European Journal of Geography

The publication of the European Journal of Geography (EJG) is based on the European Association of Geographers' goal to make European Geography a worldwide reference and standard. Thus, the scope of the EJG is to publish original and innovative papers that will substantially improve, in a theoretical, conceptual, or empirical way the quality of research, learning, teaching, and applying geography, as well as in promoting the significance of geography as a discipline. Submissions are encouraged to have a European dimension. The European Journal of Geography is a peer-reviewed open access journal and is published quarterly.

Research Article

Assessment of the environmental quality of Lake Skadar and its urban surroundings in Montenegro

Dragan Burić [1,*], Ivan Mijanović [1], Miroslav Doderović [1], Jovan Mihajlović [2] and Goran Trbić [3]

[1] Department of Geography, University of Montenegro, Danila Bojovica bb, 81400 Nikšic, Montenegro
[2] Faculty of Geography, University of Belgrade, Studentski trg 3/3, 11000 Belgrade, Serbia
[3] Department of Geography, Faculty of Science and Mathematics, Banja Luka, Bosnia and Herzegovina
[*] Correspondence: draganburic33@gmail.com

Received: 25/04/2023
Revised: 01/06/2023
Accepted: 20/06/2023
Published: 23/06/2023

DOI: 10.48088/ejg.d.bur.14.2.076.087

Abstract: Lake Skadar on the Balkan Peninsula faces many ecological challenges. The lake is located in the border area between Montenegro and Albania and its ecosystem interacts with important and highly populated urban centres such as Podgorica and Bar. Despite the crucial role the lake plays in the sustainability of the ecosystem and the health of the population, there is a lack of environmental quality assessment and data-based analysis. Therefore, the aim of this study is to assess both the water quality of Lake Skadar and the air pollution in Podgorica and Bar in the period from 2011 to 2018. To assess water quality, the Water Quality Index (WQI) model, i.e. the SWQI method, was used, which was calculated based on 10 parameters of physicochemical and microbiological characteristics of water from 9 hydrological stations (oxygen saturation, biochemical oxygen consumption for 5 days, ammonium ions, pH, total nitrogen oxides, orthophosphates, suspended solids, temperature, electrical conductivity and coliform bacteria). In addition, air quality in the two cities was assessed using timeseries of PM_{10} concentrations. The results showed that the water quality of Lake Skadar was of good to high quality (WQI 79-95), while the air quality in Podgorica and Bar was a serious public health problem, especially in the cold seasons in Podgorica (i.e. the average seasonal and daily PM_{10} concentrations were often > 40 and > 50 μg/m3). These results are of great practical importance for environmental management and support decision makers in applying certain environmental protection measures and strategies.

Keywords: water quality, WQI, Lake Skadar, air quality, PM10, Podgorica, Bar, Montenegro.

Highlights:

- Frequent high daily concentrations of PM_{10} (above 50 μg/m^3) in Podgorica and Bar endanger public health.
- Increasing anthropogenic pressure in the area of Lake Skadar and its surroundings.
- Environmental protection in Montenegro must be ensured through the application of integrative environmental and spatial planning measures.

1. Introduction

Water is a prerequisite for life, a public good and it is of inestimable importance to keep it clean in our environment. The demand for water is increasing, but the quality of water is deteriorating, especially in rivers, lakes and seawater that are close to urbanised areas. Water pollution is one of the greatest challenges facing societies worldwide today. A United Nations report (UN, 2017) states that more than 80% of the world's wastewater is returned to the environment without treatment. As a result, more people die each year from unclean water than from war and all other forms of violence combined. Through agricultural, urban, industrial and other activities, the anthropogenic factor is the main cause of groundwater and surface water pollution (Sasakova et al., 2018). Mine tailings often contaminate surface and groundwater, as in the case of nitrogen and phosphorus pollution of the Osam River in northern Bulgaria (Seymenov, 2022) and in the case of arsenic pollution in the Ogosta River basin in north-western Bulgaria (Marcheva et al., 2023).

Water quality monitoring is usually carried out in laboratories through various analyses of the physico-chemical or microbiological properties of the water. Therefore, water quality monitoring, especially in rivers and lakes, is crucial for assessing the safety of water for drinking, bathing, fishing, agricultural and other activities. In addition, detected changes in the quality of groundwater and underground water are a good indicator of the general state of the environment and an indication that something is happening in the catchment area of a particular water body. In recent decades, the problem of water pollution has been addressed by numerous laws and directives. For example, the EU Water Framework Directive (EU, 2000) or the US Clean Water Act (USEPA, 2009) require information on the ecological status of all lakes larger than 0.5 km^2.

The Water Quality Index (WQI) model is a popular tool for assessing the water quality of surface and groundwater. Various methods are used to monitor soil and groundwater quality such as: CWQI (Canadian Water Quality Index), CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index), OWQI (Oregon Water Quality Index), NSFWQI (US National Sanitation Foundation Water Quality Index), WAI (Weighted Arithmetic Index) and others (Lumb et al., 2006; Bharti & Katyal, 2011; Sutadian et al., 2016; Habbeb et al., 2022; Garofalo & Ferreira, 2022). To assess the water quality of the Mahananda River (West Bengal, India), Parween et al. (2022) used a modified National Sanitation Foundation water quality index (NSF-WQI), which is considered one of the most comprehensive models among all WQI types (Uddin et al., 2021). Recent research suggests that the Irish Water Quality Index (IEWQI) is a "reliable method for determining the accuracy, reliability and affordability of transitional and coastal water quality" (Uddin et al., 2023a).

Accordingly, several dozen different WQI applications are in use. The specifics and application of many of them can be found in the work of Uddin et al. (2021). WQI methods usually address the physical, chemical and biological parameters of water (Boyacioglu, 2009; Yisa & Jimoh, 2010; Rocha et al., 2014; Bhateria & Jain, 2016; Murariu et al., 2019; Drasovean & Murariu, 2021). In the Balkans and South-Eastern Europe, the regions to which Montenegro belongs, the WQI model has proven to be very useful in water resources management, for example in Romania (Mititelu-Ionuș, 2010; Georgescu et al., 2023), Serbia (Jakovljević, 2012; Josimov-Dunđerski et al., 2016; Mladenović-Ranisavljević & Žerajić, 2017; Milijasević-Joksimović et al., 2018; Babić et al., 2019) and Bulgaria (Gartsiyanova et al., 2020). The global problem with using the WQI model is that different calculation methods and classification schemes are used, so the same water properties are interpreted differently. (Uddin et al., 2023b). Therefore, the need for uniformity in WQI calculation method and class definition is pointed out. Therefore, Uddin et al. (2022a) propose to use a universal WQI calculation method and classification scheme.

As for Montenegro, the WQI model was almost not taken into account when assessing the quality of groundwater and underground water, but other techniques indicated that most of the groundwater in this country is of good quality (Vukašinović-Pešić et al., 2019; Kolarević et al., 2019). Based on data from 12 hydrological stations for the Morača River, the main tributary of Lake Skadar, it was determined that the river has good, very good and excellent water quality for the period 2011-2018 using the WQI method (Doderović et al., 2020). On the other hand, in the same period (2011-2018), the water of the Ćehotina River (Black Sea basin) belonged to the poor quality class, and the air in Pljevlja (the municipality through which the mentioned watercourse flows) was also heavily polluted with PM_{10} particles. Taking into account both water and air pollution of the river, one could argue that Pljevlja is the “hot spot" of Montenegro (Doderović et al., 2021).

Poor air quality is a major global challenge, especially in urban and industrial areas. Numerous individual indicators as well as group indicators consider several parameters that indicate the level of air pollution. For example, Jumaah et al. (2023) used the Air Quality Index (AQI) to estimate air quality in Iraq for the year 2020. Atmospheric aerosol particles or particulate matter (PM) are primarily hazardous to public health (Adams et al., 2015; Haned et al., 2021). Besides natural (dust, marine and biological aerosol, volcanic ash), PM particles can also be of anthropogenic origin (products of fossil fuel combustion, waste incineration, etc.) (Vicente & Alves, 2018). This suggests that urban populations are particularly at risk from PM particles, as there are numerous sources in cities (traffic, industry, heating plants, individual furnaces, etc.) that increase the concentration of these particles in the air (Karagulian et al., 2015; WHO, 2017; Cohen et al., 2017; Vodonos et al., 2018; Yang et al., 2018). Therefore, PM_{10} particulate matter is a mixture of smoke, soot, exhaust, dust, acids and metals and is very harmful to public health. Large cities also have a growing problem with noise pollution (Markou, 2022) and the urban heat island, which negatively affects people's health (Berila & Isufi, 2021).

Most of Lake Skadar, the largest lake on the Balkan Peninsula, is located on the territory of Montenegro. Lake Skadar is not only a hydrological, but also a tourist, agricultural and historical jewel of Montenegro and the Balkans. The lake is distinguished by its natural and cultural heritage. The Montenegrin part of Skadar Lake (about 2/3 of the area) has been declared a national park, while the part belonging to Albania (about 1/3) is treated as a nature park. What distinguishes Lake Skadar from other national parks in Montenegro is the diversity of ornithofauna and ichthyofauna, as well as the lush vegetation of the wetland (Hadžiablahović, 2018). Moreover, on the numerous islands and peninsulas of this freshwater lake, there are traces of history and rich cultural heritage: the remains of ancient cities (e.g. Žabljak Crnojevića - the capital of mediaeval Zeta - today's Montenegro, Obod - known for the first printing press among the South Slavic peoples), then numerous fortresses, churches and monasteries. The valorisation of the natural and anthropogenic values of Skadar Lake and its shores depends largely on the quality of the environment and will continue to do so in the future. Preserving the ecological and general values of Skadar Lake and its surroundings is not a platitude, but an essential necessity. The capital and largest city of the country (Podgorica) and the largest city on the Montenegrin coast (Bar) are located directly on Lake Skadar. In fact, the lake is part of the municipal territory of both cities, which means that it is the most populated part of Montenegro.

Very little is known about the quality of the environment in this area in Montenegro. The agricultural activities around the lake and its increasing tourist use, as well as the mechanical increase of the population in Podgorica and Bar, indicate an increase in anthropogenic pressure in the mentioned part of Montenegro. Podgorica undoubtedly has the characteristics of large cities, but also the environmental problems associated with such settlements. Therefore, the main objective of this study is to determine the water quality of Skadar Lake, as well as the air quality in the city centre of Podgorica and Bar, the municipalities on whose territory the mentioned lake is located. The water quality of Skadar Lake and the level of air pollution based on the concentration of PM_{10} particles in Podgorica and Bar were assessed using the WQI model. The research published by Pešić et al. (2018a) and the results presented in this paper can serve as "zero state" of the environment of the mentioned part of Montenegro and help decision-makers to take/plan appropriate protection measures.

2. Materials and Methods

2.1. Case study area

Podgorica is the capital of Montenegro and is located in the central part of the country. According to the last census of 2011, Podgorica had 187,085 inhabitants, while the municipality of Bar had 42,368 inhabitants (MONSTAT, 2011). The two mentioned municipalities together account for 37% of the total population of Montenegro (625,266 inhabitants). Skadar Lake is a border lake - almost 2/3 belong to Montenegro, the rest to Albania (Figure 1). The water surface of Lake Skadar varies throughout the year. With an average area of about 370 km^2 , it is one of the largest crypto-depressions in the Balkan Peninsula. At high tide, its water surface reaches up to 540 km^2. At mean water level, the height of Lake Skadar is 6 m, the average depth is 5 m and the maximum depth is 44 m (Doderović et al., 2018). Lake Skadar is a flowing lake that, with its tributaries and distributaries, belongs to the Adriatic Sea basin. Most of the water flows into the lake from the Morača River, about 60% (Pešić et al., 2018b). The Bojana River is the only tributary connecting Lake Skadar with the Adriatic Sea. The capital Podgorica belongs to the region of Central Montenegro. Since the last census in 2011, the population has increased significantly. It is estimated that Podgorica now has about 250,000 inhabitants, which is about 40% of the total population of Montenegro. The Zeta Plain, the largest and most fertile lowland in Montenegro, stretches from the north of Lake Skadar to the urban area of Podgorica. To the south and southwest, between Lake Skadar and the coastal town of Bar (Bar Field), stretch the mountain ranges of Rumija (1593 m above sea level) and Sutorman (1185 m above sea level) Rumija and Sutorman are thus the mountains that separate or connect Lake Skadar and the Adriatic Sea.

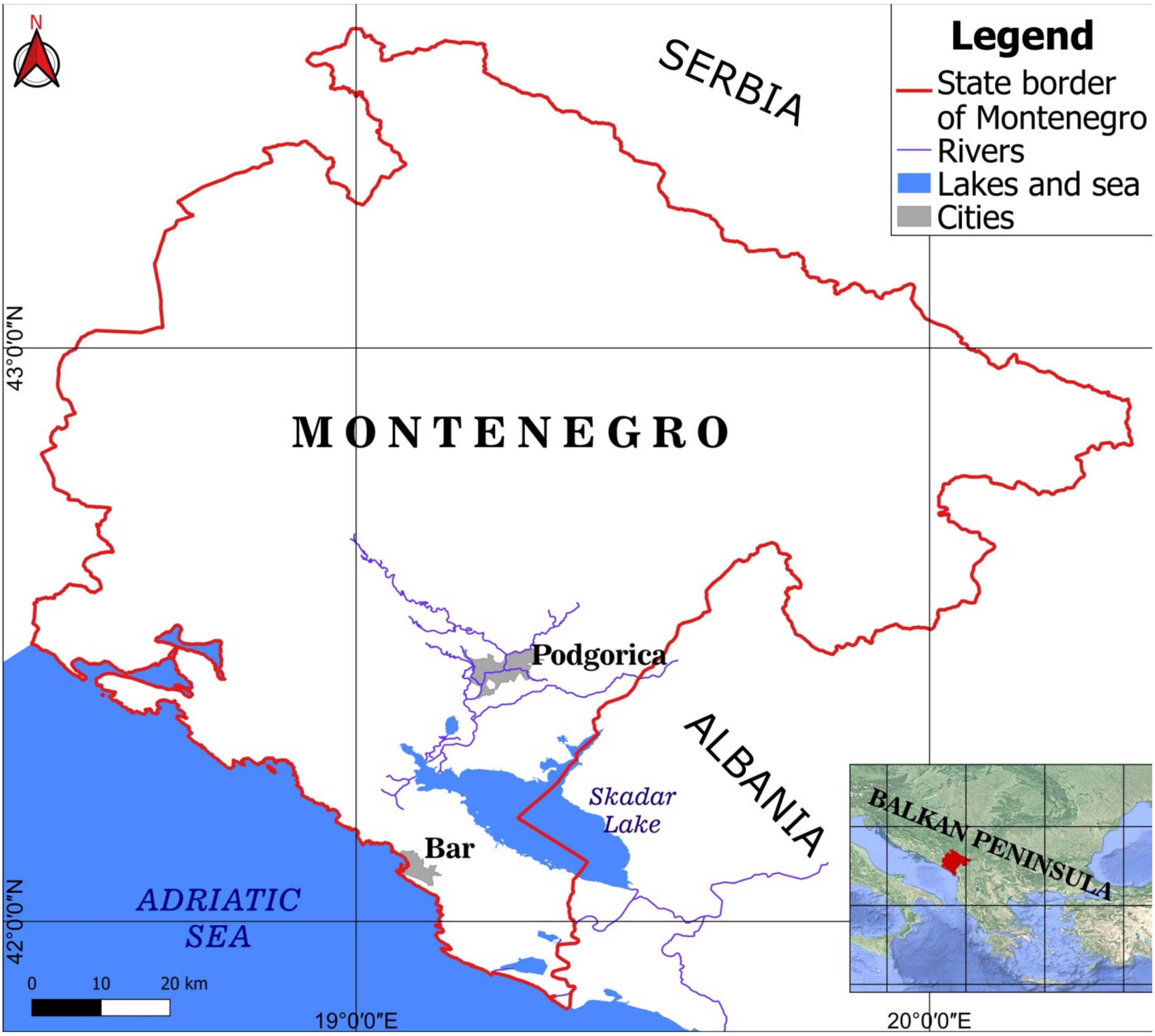

Figure 1. The location of Montenegro (MNE) on the Balkan Peninsula and the location of Lake Skadar and the cities of Podgorica and Bar.

In the extreme southeast, Lake Skadar flows into the Adriatic Sea via the Bojana River. In this area, the lake is open to the Adriatic through the lowlands, so that the Bojana River has a typical lowland character with numerous meanders. Therefore, it can flood the surrounding land during high water. In the low-lying areas around Lake Skadar, in the area of Podgorica and Bar, there is a Mediterranean climate with warm, sunny and dry summers and mild and rainy winters. According to the Koeppen climate classification, it is a Csa climate type (Burić et al., 2014; Burić et al., 2019). The average temperature of the coldest month (January) in Podgorica is 5.5^{0}C, while in Bar it is 8.6^{0}C (label C). The least precipitation falls in a very warm and sunny summer (label s), and the average temperature of the warmest month (July) is 26.9^{0}C in Podgorica and 24.3^{0}C in Bar (label a). In the period 1961-2020, the average annual temperatures were 15.8^{0}C in Podgorica and 16.1^{0}C in Bar. In the same period, the average annual precipitation was 1375.6 mm (Bar) and 1675.1 mm (Podgorica), with 9-10% precipitation in summer (from June to August).

2.2. Data used

For this work, data from the annual reports on water quality of rivers of the Institute of Hydrometeorology and Seismology of Montenegro (IHMSM, 2023) and monthly reports on air quality (mean daily concentrations of PM_{10}) of the Environmental Protection Agency of Montenegro (EPA, 2023) were used. The analysis included a total of 9 hydrological stations (HS), where water samples were collected, and 2 air quality stations in the city centres of Podgorica and Bar (Figure 2).

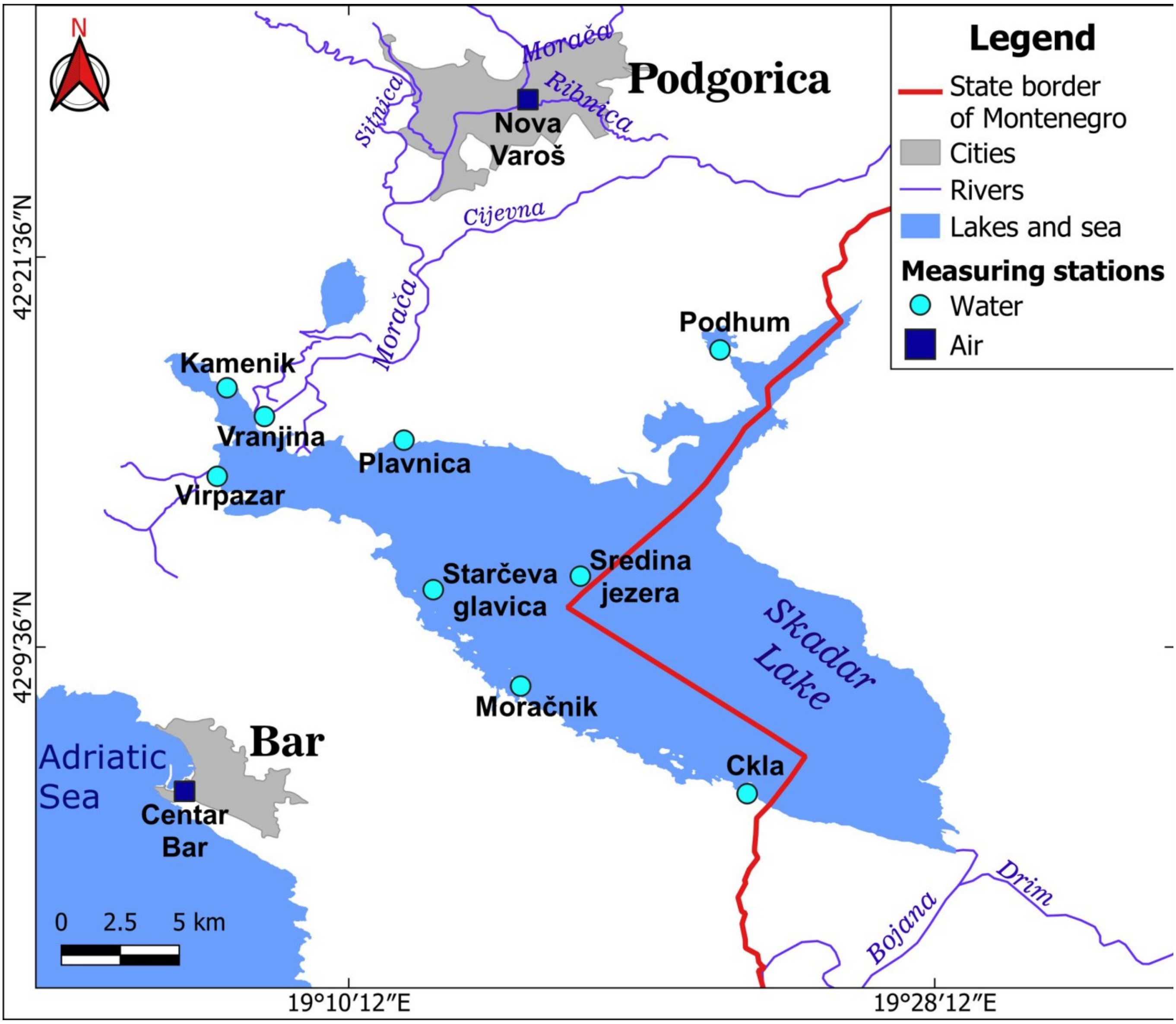

Figure 2. Locations of the stations included in the analysis.

Data from HS from the part of the lake located in Montenegro were used, namely: HS Moračnik, HS Sredina jezera, HS Podhum, HS Kamenik, HS Vranjina, HS Virpazar, HS Plavnica, HS Starčeva glavica and HS Ckla. Considering the availability of data, the assessment of water and air quality of the lake was carried out for the period 2011-2018. A total of 10 parameters of physico-chemical and microbiological water quality from 9 mentioned HS were considered (Table 1). Generally, all 10 mentioned parameters are included in the WQI calculation formula and number (index) of surface water quality was obtained as the final result.

Table 1. Indicators for WQI calculation for Lake Skadar.

No.	Parameter	Unit	No.	Parameter	Unit
1.	Oxygen saturation	%	6.	Orthophosphates	mg/L
2.	BOD_5*	mg/L	7.	Suspended solids	mg/L
3.	Ammonium ion	mg/L	8.	Temperature	^0C
4.	pH value	1-14	9.	Electrical conductivity	µS/cm
5.	Total nitrogen oxides	mg/L	10	Coliform bacteria	MPN in 100 mL

* *Biochemical oxygen consumption for 5 days*

2.3. Calculation and categorization of WQI and PM_{10}

As mentioned above, the WQI was calculated on the basis of 10 parameters. For each parameter, annual values were available as a weighted arithmetic mean. However, the share of each parameter in the total water quality did not have the same relative importance, which means that each individual parameter has its own weight (wi) and score or registered value (qi) in terms of its share in the threat to water quality. The further procedure implies the calculation of the product qi × wi for each parameter separately. Finally, the WQI was calculated as the sum of all 10 products (qi × wi), and the ideal sum of the quality share of all parameters was 100 (Veljković et al., 2008):

$$WQI = 1/100\left(\sum_{i=1}^{n} qiwi\right), \text{ where is:}$$

WQI = water quality index, dimensionless number (from 0 to 100), n = number of parameters (in this case 10),
qi = water quality of the corresponding parameters, wi = weight assigned to the corresponding parameter.

In order to avoid the analysis of individual parameters and to reduce the large amount of data, as well as to be able to make spatial and temporal comparisons, the former Serbia and Montenegro (until May 2006) accepted the WQI method, as the quality of surface water was indicated with a single figure. The established criteria for monitoring surface water quality using the WQI still function within the framework of the independent states (Serbia and Montenegro). The European Union has adopted the WQI method as a water quality assessment tool (Durlević, 2020). In order to comply with European legislation, the Environmental Protection Agency of the Republic of Serbia (SEPA) has developed a calculator for calculating the WQI, the Serbian Water Quality Index (SWQI). It was used for the purposes of this study, as the formula includes the 10 physical, chemical and biological parameters mentioned. The calculation method of the SWQI is available on the SEPA website. Purdue University in Indianapolis (USA) has developed the Simple Water Quality Index Calculator, which gives satisfactory results, but is calculated based on a smaller number of parameters and needs to be tested more thoroughly for the Balkan region. Therefore, for the purpose of this study, the classification of surface water quality according to WQI values and lower thresholds for the concentration of PM_{10} particles used by the official state EPA of Montenegro was applied (Table 2).

Table 2. Classification of surface water quality using the WQI method and limit values of PM_{10} particles.

Classification of water quality according to WQI (source: EPA, 2019, p. 48)		
Water quality	**Numerical indicator**	
Excellent	90-100	
Very good	84-89	
Good	72-83	
Bad	39-71	
Very bad	0-38	
Limit value of PM_{10} for the protection of human health (source: EEA[1] and EPA, 2023)		
Parameter	**Threshold value**	**Limit of tolerance**
Daily mean (PM_{10})	50 μg/m³	35 times annually
Annual mean (PM_{10})	40 μg/m³	/

As for PM_{10} particles with a diameter of 10 micrometres or less (≤ 10 μm), we used the average daily concentrations (μg/m³) (micrograms/cubic metre) for the study, so that the analysis takes into account seasonal and daily variations in addition to annual ones. In Podgorica and Bar, the concentration of suspended particles PM_{10} was measured at the measuring station (MS) Nova Varoš (Podgorica) and MS Centre (Bar). Based on 24-hour measurements, the mean daily value of PM_{10} was determined. As far as is known, there is still no classification for the concentration of PM_{10} particles, only limit values (lower threshold values). According to the EU Directive (EU, 2008) and the recommendations of the World Health Organization (WHO, 2017), the lower threshold value for the concentration of PM_{10} particles is 40 μg/m³ on an annual and seasonal basis, and if the daily value exceeds 50 μg/m³, this is considered a potentially hazardous concentration for public health. Since 2011, the State Environmental Protection Agency (EPA, 2023) has accepted the above thresholds as legal and has set 35 days per year as the tolerance limit, which means that exceeding them on 35 days per year with an average daily concentration of PM_{10} particles > 50 μg/m³ is not desirable.

[1] https://www.eea.europa.eu/data-and-maps/figures/particulate-matter-pm10-annual-limit-value-for-the-protection-of-human-health-3

https://doi.org/10.48088/ejg.d.bur.14.2.076.087

2.4. Data limitations

It should be mentioned that there were no missing data for WQI, while for PM_{10} there were 4.5% missing data for Podgorica as a whole and 19.9% missing data for Bar for the whole observation period (2011-2018). They were not included in the analysis. Of the 4.5% of missing data for PM_{10} in Podgorica, the majority concerned October (1.4% in total), i.e. July (1.2%), while in the other months the percentage of missing data was negligible. In Bar, there were days without data for PM_{10} particles in almost all months, but most frequently in October (total 2.7%) and January (2.6%). The reason for the missing data was temporary instrument (air quality detector) failures.

The main advantage of the WQI method, which is based on several variables, is a single number as the final result, so it is possible to compare the water quality of one water body in time and of a larger number of water bodies in space. However, notwithstanding the fact that no data were missing, it should be noted that the WQI method has weaknesses. The most important of these is that data on some important parameters, such as inorganic pollution (e.g. heavy metals) and that the WQI can be calculated even if not all the parameters mentioned are available. Moreover, the WQI method is not universal, as the type and number of parameters as well as their weighting coefficients and class intervals can be modified, i.e adapted to local and regional conditions (Hurley et al., 2012; Garcia et al., 2018; Uddin et al., 2021). The problems of using the WQI model and the possibilities of optimization techniques to improve their application, accuracy and reliability have been discussed in more detail in the papers by Uddin et al. (2021, 2022b, 2023c, 2023d).

3. Results

3.1. Analysis of the Water Quality Index (WQI) of Lake Skadar

According to the results obtained with 9 HS, the water quality of the lake varies (Figure 3). At the Kamenik monitoring station located in the western, narrowest part of the lake where the most noticeable water level fluctuations occur, water quality ranged from good, WQI = 81-83 (2013 and 2018), to very good, WQI = 85-89 (2012, 2015 and 2017), to excellent, WQI = 90-92 (2011, 2014 and 2015) throughout the monitoring period. HS Vranjina is located at the mouth of the Morača River. The Morača River flows through the urban area of Podgorica and the Zeta Plain, so in this lower part of the river course it is subject to the influence of a variety of factors that affect its quality. Nevertheless, the WQI on HS Vranjina ranged from good, WQI = 79-83 (2011 and 2017), very good, WQI = 84-88 (2012, 2013, 2015 and 2018) to excellent, WQI = 90 (2014 and 2016).

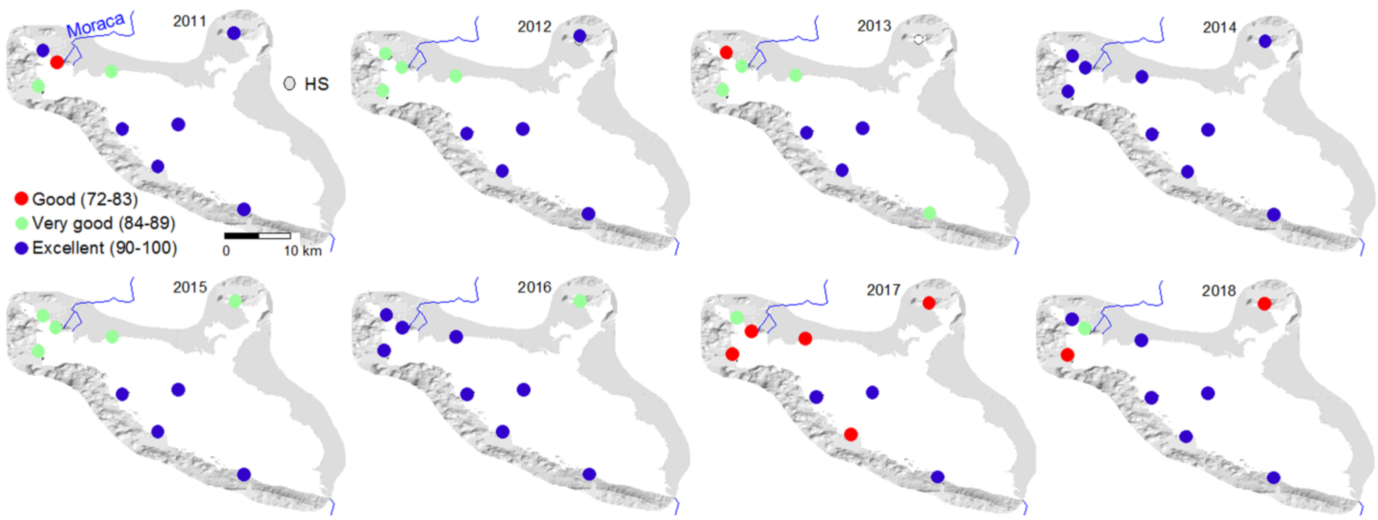

Figure 3. Average annual values of WQI at the hydrological stations (HS) of Lake Skadar for the period 2011-2018.

The Virpazar monitoring station is located at the mouth of the Crmnica River, which flows through an agricultural area and collects wastewater from this area, but even there the water quality ranged from good, WQI = 81-83 (2017 and 2018), to very good, WQI = 84-88 (2011, 2012, 2013 and 2015), to excellent, WQI = 92 (2014 and 2016). HS Plavnica is located at the mouth of the Plavnica River and had similar water quality values to the previous monitoring points almost during the entire monitoring period. The WQI of the Plavnica profile was categorised from good, WQI = 82 (2017), very good, WQI = 85-89 (2011, 2012, 2013 and 2015) to excellent, WQI = 93-94 (2014 and 2016). During the observed period, HS Podhum also recorded fluctuations in water quality. For example, in 2017 it was in the good category (WQI = 81), in 2013 and 2015 it was in the very good category (WQI = 86-88), while in 2014, 2016 and 2018 it belonged to the excellent category (WQI = 91-95). The Moračnik and Starčeva glavica monitoring stations had water quality in the excellent category almost during the entire period, but in 2018 the quality deteriorated; the water at HS Moračnik was in the good category (WQI = 81), and HS Starčeva glavica very good (WQI = 88). During the entire monitoring period (2011-2018), HS Sredina jezera (The middle of the lake) had water quality in the excellent category. Also HS Ckla had water quality belonging to the excellent category almost during the entire monitoring period, except for 2013 and 2014 when the quality was very good (WQI = 88-89).

It is encouraging that the water quality of Skadar Lake never fell into the very poor or poor category according to the WQI value during the 8-year period studied. In almost all observed profiles there were inter-annual fluctuations in water quality, most likely related to increased/decreased amount of wastewater from settlements, agricultural sources and illegal dumping and other waste on the shores or in the lake itself. Annual fluctuations in WQI are also partly due to changes in hydrological conditions. To check this, a comparison was made between the annual WQI values and the amount of precipitation. In years with an unfavourable hydrological situation (less precipitation and lower runoff than average), the lake water was generally of poor quality. This was observed in 2017 with below-average precipitation. As a result, the water quality was the poorest. According to IHMSM data, 2014 was the year with the highest precipitation (1913 mm) in Bar in the last 60 years and one of the highest precipitations (2018 mm) in Podgorica, so Skadar Lake water was of excellent quality on all profiles. Moreover, the water quality in the profile of Vranjina was the worst (here the category "good" dominated), which is due to an increased amount of municipal wastewater (mostly untreated) from the urban area of Podgorica entering the Morača River.

3.2. Analysis of the concentration of PM_{10} particles in Podgorica and Bar

The analysis of PM_{10} particle concentration was performed based on the data from one monitoring station each (MS) in Podgorica and Bar for the period 2011-2018. In Podgorica, the lowest annual mean value for PM_{10} particles was recorded in 2013 (34.0 μg/m³) and the highest in 2015 (43.8 μg/m³). This means that the average annual concentrations of PM_{10} particles were mostly below the prescribed limit value (40 μg/m³) during the observed period. Apart from the mentioned 2015, the year 2018 also stood out, in which the average annual concentration of PM_{10} particles (41 μg/m³) was exceeded. On the other hand, there was not a single year on MS Bar with an average annual concentration of PM_{10} particles above the prescribed limit of 40 μg/m³. Comparing the annual mean values of PM_{10} particles with 2 observed MS (Figure 4a), it can be assumed that the air in Bar was generally cleaner than in Podgorica.

Regarding the seasonal movement of PM_{10} particles (Figure 4b and c), the mean PM_{10} concentration in winter (December-January-February) ranged from 48.1 μg/m³ (2019) to 81.3 μg/m³ (2015) in Podgorica and from 22.4 μg/m³ (2017) to 47.2 μg/m³ (2013) in Bar. In spring (March-April-May), the highest concentrations and the only exceedances in 2018 occurred in Podgorica (43.4 μg/m³), while they were not measured in Bar. During the summer period (June-July-August), the value of 40 μg/m³ was not exceeded in Bar or Podgorica. In the autumn season, an exceedance was recorded in Podgorica only in 2011 with 45.6 μg/m³. At MS Bar, the mean concentrations of PM_{10} particles in this season ranged from 6.8 μg/m³ (2017) to 37.7 μg/m³ (2011). Therefore, it is obvious that the concentration of PM_{10} particles in Bar was lower than in Podgorica, even at the seasonal level.

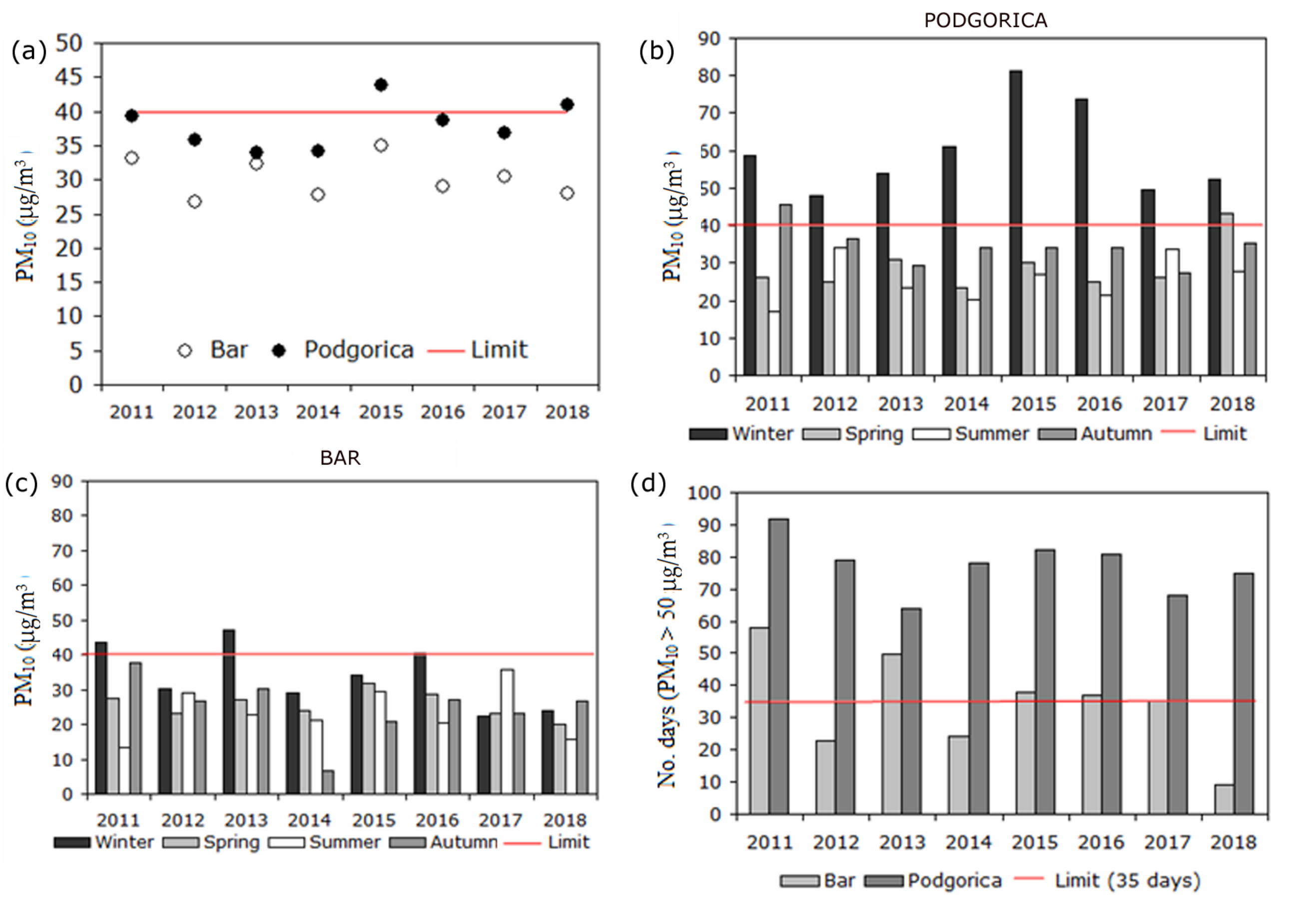

Figure 4. Average values of PM_{10} particles in Podgorica and Bar for the period 2011-2018 for the year (a), seasons (b and c) and the annual number of days with an average daily concentration of PM_{10} particles > 50 μg/m³ (d).

The results obtained also show that the highest mean concentrations of PM_{10} particles were measured in winter, i.e. in the colder part of the year. Thus, compared to other seasons, the concentration of PM_{10} particles increased in winter due to the additional pollutant emissions from individual fireplaces (heating period of houses and flats). We can draw attention to the officially established limit value of 40 μg/m³ in Montenegro. The average concentrations above the mentioned limit are considered potentially dangerous for public health. In winter, the average concentration of PM_{10} particles in Podgorica was above the prescribed limit every year, while in Bar this was the case in 2011, 2013 and

2016. In MS Podgorica, the average concentration of PM_{10} particles was also above the limit value of 40 µg/m^3 in both autumn 2011 and spring 2018. In all other cases, both in Bar and Podgorica, the air was of satisfactory quality, as the mean seasonal value of PM_{10} particles was below the prescribed threshold.

However, the analysis of the daily values shows that the situation regarding air pollution with PM_{10} particles in the two urban areas of Podgorica and Bar is difficult. In other words: Taking as a tolerance limit 35 days a year with an average daily concentration of PM_{10} particles of 50 µg/m^3, the obtained results show that this limit was exceeded every year in Podgorica and almost every year in Bar during the observed period (2011-2018). MS In Podgorica, the number of days per year when the established limit value (35 days per year) was exceeded was 1.7 to 2.4 times, while in MS Bar this value was between 0.7 (2018) and 1.7 times (year 2011). In other words, in 2013 there were 64 days with an average daily concentration of PM_{10} particles exceeding 50 µg/m^3 (or 1.7 times) in Podgorica and as many as 92 such days in 2011 (or 2.4 times the assumed threshold), while in Bar there were 9 days in 2018 and as many as 58 days in 2011 when the daily concentration of PM_{10} particles was exceeded (see Figure 4d).

Even on a daily basis, the highest levels of air pollution in the observed urban units were recorded in winter, especially in the two coldest months of the year (January and December). In 2011-2018, average daily concentrations of PM_{10} particles in Podgorica during the winter months ranged up to an incredible 222.8 µg/m^3 (absolute daily maximum registered on 23 January 2017), while in Bar the highest absolute daily maximum was 130.4 µg/m^3 (registered on 29 February 2016). A large number of days with high PM_{10} particle levels were recorded in December. Of the 248 December days in the 8 years mentioned, there were 147 days in Podgorica and 80 days in Bar when the average daily concentration of PM_{10} particles was above the prescribed limit of 50 µg/m^3. Thus, in Podgorica there were almost 60% of winter days with a potentially dangerous concentration of PM_{10} particles for humans, so this situation can be described as alarming.

4. Discussion

The increase in population, urbanisation and industrialisation have led to an increasing problem of sanitation and pollution of lakes and other surface waters (Bhateria & Jain, 2016). Nevertheless, the results of this study indicate that the water quality of Lake Skadar is currently at a satisfactory level, as the categories of very good (WQI 84-89) and excellent (WQI 90-100) dominate. The largest lowland in Montenegro, the Zeta Plain, lies on the shore of the lake. In recent years, agricultural activity has increased in the Zeta Plain area, while on the other hand some parts of it are being urbanised. In the immediate northern hinterland of Lake Skadar lies Podgorica, the capital and largest city of Montenegro. The lower course of the Morača River, the largest tributary of Lake Skadar, flows through Podgorica and the Zeta Plain. The population is increasingly leaving the northern part of the country and settling in the area of the capital. Consequently, Podgorica is experiencing significant population growth. It is estimated that the number of inhabitants of Podgorica has increased by 50-70 thousand in the last 10 years due to immigration. In the vicinity of Podgorica, illegal construction activities and pressure on infrastructure facilities (illegal connection to water, electricity and other networks), illegal waste disposal on the banks of the Morača River, as well as increasingly pronounced tourist pressure on the shores of Lake Skadar can be observed. Bar is the largest town on the Montenegrin coast, and in recent years this settlement has seen increasing immigration, even from Russia and war-torn Ukraine. The anthropogenic pressure on the environment is unmistakable. The additional inflow of mostly untreated wastewater from the Podgorica area, the increased agricultural activity in the Zetska Plain (and thus the use of pesticides, insecticides and other chemicals), the increased number of vehicles and other human activities affect the water quality of Lake Skadar and generally deteriorate the environmental quality of the observed area (the lake, Podgorica and Bar). In both cities, PM_{10} particle concentrations frequently exceed the permissible levels (daily above 50 and seasonally and annually above 40 µg/m^3), which affects public health. The situation is particularly worrying in winter, especially in Podgorica, where the average daily concentration of PM_{10} particles exceeds 200 µg/m^3. The WHO lists the concentrations of PM particles (PM_{10} and $PM_{2.5}$) as lower limits that can be achieved to minimise the impact on public health (WHO, 2017). The increase in air pollution in the observed urban units is due to a number of factors, such as exhaust fumes from cars and small and medium enterprises consuming fossil fuels, but also to the burning of wood and coal for the heating needs of individual households (houses).

The results obtained showed that the water of the lake was of poor quality in years with less precipitation. Therefore, in addition to anthropogenic pressures, climate change should also be considered in water quality. Projected climate changes by the end of the 21st century in Montenegro (Doderović et al., 2020; Burić & Doderović, 2020; Burić & Doderović, 2021), but also in the Mediterranean region in general (IPCC, 2021), indicate increasing droughts and more frequent extreme weather situations (e.g. prolonged droughts, heavy precipitation), which could deteriorate surface water quality and the environment. The Morača River, its main tributary, which flows through the largest urban settlement and the largest plain in the country, has the greatest impact on the water quality of Lake Skadar. Nevertheless, this largest lake on the Balkan Peninsula should be well preserved. To achieve this, it is necessary to reduce or control anthropogenic pressure as best as possible, to detect sources of pollution in its catchment area and to solve the problem of pollution of the Morača River in its lower reaches (through Podgorica and the Zetska Plain) in the hope of not suffering the fate of, for example, Lake Ohrid. Research shows that Lake Ohrid (on the border between northern Macedonia and Albania) has been subject to strong pressure from the anthropogenic factor in recent decades, "caused by the doubling of the population near the shore, negative impacts of industry and intensive use of agricultural land" (Iseni, 2018). Lake Prespa is also located near Ohrid, but the situation is more favourable. According to physico-chemical parameters, research results show that the water purity of Lake Prespa ranges from class I to III, and according to bacteriological parameters from class I to II (Stoilova et al., 2013). Lake Palić in Serbia is also exposed to strong anthropogenic pressures (Horvat et al., 2021).

In the last two decades, in Mediterranean Montenegro, forest fires occur frequently in summer, especially in the wider hinterland of the coast (around Bar, Podgorica and Lake Skadar), causing severe damage to the environment and occasionally negatively affecting the lake ecosystem (Pešić et al., 2020). The state takes certain measures to protect water and air, but it is obvious that these are not enough. Construction of municipal heating plants, installation of modern philtres in polluting industrial plants, cleaning of sewage, punishment of illegal waste dumping and application of other measures (e.g. controlled immigration, prohibition of illegal construction) would improve the quality of air and water in Montenegro. One of the measures is to educate the population about the importance of environmental protection. Through the education system, young people and teachers are familiarised with environmental issues (Naudet, 2022; Prodanova & Varadzhakova, 2022).

5. Policy recommendations

In order to prevent, reduce or eliminate the negative impacts on the environment of the case study area, the recommendations can be classified into four basic groups:

- Legal regulations,
- Spatial planning,
- New technologies,
- Environmental education

Legal measures regulate the protection of the environment. Montenegro has adopted numerous legal acts in the field of ecology and seeks to complement legislation with the European Union. However, based on the findings presented in this paper, it is evident that the existing legislation is insufficiently applied. In the specific case, it is necessary to apply the existing laws and adopt new legal acts, programmes, plans and other documents for the protection and improvement of the environmental quality of NP Skadar Lake and its surroundings. It is also necessary to expand and introduce regular monitoring of the state of the environment (as many monitoring stations as possible for water and air quality) so that correct assessments are based on actual data. In the area under observation, the problems have been evident for some time: untreated sewage into the rivers and lakes, uncontrolled dumping of waste on the banks and in the water bodies (in the lake and river beds), next to the roads or in other places not intended for this purpose. There is a need for a strict punitive policy, i.e. more rigorous punishment for non-compliance with the law.

It seems that there is no spatial planning for the area under observation or the existing one is inadequate. It was mentioned that the number of inhabitants has increased in both cities, especially in Podgorica. Unplanned construction and pressure on infrastructure facilities are also noticeable. The number of motor vehicles has increased significantly, as well as uncontrolled tourist activities on the shores of Skadar Lake (construction of private accommodation, motels, restaurants, a large number of boats), etc. There is no doubt that the current and future anthropogenic pressure on the environment of this most densely populated part of Montenegro could be mitigated by integrative environmental and spatial planning mechanisms, i.e. appropriate arrangement of settlements and facilities, selection of tourist, agricultural and industrial sites, integrative land-use and transport planning measures to reduce motorized transport.

Before flowing into Lake Skadar, the Morača River flows through Podgorica and the Zetska Plain. Due to the discharge of untreated municipal and other wastewater (from small and medium enterprises, poultry and livestock farms), agricultural and construction activities, and illegal waste dumping (Doderović et al., 2020), its water in the lower part has been shown to be generally of poor quality. Therefore, it is essential to detect all sources of pollution in the observed area, ban and punish illegal polluters and apply appropriate purification technologies to others (construction of sewage treatment plants, installation of philtres on factory chimneys, etc.).

Our society today is in the midst of a serious ecological crisis, which makes environmental protection one of the most important issues of contemporary civilisation. However, one has the impression that in Montenegro, a country of exceptional natural beauty, not enough attention is paid to environmental sustainability issues. Thus, one of the most crucial recommendations is an educational policy based on proven scientific literature, so that environmental problems are more present not only in scientific circles, but also in the life of every individual. It is necessary to improve the system of civic education about the importance of environmental protection, primarily at the institutional level (through the school system), but also at the non-institutional level (non-governmental organisations, volunteers, etc.).

Due to climate change, it is worth mentioning that Montenegro has recently faced more frequent floods (Burić et al., 2021). This is particularly pronounced in the studied area - the shores of Lake Skadar, the Bojana River and the lower reaches of the Morača River. Since floods have negative impacts on all areas of the environment, it is necessary to adopt a plan to regulate the water level of the lake and the mentioned watercourses. Unfortunately, as a developing country, Montenegro does not have the financial means to implement this environmental protection measure. In order to plan and implement the above and other recommendations, international technical-scientific cooperation and support is urgently needed.

6. Conclusions

This study presents the results of the water quality of Lake Skadar (using the WQI model or SWQI method) and air pollution in Podgorica and Bar, using categorisation methods. For the period 2011-2018, ten indicators of water pollution from nine hydrological stations on Lake Skadar and concentrations of PM_{10} particles from one station each in the centre of Podgorica and Bar were used. The results of the analysis of the WQI showed that the water of Lake Skadar, which is located between the mentioned urban areas, is of good quality. According to the average annual WQI values, the water of Skadar Lake belonged to the categories of very good (84-89) and excellent (90-100), rarely to the category of good (72-83, especially in 2017). The air in both Podgorica and Bar was unacceptably polluted in some years, although the situation in Podgorica is much more difficult during the winter months. Average concentrations of PM_{10} particles (daily and seasonal) were above the prescribed limits (> 40 and 50 μg/m3) in Podgorica in winter, while this was less common in Bar. In Podgorica there were 64 to 92 days per year with PM_{10} particle concentrations above 50 μg/m3, which is far above the legally set tolerance limit (35 days per year). In Bar, there were 5 years (2011, 2013, 2015, 2016 and 2017) when the number of days was above the prescribed limit. However, the results should be interpreted with caution as this study analyses a relatively short observation period for water and air quality (2011-2018). In addition, the WQI method of this work does not consider data on some important parameters (e.g. inorganic pollution), which are, however, crucial for the global comparison of surface and groundwater quality and for the creation of a universal WQI method and classification scheme. Future work should explore the application of more complex assessment frameworks using new data and environmental indicators to assist Montenegro's authorities in making data-driven environmental decisions that mitigate the impacts of existing environmental problems not only in and around Lake Skadar, but also at the country level.

Conflicts of Interest: The author declares no conflict of interest.

Data Availability Statement: The data of this work are publicly available on the following institutional websites of Montenegro: Institute of Hydrometeorology and Seismology of Montenegro (IHMSM) and Environmental Protection Agency of Montenegro (EPA).

References

Adams, K., Greenbaum, D. S., Shaikh, R., van Erp A. M., & Russell, A. G. (2015). Particulate matter components, sources, and health: Systematic approaches to testing effects. *Journal of the Air & Waste Management Association, 65*(5), 544–558. https://doi.org/10.1080/10962247.2014.1001884

Babić, G., Vuković, M., Voza, D., Takić, L., & Mladenović-Ranisavljević I. (2019). Assessing Surface Water Quality in the Serbian Part of the Tisa River Basin. *Polish Journal of Environmental Studies*, *28*(6), 4073–4085. https://doi.org/10.15244/pjoes/95184

Berila, A., & Isufi, F. (2021). Mapping summer SUHI and its impact on the environment using GIS and Remote Sensing techniques: A case study on Municipality of Prishtina (Kosovo). *European Journal of Geography, 12*(3), 113-129. https://eurogeojournal.eu/index.php/egj/article/view/111

Bharti, N., & Katyal, D. (2011). Water quality indices used for surface water vulnerability assessment. International journal of environmental sciences, *2*(1), 154–173. https://www.researchgate.net/profile/Deeksha-Katyal/publication/285977924

Boyacioglu, H. (2009). Development of a water quality index based on a European classification scheme. *Water Sa*, *33*(1), 101–106. https://doi.org/10.4314/wsa.v33i1.47882

Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: a review. *Sustainable Water Resources Management*, *2*, 161–173. https://doi.org/10.1007/s40899-015-0014-7

Burić, D., Ducić, V., & Mihajlović, J. (2014). The climate of Montenegro: Modificators and types - part two. *Bulletin of the Serbian Geographical Society*, *94*(1), 73–90. https://doi.org/10.2298/GSGD1401073B

Burić, D., & Doderović, M. (2019). Precipitation, Humidity and Cloudiness in Podgorica (Montenegro) during the Period 1951–2018. *Geographica Pannonica*, *23*(4), 233–244. https://doi.org/10.5937/gp23-23582

Burić, D., & Doderović, M. (2020). Projected temperature changes in Kolašin (Montenegro) up to 2100 according to EBU-POM and ALADIN regional climate models. *IDŐJÁRÁS, 124*(4), 427–445. http://doi.org/10.28974/idojaras.2020.4.1

Burić, D., & Doderović, M. (2021). Changes in temperature and precipitation in the instrumental period (1951-2018) and projections up to 2100 in Podgorica (Montenegro). *International Journal of Climatology, 41*(S1), 133–149. https://doi.org/10.1002/joc.6671

Burić, D., Doderović, M., Dragojlović, J., & Penjišević, I. (2021). Extreme weather and climate events in Montenegro – case study, November 2019. *Weather. 76(11), 383–388.* https://doi.org/10.1002/wea.3885

Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K., Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., Feigin, V., Freedman, G., Hubbell, B., Jobling, A., Kan, H., Knibbs, L., Liu, Y., Martin, R., Morawska, L., … Forouzanfar, M. H. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*, *389*(10082), 1907–1918. https://doi.org/10.1016/S0140-6736(17)30505-6

Doderović, M., Burić, D., & Popović, Lj. (2018). Hidrologija kopna. *Univerzitet Crne Gore* (eng. Land hydrology, *University of Montenegro*). ISBN: 978-86-7664-155-0

Doderović, M., Mijanović, I., Burić, D., & Milenković, M. (2020). Assessment of the water quality in the Moraca River basin (Montenegro) using water quality index. *Bulletin of the Serbian Geographical Society, 100*(2), 67–81. https://doi.org/10.2298/GSGD2002067D

Doderović, M., Burić, D., Mijanović, I., & Premović, M. (2021). Analysisof River Water and Air Pollution—Pljevlja as a "Hot Spot" of Montenegro. *Sustainability, 13*, 5229. https://doi.org/10.3390/su13095229

Doderović, M., Burić, D., Ducić, V., & Mijanović, I. (2020). Recent and Future Air Temperature and Precipitation Changes in the mountainous nort of Montenegro. *Journal of the Geographical Institute "Jovan Cvijić", SASA, 70*(3), 189–201. https://doi.org/10.2298/IJGI2003189D

Drasovean, R., & Murariu, G. (2021). Water Quality Parameters and Monitoring Soft Surface Water Quality Using Statistical Approaches. In: Promising Techniques for Wastewater Treatment and Water Quality Assessment Moujdin A. and Summers J. K. (Ed.). *IntechOpen*, 1–17. https://doi.org/10.5772/intechopen.97372

Durlević, U. (2020). The analysis of the quality of surface water of Danube in the Republic of Serbia for 2018. *Zbornik radova - Geografski fakultet Univerziteta u Beogradu, 68*, 53-70. https://doi.org/10.5937/zrgfub2068053D

EU. (2000). *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.* Official Journal of the European Communities, L327, 1–72. http://data.europa.eu/eli/dir/2000/60/oj

EU. (2008). *Directive 2008/50/EC of the European Parliament and of the council of 21 May 2008 on ambient air quality and cleaner air for Europe.* Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0050#d1e89-30-1

EPA. (2019). *Informacija o stanju životne sredine za 2018.* Agencija za zaštitu prirode i životne sredine Crne Gore, pp. 337. https://epa.org.me/wp-content/uploads/2019/08/Informacija-o-stanju-zivotne-sredine-2018.pdf

EPA. (2023). *Monthly Reports for the Period 2011-2018* (downloaded data for PM_{10} concentration). Environmental Protection Agency of Montenegro. Available online: https://epa.org.me/mjesecni-izvjestaji-o-kvalitetu-vazduha/

Garofalo, D., & Ferreira, M. (2022). Regionalization of water quality parameters based on the landscape characteristics of small ungauged basins: A study carried out in south-eastern Brazil. *European Journal of Geography, 13*(1), 047-068. https://doi.org/10.48088/ejg.d.gar.13.1.47.68

Gartsiyanova, K., Varbanov, M., Kitev, A., Genchev, S., & Georgieva, S. (2020). Territorial features and dynamics in the water quality change in the Topolnitsa and Luda Yana rivers. *Journal of the Bulgarian Geographical Society, 43,* 9–15. https://geography.bg/publication/magazines/item/473-vol43-2020-2

Georgescu, P., Moldovanu, S., Iticescu, C., Calmuc M., Calmuc V., Topa, C., & Moraru, L. (2023). Assessing and forecasting water quality in the Danube River by using neural network approaches. *Science of The Total Environment, 879,* 162998. https://doi.org/10.1016/j.scitotenv.2023.162998

Habbeb, M. G. H., Sulyman, M. H. A., & Jumaah, H. J. (2022). Modeling Water Quality Index using Geographic Information Systems and Weighted Arithmetic Index in Kirkuk, Iraq. Pollution Research, 41(1), 323-327. https://doi.org/10.53550/PR.2022.v41i01.047

Hamed, H. H., Jumaah, H. J., Kalantar, B., Ueda, U., Saeidi, V., Mansor, S., & Khalaf, Z. A. (2021). Predicting $PM_{2.5}$ levels over the north of Iraq using regression analysis and geographical information system (GIS) techniques. *Geomatics, Natural Hazards and Risk, 21* (1), 1778-1796. https://doi.org/10.1080/19475705.2021.1946602

Hadžiablahović, S. (2018). The Diversity of the Flora and Vegetation of Lake Skadar/Shkodra. In: Pešić,V., Karaman, G. & Kostianoy, A. (eds). *The Skadar/Shkodra Lake Environment. The Handbook of Environmental Chemistry, Springer, Cham, 80*, 203-238. https://doi.org/10.1007/698_2018_236
Horvat, M., Horvat, Z., & Pastor, K. (2021). Multivariate analysis of water quality parameters in Lake Palic, Serbia. *Environmental Monitoring and Assessment, 193*, 410. https://doi.org/10.1007/s10661-021-09195-8
IPCC. (2021). *Summary for Policymakers.* In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. 2021.
Iseni, G. (2018). The impact of pollution on the quality of the Lake Ohrid water and the Barbus meridionalis petenyi Heckel. *International Journal of Avian & Wildlife Biology, 3*(2), 102–104. https://doi.org/10.15406/ijawb.2018.03.00065
IHMSM. (2023). *Annual Reports for the Period 2011-2018* (downloaded data for the water quality of Skadar lake). Institute of Hydrometeorology and Seismology of Montenegro. Available online: http://www.meteo.co.me/page.php?id=56
Jakovljević, D. (2012). Serbian and Canadian water quality index of Danube river in Serbia in 2010. *Journal of the Geographical Institute "Jovan Cvijić", SASA, 62,* 1–18. https://doi.org/10.2298/IJGI1203001J
Jumaah, H. J., Ameen, M. H., Mahmood, S., & Jumaah, S. J. (2023). Study of air contamination in Iraq using remotely sensed Data and GIS. *Geocarto International, 38*(1), 2178518. https://doi.org/10.1080/10106049.2023.2178518
Josimov-Dunđerski, J., Savić, R., Grabić, J., & Blagojević, B. (2016). Water quality of the Danube River in the Pannonian part of its flow through Serbia. *Annales Agronomy, Faculty of Agriculture, University of Novi Sad, 40*(1), 8–14. http://polj.uns.ac.rs/sites/default/files/letopis-naucnih-radova/2Josimov-Dundjerski%20et%20al.%20O2016%20Ann%20Agron.%2040%2C%208-14.pdf
Karagulian, F., Belis, C. A., Dora, C. F. C., Prüss-Ustün, A. M., Bonjour, S., Adair-Rohani, H., & Amann, M. (2015). Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level. *Atmospheric Environment, 120,* 475–483. http://dx.doi.org/10.1016/j.atmosenv.2015.08.087
Kolarević, S., Kračun-Kolarević, M., Jovanović, J., Ilić, M., Paunović, M., ..., & Vuković-Gačić, B. (2019). Microbiological Water Quality of Rivers in Montenegro. *The Handbook of Environmental Chemistry, 93,* 135–155. https://doi.org/10.1007/698_2019_420
Lumb, A., Halliwell, D., & Sharma, T. (2006). Application of CCME Water Quality Index to Monitor Water Quality: A Case Study of the Mackenzie River Basin, Canada. *Environmental Monitoring and Assessment, 113,* 411–429. https://doi.org/10.1007/s10661-005-9092-6
Markou, D. (2022). Exploring spatial patterns of environmental noise and perceived sound source dominance in urban areas. : Case study: the city of Athens, Greece. *European Journal of Geography, 13*(2), 060-078. https://doi.org/10.48088/ejg.d.mar.13.2.060.078
Marcheva, Z., Kotsev, T., Tchorbadjieff, A., & Stoyanova, V. (2023). Modeling of arsenic dynamics in groundwater of a river floodplain contaminated with mine tailings: Ogosta River case, NW Bulgaria. *Journal of the Bulgarian Geographical Society, 48,* 3-14. https://doi.org/10.3897/jbgs.e99206
Mititelu-Ionuș, O. (2010). Water Quality Index - Assessment method of the Motru river water quality (Oltenia, Romaia). *University of Craiova, Series: Geography, 13,* 74–83. https://www.researchgate.net/publication/281863374
Milijasević-Joksimović, D., Gavrilović, B., & Lovic-Obradović, S. (2018). Application of the water quality index in the Timok River basin (Serbia). *Journal of the Geographical Institute "Jovan Cvijić", SASA, 68*(3), 333–344. https://doi.org/10.2298/IJGI180610007M
Mladenović-Ranisavljević, I. I., & Žerajić, S. A. (2017). Comparison of different models of water quality index in the assessment of surface water quality. *International Journal of Environmental Science and Technology, 15,* 665–674. https://doi.org/10.1007/s13762-017-1426-8
Murariu, G., Iticescu, C., Murariu, A., Rosu, B., Munteanu, D., & Buruiana, D. L. (2019). Assessment of Water Quality State Dynamics Using Adaptive Filtering Methods and Neural Networks Approaching. Case study - Danube River in Galati area. *Revista de Chimie, 70*(6), 1914–1919. https://doi.org/10.37358/RC.19.6.7246
MONSTAT. (2011). *First Results Census of Population, Households and Dwellings in Montenegro.* Institute for Statistics of Montenegro, 57 pp. https://www.monstat.org/userfiles/file/popis2011/saopstenje/knjiga_prvi%20rezultati(1).pdf
Naudet, C. (2022). Using "Spontaneous Geography" to reason about environmental problems. *European Journal of Geography, 13*(5), 045-057. https://doi.org/10.48088/ejg.c.nau.271
Parween, S., Siddique, N. A., Diganta, M. T. M., Olbert, A. I., & Uddin, M. G. (2022). Assessment of urban river water quality using modified NSF water quality index model at Siliguri city, West Bengal, India. *Environmental and Sustainability Indicators, 16,* 100202. https://doi.org/10.1016/j.indic.2022.100202
Pešić, V., Karaman, G., & Kostianoy, A. (2018a). Introduction. In: Pešić, V.,Karaman, G.&Kostianoy,A.G.(eds), The Skadar/Shkodra Lake Environment. The Handbook of *Environmental Chemistry*, vol 80. Springer, Cham, pp. 1–10. https://doi.org/10.1007/698_2018_258
Pešić, V., Karaman, G., Kostianoy, A., & Vukašinović-Pešić, V. (2018b). Conclusions: Recent Advances and the Future Prospects of the Lake Skadar/Shkodra Environment. In: Pešić, V., Karaman, G.& Kostianoy, A. (eds), The Skadar/Shkodra Lake Environment. The Handbook of *Environmental Chemistry*, vol 80. Springer, Cham, pp.481–500. https://doi.org/10.1007/698_2018_274
Pešić, V., Kostianoy, A. G., & Soloviev, D. M. (2020). The impact of wildfires on the Lake Skadar/Shkodra environment. *Ecologica Montenegrina, 37*(9), 57–65. http://dx.doi.org/10.37828/em.2020.37.7
Prodanova, H., & Varadzhakova, D. (2022). How individual scores affect the final expert-based assessments of ecosystem services: Range and mean scores analysis of natural heritage supply maps. *European Journal of Geography, 13*(4), 074-097. https://doi.org/10.48088/ejg.h.pro.13.4.074.097
Rocha, F. C., Andrade, E. M., & Lopes, F. B. (2014). Water quality index calculated from biological, physical and chemical attributes. *Environmental Monitoring and Assessment, 187,* 4163. https://doi.org/10.1007/s10661-014-4163-1
Sasakova, N., Gregova, G., Takacova, D., Mojzisova, J., Papajova, I., ... & Kovacova, S. (2018). Pollution of Surface and Ground Water by Sources Related to Agricultural Activities. *Frontiers in Sustainable Food Systems, 2,* 1–11. https://doi.org/10.3389/fsufs.2018.00042
Stoilova, S., Popova Ramova, E. L., & Stoilov, B. (2013). Prespa lake water quality and protection. *Jokull Journal, 63*(9), 1–5. https://www.researchgate.net/publication/283316217
Sutadian, A. D., Muttil, N., Yilmaz, A. G., & Perera, B. (2016). Development of river water quality indices—A review. *Environmental Monitoring and Assessment, 188,* 1–29. https://doi.org/10.1007/s10661-015-5050-0

Seymenov, K. (2022). Assessment of water pollution with nitrogen and phosphorus along the course of a river: A case study from Northern Bulgaria. *Journal of the Bulgarian Geographical Society,* 47, 35-44. https://doi.org/10.3897/jbgs.e97971
Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators, 122*, 107218. https://doi.org/10.1016/j.ecolind.2020.107218
Uddin, M. G., Nash, S., Rahman, A., & Olbert, A. I. (2022a). A comprehensive method for improvement of water quality index (WQI) models for coastal water quality assessment. *Water Research, 219,* 118532. https://doi.org/10.1016/j.watres.2022.118532
Uddin, M. G., Nash, S., Diganta, M., Rahman, A., & Olbert, A. I. (2022b). Robust machine learning algorithms for predicting coastal water quality index. *Journal of Environmental Management, 321*, 115923. https://doi.org/10.1016/j.jenvman.2022.115923
Uddin, M. G., Nash, S., Rahman, A., & Olbert, A. I. (2023a). A sophisticated model for rating water quality. Science of The Total Environment, 868, 161614. https://doi.org/10.1016/j.scitotenv.2023.161614
Uddin, M. G., Nash, S., Rahman, A., & Olbert, A. I. (2023b). Performance analysis of the water quality index model for predicting water state using machine learning techniques. *Process Safety and Environmental Protection, 169,* 808-828. https://doi.org/10.1016/j.psep.2022.11.073
Uddin, M. G., Nash, S., Rahman, A., & Olbert, A. I. (2023c). Assessing optimization techniques for improving water quality model. *Journal of Cleaner Production, 385,* 135671. https://doi.org/10.1016/j.jclepro.2022.135671
Uddin, M. G., Nash, S., Rahman, A., & Olbert, A. I. (2023d). A novel approach for estimating and predicting uncertainty in water quality index model using machine learning approaches. *Water Research, 229,* 119422. https://doi.org/10.1016/j.watres.2022.119422
USEPA. (2009). *National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes.* U.S. Environmental Protection Agency, 1–118. https://www.epa.gov/sites/default/files/2013-11/documents/nla_newlowres_fullrpt.pdf
UN. (2017). *Wastewater: The Untapped Resource*. The United Nations World Water Development Report 2017. https://www.unep.org/resources/publication/2017-un-world-water-development-report-wastewater-untapped-resource
Veljković, N., Lekić, D., & Jovičić, M. (2008). Case study of Integrated Water Quality Management: Serbian Water Quality Index. Proceedings from XXIV Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management, Slovenian National Committee for the IHP UNESCO, 171–178.
Vicente, E. D., & Alves, C. A. (2018). An overview of particulate emissions from residential biomass combustion. *Atmospheric Research, 199,* 159–185. https://doi.org/10.1016/j.atmosres.2017.08.027
Vodonos, A., Awad, Y. A., & Schwartz, J. (2018). The concentration-response between long-term $PM_{2.5}$ exposure and mortality; A meta-regression approach. *Environmental Research, 166*, 677–689. https://doi.org/10.1016/j.envres.2018.06.021
Vukašinović-Pešić, V., Blagojević, N., Savić, A., Tomić, N., & Pešić V. (2019). The Change in the Water Chemistry of the Rivers of Montenegro over a 10-Year Period. In: *The Handbook of Environmental Chemistry, Springer: Cham, Switzerland, 93*, 83–109. https://doi.org/10.1007/698_2019_417
Walker, D., Jakovljević, D., Savić, D., & Radovanović, M. (2015). Multi-criterion water quality analysis of the Danube River in Serbia: A visualisation approach. *Water Research, 79,* 158–172. https://doi.org/10.1016/j.watres.2015.03.020
WHO. (2017). *Regional Office for Europe. Evolution of WHO air quality guidelines: past, present and future*. World Health Organization. Regional Office for Europe, 32 pp. https://apps.who.int/iris/handle/10665/341912
Yisa, J., & Jimoh, T. (2010). Analytical Studies on Water Quality Index of River Landzu. *American Journal of Applied Sciences, 7*(4), 453–458. https://doi.org/10.3844/ajassp.2010.453.458
Yang, D., Ye, C., Wang, X., Lu, D., Xu, J., & Yang, H. (2018). Global distribution and evolvement of urbanization and $PM_{2.5}$ (1998-2015). *Atmospheric Environment, 182,* 171–178. https://doi.org/10.1016/j.atmosenv.2018.03.053

https://doi.org/10.48088/ejg.d.bur.14.2.076.087