J3.8 URBAN HEAT ISLANDS AND ENVIRONMENTAL IMPACT

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ABSTRACT

The rapid urbanization and industrialization have brought about microclimatic changes particularly with regard to its thermal structure. The well documented climatic modification of the city is urban heat island. The present paper discusses the nature and intensity of heat islands at Visakhapatnam, the tropical coastal city of South India. A detailed study was carried out with regard to urban heat islands for the last ten years. The study reveals that the intensity of heat island varies from 2^0C to 4^0C and intensity is high during winter season compared to summer and monsoon seasons. At Visakhapatnam the formation of heat island is controlled by topography and urban morphology. The land and sea breeze circulation also interacts with the heat island. It has been found that cooling at night time is less inside the builtup area than the suburban. Urban cooling rates are compared with the sub-urban and rural environment. The urban heat island helps in setting up of the recirculation of pollutants thus making the pollution problems more serious. Heat island coupled with heat wave conditions during summer season causes human discomfort and higher death rates. At Visakhapatnam, summer months of April, May and June with maximum temperatures of 35^0C to 40^0C are uncomfortable with oppressive heat. There is a record of 94 heat waves during 1951-2000. Prevalence of heat wave conditions and heat island deteriorate the situation further and residents experience thermal stress and heat deaths. Thermal comfort can be improved by developing green belts which control temperature and reduce heat island effect. Cities must be planned with climate input to make the environments more pleasant and healthier places and to reduce undesirable effects.

1. INTRODUCTION

An understanding of the urban heat island is important for a variety of reason. The radiation absorbed warms the ambient air increasing the low level stability and consequently preventing the pollution dispersal which will result in an increase in pollution concentration. The urban heat island adds to the development and self sustenance of a 'dust-dome' and a 'hazehood" of contaminating particles. It also helps in setting up of the recirculation of pollutants thus making the pollution problems more serious. With the increasing emphasis on planning for healthier ad comfortable physical environments in cities, the need to recognise the role of cities in causing and meeting the challenges posed by climate change has become greater. The very presence of a city affects the local climate and as the city changes, so does, its climate. The modified climate adds to the city residents' discomfort and even ill-health. The well documented climatic modification of the city is urban heat island. The higher temperatures are best developed over city cetres at night under stable conditions and the situation is often referred to as the 'urban heat island'. It is not an instantaneous phenomenon but progressively develops following sunset. The magnitude or intensity of heat island depends on various factors such as, heat storage by buildngs and pavements; heat generated by industrial processes, transportation, air conditioning and also as a result of reduced evaporational cooling from vegetation Their combined effect, however, results in the formation of the 'heat island' which varies in intensity from city to city and from season to season.

Of the many meteorological parameters that are affected by urbanization, temperature anomalies are widely reported (Landsberg, 1970; Chandler, 1970) and Lowry (1977). Most of the reports were based on temperature observations from mid latitude cities. Oke (1974, 1979, 1984 & 1999) has given a comprehensive review of urban heat island studies. Philip, Daniel and Krishnamurthy (1974) and Murthy (1979 & 1999) have analysed the formation of heat islands in some Indian cities during winter months. There are many reports about heat island phenomena from all over the world. Number of technical papers were presented during the international conference on urban climate organised by WMO during Nov'99 at Sydney. International organizations such as WMO, WHO, UNEP and International Geographical Unions are actively involved in the urban climatic studies.

The present study focuses on the nature and intensity of urban heat islands in the city of

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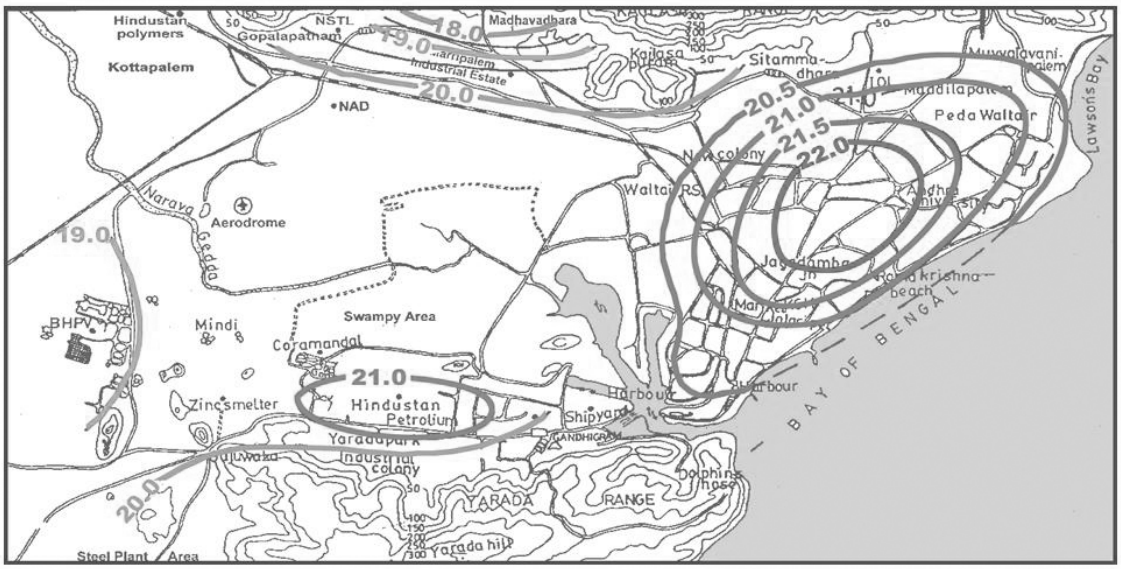

Fig.1 Surface temperature (^{0}C) distribution (11th February' 2004)

Visakhapatnam, multifunctional port city of South India. It is one of the fast growing cities of India with more than 1.5 million population. The city is bounded by hill ranges in north and south and Bay of Bengal forms the eastern boundary. Being a coastal station the city enjoys moderate climate with mean annual temperature ranges from 22^{0}C to 31^{0}C. Visakhapatnam is presently witnessing rapid industrialization and urbanization and consequent landuse changes which affect local climate to large extent.

2. METHODOLOGY

Field surveys were carried out in and around Visakhapatnam and surface temperature data were collected using thermometers at a number of predetermined points. The observational points were so chosen as to ensure adequate representation of all parts of the city. The observation period was near the minimum temperature epoch, when the heat island effects are known to be most prominent. Days with clear skies and calm winds were chosen as far as possible. Thermographs were also installed at represetative locations to know the temperature trend. The temperatures were then plotted on a map of city and isotherms were drawn taking topography into consideration and maps were interpreted.

3. RESULTS AND DISCUSSION

The study reveals that urban heat islands are complicated zones with multiple cores corresponding to the urban morphology. It was observed that heat island was noticed over thickly built up area (Fig. 1). A concentric pattern of isotherms with a warm core at the centre, corresponding to the business district of Visakhapatnam could be noticed. Temperature varies from 18^{0}C in the north along the foot hill zone to 22^{0}C over city centre with the intensity of 4^{0}C. Warm pocket was also identified over the industrial area in the south. Having seen the general pattern of temperature distribution over the city and having identified the general areas susceptible to the formation of heat island, some more surveys were conducted during the winter period for the last 10 years. Intensity of heat island varies from 2^{0}C to 4^{0}C. Temperature surveys were conducted during summer period also to observe the intensity of heat islands during summer season. It was observed that the temperature difference between the city centre and suburb was 2.5^{0}C. In general temperatures were high all over the city, varying from 31^{0}C to 34^{0}C as it was summer season. Here, the highest temperature of 34^{0}C was observed over interior places (residential colonies) unlike previous cases. Along the coast temperatue varies from 31^{0}C to 32^{0}C due to maritime influence. The reason to have selected the summer season for survey was to find out the impact of heat island on human comfort as Visakhapatnam is a tropical coastal city and summer is oppressive and uncomfortable. The discomfort during the summer is not only due to high temperature but also due to high humidity and it varies from 72% along the coast to 60% towards interior places. The growth and intensity of heat island depends upon the cooling rates of urban and rural environments. Because of the markedly different surfaces, the rates of cooling of urban/rural environs differ widely and the growth of the heat island intensity varies with the time of the night. Fig. 2 shows urban and rural cooling rates during Feb' 2004. It was observed that the rate of decrease of temperature during winter nights was 0.3^{0}C/hr in urban area whereas it was 0.5^{0}C/hr in rural area.

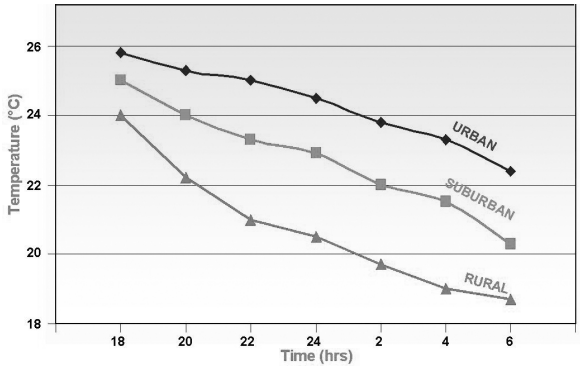

Fig.2 Urban and Rural cooling rates

Temperature surveys were conducted in and around Visakhapatnam during different periods, under varying meteorological conditions. It was observed that the heat islands can be formed under all meteorological conditions during all seasons. But heat islands of higher intensities can be developed only during winter season under calm conditions. At Visakhapatnam, the formation of heat island is controlled by topography, urban morphology and proximity to a large water body, i.e. the Bay of Bengal. The land and sea breeze circulation also interacts with the heat island. Hence, intensity of heat island is 2^0C to 4^0C at Visakhapatnam unlike other Indian cities, where the intensities are more than 4^0C.

Heat island increases the discomfort both outdoors and indoors. The stress imposed by high temperatures may lead to sickness. During summer season demand for electricity increases in tropical cities and urban heat island magnifies this demand and more energy is used for indoor cooling. As energy consumption is a major source of greenhouse gases, the concentration of greenhouse gases increases with intense use of energy which leads to climate change. By designing, building and operating urban areas in an energy efficient way, significant decreases in greenhouse gas emissions can be achieved.

It is clear that climatic discomfort is strongly increased by urban heat islands. Heat wave conditions coupled with heat island during summer season causes human discomfort and higher death rates. Visakhapatnam being a tropical coastal station exhibits extreme temperatures and higher humidities, which cause distress conditions. The summer months of April, May and June with maximum temperatures of 35^0C to 40^0C are uncomfortable with oppressive heat. The analysis of summer maximum temperatures shows that the city experienced ninety four heat waves, out of which sixty three are moderate and thirty one are severe heat waves over a period of fifty years i.e. from 1951 to 2000. During heat waves, urban heat island causes extra thermal stress resulting in increased urban death rates. There is evidence that aggressive behaviour and heat deaths are increased in tropical cities during hot weather.

Indoor discomfort also increases with high temperatures and it can be reduced by making modifications in the design and orientation of building. Careful setting of vegetation around the building has been recognised as a means of cooling. A direct consequence of landscaping would be lower temperature effect on building surfaces as it reduces the thermal load on building and create comfortable environment. In an investigation, the surface temperature of a common brick wall were compared with those of a brick wall covered with vegetation. It was noticed that the surface temperatures at the inner side of the covered wall were about 2^0C lower than those at the uncovered wall throughout the whole day. Vegetation in and around buildings as well as on the roof tops and hanging creepers can be effectively used to achieve better comfort conditions.

It can be possible to achieve indoor comfort by appropriate constructional measures. It is not so much the urban heat island itself which is causing an uncomfortable climate but in some cases it is the unfavourable urban building properties.

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