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THERMAL COMFORT OF UGLJEVIK TOWN FOR THE YEAR 2021 OBSERVED THROUGH THE BIOCLIMATIC INDEX WBGT

Đurić Dijana¹, Jakšić Vanja², Šelić Aleksandar³, Vlajić Ilija⁴

¹Faculty of Civil Engineering Subotica, University of Novi Sad, Serbia
email: dijana.djuric.gf@gmail.com

²WWF Adria, Serbia

³Faculty of Mining and Geology, University of Belgrade, Serbia

⁴Faculty of Geography, Department for Geospatial and Environmental Sciences, University of Belgrade, Serbia

ABSTRACT

This paper researches thermal comfort of the town of Ugljevik in Bosnia and Herzegovina for the year 2021, by analyzing bioclimatic index Wet bulb globe temperature (WBGT). The analysis is a continuation of the research on the bioclimatic conditions of the area of Semberija plain and Majevisa mountain, which has so far covered only the city of Bijeljina, as the most urbanized area of the researched space.

All five categories of the WBGT index are present during a year, with different number of days for each category. For thermal comfort the most important factors should be observed during summer months of the year, June, July and August, due to the highest number of days in categories with values over 28, that are dangerous for human organism and outdoor activities.

The accent in this research was put on the number of categories that are present during one month, but also during just one day, by using mean, maximum and minimal temperatures for calculations. This type of research allows us to see how many different categories one day has.

Keyword: *thermal comfort, WBGT, bioclimatic indices, summer months, outdoor activities*

INTRODUCTION

Human thermal comfort is defined as a condition of mind which expresses satisfaction with the surrounding environment and is assessed by subjective evaluation [1]. 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 [2].

Thermal comfort is an increasingly common research topic in the Balkan countries. Previous bioclimatic research of the thermal comfort of Bosnia and Herzegovina covered mostly cities with over

30 000 inhabitants [2,3,4,5]. Researches involving smaller places or locations are rare [6]. Many places in the country are experiencing population decline, while a small number of larger cities are constantly growing [7]. This is why towns and villages have not been a subject of many bioclimatic researches. However, the importance of knowing the thermal comfort of such places is not negligible. Moreover, knowing the thermal comfort of smaller places can be useful for the improvement and enhancing of the area of larger cities, by looking at the basic characteristics that reduce the discomfort of the organism, such as the presence of greenery.

Bioclimatic research is important element of improvement of certain area, mostly about planning and construction. Also by knowing the thermal comfort, we can determine the benefits of a certain area for the development of tourism, as well as recreation zones in urban and rural environments. Sometimes it is possible to use data from one place and implement it to another, with following certain rules of the area that has favorable climate conditions. Specifically in this paper, knowledge of the thermal comfort of Ugljevik can be useful for improving the situation in the city of Bijeljina, which is at an air distance of less than 20 kilometers.

STUDY AREA

The municipality Ugljevik is located in the northeast part of Bosnia and Herzegovina, in the Republic of Srpska entity, on the edge of the Majejica mountain. The center of the municipality is the town Ugljevik which has 4 025 inhabitants and the whole municipality 15 710 inhabitants [7]. Compared to the 1991 census, there is a decrease in the number of inhabitants [8]. The distance from the cities with over 30,000 inhabitants is less than 60 kilometers by air (table 1).

Table 1. Distance of town Ugljevik from larger cities in the area

| Name | Approximate distance in km [9] | Population number of the city [7,10] | Population number of the municipality [7,10] | Entity/Country |
|-----------|--------------------------------|--------------------------------------|--|---|
| Bijeljina | 20 | 42 278 | 107 715 | Republic of Srpska / Bosnia and Herzegovina |
| Loznica | 25 | 19212 | 76 390 | Republic of Serbia |
| Brčko | 25 | 39 839 | 83 516 | Brčko District / Bosnia and Herzegovina |
| Tuzla | 30 | 74 457 | 110 979 | Federation of Bosnia and Herzegovina / Bosnia and Herzegovina |

The wider area is characterized by forest and agricultural lands. Land degradation is most noticeable in the area of the Mine and Thermal power plant Ugljevik, located in the western part of the town. Climate is continental. It is characterized by warm summers and relatively cold winters. The average vegetation period lasts from 150 to 200 days [11].

The measuring station from which the meteorological data necessary for the calculation of the WBGT bioclimatic index was used, is located within the Mine and Thermal Power Plant Ugljevik, at the foot of the Mejjica mountain at an altitude of about 250 m above sea level. It is located about 3 km by air from the center of Ugljevik town (figure 1). Meteorological parameters measured by the measuring station hourly are: air temperature, relative humidity, air pressure, wind speed and wind direction. Besides that station is equipped for measurement of polluting particles in the air: SO₂, NO, NO₂, NO_x and PM₁₀.

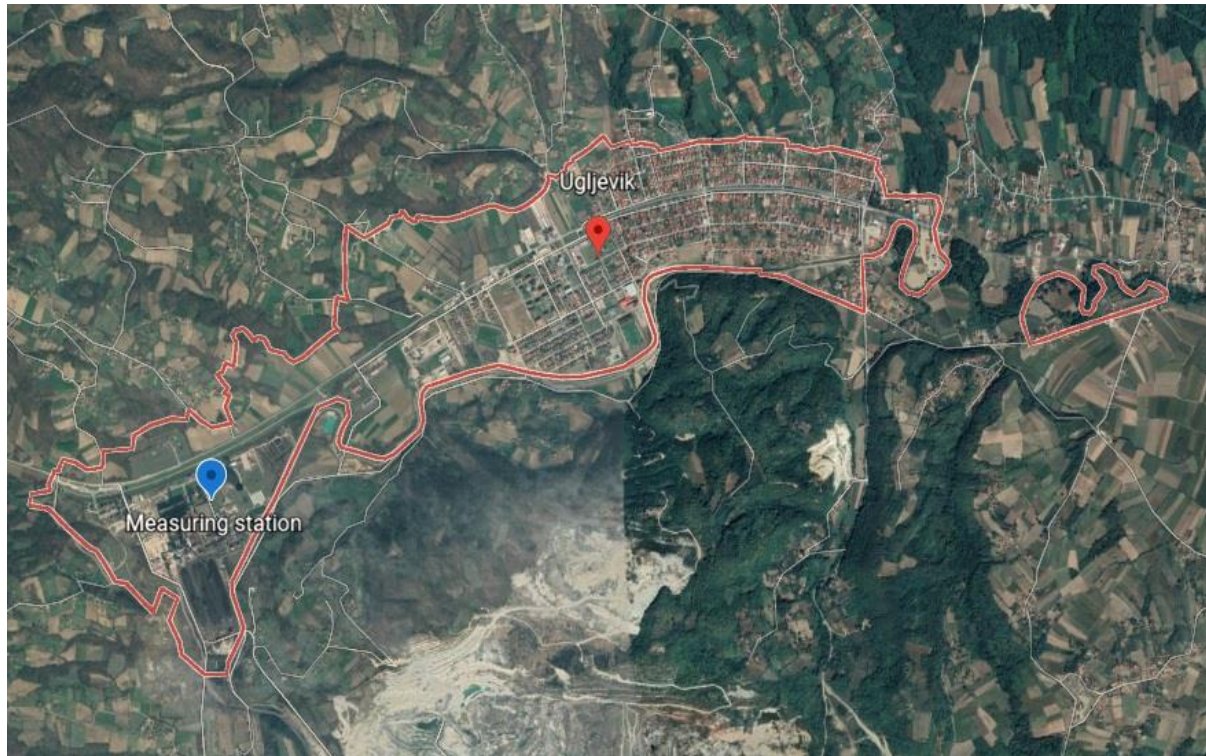


Figure 1. Location of the measuring station in relation to the town Ugljevik [9]

METHODOLOGY

For this research was used bioclimatic model WBGT. According to National weather service [12] 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). It was developed by Yaglou and Minard in 1957 and is regarded as one of the main experimental indices for measuring heat stress [13]. The first use of WBGT was in 1950s and it was as a component of a successful campaign to reduce heat-related illnesses in the training camps of the US Army and Marine Corps [14].

WBGT is commonly used index of heat stress today, especially by military, universities and sports organizations. Its purpose is to keep people safe while performing outdoor activities at high temperatures. Many athlete organizations are using this bioclimatic index, so the athletes could reach a full potential without being put in health danger. WBGT is also widely used for the presentation of possible heat stress for workers whose activities are carried out outside [2].

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 [15]. Many countries have national standards based on this international standard for WBGT limit values [16].

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 [12]. These recommendations should be followed in order to preserve health and obtain comfort of human body while carrying out outdoor activities [2].

In this paper WBGT addresses the physical activities that human body can stand in different climatic conditions, regarding different seasons in the area of Ugljevik. In table 2 are presented values of WBGT and recommendations for involvement in outdoor activities for every value of the index [17].

Table 2. WBGT categories and recommendations for outdoor activities

| Category | 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 unacclimated 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 |

For the area of the town of Ugljevik, within this research, values were observed during 2021, for all 12 months of the year. Due to the lack of meteorological data, values for the month of May were calculated for 30 days (1 - 30.05.2021) and for the month of August 22 days (1 - 20, 30. and 31.08.2021). The calculation of WBGT was done by using the program BioKlima 2.6 [18].

Also, this research included the calculation of different categories during one day. Instead of medium daily temperatures were used maximum and minimum values. Maximum values in the area of Ugljevik town are present during the afternoon hours, from 15 to 17 during winter months and from 16 do 19, during summer months. Minimum values are present after 22, and early in the morning at around 6, 7 o'clock. This was done to show the different level of stress that human body goes through, during just one day.

RESULTS

The results for the observed period, January - December 2021 show the days in all five different categories, which alternate with the change of seasons. According to table 1, for human organism outdoor activities are harmful at any day that has value over 18, whit different level of dangerous, especially the last two categories, Heat stroke at acclimated and Activity should be stopped.

Only one category has value under 18, and that is the category Unlimited. Days within this category values were not recorded only during the months of July and August. They are most numerous from March to April and from October to December, ie in the colder period of the year. Their presence dictates the opportunities for the sport activities, outdoor work or activities such as recreation and tourism in general.

Category Possible heat stress represents slightly higher danger value that Unlimited, that is present during spring and autumn months of the year, especially during May and September months. Days within the category Heat stroke at unacclimated occur from April to November, with the largest presence during the months of May and September.

The last two categories with values higher than 28, Heat stroke at acclimated and Activity should be stopped, which are the most dangerous for the human body, are present during the months of June, July and August. Days within the category Heat stroke at acclimated appear from June to September and days within the category Activity should be stopped are mostly present during July, less June and August. Knowing the presence of days with high values during the year is important for the

management and organization of outdoor activities such as sport manifestations and also outdoor works, such as construction (figure 2).

According to the average daily values of temperatures, the categories Heat stroke at acclimated and Activity should be stopped occur during June, July and August. However, if we use the maximum daily values of temperatures in the calculation, we get that these categories appear from the month of April to October (figure 3).

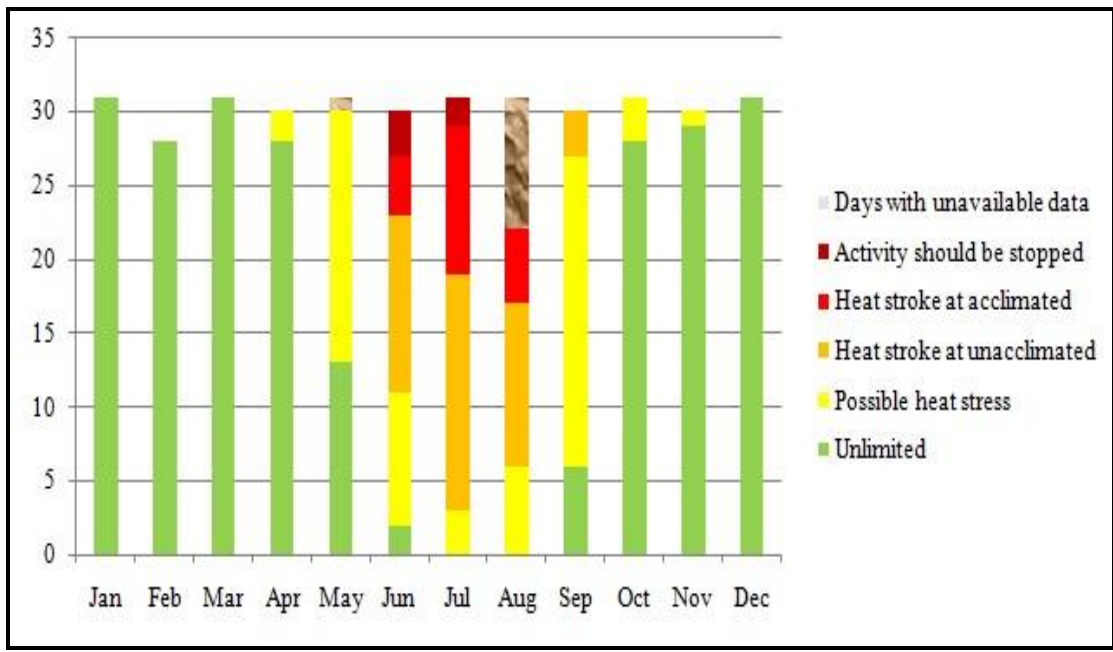


Figure 2. Number of days for every WBGT category for the 12 months of the year 2021, with the calculation of medium daily temperature values

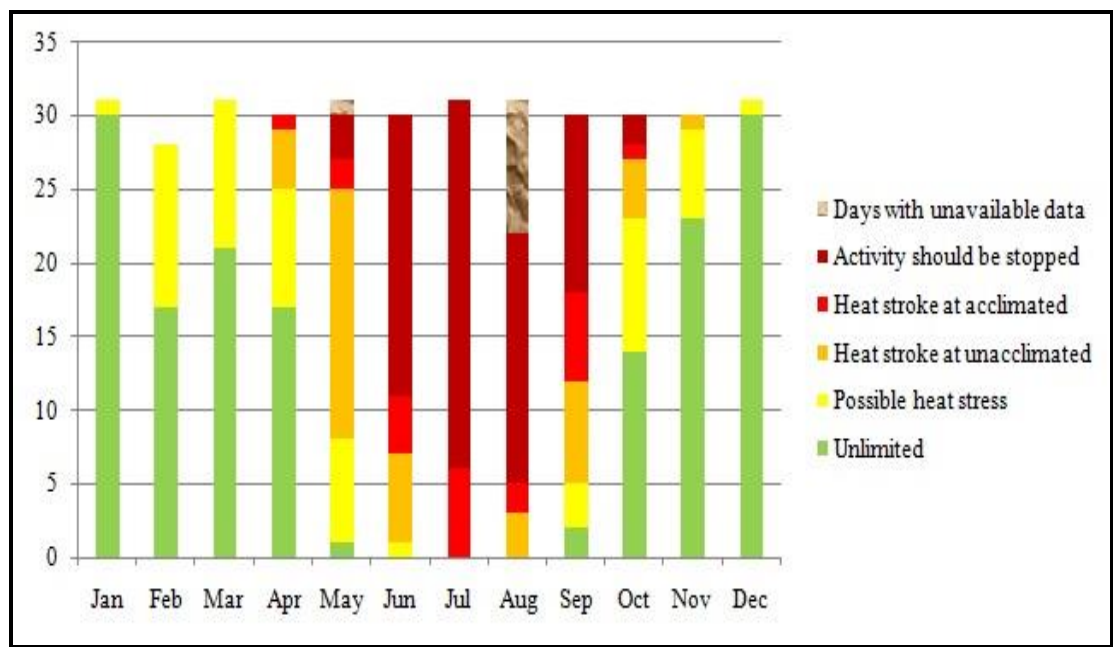


Figure 3. Number of days for every WBGT category for the 12 months of the year 2021, with the calculation of maximum daily temperature values

If we use maximum and minimum temperatures to calculate WBGT, we can obtain results for different parts of the day. For the maximum temperatures, we observed a period during the afternoon,

between 16 and 19 o'clock. For the minimum temperatures was observed period after 22 o'clock and early in the morning between 5 and 7 o'clock.

Obtained results showed that it can be assumed the presence of all five categories of WBGT during just one day, considering that the values goes from category Unlimited to the category Activity should be stopped. However, many days have no value in the category Unlimited, not even for the minimum temperature, which shows the high level of stress that certain days have on human organism (table 3).

Table 3. Daily values of WBGT for medium, maximum and minimum temperature

| DAY | JUNE | | | JULY | | | AUGUST | | |
|-----|------|------|------|------|------|------|--------|------|------|
| | m | max | min | m | max | min | m | max | min |
| 1 | 17.3 | 22.4 | 12.1 | 24.5 | 34.0 | 18.4 | 29.3 | 42.6 | 18.0 |
| 2 | 17.6 | 25.6 | 10.2 | 22.7 | 28.9 | 17.2 | 25.2 | 31.7 | 19.6 |
| 3 | 20.5 | 25.5 | 10.6 | 22.9 | 29.3 | 17.9 | 25.4 | 33.9 | 17.2 |
| 4 | 19.7 | 27.7 | 11.9 | 24.3 | 31.4 | 16.2 | 26.5 | 36.5 | 17.6 |
| 5 | 21.3 | 29.9 | 12.4 | 25.3 | 30.7 | 21.4 | 24.6 | 34.9 | 20.2 |
| 6 | 23.0 | 32.2 | 17.3 | 26.9 | 34.9 | 19.9 | 23.5 | 31.6 | 15.9 |
| 7 | 23.3 | 31.1 | 18.4 | 28.4 | 40.6 | 18.4 | 25.2 | 35.5 | 15.4 |
| 8 | 23.1 | 31.6 | 15.7 | 29.2 | 40.9 | 19.0 | 28.1 | 38.1 | 18.3 |
| 9 | 23.6 | 28.2 | 15.6 | 28.6 | 41.1 | 22.5 | 28.5 | 36.5 | 22.6 |
| 10 | 22.1 | 27.1 | 17.0 | 26.3 | 32.5 | 21.8 | 29.1 | 38.9 | 21.6 |
| 11 | 22.1 | 29.6 | 16.3 | 27.1 | 35.8 | 19.4 | 27.9 | 38.7 | 20.3 |
| 12 | 23.5 | 31.0 | 16.0 | 27.5 | 36.2 | 20.1 | 26.0 | 36.0 | 18.0 |
| 13 | 20.9 | 26.0 | 15.1 | 29.6 | 28.1 | 20.1 | 25.9 | 36.2 | 16.6 |
| 14 | 18.6 | 23.2 | 14.2 | 29.5 | 40.2 | 21.5 | 27.0 | 37.6 | 17.8 |
| 15 | 21.2 | 28.4 | 16.3 | 27.1 | 43.2 | 21.9 | 28.0 | 39.1 | 18.7 |
| 16 | 22.6 | 30.6 | 14.6 | 25.8 | 34.5 | 21.9 | 28.2 | 39.8 | 19.9 |
| 17 | 24.1 | 33.2 | 15.5 | 25.1 | 29.1 | 22.0 | 22.4 | 27.5 | 19.0 |
| 18 | 25.8 | 35.2 | 16.9 | 25.1 | 31.1 | 21.3 | 20.5 | 26.0 | 14.6 |
| 19 | 27.0 | 36.3 | 18.2 | 24.2 | 28.2 | 21.6 | 20.5 | 28.5 | 12.9 |
| 20 | 27.4 | 36.5 | 18.9 | 25.2 | 32.7 | 19.4 | 22.1 | 30.5 | 13.6 |
| 21 | 29.4 | 41.1 | 19.3 | 22.4 | 29.3 | 16.3 | - | - | - |
| 22 | 30.8 | 41.9 | 21.9 | 23.2 | 31.5 | 15.5 | - | - | - |
| 23 | 30.7 | 42.8 | 21.5 | 24.1 | 32.7 | 16.7 | - | - | - |
| 24 | 30.4 | 42.7 | 20.9 | 24.9 | 33.4 | 16.9 | - | - | - |
| 25 | 28.7 | 36.3 | 23.5 | 28.3 | 39.3 | 18.4 | - | - | - |
| 26 | 26.3 | 33.8 | 20.3 | 29.0 | 39.0 | 23.2 | - | - | - |
| 27 | 25.5 | 34.7 | 17.5 | 30.1 | 41.9 | 21.0 | - | - | - |
| 28 | 26.8 | 37.5 | 17.0 | 30.7 | 44.3 | 21.1 | - | - | - |
| 29 | 29.2 | 41.2 | 22.9 | 29.2 | 37.1 | 22.6 | - | - | - |
| 30 | 28.8 | 39.7 | 20.9 | 29.1 | 39.8 | 20.5 | 20.3 | 25.9 | 14.1 |
| 31 | | | | 28.9 | 37.3 | 20.6 | 20.3 | 28.6 | 16.5 |

m – medium t; max – maximum t; min – minimum t

Observed in general, July is was the hottest month in 2021, for the area of Ugljevik town. Over 10 days were in the WBGT categories with values over 28 (for medium temperatures) and all days for the maximum temperature. This indicates that the temperatures that are present during the most part of the day are very harmful for outdoor activities that should be avoided during the peak hours of the day.

CONCLUSION

This paper presented the WBGT values of the area of Ugljevik town in northeast part of Bosnia and Herzegovina, for the year 2021. Results showed the presence of all five categories, with presence of lower during the colder part of the year and higher during the hotter part of the year, especially during the summer months of June, July and August.

The research is a part of the bioclimatic research of the area of Semberija plain and Majevisa mountain, which included the calculation of the city of Bijeljina, that is less than 20 kilometers distant from Ugljevik by air. All obtained data give useful informations about the area of the foot of the mountain Majevisa, which can be used for the improvement of urbanized areas nearby, in order to obtain healthier environments. Obtained information also showed us the difference during parts of the day that need to be taken into account while planning outdoor activities.

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 [2]. This is why this index was used specifically for this research.

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