Spatial Variation of Urban Heat Island in Pathanamthitta

George Thomas, Sreya P and Hafsa L S

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George Thomas\textsuperscript{a*}, Sreya P\textsuperscript{a} and Hafsa L S\textsuperscript{b}

\textsuperscript{a}Catholicate College, Pathanamthitta, India
\textsuperscript{b}S.A.S.S.N.D.P. Yogam College, Konni, India

\*Corresponding author - Email: geonce@gmail.com Phone: +91 9846415414 Fax: +91 468 232522

Abstract

Urban Heat Island is the name given to describe the characteristic warmth of both the atmosphere and surfaces in urban areas compared to their non-urbanized surroundings. The temperatures are higher in more densely built up areas and lower near parks or open areas. Surface temperatures are particularly sensitive to surface conditions. The present study focuses on the Urban Heat Island effect (UHI) in the city of Pathanamthitta in the southern India. Mobile surveys were conducted in the city during summer and winter seasons, covering pre-dawn and late evening periods. It is found that late evening UHI is stronger than pre-dawn intensity in this region. Early night UHI intensity during summer and winter were 2.6\(^\circ\)C and 2.0\(^\circ\)C respectively. Pre-dawn UHI intensity during winter and summer were 1.4\(^\circ\)C and 1.6\(^\circ\)C respectively. It is observed that the marshy lands found in core city region help to reduce heat in this region.

Keywords: Urban Climate, Urban Heat Island Effect, Cooling Rates, Urban Canopy

1. Introduction

Urban heat islands are “islands” of warm surface air centered on urbanized landscapes and surrounded by progressively cooler air over suburban/rural areas. The urban heat island is a result of extensive paved surfaces and the lack of vegetation and surface moisture, the canyon effects of buildings, and the artificial heating of buildings in the urban areas (Landsberg, 1981; Oke, 1979; Akhtar et al., 2016). Closely built buildings form canyons that trap heat reflecting from their walls. Air-conditioning vents, especially in narrow alleys, further warm up buildings and nearby areas. Trees, shrubs, grass and soil absorb heat and cool the land, but these are increasingly absent in the Indian urban design. Extensive use of concrete and asphalt intensify the absorption of solar radiation at day time, that results in the atmosphere staying hot for many hours at night.

Most of the materials used in construction provide a low albedo surface, resulting in increased absorption of solar radiation at day time (Voogt, 2002; Lowry, 1991; Nunez and Oke, 1977; He, 2018). High albedo materials in the urban area reduce the amount of solar radiation absorbed through building envelop and urban structures, and keep their surface cooler. Materials with low albedo and emittance retain the higher surface
temperature when exposed to solar radiation (Morina et al., 2016). Materials which are usually found in the urban areas like asphalt, concrete surface, and gravel absorb incident solar radiation and dissipate a percentage of the absorbed heat through convective and radiative processes in the atmosphere, increasing the ambient temperature (Magli et al., 2015; Baldinelli et al., 2015). So materials used in the urban fabric play a very important role in the urban thermal balance. The aim of the present study is to investigate the development of the Urban Heat Island in Pathanamthitta city in southern India.

2. Study area

Pathanamthitta is a town and a municipality situated in the central Travancore region in the state of Kerala, South India, spread over an area of 23 km² at 9° 16' 0" N and 76° 47' 0" E. It is the administrative capital of Pathanamthitta district. The town has a population of 38,000. Pathanamthitta has an average elevation of 18 metres (62 ft) above sea level. The town enjoys a tropical climate, and the monsoons start in June. The maximum temperature observed here is 37.0°C in summer 2018. The best weather conditions are from October to February. The map of the study area is shown in Figure 1.

3. Methodology

The Urban Heat Island intensity in the Pathanamthitta city was recorded by mobile traverse method in winter and summer. Details of the survey are given in Table 1. Measurements were carried out from 07:30 pm to 10:30 pm in evening and from 04:00 am to 06:00 am before sunrise at pre-dawn during both seasons. Observational points were so chosen as to ensure adequate representation of urban, semi urban and rural area. Air temperature was recorded with high resolution RTD probe (MadgTech USA, Model: RTD Temp 101), mounted inside a radiation screen on a vehicle. The vehicle was stopped for 1 minute at each observational

![Figure 1. Map of the study area in Pathanamthitta](source: Google Earth)
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point along the route to eliminate error in measurements of RTD probe before reaching the steady state. The reference temperature was taken from a temperature recorder installed at Vadakkupuram (76°50'00.9"E, 9°16'12.4"N), a rural area adjacent to Pathanamthitta town. The instantaneous temperature difference between all observational points and the reference site was calculated in order to determine UHI intensity (WMO, 2008).

4. Results and Discussion

The Urban Heat Island Intensity at Pathanamthitta is seen to be related with urbanisation. The existence of a moderate urban heat island is clearly visible here. Four mobile surveys were carried out at predawn and late evening to cover summer in 2018 and winter seasons in 2017. Survey number S1 – S2 and S3 – S4 were carried during summer and winter season respectively. Details of the survey are shown in the Table 1. The highest observed urban heat island intensity in Pathanamthitta was 2.6°C during summer evening in 2018. Peak UHI intensity during summer morning was 1.6°C. The highest observed UHI during winter evening and predawn was 2.0°C and 1.4°C respectively.

Table 1. Magnitude of UHI intensity during mobile survey.

<table>
<thead>
<tr>
<th>Survey Number</th>
<th>Time</th>
<th>Date</th>
<th>Year</th>
<th>*Peak UHI Intensity (°C)</th>
<th>Sky Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Predawn</td>
<td>7th April</td>
<td>2018</td>
<td>1.6</td>
<td>Clear Sky</td>
</tr>
<tr>
<td>S2</td>
<td>Late evening</td>
<td>6th April</td>
<td>2018</td>
<td>2.6</td>
<td>Clear Sky</td>
</tr>
<tr>
<td>S3</td>
<td>Predawn</td>
<td>10th February</td>
<td>2017</td>
<td>1.4</td>
<td>Clear Sky</td>
</tr>
<tr>
<td>S4</td>
<td>Late evening</td>
<td>11th February</td>
<td>2017</td>
<td>2.0</td>
<td>Clear Sky</td>
</tr>
</tbody>
</table>

*Peak UHI Intensity – Maximum value of UHI intensity observed during each mobile survey

The growth and the intensity of heat island depend on the cooling rates of the urban and rural environments. Heat island intensity is enhanced by dense building materials that are slow to warm and cool, and store a lot of energy during the day time and release it during night. In summer, maximum cooling was observed in the rural areas with 1.1°C/hr. The cooling rate in the city centre was 0.6°C/hr during the same period. Cooling rates of 1.8°C/hr and 0.7°C/hr was observed in rural and urban regions respectively during winter season. Surface temperatures have an indirect influence on air temperatures in the canopy layer. Dense built-up areas typically lead to warmer air temperature nearby. However parks, marshy lands and vegetated areas which typically have cooler surface temperatures contribute to cooler air temperatures. It is observed that UHI intensity in the evening is higher than predawn value. This is in contradiction with previous reports of stronger early morning intensity compared to early night intensity (Padmanabhamurthy & Bahl, 1982; Thomas et. al., 2014). During day time, buildings act as thermal storage and retain heat well into night. After sunset, the pavements and buildings release stored heat energy, while the air around them begins to heat up, consequently maintaining elevated temperature well in to the night. The cooling rate of rural open...
area is much higher compared to the compact urban regions. The marshy lands found in the core city region help reduce heat in this region, especially as night advances. Cooling rates as well as differences in cooling rates between these sites reduce at night and attain a minimum value at predawn in Pathanamthitta due to the presence of these marshy lands. Studies on the strategies to reduce urban heat island were carried out by several authors all over the world. Worldwide strategies adopted for the urban heat island mitigation are trees and vegetation, green roofs, cool roofs, cool pavements, etc. Various authors reported the mitigating effect of vegetation, trees and green roofs on the Urban Heat Island (Kurn et al., 1994; Akbari, 2001; McPherson et al., 2005; Clark et al., 2008; Norton et al., 2015). High solar reflectance cool roof helps to reflect sunlight and heat away from the building and reduce roof temperature (Miller et al., 2004).

5. Conclusions

The maximum Urban Heat Island Intensity at Pathanamthitta was observed to be 2.6°C during summer evening in 2018 and 2.0°C during winter evening in 2017. The maximum cooling rate observed in the rural areas during summer was 1.1°C/hr. The cooling rate at the city centre was 0.6°C/hr during the same period. Cooling rates of 1.8°C/hr and 0.7°C/hr were observed in rural and urban regions respectively during the winter season. If we retain or increase vegetation in our city without disturbing the ecological balance, we can reduce the urban heat island to some extent. The marshy lands found in Pathanamthitta help reduce heat in this region. Protection of these lands is of utmost importance to control the rise in temperature in this area. Proper planning of the built environment and selection of raw materials are necessary to reduce the problem of excessive nocturnal heat loads within the built environment. Wood has been the primary choice of construction material in India, especially in rural areas. Bricks and blocks made of clay or mud, and coming in several shapes, offer high strength to the construction. They have been used for a long time to construct homes and offices across India. Concrete, as in cement, brings in the same set of advantages and disadvantages. It is a long lasting building material and has become the foundation for India’s bridges, highways, and reservoirs, dams, parking structures and everything big. However the heat capacity and thermal emittance of these materials also play a vital role in the growth of heat island. Concrete, bricks, steel and stone used in the urban areas have higher heat capacity than dry soil, wood and sand in the rural environment. Similarly, materials with less thermal emittance, that is, it refers to the surface’s ability to shed heat or emit long wave radiation, also influence heat island developments. Cool pavements are also considered as an effective method for the reduction of Heat Island Intensity.

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This original article is reviewed by: Dr. Ligi K. Cherian, Associate Professor, Christian College, Chengannur. Her areas of interests are space physics, ionosphere and thin films.

Email: ligicherian@gmail.com