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Role of Built Environment on Factors Affecting Outdoor Thermal Comfort - A Case of T. Nagar, Chennai, India

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Abstract

Background: Urban morphology plays a critical role in controlling the factors that influence outdoor thermal comfort. This research aims to quantify the impact of urban growth pattern characterized by orientation, ground cover, street geometry etc. on variations in climate parameters. **Method/Analysis:** Air temperature and relative humidity data were recorded in nine different locations of the study area (T. Nagar, Chennai, India) characterized by different urban morphology on a typical winter day. The data collected were simulated using Rayman Pro to analyze the impact of sky view factor, height to width ratio on thermal comfort parameters. Also the relationship between the spatial distribution of the recorded values and urban morphology were analyzed. **Findings:** The results of the study establish a clear relationship between urban character and microclimate modifications. The distribution curve of air temperature and humidity establish high thermal stress during day time in high activity zone due to anthropogenic heat and hard surfaces. The isotherms clearly reinforce the presence of urban heat island effect in dense areas during night time attributed to lesser opportunity for re-radiation. Further wider streets show high difference in the diurnal temperature which in turn create cool pockets. The role of urban parks and vegetation in improving the comfort conditions are clearly evident in the study. **Applications/Improvements:** The study can be applied on the Local Climate Zone (LCZ) map of tropical city of Chennai. This will help in establishing a new development control rules for the city which will be responsive to the Micro Climate.

Keywords: Chennai, Street Geometry, Urban Heat Island, Urban Morphology, Outdoor Thermal Comfort

1. Introduction

Cites of most developing countries today are tirelessly involved in expanding its boundaries largely due to the increase in population, economy, infrastructure. The built environment of such developing cities is driven by economic needs and not on the basis of human comfort. This has made life in streets and other un-built spaces very stressful. If thermal comfort conditions exist in outdoor environments people would prefer to be pedestrian when they move in their neighborhood. In order to improve the quality of urban life one need to understand the relationship between microclimate and built environment.

Urban fabric influence climate elements, such as solar radiation, air temperature, humidity and wind and urban areas act as climate modifiers[1]. Cities act as sources of heat and the effect of pollution is seen in the thermal structure of the atmosphere above them[2]. The relationship between street geometry, orientation, height-to-width ratio (H/W) and the resultant variation in the micro climate affect outdoor thermal comfort[3]. Besides sky view factor (SVF) and its role on thermal comfort has added a new dimension to microclimate studies[4]. Research also shows albedo and urban greening will have positive impact in reducing heat stress of high density urban centers[5].

GIS helps in understanding the relationship between land cover and thermal sensation and its impact on

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urban heat island by using thermal imagery[6,7]. GIS is used to simulate wind and temperature variations in the research carried out in Gothenburg urban district[8]. Landscaping design elements, like lakes and vegetation, impact on microclimate and help in developing cooling communities[9,10]. Further Computational Fluid Dynamics (CFD) can also be used to study the fluid flow patterns in urban thermal environments[11].

2. Area of Study

Chennai is the capital of Tamil Nadu a southern state of India. This metropolitan city is geographically located at 12°50'0" - 13°15'0" N latitude and 80°0'0"- 80°20'0" E longitude (Figure 1). The topography is relatively flat and climate experienced is hot humid climate. The maximum air temperature varies between 41°C in the month of May and 20°C in the month of December. Relative humidity reaches 80% in the month of November. The average precipitation is 1200mm and it enjoys predominant wind from south or southeast direction at an average speed of 2 km/hr.

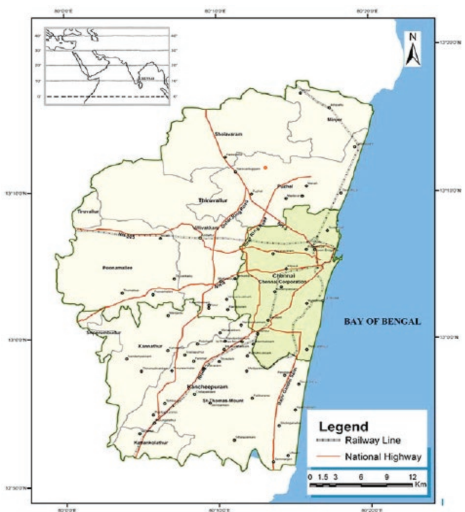

Figure 1. The geographical extent of Chennai Metropolitan Area and the location of T. Nagar Neighbourhood.

In Chennai, T. Nagar (Figure 1) a mixed residential neighborhood is considered for the study. It is characterized by the shopping activity on all its major roads. It also accommodates temples, schools and some offices. This low rise high density neighborhood is slowly witnessing the growth of high-rise structures. The street shopping activity is very high particularly during festive season and so thermal comfort plays a significant role in the quality of such urban spaces.

3. Methodology

T. Nagar Neighborhood has been divided in to nine zones (Figure 2) based on the built density, street geometry, orientation, height-to-width ratio (H/W). The air temperature and relative humidity values were recorded in each of the nine measurement location for a typical winter day using HOBO Pro V2 data loggers from 0700 hrs to 1900 hrs at regular 30 minute interval.

The characteristics of the built environment around each of the measurement location have been mapped through Plans and sections of 100mX100m grid (Figure 2a) around the point of measurement where the instrument was installed.

Further the Sky view factor of each location is simulated using the software tool RayMan Pro. The height to width ratio is calculated from the sections drawn at each of the measurement location

Figure 2. The nine measurement locations in T. Nagar.

The data recorded were analyzed to identify the influence of built geometry on air temperature and humidity variations and isopleths are plotted using GIS application.

The Temperature and Humidity isotherms were generated for 0700hrs, 1200hrs and 1900hrs. This helps in understanding the spatial distribution of microclimate parameters throughout the neighborhood.

The relationship between the urban built environment and the spatial distribution of air temperature and humidity variations are analyzed.

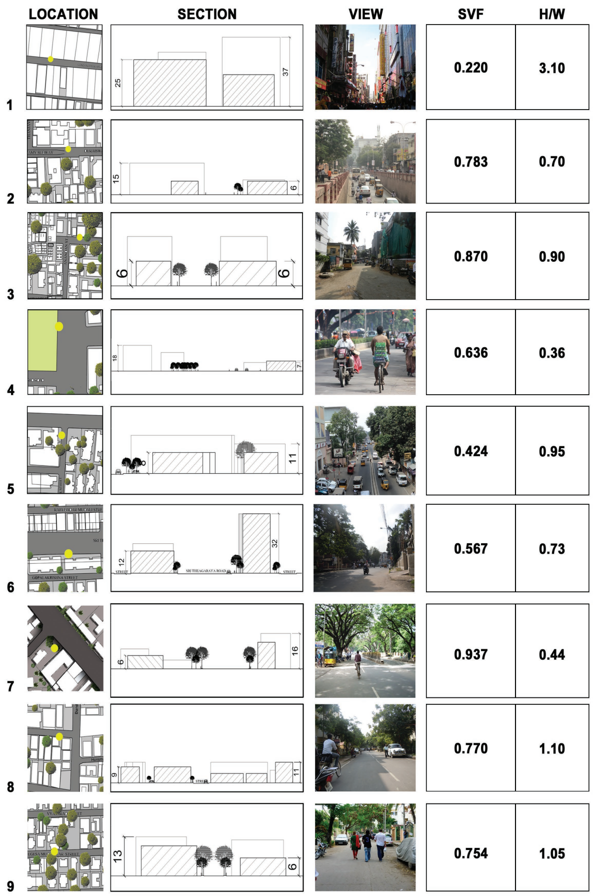

Figure 2a. The built characteristics of the nine measurement location.

4. Results and Discussions

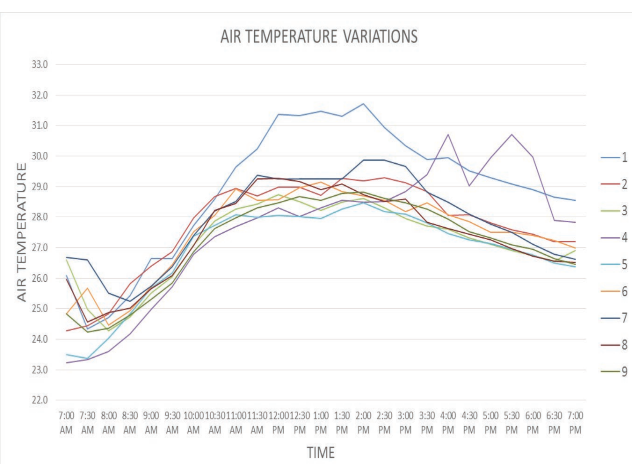

Figure 3a. Air Temperature distribution in the measurement locations.

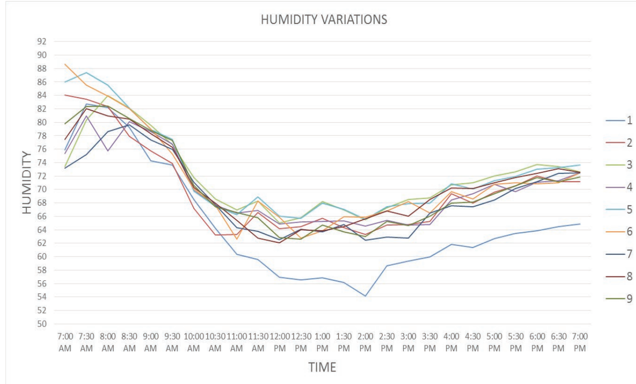

Figure 3b. Relative Humidity distribution in the measurement locations.

Figure 3a shows the air temperature distribution at the measurement locations. At 7.00hrs, temperature difference of 3.4^0C exists and the maximum of 26.7^0C were recorded at location 7 and a minimum of 23.2^0C were recorded at locations 4. The minimum temperatures at locations 4 can be attributed to high vegetation cover and less percentage of hard surfaces. The maximum temperatures are mainly due to the presence of dense hard built spaces, wider streets with an h/w ratio of 0.44. This allows direct radiation to increase the thermal stress.

At 14.00hrs, location 1 recorded the maximum temperature of 31.7^0C and the humidity level was at 54.15%. This can be attributed to the high density and the presence of anthropogenic heat from the bus terminus nearby. The absence of any vegetation has complemented the increase in air temperature. At 19.00hrs in the same location the air temperature is at 28.5^0C which is largely due to less SVF (0.22) which has reduced the effect of re-radiation, signify the presence of urban heat island.

The sudden increase in air temperature in location 4 between 16.00hrs to 18.00hrs is because of the heavy traffic at this location, as traffic from all the radial roads meet at this junction.

Figure 3b shows the relative humidity distribution at the measurement locations. At 7.00hrs, humidity ranges from 73.5% to 88% at location 2 and 5 respectively largely due to low air temperature. At 12.00hrs it varies from 56% to 65% mainly attributed to the dense vegetation. But at 19.00hrs, it ranges from 64% to 73 % at location 1 and 4. At location 1 the humidity is low throughout the day mainly because of heavy traffic and its proximity to the bus terminus.

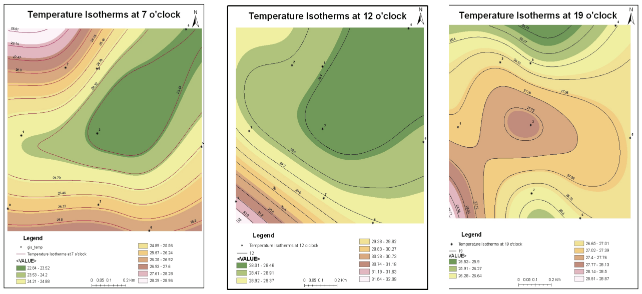

Figure 4. The Temperature Isotherms of the Neighbourhood.

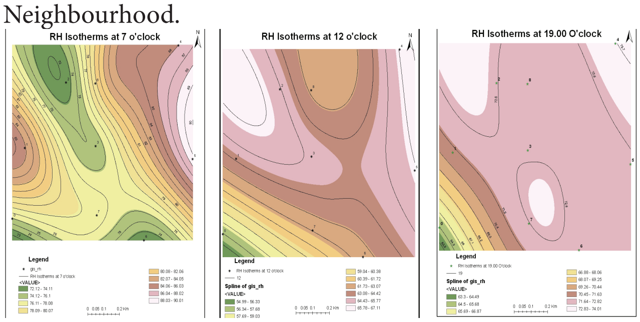

Figure 5. The Humidity Isotherms of the Neighbourhood.

A cool island at 7.00hrs and 12.00hrs and a heat island at 19.00hrs were recorded at location 4. This may be attributed to the heavy traffic density in the evenings and reduced sky view factor that reduces the re-radiation of the absorbed heat back to the atmosphere.

At 12.00hrs temperature difference of 3^0C exists and the maximum of 31.4^0C were recorded at location 1 and a minimum of 28.5^0C were recorded at locations 3 and 4. (Figure 4, 5) The temperature isotherms reflect similar pattern as that of 7.00hrs except the area of Cool Island is reduced. At 19.00hrs although the temperature differences are same as that of 12.00hrs the formation of heat island around location 3 is clearly visible. This is mainly attributed to lesser SVF and anthropogenic heat due to business activities.

5. Conclusion

The study clearly establishes the impact of urban geometry, orientation, ground cover on thermal sensation in the tropical city of Chennai. Further the role of sky view factor and its impact on re-radiation in developing heat island is clearly evident in the results of the study. The study can help designers in formulating the parameters that help in creating comfort conditions in integrating sustainable solutions that can control outdoor thermal environment through appropriate planning.

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