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Danube water quality and assessment on ecotourism in the biosphere reserve 'Bačko Podunavlje' in Serbia

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ABSTRACT

'Bačko Podunavlje' represents one of the largest and the best-preserved wetland areas of the upper Danube. Water quality is crucial for nature in protected areas and ecotourism. The paper is based on data for the period 1992–2016. Using multivariate statistical analysis, water quality was defined. One-factor analysis of variations is the starting point for the analysis of time variables (annual and monthly analysis). The principal component analysis (PCA) of the ten quality parameters is in the three factors that determine the greatest impact on the change in water quality. Results revealed the satisfactory ecological status of the Danube River in these sections (Bezdan and Bogojevo) and there is no threat that the biodiversity of this area is endangered by poor water quality, which fully justifies the possibilities for intensive development of ecotourism in the biosphere reserve. Suspended solids are the only parameter that exceeds the allowed limit values in a larger number of measurements, especially in the summer period of the year. Other analyzed water quality parameters range within the allowed limit values for the second class of surface water quality based on the Law on Waters (Republic of Serbia) and in accordance with the Water Quality Classification Criteria of ICPDR.

Key words | 'Bačko Podunavlje', biosphere reserve, ecotourism, multivariate analysis, Serbia, water quality

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INTRODUCTION

The concept of sustainable tourism can be seen as an umbrella that unites various forms of tourism in nature-protected areas, such as ecotourism, bird watching, community-based tourism, and adventure tourism. Tourism and nature protection are connected in many ways and affect one another. Ecotourism plays an important role in biosphere reserves around the world. It depends on the protection of nature and its preservation for future generations (Prato & Fagre 2005). The basis of sustainable development is ecological, social and economic sustainability. In order to achieve these goals, many scientists refer to tourism that represents the 'majority' that connects conservation and development (Newsome *et al.* 2002). One of the key strategies of the Swedish biosphere reserves is the sustainable development of tourism (Hedin 2013). Even in biosphere reserves which have not yet been formally established, tourism has been portrayed as an important part of the strategy and a hope for achieving a positive impact on both nature and employment of the local population. Tourism also appears as an argument for the establishment of new biosphere reserves in the world (Nilsson *et al.* 2018). Tourism that is carefully regulated, in small groups interested in scientific and environmental education, will not only be of significance for the protection of nature but may also be of importance for its popularization (Holden 2000). Ecotourism is also called an educational tool for sustainable development, it

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encourages development that is consistent with nature (Nepal 2002) and has often been characterized and employed as a panacea for sustainable development (Montes & Kafley 2019). Numerous biosphere reserves around the world have developed ecotourism to develop the human awareness of nature conservation and protection and emphasized the importance of sustainable development (Hearne & Santos 2005), as with biosphere reserve Monviso (Italy), Šumava (Czech Republic), Agtelek (Hungary), Slovenski Kras and Polana (Slovakia), Maya Biosphere Reserve (Guatemala), Nanda Devi Biosphere Reserve (India) and Changbai Reserve biosphere (China).

Well-preserved nature is a rudiment of tourism in Serbia. The diversity of natural resources is another reason why the development of ecotourism is considered as an important means of sustainable tourism development and a consistent and long-term approach to achieving sustainability. Water quality is very important, especially from the perspective of sustainable use and ecotourism development. In the biosphere reserves, the effort to increase excellent water quality should be promoted and threats to water ecosystems should be minimized (Sinuraya *et. al.* 2018). Today the biggest problem concerning rivers in Serbia is their degradation mainly by deployment of wastewater and toxic materials into rivers (Leščešen *et al.* 2015). The main producer of these harmful materials is human activity, and the consequence is that the usage of river water is in most cases difficult or even impossible (Ocokoljić *et al.* 2009) and protected natural resources are endangered (Nježić *et al.* 2010; Gavrić *et al.* 2017). In order to provide the sustainability of ecological balance, the presence and quality of water are very important and there have been more studies based upon water quality observing (Ocokoljić *et al.* 2009; Pantelić *et al.* 2012; 2015; Leščešen *et al.* 2018).

AN OVERVIEW OF CASE STUDY AREA

The International Coordination Council of the UNESCO Man and Biosphere program included Bačko Podunavlje biosphere reserve in the World List of Biosphere Reserves on June 6, 2017 (UNESCO 2017). The proposed Biosphere Reserve lies in the northwest part of the Republic of Serbia and its Autonomous Province of Vojvodina. It partially follows the state borders of Serbia with Croatia and Hungary (Figure 1). Biosphere reserve 'Bačko Podunavlje' (BRBP) represents one of the largest and the best-preserved wetland areas of the upper Danube through Serbia and covers 176,635 ha. The area of the BRBP has 147,405 inhabitants in 26 settlements (UNESCO 2016).

Together with the transboundary biosphere reserve 'Danube-Drava' located in Croatia and Hungary, BRBP makes up one ecological unit, that is, the largest wetland area on the midstream of Danube. This is why it is called 'the European Amazon'.

The area of the proposed BRBP has a specific combination of ecological conditions: it is situated in the contact zone between the Central European and South Eastern European forest zone with steppes, and it has characteristic hydrological dynamics. In combination with complex and centuries-long human influences, those natural preconditions have resulted in a very rich and specific landscape, habitat and species diversity. The primary habitats are alluvial forests, Pannonian salt steppes, and salt marshes, mesotrophic standing waters, natural eutrophic lakes, muddy river shores, alluvial wetlands, wet meadows, sand deposits, river islets, sand shores, floodplains, oxbows, abandoned river beds and meanders. The Danube is, to a large degree, free-flowing here and is exposed to natural variations of water levels, caused by spring/summer floods. The largest floodplain areas are Bogojevo, the former river basins Živa and Berava, Plavna and Bačko Novo Selo (UNESCO 2016). The floodplain is automatically connected to the Danube. The flooding of large rivers largely reflects on biodiversity. With numerous meanders, sleeves, bars, and dams, the Danube creates a special hydrographic whole in the reserve area. High water levels are of utmost importance for the ecosystems of this protected natural asset. The water that accumulates in the floodplain retains its numerous channels, sleeves, and bars, giving a key ecological significance to this area. Alongside the Danube, there are two small rivers, Plazović and Mostonga, which also provide ecological conditions for many important and still conserved habitats along the banks, such as alkaline pastures and ponds, fish farms with extensive fish production and hardwood forests as the most important. Looking over the borders, the BRBP is only a part of the alluvial complex along the Danube, which comprises very similar landscapes

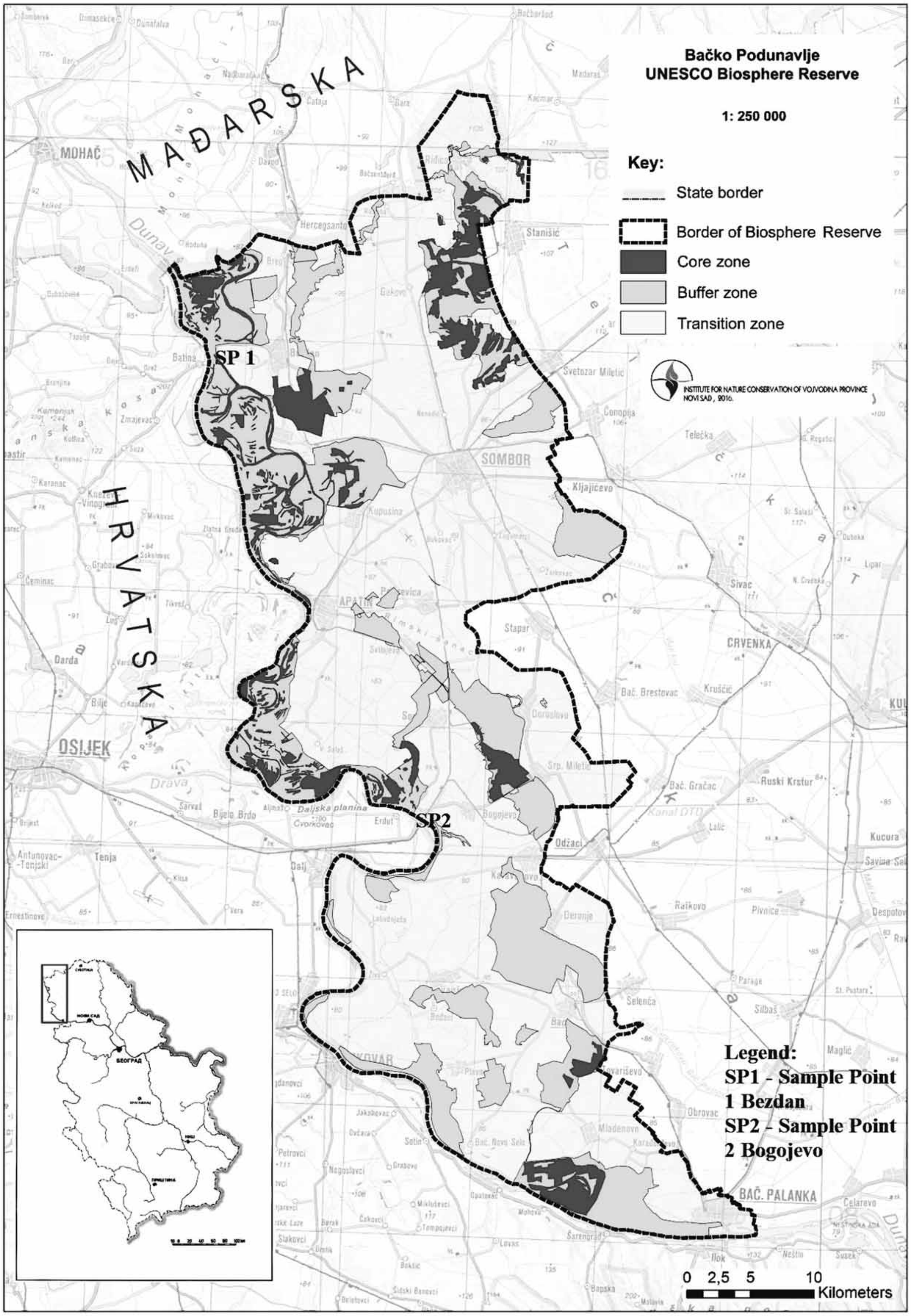

Figure 1 | Map of the biosphere reserve 'Bačko Podunavlje'. *Source*: UNESCO (2016).

along the Mura, Drava and other rivers in the Danube basin in Slovenia, Croatia, Austria, and Hungary. The significance of this transboundary asset in the center of Europe is immense and irreplaceable. This unique mosaic of wetlands, marshes and terrestrial habitats is an important center of plant diversity, with a large number of species of national and international importance (IPA, IBA, PBA, Ramsar) (UNESCO 2016).

Due to the direct zone of the river basin, where vegetation is hydrologically conditioned, the living world is rich, diverse, specific and unique. The exact number of species has not yet been established, but it is known that there are over 1,000 species of plants (IPA area), 270 bird species (IBA area), about 60 fish representatives, 11 species of amphibians and nine species of reptiles. Among 60 species of mammals, an important representative of this area is a strictly protected type of otter (*Lutra lutra*), which is registered as a bioindicator species since it is very sensitive to pollution and degradation of the habitat, via the food chain. The BRBP is particularly characterized by oak (*Quercus robur*), deer (*Cervus elaphus*) and eagle (*Haliaeetus albitilla*) (UNESCO 2016). Moreover, the area of the BRBP includes another five protected nature areas: special nature reserve 'Gornje Podunavlje', special nature reserve 'Karađorđevo', nature park 'Tikvara', natural monument 'Šuma Junaković' and regional nature park 'Bikinski hrastik'.

The Danube River represents the main waterway through the territory of the European Union and provides new opportunities for the development of tourism, transport, trade and other industries (Dragin *et al.* 2009). One of the major threats for the development of tourism could be water quality and pollution of the Danube. Appropriate measures of revitalization and protection in the area of the Danube Region are of great importance for the further perspective of the development of this region. Danube waters accumulate untreated wastewater from cities, chemicals from agriculture, waste from factories, oil stains and combustion products of propulsion engines. Part of this pollution settles over time on the banks of the river and disturbs the natural balance of ecosystems with serious consequences for flora, fauna and the population itself (Thielen *et al.* 2004). This problem was observed relatively late, at the end of the 1980s, after many harmful chemical substances in the water caused the disappearance of a part of the living world, especially fish (Jarić *et al.* 2011). Water quality is variable in time and space. Therefore, monitoring and knowledge of the current status of water quality in the river are of utmost importance. Rapid economic development often leads to disruption of water quality. Therefore, research related to water quality has been increasingly intensive, especially during the last decade.

The wetland parts of the BRBP are directly related to the Danube River and its water quality. Changes in water quality can cause changes in the biodiversity of this area, which further directly influences the implementation and development of ecotourism in this area. For this reason, there is a need to further analyze the link between these three actors (water quality – impact on biodiversity – development of ecotourism) in the BRBP.

Analysis and valorization of tourism potentials

The ecotourism potentials are linked to the fact that the BRBP is one of the few remaining and well-preserved floodplains along the banks of the Danube River.

Micro-relief forms contribute to a dynamic region and it can be considered as an important ecotourism potential. Climate represents an important prerequisite for taking part in tourism activities and can be considered also as an important tourism potential. When it comes to potentials of exceptional importance there are hydrography and plants and wildlife. Hydrography potentials are of exceptional importance for ecotourism development and one of the most significant potentials of Bačko Podunavlje. Key resources are: Danube, Bajski Canal, Baračka, Veliki Bački Canal, River Plazović, Monoštorski Dunavac, Lake Provala, River Mostonga, Kupinski, Tikvara and Karađorđevo. Plants and wildlife represent an essential phenomenon of Bačko Podunavlje and are of crucial importance for the development of ecotourism. Key resources are: large game, ornithofauna, ichthyofauna, alluvial forests, salt steppes, marshes, reed beds, well-protected forests, wetlands, meadows, IPA, IBA, Ramsar.

According to tourist valorization the greatest potentials for ecotourism development in the BRBP are based on hydrography and nature, plants and wildlife. That is why water quality is very important – key resources (ecotourism potentials) depend on water (Stojanović et al. 2014).

DATA AND METHODS

In order to achieve satisfactory surface water quality, monitoring is a crucial part of water management. When it comes to temporal monitoring programs, statistical methods are most commonly used to process a large data set. Some of these methods are multivariate statistical methods such as factor analysis and principal component analysis. These methods make it possible to reduce large amounts of monitoring data and to define problematic quality indicators. Multivariate statistical methods allow identification of the possible factors responsible for the variability of water quality. Multivariate statistical methods are used to characterize and evaluate the water quality of water bodies and are a useful tool for determining temporal and seasonal variations due to natural and anthropogenic pressures. They also enable the identification of pollution sources and thus provide a useful tool for developing an appropriate strategy to achieve efficient management of water resources (Ayeni & Soneye 2013).

The database of the Republic Hydrometeorological Service for the 25-year period 1992–2016 (RHMS, 1992–2016) was used to analyze the status of Danube River water quality. Ten physical and chemical water quality parameters were measured at two sampling points (SP) on the Danube River located at Bezdan and Bogojevo.

At every SP ten parameters were analyzed (temperature, pH, conductivity, dissolved oxygen, BOD_5, suspended solids, nitrate, nitrite, orthophosphates and ammonium). The obtained data are analyzed in the statistical program SPSS (IBM 2016).

One-way analysis of variance

The presented results were obtained according to one-way analysis of variance (ANOVA) (Dalu et al. 2012). The post hoc Scheffe test was applied for definition of difference significance between certain groups (Leščešen et al. 2015). Descriptive statistical analysis was applied for definition of parameter mean values according to profiles and time periods. ANOVA was used to define if there is a statistically significant correlation between dependent variables (temperature, pH, conductivity, dissolved oxygen, BOD_5, suspended solids, nitrate, nitrite, orthophosphates, and ammonium) and independent variables (annuals and months).

One-way analysis of variance is a statistical procedure which ensures difference testing between several arithmetic means. The post hoc Scheffe test, was applied for definition of difference significance between certain groups. If the F-test proves there are statistically significant differences, it is important to define the groups among which there are statistically significant differences. The results of the F-test can only prove significance of difference between the groups with the lowest and highest arithmetic means.

The Scheffe post hoc test, as one of the most strict and most often applied tests, was used in this research. The test procedure includes the following steps as described by Petz (1981).

1. After F-values in variance analysis have been defined, the following equation is applied for each pair of arithmetic means, where M_{ai} and M_b are the means of the samples being compared, N_a and N_b are the respective sample sizes, and the within-group variance is MS_{wg}:

$$F = \frac{(M_{ai} - M_b)^2}{MS_{wg}(N_a + N_b) \div N_a N_b}$$

2. The F-value for the needed significance level for the freedom degrees ((k–1) and (N–1)) is read from F table.
3. The set F-value is multiplied by (k–1), and a new limit value (F') is obtained.
4. F is calculated according to the above-mentioned formula for all pairs of arithmetic means and the obtained value is compared with F'. If F is higher than F', that difference can be considered to be statistically significant at the significance level set in step 2.

The sample fulfils the basic conditions for parameter test application, i.e. the data used in analysis originate from the interval scale and they are normally distributed.

Principal component analysis

Principal component analysis (PCA) has the ability to identify and eliminate redundant data from results. By applying

PCA, the amount of available data is reduced, and as a result different numbers of new variables are obtained, the so-called main components (principal components, PC). The main component, PC, is in fact a linear combination of original variables (Vastag et al. 2013). High correlation of data in factor analysis (positive or negative) also assumes a high probability that the data are influenced by the same factors, while relatively uncorrelated data are influenced by different factors, which is also an axiom of factor analysis (Mustapha & Aris 2011).

In this paper, according to Liu et al. (2003), the following criteria of factor loadings were used: >0.75, the association is considered 'high', and if the value of factor loadings ranges from 0.75 to 0.5, the association is 'medium'. Also, according to Varol & Şen (2009), it is accepted that an eigenvalue of 1 or greater than 1 is considered significant. When choosing a number of factors, the Kaiser Criterion (Liu et al. 2003) was applied to retain only those factors with characteristic values greater than 1, as well as a Scree-test, which is a graphical representation of the eigenvalues of all components and suggests that those components that significantly (visually) deviate from the rest in the analysis are retained in the analysis. When choosing a number of factors, the Kaiser Criterion was decisive.

RESULTS AND DISCUSSION

Results of one-way ANOVA

Water temperature is important because it affects the rates of biological processes and chemical processes. The optimal health of aquatic organisms from microbes to fish depends on water temperature. If temperatures are outside the optimal range for a prolonged period, organisms are stressed and can die. Water temperature is affected by the seasons and can also be affected by weather, removal of shading stream-bank vegetation, building dams on rivers, discharging cooling water, discharging stormwater, and groundwater influx (http://scecoinstitute.com/documents/How_Water_Quality_Indicators_Work.pdf).

The mean annual water-temperature values (Figure 2), for the 25 -year period at sampling points Bezdan and Bogojevo, are relatively uniform and do not show statistically significant differences, but mean monthly values (Table 1) as expected show the existence of statistical significance ($p = 0.000$, $F = 222.710$). The trend line shows a slight increase in mean monthly water temperatures (Figure 2).

The pH of surface waters is vital to aquatic life. It affects the ability of aquatic organisms to regulate basic life-sustaining processes, primarily the exchange of respiratory gasses and salts with the water in which they live (Gong et al. 2013). The pH is also a useful indicator of the chemical balance in the water. A high or low pH will adversely affect the availability of certain chemicals or nutrients in the water for use by plants (http://scecoinstitute.com). Statistical analysis of pH for the observed period shows statistical significance and significant differences for mean annual values ($p = 0.000$, $F = 2.583$) and mean monthly values ($p = 0.000$, $F = 5.637$). According to annual values, the largest differences are noticed in 2003 and 2014 when the lowest and highest values of this parameter are registered. Also, higher pH values are registered during the warmer period of the year, especially during the spring (Table 1). The registered values for pH during the entire observed period at the measurement points of Bezdan and Bogojevo are in fact balanced, even within the limits as established for Class-II water quality. Measured values of this parameter are closer to the upper limit (6.5–8.5), which indicates an increase in water basicity. Base water in itself has several negative OH-ions, which can lead to higher availability of oxygen and better water quality. During the investigated period, the pH values show a slight upward trend.

Electrical conductivity is related to the amount of total soluble salts or diluted ions in water (Dalmacija 1998). The electrical conductivity of water is directly related to the concentration of dissolved solids in the water. High-conductivity water is harmful to the health of living organisms. Measured values of conductivity for the research period show statistical significance at annual ($p = 0.000$, $F = 6.259$) and monthly ($p = 0.000$, $F = 25.235$) levels. The largest differences are noticed in 2015 and 2002 when the lowest and highest values of this parameter are registered. Significantly lower values of electrical conductivity are registered during the summer period of the year (June, July and August) as shown in Table 1. The values of electrical conductivity during the observed period are found to be below the threshold limit for Class-II water quality and do not

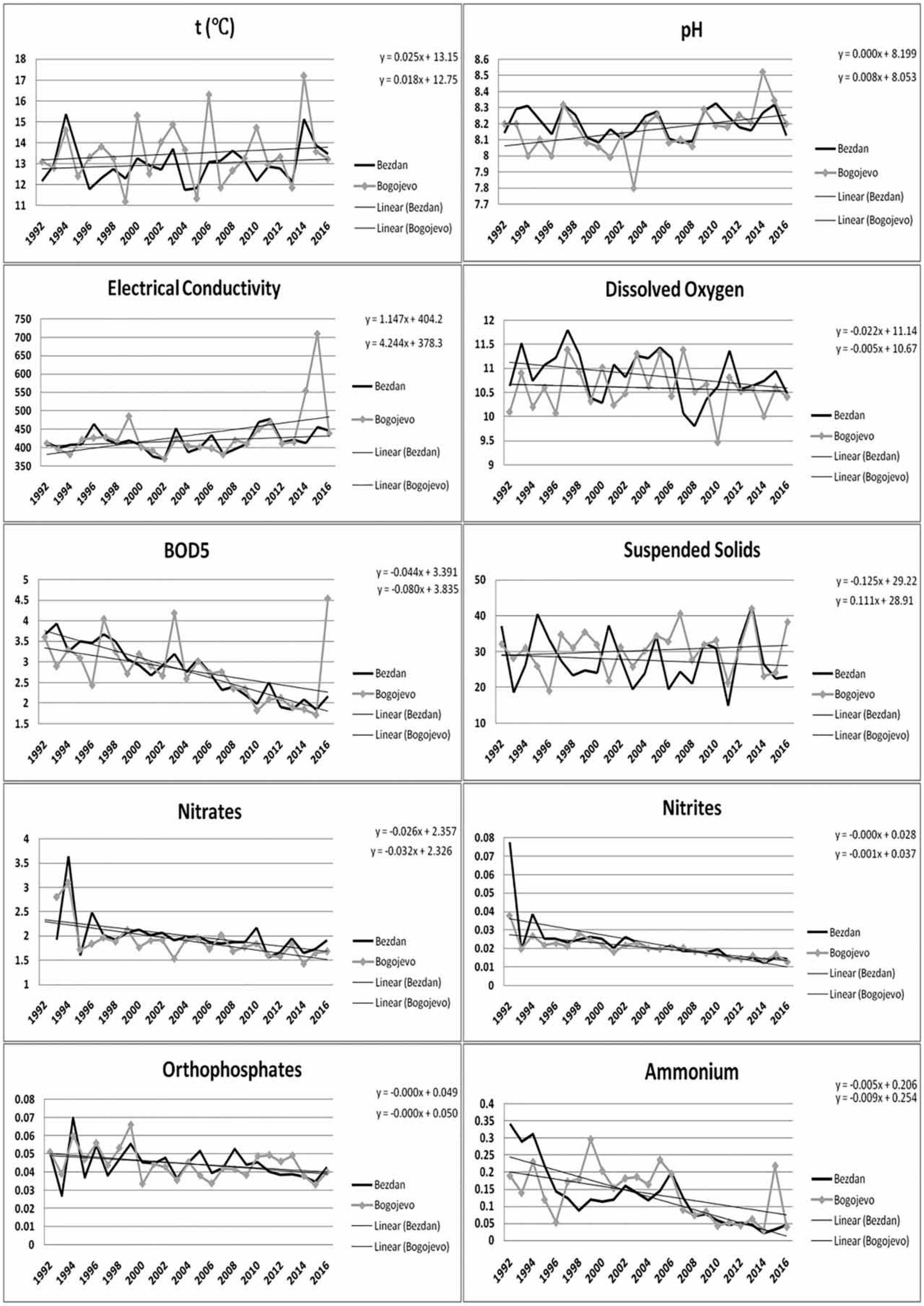

Figure 2 | Mean values of water quality parameters for sampling points Bezdan and Bogojevo and ANOVA results per year. *Source*: created by the author based on data analysis in SPSS 24.0.

Table 1 | Mean monthly values of water quality parameters for SP Bezdan and Bogojevo and ANOVA results

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
t (°)	Mean	2.9	3.5	6.9	11.7	17.2	20.1	22.1	22.5	18.8	14.7	9.9	4.7
	F	222.710											
	p	0.000*											
pH	Mean	8.02	8.12	8.23	8.32	8.38	8.28	8.17	8.20	8.13	8.16	8.11	8.07
	F	5.637											
	p	0.000*											
Electrical conductivity (μS/cm)	Mean	510	504	489	452	391	362	361	360	385	426	449	478
	F	25.235											
	p	0.000*											
Dissolved oxygen (% O_2)	Mean	11.59	12.39	12.48	11.85	11.04	10.11	9.55	9.29	9.34	10.05	10.74	11.26
	F	18.636											
	p	0.000*											
BOD (O_2mg/L)	Mean	2.2	2.6	3.0	3.2	3.3	3.4	3.1	2.9	2.7	2.2	2.1	2.0
	F	6.863											
	p	0.000*											
Suspended solids (mg/L)	Mean	24.9	30.5	30.4	31.0	28.2	37.5	32.3	37.0	32.7	22.1	21.3	18.1
	F	5.175											
	p	0.000*											
Nitrate (NO_3^-) (mg/L)	Mean	2.711	2.724	2.640	2.113	1.404	1.247	1.113	1.065	1.350	1.662	2.089	2.373
	F	32.158											
	p	0.000*											
Nitrite (NO_2^-) (mg/L)	Mean	0.034	0.031	0027	0.020	0.016	0.017	0.016	0.015	0.014	0.017	0.023	0.027
	F	10.902											
	p	0.000*											
Orthophosphate (PO_4^{3-} as P mg/L)	Mean	0.078	0.067	0.042	0.041	0.022	0.028	0.034	0.035	0.042	0.062	0.059	0.069
	F	5.096											
	p	0.000*											
Ammonium (NH_4-N mg/L)	Mean	0.289	0.183	0.116	0.096	0.080	0.096	0.104	0.095	0.087	0.301	0.130	0.179
	F	1.485											
	p	0.133											

Source: created by the authors based on data analysis in SPSS v24.0.
*$p < 0.01$; $F > 3.32$.

exceed 1,000 μS/cm. Conductivity has a rising trend during the investigated period.

Dissolved oxygen (DO) refers to the amount of oxygen (O_2) dissolved in water. Since fish and other aquatic organisms cannot survive without oxygen, DO is one of the most important water quality parameters. Aquatic life is put under stress when the DO concentration falls below 5.0 mg/L. The mean annual values of the dissolved O_2 at the measuring points of Bezdan and Bogojevo (Figure 2) are relatively uniform and do not show differences with statistical significance, while mean monthly values show differences with statistical significance ($p = 0.000$, $F = 18.636$). All measured DO are below the limit value for Class-II water quality, but they clearly show slightly higher values and better water quality during the winter period of the year (during January, February and March). Based on the trend line plotted for DO in Figure 2, we see that the dissolved oxygen has a decreasing trend which may affect aquatic life negatively.

Biochemical oxygen demand (BOD_5) is a measure of the amount of oxygen consumed by micro-organisms in a water sample in order to oxidize organic carbon, which indirectly determines the amount of organic matter in the water (Dalmacija 1998). An increase in temperature causes an increase of biological oxygen demand (Pantelic *et al.* 2015) Sources of organic materials in water can be natural (swamps, ponds, leaves falling, etc.), anthropogenic (food industry and wastewater treatment) and diffuse (surface runoff from urban and agricultural areas). Differences in BOD_5 values are statistically significant on a yearly ($p = 0.000$, $F = 6.049$) and monthly basis ($p = 0.000$, $F = 6.863$). The greatest differences are observed between 2015 and 2016 when the lowest and highest values are registered. Lower values of BOD_5 and better water quality are registered during the cold period of the year (during November, December and January). The values of BOD_5 during the observed period meet the Class-II water quality standard of 4.0 mgO_2/L. BOD_5 values have a decreasing trend, which means that the amount of organic pollution in the Danube water is decreasing over time.

Suspended solids are closely linked to erosion and transport of nutrients (phosphorus, especially), metals, industrial waste, and chemicals used in agriculture (Directive 2000). The values of suspended solids at SP Bezdan and Bogojevo show significant statistical differences at annual ($p = 0.004$, $F = 1.974$) and monthly level ($p = 0.000$, $F = 5.175$). The greatest differences are observed between 2011 and 2013 when the lowest and highest values are registered. The increased concentration of suspended solids occurs during the hottest months of the year (June, July, and August) and indicates somewhat poor water quality during the summer period. During the observed period, measured values exceed the permitted limit value for Class-II water quality of 25 mg/L, especially during the spring and summer period of the year.

The amount of suspended solids in the Danube waters for SP Bezdan is in a slight declining trend, and for SP Bogojevo it is the opposite, the trend is increasing slightly. That is expected because of river bed and river bank geology in this Danube section. On the part of the Danube stream between SP Bezdan and SP Bogojevo there is Special Nature Reserve 'Gornje Podunavlje', a large wetland area.

Nitrate and nitrite are inorganic forms of nitrogen in the aquatic environment. Nitrate is regulated to protect human health as well as aquatic environments. Once in the water, nitrates can stimulate excessive plant and algae growth. Decomposition of the plants and algae by bacteria can deplete DO, adversely impacting fish and other aquatic animals. Sources of nitrates are the atmosphere, inadequately treated wastewater from sewage treatment plants, agricultural runoff, storm drains and poorly functioning septic systems (http://scecoinstitute.com). Mean values of nitrate (NO_3^-) show significant statistical differences at the annual ($p = 0.000$, $F = 4.602$) and monthly ($p = 0.000$, $F = 32.158$) level. The greatest differences are observed between 2014 and 1994 when the lowest and highest values are registered. Lower nitrate (NO_3^-) values and better water quality are registered during the warm period of the year (during spring and summer). For all the observed period, nitrate concentrations were below the limit of 6.0 mg/L as N for Class-II water quality. The analysis of nitrite (NO_2^-) for the observed period indicates a positive statistical significance at annual ($p = 0.000$, $F = 16.337$) and monthly level ($p = 0.000$, $F = 10.902$). At the annual level, the greatest differences are observed between 1995 and 2014 when the highest and lowest values of this parameter are registered. Also lower nitrite (NO_2^-) and better water quality occur during the warmer period of the year. The registered nitrite (NO_2^-) values during the entire period of observation at the SP of Bezdan and Bogojevo are mainly within the limits of the allowed limit values (<0.03) for water quality of the second class. The values of nitrate and nitrite have a slight downward trend; only during January and February do the values for nitrite (NO_2^-) exceed the limit of 0.03 mg/L NO_2^- as N as required for Class-II water quality (Table 1).

Orthophosphates, also known as reactive phosphates, are the main constituent in fertilizers used for agriculture and residential purposes. Orthophosphates found in natural water provide a good estimation of the amount of phosphorus available for algae and plant growth. This is the form of phosphorus that is most readily utilized by biota. Differences in orthophosphate values are statistically significant at the annual ($p = 0.000$, $F = 7.233$) and monthly ($p = 0.000$, $F = 5.096$) level. The greatest differences are observed between 1992 and 1993 when the highest and lowest values of this parameter are registered. Lower values of orthophosphates and better water quality are registered during the warmer period of the year (late spring and early summer), similarly to nitrates and nitrites. Orthophosphates are within the limits for Class-II water quality and do not exceed the threshold value of 0.2 mg/L as P. Based on the trend line, we see that the orthophosphate concentrations are slightly decreasing over time.

When ammonium is present in water at high enough levels, it is difficult for aquatic organisms to sufficiently excrete it, thus leading to a toxic buildup in internal tissues and blood and potentially to death. Environmental factors, such as pH and temperature, can affect ammonia toxicity to aquatic animals. The increased presence of ammonium ions in surface waters indicates the presence of contaminated wastewater from industry or from agricultural areas. Mean values for ammonium concentration at SPs Bezdan and Bogojevo show significant statistical differences at annual level ($p = 0.049$, $F = 1.542$), while monthly values are relatively equal and statistically not significant. The greatest differences are observed between 1992 and 2014 when the highest and lowest values of this parameter are registered. The increased concentration of ammonium ions occurs during the cold period of the year and indicates a slightly lower water quality during the winter period. All measurements during the observed period indicate that the measured values do not exceed the permitted limit value of 0.6 mg/L as N for Class-II water quality. The value of ammonium concentration was observed to decrease over time.

Results of PCA

For SP Bezdan, ten water quality parameters were subjected to a principal component analysis. Prior to conducting PCA, the suitability of the data for factor analysis was assessed. Examination of the correlation matrix revealed a number of coefficients of 0.3 and higher. The value of the Kaiser–Meyer–Oklin indicator is 0.669, which corresponds to the recommended value >0.6. Also, Bartlett's test of specificity reached statistical significance ($p = 0.000$), indicating the factoribility of the correlation matrix. PCA revealed the presence of three factors with characteristic values greater than 1.0, which explains 35.68%, 19.73% and 14.66% of the variance, respectively. A closer review of the flowchart revealed the existence of a clear breaking point behind the third component or factor. Based on Ketel's criteria, it was decided to retain all three factors for further research. This was supported by the results of a parallel analysis, with three factors whose characteristic values exceed the corresponding threshold values obtained using an equally large random number matrix (10 quality parameters × 300 samples).

The three-component solution explained a total of 70.07% of the variance. In order to help interpret these three factors, oblimin rotation was also conducted. The rotated solution revealed the existence of a simple structure, with all three factors having large factor weights of individual parameters.

The first factor contributes with 35.68% to the total variability and is most correlated with the parameters nitrites, orthophosphates, ammonium and nitrates. The first factor has a high positive load for nitrites (0.934) and orthophosphates (0.777), a medium positive load for ammonium (0.684) and nitrates (0.649) and a small negative load for pH (−0.322) and water temperature (−0.338). The first factor can be termed the point source of pollution which includes nitrates, nitrites, orthophosphates and ammonium, while pH and water temperature should be excluded from this group because they are negatively correlated, as can be clearly seen in Table 2.

The second factor contributes with 19.73% to the overall variability and is most correlated with the parameters BOD_5, pH and dissolved oxygen. The second factor has a high positive load for parameters BOD_5 (0.820) and pH (0.759) as well as medium positive load for dissolved oxygen (0.747). The second factor can be referred to as a eutrophication factor from which BOD_5 must be excluded (Table 2).

The third factor contributes with 14.66% to the total variability and is most correlated with the parameters nitrates, dissolved O_2, electrical conductivity, water temperature and suspended matter. The third factor has a high negative load for conductivity (−0.864) and a high positive load for water temperature (0.768), a medium positive load for suspended solids (0.528) and a medium negative load for dissolved O_2 (−0.574) and a low negative load for nitrates (−0.433). The third factor can be referred to as the hydrochemical factor from which conductivity, dissolved O_2 and nitrates must be excluded (Table 2).

Figure 3 shows that electrical conductivity is not grouped with any of the other water quality indicators. The electrical conductivity is directly related to the concentration of dissolved solids. The content of dissolved solids in water bodies is a consequence of the control of the system itself, that is, a consequence of a conductive regime of water flow. Bezdan's lock on a river has a significant impact on sediment dynamics and indirectly on electrical conductivity.

Table 2 | Factor score coefficient matrix and correlation of variables for PCA with oblimin rotation for water quality parameters at SP Bezdan

Water quality parameters	Factor weights			Correlation coefficients of variables and factors			Part of the variance explained by a common factor
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	
Nitrites (NO_2^-)	**0.934**	0.005	−0.028	**0.939**	−0.049	−0.186	0.882
Orthophosphates	**0.777**	−0.214	0.023	**0.785**	−0.257	−0.117	0.662
Ammonium	**0.684**	0.157	0.058	**0.729**	−0.177	− **0.548**	0.471
Nitrates (NO_3^-)	**0.649**	−0.122	− **0.433**	**0.665**	0.121	−0.051	0.732
BOD_5	0.166	**0.820**	0.291	0.071	**0.823**	0.298	0.774
pH value	− **0.322**	**0.759**	−0.003	− **0.364**	**0.777**	0.084	0.707
Dissolved oxygen	0.067	**0.747**	− **0.574**	0.122	**0.719**	− **0.554**	0.864
Electrical conductivity	0.172	0.090	− **0.864**	**0.313**	0.043	− **0.889**	0.826
Water temperature	− **0.338**	0.061	**0.768**	− **0.471**	0.113	**0.828**	0.803
Suspended solids	0.195	0.073	**0.528**	0.102	0.084	**0.498**	0.289
Eigenvalues	3.57	1.97	1.47				
% of variance by component	35.68	19.73	14.66				
Cumulative % of variance	35.68	55.41	70.07				

Note: factor load value greater than 0.75 – connection 'high'; factor load value from 0.50 to 0.75 – connection 'medium'; factor load lower than 0.50 – connection 'low'.
Source: created by the authors based on data analysis in SPSS v24.0.

For SP Bogojevo, ten water quality parameters were also subjected to PCA. As for SP Bezdan, examination of the correlation matrix for SP Bogojevo revealed a number of coefficients of values 0.3 and higher. The Kaiser–Meyer–Oklin indicator is 0.697, while the Bartlett test of specificity shows statistical significance ($p = 0.000$). The PCA revealed the presence of four factors with values over 1, which explain 33.14%, 16.61%, 13.13% and 10.12% of the variance. Review of the flowchart revealed the existence of a clear breaking point behind the third component or factor. Based on Ketel's criterion, it was decided to retain the first three factors for further research. This was supported by the results of a parallel analysis, with three factors whose characteristic values exceed the corresponding threshold values.

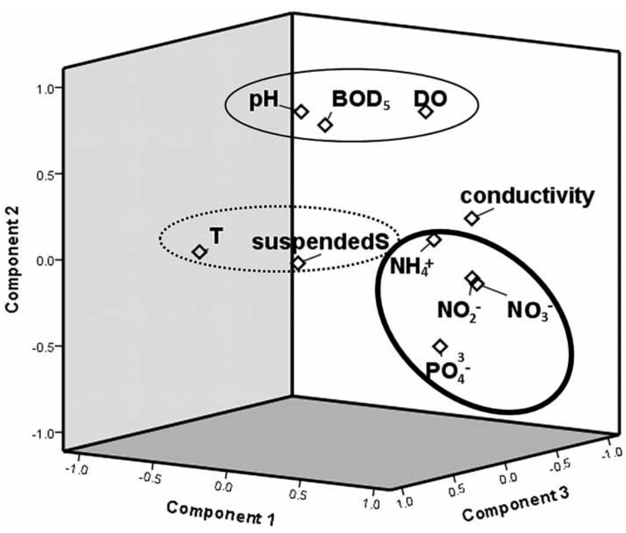

Figure 3 | Correlation of PCF1/PCF2 of investigated parameters for SP Bezdan.

The three-component solution explained a total of 62.88% of the variance. For ease of interpretation, oblimin rotation was also performed. Oblimin rotation revealed the existence of a simple structure, with all factors having high factor weights of individual parameters.

The first factor contributes with 33.14% to the overall variability and is most correlated with the parameters nitrates, water temperature, nitrites, electrical conductivity, dissolved O_2 and orthophosphates. The first factor has a high positive load for nitrates (0.921) and a high negative load for water temperature (−0.914) and a medium positive load for nitrites (0.775), electrical conductivity (0.500), dissolved O_2 (0.528) and orthophosphates (0.523). The first factor can be termed the point source of pollution, but the parameter water temperature must be excluded (Table 3).

Table 3 | Factor score coefficient matrix and correlation of variables for PCA with oblimin rotation for water quality parameters at SP Bogojevo

Water quality parameters	Factor weights: Factor 1	Factor weights: Factor 2	Factor weights: Factor 3	Correlation coefficients of variables and factors: Factor 1	Correlation coefficients of variables and factors: Factor 2	Correlation coefficients of variables and factors: Factor 3	Part of the variance explained by a common factor
Nitrates (NO_3^-)	**0.921**	−0.025	−0.002	− **0.924**	−0.059	0.207	0.851
Water temperature	− **0.914**	−0.078	0.109	**0.922**	−0.047	−0.098	0.871
Nitrites (NO_2^-)	**0.775**	−0.216	0.248	**0.754**	−0.24	0.173	0.679
Electrical conductivity	**0.500**	0.273	− **0.323**	**0.527**	0.270	− **0.382**	0.460
pH value	−0.138	**0.740**	−0.172	−0.138	**0.747**	−0.177	0.603
Dissolved oxygen	**0.528**	**0.719**	0.172	**0.493**	**0.702**	0.098	0.782
Orthophosphates	**0.523**	− **0.585**	−0.285	**0.566**	− **0.590**	− **0.325**	0.734
BOD_5	−0.159	**0.310**	**0.724**	−0.242	0.296	**0.733**	0.661
Suspended solids	−0.119	−0.162	**0.609**	−0.179	−0.174	**0.625**	0.430
Ammonium	0.167	−0.009	**0.452**	0.120	−0.024	**0.435**	0.217
Eigenvalues	3.314	1.661	1.313				
% of variance by component	33.14	16.61	13.13				
Cumulative % of variance	33.14	49.75	62.88				

Note: factor load value greater than 0.75 – connection 'high'; factor load value from 0.50 to 0.75 – connection 'medium'; factor load value less than 0.50 – connection 'low'.
Source: created by the authors based on data analysis in SPSS v24.0.

The second factor contributes with 16.61% to the total variability and is most correlated with the parameters pH, dissolved O_2, orthophosphates and BOD_5. The second factor has a medium positive load for the pH parameter (0.740) and dissolved O_2 (0.719), a medium negative load for orthophosphates (−0.585) and a low positive load for BOD_5 (0.310). The second factor can be referred to as an environmental factor from which parameters BOD_5 and orthophosphates whose values are lower or negatively correlated must be excluded (Table 3).

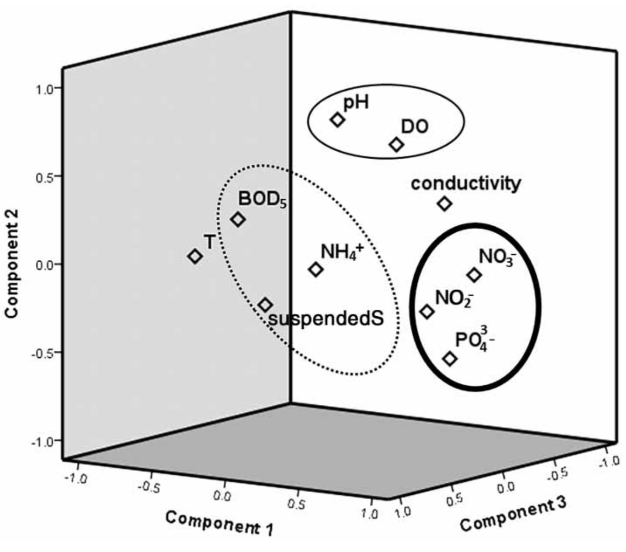

Figure 4 | Correlation of PCF1/PCF2 of investigated parameters for SP Bogojevo.

The third factor contributes with 13.13% to the total variability and is most correlated with parameters conductivity, suspended solids, BOD_5 and ammonium. The third factor has a medium positive load for BOD_5 (0.724) and suspended solids (0.609), a low positive load for ammonium ions (0.452) and a low negative load for electrical conductivity (−0.323). The third factor can be referred to as the eutrophication factor, where electrical conductivity, which is negatively correlated, must be excluded.

Figure 4 shows that conductivity is not grouped with any of the other water quality indicators. As with sample point Bezdan, the lock on a river has a significant impact on sediment dynamics and indirectly on electrical conductivity. Water temperature is excluded because of the correlation's high negative values.

CONCLUSION

In this study, the water quality status of the BRBP was assessed through the analysis of ten water quality parameters measured for a 25-year period at two sampling points as provided by the Republic Hydrometeorological database.

Based on the summary results, it can be concluded that the quality of the Danube water at the entrance to the Republic of Serbia, at the SPs of Bezdan and Bogojevo, is satisfactory and consistently meets with Class-II water quality standards. Suspended solids are the only parameter that exceeds the allowed limit values in a larger number of measurements, especially during summer. As the Danube in this part of the stream has the characteristics of a typical Pannonian and plain river, an increased amount of suspended solids is expected and justified. The values of all observed parameters vary over the period. The trend lines of temperature, pH and electrical conductivity are slightly increasing, and in contrast, the trends of other parameters are declining slightly. Although the parameters vary, all values are within the quality water (Class-II). Because all measured values of these parameters are, even in summer, within the limits of the allowed values, there is no fear that they could endanger ecotourism.

Using PCA, three factors are defined that explain 62.88% (for Bogojevo) and 70.07% (for Bezdan) of the total variability and may be responsible for the variability of water quality at both SPs. Point sources of pollution, and environmental and hydrochemical factors are distinguished. It has been established that certain pressures exist and are most pronounced through factor 1 or so-called sources of pollution (elevated values of nitrite, nitrate and orthophosphate), which most often occur as a result of washing away from agricultural land. These pressures are not large and do not greatly disturb the water quality in this part of the Danube.

Considering the satisfactory ecological status of the Danube on these sections, there is no threat of the biodiversity of this area being endangered by poor water quality, which fully justifies the possibilities for intensive development of ecotourism in the BRBP. Ecotourism positively affects all the functions of the biosphere reserve and whether the biosphere reserves provide a strong and positive experience for ecotourists.

Ecotourism in the BRBP is still relatively undeveloped. The results of this research show complete justification for this type of tourism to develop more intensively in this area.

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