Interreg Danube Region

Co-funded by the European Union

Be Ready

Urban heat islands vulnerability and risk assessment

Capital City Podgorica

Specific objective 1	Provide assessment and operational instruments to cities to better understand UHI drivers & effects
Activity 1.3.	Testing the methodology and tools: conducting vulnerability and UHI risk assessments in the partner cities
Deliverable 1.3.1	City reports from UHI risk assessment
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History

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List of Abbreviations

UHI	Urban Heat Island
LV (DSV)	Limit value (daily mean value)
GV (MD8hSV)	Limit value (max, daily eight-hour mean value)
GV	Limit value (annual mean value)
CV (MD8hSV)	Target value (max, daily eight-hour mean)

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GLOSSARY

Adaptation: Adaptation in natural or human systems in response to observed or expected climate change or its impact. Adaptation mitigates damage (risks) or takes advantage (opportunities). There are several types of adaptation, including those expected, independent and planned (IPCC, 2007; Ribeiro et al. 2009). When the term adaptation is used in this report, it refers to a planned adaptation – i.e. an adaptation that is the result of a deliberate political decision.

Adaptation capacity (in relation to climate change impacts): The adaptation capacity describes the ability of a system to adapt to climate change (including variability and climate extremes) to mitigate potential damage, exploit opportunities and cope with consequences.

Impact of climate change: Impact or consequences of climate change on natural or human systems (IPCC, 2007).

Extreme Weather Conditions/Events: Events associated with extreme weather conditions, such as heat, thunderstorm, or heavy rainfall, that occurs infrequently in a specific place and time (Birkmann et al. 2011). The definition of "rare" varies, but an extreme weather event is usually less common than the 10^{th} or 90^{th} percentile of probability observed as a function of density. By definition, characteristics of what is considered extreme weather can vary from place to place in absolute terms.

Effect of heat island or urban heat island: This effect describes possible temperature differences between rural and built-up urban areas. The effect can be explained by the absorption of solar radiation by materials in cities (e.g. dark surfaces: tar, etc.). In addition, in cities buildings block air exchange with the outside and cooler surroundings.

Receptor: Receptors describe the local physical characteristics and socio-economic conditions of cities and regions affected by the weather. These include the main functions and characteristics of the city such as population, infrastructure, built environment, economy and natural resources.

Vulnerability: Vulnerability is the degree to which a particular system is susceptible to (or unable to cope with) the negative effects of climate change, including variation and climate extremes. Vulnerability is a function of the character, size or rate of climate change and the variations to which a particular system is exposed, its sensitivity and its adaptation capacity.

Risk: In the method used in Podgorica, "risk" is a combination of current vulnerability (based on the current state of the climate) and potential future impacts of climate change (concluded from climate change trends). Often, the term risk is defined as a combination of the probability of occurrence and the magnitude of the consequence or hazard. In the method used here, the probability of occurrence is not evaluated, as the impact of climate change is based on tendencies and qualitative descriptions. Uncertainties of climate change projections are, at least for some climatic parameters, very high (uncertainties from scenarios, models or unreliability of sampling).

Urban heat island: An urban heat island is a phenomenon that shows that certain urban areas are significantly warmer than the surrounding rural areas. This phenomenon occurs due to the high concentration of concrete, asphalt, buildings and other heat-absorbing and radiating infrastructures.

1. Introduction

ABOUT THE PROJECT

Urban heat islands (UHI) are the common challenge of the project that 19 partners and 9 ASPs from 12 countries will tackle with the aim to strengthen the preparedness and adaptive capacity of the society to cope with impacts of climate change and foster resilience at city level. The project approach will allow partners, to take targeted, small powerful, context-based measures to deal with UHI in critical urban areas. City pilots will test solutions in three areas: “green acupuncture” (vegetation-based interventions); “white acupuncture” (based on innovative surfaces and materials); and “blue acupuncture” (novel uses of water resources). The approach of jointly developing, testing and evaluating solutions contributes to most effective use of shared expertise for better understanding the effects of UHI in and building institutional capacity at local/regional level, for policy development and practical interventions.

The capital city of Podgorica as a partner participates in the implementation of a project Be Ready – urBan hEat islands Resilience, prepAreDness and mitigation strategY within the Danube Transnational Programme.

The lead partner organization in the implementation of this project is the City of Sofia Development Agency.

The aim of the project is to promote climate change response capacities in the Danube region and disaster management at transnational level in relation to environmental risks based on an ecosystem approach.

The common challenge of all 19 partners and 9 associated partners in 12 countries (Bulgaria, Czech Republic, Romania, Moldova, Serbia, etc.) in the implementation of project activities is to tackle issues related to urban heat islands and define climate innovative solutions through applicable policies, programs, spatial plans, etc.

Within the project, the project partners developed a Methodology with 4 groups of tools on the basis of which the Urban Heat Island Risk and Vulnerability Assessment is made for the specific area in the territory of the Capital City of Podgorica (hereinafter: the Assessment).

After analyzing the structure of urban settlements in Podgorica and conducting an online survey, it was unequivocally determined that the area called City Kvart is potentially the most pronounced with parameters related to the subject of the Assessment, and for this reason that part of the city is treated with this document.

ABOUT THE REPORT

The main aim of the document Deliverable 1.3.1 City reports from UHI risk assessment is to test the join methodology and tools developed for 4 vulnerability elements (figure 1): exposure, sensitivity, preparedness and adaptive capacity and risk groups (Deliverable 1.1.1. Shared methodology and tools for UHI vulnerability and risk assessment).

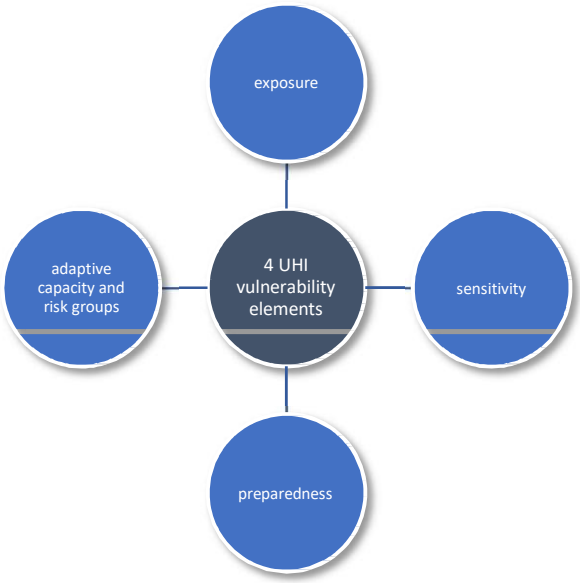

Figure 1: UHI vulnerability elements

Project partner cities are carrying out UHI risk assessments for their cities as a preparatory activity for the implementation of pilot actions as part of the Specific objective 2 Co-creating, testing, and validating jointly developed solutions to mitigate UHI effects in cities. The assessments draw upon historical data and statistics, as well as from other information and data from different sources.

The risk assessment is carried out with the support of the local coalitions (Activity 1.3), which enables community engagement and raising awareness city-wide about the project objectives and expected results.

The partner cities choose which city zones to be included in the risk assessment, but must ensure comparability of the results and of the applicability as well as usability of the tools, which is why it is expected the UHI assessment to cover an area with high density of construction; an industrial zone; a densely populated area with mid- to low-income residents. Task leaders are the partner cities (conducting the risk assessment and drafting the resulting report; knowledge partners provide consultation and feedback.).

Each city is planned to develop one report, and in this task the cities are supported by knowledge partners. The city reports include an analysis of the usability of the tools and recommendations for adjustment of the methodology, where needed. The reports feed into the City Climate Sandbox concept and pilots.

AREA OF THE INTERVENTION

Territorial context

City: Capital City Podgorica

Municipality: City Kvart neighbourhood

Region: /

State: /

Country: Montenegro

Statistical data – City Kvart

Surface Area 0.9 km^2

Population: 3,370

GDP per capita (€)[1]

Minimum Wage (€/year)[2]

ABOUT THE CITY

Note: Some of the data used for this Assessment concerning the Capital City Podgorica refer to the situation before the formation of new local self-government units Tuzi and Zeta, which previously were Podgorica municipalities, and until the moment of drafting this document, no territorial demarcation was completed between Capital City Podgorica and the municipalities of Tuzi and Zeta.

The administrative boundaries of the Capital City Podgorica extend to the southeastern part of the territory of Montenegro, i.e., within the coordinates 42° 11' and 42° 43' N and 19° 02' and 19° 43' E.

Podgorica occupies an area of 1,441 km^2, which represents 10.43% of the territory of Montenegro, which is bordered to the east by the Republic of Albania, to the south and southeast by the municipalities of Tuzi and Zeta, to the west by the Capital of Cetinje and the municipality of Danilovgrad, to the north by the municipalities of Kolašin and Andrijevica. The distance from the sea is 40 km straight line. According to the 2023 census, the Capital City has a population of 179,505. The population of the Capital City of Podgorica makes up 28.78% of the total population of Montenegro. With the adoption of the Law on the Capital City on October 27, 2005, the former Municipality of Podgorica was pronounced the Capital City of Podgorica[3].

The capital is located at an average altitude of 52 m above sea level and in terms of its geographical characteristics, this area makes an integral part of the Southern Dinarides, which are characterized by distinct geographical forms. The area clearly distinguishes between the plain and the hilly-mountainous

[1] Data not available
[2] Data not available
[3] Official Gazette of the Republic of Montenegro, No. 65/05

part, i.e. three distinct relief groups, which are more or less different from each other in other ecological characteristics (climatic, pedological).

Figure 2: The territory of Podgorica within Montenegro

Relief – Geological and geomorphological characteristics

The geological background of this area consists of terrains that build Cenozoic fluvioglacial quaternary sediments in plain areas and Mesozoic sediments of Cretaceous age that characterize the area of urban and surrounding hills. Morphology, geological structure, climate, etc. have conditioned the city's terrains with various physical-geological processes and phenomena. The developed processes are: karstification of limestone and limestone-dolomite masses, undercutting of river banks with the creation of subcaps of different dimensions in terrace sections, and sufosia (filtration destruction of the environment) were also observed. The dynamics of erosion and denudation processes is relatively poorly expressed, except in the domain of riverbeds, and the phenomena of sliding and dredging of significant proportions are absent. A special place is occupied by the flooding of parts of the surfaces along the alluvial plane of Ribnica.

The hilly or transitional area edges the plain part in the form of eroded and heavily bare hills up to 800 m altitude. Building on the area of low hills, the mountainous area climbs steeply, but also quite abruptly, because at a relatively short distance from the plain it reaches a height of over 2,000 m (Žijevo 2,183 m, Komovi 2,484 m, etc.). The largest part of the city lies on the fluvioglacial terraces of the Morača

River and its left tributary Ribnica, between Malo brdo (205 m) and Gorica (131 m) in the north and Dajbabska Gora (170 m) and Donja Gorica (102 m) in the south and southwest, respectively. In addition to the the hills, from the level of the river terraces, the limestone elevations of Kruševac break out, barely noticeable on the right side of the Morača and Ljubović rivers (100 m) on the left side of this watercourse. The data indicate that the given area consists of limestone rocks, that is, deposits that formed in the Mesozoic, but which suffered certain changes during the Tertiary period. In the process of creating certain shapes, the appearance of caves with characteristic features of crags, sinkholes, bays and karstic valleys stands out.

From a micro seismic point of view, the territory of Podgorica is located within an area with very pronounced seismic activity. From the point of view of seismic in this area, there is an intense coupling of forces, and occasional phases of increased tension affect the differential lifting or lowering of blocks.

In geoseismic terms, this territory cannot be considered favorable, as it is located in a zone of high geoseismic risk. As a more favorable fact, the depreciation role of thick quaternary deposits can be considered, but this does not prevent the zone from being marked unstable. The 1979 earthquake, as well as those previously recorded, show that earthquakes of 8 to 9 degrees of the Merkalli scale can occur in this area. Therefore, the construction and exploitation of facilities must be in accordance with the applicable regulations and principles for antiseismic design and construction.

Hydrological characteristics

The rivers Morača, Ribnica, Zeta, Sitnica and Cijevna represent a special value and natural beauty of the city. What makes these rivers specific are their limestone beds, rocky canopies, caves and picturesque canyons, with plenty of beaches, rapids, bends and whirlpools.

Surface waters

The territory of the Capital City is very rich in surface watercourses. Riverbeds divide the city territory into three parts. Morača is the main watercourse on the territory of the Capital City and also the main watercourse of the Adriatic Basin in Montenegro. Morača is formed above the village of Ljevišta (970 m), by connecting the water coming from the Grlo spring (located in the pleistocene cirque Vragodo, at 1,370 m), and the Koritski and Rupočajski stream, and after 2.5 km it gets the waters of the Javorski stream, on the left. In addition to the numerous smaller streams that feed Morača, especially in the rainy season, its left tributaries are significant: Koštanica, Sjevernica, Kruševački potok, Mala Rijeka, Ribnica and Cijevna, as well as the right ones: Ratnja Rijeka, Ponja, Mrtvica, Ibrištica, Bogotovski potok, Zeta and Sitnica. The area of the Morača basin to the mouth of Zeta (Vranićka Njiva) is 1,023.7 km^2, while the total area of the basin to the mouth of Skadar Lake is 3,260 km^2 (Hrvavčević, 2004).

The Zeta River is the main tributary of Morača, which has a special significance due to water recharge. Ribnica appears in the form of a broken spring in the area of the so-called Ribnica springs located in the Ribnica riverbed itself, at elevations from 60 to 100 m above sea level and in the length of up to 5 km. Nevertheless, upstream of these springs, a dry riverbed with the occasional appearance of water in a favorable precipitation regime is clearly defined. Traces of the bottom and banks of this riverbed exist all the way to the area of Dinoški Polje near the Cijevna River. The total length of the Ribnica River from the confluence to the Ribnica springs is about 4.5 km. The length of the course with the dry riverbed in the stretch upstream from Ribnik springs to the border of its basin in the area of the sinkhole zones of

the River Cijevna is about 5 km. Its water regime is directly dependent on precipitation and the variable abundance of springs, so that it dries out during most of the summer months.

Sitnica is a tributary of the Morača River, and its course begins at the border of Lješkopoljski lug and Lješkopolje. The lower course is often without water, because the river dries up in that part.

Mala rijeka flows through a unaccessibly canyon towards Bioč, where it flows into Morača. During the summer it dries out, and during the autumn and spring it acquires a torrential character.

In addition to the aforementioned rivers, the territory of Podgorica also includes the upper parts of the Tara and Mojanska river basins.

Tara springs on the slopes of Komov and Kučke mountains, by connecting two mountain rivers Veruša and Opasanica, and the length of the course belonging to the territory of the city is 14 km.

Figure 3: Ribnica River mouth

The territory of Podgorica also includes two mountain (glacial) lakes: Bukumir and Rikavačko, located in the Kuč mountains.

Groundwater

In the karst terrains of Podgorica, groundwater is present in the form of compacted aquifers. This is the case with the terrains of the Zeta plain; alluvial sediments in the riverbeds of the watercourses (Morača with tributaries) and in the terraces of these watercourses, and under the regime of the waters of the riparian watercourse. Groundwater from the terrain around Podgorica is drained to the main erosion bases. The main erosion base for the terrain in question is Skadar Lake with its tributaries, i.e. the main tributary of the Morača River. In the Morača River basin, groundwater, its eastern territory, outside the Zeta Plain, is drained in the watercourses of the Morača tributaries: in the rivers Cijevna, Ribnica and Mala, as well as, partly, in the Morača watercourse itself. The terrains of the Capital City of Podgorica west of the Morača watercourse are drained directly in its watercourse and in the watercourses of Zeta and Sitnica. In the Zeta plain itself, dynamic reserves of groundwater of the plain are flowing and renewed, through numerous permanent and occasional karst springs, estavelles and along the southern edge of the plain on the shore of Skadar Lake, through occasional and permanent springs and subductions.

Based on the conducted researches of underground connections in the karst terrains of Podgorica, it has been understood that these speeds are very variable and that they range from 1 to 11 cm/s. In the Zeta Plain, groundwater generally moves from the northeast, north and northwest towards the Skadar Lake basin in the northern part of the plain, and in the southern part of the plain, this flow is generally directed towards the south.

The city of Podgorica and its suburban settlements are supplied with water through a water supply system with several locations. The narrower and wider area of the site is supplied with water from the source Zagorič and the source Mareza. The Zagorič springs are located in the settlement of the same name. It consists of 4 wells ø 500-600 mm, depth 50-75 m. In total, some 400 l/s is delivered from this source to the water supply system of Podgorica. This water supply system is in the ring with the water supply system from the source Mareza, which is the most important source in the water supply system of Podgorica. The minimum yield of the source is some 1.7 m^3/s, with the maximum installed capacity of 1,150 l/s.

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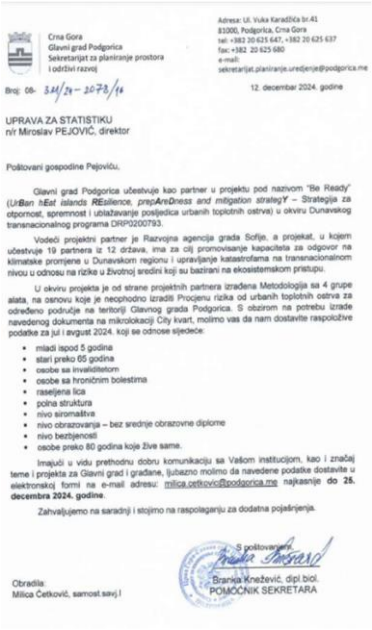
2. Methodology of the assessment

SUMMARY OF THE PROCESS

PREPARATORY PHASE

At the initial phase, we analyzed the situation related to the various stakeholders that can send to us all important data for developing of the Risk assessment for UHI in City Kvart and we prepared the official requests that were sent to all these institutions. On figure 4, one of that as example.



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Broj: 06- 341/24- 2073/14

12. decembar 2024. godine

UPRAVA ZA STATISTIKU
n/r Miroslav PEJOVIĆ, direktor

Poštovani gospodine Pejoviću,

Glavni grad Podgorica učestvuje kao partner u projektu pod nazivom "Be Ready" (*UrBan hEat islands REsilience, prepAreDness and mitigation strategY* – Strategija za otpornost, spremnost i ublažavanje posljedica urbanih toplotnih ostrva) u okviru Dunavskog transnacionalnog programa DRP0200793.

Vodeći projektni partner je Razvojna agencija grada Sofije, a projekat, u kojem učestvuje 19 partnera iz 12 država, ima za cilj promovisanje kapaciteta za odgovor na klimatske promjene u Dunavskom regionu i upravljanje katastrofama na transnacionalnom nivou u odnosu na rizike u životnoj sredini koji su bazirani na ekosistemskom pristupu.

U okviru projekta je od strane projektnih partnera izrađena Metodologija sa 4 grupe alata, na osnovu koje je neophodno izraditi Procjenu rizika od urbanih toplotnih ostrva za određeno područje na teritoriji Glavnog grada Podgorica. S obzirom na potrebu izrade navedenog dokumenta na mikrolokaciji City kvart, molimo vas da nam dostavite raspoložive podatke za jul i avgust 2024. koji se odnose sljedeće:

- mladi ispod 5 godina
- stari preko 65 godina
- osobe sa invaliditetom
- osobe sa hroničnim bolestima
- raseljena lica
- polna struktura
- nivo siromaštva
- nivo obrazovanja – bez srednje obrazovne diplome
- nivo bezbjednosti
- osobe preko 80 godina koje žive same.

Imajući u vidu prethodnu dobru komunikaciju sa Vašom institucijom, kao i značaj teme i projekta za Glavni grad i građane, ljubazno molimo da navedene podatke dostavite u elektronskoj formi na e-mail adresu: milica.cetkovic@podgorica.me najkasnije **do 25. decembra 2024. godine**.

Zahvaljujemo na saradnji i stojimo na raspolaganju za dodatna pojašnjenja.

S poštovanjem,

Branka Knežević, dipl.biol.
POMOĆNIK SEKRETARA

Obradila:
Milica Četković, samost.savj.I

Figure 4: Example of a letter sent to participating organizations

EVENTS/ACTIVITIES

On October 24, 2024 an event was held in Podgorica, in which the identified stakeholders from both the local and national levels participated, and whose participation can contribute to the reduction of the harmful effects of climate change, i.e. the negative impact of hot islands. At this event, it was agreed to send letters to all partners demanding available data and information.

The requests are sent to the following organizations:

1. Institute of Hydrometeorology and Seismology of Montenegro
2. Faculty of Civil Engineering, University of Montenegro
3. City's Head Architect's Office, Capital City Podgorica
4. Secretariat for transport, Capital City Podgorica
5. Zelenilo d.o.o., Podgorica (municipal greenery management company)
6. Vodovod i kanalizacija d.o.o., Podgorica (municipal water supply and sewerage company)

7. Secretariat for social welfare, Capital City Podgorica
8. Agencija za stanovanje d.o.o., Podgorica (municipal housing agency)
9. Directorate for climate changes and environmental protection, Ministry of ecology, sustainable development and the development of the North of Montenegro
10. Environmental Protection Agency of Montenegro
11. Centar for Climate Changes, Natural Resources and Energy, University of Donja Gorica, Podgorica
12. Institute for Emergency Medical Care of Montenegro
13. Public Institution Health Center, Podgorica
14. Statistical Office of Montenegro – MONSTAT
15. Montenegrin Center of Energy Efficiency
16. Protection and rescue service, Capital City Podgorica
17. Non-governmental Association Biciklo.me, Podgorica
18. Secretariat for Spatial Planning and Sustainable Development, Capital City Podgorica

On December 5, 2024, a public event was held that brought together individuals, citizens, organizations and institutions focused on climate change and its impact on life in cities. It was an opportunity to discuss both the project itself and the practical solutions, challenges and problems that citizens face due to excessive temperatures in urban areas. Expert opinions were exchanged, as well as those of students and citizens who increasingly see the negative consequences of the UHI. In addition, the results of a survey on the phenomenon of heat urban islands were presented, which showed that the public is quite familiar with this phenomenon and that they mostly map challenges and recognize potential solutions in the same way. In the context of the story of urban heat islands, the results of a survey were also presented, which showed that the City Kvart is a settlement in Podgorica that most citizens recognize as a heat island. There are also parts of the city such as Trg nezavisnosti (Independence Square), Stari aerodrom, Zabjelo. When asked whether urban heat islands affect the formation of tropical nights, over 90% of respondents said yes. In addition, more than 90% of respondents answered that the density of construction and the coefficient of green cover affect the formation of heat islands in cities. As potential solutions for reducing negative effects, citizens mostly pointed out the increase in the green fund and sustainable planning when it comes to the construction of facilities, but also better regulation of stationary traffic.

3. Urban climate

GENERAL INFORMATION ABOUT URBAN CLIMATE TRENDS

The Institute of Hydrometeorology and Seismology is the competent administrative authority that, with the application of scientific methods and knowledge, prepares relevant data related to this Assessment. The Institute monitors the state of the climate, activities in the field of climate change, including climate variability and climate extremes (heat waves, droughts, etc.), and monitors meteorological processes and their phenomena. The following tabular overview shows the data of the Institute that are relevant from the aspect of the preparation of the Assessment.

Podgorica	2024	
Measurement	July	August
Average monthly relative air humidity (%)	42	42
Average monthly air temperature (°C)	39.9	39.5
Monthly rainfall (mm)	21.6	45.5
Highest daily air temperature (°C)	41.1	41.1
Lowest daily air temperature (°C)	17.8	20.6
Average daily air speed (m/s)	3.4	3
Number of tropical days	29	31
Number of tropical nights	30	31
Average global radiation (W/m2)	328	272
Monthly rainfall (mm)	July	August
2020	29.2	112.4
2021	19.6	45
2022	6.9	18.9
2023	34.3	191.5
2024	21.6	45.5

Table 1: Podgorica meteorological data

Air Temperature

Podgorica is characterized by the immediate influence of the Mediterranean climate or the proximity of the Adriatic Sea and the influence of the mountainous hinterland, which results in the appearance of an altered Mediterranean type of climate with its specific characteristics, warm and hot summers and mild and rainy winters. With its structure and diversity of human activities, the city is changing the environment and the natural climate. As a result, a multitude of microclimate units are created, and the city itself gets a characteristic local climate.

Using data from the Landsat 8 and Modis satellites, the figure below shows the land surface temperature (LST), on 6 July 2024 in Podgorica (data source for LST: RSLab). This example points to the existence of urban heat islands in the city owing to the great warming of the earth's surface by solar radiation, urbanization and global climate changes due to the rise of greenhouse gases. The figure below shows that the temperature of the earth's surface on July 6, 2024 at 09:21 in certain parts of the city was as high as 48°C.

Figure 5: Land surface temperature in Podgorica

HEAT WAVES

Multiple heat waves were recorded in Podgorica in 2003, 2004, 2005, 2006, 2007, 2011, 2012, 2013 and 2014. In these periods, records were also measured in the maximum daily temperature in Montenegro: 42.2°C (August 2003), 44.8°C (August 2007) and 44°C (August 2012). In 2011 and 2012, the number of tropical days and tropical nights was higher than the climatological normal. Heat waves caused increased heat stress among the population, with a particularly negative impact on the health of vulnerable groups (the elderly, children, people with cardiovascular and heart diseases and mental patients). In addition, there was a decrease in work productivity, especially in the sectors of agriculture, infrastructure and construction, a decrease in other economic activities (trade, utility services), increased electricity and water consumption.

The urban parts of Podgorica, Tuzi and Golubovci were most affected, as well as city parks (Njegošev, Karađorđev, Kraljevo, Central, Ivanov and Kruševac), forest park, block and linear greenery.

DROUGHT

The period from 1 June to 10 September 2003 was marked by a drought, which developed into agricultural drought (adopted terminology). A very warm spring and an extremely warm summer contributed to the drought.

In the period from 1 June to 19 October 2007, the maximum number of 56 consecutive days without precipitation was recorded, which is the third record number and equal to the values from 1988 and 1989. In 2007 it was an extremely warm spring, summer and winter.

Extreme dry conditions were recorded throughout 2011. The drought has developed to hydrological. The mean air temperature was above the average for most of the year. November 2011 was the driest observed since 1970. The spring was very warm, the summer extremely warm, and both the autumn and winter in the category of warm.

During the 2012 summer season, conditions were very dry. Due to the hydrological drought in the previous year (2011), suitable conditions for large-scale forest fires were created. Spring was very warm, and summer, autumn and winter extremely warm.

Droughts caused restrictions in the availability of drinking water, while agricultural production in suburban settlements has suffered extensive damage. The water level in the rivers reached minimum values. Minor flows have dried up. Damage to biodiversity wad recorded, as well as drying of vegetation less resistant to high temperatures and with higher water needs.

As a side effect of drought, overheated asphalt surfaces further increased air temperatures. Green and park areas in the city were particularly affected, as well as home gardens and house yards in suburban settlements. Operation of the wastewater treatment plant faced difficulties too.

FIRE

As a result of the heat waves and dry periods, several large-scale fires were recorded in Podgorica, namely: on 4 August 2007, 24 August 2011, 16 July 2012, 24 July 2012 and 31 July 2013.

Surface Temperature

The data shows that the biggest number of sunny hours was, as expected, recorded in the summer months, while the average monthly value, recorded for 2008, is 206.5 hours. The warmest year in Montenegro was 2003, when Podgorica recorded a period of 100 tropical days (days with a maximum temperature greater than or equal to 30°C) continuously. The highest daily temperature in Podgorica of 44.8°C was measured in August 2007. The period of average daily temperatures above 0°C lasts over 320 days a year, and above 15°C about 180 days.

Solar Radiation

In Podgorica, the mean annual temperature is 15.5°C with a minimum of 5°C in January and a maximum of 26.7°C in July. Podgorica is one of the hottest cities in Europe. The mean annual number of tropical days (maximum temperatures above 30°C) here is from 50 to 70 days.

Humidity

The average relative humidity for Podgorica is 63.6%.

The mean annual precipitation is 136.4 l/m^2, and the relative humidity is approximately 59.6%. The average number of rainy days is about 115, i.e. over 260 days without precipitation.

Wind Speed and Direction

In the area of Podgorica, two of the numerous wind blowing directions are mostly weather-bearers: the winds locally called sjever ("north") and jugo ("southern one") that mostly blow between September and April. In average, there is some 60 days with wind, which has a special impact on the climate of Podgorica, affecting the subjective experience of temperature, making it a couple of degrees lower.

Precipitation

The data provided from Podgorica Water Supply and Sewerage company (Vodovod i kanalizacija) show that all atmospheric water from the area is collected in the municipal collector DN2200 mm and discharged into the Morača River. The main collector is over 6 m deep.

On the total total area of City Kvart of 18,865 m^2, there is only 13% green areas, a piece of information that differs from what is claimed by the municipal company managing the green areas (Zelenilo), since they say that there are no green areas whatsoever in this neighbourhood.

The neighboorhood is characterized by frequent flooding even at low rainfall intensity, as well as high runoff from impermeable surfaces.

Figure 6: City Kvart water supply network

Legend: Circle – manhole covers;

Purple lines – water supply network;

Cyan – residential buildings;

Red outline – City Kvart boundaries;

Basemap: OpenStreetMap

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4. Assessment of the city based on 4 vulnerability elements, exposure, sensitivity, preparedness and adaptive capacity and risk groups

EXPOSURE OF BUILDINGS AND SURROUNDINGS

Urban morphology/urban form

The research conducted by the NGO Biciklo.me from 12 to 24 November 2024 among the residents of the Capital City with the support of the Heinrich Bell Foundation Regional Office in Belgrade[4] contains the findings of a survey on the conditions for walking and cycling in Podgorica. The most important findings of the research are as follows:

- some three quarters of pedestrians and cyclists in Podgorica do not feel safe when crossing the street or cycling in the Capital City,

[4] https://biciklo.me/biciklisti-i-pjesaci-se-ne-osjecaju-bezbjedno-u-podgorici/

- as far as bicycle use is concerned, the number of those who do not feel safe increased significantly compared to the previous five years, when this percentage varied between 57% and 64%.

It is important to emphasize that out of 635 respondents, 11.6% of respondents are from City Quarter (5.8% pedestrians and 5.8% cyclists).

Building coverage ratio (BCR)

The City Quarter area covered by the Assessment is an area of 0.9 km^2, while 21 buildings in this area cover an area of 22,407 m^2.

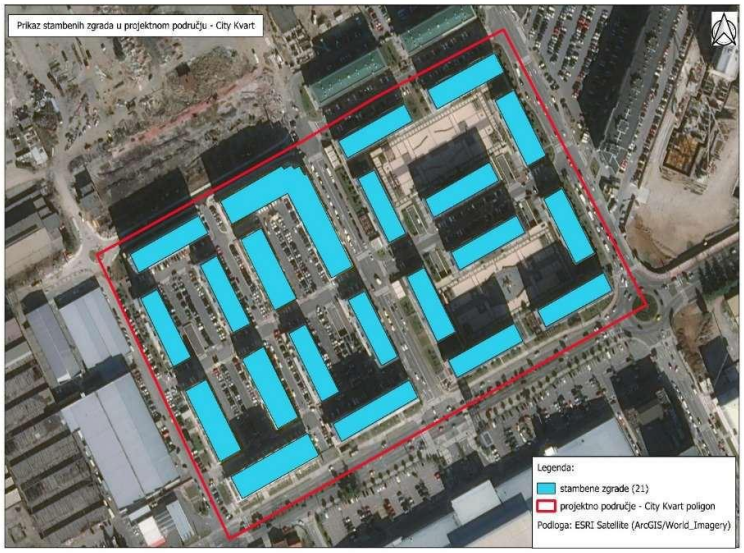

Figure 7: Residential buildings in the City Kvart neighbourhood;

Legend:

Cyan – residential buildings (21);

Red outline – City Kvart area;

Basemap: ESRI Satellite (ArcGIS/World_Imegery)

Green urban spaces and vegetation

Public green spaces and special-purpose green spaces are considered green spaces.

Public green spaces are:

- Parks (sports, memorial, botanical, entertainment, etc.);
- Green areas with squares and squares;
- Forest parks;
- Green areas along city roads, street lawns, tree lines, green lanes along paths, hedges, etc.
- Green areas along the landscaped river banks;
- Green areas next to and around residential buildings in residential areas and between blocks of residential buildings;
- Green areas surrounding memorials;
- Green areas in front of community centers.

Special-purpose green areas are:

- In the areas of health, social, educational, educational, scientific, sports and other institutions;
- In the areas of commercial and other business facilities;
- In courtyards around residential and other buildings;
- In courts intended for sports and recreation;
- Greenery in city cemeteries;
- Wind protection and ameliorative plantations, etc.

City parks (75,344 m^2), linear greenery (88,339 m^2) and block greenery (361,684 m^2) are part of Podgorica's greenery system and have a positive impact on the city microclimate by reducing the impact of high temperatures, north wind gusts, reducing noise and purifying the air from pollution.

According to the municipal company Zelenilo d.o.o., which manages the city greenery, there are no green public areas in the City Kvart. The Ministry of Ecology, Sustainable Development and Development of the North provided the authors of the Assessment that they have no usable data concerning this area.

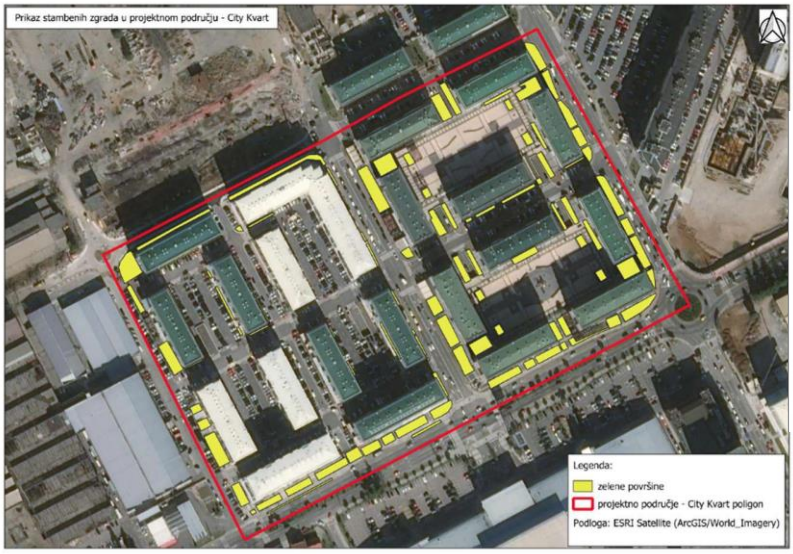

Figure 8: Green areas in City Kvart

Legend:

Yellow – green spaces;

Red outline – City Kvart area;

Basemap: ESRI Satellite (ArcGIS/World_Imegery)

Green coverage ratio

As shown in the previous figure, out of the total area of the project area under consideration, which amounts to 0.9 km^2, 8,131 m^2 are green areas.

Tree canopy coverage

It is important to emphasize that the tree rows in the City Kvart occupy an area of 121 m^2, mostly low and medium-size trees.

The municipal greenery management company Zelenilo d.o.o. Podgorica does not maintain the green areas in the City Kvart.

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Permeability of surfaces

The data for permeability of surfaces in the City Kvart is not available.

Human activities

The data for human activities in the City Kvart is not available.

Land use

The following figures (the picture and the table) show an overview of asphalt and other surfaces in the City district area:

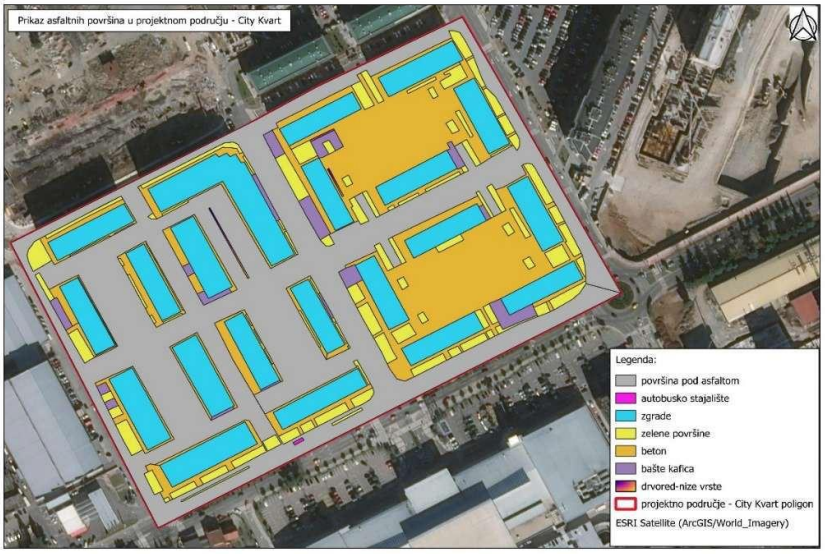

Figure 9: Sealed surfaces in the City Kvart

Legend:

Grey – asphalt;

Magenta – bus station;

Cyan – buildings;

Yellow – green spaces;

Orange – concrete;

Purple – café terraces;

Purple/red/yellow – street tree lines (low trees);

Red outline – City Kvart area;

ESRI Satellite (ArcGIS/World_Imegery)

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Figure 10: City Kvart – asphalt surfaces

Legend: Purple – asphalt surfaces;

Red outline – Sity Kvart area

Basemap: OpenStreetMap

Material	Area (m^2)
Asphalt	37,584
Building	22,407
Concrete	21,028
Green area	8,131
Cafe terrace	2,048
Tree row	121
Bus stop	17

Table 2: Coverage types in the City Kvart neighbourhood

Energy consumption of buildings

The data for energy consumption of buildings in the City Kvart is not available.

Energy consumption of transportation

The data for energy consumption of transportation in the City Kvart is not available.

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SENSITIVITY OF EQUIPMENT AND MATERIALS

Albedo (Reflectivity) Coefficient

The data for calculating the albedo in the City Kvart is not available.

Thermal Conductivity

The data for calculating the thermal conductivity in the City Kvart is not available.

Heat Capacity

The data for calculating the heat capacity in the City Kvart is not available.

Surface Temperature

The data for calculating the surface temperature in the City Kvart is not available.

Emissivity

The data for calculating the emissivity in the City Kvart is not available.

Material Condition

The data for calculating the materials' condition in the City Kvart is not available.

Coverage Area

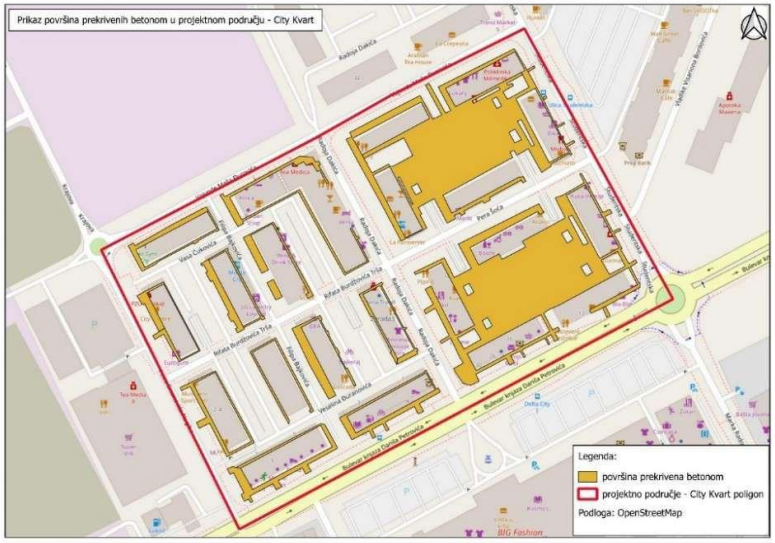

Figure 11: Concrete-covered surfaces in the City Kvart

Legend:

Yellow – concrete-covered surfaces;

Red outline – City Kvart area;

Basemap: OpenStreetMap

The Center for Ecotoxicological Testing – CETI provided the data on traffic-generated air pollution in Podgorica obtained through measuring conducted at three locations in the Capital City of Podgorica, one of which is a measuring point in the City Quarter near the street. The measurings were conducted in the III quarter of 2024 for the period July-August. The report was published on 15 August 2024.

Measuring points: On the route of Josip Broz Boulevard, near traffic roads, intersections (near the Voli supermarket), assessing the traffic-generated pollution; Zagorič neighborhood, with the measuring point in a residential district, outside the direct influence of roads, intersections and other local emitters such as gas stations, etc; **Delta City measuring point** – across the street from the City Kvart, near a traffic-heavy street.

Figure 12: Measuring points in Podgorica

Legend:

Yellow pin – measuring points

Measured pollutants

The air quality monitoring includes the measurement of basic pollutants as required by the Regulation on the determination of types of pollutants, limit values and other air quality standards[5], as shown in the following table.

No.	Formula	Name of pollutant	Measuring unit	Averaging time
1.	SO_2	Sulfur Dioxide	µg/m^3	1 hour 24 hours
2.	NO	Nitric Oxide	µg/m^3	1 hour 24 hours

[5] Official Gazette of Montenegro, No. 25/12

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3.	NO_2	Nitrogen Dioxide	µg/m^3	1 hour 24 hours
4.	NO_x	Total nitrogen oxides	µg/m^3	1 hour 24 hours
5.	O_3	Ozone	µg/m^3	8 hours
6.	CO	Carbon Monoxide	mg/m^3	8 hours
7.	PM_{10}	Suspended particles that do not exceed 10 micrometers in diameter	µg/m^3	24 hours
8.	C_6H_6	Benzene	µg/m^3	24 hours
Ananalysis of cumulative weekly samples of suspended PM_{10} particles by content of:				
7.1.	Pb	Lead	µg/m^3	7 days
7.2.	Cd	Cadmium	ng/m^3	7 days
7.3.	As	Arsenic	ng/m^3	7 days
7.4.	Ni	Nickel	ng/m^3	7 days
7.5.	BaP	Benzo[a]pyrene	ng/m^3	7 days

Table 3: Measured pollutants

Methods

For the implementation of measurements in accordance with the Rulebook on the manner and conditions of air quality monitoring[6], the methods presented in the following table are used:

Standard referent method / name	Designation
Standard method for measuring the concentration of Sulphur dioxide by ultraviolet fluorescence	MEST EN 14212
Standard method for measuring nitrogen monoxide and nitrogen dioxide concentrations by chemiluminescence	MEST EN 14211
Standard method for the determination of carbon monoxide concentration by non-dispersive infrared spectroscopy	MEST EN 14626

[6] Official Gazette of Montenegro" No. 21/11, 32/16

Standard method for determination of ozone concentration by ultraviolet photometry	MEST EN 14625
Standard gravimetric measurement method for determining the mass concentration of suspended PM_{10} or $PM_{2.5}$ particles	MEST EN 12341
Standard method for determination of benzene in ambient air by automatic pump sampling with on-site gas chromatography	MEST EN 14662-3
Standard method for determining the concentration of benzo(a)pyrene in ambient air	MEST EN 15549
Standard method for determining the concentration of Pb, As, Cd and Ni in samples of suspended PM_{10} particles	MEST EN 14902

Table 4: Standard referent measurement methods

The methods listed in Figure 14 are accredited in accordance with the standard MEST ISO/IEC 17025:2018 by the Accreditation Body of Montenegro.

Occasional measurements of ambient air quality, processing and analysis of results were performed in accordance with:

- Law on Air Protection[7],
- Regulation on the Determination of Types of Pollutants, Limit Values and Other Air Quality Standards[8],
- Rulebook on the manner and conditions of air quality monitoring[9],
- Regulation on the establishment of a network of measuring points for air quality monitoring[10].

Measuring results

This Report presents the results of air quality measurements for the third measurement cycle in 2024. The measurement results are presented in parallel with the prescribed limit/target values, as follows:

a) The table:

- Daily mean values during 14-day measurements for: PM_{10}, SO_2, NO, NO_2, NO_x, C_6H_6 and maximum daily eight-hour mean values for CO and O_3,
- Statistical processing of daily mean values of suspended PM_{10} particles, one-hour or daily values of gaseous pollutants: SO_2, NO, NO_2, NO_x, C_6H_6 and maximum daily eight-hour mean values of CO and O3,

[7] Official Gazette of Montenegro, Nos. 25/10, 40/11 and 43/15
[8] Official Gazette of Montenegro, No. 25/12
[9] Official Gazette of Montenegro, No. 21/11, 32/16
[10] Official Gazette of Montenegro, no. 44/10, 13/11, 64/18

- The content of heavy metals (Pb, Cd, As and Ni) and benzo(a)pyrene in seven-day aggregate samples of suspended PM_{10} particles.

b) Graphs

- One-hour mean values of SO_2, NO, NO_2 and NO_x,
- Daily mean values of suspended PM_{10} and SO_2 particles,
- Maximum daily eight-hour mean values of O_3 and CO.

The statistical survey of pollutants includes:

- the total number of 24-hour measurements,
- minimum, lowest 24-hour value for the specified measurement period,
- maximum, highest 24-hour value for the specified measurement period,
- daily mean concentrationvalute (hereinafter referred to as 24-hour value) for the specified measurementperiod,
- median or central value,
- the total number of one-hour measurements,
- minimum, lowest one-hour value for the specified measuring period,
- the maximum, highest one-hour value for the specified measurement period,
- one-hour mean value for the specified measurement period,
- median or central value,
- the number of exceedances of the prescribed limit value,
- statistics, maximum daily eight-hour mean values of ozone and carbon monoxide,

The tabular and graphical presentation of all examined parameters were followed by an opinion made on the basis of comparison with the Regulation standard values.

Tabular and graphical presentation of the measurement results at the location near the shopping center Delta City – across the street from the City Kvart – below.

Measuring period	PM_{10}	SO_2	NO	NO_2	NOx	C_6H_6	O_3	CO
	$\mu g/m^3$							mg/m^3
19-20 July	35.64	3.64	8.85	80.04	93.59	0.90	98.62	0.49
20-21 July	31.82	3.92	10.53	78.51	94.63	0.62	91.65	0.46
21-22 July	29.55	3.36	4.77	53.99	61.29	0.65	93.39	0.38
22-23 July	24.64	3.64	9.46	68.64	83.12	0.67	82.05	0.40

23-24 July	28.09	3.73	7.39	75.07	86.37	0.88	79.27	0.43
24-25 July	30.73	3.41	3.27	47.47	52.48	0.81	74.84	0.33
25-26 July	17.27	3.39	3.03	44.31	48.95	0.59	66.46	0.28
26-27 July	14.73	3.88	11.75	74.96	127.32	1.03	57.52	0.46
27-28 July	24.00	4.33	16.87	78.74	146.29	1.03	63.65	0.53
28-29 July	28.18	4.13	6.44	63.14	106.45	1.15	71.19	0.48
29-30 July	29.09	3.93	2.16	38.34	61.97	0.94	70.95	0.28
30-31 July	18.55	3.60	1.98	37.71	60.73	0.86	62.21	0.30
31 July – 1 August	19.73	4.27	15.22	96.47	170.89	0.97	49.69	0,64
1-2 August	34.64	3.80	2.92	24.44	41.85	1.00	105.20	0.63
GV (DSV)	50	125						
CV MD8hSV							120	
GV MD8hSV								10
GV (SGV)	40			40	30	5		

Table 5: Daily mean values of suspended PM_{10} particles and gaseous pollutants

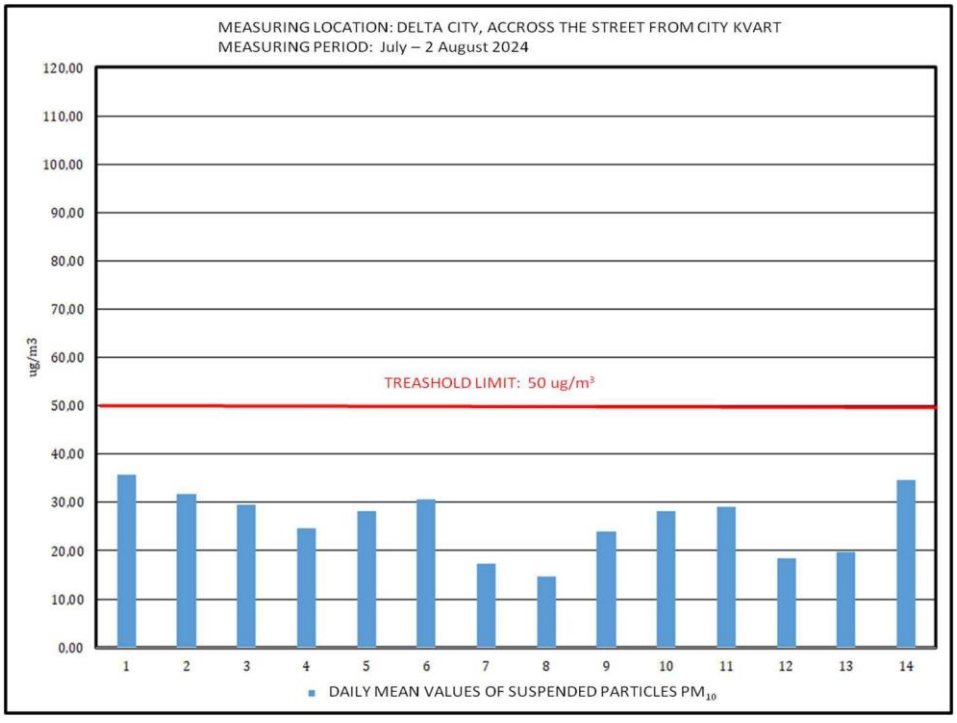

Figure 13: Daily mean values of suspended particles PM_{10}

Suspended particles PM_{10}

Number of 24-hour measurements	14
Minimum 24-hour value (µg/m^3)	14.73
Maximum 24-hour value (µg/m^3)	35.64
Mean 24-hour averaging times (µg/m^3)	26.19
Median 24-hour averaging times (µg/m^3)	28.14
Number of 24-hour LV exceedances	0
Averaging period	Threshold limit
Daily mean value	50 µg/m^3, max. 35 times/year
Annual mean value	40 µg/m^3

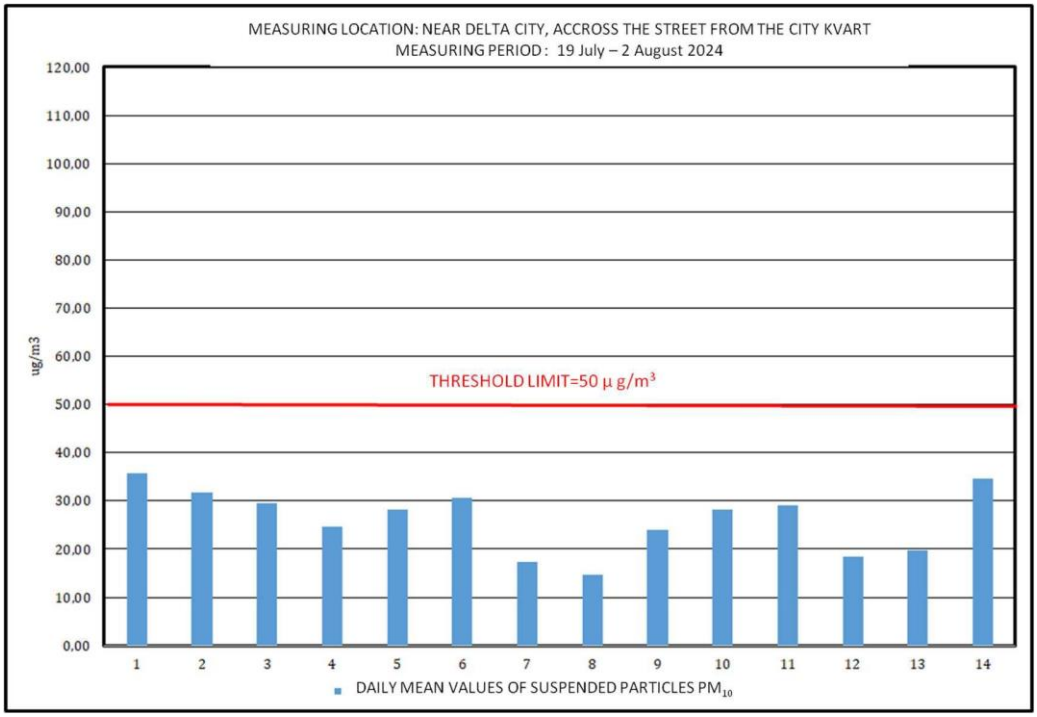

Figure 14: Daily mean values of suspended particles PM_{10}

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Daily mean values of suspended PM_{10} particles were compared with the prescribed limit value for the daily mean value (50 µg/m^3). All daily mean values of PM_{10} at this location in the summer measurement cycle were below the prescribed limit value.

Sulfur dioxide

Number of 1-hour measurements	336
Minimum 1-hour value (µg/m^3)	1.00
Maximum 1-hour value (µg/m^3)	6.18
Mean value of 1-hour averaging times (µg/m^3)	3.79
Median 1-hour averaging times (µg/m^3)	3.67
Number of 24-hour measurements	14
Minimum 24-hour value (µg/m^3)	3.36
Maximum 24-hour value (µg/m^3)	4.33
Mean 24-hour averaging times (µg/m^3)	3.79
Median 24-hour averaging times (µg/m^3)	3.77
Number of 1-hour LV exceedances	0
Number of 24-hour LV exceedances	0
Averaging period	Threshold limit
1-hour mean value	350 µg/m^3, max. 35 times/year
Daily mean value	125 µg/m^3, max. 35 times/year

Table 6: Statistical processing of sulphur dioxide measurement results

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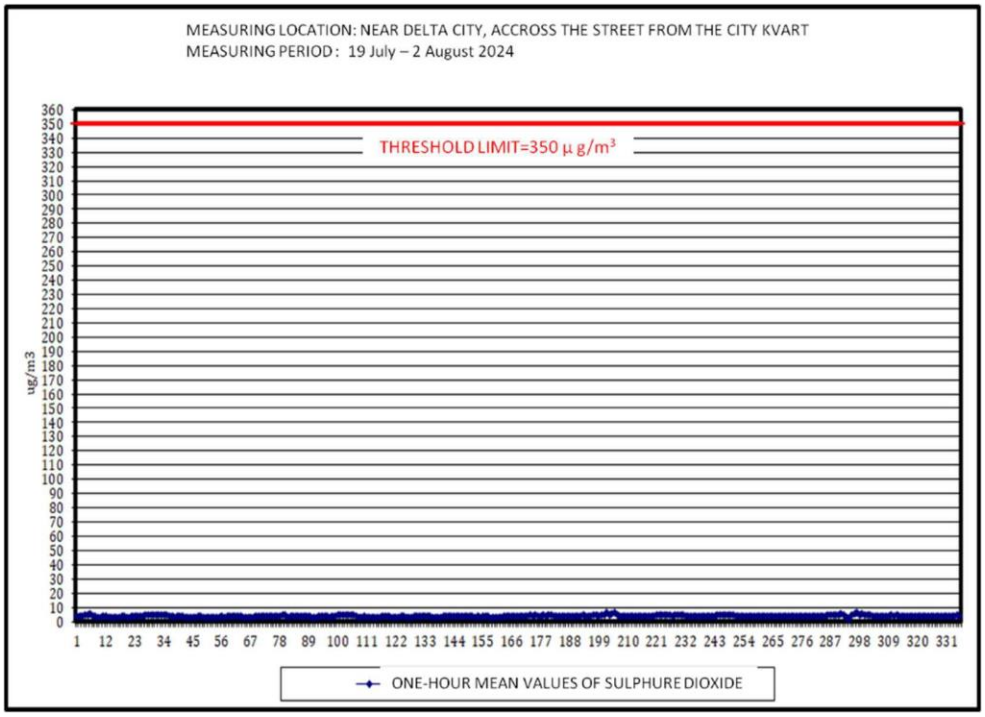

Figure 15: One-hour mean values of sulphur dioxide

The results of sulphur dioxide measurements were compared with the prescribed limit values for one-hour mean (350 µg/m^3) and daily mean (125 µg/m^3). All the measured values of sulfur dioxide were below the prescribed limit values.

Nitric oxide

Number of 1-hour measurements	336
Minimum 1-hour value (µg/m^3)	0.62
Maximum 1-hour value (µg/m^3)	104.11
Mean value of 1-hour averaging times (µg/m^3)	7.38
Median 1-hour averaging time (µg/m^3)	3.21

Table 7: Statistical processing of nitric oxide values

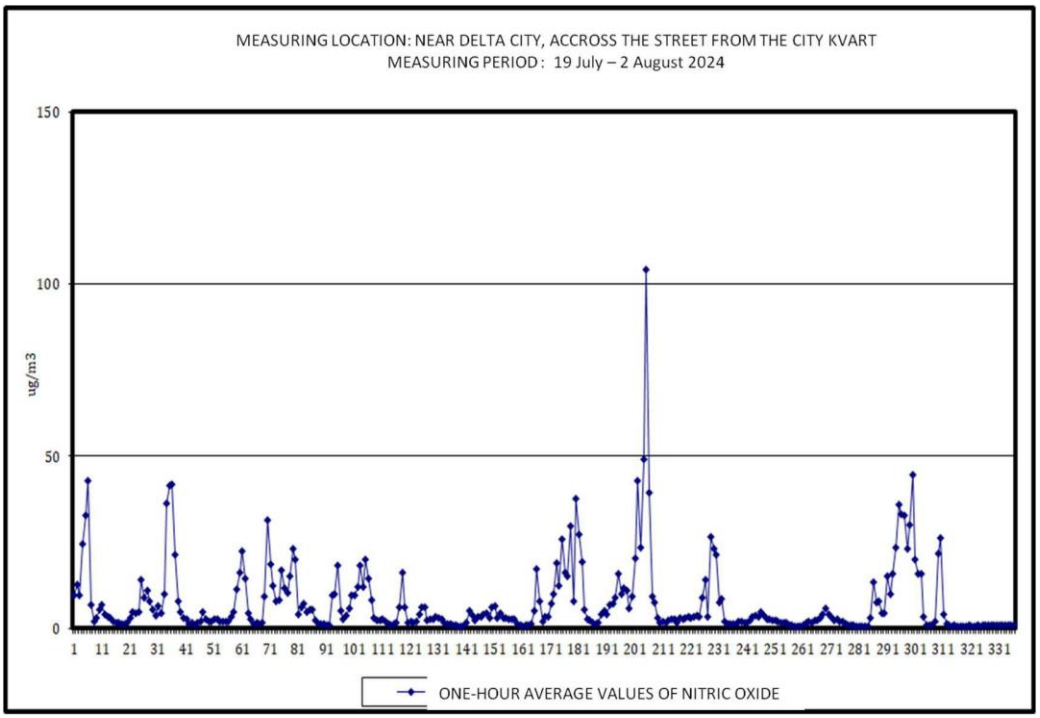

Figure 16: One-hour average values of nitric oxide

No threshold value is set for nitric oxide; there is only the control measure.

Total nitrogen oxides expressed as NO_2

Number of 1-hour measurements	336
Minimum 1-hour value (µg/m^3)	11.18
Mean value of 1-hour averaging times (µg/m^3)	324.16
Median 1-hour averaging times (µg/m^3)	87.47
Median 1-hour averaging times (µg/m^3)	70.67

Table 8: Statistical processing of the results of total nitrogen oxides

For total oxides of nitrogen expressed as nitrogen dioxide, a limit value is prescribed for the protection of vegetation of 30 µg/m^3 per year.

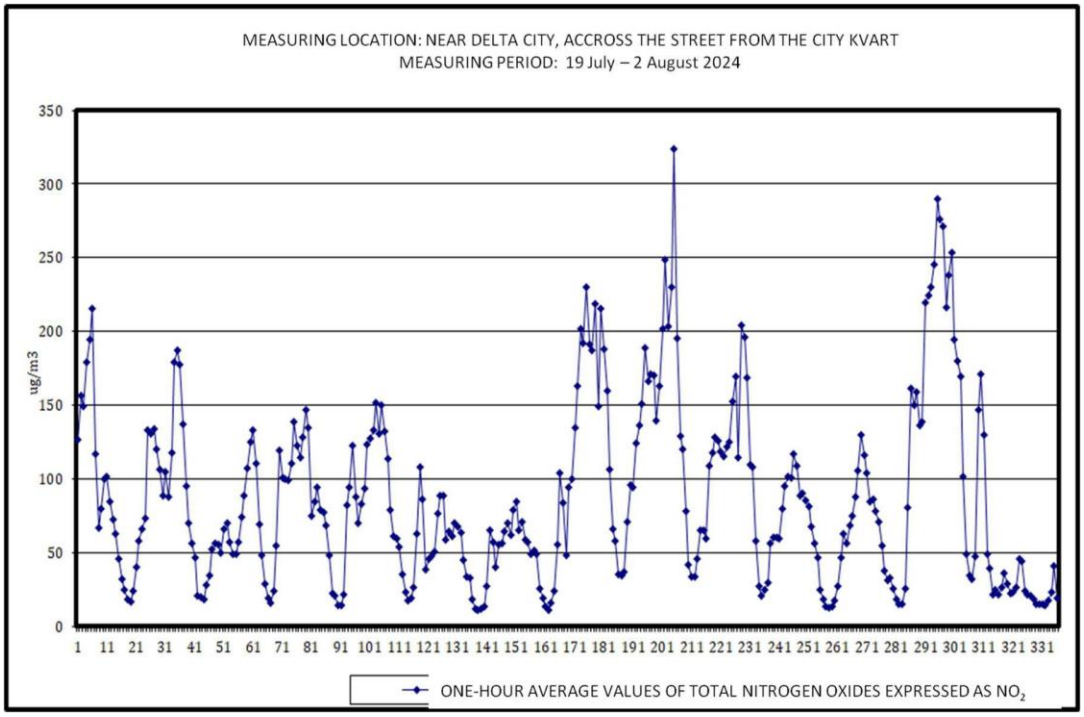

Figure 17: One-hour average values of total nitrogene oxides expressed as NO_2

Ozone

Number of maximum, daily 8-hour mean values	14
Minimum daily 8-hour mean value (µg /m^3)	49.69
Maximum daily 8-hour mean value (µg /m^3)	105.20
Mean value of maximum, daily 8-hour mean value (µg /m^3)	76.19
Median of maximum daily 8-hour mean value (µg /m^3)	73.01
Number of exceedances maximum, daily 8-hour mean value CV	0
Averaging period	Target value

Maximum daily eight-hour mean ozone values	120 µg /m^3

Table 9: Statistical processing of ozone measurements

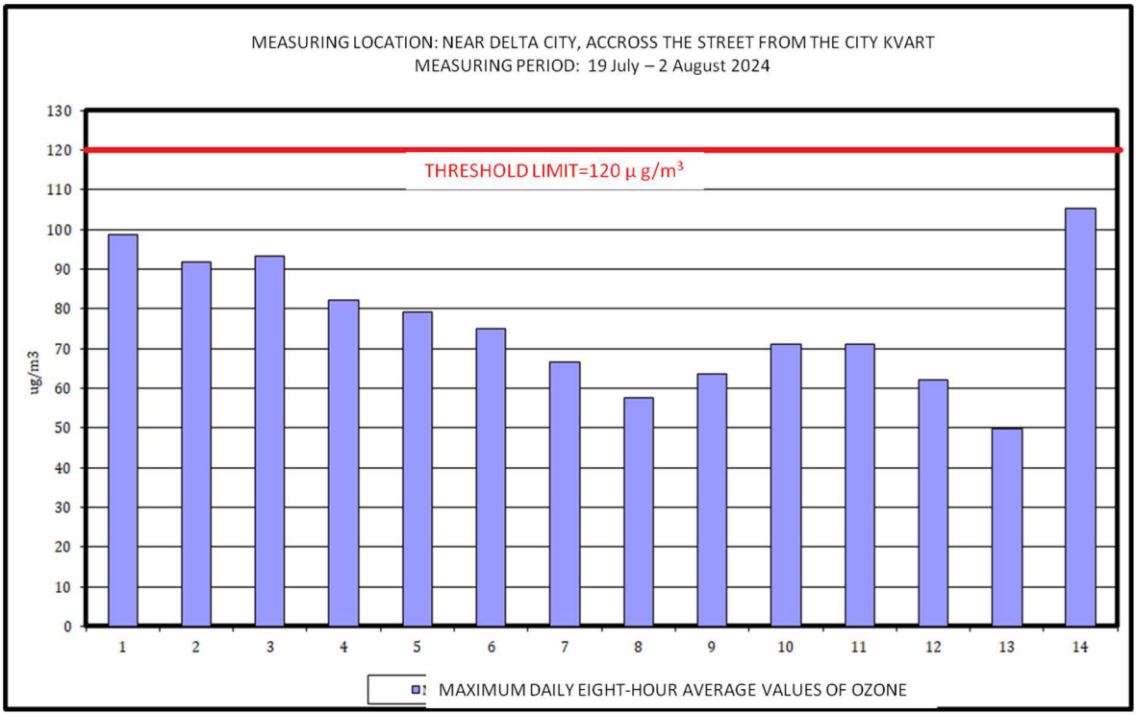

Table 10: Maximum daily 8-hour averages values of ozone

Maximum daily eight-hour mean ozone values were compared with the prescribed target value of 120 µg/m^3. All maximum daily eight-hour mean values of ozone during measurements in the summer fourteen-day cycle were below the prescribed target value.

Carbon monoxide

Number of maximum, daily 8-hour mean values	14
Minimum daily 8-hour mean value (µg /m^3)	0.28
Maximum daily 8-hour mean (mg/m^3)	0.64
Mean value of maximum, daily, 8-hour mean value (µg/m^3)	0.43

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Median of maximum, daily, 8-hour mean value (µg/m^3)	0.45
Number of exceedances, maximum, daily 8-hour mean value CV	0
Averaging period	Threshold limit
Maximum daily 8-hour mean value	10 mg/m^3

Table 11: Statistical processing of carbon monoxide measurement results

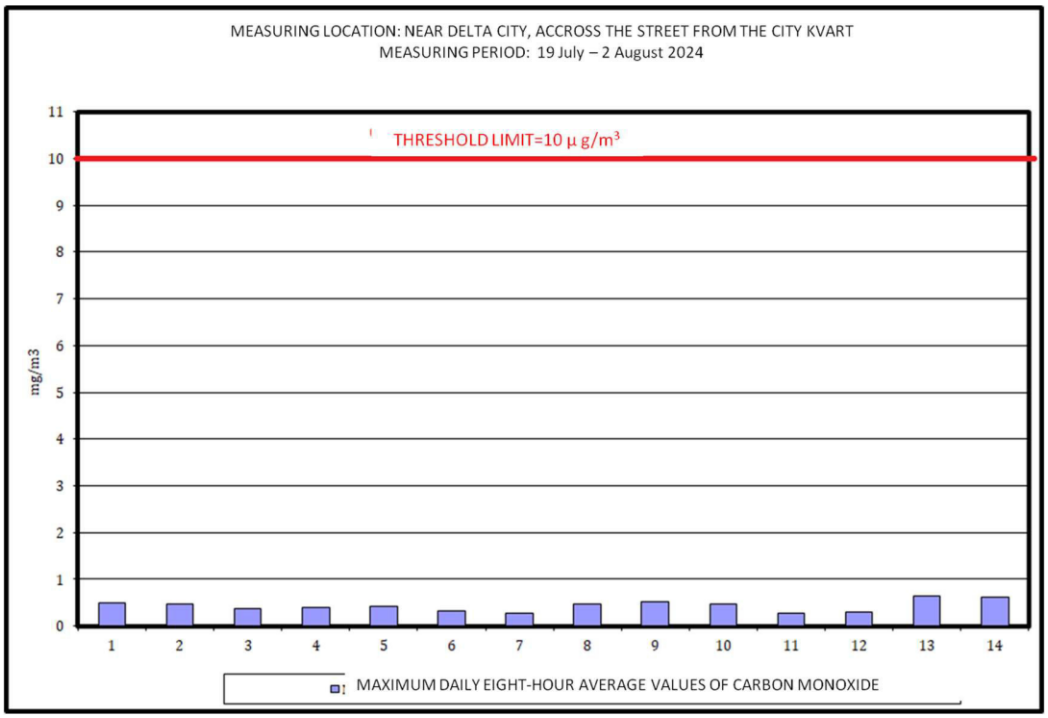

Figure 18: Maximum daily eight-hour mean values of carbon monoxide

All maximum daily eight-hour mean values of carbon monoxide were below the prescribed limit value during the 14-day measurement in the summer cycle.

Benzene

Number of 24-hour measurements	14
Minimum 24-hour value (µg/m^3)	0.59
Maximum 24-hour value (µg/m^3)	1.15

Mean 24-hour averaging times (µg/m^3)	0.86
Median 24-hour averaging times	0.89
Averaging period	Threshold limit
Annual mean value	5 µg/m^3

Table 12: Statistical processing of benzene measurement results

For benzene, a limit value of 5 µg/m^3 is prescribed on an annual basis.

Heavy metals and Benzo(a)pyrene

Content of heavy metals (Pb, Cd, As and Ni) and Benzo(a)pyrene in seven-day aggregate samples of suspended PM_{10} particles is shown in the following table:

Measurement period	Pb	As	Cd	Ni	B(a)P
	µg/m^3	ng/m^3			
Week one	<0.015	<0.5	<0.5	<1.0	0.03
Week two	<0.015	<0.5	<0.5	<1.0	0.15
GV (SGV)	0.5				
CV (SGV)		6	5	20	1

Table 13: The content of heavy metals (Pb, Cd, As and Ni) and benzo(a)pyrene

- The content of arsenic, cadmium and nickel in the aggregate weekly samples of PM_{10} was below the target values (mean values for the calendar year) prescribed for the purpose of health protection,
- The Benzo(a)pyrene content in the pooled weekly PM_{10} samples during the summer measurement cycle was below the target value of 1.0 ng/m^3 (mean value for the calendar year).

SUMMARY

Sulphur dioxide – SO_2

In the third, summer, cycle of air quality measurements in 2024, all measured concentrations of sulfur dioxide (presented as one-hour mean and daily mean values) at three measuring points (two near traffic roads and the third outside the direct impact of traffic, the Zagorič settlement), were below the prescribed limit values.

Nitric oxide – NO

No limit value is prescribed for nitric oxide, only a control measure.

Nitrogen dioxide – NO_2

In the summer measurement cycle, at all measuring points in the Capital City, all one-hour mean values of nitrogen dioxide were below the prescribed limit value (200 µg/m3).

Total nitrogen oxides expressed as NO_2

For total oxides of nitrogen expressed as nitrogen dioxide, a limit value is prescribed for the protection of vegetation of 30 µg/m^3 per year.

Suspended PM_{10} particles

The daily mean values of suspended PM_{10} particles were compared with the prescribed limit value for the daily mean value of 50 µg/m^3, which should not be exceeded more than 35 times during the year. In the summer measuring cycle of 2024 at the measuring point Stari Aerodrom, Zagorič, three daily mean values of PM_{10} were above the prescribed limit value of 50 µg/m^3. According to the report of the Institute of Hydrometeorology and Seismology of Montenegro, at the beginning of the third decade of June, there was an influx of warm air, strong southern currents, when dust and fine sand from the Sahara Desert arrived in Montenegro (an unusual but increasingly common phenomenon in recent years), thus settling in the air. According to data from all seven stations of the State Air Quality Monitoring Network in Montenegro, both in the southern, central zone and in the north of the country, in the period from 20 to 24 June 2024, the air was loaded with a high content of suspended PM_{10} particles, as a result of this phenomenon. In the stated period, daily mean PM_{10} values were also exceeded at the Stari aerodrom location. At the location near the Delta City shopping center and in Zagorič during the 14-day measurements in the summer cycle, all daily mean values of PM_{10} were below the prescribed threshold value.

Ozone – O_3

Maximum daily eight-hour mean values were compared with the prescribed target value of 120 µg/m^3. Maximum daily eight-hour mean daily ozone values, at all locations (three measuring points) during the summer measurement cycle were below the prescribed target value.

Carbon monoxide – CO

The maximum daily eight-hour mean values of carbon monoxide concentrations were compared with the limit value for the maximum daily eight-hour mean value. During the summer measurement cycle, all maximum daily eight-hour mean values of carbon monoxide at all three locations in the Capital City were below the prescribed limit value of 10 mg/m^3.

Benzene – C_6H_6

An annual mean limit value is prescribed for this pollutant.

Heavy metals

Suspended PM_{10} particles were analyzed for the content of heavy metals for which air quality standards were prescribed on an annual basis.

In all three locations, in the Capital, during the summer measurement cycle:

- The lead content in seven-day samples of PM_{10}, at all three measuring points, was significantly below 0.5 µg/m^3, the prescribed norm for the annual mean value,
- The contents of arsenic, cadmium and nickel were below the target values (mean values for the calendar year) with the aim of protecting human health at all three measuring points.

Benzo(A)pyrene

At the measuring points in Podgorica, the content of benzo(a)pyrene in all analyzed PM_{10} samples was below the prescribed target value of 1.0 ng/m^3 (mean value for the calendar year).

VULNERABLE GROUPS

Demographic characteristics[11]

According to the official 2011 census, the population of Podgorica is 185,937, which makes up 29.99% of the total population of Montenegro. There were 90,614 men and 95,323 women. The city population of Podgorica had 155,725 inhabitants, and the rural population 30,212. According to the 2011 census, the municipality of Tuzi covering the area of Malesia and had 12,096 inhabitants, while the municipality of Golubovci had 16,093 inhabitants.

Name	Number of inhabitants	Households	Apartments
Podgorica	155,725	48,836	58,925
Golubovci	16,093	5,407	4,339

[11] Data from the 2023 Census to be included when available, as announced by MONSTAT, and to be compared with the data from previous censuses.

Tuzi	12,096	3,208	2,749

Table 14: Data of the 2011 census in Podgorica and urban municipalities

According to the data from the latest (2023) census conducted by the Statistical Office of Montenegro, the population of Podgorica is 179,505, which makes 28.78% of the total population of Montenegro (623,633). Between the two censuses, the population of Podgorica has increased 15.27%.[12]

Name	Number of inhabitants
Podgorica	179,505
Zeta (ex Golubovci)	16,079
Tuzi	12,979

Table 15: Data of the 2023 census in Podgorica and urban municipalities

Social protection is achieved through the existing institutions. There are 17 different institutions dealing with social and child protection in Montenegro. Within this framework, there are six institutions for children and youth, one institution for adult care and ten centers for social work. In addition to these, various non-governmental organizations are engaged.

Some of those institutions are located in Podgorica:

- Special Institute for Children and Youth in Podgorica (2,400 m^2);
- Institute for Education of Children and Youth in Podgorica, where some 30 children live;
- Center "1. jun" in Podgorica (3,000 m^2, capacity of 130 students, of which 60 in boarding school);
- Institute for Education and Vocational Rehabilitation of Disabled Children and Youth in Podgorica (3,420 m^2, 88 students, of which 46 in boarding school).

Socio-economic indicators

Young people

The data for young people in the City Kvart is not available.

Elderly people

[12] Data from the 2023 Census to be included when available, as announced by MONSTAT, and to be compared with the data from previous censuses.

The data for elderly people in the City Kvart is not available.

Poverty rate

According to the data provided by the Secretariat for Social Welfare of the Capital City of Podgorica:

- One-off financial assistance was granted to 46 persons in July 2024.
- Free meal at the soup kitchen. Number of individuals/families (claimants, meaning not including individual family members), who use the free meal in the soup kitchen:
  - July 2024: Home delivery 131; meal at facility 153;
  - August: Home Delivery 131; meal at facility 152.

Thus, in July, 284 individuals/families were entitled to a free meal, and a total of 700 meals were distributed. In August, 283 individuals/families were entitled to a free meal, and a total of 700 meals were distributed. These are the data for the entire territory of Podgorica, there are no data specific for the City Kvart.

Unemployment rate

The data for unemployment rate in the City Kvart is not available.

Gender

The data for gender in the City Kvart is not available.

Immigrated people

The data for imigrated people in the City Kvart is not available.

Low-skilled jobs

The data for low-skilled jobs in the City Kvart is not available.

Social housing

The data for social housing in the City Kvart is not available.

Retired people

The data for retired people in the City Kvart is not available.

Health conditions

There are no data specific for the City Kvart concerning the emergency healthcare.

Ill people

The data for iII people in the City Kvart is not available.

Disabled people

The data for disabled people in the City Kvart is not available.

Mentally ill people

The data for mentally ill people in the City Kvart is not available.

Mortality rate

The data for mortality rate in the City Kvart is not available.

Infrastructure

Hospitals capacity

The data for hospitals capacity in the City Kvart is not available.

Health centres

Health institutions

The Health Center of Podgorica has a special significance in the health care of the local population. The Center has a mobile medical unit, a diagnostic center, a center for children with special needs, a center for pulmonary diseases and tuberculosis, a center for mental health, an education center, a center for prevention and a center for special health care. The Health Center in Podgorica does not have accommodation capacity, so all patients are referred to the Clinical Center of Montenegro. The main health center locations are in Block V, Pobrežje, Radio Stanica, Konik, Stari aerodrom, Centar – VMC,

Golubovci and Tuzi. In addition, there are 34 outpatient clinics and health stations located in local communities in the City.

165 private health institutions – outpatient clinics have a significant role in the primary health care of the population of Montenegro. These institutions are located in several municipalities and provide services for 34 different medical activities. Most of them are located in Podgorica 73 or 44.24%.

Hospital health care of the population in Podgorica is provided through: Clinical Center of Montenegro, which, in addition to general hospital activities for the municipalities of Podgorica, Danilovgrad and Kolašin, also provides territorial health care of all levels for the state. The capacity of the Clinical Center is 715 beds, 229 employed doctors and 496 nurses and technicians. Capacity utilization is 71.86%.

Public health institutions, the Institute of Public Health and the Pharmacy Institution Montefarm with 40 pharmacies, 9 of which are in Podgorica, as well as a significant number of private pharmacies are also of importance for outpatient health care.

Retirement houses

The data for retirement houses in the City Kvart is not available.

Social housing

MONSTAT[13]

- Young people under 5 years of age;
- Over 65 years old;
- Persons with disabilities;
- People with chronic diseases;
- Displaced persons;
- Gender share;
- Poverty level;
- Level of education – no secondary education diploma;
- Security level;
- People over 80 living alone.

No data about these categories are available from the relevant sources – the city's Secretariat for Social Welfare and the Housing Agency.

Health Center Podgorica

No response was received from the Heath Center of Podgorica upon request for the following data:

[13] Data from the 2023 census to be included when published.

- Number of persons who requested medical assistance during July and August 2024 (and locations of health institutions where assistance was sought);
- Data on persons living in the City Kvart;
- Data on types of diseases: cardiovascular diseases, asthma, diabetes.

Institute for Public Health

- Number of persons who requested medical assistance during July and August 2024 (and locations of health institutions where assistance was sought);
- Data on persons living in City Kvart;
- Data on adverse events during the summer;
- Data on types of diseases / cardiovascular diseases, asthma, diabetes.

The Institute of Public Health did not send the requested data.

Vulnerability Index

Data to be collected:[14]

- Share of young people (< 5 years);
- Share of elderly (> 65 years);
- Share of migrants;
- Structure of households.

Socioeconomic data:[15]

- Share of unemployed persons;
- Share of people/households below the poverty line;
- Share of pensioners;
- Share of energy-poor households.

Health risks and vulnerable groups – required data

- Proportion of people with chronic health conditions (young and elderly; focus on asthma, heart disease, diabetes);
- Share of persons with disabilities (youth <5 and older >65 years);
- Death rate;
- Hospital capacity;

[14] To be added when provided by Monstat as announced.
[15] To be added when provided by Monstat as announced

- Locations of health centers/hospitals.

During the data collection, no results were achieved; however, data from the Statistical Office are still pending, so the analysis of vulnerable groups was not possible at this time. Data is expected to be received within the next 10 days, so it will be possible to perform their analysis.

Preparedness and adaptive capacity of cities and municipalities

Institutional factors

Governance structures

The Capital City administrative body directly responsible for the issue of climate change at the local level is the Secretariat for Spatial Planning and Sustainable Development. Furthermore, implementation of activities within the competence of other city services and companies, in terms of greening public city areas, adequate waste management, management of protected natural areas, contributes to the mitigation of the consequences of climate change, i.e. the prevention or mitigation of the consequences of the urban heat island phenomenon (UHI). When it comes to disaster risk management, this issue is a direct competence of the city's Protection and Rescue Service, certainly in cooperation with other city and state services and authorities.

Legislative and regulatory regimes

The issue of climate change has been recognized both directly and indirectly, through a series of legal solutions that, among other things, define the competencies of local self-governments. In addition to the Law on Protection against the Negative Impact of Climate Changes, there are the Law on the Environment, the Law on Environmental Impact Assessment, the Law on Strategic Environmental Impact Assessment, the Law on Air Protection.

Relevant documents at the local level are also the Climate Change Adaptation Strategy, Protection and Rescue Plans for Different Types of Risks, Pre-Feasibility Study for Green Roofs, etc.

Policies and plans

The data for policies and plans is not available.

Protection and rescue plans covering the risks associated with climate change are:

- Fire protection and rescue plan, and
- Flood protection and rescue plan.

Institutions

The data for institutions is not available.

Social factors

Social connections

The data for social connections is not available.

Community cohesion

The data for community cohesion is not available.

Self-learning/self-organizing capacities of communities

The data on administrative capacities of the Capital City of Podgorica are characterized by the following:

- ✓ Currently, the Sustainable Development Sector of the Secretariat for Spatial Planning and Sustainable Development has 7 employees. Specialized technical knowledge is not significant, and for this reason, experts outside the structures of local authorities are mostly "outsourced", i.e. hired;
- ✓ As for administrative capacities, 91 employees are employed in the Protection and Rescue Service, out of which 62 were operational employees (with the Acting Commander of the Service). Analyzing the needs as well as the competence for certain types of accidents, members are filled in within the rescue teams: the mountaineering team has 12 members; the swift water rescue team has 12 members; the flood team has 18 members; the chemical accident team has six members; the USAR (urban search and rescue) team has 19 members. The Service has a total of 31 vehicles: 24 specialized firefighting vehicles, one freight and 6 passenger vehicles. Also, the Service owns 4 boats and two snowmobiles. As far as the equipment is concerned, the Service has: fire extinguishing equipment, both for the outdoor and indoor interventions; equipment for technical interventions: for rescue at heights and in depths, for rescue from traffic accidents, for rescue from rubble, for chemical accidents, from high-speed waters, high-capacity pumps; as well as drones for terrain search.

The educational process does not recognize the UHI topics, while, on the other hand, raising public awareness on topics related to climate change and UHI is carried out within promotional and educational campaigns within the framework of daily regular activities, as well as through numerous programs and projects. Education in the field of UHI and climate change is the responsibility of the ministry dealing with education, however, at the moment no programs on these topics have been developed.

Available skills and knowledge

Members of the Protection and Rescue Service are trained to act in cases of various risks in accordance with national and international standards.

Economic factors

Public financial resources

In the budget of the Capital City of Podgorica for 2025, as for previous years, no separate funds are allocated for activities related to the mitigation of the effects of climate change, i.e. UHI.

Household income

The data for household income is not available.

Access to financial resources

The following EU-funded projects related to climate change, i.e. UHIs, are currently being implemented in the Capital City:

- ✓ *Improving urban climate change adaptation capacities by testing and promoting the 'sponge city' methodology on transnational level – SpongeCity.* Sponge city is an innovative method of rainwater management. The partnership identified 12 pilot areas with different geographical and topographical characteristics, with the aim of applying the sponge city concept through wich the access rainwater is harvested for use in dry periods. Within the project the water absorption/retention capacity of rain gardens is tested and analyzed under different conditions. Other municipalities are offered the opportunity to evaluate the results of the pilot area most closely related to their characteristics, providing them with reliable and detailed data so that they can prepare their sponge city investments. The partners test the use of a manual providing technical parameters for the investment, develop their local sponge city action plans and feasibility studies. The leading partner is the University of Pécs, Hungary.
- ✓ *Nature-Based Solutions for Climate Resilience – NBS4RESILIENCE.* The project addresses the complex issues of various negative climate phenomena and offers several appropriate solutions (NBSs), in order to increase climate resilience, security and overall improve the state of the environment in the IPA ADRION region. The main objective is to jointly create, investigate, simulate and translate into policies and action plans climate-resilient and risk-reducing solutions, taking into account and assessing all their benefits in terms of climate regulation and disaster risk as their primary intent and objective. Based on a comprehensive co-creation process, this will empower public actors to take action through the presentation of 6 pilot projects in the IPA ADRION region, in 6 IPA ADRION countries, to try to address 6 types of negative climate phenomena: floods (SIOVENIA), erosion and landslide risk, heat waves (MNE), drought and water flow regulation, coastal resilience to climate change (Greece) and forest fire prevention (BiH). The leading partner is the Development Agency of the City of Prijedor, BiH.

Insurance contracts

The data for insurance contracts is not available.

Technological factors and scientific knowledge

Availability of technological, social, institutional, environmental and other innovations

The data for availability of technological, social, institutional, environmental and other innovations is not available.

Ability to use the innovations

The data for ability to use the innovations is not available.

Availability of information on adaptation to climate change

A document provided by the Agency for Construction and Development of Podgorica, ltd. Podgorica (Amendments to the Detailed Urban Plan Radoje Dakić in Podgorica of 2021) shows how the local zoning plan envisages the area of City Kvart.

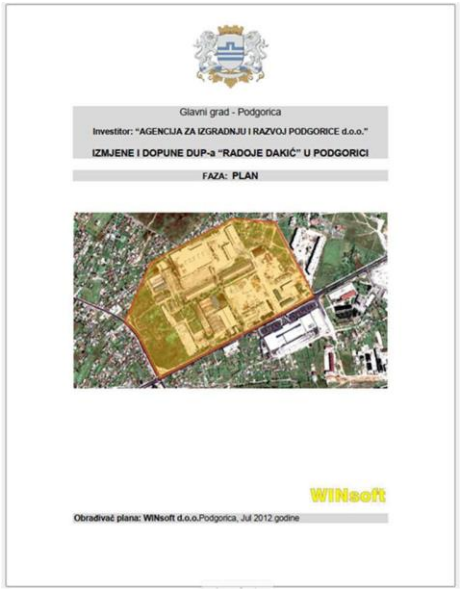

Figure 19: Layout of the 2012 project area

These activities are implemented through participation in international projects and initiatives, such as the EU Mission: 100 climate-neutral and smart cities by 2030 and the UN campaign entitled Making cities resilient 2030.

5. Conclusions

Bearing in mind the expected air temperature increase owing to the climate change in the coming years, and the practically unavoidable emergence of urban heat islands (UHIs) in the Capital City of Podgorica during the summer months, it is necessary to envisage and implement structural and non-structural measures in order to reduce the consequences of both climate change and the occurrence of urban heat islands (UHIs).

The measures to be implemented are:

1. **Structural**

- ✓ As part of this project, greening the bus stop at the City Quarter location accross the street from the City Kvart as the pilot location;
- ✓ Increasing the percentage of green spaces in neighborhoods;
- ✓ Greening of public plazas and squares with pergolas;
- ✓ Planting greenery types that are resistant to extreme weather conditions in public green spaces;

  and
- ✓ Development of a cadastre of green areas based on GIS technology for all public green areas.

2. **Non-structural**

- ✓ Planning and implementation of measures of mitigation and adaptation to the climate change;
- ✓ Education and information campaigns on climate change;
- ✓ Establishment of a system for information and alerting citizens to adverse weather conditions/cyclones;
- ✓ Establishing care for vulnerable groups (assistance in case of extreme situations);
- ✓ Correction of working hours and adaptation to extreme weather conditions during the summer period;
- ✓ Implementation of the Sustainable Urban Mobility Plan of the Capital City Podgorica;
- ✓ Transition from fossil fuels to renewable energy sources;
- ✓ When adopting urban plans, making sure that the design and construction of new facilities is carried out taking into account the local wind rose and thus does not endanger natural circulation and air flow as an important natural factor in air purification;

  and
- ✓ Cooperation with primary and secondary schools in the territory of Montenegro, in order to raise environmental awareness among the younger population, through promotional films or lectures.

Literature

- Climate Change Adaptation Strategy of the Capital Podgorica;
- Strategy for Disaster Risk Reduction 2025-2030 with Action Plan 2025-2026;
- Communication Strategy for Promoting Energy Efficiency and Climate Change Protection Measures in the Capital City Podgorica;
- Law on Protection against the Negative Impact of Climate Change;
- Environmental Law;
- Law on Environmental Impact Assessment;
- Law on Air Protection;
- Energy Efficiency Improvement Programme 2018-2020;
- Energy Efficiency Improvement Program of the Capital City Podgorica for the period 2021-2023;
- Fire Protection and Rescue Plan of the Capital City Podgorica;
- Fire Protection and Rescue Plan of the Capital City Podgorica;
- Flood Protection and Rescue Plan for the Capital City Podgorica;
- Environmental protection plan of the Capital City Podgorica 2010-2014;
- Air Quality Plan for the Capital City Podgorica;
- Local Energy Plan Capital City Podgorica 2015-2025;
- Vulnerability Assessment and Action Plan for Adaptation to Climate Change of the Capital City Podgorica;
- Sustainable Development Action Plan for the Capital City Podgorica;
- Noise Protection Action Plan 2019;
- Biodiversity Action Plan of the Capital City Podgorica;
- Report on the state of the environment for the territory of the Capital City Podgorica for the period 2011-2014;
- Decision on the Establishment of Acoustic Zones on the Territory of the Capital City Podgorica;
- Certificate – ECO Municipality of Montenegro 2013;
- Sustainable energy action plan of the Capital city Podgorica;
- Guide Through Environmental Regulation;
- Vulnerability Book, Concept and Guidelines for Performing a Standardized Vulnerability Assessment;
- Adapting urban areas to climate change in Europe, challenges and opportunities for cities with national and European policies to support;
- European Commission, 2013, Instructions for Preparing Development Adjustments http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_134_en.pdf);
- Hallegatte, S. 2009, Strategies for adaptation to uncertain climate change;
- Global Environmental Change;
- UN Framework Convention on Climate Change;
- Kyoto Protocol;
- Doha Amendments;

- Intergovernmental Panel on Climate Change (IPPC), 2007, Climate Change: Impact, Adaptation and Vulnerability;
- FC (2013) Adaption Compass Future Cities – Urban Networks Facing Climate Change, Guidelines for the Development of Climate Resilient Cities, Lippeverband, Essen, 2013;
- Ivanov (2014) excerpt from the First and Second National Communications of Montenegro under the United Nations Framework Convention on Climate Change [submitted by Mirjana Ivanov, Department of Hydrometeorology and Seismology], Podgorica;
- Ivanov (2015) Mirjana Ivanov, Master of Meteorology, Department of Hydrometeorology and Seismology (ZHMS), Podgorica.