EXAMINATION OF THE SIMULATED THERMAL CONDITIONS IN A POPULAR PLAYGROUND RELATED TO THE HUMAN REACTIONS AND THE JUDGMENT OF THE AREA DESIGN

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ABSTRACT. – Examination of the simulated thermal conditions in a popular playground related to the human reactions and the judgment of the area design. In the field of urban bioclimatology an important and timely research direction today is to examine the thermal conditions of public places. In our study, human thermal comfort analysis was performed in a modern and well-attended children playground located in Szeged (Hungary). The aim of the paper is to reveal the changes in the thermal comfort conditions between two seasons and also the resulting subjective thermal reactions of visitors in this relatively small area. Thermal comfort conditions were quantified by the Physiologically Equivalent Temperature (PET). For typical summer and autumn days of 2011 numerical simulations of thermal comfort conditions in the playground were carried out by means of the urban microclimate model ENVI-met. Spatial distribution of the simulated PET, i.e. thermal stress maps were created in two different times of the selected days in order to characterize the distinct microclimatological conditions appearing in the area. The relationship between the momentary spatial patterns of visitors and the thermal conditions was also under investigation. Additionally, onsite questionnaire survey was implemented which highlights the people's subjective evaluation related to the design of the playground.

Keywords: thermal comfort, ENVI-met, subjective reactions, Physiologically Equivalent Temperature

1. INTRODUCTION

In urban environment climate parameters are modified compared to the natural areas and they have various effects on human organism. Urban bioclimatology examines the physiological impacts of these parameters on the human health and the thermal comfort requirements. In the last years there were several urban bioclimate research projects to evaluate the microclimate and thermal comfort conditions of different design public areas, e.g. streets, squares and parks (e.g. Nikolopoulou and Lykoudis, 2006; Eliasson et al., 2007; Mayer, 2008).

It is not sufficient to design spaces only according to architecture facets. Urban planners and architects need to create also comfortable and enjoyable micro-scale climate conditions in the urban spaces taking into account the health and well-being of the citizens (Mayer and Höppe, 1987). Microclimate aspects

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substantially determine also the subjective thermal reactions and the judgments of visitors. However, human comfort aspects usually do not considered in the urban planning processes in several countries (e.g. in Hungary). This gap can be filled by means of micro-scale numerical models in the planning phases or before the construction starts by providing an opportunity to reveal the different thermal conditions within the public areas. This study analyzes the changes of the simulated microclimate conditions between different seasons and times with aid of an urban micro-scale model ENVI-met and also the resulting human reactions of visitors in a popular playground of Szeged, Hungary.

2. MATERIALS AND METHODS

2.1. Study area

Children playgrounds play a significant role in social life of the neighboring dwellers. The groups most at risk of heat stress are just young children (WHO, 2004), therefore the examination of these type of public places is a particularly important research topic. Consequently, our examination was carried out in a modern playground located in Szeged (46°N, 20°E).

The examined area is approximately 3300 m^2 large where children can use several toys, jungle gyms as well as swings. The surface of the area is primarily covered by gravel and a large amount of deciduous trees are planted mainly at the boundaries of the playground (Fig. 1). Therefore during forenoon and in the early afternoon hours considerable part of the area is exposed to the direct sunlight.

Fig. 1. ***The layout of the investigated playground***

2.2. Methods

Our study applies the model ENVI-met which is a three-dimensional non-hydrostatic climate model. It is capable to simulate the interactions in the surfaceatmosphere-vegetation system with relatively high temporal (10 min) and spatial (0.5–10 m) resolution (Bruse and Fleer, 1998). The simulation required two groups of input data: the configuration file (.cf) contains the basic settings and the necessary meteorological parameters of the simulation while the area input file (.in) includes the morphological elements (buildings, plants, land covers etc.) of the area. The thermal conditions were quantified by a widely used human bioclimatological index, the Physiologically Equivalent Temperature (PET). PET is defined as the air temperature at which, in a typical indoor room, the heat budget of the body would be balanced with the same core and skin temperature as under the prevailing outdoor conditions to be assessed (Höppe, 1999). The PET value ranges were defined according to different thermal perceptions (Fig. 2).

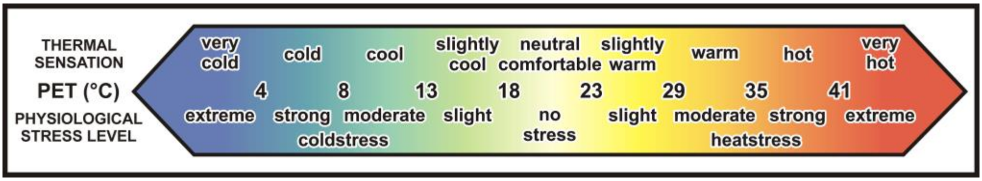

Fig. 2. ***PET ranges for different human thermal sensations and stress levels (Matzarakis et al., 1999)***

In this paper the simulation of ENVI-met concerned a typical hot summer day (12th July 2011) and a temperate autumn day (3rd October 2011). The model was run in a spatial resolution of 1.5 m and the results were regarded to the bioclimatological reference height of 1.1 m. Table 1 shows the necessary initial meteorological data (at 12 a.m. CET) obtained from the meteorological station of the Hungarian Meteorological Service located in the suburban area of Szeged. Thermal stress maps, i.e. spatial distributions of the modelled PET were created by the software Surfer 8 for ten different hours of the selected days (from 9 a.m. to 6 p.m. in accordance to the opening hours). In the study the maps at 11 a.m. and 4 p.m. are presented. The momentary spatial patterns of visitors as their behavioral reactions to the thermal conditions are also illustrated and analyzed. Additionally, the people were asked by onsite questionnaire survey to evaluate the design of the playground. The survey consisted of a few questions relating to the satisfaction with the area, the positive or negative judgments and the possible modification requirements of the visitors. The survey was conducted during the summer of 2011 and 2012 (n=226) and the autumn of 2011 (n=329); the dataset from each season comprises 6 days.

Table 1. ***Basic input parameters of the simulation at 12 a.m. CET***

Parameters	12th July	3rd October
Air temperature (K)	294	285
Relative humidity at 2 m (%)	75	70
Wind speed at 10 m (m/s)	3.3	1.3
Wind direction (°)	10	60
Spec. humidity at 2500 m (g/kg)	4	2

3. RESULTS

3.1. Spatial distribution of the thermal conditions and the momentary attendance

In the first part of the analysis, the spatial patterns of PET and their relationship with the momentary attendance of the playground were examined. The heat stress maps highlight remarkably differences in the patterns between summer and autumn and also in the investigated times.

The heat load is more dominant in the summar day (Fig. 3) in the whole area than in autumn (Fig. 4). It should be note that the thick black curve indicates the border of the playground where the analysis concerns. In summer forenoon (Fig. 3a), the highest heat load appears around the playhouse. The PET values here exceeded 41°C denoting extreme heat stress (very hot thermal sensation). It can be explained by the strong heat radiation of the pavement (Fig. 1) highly heated by the direct solar radiation. In the middle and northern parts of the playground more moderate thermal conditions can be found, but even so mainly warm thermal sensation (29–35 °C PET) occurs. Due to the shading effect of the dense foliage thermal conditions were much pleasant (meaning comfortable thermal sensation, i.e. 18–23 °C PET) near to the southern and eastern edges of the area, as well as around the single trees. Although the spatial distribution of the visitors can be highly influenced by the location and the preference of the toys, it has some connections also with the patterns of the thermal conditions. Some visitors spent their time at the toys exposed to the direct sunlight, seemingly they did not care about the existing heat load too much. However, most people preferred the comfortable spaces protecting themselves from the direct sunlight.

The thermal conditions were quite remarkable in the afternoon (Fig. 3b). Despite the lower position of the sun there were more unpleasant conditions in the

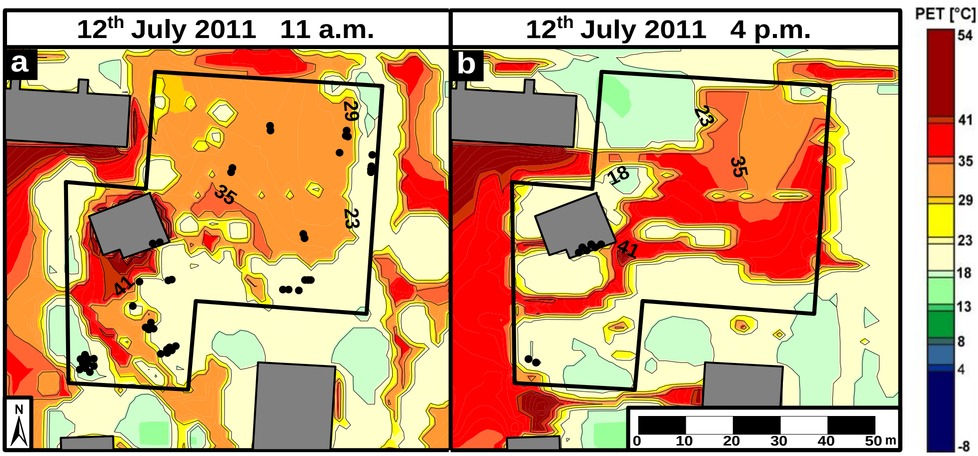

Fig. 3. *Heat stress map (PET) and spatial distribution of visitors (black markers) at 11 a.m. (a) and 4 p.m. (b), 12th July 2011*

places exposed to the sunlight compared to the forenoon. Besides the direct radiation, it might be related to the strong radiation from the heated surface. The most unpleasant conditions corresponding to warm to hot thermal sensations (29–41 °C PET) were in the sunny middle and eastern part of the area. Similarly to the situation at 11 a.m., comfortable conditions prevail in the southern shaded area. However, due to the altered shading conditions of the trees the thermal sensation around the playhouse became also comfortable. The attendance followed the spatial pattern of the thermal conditions, i.e. people were not exposed to the direct sunlight at all. Nevertheless, there were fewer people in the playground at this time compared to forenoon. The more stressful thermal load and as a consequence the increasing number of sun-heated toys may play a role in this phenomenon.

The selected autumn day can be characterized with lower thermal load (Fig. 4). At this time, cold stress also appeared in large areas. In the forenoon (Fig. 4a), similar to the summer day, warm load prevails primarily in the north and near to the house, more precisely on the western side of it in this case (corresponding to warm to hot conditions with 29–41 °C PET). In these places practically nothing protects the people from the direct radiation. Due to the lower elevation of the sun in autumn greater parts of the area are shaded by the southern vegetation and the buildings. The PET values decreased there below 13 °C which means already cool conditions (moderate cold stress). One can therefore conclude that areas with comfortable conditions are negligible, thus people could choose only thermal stress places. Most people favoured the shady, cold conditions (Fig. 4a) which can be considered to be a real human reaction in autumn, after a hot summer period. However, several children enjoyed their time on a jungle gym exposed to the direct sunlight evolving moderate heat stress (29–35 °C PET).

In the late afternoon of the autumn day (Fig. 4b), cool and cold thermal sensations (below 13 °C PET) occured in the largest part of the area because direct

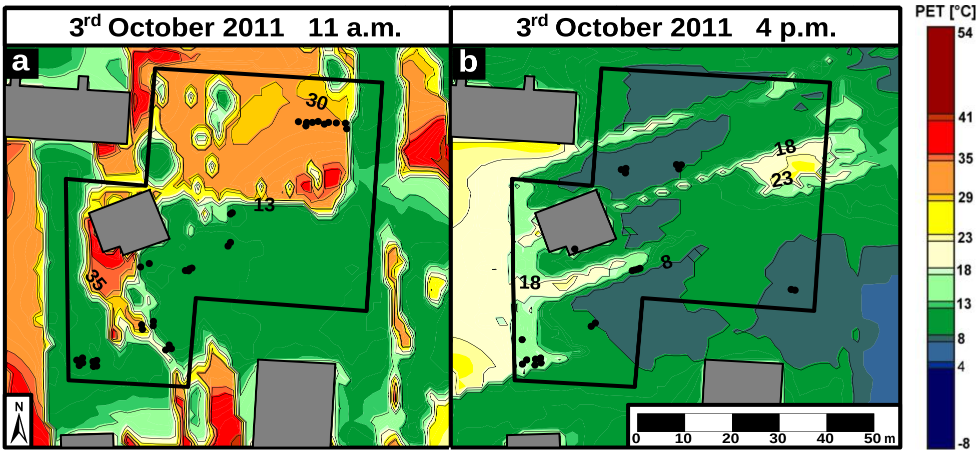

Fig. 4. ***Heat stress map (PET) and spatial distribution of visitors (black markers) at 11 a.m. (a) and 4 p.m. (b), 3rd October 2011***

sunlight is no longer reached the ground. The number of people was much lower at this time and their distribution did not follow strictly that of the thermal conditions.

3.2. Subjective evaluation of the visitors related to the design of the playground

As mentioned above, onsite questionnaire survey was conducted in the summer of 2011 and 2012 and the autumn of 2011. The responses are fairly well representative for the population regularly visiting the playground. Now the subjective evaluation of the visitors pertaining to the design of the area is analyzed in detail. At first, general satisfaction with the area was surveyed by a seven-point semantic differential scale (–3 very unpleasant to +3 very pleasant) (Fig. 5). Vast majority of the votes correspond to the 'pleasant' categories (94.6% in summer and 96.4% in autumn, respectively), moreover more than two-thirds of the respondents were fully satisfied (74.3% and 68.4%).

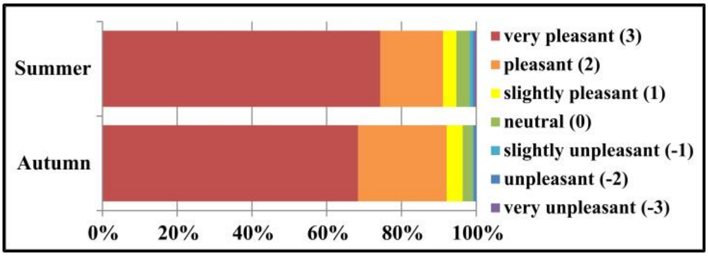

Fig. 5. ***The percentage distribution of the general satisfaction with the playground***

In order to assess the underlying causes of these judgments of the people, opinions provided by the visitors about the area design were also explored (Fig. 6). The differences between the seasons are small. As a positive factor, most people pointed out the diversity and high quality of the toys and the closure and security of the playground. Many of the people found the park to be clean and well-equipped. The size of the area, the amount of shady places and the existence of the playhouse were also mentioned a few times (Fig. 6a). The high level of satisfaction is reflected by the fact that 58.3% (in summer) and 57.1% (in autumn) of the interviewees did not mention any problem. However, absence or small amount of shade was stressed out by several people (18.7% and 16.9%, respectively). As a negative factor, a few people pointed out the type of the dominant land cover (gravel instead of grass) and the absence of (drinking) fountain or pool (Fig. 6b).

The mentioned dissatifactions confirm the importance of creating more pleasant thermal conditions in the area. To facilitate this process, finally the possible modification requirements in the area were surveyed. In accordance with the overall satisfaction and the few deficiencies found, about 60% of the people would not change anything in the design in both seasons and only a few percent of them would modify it significantly (not shown). The most frequently marked

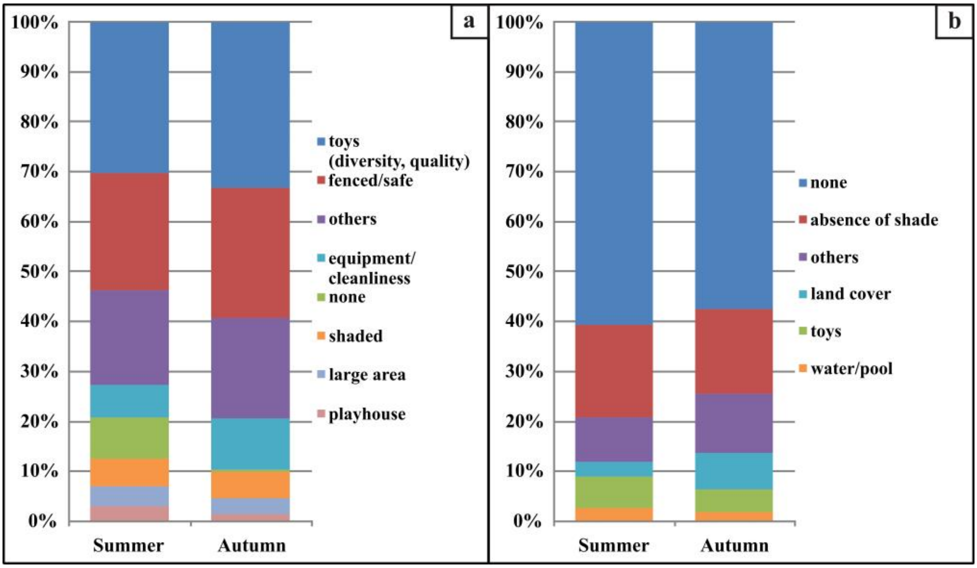

Fig. 6. ***Preferences (a) and deficiencies (b) according to the judgments of the respondents (a person could mention more than one assessment)***

responses reflecting the main deficiency (Fig. 6b) are concerned with mainly human thermal aspects, i.e. plant trees and construct shade structures (Fig. 7). It reflects that most people would prefer shady conditions in both seasons. The shade structures would be more desired in summer probably due to the intense heat load. However, more plants are desired in autumn which may have primarily aesthetic facet because of the decline of vegetation. Further important demands are change in land cover (grass instead of gravel) and placement of fountain which have aesthetic and also thermal aspects.

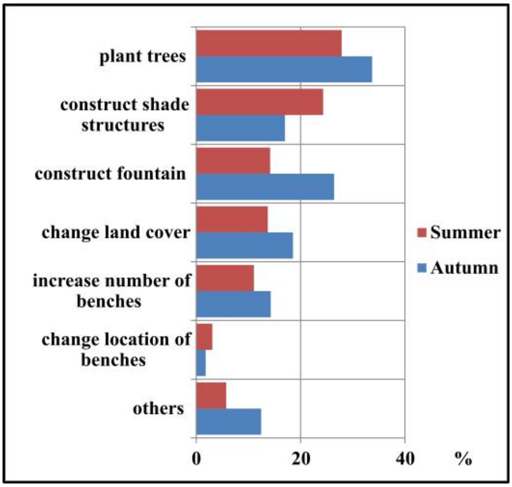

Fig. 7. ***The modification demands of the respondents (a person could mark more factors)***

4. CONCLUSION

The study investigated the changes of the thermal conditions between different seasons and times in a popular playground based on simulations of the bioclimatological conditions. The resulting human reactions of the visitors were also analyzed according to their momentary spatial patterns and subjective evaluation related to the design of the area.

According to the simulated thermal conditions, remarkable differences were found depending on the position of the sun and the resulting shady conditions of the vegetation and buildings. Besides the direct sunlight, the radiation of the heated surfaces could greatly contribute to the thermal stress conditions.

As regards the spatial distribution of the visitors, it seems to be highly influenced by the patterns of the thermal conditions. Furthermore, the location and the preference of the playground toys also have significant impact on it in both seasons which increases the probability of exposure to thermal stress. In order to decrease the unpleasant effects of heat load artifical and temporary shade structures and vegetation should be placed especially in the middle of the playground. This is clearly reflected in the demands of the visitors according to the questionnaire surveys and can contribute to the development of comfortable thermal conditions.

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