170: Patterns of attendance and thermal conditions on a pedestrian street

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Abstract

This study reports about the area usage of people in the Hungarian city of Szeged in point of view of thermal comfort. The main pedestrian street of the city was chosen to survey the spatial pattern of visitors against the momentary thermal environment and shading conditions. To achieve this, attendance of the street was observed through mapping the seated visitors in every 30 minutes from 10 a.m. to 6 p.m.; moreover it was also marked whether they were exposed to the sun. Besides, key factors of thermal comfort (air temperature, relative humidity, wind velocity) were recorded in every minute on two spots of the pedestrian street – one micro-bioclimate station was placed in the sun, while the other one was permanently shaded by the nearby buildings. Unobstructed global radiation data was obtained from the inner city meteorological station of Szeged. Thermal conditions of the area were quantified by the popular human biometeorological comfort index, Physiologically Equivalent Temperature (PET), calculated by the RayMan software from the above mentioned meteorological parameters. PET was assigned for more than 1000 points of the street according to a 5 m × 5 m grid net, and from these data heat stress maps were created for specific time periods. Comparison of the resulted thermal stress maps with the visitor's spatial distributions shed light on the patterns of area usage in the different seasons of summer and autumn.

Keywords: thermal comfort, physiologically equivalent temperature, area usage of sunny and shaded places

1. Introduction

Due to the increasing global population and the rapid urbanization, more and more people decide to live and work in cities [1]. Therefore, the question of urban thermal comfort, i.e. which thermal conditions and which urban spaces are the most comfortable and enjoyable for the city dwellers, becomes of even higher importance as confirmed by numerous urban bioclimate research projects all over the world [e.g. 2,3,4].

Urban planning and development needs to take into account the health and well-being of people living or working in urban areas [5,6]. This can be supported by small-scale micro-bioclimate models, which provide an opportunity for the forecast of thermal conditions and the resulted bioclimatological impacts of an outdoor place as early as in the planning phase. Modelling can also assist the reconstruction of thermally uncomfortable squares, playgrounds, streets or other urban structures [7,8].

This study aims to reveal the connection between the patterns of attendance on a popular pedestrian street in Szeged (a South-Hungarian city) with the thermal conditions quantified by the Physiologically Equivalent Temperature [5,9]. To achieve this, heat stress maps were created through modelling procedure and on-site investigations (micro-meteorological measurements and observations) which were carried out in the frame of a long term urban bioclimate project in Hungary.

2. Materials and methods

2.1 Study area

The Hungarian urban bioclimate project has started in the city of Szeged (Southeast Hungary, 46°N, 20°E) and has seven popular open-air public places as investigation areas until now. One of them is the most frequently attended part of the city: it is the main pedestrian street, namely the Kárász Street. On the two sides of the street numerous shops and catering places are located, thereby large groups of local people and tourists visit this area throughout the year (Fig. 1). The investigation area consist not only the main street but also a smaller crossing street (Kölcsey Street) and a square (Klauzál Square) too, as these places are also well-attended and practically belong to the concidered pedestrian zone.

Fig 1. Photograph of the Kárász Street in Szeged, Hungary

The surface of the investigated area is primarily covered by red paving-stone that quickly runs hot in the warmer seasons. Beside this fact, no vegetation can be found in the area (except for a few large flower pots), and only the surrounding buildings and the sunshades of the catering places provide shadows for the visitors.

2.2 Methods

This paper reports about the use of a human biometeorological survey method in order to investigate the relationship between the attendance of a popular street and the actual thermal conditions.

The investigation of the attendance included the registration of the number of visitors sitting on the benches (located on the sides of the two streets) and in the outdoor sections of cafés by means of area usage maps. The observations were conducted between 10 a.m. and 6 p.m. in each day in every 30 minutes. In addition, for each visitor the exposure to sun was also marked, i.e. if the given person was sitting in the sun or not.

The thermal conditions were described with Physiologically Equivalent Temperature (PET) [5,9], calculated by the bioclimate model RayMan [8] from measured meteorological parameters. 1-min averages of these meteorological factors were recorded by two mobile stations equipped with thermometer, hygrometer, ultrasonic anemometer and rotatable net radiometer (containing pyranometers and pyrgeometers). One of the stations was located in the shade, while the other station was exposed to the sun. This simultaneous measurement ensure the exact calculation of PET values on a typical sunny point of the street and in an another point shaded by buildings.

In addition, heat stress maps, i.e. spatial distribution of PET values were determined through a new interpretation of the RayMan model. The PET-map of the whole study area was created on a 5m×5m grid net, using a 1282-point simulation of RayMan. The required obstacle files were obtained from the high-resolution building database of Szeged by a special algorithm. The global radiation data (10-min averages) that were necessary to the model calculations derived from the meteorological station of the Hungarian Weather Service located in the inner city (distance from the measurement area is less than 1 km). All the other meteorological parameters (air temperature, relative humidity, wind velocity) were obtained by the above mentioned on-site measurements as 10-min averages of the two datasets from the sunny and shady stations.

The examinations were carried out in different seasons of outdoor activity and altogether 12 investigation days were conducted during the summer and autumn of 2011, and the spring of 2012. The results are demonstrated through a typical summer day (23rd August 2011) and a typical autumn day (18th October 2011).

3. Results and discussion

3.1. Temporal variations of the attendance and the PET values

As the investigated summer day fell into a heat wave period the thermal conditions were quite incriminating (Fig. 2). The PET values in the sun were always above 40°C between 10 a.m. and 6 p.m., sometimes exceeding even 50°C meaning strong to extreme heat stress for the human organism. In the shaded part of the street, lower values appeared and they ranged between 27 and 38°C, indicating slight to moderate heat stress in the most cases.

As illustrated by the Fig. 2, the visitors preferred the shaded benches almost all day. The number of people attending the investigated area was considerably higher before noon and after 4 p.m., when the thermal conditions were slightly cooler. In these periods, more than 40 visitors sojourned on the benches. The attendance of the sunny benches was surprisingly high around 2 p.m. This can be explained by the fact that in this period the visitors could choose only a few shaded benches due to the high position of the Sun.

In the case of the catering places, the number of those people who sat in the sun was negligible (Fig. 3). Fig. 3 clearly shows that the visitors in the cafés found shaded seats all day; the number of the visitors in the shaded places significantly exceeded 100 at noon and immediately after midday, while after 4 p.m. they reached even 200.

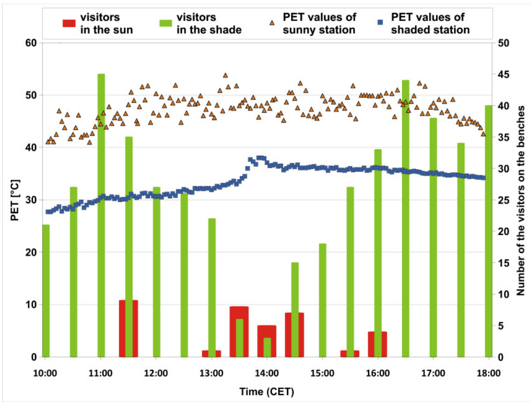

Fig 2. PET values at the sunny and shaded points and the attendance of the benches, 23rd August 2011

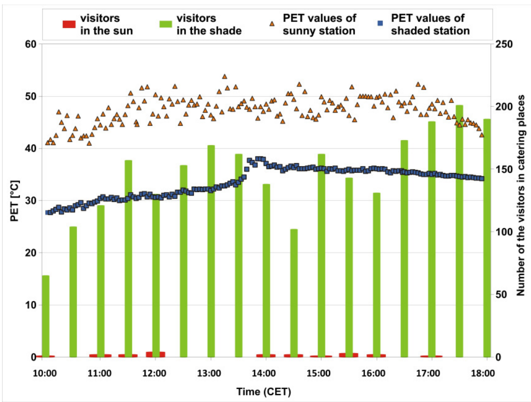

Fig 3. PET values at the sunny and shaded points and the attendance of the catering places, 23rd August 2011

The selected autumn day can be characterized with cooler thermal conditions. PET values were about 20°C between 10 a.m. and 3 p.m. in the sun-exposed parts of the area meaning comfortable thermal conditions (no thermal stress) (Fig. 4). However, in the shade the PET values remained under 10°C throughout the day which means already cool conditions (moderate cold stress in the most cases) for the human body. On this day, the attendance of the benches and the catering places did not achieve the half of the value observed on the summer day, and the visitors of the benches preferred rather the sunny seats. After 4 p.m. people could not chose seat exposed to sunlight anymore as the buildings overshadowed the whole street due to the low position of the Sun. Similar tendency can be observed in case of the catering places: due to the cooler thermal conditions, more people sat exposed to direct sunshine than in summertime (Fig. 5).

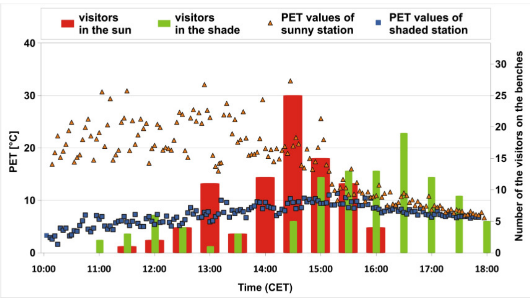

Fig 4. PET values at the sunny and shaded points and the attendance of the benches, 10th October 2011

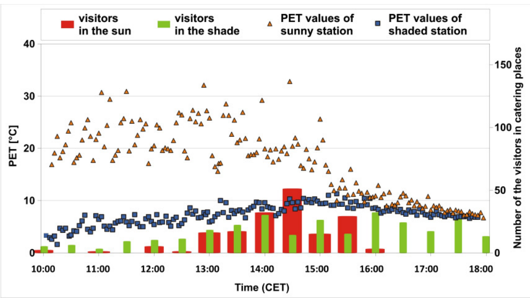

Fig 5. PET values at the sunny and shaded points and the attendance of the catering places, 10th October 2011

3.2 Spatial patterns of the attendance and the thermal conditions

Figs. 6 and 7 show the spatial patterns of the modelled PET values as well as the momentary attendance of the study area at 2 p.m. These maps highlighted also significant differences in the thermal conditions of the two investigated days. However, it is important to note that some uncertain values occur on the maps due to the relatively coarse resolution (5 m) of the grid net used in the course of the modelling procedure.

In summer, PET values were very high in the whole study area (Fig. 6). The most unpleasant part of the study area situated primarily in the middle of the Kárász Street, where PET values exceeded 44°C. Due to this strong heat stress pedestrians did not spend long time on the street with sightseeing or shopping as well as the benches along the main street were almost unused in this period. Cooler (PET<40°C) thermal conditions only occurred close to the walls due to the shading effect of the surrounding tall building blocks.

The most visitors sat in the outdoor sections of the catering places in this hot period (Fig. 6), where not only the modelled PET values were lower, but additionally, many sunshades protected the visitors from the direct radiation. Therefore the actual thermal conditions in that places could be more comfortable compared to the calculated values as the modelling procedure took into account only the shading effect of the buildings. An interesting observation was that while the thermal conditions in the crossing pedestrian street were cooler than in the main street, the number of the visitors was smaller. It can be explained by the fact that in this part of the area the number of the popular benches and cafés are limited.

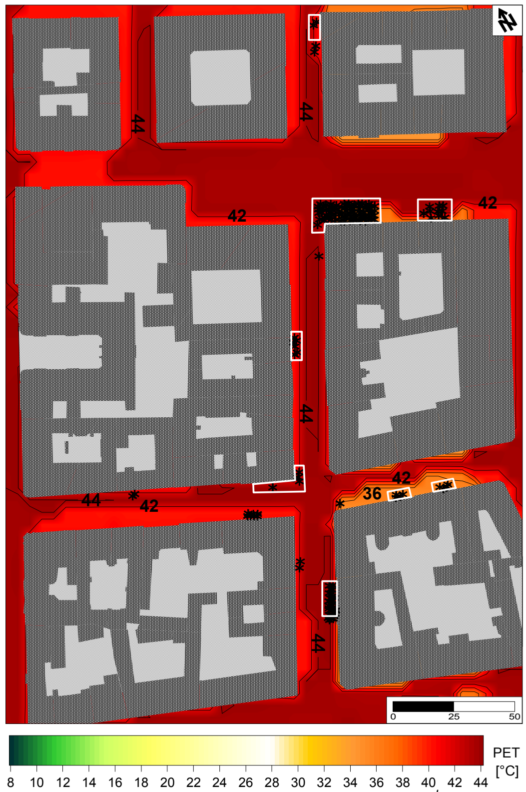

Fig 6. Heat stress map (PET) at 2 p.m., 23rd August 2011 and momentary distribution of visitors (white polygons show catering places)

According to Fig. 7 the PET values in the autumn day at 2 p.m. on the investigated area varied between 10 and 14°C. These values belonged to the slight to moderate cold stress categories. The warmest thermal conditions (PET=14°C) were mainly found in the Klauzál Square, where the direct radiation could heat up a larger area. In the vicinity of the buildings, where the benches were located, as well as around the catering places the PET values remained under 11°C.

The attendance did not follow strictly the spatial pattern of the thermal conditions, i.e. the visitors did not sit solely in the warmest (PET=14°C) parts of the area. This fact may be caused by the fixed position of the benches and cafés. This observation suggests that it would be advisable to place benches also in the Klauzál Square as in the colder months of the year the square is the only part of the investigated area which is big enough to receive solar radiation during the day and it warms up. This small change would be beneficial in point of view of subjective human thermal comfort. Indeed, according to the earlier findings of the Hungarian project local people prefer warmer conditions and sunny places in the transient seasons [10].

Fig 7. Heat stress map (PET) at 2 p.m., 10th October 2011 and momentary distribution of visitors (white polygons show catering places)

4. Conclusion

This study investigated the attendance of a popular pedestrian street and its surroundings under various thermal conditions. The results of observations showed that in summer, when PET values exceed even 40°C, visitors mainly preferred the shaded seats of the catering places. On such days, the numbers of people attending the street was above 100 during almost the whole day. The visitors favoured the shaded benches; however, this fact seemed to change around midday, when people could only choose seats in the sun. In autumn, the attendance of the street dropped below 50% of the summer attendance due to the cool thermal conditions. The sunny seats became preferred not only in the catering places but also among the benches in this period. According to the combined area usage and heat stress maps, in summer the thermal conditions were tolerable almost exclusively in the catering places, where the buildings and the sunshades offered shading. In contrary, in autumn the more comfortable parts of the area are located far from the benches and cafés. Therefore it is highly suggested to select the locations of the benches considering the local and seasonal thermal conditions.

Similar investigations should be extended to other public places to get a more accurate picture on the relationship between the seasonally varied thermal conditions and the attendance. Besides, it would be worth to test the modelled PET values with finer spatial resolutions in order to reduce the uncertainty of the results.

5. Acknoweledgement

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