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THERMAL COMFORT DEFINED BY UTCI FOR THE MONTH AUGUST OF 2017 IN THE CITY OF BIJELJINA

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ABSTRACT

Knowledge of the thermal comfort of an area is of increasing importance when planning space, tourism, recreation and the health of the population that lives or is currently located there. Due to the great anthropogenic changes of nature, the temperature is rising, which is expressed especially in urban environments. The impact of temperature rise is best seen in Europe by monitoring summer meteorological parameters.

The research was done by analyzing meteorological parameters of the city of Bijeljina, which is a thermal island in the area of Semberija in Bosnia and Herzegovina. Meteorological parameters during the summer months are unfavorable and affect thermal comfort, which often reflects through the health of the population.

For this research were observed and calculated values of bioclimatic index UTCI or Universal thermal climate index, for the month August of 2017 which was one of the hottest months in the 21th century.

Keyword: *thermal comfort, UTCI, bioclimatic indices, urban environment*

INTRODUCTION

Due to the increasing development of the cities, the population is unevenly populated. Populations in cities are growing, while in villages are declining. As a consequence, appear many problems such as overcrowding of certain areas, which further leads to changes in space that affect the growth of temperature in urban environments, such as concrete and asphalt surfaces, lack of green areas, increasing number of cars, etc. Many cities have higher temperatures than the environment due to the level of urbanization that modifies land use, creating a specific phenomenon, urban heat islands [1,2].

According to the audit of the world perspective of urbanization from 2018, 68% of the population will live in urban areas by 2050 [2,3]. The quality of urban living conditions often depends on the thermal comfort of the open urban spaces, which are used on a daily basis [4].

Bijeljina is a characteristic example of heat island in Bosnia and Herzegovina. Construction of facilities since the beginning of the 21st century made a complete transformation of the space and created from small town an urban environment [5,6]. According to the last Census in 2013, Bijeljina has 42 278 inhabitants, which is 16 1 % more than in the year 1991 [7]. According to the previous research, the city of Bijeljina shows unfavorable characteristics of thermal comfort, which are pronounced during the warmer part of the year (especially months Jun, July and August) [5,6,8,9,10].

Human thermal comfort is defined as a condition of mind which expresses satisfaction with the surrounding environment, according to ANSI/ASHRAE Standard 55 [11]. High temperatures and humidity provide discomfort sensations and sometimes heat stress. People react differently to environmental elements, depending on the physical and mental health and their adaptation to certain conditions. Common for everyone is that they are not immune to meteorological conditions, especially air temperature and humidity [9].

In 2011, the International Society of Biometeorology (ISB) announced a new thermal index for outdoor thermal environments called the Universal Thermal Climate Index (UTCI). It is a heat budget index in function of both physiological and meteorological parameters, which describes the physiological heat stress that human body experiences in the attempt to maintain thermal equilibrium with the surrounding outdoor environment [10,12]. In recent years this index was used for the purpose of understanding thermal comfort in the researched area [10].

METHODOLOGY

The researched area is located in the northeast of Bosnia and Herzegovina, in the southern part of the edge of the Pannonian Basin. The location at the crossroads between Serbia, Croatia and internal Bosnia and Herzegovina, has enabled this area accelerated development and increase of the population since the beginning of the 21st century.

The weather station is located about 1.5 km by air from the city center. According to Köppen's climate classification, Bijeljina belongs to the Cfb type – where the climate is moderate continental, with moderately cold winters and warm summers [10,13].

For the purposes of this research, the bioclimatic index of UTCI was used, which has a total of 10 thermal stress categories [12,14]. The data is calculated for the month August of 2017, which was one of the warmest in this millennium on the researched area. The maximum daily temperatures crossed 40^{o}C. In addition to high temperatures, this area is characterized by the lack of wind. Medium monthly and annual speeds do not exceed 2 m/s. Humidity, which also affects the thermal comfort is unfavorable during the whole year [5,13]. The value ranges of this index are given in the table 1.

Table 1. UTCI thermal stress classification

UTCI (^{o}C)	Stress category
UTCI > 46	Extreme heat stress
38 < UTCI < 46	Very strong heat stress
32 < UTCI < 38	Strong heat stress
26 < UTCI < 32	Moderate heat stress
9 < UTCI < 26	No thermal stress
0 < UTCI < 9	Slight cold stress
-13 < UTCI < 0	Moderate cold stress
-27 < UTCI < -13	Strong cold stress
-40 < UTCI < -27	Very strong cold stress
UTCI < -40	Extreme cold stress

To calculate the human thermal balance, two types of data are needed, meteorological and physiological. The meteorological data in this research refer to daily average values. The meteorological parameters that are taken into account for calculating UTCI involve dry temperature, mean radiation temperature, the pressure of water vapor or relative humidity, and wind speed (at the elevation of 10 m) [15].

For physiological parameters were used universals data that represent constants in the model. These are: metabolic heat of 135 Wm^{-2}, which refers to a person that is moving 1.1 ms-1, skin temperature of 32°C, thermal insulation of 1 clo, which is achieved in a person that is resting at a temperature of 21° C and a relative humidity of 50 % and implies a man dressed in a business suit, albedo of the skin of 30%, albedo of earth of 17% and skin moisture which represents a dimensionless size [5,8,16,17,18]. The calculation of UTCI index was done with the use of BioKlima 2.6 software package [19].

RESULTS

On the research area, during the month August of 2017, are present 4 categories in total: No Thermal Stress, Moderate Heat Stress, Strong Heat Stress and Very Strong Heat Stress. The categories show an uneven presence, with the largest number of days within the categories belonging to intense heat stress.

For the human body, the most favorable days are within the category comfortably, ie category without thermal stress, with values between 9 and 26, which are rare during the summer months. During August 2017, a total of 2 days were recorded within this category (13th and 20th). There are no specific guidance or behavior instructions during these days, given that they are considered as days with a good thermal comfort and outdoor activities. This month has the least number of days, in relation to all other months during the year, based on the earlier research in the observed period of 14 years, 2005 - 2018 (figure 1) [20].

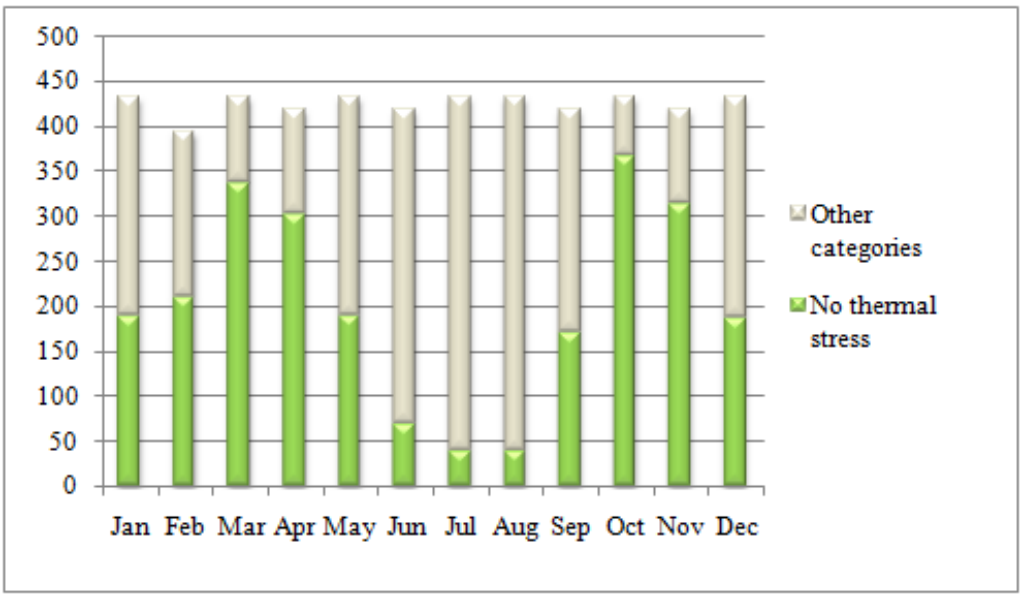

Figure 1. Number of days in the category No thermal stress per month

Total number of days within the Moderate Heat Stress category, with values between 26 and 32, is 10. This category is a slightly unfavorable category for human organism. Guidelines and instructions related to the behavior during the days within this category are mainly related to the amount of water intake. It is recommended to drink more than 0.25 l per hour [21].

Within the Strong Thermal Stress category, with values between 32 and 38, during the month of August 2017, a total of 16 days were present. This category is very unfavorable for the human organism. During theese days it is necessary to limit direct sun exposure, use shaded places, reduce physical activity temporarily, move it to morning hours, limit alcohol, drink more than 0.25 l per hour eat light meals, protect children, elderly and people in need of care [21].

The last present category is Very Strong Thermal Stress, with values between 38 and 46. A total of 3 days in the observed period of time (3rd, 4th and 9th August) were recorded. Days in this categorie are very dangerous for human organism and repsresent days with very poor thermal comfort. During these days, it is necessary to take care of physical activity and the amount of water intake, so the body does

not dehydrate. It is necessary to limit direct sun exposure, use shaded places, reduce physical activity temporarily, move it to morning hours, limit alcohol, drink more than 0.5 l per hour eat light meals, use air conditioner, keep your apartment cool, protect your rooms from the direct sunlight, wear light and comfortable clothing, protect children, elderly and people in need of care [21].

The ratio of categories within the month of August goes in favor of categories with pronounced thermal stress, Strong Thermal Stress and Very Strong Thermal Stress. As such, the month of August has adverse thermal comfort which is poorly reflected on the state and health of the human body and it is necessary to take care of the activities that place during such days.

In table 2 are given the following meteorological data: mean daily temperature (t), maximum daily temperature (tmax), relative humidity (f), wind speed (V) and cloud cover (N) and the UTCI numerical value, and in figure 2 is shown the ratio of all thermal stress categories.

Table 2. Meteorogical data and UTCI values in the city of Bijeljina for August, 2017 [13]

date	t	tmax	f	V	N	UTCI
1.8.2017	29.0	37.2	59	1.3	0	36.15
2.8.2017	29.4	39.3	58	0.7	0	37.38
3.8.2017	29.9	37.7	58	0.7	2	38.01
4.8.2017	30.6	40.7	56	0.3	0	38.73
5.8.2017	29.9	37.4	57	2.0	0	35.74
6.8.2017	30.3	39	60	1.7	6	36.94
7.8.2017	22.6	28	83	1.7	8	29.93
8.8.2017	26.4	32.3	71	1.3	5	34.08
9.8.2017	30.7	40	60	0.3	1	39.13
10.8.2017	31.8	40.6	49	2.0	0	37.39
11.8.2017	31.1	40	50	2.0	2	36.63
12.8.2017	20.8	30	79	2.0	7	27.01
13.8.2017	18.2	20.2	88	2.3	9	23.87
14.8.2017	21.4	27	75	0.7	4	30.45
15.8.2017	23.1	30.4	71	0.3	3	32.26
16.8.2017	24.3	32.7	71	0.3	1	33.35
17.8.2017	24.8	33	64	0.3	1	33.37
18.8.2017	25.6	35.2	66	0.3	3	34.25
19.8.2017	27.6	36.6	60	1.0	2	35.00
20.8.2017	17.5	22.8	92	1.7	10	25.01
21.8.2017	18.3	24.3	76	0.7	4	27.72
22.8.2017	17.6	25.4	71	0.7	2	26.90
23.8.2017	18.2	27	73	0.7	2	27.49
24.8.2017	21.8	32.6	65	0.3	0	30.63
25.8.2017	25.1	36.4	67	0.3	0	33.71
26.8.2017	25.5	38.4	64	0.7	0	33.51
27.8.2017	25.0	35.8	63	0.3	2	33.35
28.8.2017	23.9	30.8	72	1.0	7	31.93
29.8.2017	20.5	29	66	0.7	3	28.95
30.8.2017	21.1	31	67	0.0	0	30.20
31.8.2017	24.0	34.4	64	0.0	0	32.47
Average	24.7	33.1	67	0.9	3	/

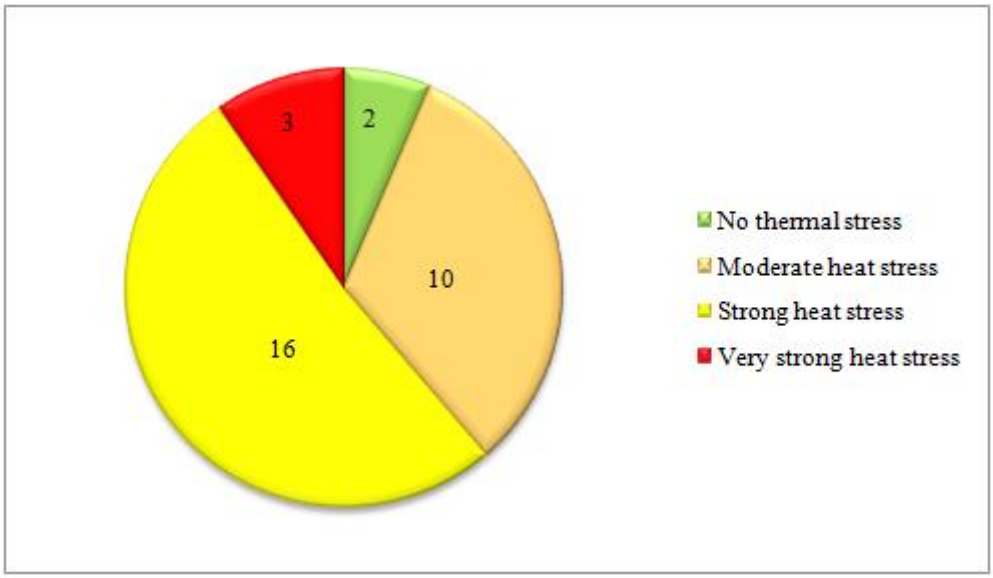

Figure 2. The ratio of the number of days within categories in August, 2017

CONCLUSION

Analysis of the month of August of 2017, in the area of Bijeljina, by using the bioclimatic index UTCI, has shown bad results. Only a few days within the month are in the category without thermal stress, which are the most favorable for the human organism. The largest number of days show an intense thermal stress, which poorly reflects on human health.

Due to the overcrowding of the city, temperatures are higher in relation to the environment, which creates an additional burden and stress to human organism. In order to make such days more pleasant for the population, it is necessary to work on the landscaping of the area and to reduce traffic, especially in the city center. It is also necessary to respect guidelines and instructions, regarding dehydration, excessive physical activity and exposure directly to the sun during warm classes.

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