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TERMAL COMFORT IN THE CITY OF BIJELJINA, FOR THE PERIOD 2009 – 2018 DEFINED BY WGBT

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ABSTRACT

In paper are presented results of bioclimatic model Wet bulbe globe temperature (WBGT) for the area of the city of Bijeljina, for the period of 10 years, from 2009 to 2018. The city is located in the north east part of Bosnia and Herzegovina and has a moderate continental climate. Results were obtained by calculation of meteorological data in software program Biklima 2.6. They show the presence of all five values defined with the WBGT index. Results differ in during the year, and seasons and have different number of days with the Unlimited (<18) being the most common value and Activity should be stopped (>30) the least presence. Some years have the high number of high values (over 30) and present a potential danger for a human organism if exposed to physical activities. Number of consecutive days with high value rises and presents danger for human organism.

Key words: *bioclimatic model, WBGT, heat stress, thermal comfort*

INTRODUCTION

This study was conducted in the city of Bijeljina, which is located on the north east part of Republic of Srpska, Bosnia and Herzegovina. Population of the municipality that has 67 settlements is 103 874, and the population of the city is 41 121 [1]. Location of the city is near the perimeter of the Pannonian basin, at the mouth of the river Drina in Sava. It has moderate continental climate, characterized with all four seasons, spring, summer, autumn and winter. Summers are warm, with the highest temperatures in July and winters are moderately cold, with the lowest temperatures in January. Springs are rainy and the autumns are mild. The differences between winter and summer, as well as transitional seasons are very well expressed during outdoor activities that are one of the main reasons of this research. Most of the happenings and cultural and sports events take place during the summer mounts, which have uncomfortable days for human organism. Outdoor activities are determined in general by meteorological parameters.

Bioclimatic data were obtained based on data from the synoptic meteorological station in Bijeljina that is located 1.5 km (distance by air line) from the center of the city. Bijeljina is the city that has highest population influx, since the civil war in Bosnia and Herzegovina. It has led to intense infrastructural building, pollution, noise and lack of green areas, faster way of life which all have an effect on thermal comfort of people. In combination with unfavorable meteorological elements it can have dangerous effect on human organism.

Human thermal comfort is defined as a condition of mind which expresses satisfaction with the surrounding environment. High temperatures and humidity provide discomfort sensations and sometimes heat stress. People react differently on 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 characteristics, especially temperature and humidity. No matter the physical readiness, there are environmental and meteorological factor that has to be taken into consideration in order to preserve health. Unfavorable weather elements, especially high temperatures can lead to heat stress. High temperatures are present during summer months, June, July and August.

All categories of people are considered while researching and analyzing the results of WGBT. Some however, are more prone to experience heat stress. Discomfort and heat stress reduce productivity of workers and may lead to more serious health problems, especially for aged persons [2].

METHODOLOGY

There are a lot of different bioclimatic model and indices that are used today for the analysis of thermal comfort in certain areas. For the purpose of this paper was used bioclimatic model, Wet bulb globe temperature (hereinafter referred to as WBGT). Values, obtained from the meteorological station in the city, are calculated in software program Bioklima 2.6. The study includes a 10 year period in the area of the city of Bijeljina, from 2009 to 2018. This period is characterized with occurrence of floods, in December of 2010 and in May of 2014 when the river Drina reached its highest level in the last 100 years. They had a huge impact on development of the area and acclimatization of people to certain conditions.

According to National weather service [3] WBGT is a measure of heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). WBGT was developed by Yaglou and Minard in 1957 and is regarded as one of the main experimental indices for measuring heat stress [4]. It was first used during the 1950s as a component of a successful campaign to reduce heat-related illnesses in the training camps of the US Army and Marine Corps [5]. WBGT is commonly used index of heat stress today, especially by military, universities and sports organizations. One of its purposes is to keep people safe while performing outdoor activities at high temperatures. For this reasons, athlete organizations are using this bioclimatic index, so the athletes could reach a full potential without being put in health danger. WBGT addresses the physical activities that human body can stand in different climatic conditions, regarding different seasons in the area of Bijeljina in this paper. In table 1 are presented values of WBGT and recommendations for involvement in outdoor activities for every value of the index [6].

Table 1 Recommendations for outdoor activities for wet bulb globe temperature (WBGT) values

	VALUE	DESCRIPTION
Unlimited	<18	Unlimited
Possible heat stress	18-23	Keep alert for possible increases in the index and for symptoms of heat stress
Heat stroke at unacclimated	23-28	Active exercise for unacclimatized persons should be curtailed
Heat stroke at acclimated	28-30	Active exercise for all but the well-acclimated should be curtailed
Activity should be stopped	≥30	All training should be stopped

The core body temperature of all humans is maintained close to 37°C. The main mechanism of internal heat gain is the heat generated by muscles that work at approximately 20% efficiency. Heat can be transferred to/from the body by convection, conduction, radiation and evaporation of water (sweat). Environmental factors that influence these heat transfer mechanisms, and the resulting heat stress, are air temperature, wind speed, humidity and heat radiation. The heat stress is also dependent on the clothing and the intensity of muscular work (the metabolic rate) of the person [7].

WGBT is widely used for the presentation of possible heat stress for workers whose activities are carried out outside. The International Standard for heat stress uses WBGT to recommend work – rest limits for work in hot environments in order to ensure that average core body temperatures of worker populations does not exceed 38°C. Chapter 8.1.2 of the standard states that workers should be allowed sufficient time to acclimatize to an extremely hot or cold environment, including major changes in climatic conditions [8]. Many countries have national standards based on this international standard for WBGT limit values [9].

If the value of WBGT is within Heat stroke at unacclimated level, body is stressed after 45 minutes of working out. It is necessary to take breaks of 15 minutes. If the value of WBGT is within Heat stroke at acclimated level, body is stressed after 20 – 30 minutes of working out. It is necessary to take breaks of 30 – 40 minutes. Finally, if the value of WBGT is within Activity should be stopped level, body is stressed after 15 minutes of working out and should have at least 45 minutes breaks [3]. These recommendations should be followed in order to preserve health and obtain comfort of human body while carrying out outdoor activities.

RESULTS

Results were obtained for every value of WBGT in table 1, through calculation of meteorological data, for the period of 10 years, 2009 – 2018, in software program Bioklima 2.6. The values include Unlimited (numerical values is less than 18), Possible heat stress (numerical values is between 18 –and 23), Heat stroke at unacclimated (numerical value is between 23 and 28), Heat stroke at acclimated (numerical value is between 28 and 30) and Activity should be stopped (numerical value is over 30). All values are present on the studied area, during different period of the year, with presence from several days to several months.

For the human organism, value for Unlimited is the most favorable. Overheating of a human organism depends mostly from physical readiness of the body. Studied area has the most days during the year with numerical value less than 18. This makes the city of Bijeljina favorable for outdoor activities and generally thermally comfortable for people during most part of the year. Months that are characterized with the comfortable conditions for the human body and physical activities, based on table 1 values are January, February, March, November and December, ie autumn and winter months. In observed period July and August are the only months without numerical value of WBGT less than 18. On average, in observed period, one year has 210 days of this value.

The following value, from 18 to 23, presents Possible heat stress during physical activity of the human body. The studied area has the second highest number of days, with this value, mostly present in May, June and September. Some of the years go in favor of the following value, Heat stress at unacclimated. Comparison of the two is presented in the figure 1. The year with the highest number of consecutive days in the observed period is 2013, from August the 28th to September the 16th. In total 20 days. From 2016 and above, this value is present in winter months, mostly December. On average, in observed period, one year has 75 days of this value.

Heat stroke at unacclimated, value 23 – 28 is the third most common with the number of days that ranges from 46 in 2017 (the lowest number of days) to 94 in 2018 (the highest number of days) for the observed period. Value heat stroke at unacclimated on the area of the city of Bijeljina is present during several months: April, May, June, July, August, September and October. The highest presence is during June – August, then in May and September and the lowest presence, with a few days or none is

in April and October. Days with this value are regarded as dangerous for tourism, because of the acclimation of human's organism. The year of 2014 is characterized with the highest number of consecutive days of this value, in period from July the 27th to August the 15th. In total 19 days. On average, in observed period, one year has approximately 69 days of this value.

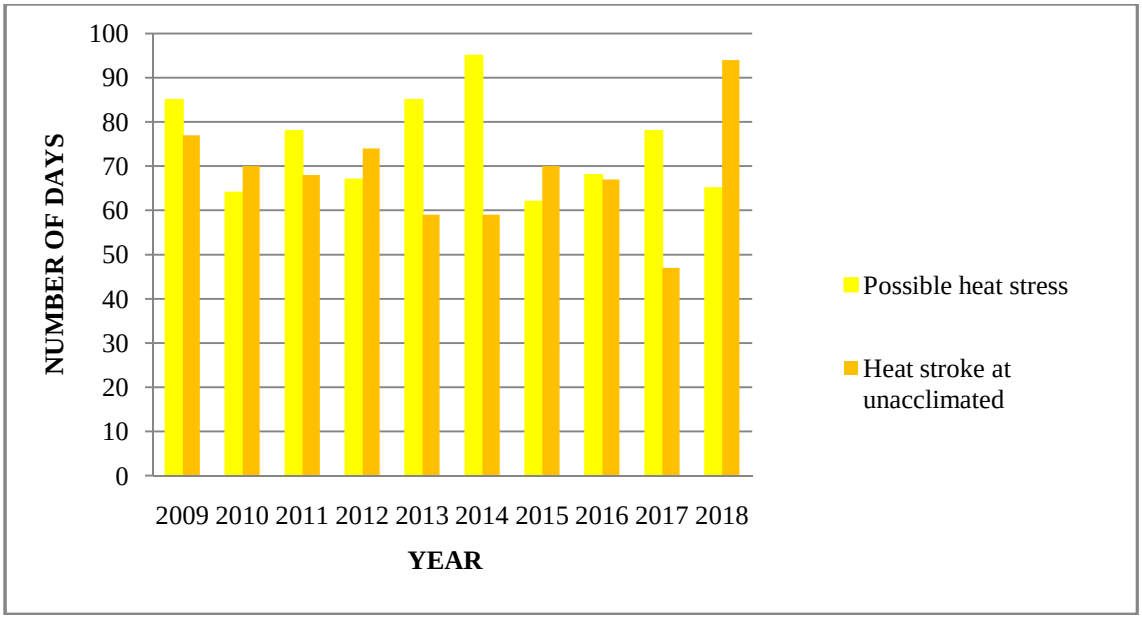

Figure 1. Comparison of number of days with 18 – 23 (Possible heat stroke) and 23 – 28 (Heat stroke at unacclimated) values for the period 2009 – 2018 in the city of Bijeljina

The last two values are the most dangerous for human body, with numerical values higher than 28. They are presented with Heat stroke at acclimated and Activity should be stopped. Both are present in summer months in the studied area and have the least presence during the year in general (figure 2). However total number of days rises, with the highest number in 2015, and the least in 2014.

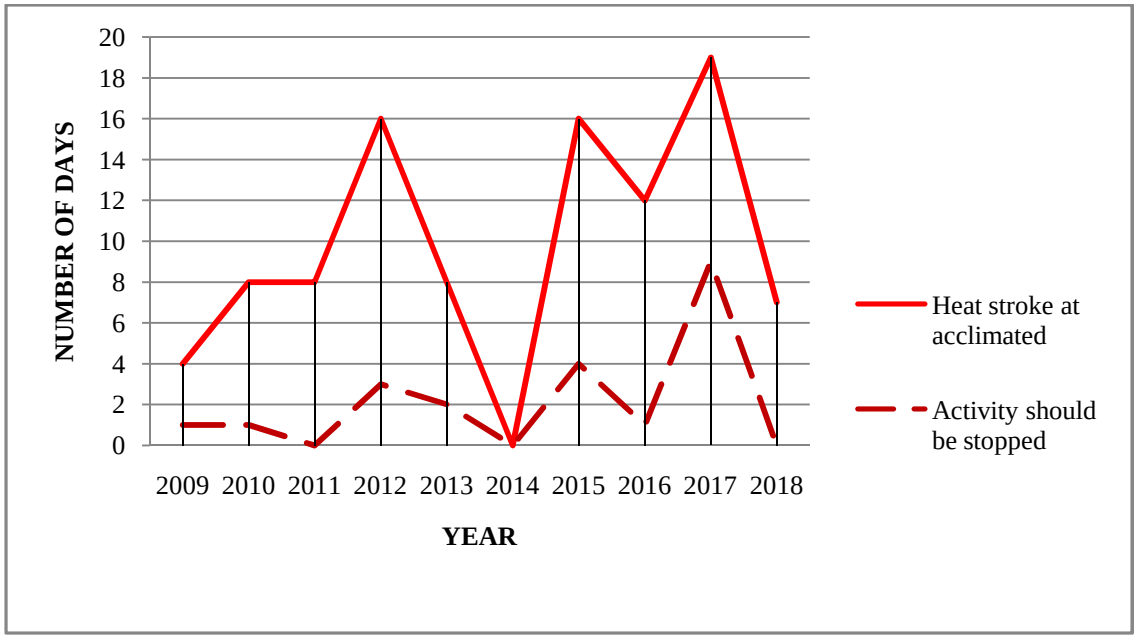

Figure 2. Number of days with 28 – 30 (Heat stroke at acclimated) and higher than 30 (Activity should be stopped) values for the period 2009 – 2018 in the city of Bijeljina

Heat stress at acclimated is a high value of WGBT, that characterizes summer months, June – August, for the observed period of studied area with one exception in 2009, when it also appeared in May (2

days). The presence of this value varies. Year with the highest number of days was 2017 with 19 days. In observed period 2014 year had 0 days of this value. On average a year has 8 days of this value. The period characterized with the highest number of consecutive days was from June the 30th to July the 5th, 5 days in total (year 2012).

The last value, *Activity should be stopped*, has a numerical value over 30 and it appears only during summer months (June – August) with one exception for the observed period, in 2009 when May had one day with this value. It is described as the state when all activity should be stopped. It is the most dangerous value that in the studied area has a tendency of appearing a few days a year. The highest number had the year 2017, with total of 9 days. The most consecutive days happened in 2017 (4 days in July), then 2017 again (3 days in July) and 2012 (2 days in August).

In combination, last two values are considered dangerous, if last several days without breaks. During 10 observed years, the exceptions for this occurrence were the years 2009 and 2014. The highest number of mixed consecutive days were in 2015 (10 days), 2017 (7 days) and 2012 (6 days). The number of days with high value, over 28, rises. This represents danger for people of studied area, because level of acclimatization is not sufficient for the newly created conditions.

Increased heat exposure raises the core body temperature of the human body. While some increase in core temperature above 37°C is acceptable, an increase beyond 39°C creates health risks, which vary from person to person, depending on ethnic group, age, gender, the duration of high heat exposure, and the degree of acclimatization. The core body temperature of all humans is maintained close to 37°C. The main mechanism of internal heat gain is the heat generated by muscles that work at approximately 20% efficiency [3,10]. As mentioned, physical readiness is different for people of certain groups, but everyone are affected by meteorological factors, especially those that are new and that human organism of certain area is not used to them.

CONCLUSION

This paper is a part of conducted research of the area of Majevica and Semberija. The idea was to show thermal comfort in the area of the city of Bijeljina, which represents the point of researched area with the highest population density, by using meteorological data for the calculation of bioclimatic model WGBT. Observed period included 10 years, 2009 – 2018. Obtained data were analyzed for every value of the model, focusing on highest and the lowest number of days for every value.

The area is characterizes with a large number of favorable value (Unlimited) that enables the human organism to be involved in physical activities depending on level of readiness. Problem lies in the fact that days with this value are mostly present during winter months when people have least physical activity, especially athletes and workers. On the other hand, this area also has an increased number of last two values, which are the most dangerous for heat stroke and thermal stress. They are mostly present during summer months that is characterized with outdoor activities such as tourism, sports and construction. This has a negative effect on human body and health. In the period of 10 years, two years were recorded with the highest values, when all activity should be stopped. Those were 2012 with 2 consecutive days in August and 2017 with 4 consecutive days in July. In combination with value from 28 to 30, consecutive days extend to 10 (in 2015).

Data obtained for the period 2009 – 2018 for the area of city of Bijeljina show that human body is acclimated on different temperatures during just one year. However, people have to be careful with physical activities during summer months, because it has the highest level of negative effect on human health. Outdoor activities should be limited and reduced in the period from 11 am to 17 pm in order to prevent heat stress of an organism. Also, it is necessary to take breaks from 15 to 45 minutes, depending from the stress level that is present and the activity that is carried out in the outdoor environment. The WBGT model is helpful in determining days when people should be careful and minimize outdoor activities in order to preserve health and comfort of the organism.

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