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AN ASSESSMENT OF CONDITIONS OF HUMAN COMFORT IN OPEN LANDSCAPED AREAS OF LODZ

OCENA KOMFORTU CZŁOWIEKA W STREFIE NIEZABUDOWANEJ ŁODZI

A b s t r a c t

The paper presents an assessment of human comfort conditions in the suburban area of Lodz. The proposed criteria for comfort were based on thermal loads on the human body. An analysis of meteorological data for a 30 year period was used to determine the probable comfort levels.

Keywords: *human comfort*, *thermal loads*, *open landscape*

S t r e s z c z e n i e

W artykule przedstawiono ocenę komfortu człowieka w środowisku niezabudowanym Łodzi. Zaproponowano kryterium komfortu oparte o progi obciążenia cieplnego organizmu. Na podstawie analizy danych meteorologicznych z okresu 30 lat określono prawdopodobieństwo wystąpienia warunków komfortu.

Słowa kluczowe: *człowieka*, *obciążenia cieplne*, *teren otwarty*

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1. Introduction

Anthropogenic factors such as air pollution, heat emission, the systematic limitation of green areas and urban development have a major impact on climate changes both at the global and urban level. The scale of the problem is reflected in the action taken by international organizations, the European Union and also individual countries. For example, in Poland the Ministry of Environment published the National Strategy for Adaptation to Climate Change in 2013 (SPA 2013) [1], which emphasized the need for the development of comfortable microclimatic conditions in cities. In order to foster such an environment, more information is required the criteria for human comfort and the prevailing climatic conditions.

Considering the problem of heat exchange between man and the environment, it is noted that the increase or loss of internal body heat is an essential factor. An excessive degree of heat gain and loss can be dangerous for the human body. An equilibrium can only be attained over a period of time (e.g. one day). Since the heat exchange balance is formed both as a result of physiological and meteorological factors, the balance may be an indicator of the thermal load on the body and an indicator of thermal sensations.

To determine whether the environment is comfortable for inhabitants, a simple criterion of comfort has to be established. This criterion must take into account the complex nature of heat exchange between man and the environment. Secondly, it is essential to determine the probability for comfortable and uncomfortable conditions based on long-term meteorological data. In the case of built up areas, the situation is more complicated due to the effect of the urban landscape and the arrangement of buildings on wind flow. This paper is limited to examining non-built-up suburban areas of Lodz.

2. Comfort and discomfort criteria based on heat loads on the body

The comfort sensation is associated with changes in body temperature caused by an increase or decrease in ambient temperature, the cooling effect of wind, the convective and the radiative heat loss from the body. There are a number of factors affecting the heat exchange between man and the external environment. The most important physical parameters include: air temperature, wind speed, solar radiation, relative humidity and radiation temperature. Equally important are the parameters related to the individual person, such as the activity, exposure time, clothing thermal insulation and finally the psychological factors associated with the level of adaptation, expectations or previous experiences. The inclusion of so many factors requires the application of complex models and detailed meteorological and physiological data, which in practice are difficult to obtain. As a result there is a need for a more simplified method of determining criteria for human comfort in open areas.

In the light of extensive research carried out in many countries [2] it can be demonstrated that there isa correlation between the intensity of heat fluxes with air temperature and wind speed, which allows approximations to be applied. In order to identify thermal criteria based on heat balance equations, some assumptions have been made:

– Metabolism M – 70 W/m^2,
– Thermal insulation of the cloths 1 clo,

– Solar radiations absorption R – 30W/m^{2,}
– Heat exchange through evaporation Q_E – 8W/m^2 for T_a < +5ºC, 20 W/m^2 for $T_a \geq$ +5ºC,
– Heat exchange through conduction Q_K is not taken into account,
– Heat loss caused by respiration Q_R – 8W/m$^{2.}$

Further more heat transfer by convection and long wave radiation, based on temperature and wind speed, are specified thus:

For weather conditions where wind speed $U \leq$ 4 m/s and temperature $T_a \geq$ +5ºC

$$Q_C + Q_L = 3.4T_a + 0.2\bar{U} - 118.8 \tag{1}$$

Where the wind speed $U \leq$ 4m/s and temperature T_a < +5ºC

$$Q_C + Q_L = 1.7T_a + 6.0\bar{U} - 101.4 \tag{2}$$

Where the wind speed U > 4 m/s and temperature $T_a \geq$ +5ºC

$$Q_C + Q_L = 3.3T_a + 0.2\bar{U} - 127.8 \tag{3}$$

Where the wind speed U > 4 m/s and temperature T_a < +5ºC

$$Q_C + Q_L = -3.31.5T_a + 0.3\bar{U} - 126 \tag{4}$$

By applying the above to the heat balance equation, thermal loads on the body were derived [3]. The parameter can be used for relative comparison of different environmental conditions.

In weather conditions where wind speed $U \leq$ 4 m/s and temperature $T_a \geq$ +5ºC

$$\Delta Q = 2.8T_a - 4.8\bar{U} - 29.8 \tag{5}$$

Where the wind speed $U \leq$ 4 m/s and temperature T_a < +5ºC

$$\Delta Q = 1.7T_a - 6.0\bar{U} - 23.0 \tag{6}$$

Where the wind speed U > 4 m/s and temperature $T_a \geq$ +5ºC

$$\Delta Q = 2.3T_a - 3.5\bar{U} - 35.4 \tag{7}$$

Where the wind speed U > 4 m/s and temperature T_a < +5ºC

$$\Delta Q = 1.5T_a - 3.0\bar{U} - 34.0 \tag{8}$$

Taking into account the efficiency ranges of the thermoregulatory systems, which are applied in thermo physiology, it is assumed that $|\Delta Q|$ < 20 W/m^2 does not trigger system loads. However, where there is deficiency and excess heat ΔQ equal to 20–40 W/m^2 then unfavourable loads will affect the body. Strong heat load can be observed when ΔQ is between 40–80 W/m^2. Higher values than the threshold value 90 W/m^2 can trigger disturbances in the proper function of the thermoregulatory system, which consequently can lead to dangerous overheating or conversely hypothermia.

Finally the criteria for thermal comfort were established based on the following thresholds for heat loads on the body ΔQ:
– $|\Delta Q|$ < 20 W/m^2 – comfortable condition,
– $|\Delta Q|$ in ranges 20–40 W/m^2 – unfavourable loads on the body,
– $|\Delta Q|$ in ranges 40–80 W/m^2 – strong unfavourable loads on the body,
– $|\Delta Q|$ > 80 W/m^2 – dangerous loads on the body.

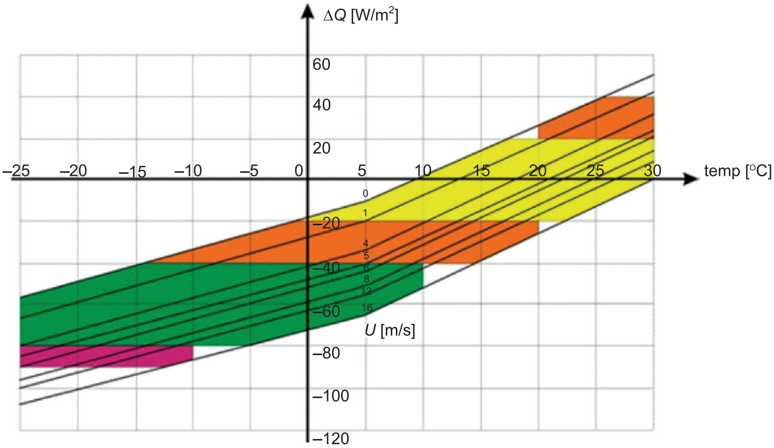

Fig. 1. Threshold values of the thermal loads on the body

Figure 1 presents the relationship between ΔQ and air temperature T_a and wind speed as well as body heat load thresholds.

The detailed analysis of body heat loads with the corresponding ranges in temperature and wind speed are presented in [3].

3. Selected meteorological data of suburban area of Lodz

In order to assess the conditions for human comfort in the selected open area of Lodz, meteorological data has been analysed based on 30 years of records and hourly mean values. As the comfort criteria relates to thermal loads on the human body, the analysis focused mainly on temperature and wind speed.

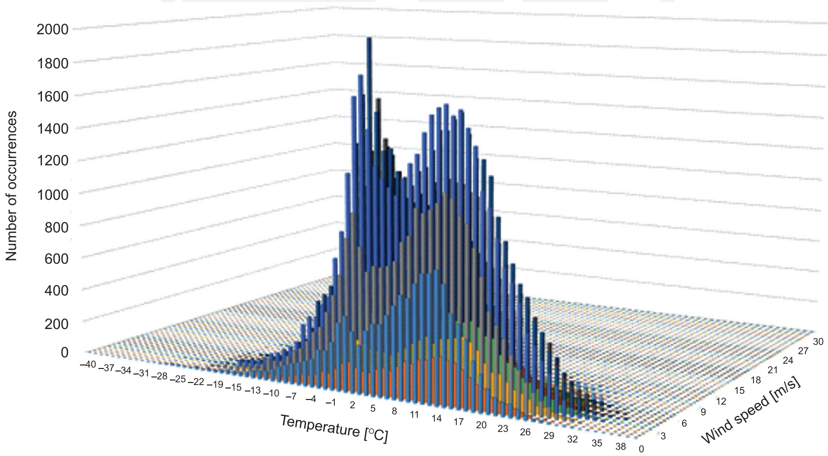

Fig. 2. Wind speed frequency and temperature in Lodz

However, other meteorological parameters such as solar radiation were also taken into account. Since the evaluation concerned comfort in non-urban developed areas, wind direction was not included in the data. Fig. 2 shows the frequency distribution of wind speed and temperature over the time period analyzed.

4. Probability of conditions of comfort and discomfort in the open landscape of Lodz

With the previously outlined assumptions taken into account, temperature and velocity combinations that satisfy the human comfort criteria can now be specified. Fig. 3 and Fig. 4 express the probability density function levels for instances of specific ranges of thermal loads, depending on wind speed and temperature respectively. In view of the fact that the velocity and temperature values which fulfill the requirement of $\Delta Q > 80$ W/m^2 are very rare occurrences (probability of occurrence $P = 0.0004$ these were not included for further consideration.

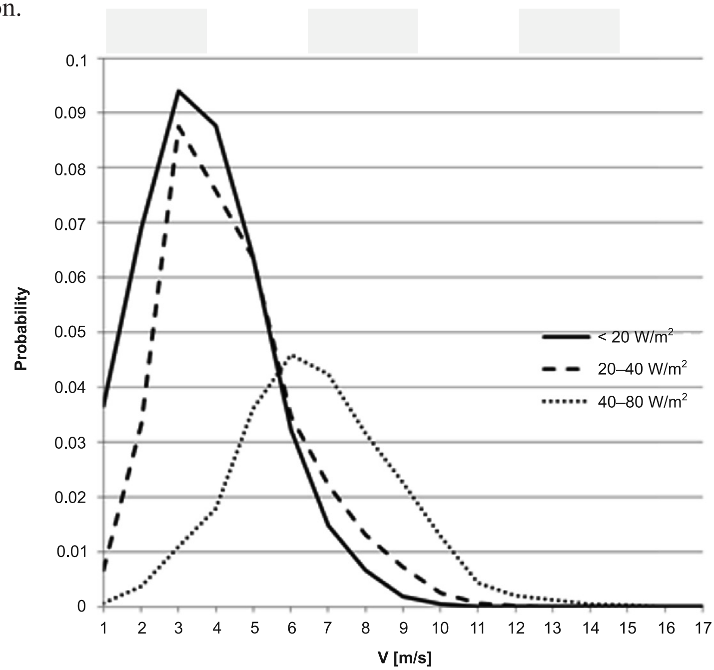

Fig. 3. Probability density function levels for the occurrence of thermal loads, depending on wind speed

Figure 5 illustrates how the wind speed and temperature ranges for comfort conditions were established. Instances where the probability of occurrence was less than 0.001 did not form part of the analysis.

As illustrated in Fig. 5, comfortable conditions ($\Delta Q < 20$ W/m^2) occur mainly when the temperature ranges between 8 and 22ºC and wind speed is up to 5m/s. Such conditions correspond to probability $P = 0.37$.

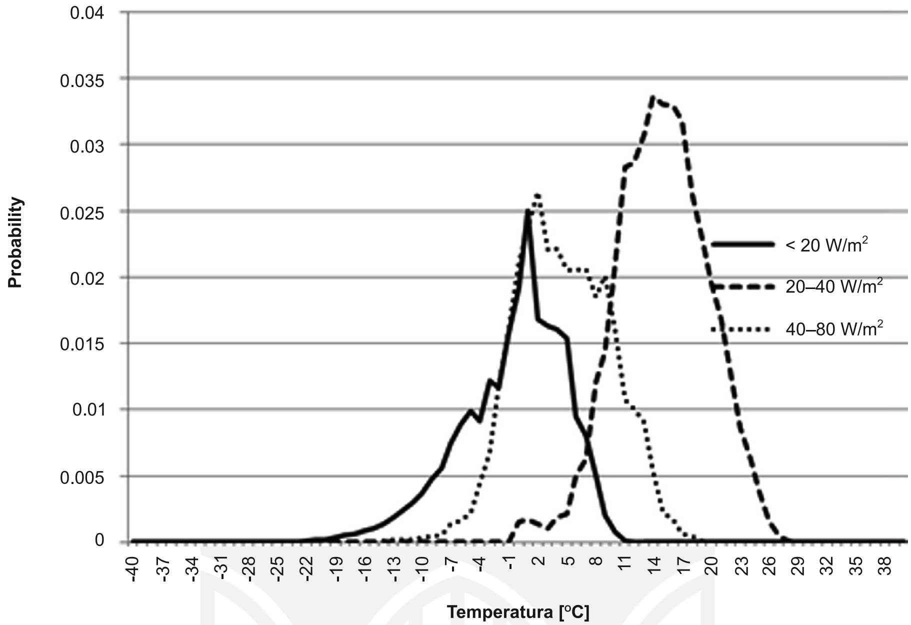

Fig. 4. Probability density function levels for the occurrence of thermal loads, depending on temperature

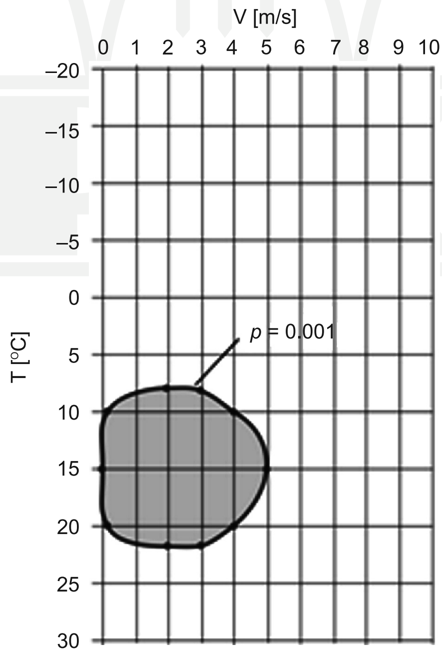

Fig. 5. Wind speed and temperature ranges providing comfortable conditions($\Delta Q < 20$ W/m^2)

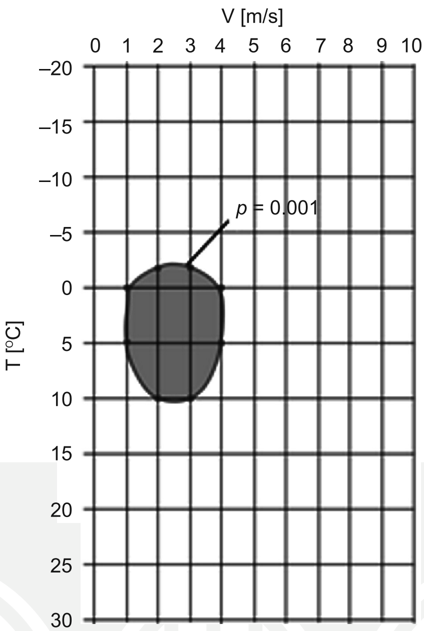

Fig. 6. Ranges of wind speed and temperature providing conditions of discomfort $\Delta Q = 20 – 40$ W/m^2)

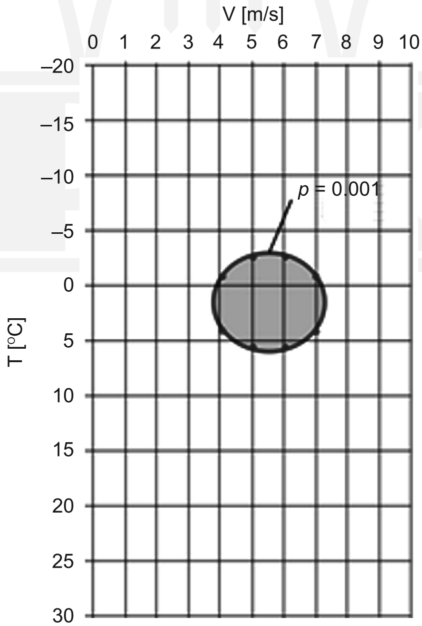

Fig. 7. Ranges of wind speed and temperature providing strong conditions of discomfort ($\Delta Q = 40 – 80$ W/m^2)

Conditions in which unfavorable loads on the body occur (ΔQ = 20 – 40 W/m^2) are presented in Fig. 6. As in the previous instance, only situations with a probability exceeding 0.001 were taken into account.

In the case of uncomfortable conditions, the temperature reaches a value between –2 and +10ºC and wind speed varies between 1 and 4 m/s. The probability of an occurrence of discomfort in such conditions over the 30-year analysis period is at a level of 0.26.

The third of the proposed thresholds refers to strong unfavorable loads, in which ΔQ = 40 – 80 W/m^2. Figure 7 presents the ranges of temperature and wind speeds in which such conditions of discomfort may occur.

The analysis establishes that strong conditions of discomfort will occur when air temperature acquires values between –3 and +5 and wind speed reaches between 4 and 7 m/s. In such meteorological conditions, the probability of an individual experiencing strong discomfort is approximately equal to 0.15.

5. Conclusions

The analysis drew on data from the open suburban area of Lodz, located near a meteorological station, and reflects only climatic influences on comfort conditions. In the case of a built-up area, the problem becomes more complicated. The most important factor, which significantly affects microclimatic conditions (and thereby human comfort) are buildings. Depending on the arrangement of buildings and the location in relation to Compass North, different wind speeds can be expected. Particular attention has to be paid to high buildings above 20m, which generate strong winds in their vicinity. In order to assess conditions for human comfort in urban areas, a detailed analysis should be carried out taking heat and mass transfer into account.

References

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