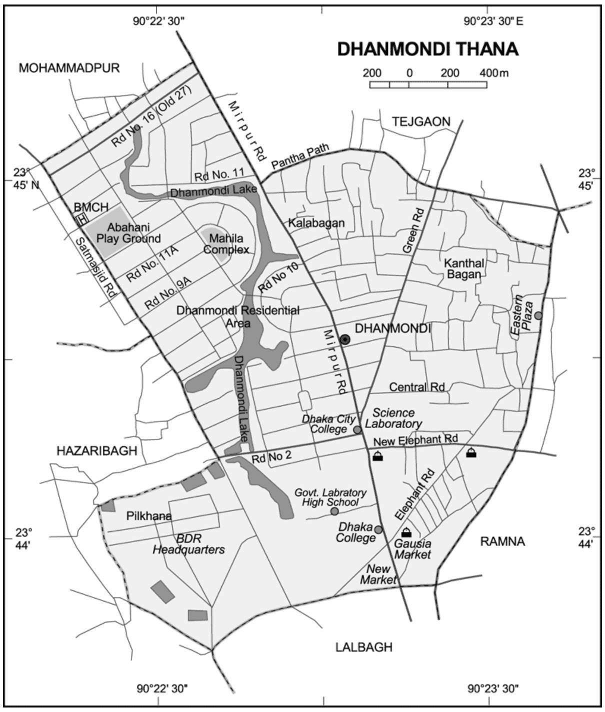
- Water shortages has been attributed to rapid urbanization and industrialization, population growth and inefficient water use, which are aggravated by changing climate and its adverse impacts on demand, supply and water quality.

On the whole these result in elevated temperatures, particularly during the summer, which can affect a community's environment and quality of life by increased energy consumption and compromised human health and comfort.

3. Study Area

The study was conducted in Dhanmondi residential area (Fig 3), designated as Ward no. 49. It is located at 23.7389° N 90.3847° E in the Dhaka District of Bangladesh. It has 33451 houses and a total area of 9.74 km². (Bangladesh Bureau of Statistics, retrieved on November 10, 2006). Dhanmondi Residential Area was planned as sites and services scheme with a regular system of roads to provide residential accommodation. Dhanmondi has a grid-iron pattern of roads and almost all the plots are rectangular and of the same size (14,400 sft). Of the total area, more than 61.4 % land was proposed for housing purpose, 9.2% for open space, 9.2% for water bodies and more than 18% for internal road circulation. Open space included the water bodies, play ground children's parks, etc., totaled to about 18.4%. Dhanmondi has an edificial lake which has been dug and extended to form an irregular shape. This is the only break in the monotonous layout of the Dhanmondi Area (Islam 2004).

Figure 03: Map of Dhanmondi Residential Area Source: Dhaka City Corporation



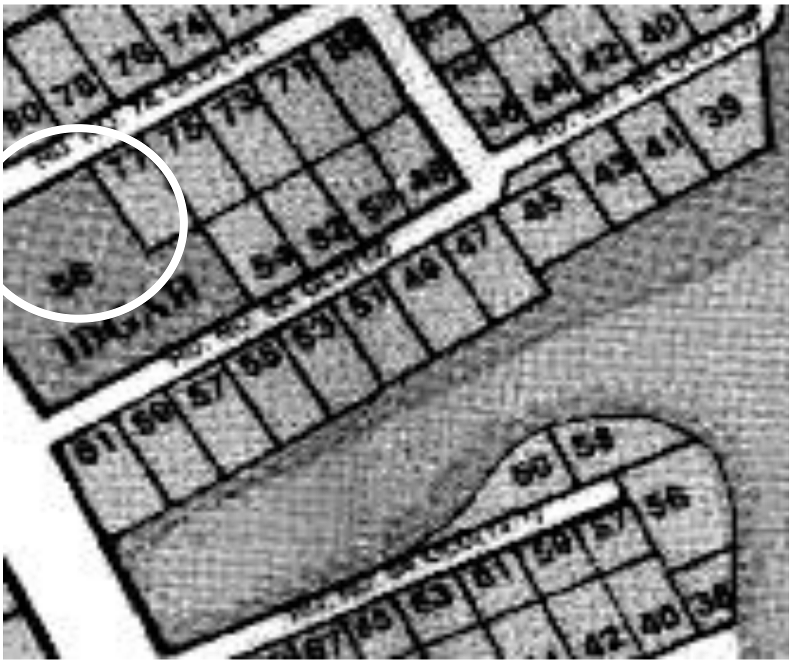
4. Methodology

The study aims to analyze the influence of urban water bodies on inducing lower temperature by evaporative and convective cooling inside apartment building beside water body. Thus resulting in a series of data that can make a contribution towards the knowledge of developing and designing residential apartment beside water body and to maximize the use of cooling effect of water body and so reduce the use of energy consumption. In terms of the various categories of buildings that are present in Dhaka, the study will be delimited to residential apartment buildings of a planned area, inhabited by upper middle-income groups.

4.1. Site and Observation

The climate of open spaces within a complex urban setting is influenced by a variety of factors related to building geometry and surface properties, anthropogenic heat release, and vegetation. This complexity makes it difficult to identify comparable urban sites in which the effects of individual parameters such as treatment of water body may be analyzed empirically. The present study addresses these problems by establishing a controlled experiment in two equal sized plots in Dhanmondi residential area, which are similar in their plot geometry and building heights but differ only in their south facades' exposure. One is plot no. 52, bounded by approximately 30' wide road on the south side and six storey buildings on three sides and the other is plot no. 51, bounded by 30' wide road on the north side, two six storey buildings on the two linear sides and lake on the south side (Fig 4).

Figure 04: Blow Up Map of 6/A, Dhanmondi Source: Dhaka City Corporation



4.2. Measurement Setup

In each of the two buildings, readings were taken at three different heights: inside the 1st, 3rd and 5th floors' apartments of the lake facing and road facing plots. The measurements include dry-bulb and wet-bulb temperatures, relative humidity, maximum and average wind speed and dew point temperature inside the south facing bed rooms of each apartment. All the measurements are taken using a single instrument known as kestrel. The measurements were taken on two consecutive sunny days during the mid of August that is, in the monsoon season (June to

October). The measurements are taken from 11 am to 12 noon on plot 51 and 12:30 to 2:30 on plot 52 on the first day and on the second day the first reading was taken on plot 52. The prevailing wind direction was also noted. From all the measurements, the indoor temperature in ^{o}C, relative humidity in percentage and average wind speed are analyzed to deduce the findings.

Due to unavailability of measurement taking instrument, Kestrel, simultaneous measurements on both the side at a single time was not possible. So readings were taken on the two plots on two different days in the manner described above.

4.3. Empirical Findings

The climatic effects of the water body studied are analyzed under relatively uniform building and environmental effects. The findings of this section focus on individual climatic parameters measured within the settings and are tabulated and plotted in climate graphs for possible outcomes.

Table 01: Measurements of Climatic Parameters on Plot No 51 & 52, Dhanmondi

1st day measurements on Plot 51								**2nd day measurements on Plot 52**						
Time (11:0 am to 01:30 pm)	Max. Wind Speed (m/s)	**Avg. Wind Speed (m/s)**	**Temp (^{o}C)**	Dry Bulb Temp (^{o}C)	**RH (%)**	Wet Bulb Temp (^{o}C)	Dew Point Temp (^{o}C)	Max. Wind Speed (m/s)	**Avg. Wind Speed (m/s)**	**Temp (^{o}C)**	Dry Bulb Temp (^{o}C)	**RH (%)**	Wet Bulb Temp (^{o}C)	Dew Point Tem p (^{o}C)
11:00	0.4	**0.3**	**28.1**	28.1	**78**	36.9	25.6	0.2	**0.1**	**30.1**	30.1	**74**	37.8	25.8
11:15	0.4	**0.3**	**28.2**	28.2	**78**	36.7	25.3	0.2	**0.1**	**30.2**	30.2	**74**	36.9	25.5
11:30	0.5	**0.3**	**28.7**	28.7	**75**	35.7	25.7	0.4	**0.2**	**30.5**	30.5	**73**	37.1	25.7
11:45	0.4	**0.3**	**29.0**	29.0	**75**	36.1	24.8	0.3	**0.2**	**30.9**	30.9	**73**	37.3	24.7
12:00	0.5	**0.4**	**29.1**	29.1	**74**	36.3	24.7	0.3	**0.2**	**30.9**	30.9	**73**	37.6	24.6
1st day measurements on Plot 52								**2nd day measurements on Plot 51**						
12:30	0.2	**0.1**	**30.5**	30.5	**74**	36.7	25.2	0.4	**0.3**	**28.5**	28.5	**75**	36.8	24.7
2:45	0.3	**0.2**	**30.8**	30.8	**74**	35.4	24.8	0.4	**0.3**	**29.2**	29.2	**75**	36.9	24.7
01:00	0.3	**0.2**	**30.9**	30.9	**73**	35.6	24.6	0.5	**0.4**	**29.6**	29.6	**74**	35.6	24.4
01:15	0.4	**0.3**	**31.1**	31.1	**73**	36.1	24.2	0.7	**0.5**	**30.1**	30.1	**74**	35.7	24.6
01:30	0.3	**0.2**	**31.6**	31.6	**73**	34.6	23.5	0.6	**0.4**	**31.1**	31.1	**73**	35.5	24.9

The study was conducted during the monsoon season. During this season the diurnal variation in temperature are comparatively low. Relative humidity remains high at about 75% for most of the time but can vary from 55% to even 100%. Wind velocities are low but sometimes strong wind occurs evening out indoor and outdoor temperature. So the variation in reading obtained in this study, have a low range.

5. Analysis

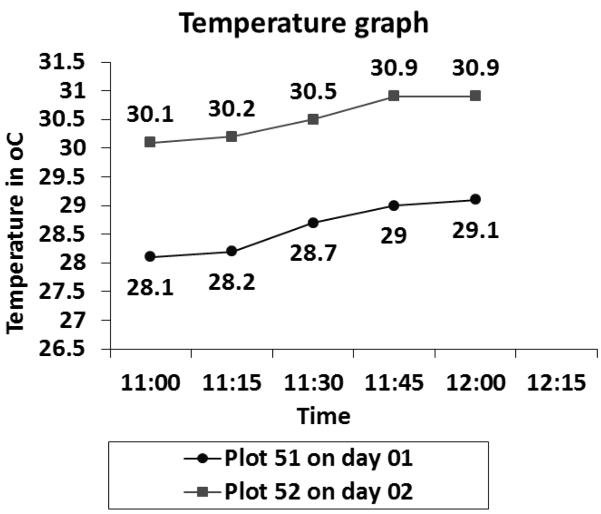
With the help of climate graphs given below, comparative analysis of temperature, humidity and wind speed between the two plots are deduced.

5.1. Temperature

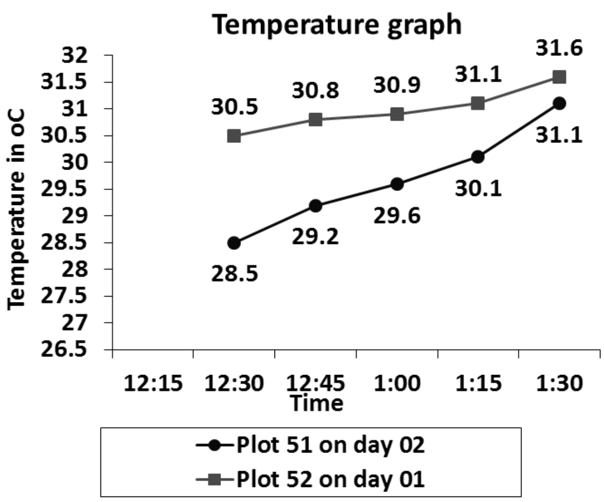
The cooling effect is estimated firstly by the difference in air temperature between the plot facing road and that of the plot facing lake. Temperature in plot 51 is comparatively low than that of plot 52. This is due to presence of lake beside plot 51.

As the sun beats down upon the earth, land surfaces absorb the heat and quickly release it back into the air again. Water, on the other hand, has a larger capacity than land thus heat is not released instantly into the air as in the case of land. So the air above the water body is comparatively cooler than that over the land during the day, imparting a cooler breeze towards the building beside it.

Graph 1.1: Temperature (11:00 Am to 12:00 Pm)



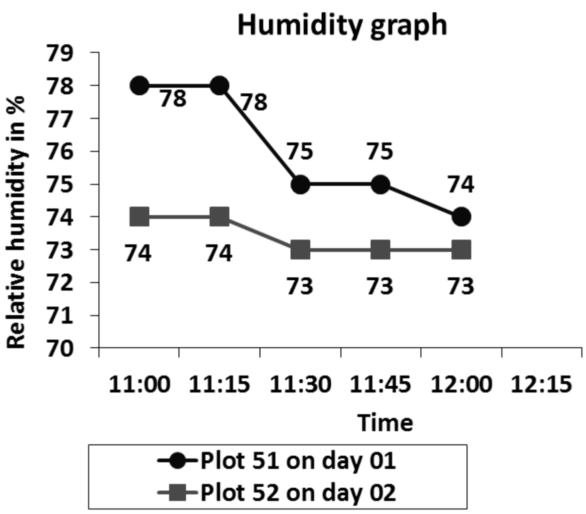
Graph 1.2: Temperature (12:30 Am to 01:30 Pm)



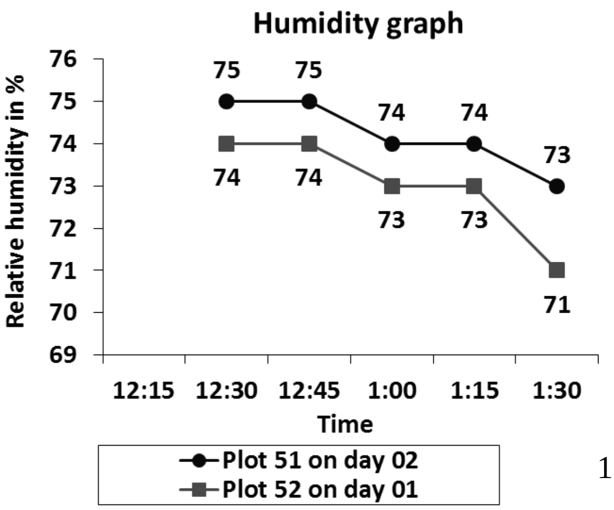
5.2. Humidity

Large bodies of water can moderate temperatures and can generate winds that convect heat away from the building. Since in warm humid season humidity content of air is high, RH is comparatively high throughout the time of experiment in the both days. RH is generally highest at 6am in the morning and decreases as the days grows and lowest at 3pm as the intensity of suns radiation increases gradually from morning to afternoon. There is a slight difference in humidity between plot 51 and 52 with a comparatively higher percentage in plot 51. The difference between the wet and dry bulb temperatures indicates the environment's capacity for cooling by evaporation.

Graph 2.1: Humidity (11:00 Am to 12:00 Pm)



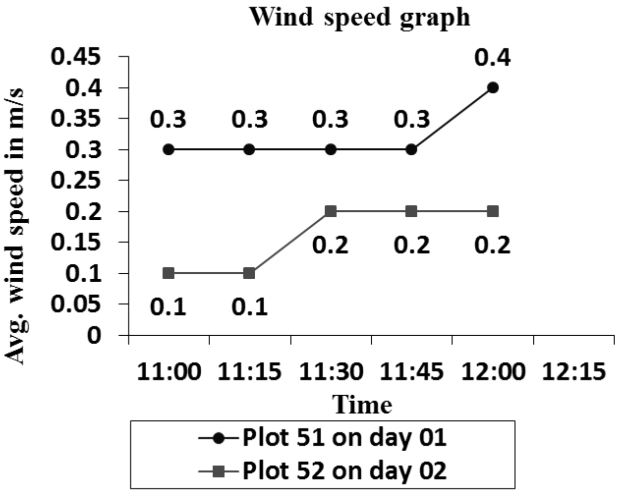
Graph 2.2: Humidity (12:30 Am to 01:30 Pm)



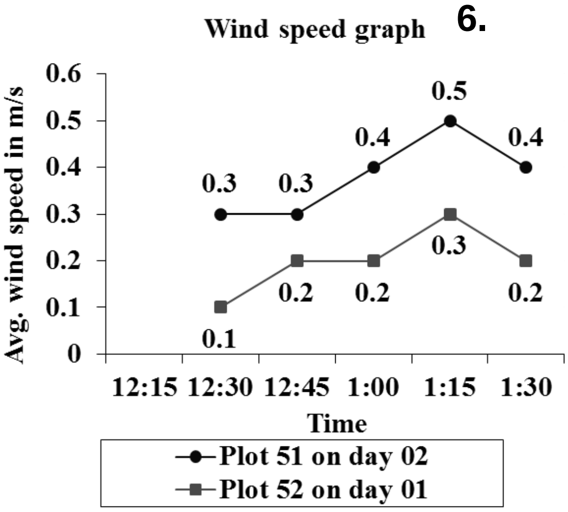
5.3. Wind Speed

Usually during warm humid season wind velocity are low. However, it is noted that there is little variation between the two plots reading. Wind speed in plot 51 is comparatively high as wind over the lake can flow without any obstruction whereas in plot 52 the flow is obstructed by the buildings in front of it.

Graph 3.1: Av. Wind Speed (11:00 am to 12:00 pm)



Graph 3.1:Av. Wind Speed (12:30 am to 01:30 pm)



6.

6. Conclusion

This study deals with empirical findings regarding the cooling effect of water in urban residential neighborhood. The study introduces a criterion for judging the merits of a water body in planned area by computing on temperature, relative humidity and average wind speed with respect to site location. The above findings indicate that the inclusion of water bodies in urban areas would reduce the indoor air temperature of nearby residential buildings during the daytime hours under warm humid weather conditions. This reduced daytime air temperature will in turn reduce the energy demand for active cooling of the interior of the building and thus can contribute to a balanced energy supply and demand in urban areas as well aid to contribute to a overall sustainable urban development in the long run.

Two days of field observations which were analyzed in detail, were used for evaluating the effects induced by water body. The results obtained can be applicable to other urban settlement around water bodies and thus ensuring lower temperature. In doing so we might seek to expand the original study to some more sub-categories and expect a better climatic responsiveness in urban forms besides water bodies. All the instruments and method, which are used in this study, will produce the same type of result if the same study is conducted in any other water body oriented urban region under the same conditions. However, since the study was conducted during the monsoon season, the variation in reading obtained in this study, have a low range.

Armed with the reliable standardized instruments and measurements specifications another researcher can choose to replicate this study, providing yet another sets of results, focusing on the warmer and dryer season of the country. The study can further be extended to investigate the size, depth and distance of the water body from the building to analyze proficiently the efficiency of water body for cooling indoor areas of residential as well as official buildings in its vicinity and even open areas surrounding the water body. This can contribute to a sustainable urban development in Dhaka's urban context by lowering the gross energy demand for regular city activities.

References

Hossain, N., Zahir, I., and Apurba, P. (2009), 'Making an Urban Oasis: The Use of Space Syntax in Assessing Dhanmondi Lake Revitalization Project in Dhaka, Bangladesh'. *Proceedings in the 7th International Space Syntax Symposium,* Stockholm, KTH.

Islam, K. (2004), 'The Death of Dhaka's Posh Spots'. *The Daily Star*, Dhaka, 16 June.

Oke, TR. (1987), '*Boundary Layer Climates',* Methuen & Co., London. Chapters 7-9.

Novak, J; (1993), 'Bangladesh: Reflections on the Water', *Indiana University Press,* Indianapolis, USA.

Saaroni, H., and Ziv, B. (2003), 'The impact of a small lake on heat stress in a Mediterranean urban park: The case of Tel Aviv, Israel', *International Journal of Biometeorology,* 47,156–165.

Santamouris, M. (2001) 'Energy and Climate in the Urban Built Environment', *James and James Science Publishers*, London.