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Human biometeorological approaches have an important role in applied urban climatology. Several different thermal indices were developed in the last decades to describe the heat stress of the human body and the energy fluxes between the body and environment. In this study some results of recent biometeorological investigations in a South-Hungarian city, Szeged (population 160,000) are presented. From point of view of human biometeorology, the key question is whether the examined body is in the shade or is exposed to direct radiation. Our sample area is in a heavily built-up city centre region with narrow streets and several 20-30 year old (20-30 m tall) trees, so radiation fluxes are determined basically by these factors. This paper shows how the bioclimatic indices, Predicted Mean Vote (PMV), Physiological Equivalent Temperature (PET) depend on the situation of radiation at a certain place. It was examined what is the relation between the structure and possible changes of the built-up area and the indices. All the calculations, , PMV and PET were performed with RayMan model.

Key-words: radiation fluxes, thermal comfort, mean radiant temperature, bioclimatic indices, Szeged, Hungary

1. INTRODUCTION

One of the environmental stress factors on human being living in the urban area is the urban climate conditions, which is formed mainly by the area’s building up.

An important task of the bioclimatological research to evaluate physiologically the thermal and radiating environment of human beings, because it determines basically the energy balance of the body (Höppe, 1993). The physiologically relevant assessment of urban climate, and especially different urban microclimates, requires the use of methods and indices, which combine meteorological parameters with personal parameters (Mayer, 1993). Human comfort issues and quantitative bioclimatological indices generate valuable information for urban planners, helping them to increase the well-being of urban population by planning suitable and healthy environment.

This study is based on earlier bioclimatic and recent urban climatological studies in a South-Hungarian city, Szeged. Recent studies show that on annual average an urban heat island intensity of 2.7ºC can be measured in Szeged which can extend up to 6.8ºC at clear, anticyclonal weather conditions (Sümeghy et al., 2003). It means a significant heat-stress to the human body, especially in summer. In earlier bioclimatic studies, with the help of suitable indices for the available data set, differences in the annual and diurnal variation of human bioclimatic characteristics between an urban and rural environment are evaluated over a 3-year period (Unger, 1999). According to the results, the city favourably modifies the main climatological elements within the general climate of its region; periods likely to be comfortable are therefore found more frequently in the city than in rural areas.

2. STUDY AREA AND METHODS

2.1. Study area

Szeged is located in the south-eastern part of Hungary (46ºN, 20ºE) at 79 m above sea level on a flat plain, with 160 000 inhabitants (Fig. 1). The city has a boulevard-avenue road system structure, with several different land-use types from the densely built centre to the detached housing suburb region. Fig. 1D shows the area of investigation (200*200 m) in the heavily built-up city centre region with narrow streets and several 20-30 year old (20-30 m tall) trees.

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2.2. Parameters and methods

A 3-D map of the examined area was made with the help of RayMan 1.3 model, which gives precise and high resolution data of the surrounding area of the observation point. The observation day was a calm, clear (undisturbed sunshine) summer day (4th August 2000). Meteorological parameters (air temperature, global radiation, wind speed, relative humidity) were logged by a VAISALA-MILOS 500 automatic weather station, which is located at the centre of the investigation area signed with (●) on Fig. 1D.

By RayMan estimated indices were mean radiant temperature ($T_{mrt}$), (which is the most important input parameter for the energy balance during sunny weather), Predicted Mean Vote (PMV) and Physiological Equivalent Temperature (PET) (Matzarakis et al., 2000).

$T_{mrt}$ is defined as “the uniform temperature of a surrounding surface giving of blackbody radiation (emission coefficient $\varepsilon=1$) which results in the same energy gain of a human body as the prevailing radiation fluxes”. A lot of human-biometeorological thermal indices based on $T_{mrt}$ (Matzarakis et al., 1999).

PMV predicts the mean assessment of the thermal environment for a large sample of human beings by value according to the seven-step Ashrae comfort scale (in really extrem weather-situation PMV can be higher than 3.5, or lower than -3.5) (Mayer and Matzarakis, 1997).

PET is one of the most popular and useful bioclimate index, because it has a widely known unit ($\degree$C), which makes results easy understandable and comprehensible for urban planners and decision-makers. PET is defined as the air temperature at which the human energy balance for the assumed indoor conditions is balanced by the same skin temperature and sweat rate as the calculated for the actual outdoor conditions (Mayer and Matzarakis, 1997).

Lots of models are developed to estimate the radiation fluxes, and the energy balance of human body including various meteorological parameters, albedo of the surface and solid angle proportion. One of them is the RayMan model, which is well-suited to calculate radiation fluxes because it considers more precisely effect of the complex urban structure (Matzarakis, 2002). Among others a final output of the model is in polar coordinates about the area including the sun path of the observation day at the place, with the shadow of buildings, trees, or other obstacles.

3. RESULTS

The bioclimatic situation at the observation point was examined in three cases.
- real situation considering trees and buildings (Fig. 2A)
- hypothetical situation with buildings only (Fig. 2B)
- hypothetical situation with trees only (Fig. 2C)

The calculated obstacle structures in these cases are shown in polar coordinates, as an output of RayMan (Fig. 2).
Fig. 2. Output fisheye diagram about the investigation area with buildings and trees (A), with only buildings (B), with only trees (C) and the sun path on 04th August 2000, for the calculation of the sky view factors in RayMan.

There are notable differences in the radiation conditions between the three situations, on the one hand due to different sky view factors (case **A**: 0.278, case **B**: 0.431, case **C**: 0.560), on the other hand the shading of direct radiation by obstacles.

Fig. 3. The mean radiant temperature $T_{\text{mrt}}$ computed by RayMan in three urban structures and air temperature $T_a$ on 4th August 2000.

Estimated $T_{\text{mrt}}$ values based on the model are shown on Fig 3. Because (i) $T_{\text{mrt}}$ values have strong correlation with global radiation values and (ii) there was undisturbed sunny day on the day of measurement; significant alterations in the shape of curves caused mainly by the situation when the observation point was shadowed or hit by direct radiation.
Fig. 4. Physiological Equivalent Temperature PET (A) and Predicted Mean Vote PMV (B) in three urban structures on 4th August 2000

By model calculated PET and PMV values are shown on Fig. 4A and Fig. 4B, respectively. Heat stress was experienced on the examined day: the highest value of PET was 46.8°C; and in the case of PMV Scale (based on the ASHRAE scale) it was 4.4, which is a „very hot” thermal stress level. Both indices show strong correlation with $T_{mrt}$ values. These results represent well the difficult radiation fluxes that are caused by the complex urban structure.

4. CONCLUSION

The following conclusions are reached from the analysis presented:

(i) The presence of natural and artificial obstacles around the human body has impact on the radiation fluxes so on the energy balance of the body.

(ii) Changes in the radiation situation cause changes in thermal comfort sensation.

(iii) Disadvantageous bioclimatic conditions can be improved (e.g. planting trees) even in the case of old “inherited” city structure.

(iv) In the course of planning of new districts in a city bioclimatic conditions must be taken into consideration.

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