ACTA CLIMATOLOGICA ET CHOROLOGICA
Universitatis Szegediensis, Tomus 44-45, 2011, 73-81

AREA USAGE OF TWO OUTDOOR PUBLIC PLACES WITH REGARD TO THE THERMAL CONDITIONS − OBSERVATION-BASED HUMAN THERMAL COMFORT STUDY IN THE CENTRE OF SZEGED

L ÉGERHÁZI and N KÁNTOR

Department of Climatology and Landscape Ecology, University of Szeged, P.O.Box 653, 6701 Szeged, Hungary
E-mail: egerhazi@geo.u-szeged.hu

Summary: The long-term observations of urban public parks and other green places provide useful information to estimate the impacts of the climatic and other factors on the area usage as well as on the thermal sensation of the people. This paper presents a thermal comfort investigation carried out in two squares located in the city centre of Szeged (Hungary). The survey which consisted of three study periods (three times 5 weeks in transient seasons) applied a complex methodology: the subjective approach included the investigation of the human attitude and the objective method was based on the measurement of the microclimatic parameters. The thermal conditions were quantified by one of the most popular human comfort index, Physiologically Equivalent Temperature (PET), calculated by the bioclimate model RayMan from measured meteorological parameters. The results confirm that actual thermal conditions have an effect on the attendance of the public places: the utilization of the squares increases with higher PET values, although exposure to the sun becomes lower with warmer conditions. The experienced tendencies draw attention to the importance of the detailed analyses of thermal comfort conditions in urban outdoor places.

Key words: city squares, area usage, Physiologically Equivalent Temperature (PET), behavioural adaptation

1. INTRODUCTION

Due to a rapidly growing global population more and more people need to live and work in cities. Therefore, the question of urban thermal comfort, i.e. which thermal conditions are the most comfortable and enjoyable in urban environments, becomes of even higher importance. The increasing number of cities transform the natural areas, and inhabitants unavoidably become subjects of the strain of the new environment such as noise, air pollution, accelerated lifestyle and last but not least thermal stress (Unger 1999). Since the ’green islands’ in settlements have significant positive effects on life quality, the role of human comfort investigations in these places grows permanently. These public areas provide not only an aesthetical and pleasant environment for the citizens, but also increase the duration of their outdoor activities (Nikolopoulou et al. 2001, 2003, Thorsson et al. 2004).

A relationship can be detected between the utilization of open public places and the thermo-physiologically comfortable microclimate offered by them (Mayer 2008). Therefore it should be a very important part of city planning and development to take into account the well-being of people in urban areas. This task assumes bioclimatological approaches, i.e. the analysis of cities from a physiological point of view (Jendritzky 1993).

The presented investigations were carried out in Szeged, where extensive urban climate and human thermal comfort research has been conducted for several years (Unger at al. 2001, Gulyás et al. 2006, Unger 2006, Kántor et al. 2007) In this study, the relationship between a bioclimatic comfort index, PET (physiologically equivalent temperature) and the (relative) attendance of two local open public places (Ady square and Honvéd square) is presented. PET was calculated by a bioclimate model (RayMan) using objective meteorological parameters (air temperature, air humidity, wind velocity, and global radiation) to evaluate the thermal stress affecting the human body. In addition, the behavioural adaptation of people in accordance with the thermal comfort conditions was also examined.

2. MATERIAL AND METHODS

2.1. Study areas

The two investigated squares are located in a Central-European city, Szeged (Southeast Hungary, 46°N, 20°E), situated at 75-85 m above sea level, having a population of 160,000 and an administration district of 281 km^2. The city belongs to the climatic region C*f* according to Köppen's classification (temperature warm climate with uniform annual distribution of precipitation) or to the climatic region D.*1* according to Trewartha's classification (continental climate with a long warm season) (Péczely 1979).

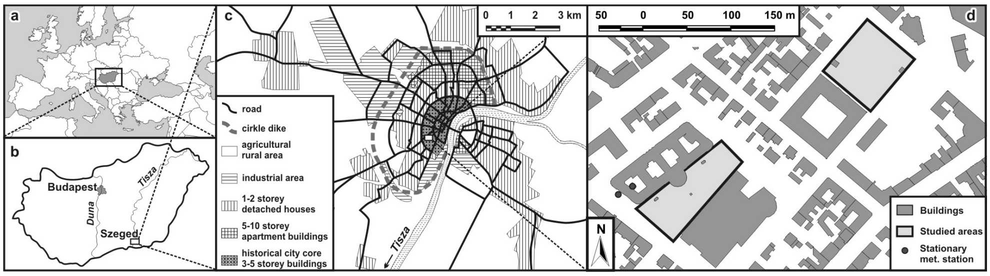

Fig. 1 Geographical location of Hungary and Szeged (a, b); detailed map of Szeged (c); locations of the investigation areas and the automatic stations (d)

The two public squares investigated, namely Ady square and Honvéd square, are located in the centre of Szeged. These squares are close to each other and to an automatic station providing meteorological data for the research (Fig. 1).

Ady square is situated between a congress centre (József Attila Information Centre) and the building of the University, two complexes mostly attended by university students. Thereby in the warmer periods of the academic year (spring and autumn), these students form the largest group of the visitors of Ady square (Kántor and Unger 2010). The area of Ady square is about 5500 m^2, almost entirely covered by grass. A small paved pathway runs across the large grassy sector, along which a few 4-5 m tall trees have been planted. These trees provide only scanty shade in the vegetation period. The large grassy sector is belted by a morphological step hence the centre surface of the square is located about 1 m lower than the ambient areas. The northwestern side of the park is bordered by a group of about 20-30 m tall trees providing shading to this area, and causing a quite different microclimate here. 10 benches offer seating places for the visitors: 8 of them are situated along the pathway, and 2 benches are on the northeastern and southwestern ends of the large grassy sector.

The second investigated public area, named Honvéd square, is slightly greater and has an area of 6000 m^2 (Fig. 1). The main reason people visit Honvéd square is the playground equipment installed in the middle of the square. Therefore the age of the visitors of Honvéd square shows larger variety than that of the visitors of Ady square, since the latter is mostly attended by students in their twenties. The shading conditions of Honvéd square are also appreciably diffent from that of the first area due to the numerous old trees offering shadow and penumbra to almost the whole park (Fig 2).

Fig. 2 Photographs of the two investigated areas: small parks in (a) Ady square and (b) Honvéd square

2.2. Methods

The examinations were carried out in three study periods to get an overall picture of the bioclimatological conditions during transient seasons. These periods were: spring of 2008 and 2009 (from the second week of April to the middle of May) and autumn 2009 (between 8 September and 8 October) (Table 1).

To estimate the area usage of the squares as a function of thermal comfort and bioclimatological features environmental and human monitoring are required (Nikolopoulou and Steemers 2003, Thorsson et al. 2004). The environmental monitoring i.e the objective approach used in our studies is based on human thermal comfort index calculation from a set of meteorological variables measured at regular intervals. As a subjective method, human attitude was observed in the afternoon hours (12–3 p.m.) each Thuesday, Wednesday and Thursday within the frame of a 5-week long systematic study in every period.

2.2.1. Objective method – Environmental monitoring

As an objective measure of thermal comfort sensation, a widely used biometeorological index, PET (Physiologically Equivalent Temperature) was selected (Mayer and Höppe 1987). PET is a popular index, which describes the thermal conditions in a physiologically relevant manner, and it is able to indicate the thermal stress of the body in a widely known unit (°C). PET is defined as the air temperature at which the heat budget of the human body in a typical indoor setting is balanced with the same core and skin temperature as under the actual, complex outdoor conditions to be assessed (Höppe 1999). This index provides an assessment of the thermal environment by values according to a comfort scale where PET values around 20°C correspond to neutral, comfortable thermal conditions. PET values higher than 23°C and lower than 18°C indicate increasing probability of thermal discomfort as well as physiological stress due to hot and cold conditions, respectively (Höppe 1999, Matzarakis et al. 1999) (Fig. 3).

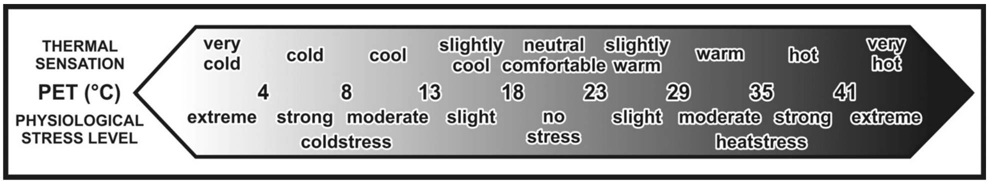

Fig. 3 PET scale for various thermal sensation and stress levels (according to Matzarakis et al. 1999)

As a first step to calculate the PET index, the 10-minute values of air temperature, relative humidity, wind velocity, and global radiation were recorded by a QLC 50 type automatic climate station. The air temperature and the relative humidity values were observed in a Stevenson screen at street level near the university building, while wind velocity and global radiation were measured on the roof of the university building near the green areas (Figs. 1 and 4). The measured wind speed data were transformed to the reference height of 1.1 m with the help of a special formula according to Matzarakis et al. (2009), but the measured global radiation data were applied without reduction. Using these measured parameters as input, the PET comfort index was calculated by means of a radiation and bioclimate model, RayMan, developed according to the guideline 3787 of the German Engineering Society (VDI 1998, Gulyás et al. 2006). The calculated PET values refer to a standard person (1.75 m, 75 kg, 35 year-old standing male) who stays in the sun.

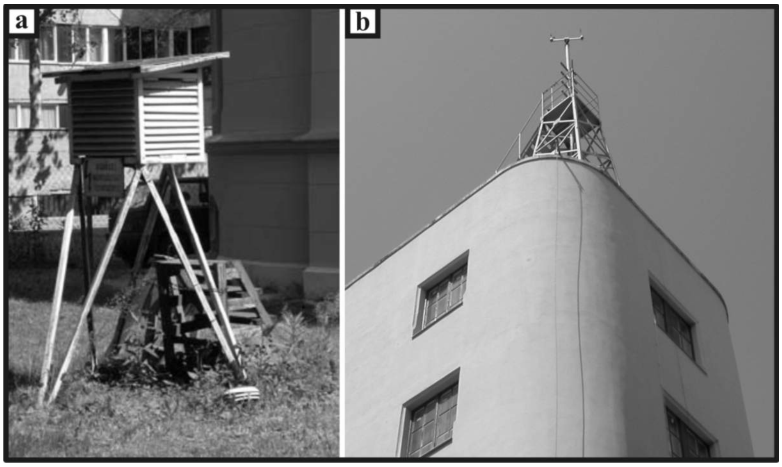

Fig. 4 Parts of the automatic station: the Stevenson screen (a) at the street level and (b) on the roof of the university building

2.2.2. Subjective method – Human monitoring

In the frame of the subjective method, the visitors' area usage and their individual features were observed in the two public places. The Ady-square survey began one year earlier resulting in data obtained from three study periods, while data for Honvéd square are available only from the past two periods (Table 1).

Table 1 The outdoor study periods of the two green areas

Study area	**Human monitoring**			
	Momentary attendance		**Cumulative attendance**	
Ady Square	spring 2008 spring 2009 autumn 2009	13 + 14 + 14 days	spring 2008 spring 2009 autumn 2009	14 + 14 + 14 days
Honvéd square	spring 2009 autumn 2009	15 + 15 days	spring 2009 autumn 2009	15 + 15 days

Human monitoring consisted of observing the attendance momentarily and cumulatively in given time-intervals between 12 and 3 p.m. Momentary attendance was derived from counting people hanging around in the studied parks in every 10 minutes. In Ady square the visitors were registered according to their solar exposure, namely whether they stayed in the sun, in penumbra or in shade. In the case of the other green area, the people were counted according to their activity-type as passive (standing, sitting, lying) or active (playing, walking around).

In the frame of the cumulative measurements, the location and some personal features of the visitors were also recorded (Table 2). The cumulative measurements were carried out in 30-minutes intervals (i.e. 6 times per days) in Ady square and in 15-minutes intervals (i.e. 12 times per days) in Honvéd squre.

Table 2 Observed parameters during the outdoor thermal comfort research

	Ady square		**Honvéd square**	
Momentary attendance	*every 10 minutes* according to **exposure** (sun / penumbra / shade)		*every 10 minutes* according to **activity** (active / passive)	
Cumulative attendance	*in 30-minutes intervals*		*in 15-minutes intervals*	
	location	(marked on a map with ID number)	**location**	(number of a bench)
	gender	(male / female)	**gender**	(male / female)
	age-group	(child / young / middle aged / old)	**age-group**	(child / young / middle aged / old)
	clothing	(<0.45 clo / 0.45-0.9 clo / 0.9 clo<)	**clothing**	(<0.45 clo / 0.45-0.9 clo / 0.9 clo<)
	activity	(active / passive)		
	exposure	(sun / penumbra / shade)	(only visitors sitting on benches)	

In Ady square, the locations of the people staying at least five minutes long were marked by means of ID numbers on the map of this area. An own map and an associated table belonged to each half-hour interval on each day in the monitoring periods. The table contained the registered individuals' gender, age-category (determined by the look), description of clothing, type of activity and solar exposure (if the presence of direct solar radiation allowed distinguishing sunny, semi-shady and shady sites). In thermal comfort studies, the insulation value of clothing is measured with the 'clo-units', where 1 clo (= 0.155 m^2KW^{-1}) corresponds to a person wearing a typical business suit and 0 clo means a naked body. Since the observations were carried out in transient seasons, the following three clo-categories were distinguished based on the registered clothing elements: (1) under 0.45 clo e.g. short and T-shirt, (2) 0.45-0.9 clo e.g. trousers and light pullover and (3) above 0.9 clo e.g. additional jacket or thick vest.

As the presented "cumulative-observation" method can cope only with "resting place conditions" and mainly sedentary visitors, in the case of Honvéd square we ignored the crowds of children milling in the playground and registered only the visitors sitting on benches. The locations of these subjects were not marked on a map, but the table of personal characteristics contained a plus item to describe the bench-number where the individuals were seated. Overall the observation periods, 6775 and 5668 visitors' data were collected in Ady square and Honvéd square, respectively.

3. RESULTS AND DISCUSSION

3.1. Momentary attendance

In the first part of the analysis the momentary attendances were examined as the function of the measured air temperature (T_a) and the calculated PET values (Fig. 5). Fig. 5 clearly shows that in the case of low air temperature and PET values, the momentary attendance approximated zero, while the number of visitors increased with warming conditions. Quadratic functions were fitted on the datasets, which in Ady square indicate a stronger correlation between attendance and PET values (R^2 = 0.36) than with T_a (R^2 = 0.32). Contrary to this, in Honvéd square the coefficient of determination R^2 is larger for T_a (R^2 = 0.18) than for PET (R^2 = 0.12). The maxima of the fitted functions for Honvéd square can be found in the examined T_a and PET domains (Fig. 5b). However, according to the fitted curves for Ady square, the maximum number of visitors may be expected under very hot conditions (Fig. 5a).

Fig. 6 shows that the PET values influenced the physical adaptation, i.e. the preference for sunny or shady position (Ady-square survey), as well as the activity-type of the visitors (Honvéd-square survey). This process confirms the fundamental behavioural changes, which can be observed during an increasing thermal load (Thorsson et al. 2004). Namely, with rising PET values, the visitors increasingly prefer the outdoor places in shadow as well as passive behaviour.

However, in Ady square there were several occasions when despite the hot conditions (PET > 35°C) a relatively large percentage of the subjects lingered in the sun (more than 50%, Fig. 6a). This can be explained by the fact that after a long cold winter season people enjoy staying outdoors; therefore in springtime they can bear a higher level of thermal stress than in autumn. In the spring of 2008 and 2009, a larger percentage of the visitors stayed in the sunny parts of the green areas (despite PET values above 36°C) than in the autumn study period (Fig. 6a).

The ratio of the active subjects as the function of PET values decreased also in the other square due to the smaller utilization of the square in the cooler thermal conditions (Fig. 6b). Although the correlation is significant at 1% level, the coefficient of determination R^2 is relatively small (R^2 = 0.0538) indicating that this decreasing tendency is not so obvious.

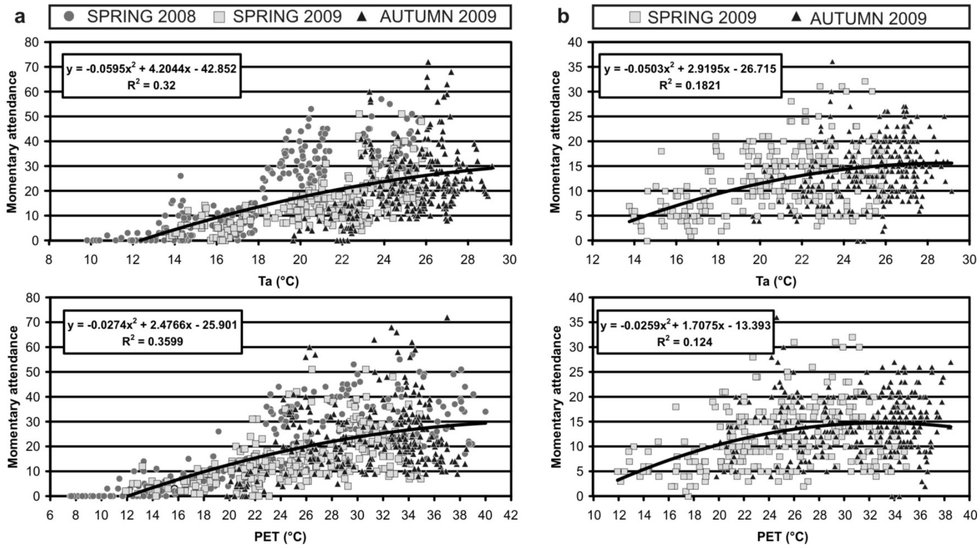

Fig. 5 Momentary attendance of Ady square (a) and Honvéd square (b) as a function of air temperature (T_a) and PET

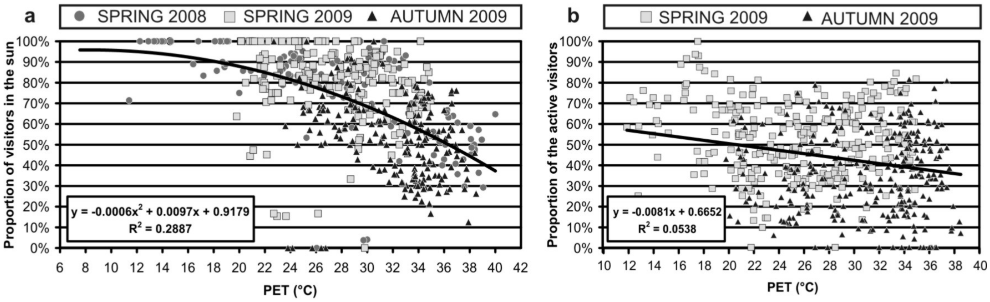

Fig. 6 Percentage of the visitors being in the sun in Ady square (a) and the percentage of the active visitors in Honvéd square (b) as the function of PET

3.2. Cumulative attendance

The distribution according to gender indicates that significantly more females (Ady: 65.3%, Honvéd: 59.7%) attended these public places than males (Ady: 34.7%, Honvéd: 40.3%) in the examined periods. Another observation was that passive (standing, sitting, lying) behaviour was more dominant, especially in Ady square. In case of both green areas, the large majority of the visitors belonged to the 'young' age group (students in their twenties), which can be explained by the educational buildings nearby. However, it should be emphasized that if each visitor had been observed in Honvéd square (and not only sedentary people on the benches), the ratio of actively and passively behaving people would be probably higher.

In this study, from the results of the cumulative analysis only the percentages of the clo-categories as a function of PET values will be presented. According to Fig. 7 an increasing portion of visitors wore ligther clothings with higher PET values in both public places.

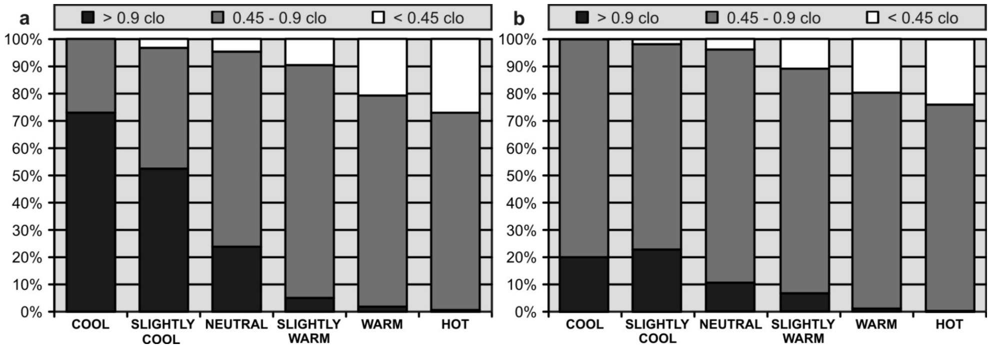

Fig. 7 Percentages of clo-categories as a function of the thermal conditions (based on the PET values) in Ady (a) and Honvéd (b) square

The relationship between the PET values and the clothing insulation is statistically significant and the Spearmen's rho rank-correlation coefficient (ρ) indicates a bit stronger link in the case of the Honvéd square (Ady square ρ = -0.388, Honvéd square: ρ = -0.450). However, if air temperature (T_a) values are examined as predictor variable (instead of PET), the statistical relationship is somewhat stronger (Ady square: ρ = -0.402, Honvéd square: ρ = -0.485). This can be explained by the fact that in everyday life the selection of clothes is based on rather the information on air temperature than PET.

4. CONCLUSIONS

The paper presented some selected results of a long-term (3 study periods) research project carried out in two public places (Ady square and Honvéd square) in the city centre of Szeged (Hungary). The study investigated the usage of the mentioned green areas under various thermal conditions by means of human and environmental observations. From measured meteorological parameters a popular human bioclimatological comfort index, PET, was calculated in order to characterize the thermal conditions.

The obtained results of our observations confirmed the dependence of the attendance of outdoor places on the thermal conditions. It is prominent that the preference of the outdoor places generally increases with warming thermal conditions and in many cases the visitors tolerate a higher level of the thermal stress. This tendency, namely the toleration of unconvenient thermal conditions, is a good example of the mechanism of behavioural adaptation. The quantitative analysis revealed that a higher percentage of the visitors was exposed to the Sun in spring than in autumn, because people apparently desire warmer thermal conditions after the cold wintertime. In addition, the results clearly show that the generally dominant passive behaviour (lower activity level) becomes more frequent with increasing PET values, and visitors wear lighter clothes in warmer weather conditions.

The main objective of the present study was to give a hand, furthermore provide useful information for city planning and development in the processes of the design of public places in order to develop a comfortable environment and an attraction of these public places to increase their attendance.

Acknowledgements: The study was supported by the Hungarian Scientific Research Fund (OTKA K-67626) and by the „TÁMOP-4.2.1/B-09/1/KONV-2010-0005 – Creating the Center of Excellence at the University of Szeged". The authors' special thank to Eszter Tanács for the language revision of the manuscript.

REFERENCES

Gulyás Á, Unger J, Matzarakis A (2006) Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements. Build Environ 41:1713-1722

Höppe P (1999) The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. Int J Biometeorol 43:71-75

Jendritzky G (1993) The atmospheric environment – an introduction. Experientia 49:733-740

Kántor N, Unger J (2010) Benefits and opportunities of adopting GIS in thermal comfort studies in resting places: An urban park as an example. Landscape Urban Plan 98:36-46

Kántor N, Unger J, Gulyás Á (2007) Human bioclimatological evaluation with objective and subjective approaches on the thermal conditions of a square in the centre of Szeged. Acta Climatol et Chorol Univ Szegediensis 40-41:47-58

Matzarakis A, Mayer H, Iziomon M (1999) Applications of a universal thermal index: physiological equivalent temperature. Int J Biometeorol 43:76-84

Matzarakis A, De Rocco M, Najjar G (2009) Thermal bioclimate in Strasbourg - the 2003 heat wave. Theor Appl Climatol 98:209-220

Mayer H (2008) KLIMES – a joint research project on human thermal comfort in cities. Ber Meteorol Inst Univ Freiburg 17:101-117

Mayer H, Höppe P (1987) Thermal comfort of man in different urban environments. Theor Appl Climatol 38:43-49

Nikolopoulou M, Steemers K (2003) Thermal comfort and psychological adaptation as a guide for designing urban places. Energy Build 35:95-101

Nikolopoulou M, Baker N, Steemers K (2001) Thermal comfort in outdoor urban spacers; understanding the human parameter. Sol Energy 70:227-235

Péczely Gy (1979) Éghajlattan. [Climatology. (in Hungarian)] Nemzeti Tankönyvkiadó, Budapest

Thorsson S, Lindqvist M, Lindqvist S (2004) Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. Int J Biometeorol 48:149-156

Unger J (1999) Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city. Int J Biometeorol 43:139-144

Unger J (2006) Modelling of the annual mean maximum urban heat island with the application of 2 and 3D surface parameters. Climate Res 30:215-226

Unger J, Sümeghy Z, Zoboki J (2001) Temperature cross-section features in an urban area. Atmos Res 58:117-127

VDI (1998) VDI guideline 3787, Part 1: Environmental Meteorology, Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning. Beuth, Berlin. 29