REASONS AND REMIDES OF HEAT ISLAND PHENOMENA FOR DHAKA CITY: A REVIEW

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ABSTRACT

Dhaka is the eighth largest city in the world. It is becoming busier every day. Different services and infrastructures are frequently growing at a fast pace to cope with the ever growing population as well as the growing demand for domestic, commercial and industrial spaces. Unplanned and haphazard urbanization and industrialization is one the major causes of climate change in urban cities. The greeneries and water bodies are at an alarming state, demolishing with the replacement of concrete surfaces. These emit significant amount of heat causing the change of urban areas in the energy balance, which induces to higher temperature than the rural areas. This phenomenon of rise in superficial heat of urban areas is known as "URBAN HEAT ISLAND" (UHI). Urban heat island affects the microclimate and eventually our health and wellbeing in many ways. For the sake of our own prosperity huge sum of greenhouse and other gases are emitted by us every day. Increasing use of motor vehicle, reduction in green spaces, scarce vegetation, increased amount of built-up areas and many more impart their contribution to the increment in urban heat island. Increasing open spaces and greenery, modifying the geometry and materials of buildings to increase ventilation. Also ground water table can ameliorate the micro-climate of the surrounding area. In this paper we will elaborately discuss about the harmful effects of the UHI and the remedial measures that are to be taken to save our beloved city from this environmental crisis.

Keywords: *Urban heat island, Dhaka, microclimate, greenhouse gases*

1. INTRODUCTION

Urbanization and industrialization has made our life easy but blessed us with many devastating consequences such as global warming, air pollution, water pollution, noise pollution, industrial waste and many more. As urbanization and industrialization is increasing day by day, it affects the global environment seriously. Though the global impacts are serious, the regional effects of urbanization are more serious in the areas where various industries are emerged or complex construction materials are randomly used. This phenomenon affects the natural environment and ecology to a great extent. An urban heat island is a climatic phenomenon in which urban areas have higher air temperature than their rural surroundings as a result of anthropogenic modifications of land surfaces, significant energy use and its consequent generation of waste heat (Shahmohamadi et al., 2010). One of the primary factors of urban heat island formation is population. According to Oke's heat island parametric model-UHI intensity and higher population are directly related and pave the way for the consumption of maximum energy for heating and cooling buildings (Oke. 1987). In addition urban factors such as air pollution, anthropogenic heat, urban geometry, surface waterproofing and thermal properties of fabric that increase the energy loads for cooling buildings and peak electricity loads contribute to the UHI. (Memon et al., 2007) reported that harmful effects of UHI included the deterioration of living environment, increase in energy consumption and mortality rate, elevation in ground level Ozone and so on. Therefore this phenomenon in no doubt will put the urban population at great risk for morbidity and mortality. The conditions being complex in the big cities, it is difficult to determine the quantity of UHI as well as its mitigation. In this paper we will discuss the causes, problems and mitigation processes associated with the UHI based on the available review and journal papers and also a short review on Dhaka city as the UHI will be done.

2. WHAT IS URBAN HEAT ISLAND

Around half of the world's human population lives in urban areas. In the near future it is expected that the global rate of urbanization will increase by almost 70% of the present world urban population by 2030, as urban/city based activity increases and people are willing to move to the large cities for better facilities and lifestyle.

Urbanization causes negative effects on environment, human and animal life by the production of pollution, the change in the physical and chemical properties of the atmosphere, the covering of the soil surface and soil properties and so on. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the nearby area's natural landscape (Arrau et al., 2008). Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. The UHI has a long term negative impact on the rural areas as the environment may pollute because of this phenomenon. The ecosystem of a area can totally be changed by this. This will in turn change the world environment in many respects. The UHI will ultimately cause the production of greenhouse gases which will lead to global warming.

A heat island is best visualized as a dome of stagnant warm air over the heavily built-up areas of cities (Emmanuel, 2005). The heat that is absorbed during the day by buildings, roads and other constructions in an urban area is re-emitted after sunset, creating high temperature differences between urban and rural areas (Asimakopoulos et al., 2001). The actual size and form of UHI varies in time and space as a result of meteorological, regional and urban characteristics (Oke, 1987).As seen in Figure 1, Oke (1987) stated that in a larger city with a cloudless sky and light winds just after sunset, the boundary between the rural and the urban areas exhibits a steep temperature gradient to the urban heat island and then the rest of the urban area appears as a "plateau" of warm air with steady but weaker horizontal gradient of increasing temperature towards the city centre. In the large city areas, the urban city centre shows a final "peak" in the urban heat island where the urban maximum temperature is found. The difference between this value and the background temperature of the rural area defines the 'urban heat island intensity'. This phenomenon may occur during the day as well as at night,

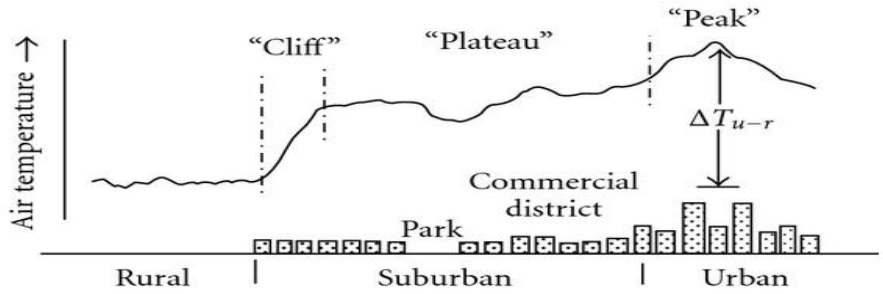

Figure 1: Generalized cross-section of a typical Urban Heat Island (Oke, 1987)

3. FACTORS INFLUENCING URBAN HEAT ISLAND

UHI may occur because of many factors and they are interrelated to each other in many ways. These factors can broadly be categorized as controllable and uncontrollable factors as shown in Fig.2.and the controllable and uncontrollable factors could further be classified as the temporary effect variables such as green areas, sky view factors and building material and cyclic effect variables such as solar radiations and anthropogenic heat sources(Memon et al., 2007). The heat generated and contained in an area comes from the sun in the form of solar radiations and from power plants, traffic, air-conditioners and other sources as anthropogenic heat. They enter into the environment directly. Maximum of the solar radiation is absorbed by critical urban structures and heat up the environment indirectly and only a part of the radiation heat up the environment directly. (Shahmohamadi et al., 2010) reported that according to Oke et al., (1991) the important factors responsible for the generation of UHI are as follows:

1. Thermal properties of materials may increase heat storage in the fabric of the city during the day and release the heat stored into the atmosphere after sunset. The replacement of natural soil because of the use of asphalt or synthetic materials reduces the ability to decrease the ambient temperature through evaporation and plant transpiration.
2. The combustion of fuels from various sources produces anthropogenic heat.
3. The long-wave radiation coming from the polluted atmosphere is increased by the urban greenhouse effect.
4. Canyon radiative geometry decreases the effective albedo of the system because of the multiple reflections of short-wave radiation by the canyon surfaces.
5. There is reduced turbulent transfer of heat within streets.

6. The evaporation surfaces in the city are reduced and thereby more energy is transferred into sensible heat and less amount into latent heat.
7. Canyon radiative geometry contributes to decreasing the long-wave radiation loss from street canyons as a result of the complex exchange between buildings and the screened skyline.

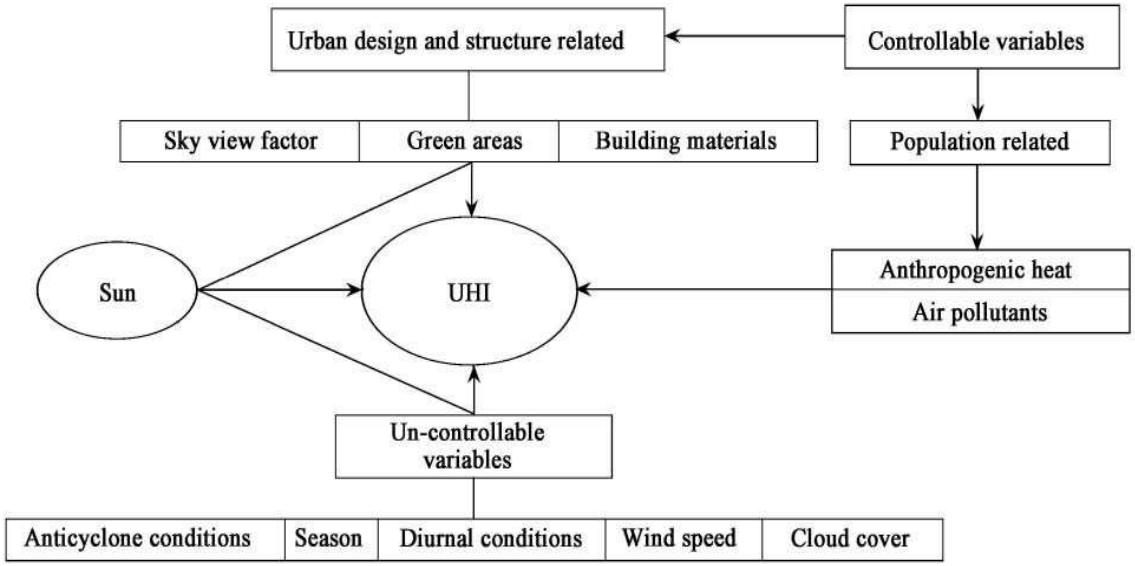

Figure 2: Generation of Urban Heat Island

4. MEASUREMENT OF UHI

4.1 Methods

There are five different methods for measuring the UHIs (Synnefa, 2013). They are as follows:

4.1.1 Fixed stations

In this method the UHI is measured comparing existing weather data from two or more fixed locations. Air temperatures are usually measured at about 1.5 meters above the ground, where standard weather observations are taken. Careful positioning of the stations is required to get representative results.

4.1.2 Mobile traverses

Entail travelling on a predetermined path throughout a region, stopping at representative locations to take readings using just a single set of weather instrumentation. A complete UHI transect study should include sample areas of various land uses and land cover so as to adequately represent the urban topography. Timing and weather conditions are also important.

4.1.3 Remote sensing

It can be used to find temperatures and other characteristics of surfaces by measuring the energy reflected and emitted from them. Specialized equipment on airplanes or satellites is used to take pictures of the visible and invisible energy radiating from cities and their surroundings. Temperatures over large areas can be visualized but remote sensing shows only a birdseye view of urban temperatures, leaving out T of walls and vegetation and T under the trees, just as important to the urban heat island as the surfaces seen from above.

4.1.4 Vertical sensing

In order to measure the differences over rural and urban boundary layers various methods are used measuring temperatures and other properties at various altitudes above the Earth's surface. These methods include sending instrumented balloons aloft, installing monitoring equipment on radio towers or flying at different altitudes in an instrumented helicopter or airplane. Taking vertical measurements around a city and its surroundings can give a better understanding of the heat island's effect on the local climate.

4.1.5 Energy balances

The energy balance equation is based on the first law of thermodynamics, which states that the energy in and out of any surface must be conserved. In the case of a surface on the Earth, this equation is generally written as: Convection + Evaporation + Heat storage = Anthropogenic heat + Net radiation

4.1.5.1 Radiation measurements

Radiation can be measured by using the following equipments
a. Incoming solar radiation (short wave) can be measured by using a pyranometer or albedometer.
b. Reflected solar radiation (short wave) can be measured by using a pyranometer or albedometer.
c. Atmospheric radiation (long wave) can be measured by using a radiometer.
d. Surface radiation (long wave) can be measured by a pyrgeometer.
Or by using single-unit equipment called net radiometer.

4.1.5.2 Convection and evaporation

The measurement of convection and evaporation is also important in the measurement of UHIs and can be measured with appropriate eddy covariance system.

4.1.5.3 Heat storage

Measured with a heat flux meter or calculated.

4.1.5.4 Local Variables

The local variables are to be considered also as they have direct influence over the climate change. Therefore affects the UHI ultimately.

5. DHAKA THE UHI

Many Asian countries are facing the increasing effects of UHI phenomenon. Dhaka, the capital of Bangladesh is also in this list. For the past 2-3 decades Dhaka has grown by leaps and bounds. This is good but the problem is the associated climatic change caused due the ever increasing urbanization and industrialization. Most of the studies on UHI in Dhaka city were done in late 2000's. These studies reported that the mean heat island intensities ranging from 0.8^0C to 8^0C.

A recent study conducted by (Das et al., 2015) is reviewed here. He used the weather research and forecasting method model to measure the UHI changes in Dhaka city. He reported that The MRF model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. The data used in this study were taken from two stations and the air temperature was taken from meteorological station. This station is operated by the Bangladesh Meteorological Department.

The locations of the observation data were Agargaon (23.77 N; 90.38 E), Dhaka and Faridpur (23.6 N; 89.95 E), Dhaka. The data were observed from 30 April 2014 to 02 May 2014. The mean maximum temperature was observed by studying annual temperature trends. The maximum temperature trend of Dhaka city shows more increasing 1961 to 2000 compared to Faridpur which is newly urbanized. After 2000 the trend is almost same for both areas due to increase in urbanization and industrialization impact (Figure 3). This study reported that the major UHI zones were found in commercial centres and densely populated areas and also the effects of UHI were very intense at night too.

Another research was carried out by (Raja, 2012) on the Land Surface Temperature (LST) in Dhaka Metropolitan Area. This was done with two specific objectives. One is to determine the land surface temperature in Dhaka city over different time periods and another is to study the impact of urban development (NDBI) and vegetation (NDVI) on LST. From the research he found that the land cover of DMA had changed rapidly during the period of 1989 to 2010. Amount of water land decreased at the highest rate (13.42%) over that period. The category of Built-up area increased by (23.18%) over the same period. By analyzing NDBI and LST, it was found that the LST value was increasing with the emerged built-up areas. This ultimately led to Urban Heat Island effect, which adversely affect the micro-climate. He also reported that highest amount of vegetation land (33.17 km^2) was converted to Built-up areas during the period of 1989 and 2000. Therefore our beloved Dhaka city is in great danger if the Urban Heat Island phenomenon cannot be checked.

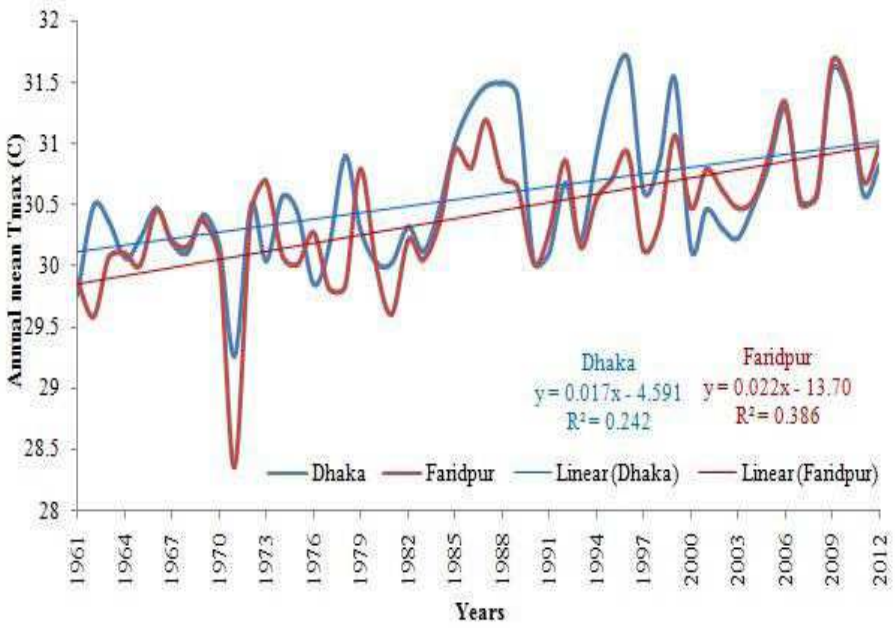

Figure 3: Annual mean maximum temperature at Agargaon and Faridpur during 1961-2012

6. IMPACTS OF URBAN HEAT ISLAND

6.1.1 Human Health and comfort

Due to UHI then day time surface temperature increases on the other hand it reduces night-time cooling and also increases air and water pollution because of industrialization and urbanization. These facts ultimately cause discomfort to general people. Respiratory difficulties, heat stroke, heat cramps and exhaustion and heat related other physical problems increase to a great extent due to UHI. The heat waves cause severe problems to sensitive populations especially children and older people as extreme heat is produced. Skin cancer may also occur due to UHI especially basal cell carcinoma, squamous cell carcinoma and malignant melanoma (Gartland, 2008). The increasing amount of ultra violet ray is also responsible for this which also occurs due to UHI.

6.1.2 Decrease in Air Quality

The UHI phenomenon ultimately produces the greenhouse gases such as C.F.C which is very dangerous for human as well as for the environment. The gases and other pollutants from various industries also cause serious problem to environment and change the biodiversity in some reasons. The pollutants also cause acid rain which causes damage to structures. The industries that use fossil-fuel as their power generating element produce co_2 to a great amount which has a negative impact on the global climate. (Gartland, 2008) reported that ground level ozone has been found to exacerbate respiratory diseases by damaging lung tissue, reducing lung function and sensitizing the lungs to other irritants.

6.1.3 Energy Consumption

Elevated summertime temperatures in the cities increase energy demand for cooling and add pressure to the electricity grid during peak periods of demand, which generally occur on hot, summer weekday afternoons, when offices and homes are running cooling systems, lights, and appliances.

6.1.4 Water Quality

Surface urban heat island pollutes the water in many ways. The main reason behind this is the thermal pollution from industries. A field study reported that runoff from urban areas was about $20\text{-}30^0$f hotter than that of from nearby rural areas on summer days when the pavement temperature is well above than the air temperature. The temperature of the runoff increases if rainfall occurs. Sometimes this causes damage to young plants.

7. MITIGATION PROCESSES OF UHI

Many studies have reported widely and successfully applied measures on mitigating the urban heat island effects with promising financial and environmental benefits. The possible mitigating measures are described below

7.1 Providing appropriate landscape

Urban and building scales should be provided with appropriate landscape so that it can contribute to energy consumption reduction. The impact of an appropriate landscape around a building on energy consumption and surrounding temperature regime is very important. Landscaping the surrounding area is a basic criteria to improve the external climatic conditions, shading from trees significantly decrease the energy required for cooling.It also Decrease the rate of heat convection inside buildings because of shaded surfaces that have a lower temperature.

7.2 Vertical green spaces

Vertical landscape can also contribute to the reduction of energy required to cool the building.Green spaces in some parts of buildings and cities can function as natural ventilation or appropriate landscapes in different layers or floors of buildings mitigating urban heat island effect cool buildings.

7.3 Horizontal green spaces

Horizontal green spaces on roofs are able to cool cities during the hot days of summer through daily dew and evaporation cycle. Green spaces absorb heat, decrease the tendency towards thermal air movement and filter air movement. In the process of evapotranspiration, plants use heat energy from their surroundings when evaporating water.

7.4 Using high albedo materials on building surfaces

Urban surface is mostly of buildings and pavements. So the temperature of urban area is mainly depended on urban building surfaces. . The surface temperature of the material is lower than that of a material with low albedo. Albedo has high reflective characteristics. This material reflects the solar radiation contributing to the reduction of the solar heat during the daytime.. If the surface temperature decreases the air temperature will also reduce mitigating the effect of urban heat islands.

7.5 Using white pavement instead of asphalt

Shahmohamadi et al., (2010) has reported that according to Santamouris et al. (2001) Asphalt temperature can reach 63°C and white pavements only reaches 45°C. This lowering of surface temperatures causes massive reduction in the air temperature also because the heat-convection intensity from a cooler surface is lower. Such temperature reductions have a significant role on mitigating measures of urban heat island effect.

7.6 Using cool roofs

Cool roofs are used in buildings as cooling equipment. It reduces the need of air conditioner thus reduce the demand for electric power. It improves thermal efficiency of the roof insulation and helps in mitigating urban heat island effects by reducing air pollution and greenhouse gas emission.

7.7 Ground water table

Water absorbs the massive heat exposed to the environment. Ground water table helps to keep the soil cool. This soil absorbs heat of the environment. So ultimately the temperature reduces mitigating urban heat island effects.

8. CONCLUSIONS

Dhaka city has a large population and increased infrastructural development. This development contributes to disruption to the city, causing environmental deterioration. The study has been carried out on elaborate discussion and review of the basic concepts of urban heat island. The factors affecting the generation of urban heat island have also been described, including the methods of measurement and mitigation of UHI. It was concluded that the UHI mainly caused by increasing anthropogenic heat and can be mitigated mainly by the increase use of green spaces. The Urban Heat Island phenomenon can seriously damage the ecosystem which will cause problems to human, animal and plant lives. Considering Bangladesh not that much work has been done yet on the UHI. Many studies on UHI is desirable because the days are not too far when the people of our country will fight against the increasing temperature growth rate for their survival. Therefore it was also concluded that more research works are needed in this field.

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