127: Bio-thermal conditions of some housing estates in Warsaw

Krzysztof Błażejczyk* [1, 2], Katarzyna Lindner-Cendrowska* [2], Magdalena Kuchcik [1], Jarosław Baranowski [1], Jakub Szmyd [1], Paweł Milewski [1]

[1] *Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsaw, Poland*

[2] *Department of Climatology, Faculty of Geography and Regional Studies, University of Warsaw, Warsaw, Poland*
**k.blaz@twarda.pan.pl, *klindner@uw.edu.pl*

Abstract

The majority of Polish population lives in urbanized areas. Polish cities are under great pressure of planning new residential districts. Developers, architects and landscape architects propose not only new technical solutions but also a new philosophy of organization of space. The modern citied should be friendlier and less stressed for citizens. Residential areas should also create optimal conditions for daily outdoor recreation for elderly people and children. The aim of the present paper is to discuss how some architectural solutions used in selected housing estates in Warsaw modify bio-thermal conditions in micro scale.

Key words: urban bioclimate, Warsaw, housing estates,

1. Introduction

The majority of Polish population lives in urbanized areas. Polish cities are under great pressure of planning new residential districts. Developers, architects and landscape architects propose not only new technical solutions but also a new philosophy of organization of space. The general idea of urban planners is to make cities friendlier and less stressed. Residential areas should also create optimal conditions for daily outdoor recreation for elderly people and children.

Planning of ideal city and housing estate is very complicated and multi-level process. Planners and architects should take into consideration different factors: economical, organizational, historical, social, environmental and others. Very specific is creation of optimal microclimatic and bio-thermal conditions. It can be obtained by rational use of existing components environment of (e.g. relief, natural vegetation, hydrology, city surroundings). In micro scale the attention should be paid for building size and orientation, the structure of trees and green carpets as well as small forms of architecture.

Warsaw is a city with an area of about 500 km^2 and with significant differentiation of land use. About 243 km^2 is a built-up area (28% no-dense and 22% dense settlements). Forests cover about 13% of city area. 85 km^2 is used as meadows and fields. Relatively great area (about 60 km^2, i.e. 12%) is covered by transport system (roads and railways).

When analysing thermal LANDSAT image we have found coefficients reducing air temperature (*TR*) for various types of land use in Warsaw. They changed from 0.85 for water bodies (river, lakes, ponds) up to 1.2 in dense settlements and industrial areas (Table 1). Spatial distribution of relative values of air temperature, derived from LANDSAT image, is presented on figure 1.

Table 1. Coefficient reducing air temperature (*TR*) for selected types of land use in Warsaw

Land use	*TR*
Settlement:	
dense	1.20
no-dense	1.15
villa	1.10
Plant cover:	
forests coniferous	0.95
forests mixed	0.90
parks	0.95
gardens	1.05
meadows	1.00

Source: Blazejczyk and Blazejczyk, 1999

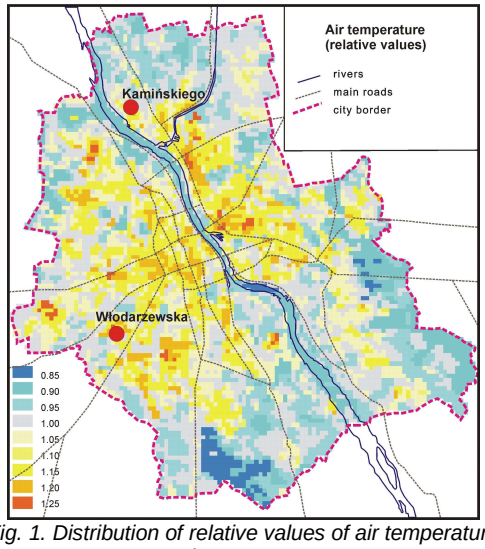

Fig. 1. Distribution of relative values of air temperature in Warsaw;
studied housing estates indicated by red circles
Source: Kozłowska-Szczęsna et al., 1996

The previous research show general overview of bio-thermal conditions in Warsaw defined by Universal Thermal Climate Index (*UTCI*), [2]. At

moderate temperature (20ºC) moderate heat stress (*UTCI* of 26-32ºC) can be found only inside industrial and very dense settlement areas. However, during sunny, hot, humid and calm weather several hot spells with extreme heat stress are found, especially in the city centre. In housing estates located at peripheral parts of the city bio-thermal conditions are relatively mild.

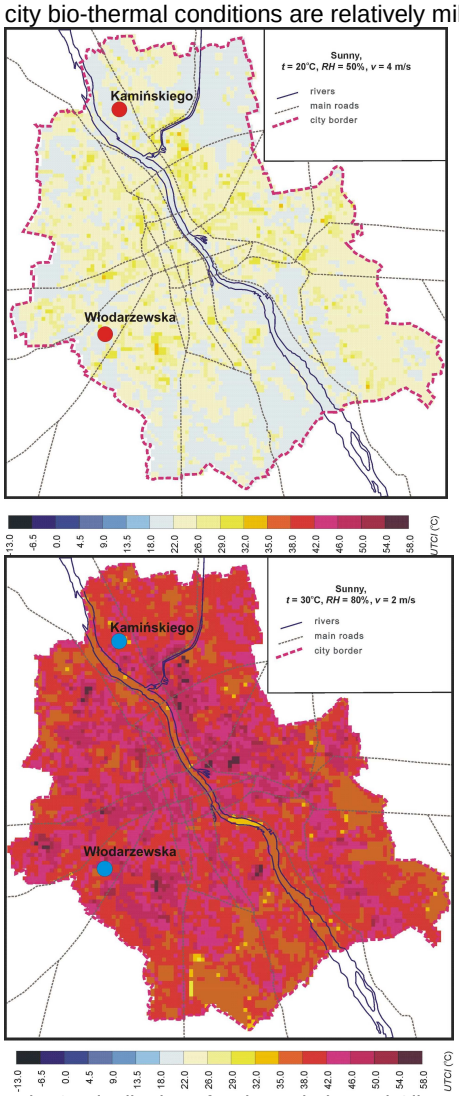

Fig. 2. Distribution of Universal Thermal Climate Index (UTCI) in Warsaw in selected weather conditions Source: Błażejczyk 2011

2. The aim

The aim of the present paper is to discuss how some architectural solutions used in selected housing estates in Warsaw modify bio-thermal conditions in micro scale. The attention is paid for evaluation how particular urban spaces influence people's physiological reactions and their well being.

3. Materials and methods

The materials used in the studies consist of two data sets: micro meteorological and environmental. Two housing estates were examined: Włodarzewska and Kamińskiego (Fig. 1).

Micro meteorological measurements have two time perspectives. The first one was long-term meteorological observations. In this purpose in each studied estates the HOBO Pro data loggers were installed in representative spatial organization site (so called base data). Air temperature and humidity were collected every 10-minutes 1.5 m above ground, over the grass.

To recognize spatial distribution of bio-thermal conditions special route measurements inside the quarters were made on chosen days of summer 2009. Measurements were carried with HOBO loggers in 6-12 posts over different surfaces and in different urban structures in each estate. The observers measured also wind speed and they noted their thermal sensation and cloud cover.

As environmental indicators we have used detailed inventory data regarded vegetation (type, height), buildings heights and orientation as well as surface cover. Created data base has been used for statistical calculations and spatial analyses relevant for ratio of biologically vital areas (RBVA) and green plot ratio (GPR) for each housing estate. RBVA is the index comprises the area of lawns, flowerbeds, hedgerows, tops of the trees as well as ground surfaces. GPR, however is based on leaf area index (LAI), which is defined as the single-side leaf area per unit ground area.

4. Results

In the present paper bio-thermal conditions in two housing estates: Kamińskiego and Włodarzewska are discussed (Fig. 1).

Fig. 3. Schematic map of Kamińskiego housing estate in Warsaw

Kamińskiego estate

The estate is located on NE suburbs of Warsaw next to the open, green area. The C-shaped, mostly 4-floors blocks of flats form some kind of courtyards of different seizes. It is fenced with openwork, metallic fencing. The RBVA is 44.5% only and GPR is very high (2.25). Parking places are organized along the fences and big parking

lot next to the estate (Fig 3). Because of the location of the housing estate close to the Vistula river bank thermal and bio-thermal conditions are in general relatively mild in comparison to the city center. However, air temperature and *UTCI* are considerably higher than on forested and open areas in the close surroundings (Fig. 1, 2).

The housing estate' structure, the mosaic of different kind of areas evenly distributed (artificial surfaces, lawns, well arranged small gardens, flowerbeds, high trees, sandy playgrounds) cause that location of the warmest or the coldest places depend mainly on insolation and its changes during the day and under different weather. The north part of the estate is under the influence of both: the outside open green and high leafy trees which are grouped mostly in that part of the estate. It chills down easily in the evening and stays cool in the morning and warm up fast in the afternoon (measure posts 8-11). In the south part of the estate little warmer than others is the lawn of south exposure (post 6). The air move inside the estate is compatible with the buildings' lay out. Due to the tunnel effect slightly higher wind speed is noted on the post 4. The highest wind velocities are noted outside the estate (measure posts 1, 2) or on its edge (11). Despite of low RBVA the estate is characterized by high participation of leafy species and quite favorable sensible climate (Fig. 4).

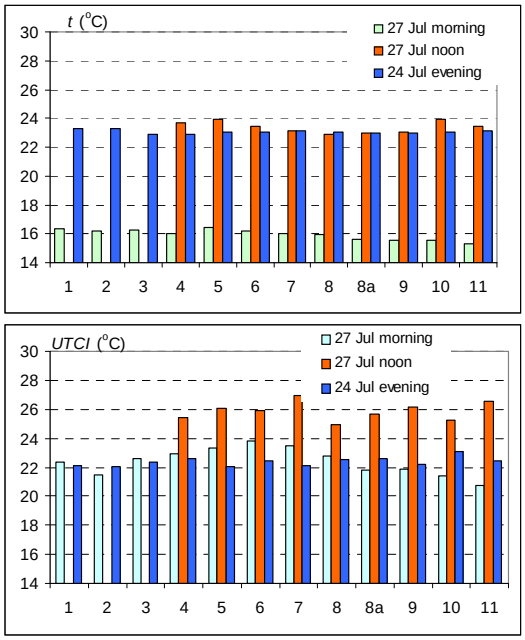

Fig. 4. Values of air temperature (t) and Universal Thermal Climate Index (UTCI) at particular measuring posts at Kamińskiego estate in Warsaw, July 2009

Włodarzewska estate

The estate is located SW from the city centre. It is surrounded by many open spaces and park, but fenced in with the wall and only open to the big, fertile meadow on SE. It is characterized by compact development, many small flowerbeds and lawns between buildings, partly organized on the top of the underground parking lot. RBVA is 40.7% and GPR is 1.28 only. The base station stayed in the shadow most of the day (Fig. 5).

Włodarzewska estate is situated at western peripheries of Warsaw. However, the distance from the city center and great residential districts is relatively small. It cause that air temperature and *UTCI* are higher than at Kamińskiego estate (Fig. 1, 2).

Fig. 5. Schematic map of Włodarzewska housing estate in Warsaw

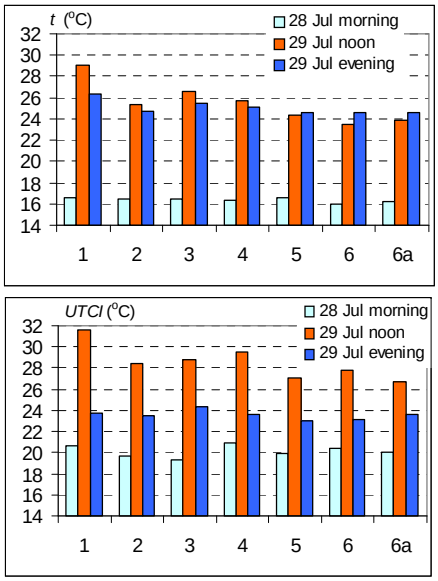

Fig. 6. Values of air temperature (t) and Universal Thermal Climate Index (UTCI) at particular measuring posts at Włodarzewska estate in Warsaw, July 2009

In the dense built area there is no evidence for the cooling effect of small green areas, especially during midday hours. Even more, the air above the small flowerbed adjacent to the building could be hotter (measure post 6) then above the concrete square (5, 6a). Because of the high brick wall fencing the estate – there is also no evidence for the cooling effect of neighboring big park. In the whole area very weak and chaotic air movement is noted. The south-east part of estate is under the influence of the fertile lawn and

residuals of meadow, which is exposed to the sun and getting warm quickly during the day and getting cold rapidly in the evening. This produces stressful bio-thermal conditions because of great heat load in the day and cold stress in the evenings (Fig. 6).

5. Conclusion

The most detail level of spatial analysis refers to individual housing estates. When comparing two studied estates we can conclude that: - the array of buildings enabled the advection of air from outside and in effect improve sensible climate; - very important is the proper maintenance of green areas: abandoned, dried lawns or only recumbent coniferous plants do not positively meliorate climate and bioclimate; - gardens next to the buildings should be sufficiently large and composed of different height leafy trees, bushes and perennials; - small flowerbeds adjacent to the buildings do not play any positive role for bio-thermal conditions; - when fencing the estates people should prefer rather openwork, metallic fencing than high brick walls which unable infiltration of the air from outside.

The results of research discussed in the paper allow to propose the following, general model of bio-thermal conditions within urbanized areas (Fig. 6). Spatial differentiation of sensible temperature is indicated for midday as well as for night hours.

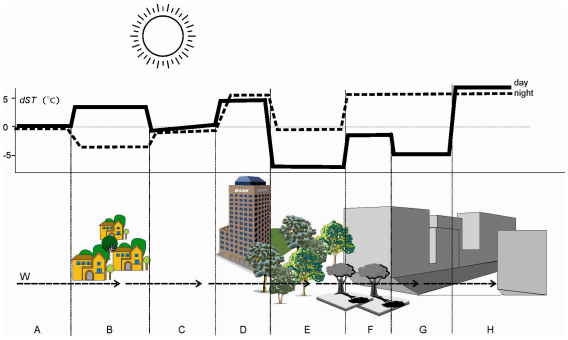

Fig. 6. The general model of bio-thermal conditions of urbanised areas; dST – relative values of sensible temperature (in comparison to rural area) during day and night hours along the profile W; A – rural area, B – suburban residential district, C – open areas inside the city, D – „block" settlements, E – park, F – trees-shaded streets, G – shaded street canyon, H – insolated street canyon Source: Blazejczyk, Kunert, 2006

6. References

1. Błażejczyk K., 2002, *Znaczenie czynników cyrkulacyjnych i lokalnych w kształtowaniu klimatu i bioklimatu aglomeracji warszawskiej* [*Influence of air circulation and local factors on climate and bioclimate of Warsaw agglomeration*]. Dokumentacja Geograficzna, 26.
2. Błażejczyk K., 2011, *Mapping of UTCI in local scale (the case of Warsaw)*, Prace i Studia Geograficzne WGSR UW, 47, p. 275-283.
3. Błażejczyk K., Błażejczyk A., 1999, *Influence of urbanisation level on the heat load in man in Warsaw*. Proc. 15th Int. Congress of Biometeorology & Int. Conf. On Urban Climatology, Sydney, Australia 8-12 Nov. 1999, eds. R.J. de Dear, J.C. Potter, Macquire University, Sydney, Australia, (CD-ROM),
4. Błażejczyk K., Kunert A., 2006, *Differentiation of bioclimatic conditions of urban areas (the case of Poland)*. [in:] 6th International Conference on Urban Climate, June12-16 2006, Göteborg, Sweden, Preprints, p. 213-216.
6. Kozłowska-Szczęsna T., Błażejczyk K., Krawczyk B., (1996), *Atlas Warszawy z.4. Środowisko fizycznogeograficzne -niektóre zagadnienia* [*Atlas of Warsaw, 4, Geographical environment – selected problems*], PAN IGiPZ.

Acknowledgments: The studies were supported by Central Europe Programme of EU in the frame of UHI project *Development and application of mitigation and adaptation strategies and measures for counteracting the global Urban Heat Islands phenomenon (UHI)*.