

Original Research

**ANALYSIS OF PHYSICAL HAZARDS IN THE ENVIRONMENT AND THEIR
IMPACT ON HUMAN HEALTH: CASE STUDY OF THE CITY OF NIŠ,
REPUBLIC OF SERBIA**

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Abstract

The subject of this paper is the identification and analysis of physical hazards (heat, microclimate parameters) transmitted through the area of Niš city. In the paper, 12 measurements of physical hazards were carried out during the day (from 6:00 a.m. to 6:00 p.m.) and in the evening (from 6:00 p.m. to 10:00 p.m.) at 12 selected monitoring places on the territory of the city of Niš from June 2024 until April 2025. Exceedances of measured physical hazards and their potential risk to human health were determined. In June and August 2024, there is a small risk of heat-related disorders for non-acclimatized persons doing heavy work outdoors. The analysis of identified physical hazards in the Niš city indicates the need to monitoring places and the application of personal and collective protective measures for people's work outdoors.

Keywords: heat, microclimate parameters, people's health.

INTRODUCTION

Physical environmental agents, including heat, light intensity, noise, and electromagnetic radiation, can have negative impacts on biological systems, affecting humans, animals, and other living organisms. While the effects of radiation are not visible to the human eye, elevated noise levels are perceived through hearing, and inadequate illumination is detected through the sense of vision [1]. Heat stress as a physical agent affects the working ability of exposed persons in warmer environments. A higher ambient temperature affects humans by causing heat accumulation in the body, which can lead to fatigue, muscle cramps, heat exhaustion, heat rash, and neurological and psychological effects, such as heat stress [2–4]. Wet-bulb globe temperature (WBGT) is an empirical index that considers thermal radiation, temperature, humidity, and airflow velocity. It is used to assess heat stress and can be determined in closed rooms, indoors (equation 1), but also in open spaces, outdoors (equation 2) [2,5–7].

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$$\text{WBGT}_{\text{in}} = 0,7 T_v + 0,3 T_g \quad (1)$$

$$\text{WBGT}_{\text{out}} = 0,7 T_v + 0,2 T_g + 0,1 T_a \quad (2)$$

where: T_v - natural ventilation wet bulb temperature (°C); T_g - temperature of the black globe thermometer (°C), and T_a - air temperature (°C).

Temperature of the black globe thermometer is a WBGT index variable used to determine heat stress [8]. Heat stress indices have advantages and disadvantages and have specific applications in various fields, such as industry, military, agriculture, and mining [2–5, 8].

Niš city is characterized by favorable conditions for living and economic development due to its moderate continental climate, advantageous geographical position, and an average altitude from 190–200 m. The mean annual air temperature is approximately 11.5 °C, while average maximum temperatures during the summer months reach from 29–30 °C. The city receives from 580–620 mm of precipitation annually, and average air humidity ranges from 60–65% in summer to 80–85% in winter [9]. In recent years, Niš city has experienced notable economic and infrastructural growth. The turnover of outdoor workers has increased, so it is necessary to identify and analyze heat and microclimate parameters in the urban environment of Niš to determine critical monitoring locations that may compromise environmental quality and the safety of people and workers.

EXPERIMENTAL PART

Description and methodology of measurements and monitoring places

Measurements of physical hazards in the environment on the territory of Niš city were carried out with portable measuring instruments at 12 selected monitoring places (Table 1) every second month from June 2024 to April 2025 (18–19 June 2024, 19–20 August 2024, 20–21 October 2024, 22–23 December 2024, 24–25 February 2025 and 22–23 April 2025).

Locations are in close proximity to gas stations, construction sites for various buildings and facilities and parks.

Table 1 Monitoring places of physical hazards in the territory of the city of Niš

Number of monitoring place	Location of the monitoring place	GPS coordinates	
		N	E
1.	Intersection of King Alexander Boulevard and Voždova Street	43°19'53.2"	21°53'11.4"
2.	Intersection of Boulevard Nemanjića and Vojvode Tankosića Street	43°19'35.1"	21°54'05.2"
3.	Čair Park – park in the city center	43°19'44.9"	21°53'52.0"
4.	Pariske komune Street – Elementary School “Dušan Radović”	43°19'30.6"	21°54'12.5"
5.	Factory Leoni (industrial zone)	43°20'28.9"	21°54'44.8"
6.	Roundabout near “Delta Planet”	43°19'20.5"	21°54'30.7"
7.	Aleksandra Medvedeva Street – Trade School	43°20'05.8"	21°53'16.0"
8.	Zetska Street – near Zlatni trag store	43°19'10.3"	21°53'25.3"
9.	Roundabout near University Clinical Center Niš	43°19'26.0"	21°53'40.6"
10.	12th February Boulevard– Technical school zone	43°20'40.2"	21°52'50.5"
11.	Roundabout of Studenička Street and Boulevard St Pantelejmon	43°33'54.3"	21°52'22.2"
12.	Boulevard Medijana – near MOL gas station	43°19'28.5"	21°54'55.0"

Physical hazards were recorded at all monitoring locations during both daytime (6:00 a.m. to 6:00 p.m.) and evening hours (6:00 p.m. to 10:00 p.m.). At each of the 12 selected sites, over the course of the monitored month, two standard 15-minute measurements were conducted—one in the daytime period and one in the evening. The paper analyzes the following physical agents: wet-bulb globe temperature (WBGT, °C), temperature of the black globe thermometer (T_g , °C), air temperature (T_a , °C), relative humidity (%), and airflow velocity (m/s).

Portable devices were used for measurement is HT30 Heat Index WBGT Meter (Extech, China) for measuring heat stress indices (WBGT and T_g), and temperature and relative air humidity, and EN 300 Environmental Meter (Extech, Taiwan) for measuring airflow velocity.

RESULTS AND DISCUSSION

Microclimatic parameters

To assess heat stress several indices have been developed, which including environmental factors (temperature, humidity, and airflow velocity) and/or individual factors (metabolic heat, insulating properties of clothing) [10]. When calculating the WBGT index, metabolic rate, age, body mass index of people, and the influence of worker acclimatization are not considered. This index is included in the International Standard ISO 7243:2017, which was also adopted in the Republic of Serbia, which assesses the impact of heat during an 8-hour working day in a hot working environment [8,11,12]. The measured WBGT values according to the ISO standard are compared with the reference values of the WBGT index, which considers the workers' physical activity (metabolic level) and acclimatization [12,13]. Acclimatization implies a gradual physiological adaptation of the worker, which improves his tolerance to heat stress. This is achieved by subjecting the worker to physical activity for a certain period under heat stress conditions similar to those in his work environment [14]. The classification or determination of the metabolic rate is carried out according to the standard SRPS EN ISO 8996:2022 [12,15]. Higher identified WBGT values than the reference ones indicate a risk of heat-related disorders, and in this case, reducing the worker's heat load is necessary. It is also necessary to perform a better assessment of the thermal stress by the worker using the standard SRPS EN ISO 7933:2023 [12,16]. The clothing worn by workers provides thermal insulation and affects the process of evaporation of sweat from the skin surface, therefore it is necessary to correct the WBGT value (effective WBGT value) when workers do not wear standard clothing (thermal insulation 0.6 clo, cotton and permeable) by the SRPS standard EN ISO 9920:2012 [12,17].

Table 2 provides an overview of the results of measuring wet-bulb globe temperature (WBGT), black bulb temperature (T_g), and air temperature (T_a) during the day and evening for the observed period at 12 monitoring places. Based on the temperature measurements of the heat stress index and air, it is observed that the average WBGT, T_g , and T_a temperatures have high values in June and August 2024. at all monitoring places. In general, temperature values are higher during the day than in the evening in all months of measurement.

Table 2 Average WBGT, T_g , and T_a values at the monitoring places for day and evening

Monitoring place	Day						Evening					
	Jun 2024	Aug. 2024	Oct. 2024	Dec. 2024	Feb. 2025	Apr. 2025	Jun. 2024	Aug. 2024	Oct. 2024	Dec. 2024	Feb. 2025	Apr. 2025
WBGT _{av} (°C)												
1.	21.1	21.4	13.2	5.9	11.2	18.8	18.3	17.6	10.4	2.9	5.5	19.6
2.	22.8	21.7	12.4	6.4	13.4	18.1	18.2	20.1	11.2	3.7	3.7	17.7
3.	24.4	22.4	12.2	9.6	9.8	18.8	19.7	18.4	10.8	8.3	6.2	18.2
4.	24.6	24.8	10.8	8.8	12.8	16.6	19.8	18.6	13.6	7.1	7.4	17.6
5.	23.2	25.9	10.9	8.2	13.8	18.1	20.2	19.5	14.1	8.1	9.8	16.7
6.	23.2	23.1	10.3	8.4	12.5	18.9	19.9	19.1	13.6	5.7	9.1	16.9
7.	24.2	23.8	11.3	7.2	11.8	19.4	18.7	19.5	12.0	7.3	6.3	17.4
8.	24.5	22.4	12.4	8.8	11.3	20.6	17.7	19.6	11.9	4.6	5.4	17.2
9.	23.6	21.7	12.6	5.4	14.1	20.4	18.7	19.4	10.7	3.5	4.8	18.6
10.	23.4	23.8	13.3	4.9	12.2	21.3	20.4	18.8	11.8	3.4	6.3	18.4
11.	20.8	19.8	11.6	4.8	11.9	19.8	15.9	17.5	9.9	2.8	5.5	17.4
12.	19.3	22.6	12.6	4.9	11.9	18.7	20.9	18.1	11.5	2.5	4.6	17.4
T _{gav} (°C)												
1.	38.1	30.0	16.8	18.4	23.6	24.1	27.0	25.7	17.1	7.9	9.5	27.3
2.	34.6	29.8	17.9	15.4	28.2	25.1	28.8	32.8	17.1	11.3	9.1	23.8
3.	41.2	30.3	20.9	12.9	24.8	25.5	30.4	27.7	16.3	7.9	19.9	23.6
4.	42.7	37.8	22.4	20.1	26.1	26.6	32.0	27.5	14.1	9.8	8.3	23.2
5.	40.5	37.3	23.2	19.7	30.1	27.5	30.7	29.4	14.9	13.1	10.1	21.9
6.	39.6	33.9	25.0	17.9	26.7	26.9	31.8	29.2	15.1	13.4	6.6	22.2
7.	42.4	33.4	25.5	19.4	29.3	27.9	32.9	29.5	17.3	11.7	15.1	22.9
8.	39.2	31.2	22.2	16.2	33.4	26.0	31.7	33.0	16.4	8.1	15.4	22.5
9.	40.2	35.0	18.7	16.3	29.6	25.1	30.4	30.9	18.2	8.4	13.2	23.7
10.	39.1	33.5	19.7	15.5	27.4	24.7	32.3	28.7	16.2	6.4	20.3	25.4
11.	39.6	32.4	20.0	14.9	19.7	23.6	26.7	25.0	17.9	9.6	11.1	24.3
12.	35.1	33.3	22.3	16.1	24.7	25.6	33.4	25.8	16.7	6.9	7.9	24.4
T _{aav} (°C)												
1.	27.3	29.0	17.7	7.0	14.6	24.4	28.6	26.9	11.6	8.0	9.5	19.1
2.	35.3	31.3	17.9	7.3	14.7	24.2	29.6	28.6	13.2	8.9	13.6	20.7
3.	36.3	31.8	16.7	13.8	14.2	24.8	30.9	28.2	12.4	8.4	11.6	21.9
4.	34.1	41.9	15.8	13.4	18.7	22.8	30.7	27.7	17.4	11.1	13.4	21.1
5.	33.5	40.9	14.0	12.3	19.7	22.1	29.2	28.3	17.0	10.1	15.1	21.6
6.	34.4	35.6	16.1	11.6	18.1	22.4	30.9	28.5	17.5	7.9	12.2	22.1
7.	36.6	34.9	14.1	11.3	13.7	22.7	28.6	28.3	11.4	10.7	16.6	19.0
8.	36.3	32.3	15.6	10.1	11.3	23.5	27.8	27.6	13.6	5.4	13.3	22.8
9.	35.3	31.1	16.7	6.6	19.7	24.3	28.7	29.2	13.9	7.3	11.6	20.7
10.	31.9	33.6	19.6	5.7	15.7	24.6	31.9	26.8	15.9	7.2	9.2	23.9
11.	23.4	25.2	16.3	6.7	12.5	22.2	24.3	26.1	9.1	7.1	9.9	19.3
12.	29.4	30.2	16.6	8.4	14.2	21.9	32.1	27.3	11.2	4.0	7.2	19.7

Table 3 shows reference limit WBGT values according to ISO 7243:2017, depending on the metabolic rate and acclimatization or non-acclimatization of persons.

The WBGT index measurements were carried out in the environment, so if we assume that the workers work in acclimatized conditions, there is no risk of heat impact on their bodies, except for the monitoring place 5 (Factory Leoni, industrial zone) for August 2024 in the daytime period measurements and a very high metabolic level of the person, 25.9°C (Table 2) [12]. Non-acclimatized workers with high and very high physical activity, who work outdoors in Niš city, are generally in June and August 2024 at most monitoring places (WBGT_{av} from 19.3 to 25.9°C) subject to probably a small heat stress in the daytime period. The same is the

case for April 2025 at monitoring places 8 ($WBGT_{av} = 20.6^{\circ}\text{C}$), 9 ($WBGT_{av} = 20.4^{\circ}\text{C}$) and 10 ($WBGT_{av} = 21.3^{\circ}\text{C}$). Intense and very intense work to the maximum rhythm of the hands and body; carrying heavy material; working with a shovel and a blacksmith's hammer; intense clutching or digging; climbing stairs or ladders; walking at a speed greater than 5.5 km/h on a flat surface, etc., is characterized by a high and very high metabolic level of workers [15]. In the evening measurement period, the limit reference values exceeded in non-acclimatized persons with a very high metabolic level ($WBGT_{ref} = 20.0^{\circ}\text{C}$) occur in June 2024. at monitoring places 5, 10, and 12 ($WBGT_{av}$ from 20.2 to 20.9 $^{\circ}\text{C}$) and in August 2024. at monitoring place 2 ($WBGT_{av} = 20.1^{\circ}\text{C}$), as can be seen from Tables 2 and 3. Heat accumulation in the human body leads to dehydration, rashes, cramps, fainting, exhaustion, and heat stroke [15]. In addition, heat-related disorders of the workers, such as fatigue and sleepiness, can cause distraction and error and thus affect the worker's ability to work and productivity. For the worker to show satisfactory work performance, the heat generated from physical activity must be released by lowering the ambient temperature [18]. When the effective temperature exceeds 25 $^{\circ}\text{C}$, worker productivity decreases, while at temperature values above 33 $^{\circ}\text{C}$, productivity decreases by half [19].

Table 3 Reference limit WBGT values for acclimated and non-acclimated people for metabolic level classes

The class (metabolic level)	Metabolic level (W)	Reference limit WBGT values ($^{\circ}\text{C}$)	
		Acclimatized persons	Unacclimatized persons
0 (resting)	115	33	32
1 (low metabolic level)	180	32	29
2 (moderate metabolic level)	300	28	26
3 (high metabolic level)	415	26	23
4 (very high metabolic level)	520	25	20

The American Conference of Governmental Industrial Hygienists (ACGIH) prescribes a workplace threshold limit value (TLV). The time-weighted average WBGT value, according to ACGIH [14], is used if work and rest are distributed over more than one location. Depending on the percentage of work and regeneration and work intensity, TLV values are defined, with the lowest values for heavy work (50 to 75% work and rest cycle), 27.5 $^{\circ}\text{C}$ and very heavy work (25 to 50% work and rest cycle), 28.0 $^{\circ}\text{C}$. The $WBGT_{av}$ values in Table 2 do not exceed the TLV values under conditions where workers are in standard clothing and acclimatized to the heat. Under these conditions (work and rest cycle, workload), the action limit for non-acclimatized healthy and hydrated workers is 24.0 and 24.5 $^{\circ}\text{C}$ [14]. Thus, workers who performed work outdoors during the daytime period of June 2024 were exposed to a low risk of heat stress at monitoring places 3, 4, 7, and 8 and in August 2024. at monitoring places 4 and 5 ($WBGT_{av} > 24.0^{\circ}\text{C}$).

From this analysis, it is concluded that workers during hard and very hard work in non-acclimatized conditions in June and August 2024, primarily in the daytime, can accumulate heat that exceeds the limits according to TLV values [14], which can lead to thermal disorders of the organism. This fact is supported by high T_{gav} and T_{aav} values in June - daytime period: $T_{gav} = 34.6$ to 42.7 $^{\circ}\text{C}$, $T_{aav} = 23.4$ to 36.6 $^{\circ}\text{C}$, evening period: $T_{gav} = 26.7$ to

33.4°C, $T_{\text{aav}} = 24.3$ to 32.1°C, and in August - daytime period: $T_{\text{gav}} = 29.8$ to 37.8°C, $T_{\text{aav}} = 25.2$ to 41.9°C, evening period: $T_{\text{gav}} = 25.0$ to 33.0°C, $T_{\text{aav}} = 26.1$ to 29.2°C.

Monitoring people's exposure to temperature, relative humidity, and airflow velocity can give a realistic picture of the impact of heat stress on them. In the Republic of Serbia, the Rulebook on preventive measures for safe and healthy work at the workplace [20] defines the values of temperature, relative humidity, and airflow velocity that ensure safe and healthy work indoors. Relative humidity has an impact on human health, and the optimal relative humidity for the workplace is in the range of 40 to 60%. The ideal lower limit of relative air humidity is reduced to 30% for heavy and very heavy work and 20% for work in the environment. At high temperatures, the relative humidity of the air should be reduced because a person may feel exhausted. At a relative humidity of over 60%, sweating and heat release become difficult, and the person's body temperature increases [18,19].

In June 2024, values exceeded the relative air humidity of 60% during the daytime at certain monitoring places. The relative humidity of the air in the daytime and evening periods in August 2024, February, and April 2025 falls below 20% relative humidity at all or individual monitoring places. In conditions of less than 40% relative humidity due to dry air, sores in the throat and nose are possible [18, 19]. Airflow velocity was not detected at most monitoring places; it was zero, while in cases where it was detected, it ranged from 0.1 to 1.1 m/s.

The obtained average WBGT, T_g , T_a , reference WBGT limit values, threshold WBGT limit value, and values of relative air humidity in June and August 2024 for high and very high metabolic levels of unacclimatized outdoor workers indicate a low risk of heat stress in the summer period. This is expected because high air temperature and WBGT index values are reached during the summer.

CONCLUSION

Nowadays, the expansion of cities and infrastructure, the growth of traffic, the widespread production of technological devices, along with phenomena such as ozone layer depletion and the greenhouse effect, have significantly increased the presence of potential pollutants and physical hazards in the environment.

The paper identified a small risk of heat impact on humans during the day and evening in the summer months. The measured values are generally within the prescribed limits so outdoor workers can feel comfortable in their working conditions. This, in turn, affects their physical and mental health and prevents the occurrence of accidental situations and serious diseases. Certain microclimate parameters, heat indices, temperature and air humidity clearly show that in June and August 2024, milder symptoms of heat stress may occur in non-acclimatized workers during heavy and very heavy outdoor work. People who work outdoors in the summer for medium- and low-intensity work are not at risk of heat stress.

Depending on the outdoor workplace, people can be protected by appropriate personal protective equipment, reduced exposure to direct sunlight, and increased rest time compared to working time.

Based on the analysis, it can be concluded that the microclimatic parameters (heat, humidity, and airflow velocity) can have a negative effect on the health of the working population of the city of Niš in the summer months.

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