URBAN FACTORS AND THE INTENSITY OF HEAT ISLAND IN THE CITY OF CHENNAI

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Abstract

Creation of cities leads to the removal of natural landscape with built up spaces, parking lots, roads etc, through highly reflective materials, affecting the local climate in a dramatic scale. The climatic changes in the urban areas are often characterized by increase in air temperatures and are termed as the Urban Heat Island Effect (UHIE). Major factors contributing to the elevated air temperatures include the size of the city, population, density of built-up spaces, street canyon geometry, thermal properties of materials, vegetation cover and waste heat from buildings. Therefore it is vital for urban designers and urban planners to study the nature of the climate variation trends in urban areas to equip them in planning sustainable and comfortable cities, and mitigate the adverse effects. This paper aims to assess the intensity of urban heat island effect in the city of Chennai and their relationship to various urban factors, through mobile recordings of urban air temperatures during summer and winter. Air temperatures were recorded through a mobile survey covering the major areas of the city in the month of May 2008 (hottest month) and January 2009 (coldest month). The results indicate the existence of heat island effect in the city of Chennai with increasing air temperatures in a radial fashion from the suburbs towards the city centre where the mean max UHI intensity reaches 2.48°C during summer and 3.35°C during winter. The study reinforces the relationship between the urban air temperature increase and the urban factors such as the built up spaces, vegetation, parking lots etc. Areas with dense vegetation recorded lesser air temperatures and high density built up spaces along with heavy traffic recorded higher temperatures.

Key words: Urban heat Island, Urban air temperatures, Urbanization, Urban land use, Diurnal variations.

1. INTRODUCTION

Creation of cities leads to the removal of natural landscape and results in distinguished climatic conditions termed the “Urban climate”. “Urban Climate” is the “Urban effects on local climate” (the changes caused by designers and planners) and the “Urban effects on regional climate” (the differences between what is observed in the city’s environs and what would have been observed there if the city was not present on the landscape) (William P. Lowry, 1988). Urban climates are distinguished from those of less built-up areas by differences of air temperature, humidity, wind speed and direction, and amount of precipitation. These differences are mainly due to the alteration of the natural landscape through construction of buildings, asphalt roads and other reflective surfaces. Oke (1976) describes the urban atmosphere as two distinct layers: Urban boundary layer and urban canopy layer. The Urban boundary layer (UBL) is the overall atmospheric system that extends for many miles above the cities and its characteristics is partially determined by the city below (Oke 1982). The Urban canyon layer (UCL) is the layer of atmosphere where most life occurs: from ground up to the mean height of roofs. Thus the climatic effects of urbanization are strongly felt in the UCL. The alterations owing to urbanization lead to higher temperatures in urban areas when compared to the surrounding rural area. This difference between urban and rural temperatures is called the "urban-heat-island” (UHI) effect. The main cause of this phenomenon is the faster rate of cooling of the open areas around cities when compared to the rate of nocturnal cooling of densely built-up centres (Baruch Givoni, 1998). The causes of the UHI includes, blocking the view to the night sky by buildings, the thermal properties of surface materials and lack of evapotranspiration in urban areas, geometric effects called the “canyon effect” and anthropogenic heat (Oke 1982, Santamouris 2002). Diminishing diurnal temperatures in cities are clear indication of the presence of UHI (Landsberg 1981, Oke 1987). The intensity of UHI during the night time is harmful as the urban residents are denied of the cool air found in rural areas (Clarke, 1972). Luke Howard (1833) carried out the first scientific study of urban climate modifications. He compared the temperature of a city weather station with that of a rural station and found that the city station was warmer. He found that the night was 3.70°F warmer and the day 0.34°F cooler in the city than in the country. He attributed this difference to the extensive use of fuel in the city. The heat island is a reflection of the microclimatic changes brought about by man-made alterations of the urban surface (Landsberg, 1981). Emilien Renou 1868, in his study in Paris suggests clearly the temperature difference between the countryside and the city is about 1°C at the same elevation (Landsberg, 1981). A heat island is a dome of stagnant air over the heavily built-up areas of cities (Akbari et al, 1992). The intensity of heat islands depends on density, population, size - Irving Hoch (Terry A. Ferrar, 1976, Oke, 1982) and morphology (physical structure) of the cities. The difference between the maximum urban temperature and the background rural temperature is defined as the urban heat island intensity. UHI have many negative impacts in the built environment. Higher temperatures in cities increases the energy use for cooling, increases health risks and aggravates accumulation of smog due to the existence of high temperatures along with atmospheric pollutants (Santamouris 2002).

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Therefore it is vital for urban designers and urban planners to study the nature of the climate variation trends in urban areas to equip them in planning sustainable and comfortable cities thereby reducing the adverse effects. This paper aims at “assessing the intensity of urban heat island effect and defining the relationship between the UHI effect and the urban factors in the city of Chennai”.

2. AREA OF STUDY

Chennai-Madras, a metropolitan city of India, is located on the Coromandel Coast of the Bay of Bengal. It is located at 13.04° N latitude and 80.17° E longitude and has a flat coastal plain with an average elevation of 6m. Chennai experiences hot humid climate due to its proximity to the sea and has little seasonal variation as it lies on the thermal equator. April, May and June are the hottest months with maximum temperatures around 38 °C, but it exceeds 40 °C for a few days in the month of May. The minimum temperatures around 24 °C are experienced during December and January.

2.1. Urban Heat Island in Chennai

It is necessary to understand the intensity of UHI as it enables us in defining the relationship between the urban factors and the UHI effect. UHI studies in Srilanka (Emmanuel 2000, 2005, Emmanuel et al 2006, Johansson 2006) suggested the thermal comfort patterns are strongly related to land cover changes. Similar study in Singapore (Nichol, 1996, Wong 2006) identified that tropical cities do not have single UHI, but have a collection of small UHIs separated by cooler areas. In Chennai the first UHI study was conducted by Jayanthi in 1987 (Jayanthi, 1988). The study revealed the existence of UHI in Chennai with three hot pockets namely Mambalam, Vepery and Ennore Industrial zone. The survey also identified a cool pocket at Guindy RajBhavan area due to considerable amount of vegetation and vast open spaces. Chennai city has foreseen lot of developments in the past twenty years and no study was conducted since 1987. Therefore to understand the nature of urban heat island effect in the present scenario, a study was conducted to assess the intensity of UHI through mobile survey during May 2008 and January 2009 in Chennai city.

3. METHODOLOGY

To map a citywide temperature distribution at night when maximum heat island intensity occurs, a mobile survey was conducted during the summer (May 2008) and winter (January 2009) months. Air Temperature data were collected using HOBO dataloggers kept inside a white open plastic box which in turn is covered by an outer covering (a vent pipe of 115mm dia painted white). The Instrument was fixed in a PVC pipe tied horizontally to the car at a height of 1.4m and approximately 75cm in front of the engine. The mobile measurements were collected simultaneously in two fixed return routes covering majority of the locations in the city on 18th May 2008 and 29th January 2009 between 12.00 midnight to 5.30am. Air temperatures were recorded every 3 minutes along the mobile route. The collected data were averaged for time correction and was used to construct a horizontal thermal map to study the intensity of UHI in Chennai city. An UHI profile for Chennai city was plotted to understand the relationship between the urban factors and the UHI intensity.

4. SITE SELECTION

The Chennai city region covers an area of 174 km² and the metropolitan region covers 1,177 km². The study area of Chennai includes both the city and the metropolitan region. The mobile routes were chosen so that it covers the majority of the urban and suburban locations in the city of Chennai. The growth pattern of the city is by and large along the three major National Highways namely NH4, NH45 and NH5. The mobile routes are chosen along these major highways. Fig 1 shows the two mobile routes chosen for the survey.

Fig. 1. Mobile Routes in the study area

Fig. 2. Temperature Profile During Summe

Fig. 3. Temperature Profile During Winte

Fig. 4. UHI Profile across the Study Area

5. RESULTS AND DISCUSSION

The data collected through the mobile survey conducted in two fixed return routes were plotted to show the temperature mapping of Chennai city during summer and winter (Fig 2 & 3). Based on the mobile survey, the UHI profile across the city was plotted in five radial cross sections namely Beach to Thiruvanmiyur (Profile A), Beach to Tambaram (Profile B), Beach to Retteri (Profile C), Beach to Koyambedu (Profile D) and Beach to Virugambakkam (Profile E) and two concentric cross sections namely and Perambur to Thiruvanmiyur (Profile F) and Retteri to Tamabaram (Profile G). Fig 4 indicates the profiles A to G. UHI across these profiles A to G were plotted for summer and winter (Fig 5 & 6). The profile clearly indicates the relationship of different land uses, presence of vegetation and the intensity of UHI. In the CBD area, absence of vegetation and high density built up spaces resulted in elevated air temperatures. The lowest temperatures are owing to the presence of dense forest vegetation at the Institution area of Anna University. The study also indicates increased intensity of UHI in winter when compared to that of summer.

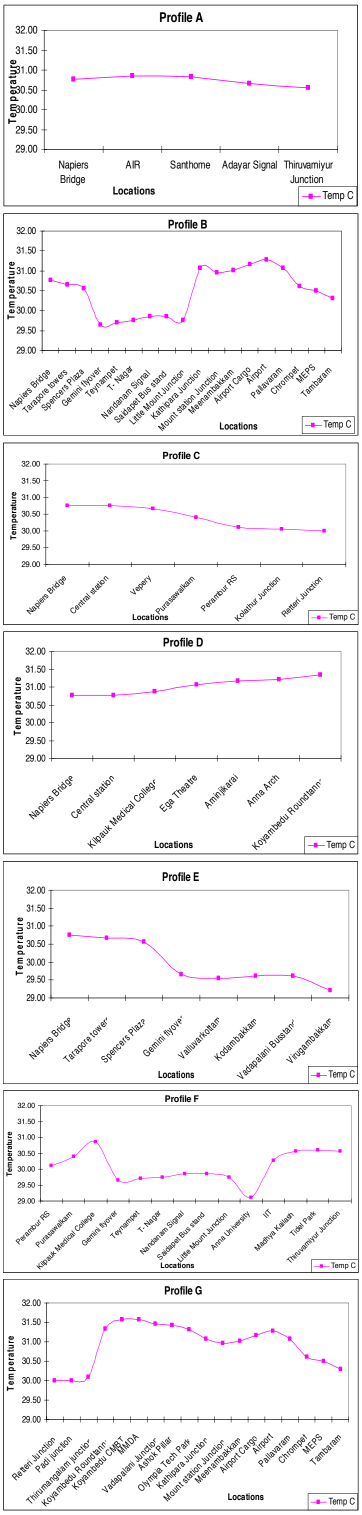

Fig.5 UHI Profile During Summer

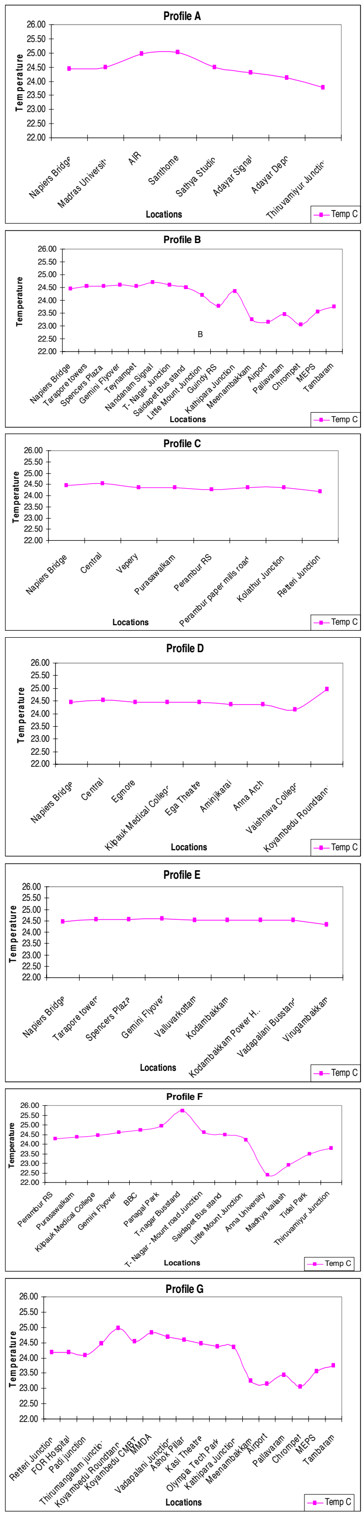

Fig.6 UHI Profile During Winter

The Summer UHI indicated the presence of cool islands in Thirumangalam, Valluvarkottam, Anna University, Gemini flyover and at RajBhavan areas in Chennai. It also helped in identifying the heat pockets at Mount Road, Koyambedu, Kathipara junction (Guindy) and Meenambakkam airport areas. These hot spots are caused by large areas of exposed hard surfaces such as concrete surfaces, runways and bus parking bays mainly due to the thermal properties of materials. In addition all these hot pockets are characterized by very high traffic leading to increase in anthropogenic heat emissions. The increased anthropogenic heat and the hard reflective surfaces results in higher air temperatures. Lower temperatures recorded within the city near RajBhavan area attributes to the presence of dense vegetation, whereas at Thirumangalam, Gemini flyover and Valluvarkottam it is mainly due to the presence of open spaces, parks etc representing cool pockets. It can be found that lower temperatures were recorded mostly away from the centre (Fort St. George) in a radial fashion. Higher temperatures were observed in the central and northern part with lower temperatures in the southern part. But areas close to the airport region experienced higher temperature due to heavy construction activity and traffic congestion. The maximum temperature of 31.58°C was recorded at Koyambedu and the minimum temperature of 29.10°C was recorded at Anna University and Thirumangalam. Therefore there existed an intensity of 2.48°C of heat island in the city of Chennai during summer.

The winter UHI reinforced the existence of UHI in Chennai city with increased UHI intensity of 3.35°C. Cool islands were identified at Anna University, MadhyaKailash and Chrompet areas in Chennai. It also helped in identifying the heat pockets at T- Nagar, Koyambedu, Santhome, Central Station, Vadapalani and Mount raod areas. Almost all the urban sites were warmer during winter when compared to that in summer. The dense built up spaces in the urban sites attributes to the elevated temperatures during nights in winter. The maximum temperature of 25.73°C was recorded at T- Nagar and the minimum temperature of 22.38°C was recorded at Anna University. Therefore there existed an intensity of 3.35°C of heat island in the city of Chennai during winter.

6. CONCLUSION AND RECOMMENDATIONS

The presence of vegetation is a major factor in cooling urban sites which was very clear in both the summer and winter surveys. The dense built up spaces, construction activities, transportation nodes etc., contributes to the increase in air temperatures. The study confirms the existence of UHI effect in the city of Chennai and indicates an intensity of 2.48°C and 3.35°C during summer and winter respectively. The intensity of UHI has a strong influence on urban factors such as the density of built up spaces, presence of vegetation, thermal properties of materials and the anthropogenic heat.

Vegetation to a large extent can improve the thermal environment. At city level, large green patches can reduce night time air temperatures. At micro level, trees and plants surrounding the built up spaces can reduce the absorption of solar radiation. The UHI effect is a common feature found in most cities. Therefore the basic strategies applicable to all cities in mitigating the negative impacts of UHI are shading the hard surfaces that are directly exposed to sun, greening the city and reducing the anthropogenic heat and use of light color materials to save cooling energy.

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