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Original Research

Assessment of Physico-Chemical, Microbiological Parameters and Diatom Algae of Badovc Lake, Kosovo

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Abstract

Through this research, we have carried out monthly water quality monitoring in Lake Badovci using microbiological, physico-chemical and diatomic indicators of algae, in order to provide credible data regarding the quality of water in Lake Badovci. The monitoring took place between December 2020 and May 2021. Three sample sites were selected: at the entrance, in the center and in the catchment area. Total coliforms, fecal coliforms, fecal streptococci, aerobic mesophyllic bacteria, and actinomycetes were all analyzed microbiologically. Dissolved oxygen, oxygen saturation, water temperature, pH value, electrical conductivity, total dissolved solids, total suspended solids, turbidity, chemical oxygen demand, biochemical oxygen demand, total nitrates organic carbon, total hardness, total hardness of calcium and magnesium, chlorides, fluorides, M-alkalinity, bicarbonates and heavy metals such as Fe, Pb, Mn, Cu and Cd. The highest levels of physicochemical and microbiological indices were found in January and lasted until February at the first sample location. This is due to the torrential rains that have resulted in increased inflows from the rivers that flow into this lake. According to diatomic indices (Descry, Rott SI, IDG, IPS, IBD, and CEE), water has an excellent ecological status and is oligo-mesotrophic, except for some indices that showed a moderate ecological status and mesotrophic level. The activities of monitoring, planning, and management of the waters in this lake, which is used for drinking water supply, washing, and fishing, have to be done regularly.

Keywords: Badovc Lake, physicochemical, microbiological, heavy metals, diatom algae

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Introduction

Because rivers and lakes are the primary suppliers of water for the human population, the buildup of different contaminants in water bodies is a worldwide concern [1]. Various factors, such as industrialization, urbanization and economic activity have continued to degrade and pollute natural resources around the world more and more [2]. According to the WHO report, 2020, 74% of the global population (5.8 billion people) used a securely managed drinking water service - that is, one located on the premises, available when needed and without contamination. At least 2 billion people use a source of fecal contaminated drinking water. Therefore microbial contamination of drinking water as a result of fecal contamination poses the greatest risk to the safety of drinking water [3]. The rapid increase in the number of urban population has resulted in increasing the need for basic services and access to proper water supply and sewerage. The rapid growth of urban areas has further affected water quality due to urban population growth, overexploitation of resources and inadequate wastedisposal practices [4]. Various pollutants are ubiquitous in the aquatic environment, mainly these pollutants resulting from the discharge of municipal wastewater effluents. The existence of these pollutants is very worrying because of the potential ecological impact they have [5]. Monitoring and controlling nutrients and heavy metals in water resources is an important problem for both ecosystems and public health [6]. Ensuring the microbiological quality of drinking water supply depends on numerous barriers and its use, both from the point of receipt to the consumer, to prevent water pollution or to reduce pollution to a safe level for drinking [7]. Pollutants such as bacteria, viruses, heavy metals, nitrate salt, enter the water as a result of inadequate treatment and disposal of human waste, livestock, industrial discharges, domestic discharges and widespread use of limited water resources [8]. Evaluation of physicochemical

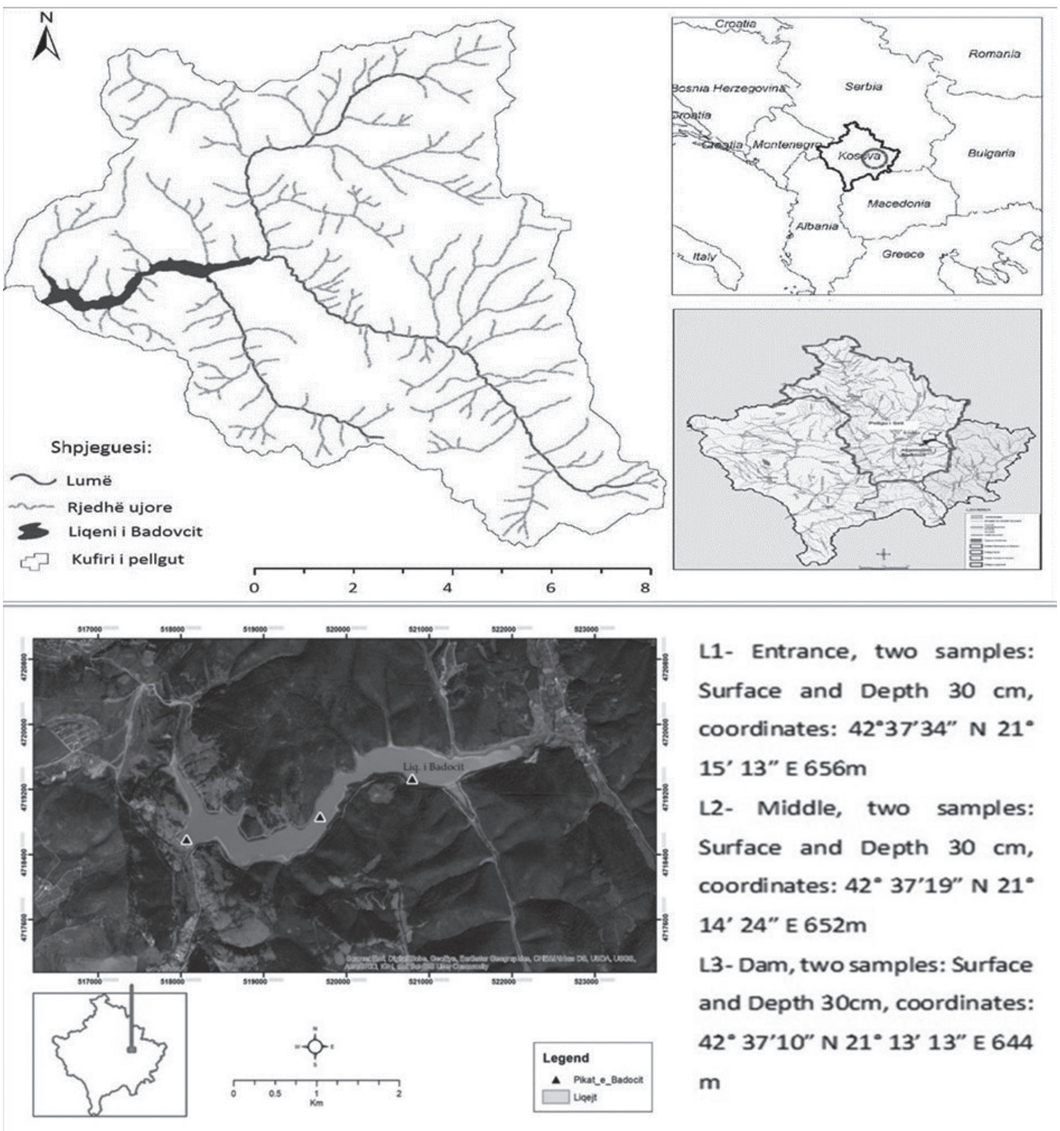

Fig. 1. Sites of taking samples in Badovc Lake.

and microbiological parameters of river and lake waters has been the subject of study of many foreign scientists such as [9-16]. These studies by different scientists have prompted the idea of this research to determine the physico-chemical, microbiological and diatom algae parameters in the water of Lake Badovci, which supplies drinking water to the region of Pristina. From this research, sufficient data have been collected to determine the degree of water pollution of Lake Badovci from river flows, recreational beaches, fishing activities as a link between these parameters in this ecosystem. The research technique used in this research can be applied in other similar research activities.

Materials and Methods

Research Area

Badovc Lake is part of the Ibar Basin, one of five basin watersheds in Kosovo, and is situated in the north-eastern region of the country, between latitude and longitude respectively 21^{o}03' to 21^{o}23' and 42^{o}40' to 42^{o}36', 13 kilometers from Kosovo's capital, Prishtina (Fig. 1). In 1965, the Badovc am was constructed in the flow profile of the Gracanka River to utilize the water gathered from this basin, resulting in the creation of the Badovc Lake. The lake water was originally intended to be used for drinking, irrigation, and industry, in the following proportions: 62 % of the volume for Hajvalia [17].

Physicochemical Water Analysis

Between December 2020 and May 2021, the monthly sampling from Lake Babovc was conducted at three sampling stations or sites, on two levels (surface and 30 cm) with a total of 66 samples. Water samples were analyzed within 24 hours after sampling, while the parameters were measured in situ were water temperature (Tu), pH, dissolved oxygen (DO), and electrical conductivity (EC). Physicochemical characteristics are determined by placing the samples in clean, high-density polyethylene bottles. Before taking the bottles are rinsed 2-5 times with sample water after being washed with dilute hydrochloric acid. Physical and chemical parameters were analyzed based on the ISO 5667-6 standard in the laboratory of the Hydro-Meteorological Institute of Kosovo. Dissolved oxygen (DO) and oxygen saturation (OS) are measured with the HI 9146 device based on ISO5814: 2012, water temperature (Tu) was measured with the device HI 98130 based on the method DIN 38404-C4, Concentration of hydrogen ions (pH) is measured with the device HI 98130 based on the standard DIN 38404-C5, Electrical Conductivity (EC) is measured with the device (WTW 315i) based on the standard method DIN EN 27888 (C8), Total Dissolved Solids (TDS) measured with the WW 315i device based on standard methods DIN EN 27888 (C8) (11/1993); measured Total Suspended Solids (TSS) with the device AADAMLAB 250 based on the standard of method EN 872, turbulence (NTU) is measured with the device AQUALITIC / PC COMPACT in ISO 7027; (11/1993); iochemical xygen Demand (BOD) is measured with Winkler equipment based on ISO 5815, Chemical Oxygen Demand (COD) is measured on chrome equipment based on ISO 15705, Total Organic Carbon (TOC) is measured with the UVSECOMAM device based on the standard of the DIN EN 1484 method (H3); nitrates, nitrites, phosphates and total phosphorus, as well as ammonium are measured with the device SECOMAM based on standard methods. While heavy metals, such as: Fe, Pb, Mn, Cu and Cd were defined in the Agricultural Institute of Peja with the equipment 4200 MP-AES [18].

Microbiological Analyses

Microbiological studies were performed using a standardized procedure [19]. The number of coliform bacteria was determined by the membrane filtration method according to ISO 9308-1: 2014 [20] with a volume of 100 ml of water samples. Membrane filters were incubated in Medium Chromatic Coliform Agar at 36±2ºC for 24 hours. After isolating the colonies lying on the filter, count with a magnifying glass as coliform bacteria and record as CFU for 100 ml. Confirmation was made through the oxidase test [19-20]. Isolation of Intestinal Enterococcus was done using the membrane filter method in Slanetz and Bartley Agar, as (CFU) for 100 ml. The developed colonies are then shot on plates with Bile aesculin azide agar preheated to 44ºC for an incubation of 2 hours. The plates with discoloration to black and with catalysis test confirmation have been confirmed as Intestinal Enterococcus [20]. To assess the amount of mesophilic aerobic bacteria, a 1 ml and 0.1 ml sample was planted in 90 mm Petri plates with cover in Yeast extract Agar (Plate Count Agar) that had been dissolved in a 44ºC water bath, then the plates were incubated at 36±2ºC for 44 hours. Reporting was done as CFU for 1ml sample [19]. Actinomycete was determined using isolomeric membrane filtration procedures in Actinomycete Isolation Agar for 7-14 days at 30ºC [19].

Determination of Diatom Algae

To determine diatoms, samples were taken in periphyton, on stones by scraping them with a brush in accordance with the standard En 13946:2003 [21]. The samples were placed in glass bottles, and their preservation and fixation were done with 4% formalin. All samples were placed in test tubes to be decanted and 10 ml of H_2O_2 was added, then placed at 90ºC for 2-3 hours. To continue further by placing them in the centrifuge for 3-4 min. While for storing samples, 1-2 drops of formalin have been added. Microscopic preparations are prepared with this material. Observation of the preparations was done with an optical microscope. Species determination was done using the keys for determination by the following authors: [22-31].

Statistical Analysis

In order to compare the values of different variables (physicochemical parameters of water and bacterial loads) between study sites, the mean±standard deviations (SD) were calculated based on raw monthly data that were considered as repetition per area. Spatiotemporal variations of physicochemical parameters of water and bacterial load values of bacteria for total coliforms (TC), faecal coliforms (FC) and intestinal enterococcus (IE) as well as actinomycetes were tested between study sites and months used. The main component analysis (PCA) was performed based on the values of a number of variables and the correlation graph from the presentation of the heat map for the metals in the tents and the microbiological parameters. While the OMNIDIA software with version 6.0 was used for the calculation of diatom indices of water quality.

Results and Discussion

Spatiotemporal Expansion of Physicochemical Parameters of Water

Spatial and temporal extent for physicochemical parameters for Badovc Lake is presented in Figs 2 and 3. The geographical and temporal distributions of physicochemical parameters measured at three sample locations and two water levels in Badovc Lake varied according to the month and sampling location. DO values range from 8.10 mg/L to 14.60 mg/L, this value recorded in March. In almost all months of the research, the values set by the WHO for drinking water were exceeded. Oxygen enters water through direct absorption from the atmosphere as well as photosynthesis by aquatic plants. Sufficient DO is required for aerobic aquatic organisms to develop and reproduce [32]. Dissolved oxygen concentrations are connected to water temperature, nutrients, sediments, and ammonia [33]. O_2 saturation results range from 68.60 mg/L recorded in December to 136 mg/L for May. High water temperatures inhibit microbial development and may exacerbate issues with taste, odor, color, and corrosion [34]. Water temperature values at all monitoring stations and for the month of the study fluctuated from 1.09ºC for the month of January to 18.70ºC recorded in the month of May, values that are within the WHO norms. According to the findings of the study, the pH of Badovci lake is on average 8.52, this value is within the limit of the standard for drinking water (6.5-8.5) by [35] while in April there were excesses with a value of 10.30 As a result, a rise in the pH value of drinking water necessitates an increase in the quantity of chlorine used to achieve the same level of disinfection efficacy [36]. Although the majority of aquatic species require a pH range of 6.5-9.0, some may survive in water with a pH outside of this range [37].

Authors Szymanski and Patterson [38] showed a slight effect of EM biopreparation on pH values. Electrical conductivity (EC) has a significant effect on the acceptance or non-acceptance of drinking water. The average result obtained in this study is 293.47 µS cm^{-1}, which is within the allowed limits of the WHO (750). Dobrzynski et al [9] noted similar results during the research where in most cases the values were 206-212 µS cm^{-1}. The lowest value of TDS was recorded in May 112 mg/L, while the highest value at 167 mg/L in March, which is below the WHO recommended limit. Values higher than 500 mg/L TDS are not considered desirable for drinking and bathing [39]. The lowest value of TSS was registered in January 13.0 mg/L, while the highest value in February with 37.0 mg/L, which is below the WHO recommended limit. The increase in TSS values occurs due to solids that increase during the rainy season due to additional runoff along with wastewater runoff [40]. Turbidity is often produced

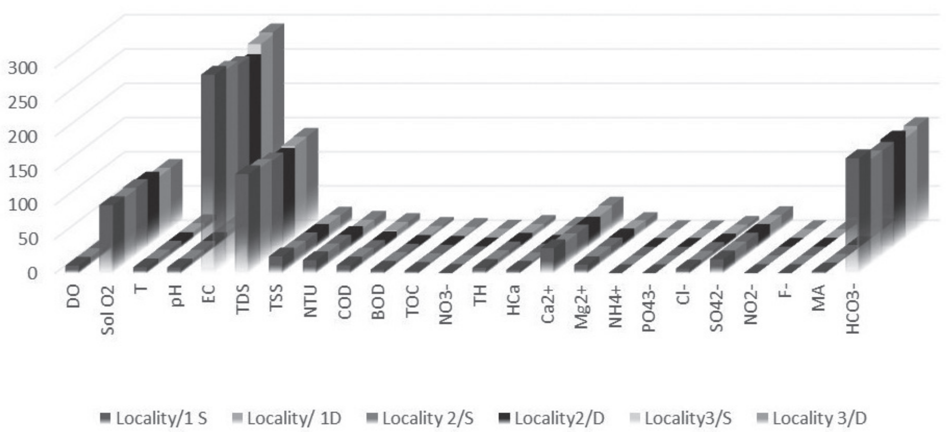

Fig. 2. Physico-chemical parameters in different localities of water in Lake Badovci.

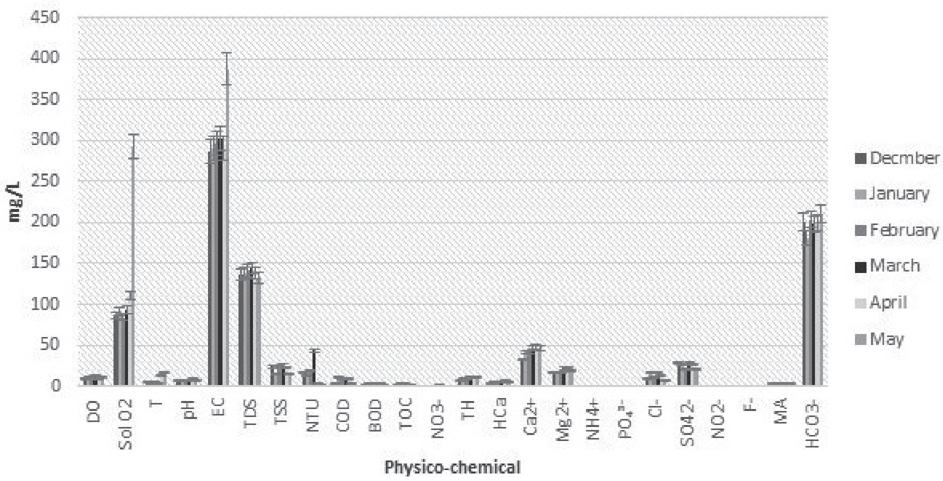

Fig. 3. Frequency distribution graph of the average of physico-chemical parameters in the months of the study.

from clay, clay, organic and inorganic materials, organic compounds with soluble dyes, plankton and other small creatures, but also by the presence of coliforms [41]. During this research, the lowest value was recorded during the month of April with 2.40 NTU, while the highest in the month of March was 8.40 NTU, this value is much higher than the value determined (5) by the WHO.

One of the critical parameters for assessing water quality in relation to organic pollutants and determining the amount of biodegradable substances in water is the biological consumption of oxygen that increases over time with rainfall [42]. Also COD reached the highest value during the rainy season with 18.8 ppm in the month while the lowest with 2.0 ppm in the month of May. As for BOD values, they range from 0.70 in May to 8.40 in January. The highest value of TOC was also in January with 5.7 mg/L while the lowest in May as a result of the load from large inflows and is an excellent indicator of water quality as raw water containing TOC should to undergo additional treatment before being allowed for consumption [43]. The results of nitrate values in the analyzed samples range from 0.09 mg/L to 2.04 mg/L, values that are within the norms established by the EPA (10 mg/L) and WHO (50 mg/L). This increase, although small, which occurred in the month of March, at the entrance of the lake, may have come mainly as a result of the flow of organic fertilizers or sewage from river flows. NO_2 range from 0.007 to 0.1 mg/L, compared to the study conducted by 0.2 to 2.04 mg/L [44] where 0.28 to 0.37mg/L and 0, 02 to 0.03 mg/L. Magnesium-rich water is beneficial to the consumer [45]. The water samples of this lake range from 11.42 mg/L recorded in May to 29.10 mg/L in March, while calcium values fluctuate from 31.03 mg/L to 56.46 mg/L these values within the WHO limit. Ammonia in water is a possible sign of bacterial contamination while phosphorus as a result of new activities carried out in the vicinity of water [46] where in the samples were found values 0.06 to 0.096 mg/L and phosphorus 0.020 mg/L to 0.16 mg/L within the values from WHO and EPA. Chlorides reached their highest value in January at 21.3 mg/L and in March at 19.3 mg/L, while other months were lower. The sulfate concentration showed an increase of 31.0 mg/L in December and continued the downward trend with a minimum value of 19.5 mg/L in March and continued for other months. The flourine had maximum increase in December and January 0.19 mg/L and the lowest value in May 0.06 mg/L. Regarding the values of M-Alkalinit, we have a variation of values starting from 1.96 mg/L to 4.0 mg/L recorded in the month of May. Bicarbonates values reached a maximum value of 244 mg/L in May and a minimum value in April of 119.60 mg/L.

Therefore, it can be said that from all the physico-chemical parameters analyzed in the months of the study, in some samples higher values were recorded than the values recommended by WHO and EPA for dissolved toxins and pH.

Heavy Metals

Mining activity related to the Kishnica mine located in the Lake Badovc region may have contributed to the increase in the concentration of these metals [47]. The values of Fe concentration in this research vary from the highest value that was recorded in December of 0.551 mg/L and is transmitted almost in other months, while the lowest 0.045 mg/L in all months of the research. As a result of continuous anthropogenic activities, such as mining can contribute to the increase of lead oncentrations in water that affects several organs in the human body [48]. The maximum concentration of Pb was found in the samples of December >0.02 mg/L, while the lowest was >0.01 mg/L in April and May. Mn concentrations have varied from the highest value of 0.44 mg/L in December and the lowest 0.001 mg/L in February and April. In the samples of this study the

Cu concentrations varied from the smallest value was 0.001 mg/L to 0.011 mg/L. Cd as a toxic heavy metal can lead to changes in living organisms when it enters the food chain [49]. The Cd matrix varies from the smallest value 0.002 mg/L to 0.005 mg/L.

Principal Component Analysis (PCA) (Fig. 4) is critical for determining the governing elements in a complex initial data set and classifying the data in a PC based on the values of a number of variables. We utilized PCA to identify the most essential metrics

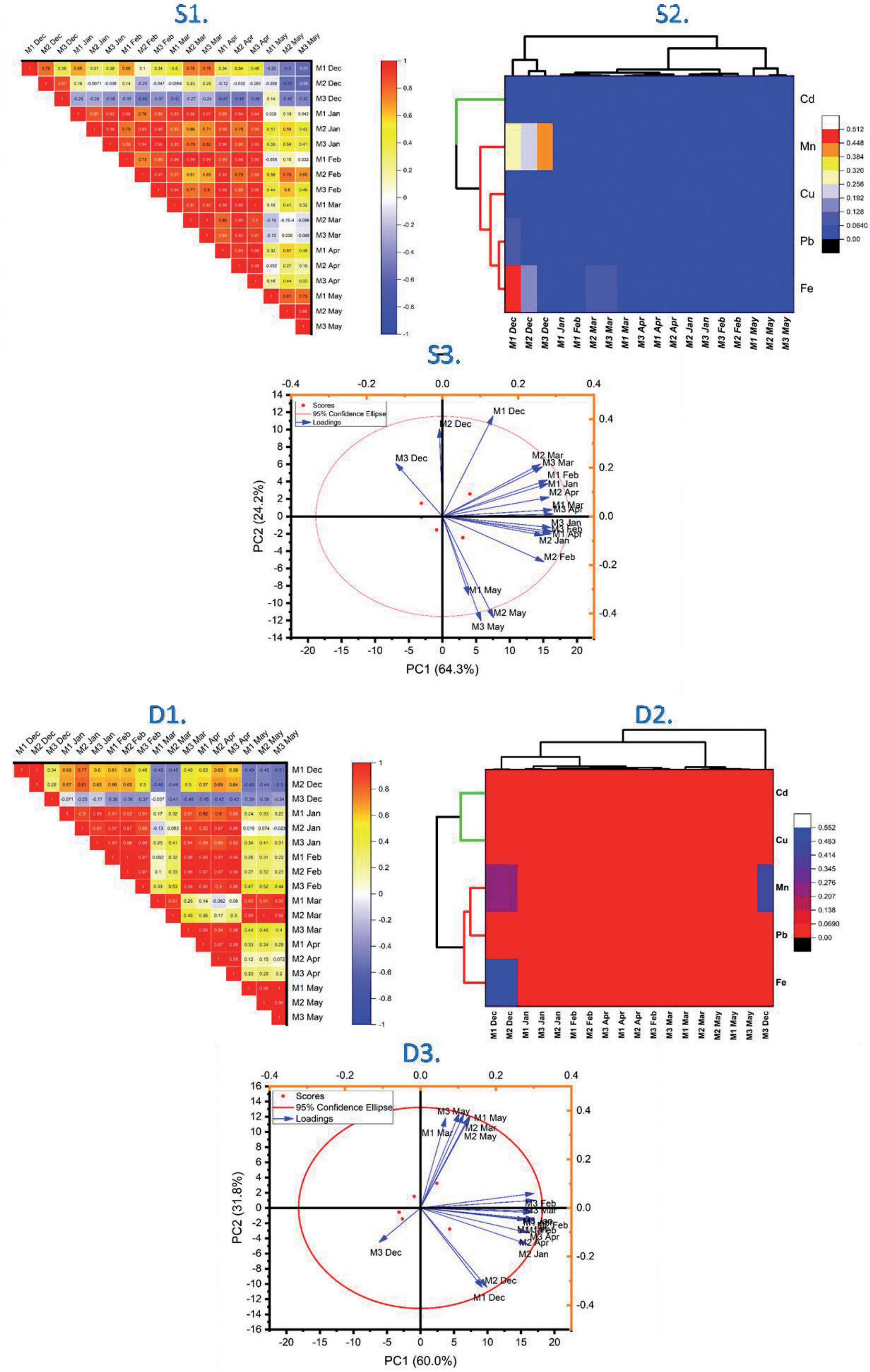

Fig. 4. Correlation plots, heatmap diagrams and PCA analysis for the heavy metals (S1-3 surface and D1-3 30 cm depth).

that may be used to predict individual differences. All parameters were separated into the first and second principal components (64.3 and 24.2 %) based on ordination plots, as shown in Fig. 4 (S2). Furthermore, in May, we had a substantial positive association with component one for M1, M2, and M3, whereas M3 was negatively connected with component one. The findings revealed that considerable alterations occurred on M3. According to the findings of the correlation graph and direct observations from the heat map presentation, the distribution of heavy metal concentration in the surface samples has some similarities between the samples observed in different months, although the M3 sample is very distinct in composition. Moreover, in terms of seasonal fluctuations (in the content of water bodies), there are two groups with comparable composition: a) February, April and May and b) December, January. The same observations are observed for samples taken at a depth of 30 cm.

Spatiotemporal Expansion of Microbiological Parameters

Spatial and temporal extent (mean±standard deviation) for microbiological parameters for Badovc Lake are presented in Table 1. In addition to the physico-chemical characteristics, the emphasis or object of study during the research in Lake Badovc was also the evaluation in the microbiological aspect. Coliform bacteria can be found in water as a result of pollution produced by human and ecological activity [50]. In the collected samples the highest concentration of Total Coliforms was detected in January L1/S, at 868 CFU/100 ml, while the lowest concentration was found in February L3/D, at 8 CFU/100 ml. While the highest concentration of Fecal Cliforms was found in January, at L1/S, at 441 CFU/100 ml, while in March, at L3/D none was registered. In surface waters, physico-chemical variables such as water temperature, precipitation, runoff, sunlight, dissolved nutrients, and competition with other bacteria all have a significant effect on the concentration of fecal coliforms [51]. Regarding intestinal Enterococcus concentration, the highest value was in January at L1/S with 784 CFU/100 ml, while the lowest concentrations were detected in December and March at L3/D. Regarding mesophilic aerobes, our study has shown that these bacteria were identified at the maximum concentration in January, at L1/S, at 420 CFU/1 ml and the lowest value in April at 4 CFU/1 ml. Although not all members of the coliform group are harmful, their presence is associated with lower water quality and may increase the risk of developing gastrointestinal disorders when water is used for various reasons such as bathing, fishing, and drinking [51].

So far no significant studies have been conducted to isolate and evaluate actinomycetes from different freshwater habitats that can produce useful and important antibiotics for science [52]. The maximum

Table 1. Spatiotemporal extent (mean±standard deviation) of microbiological parameters for Badovc Lake.

Microbiological parameters		Months: Mean±SD [min–max]					
		December 2020	January 2021	February 2021	March 2021	Aril 2021	May 2021
Total coliforms (TC)	CFU/100 ml	146.83±78.44 (79-293)	407.83±315.39 (98-868)	63.17±50.69 (8-145)	145.83±95.84 (53-285)	65.33±41.80 (25-122)	340.23±46.47 (303-412)
Fecal coliforms (FC)	CFU/100 ml	4.83±4.22 (1-11)	173.33±167.59 (48-441)	16.67±25.82 (2-68)	19.33±27.27 (0-55)	0.33±0.52 (0-1)	13.33±14.26 (3-37)
Intestinal Enterococcus (IE)	CFU/100 ml	3.83±3.19 (0-7)	354.17±254.13 (133-784)	61.00±59.39 (2-153)	20.50±29.66 (0-64)	6.33±13.08 (0-33)	34.33±8.89 (28-52)
Total Mesophiles ™	CFU/1 ml	196.33±192.18 (2-420)	293.00±90.69 (195 -408)	48.67±33.45 (28-115)	75.67±27.67 (57-130)	18.50±12.18 (4-30)	39.17±21.06 (10-65)
Actinomycete	CFU/1 ml	165.83±65.9 (98-268)	62.33±21.95 (39-98)	154.33±56.9 (97-236)	88.33±30.7 (52-125)	9.83±14.66 (14-51)	47.83±15.56 (25-68)

concentration of Actinomycetes was found in the December samples with 268 CFU/1 ml up to the lowest concentration in April with 14 CFU/1 ml.

Using PCA, we identified the most significant characteristics that may be employed as essential determinants for individual variances. Based on ordination plots corresponding to Fig. 5 (S3 and D3), all parameters were split into the first and second principal components (53.7% and 23.3%, respectively). In addition, component one was strongly positively

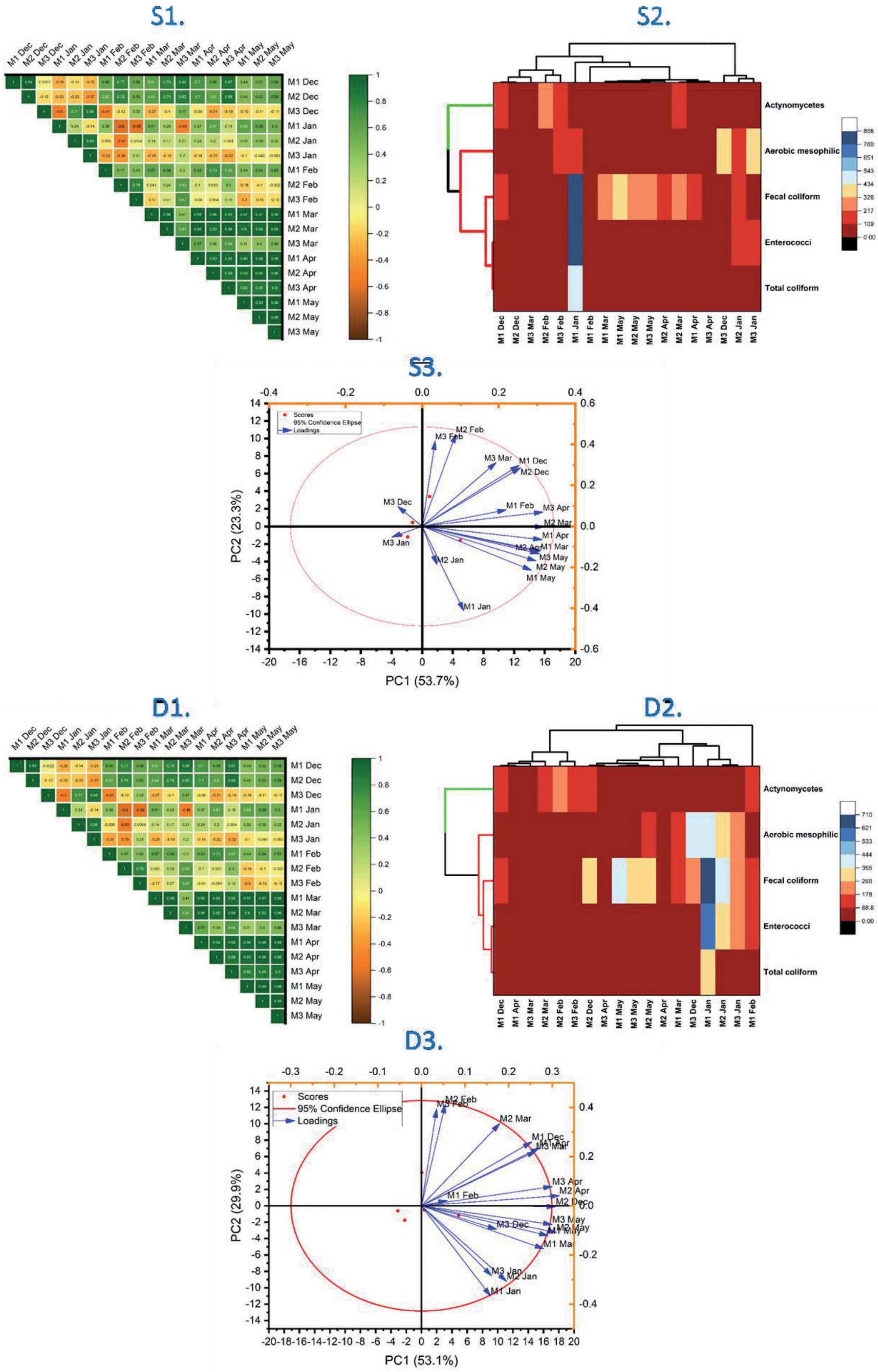

Fig. 5. Correlation plots, heatmap diagrams and PCA analysis for the microbiological parameters (S1-3 surface and D1-3 30 cm depth).

connected with M1, M2, and M3 in January, but M3 was adversely correlated with component one. The results suggested that considerable changes in the concentration and dispersion of microorganisms in surface samples occurred on M3.

Based upon the correlation plot results (Figure 5) and direct observations from the heatmap presentation, the concentration distribution of microorganisms in surface samples has some degree of similarity amongst samples observed at different months, though the M3 sample is very distinct in its microorganism content. The situation is different when the analysis of the 30 cm depth samples is performed.

In this instance, ordination plots were used to partition all parameters into the first and second principal components (53.1% and 29.9%, respectively). In January, M1, M2, and M3 had little to no association with component one. Meaning that the dispersion of microorganisms in the water is uniform.

Spatial Extent of Diatom Species

The diatom algae species discovered at three locations around Badovc Lake are listed in Table 2, where "+" indicates the presence of the species in the localities. The first locale records 230 individuals for Naviculacees, 71 for Surirellacees, 44 for Nitzchiacees, 37 for Araphidees, 11 for Brachyrapfidees, and 7 for Monorphafidees. 17 genera were also identified, with Surirella (71 spp.), Cymbella (53 spp.), Navicula (48 spp.), and Gomphonema having the most species (47 spp.). While in the research carried out in the Modrac lake, all the taxa Gomphonema (13 spp.), Navicula (11 spp.), and Nitzschia (8 spp.) were identified [53]. Eight families were found in the second locality: Naviculacees had 205 individuals, Araphodees had 59 people, Nitzschiacees had 57 individuals, and Surirellaceees had 61 individuals. Epitemiacees have six members, Centrophycidees have six members, and Monoraphides have four members. There were 23 genera recognized. Navicula (66 species), Surirella (61 species), Nitzschia (57 species), and Synedra (57 species) had the most species (27 species). Seven families have been identified in the third locality: Naviculacees with 268 members, Rphaphidees with 47 members, Nitzschiacees with 27 members, Surirellacees with 23 members, Epithemiacces with 20 members, Monoraphides with 7 members, and Centrophycidees with 6 members. Additionally, 24 genera were found, with Navicula having the most species at 84, Cymbela having 76, Amphora having 69, and Nizschia having 20.

Table 2. List of Diatom species along Badovc Lake.

CODE	TAXA	L1	L2	L3
ACCL	*Achnanthidium clevei* (Grun in Cl. & Grun.) Czarnecki	+		
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki	+	+	+
ALTC	*Amphora latecingulata* M. Peragallo in Tempere & Peragallo			+
AOAF	*Amphora ovalis* Kützing var.affinis (Kützing)Van Heurck		+	
AMCD	*Amphora macedoniensis* Nagumo		+	+
ALIB	*Amphora libyca* Ehr.		+	+
AMMO	*Amphora montana* Krasske			+
AOLG	*Amphora oligotraphenta* Lange-Bertalot	+	+	+
HSCA	*Halamphora subcapitata* (Kisselew) Levkov	+	+	+
ACOP	*Amphora copulata* (Kütz) Schoeman & Archibald	+		
AOAF	*Amphora ovalis* Kützing var.affinis (Kützing)Van Heurck	+	+	
AMMO	*Amphora montana* Krasske	+	+	
APED	*Amphora pediculus* (Kützing) Grunow	+		+
AVEN	*Amphora veneta* Kützing	+	+	+
ACOF	*Amphora coffeaeformis* (Agardh) Kützing	+		
ANOR	*Amphora normanii* Rabenhorst			+
ASAN	*Anomoeoneis sphaerophora* (Ehr.) Pfitzer var.angusta Frenguelli		+	
BPAR	*Bacillaria paradoxa* Gmelin in Linneaeus	+		
CAAE	*Caloneis amphisbaena* (Bory)Cleve var.aequata Kolbe			+
CPLI	*Cocconeis placentula* Ehrenberg var.lineata (Ehr.)Van Heurck			+

Table 2. Continued.

CBAC	*Caloneis bacillum* (Grunow) Cleve			+
CPLE	*Cocconeis placentula* Ehrenberg var.euglypta (Ehr.) Grunow		+	+
CAEX	*Cymbella excisa* Kützing		+	+
CLAN	*Cymbella lanceolata* (Agardhi)Agardh	+	+	+
CLBE	*Cymbella lange-bertalotii* Krammer	+	+	
CTUR	*Cymbella turgida* Gregory	+		+
CNCI	*Cymbella neocistula* Krammer	+		+
CNLT	*Cymbella neoleptoceros* Krammer f. anormale	+		
CCIS	*Cymbella cistula* (Ehrenberg) Kirchner	+		
CAEA	*Cymbella aequalis* W.M.Sm.var.alaskensis Manguin ex Kociolek &Reviers	+	+	+
CSMO	*Cymbella simonsenii* Krammer	+	+	+
CSLE	*Cymbella silesiaca* Bleisch in Rabenhorst (Encyonema)	+		
CPRO	*Cymbella prostrata* (Berkeley) Cleve	+	+	+
CMEN	*Cyclotella meneghiniana* Kützing		+	+
CTUM	*Cymbella tumida* (Brebisson)Van Heurck	+	+	+
CEHI	*Cymatopleura elliptica* (Brebisson)W.Smith var.hibernica (W.Sm.) Van Heurck			+
DMON	*Diatoma moniliformis* Kützing ssp.moniliformis (moniliforme?)		+	+
ELUN	*Eunotia lunaris* (Ehr.) Brebisson in Rabenhorst	+	+	
EPRO	*Encyonema prostratum* (Berkeley) Kützing	+		
EADN	*Epithemia adnata* (Kützing) Brébisson		+	+
ESAC	*Epithemia sorex* Kützing var.acuta Cleve-Euler		+	+
EPRO	*Encyonema prostratum* (Berkeley) Kützing		+	
GCAP	*Gomphonema capitatum* Ehrenberg	+	+	+
GINT	*Gomphonema intricatum* Kützing		+	
GMIC	*Gomphonema micropus* Kützing	+		
GMIN	*Gomphonema minutum* (Ag.) Agardh f. minutum	+	+	+
GOLD	*Gomphonema olivaceoides* Hustedt	+	+	
GPLA	*Gomphonema parvulum var.lagenula* (Kütz.)Frenguelli	+		
GPUM	*Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot	+	+	
GROS	*Gomphonema rosenstockianum* Lange-Bertalot & Reichardt	+	+	
GTRU	*Gomphonema truncatum* Ehrenberg	+	+	+
GYAC	*Gyrosigma acuminatum* (Kützing)Rabenhorst	+	+	+
GNOD	*Gyrosigma nodiferum* (Grunow) Reimer		+	+
MBRA	*Mastogloia braunii* Grunow	+		
MCIR	*Meridion circulare* (Greville) C.A.Agardh	+	+	+
NRAD	*Navicula radiosa* Kützing	+	+	
NACU	*Nitzschia acula* Hantzsch ex Cleve & Grunow			+
NVIR	*Navicula viridula* (Kützing) Ehrenberg	+	+	+
NRHY	*Navicula rhynchocephala* Kützing	+	+	+
NCBA	*Navicula confervacea* (Kützing) Grunow var. baikalensis Skv.	+	+	
NCAM	*Navicula cuspidata* Kützing var.ambigua (Ehrenberg) Cleve	+	+	

Table 2. Continued.

NGRE	*Navicula gregaria* Donkin	+	+	+
NHAL	*Navicula halophila* (Grunow) Cleve	+	+	+
NCTE	*Navicula cryptotenella* Lange-Bertalot	+	+	
NCPR	*Navicula capitatoradiata* Germain			+
NHIN	*Navicula hintzii* Lange-Bertalot	+	+	+
NERI	*Navicula erifuga* Lange-Bertalot in Krammer & Lange-Bertalot	+		+
NOBL	*Navicula oblonga* Kützing	+	+	+
NTPT	*Navicula tripunctata* (O.F.Müller) Bory	+	+	
NSBM	*Navicula subminuscula* Manguin			+
NANT	*Navicula antonii* Lange-Bertalot		+	+
NVEN	*Navicula veneta* Kützing	+		
NIPF	*Nitzschia paleaeformis* Hustedt	+	+	
NPAL	*Nitzschia palea* (Kützing) W.Smith	+		+
NREC	*Nitzschia recta* Hantzsch in Rabenhorst	+	+	
NSIG	*Nitzschia sigma* (Kützing) W.M. Smith	+	+	+
NSOL	*Nitzschia solgensis* Cleve-Euler		+	
NSOC	*Nitzschia sociabilis* Hustedt	+	+	+
NUMB	*Nitzschia umbonata*(Ehrenberg)Lange-Bertalot	+	+	
NDUB	*Nitzschia dubia* W.M.Smith			+
NSIO	*Nitzschia sigmoidea* (Nitzsch)W. Smith		+	+
NEVE	*Neidium vernale* (Reicheldt ex Hustedt) Metzeltin & Lange-Bertalot		+	
PIBR	*Pinnularia intermedia (*Lag.)Cl. var. bryophila Manguin ex Kociolek& Reviers		+	
RABB	*Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot			+
RGIB	*Rhopalodia gibba* (Ehrenberg) O.Müller			+
PBOR	*Pinnularia borealis* Ehrenberg	+	+	
PGIB	*Pinnularia gibba* Ehrenberg	+	+	+
PIBR	*Pinnularia intermedia* (Lag.)Cl. var. bryophila Manguin ex Kociolek& Reviers			+
PMAC	*Pinnularia macilenta* Ehrenberg	+		
PLAA	*Pinnularia lata* (Brébisson) W. Smith var. amplissima Manguin	+	+	
PPVS	*Pinnularia parvulissima* Krammer	+		
SPUP	*Sellaphora pupula* (Kützing) Mereschkowksy	+	+	
SPIN	*Staurosirella pinnata* (Ehrenberg) Williams & Round		+	+
SREC	*Sellaphora rectangularis* (Greg.) Lange-Bertalot & Metzeltin	+		+
SBBI	*Surirella biseriata* Brebisson.var.bifrons (Ehr.)Hustedt	+		
SBRE	*Surirella brebissonii* Krammer & Lange-Bertalot	+	+	
SBKU	*Surirella brebissonii* var.kuetzingii Krammer et Lange-Bertalot	+	+	
SUCA	*Surirella capronii* Brébisson & Kitton	+	+	+
SHEL	*Surirella helvetica* Brun	+	+	
SLHE	*Surirella linearis* W.M.Smith var.helvetica (Brun) Meister	+	+	+
SRBA	*Surirella roba* Leclercq			+
SUMI	*Surirella minuta* Brébisson ex Kützing			+

Table 2. Continued.

SDID	*Surirella didyma* Kützing	+	+	
SOVI	*Surirella ovalis* Brébisson	+	+	
SOVA	*Surirella ovata* Kützing	+		+
SURO	*Surirella robusta* Ehrenberg	+	+	+
SULN	*Synedra ulna* (Nitzsch.)Ehr.	+	+	
SACU	*Synedra acus* Kützing		+	
SUBI	*Synedra ulna* (Nitzsch.)Ehr.var.biceps(Kütz.)Schoenfeldt	+	+	+
UACU	*Ulnaria acus* (Kützing) Aboal			+
UBIC	*Ulnaria biceps* (Kützing) Compère	+	+	+
UULN	*Ulnaria ulna* (Nitzsch) Compère	+	+	+
HAAB	*Hantzschia amphioxys* (Ehr.) Grunow var.africana Hustedt f.brevis Compère	+		

Diatoms are regarded as excellent indicator species in aquatic ecosystems, since they may be used to ascertain the ecological state and water quality of a variety of lakes. According to Table 2, 113 species of diatoms belonging to eight families were found during the investigation in Badovc Lake. *Navicula rhynchocephala* Kützing (5.8%), *Meridion circulare* (Greville) C.A. Agardh (5.8%), *Cymbella simonsenii* Krammer (4.6%), *Surirella capronii* Brébisson & Kitton (4.5%), Nitzschia sigma (Kützing) W. M. Smith (4.3%), *Navicula erifuga* Lange-Bertalot in Kra (2.8 %). The results obtained from the principal component analysis (PCA) for the 23 physico-chemical parameters and the 6 most dominant types of diatoms (L1-L3) are shown in Fig. 7. The obtained results show that we have a biplot correlation between the variables on the PC1 axis (66.7%) and PC2 (33.3%). *Meridion circulare* (Greville) C.A. Agardh had high positive correlation with physico-chemical factors: TDS, TSS, Ca^{2+}, BOD, TOC, NH_4^+, *Surirella capronii* Brébisson & Kitton correlation with: $NH_4^{+,}$ COD, EC, *Amphora coffeaeformis* (Agardh) Kützing high correlation with: DO, Sol O_2, NTU, Cl^-, *Nitzschia sigma* (Kützing) W.M. Smith with F^-, pH, Cl, *Navicula rhynchocephala* Kützing expressed a high correlation with NO_3^-, SO_4^{2-}, T and the species *Cymbella simonsenii* Krammer expressed a high positive correlation with NH_4^+, SO_4^{2-} and T.

The following indices were employed to assess the ecological and trophic state of water throughout our research: IPS, CEE, IBD, IDG, DESCY, SLA, SHE, IDSE, IDAP, EPID, WAT, TDI, IDP, SHE (Fig. 7). According to the Descy, Rott SI, IDG, IPS, IBD, and CEE indices, the water quality in L1 is excellent, falling into the second (II) category, with an

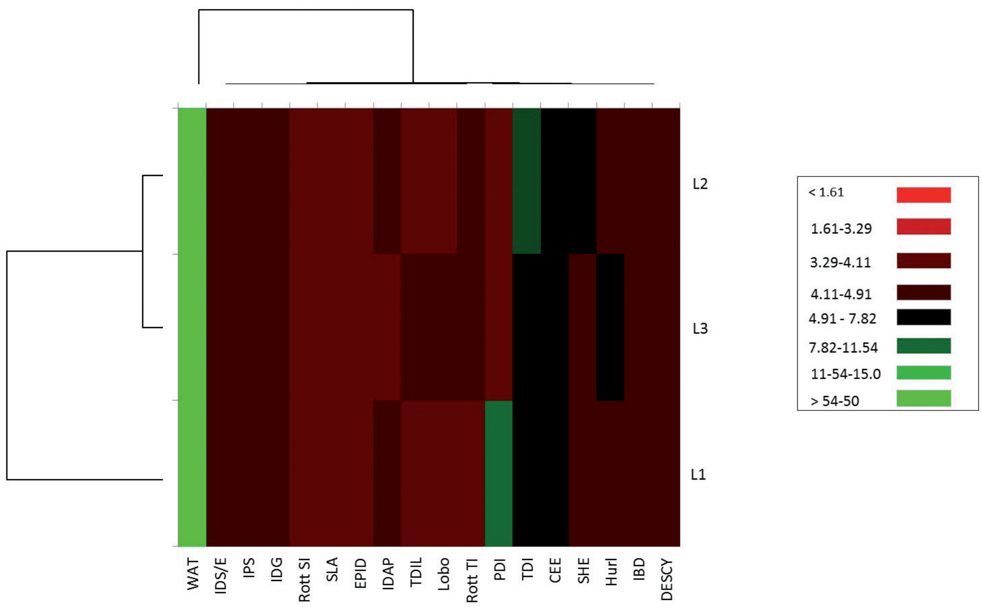

Fig. 6. Presentation of diatomic index results for Localities 1-3 through heat map.

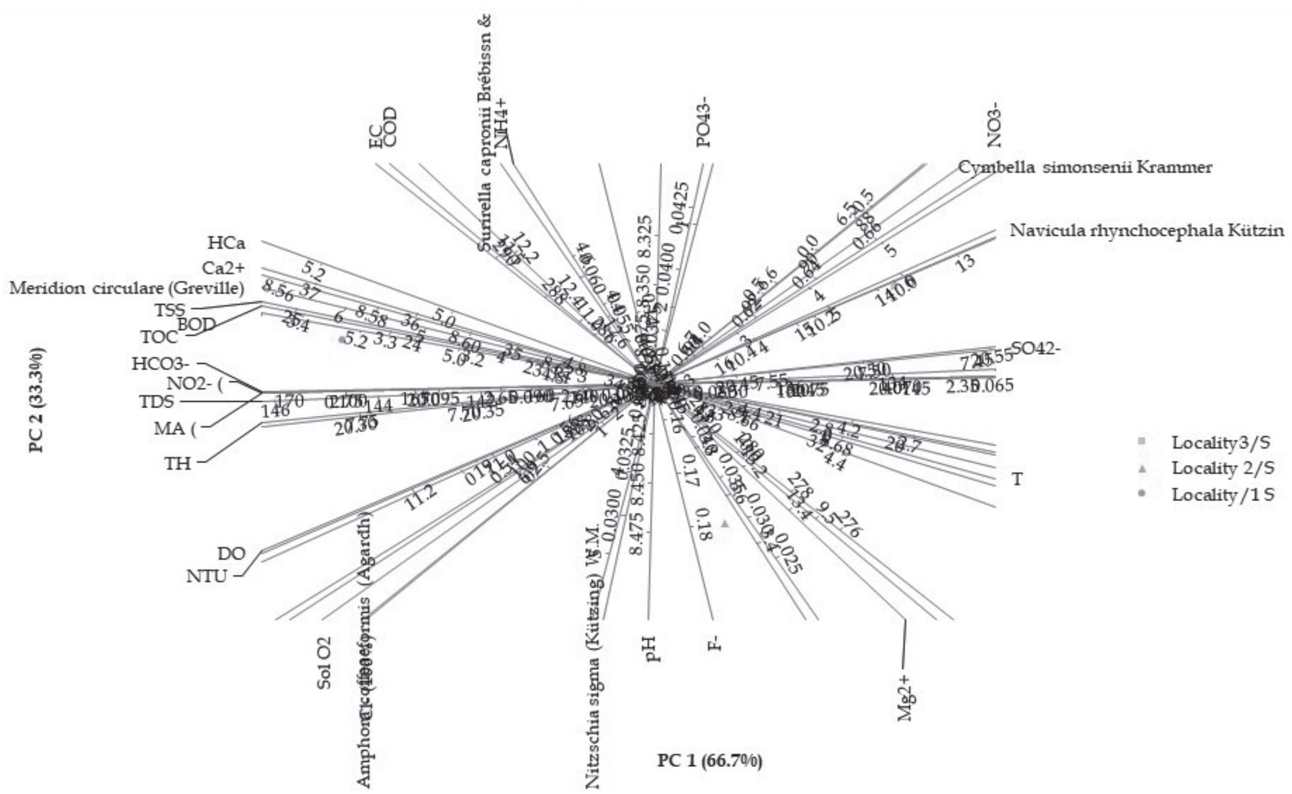

Fig. 7. Principal component analyzes (PCA) of physico-chemical parameters and dominant species of diatoms determined in localities (L1-L3).

Oligo-Mesotrophic trophic status. While the EPID, Sla, TDI, PDI, and WAT indices indicate a moderate water quality, the trophic state is Mesotrophic.

According to the Descy, Rott SI, IBD, and SHE indices, the water quality in L2 is excellent, falling into the second (II) class, with an Oligo-Mesotrophic trophic status. Additionally, according to IPS, IDG, EPID, IDAP, CEE, TDI, WAT, LOBO, HURL, and SLA, the water quality is moderate and falls into the third class (III), indicating a mesotrophic state.

Even in L3, the water quality is high, falling into the second (II) class, and the trophic status is Oligo-Mesotrophic, as determined by the Descy, IPS, IDG, IBD, Rott SI, and SHE indices. Whereas the water quality is moderate and corresponds to the third class (III) according to the Lobo, EPID, PDI, and CEE indices, and the trophic level is mesotrophic. The average of the taxa used to calculate the indices in Lake Modrac, Bosnia and Herzegovina was the highest for IPS (96%), IBD (86.67%) and EPI-D (83%) where it determined the ecological status of the water by classifying that in the second category (II) of ecological status and a positive correlation of these indices with nutrient values was shown [53]. While the study done in Lake Cebong [54] showed that over 70% of the species diversity is included in the IDG, IPS, TDI, IBD indices and show a high average ecological status. Compared to the species diversity of the lakes, the study carried out in the Lepenc River [55], for the determination of water quality, took into account the indices BD, IPS, IDG, Descy, Sla, IDSE, IDAP, EPID, CEE, WAT, TDI, IDP and SHE that classifies the water of this river with eutrophic to oligo-mesotrophic status. In the case of our research, the indices that were taken into consideration to determine the trophic and ecological status were the indices with over 70% of the species, such as IDG (100%), IBD (81.3%), IPS (93.3%), TDI (84.0 %), EPID (72.0). %). These indices were applied and the oligo-mesotrophic to mesotrophic trophic status was determined, classifying the water of this lake in the category II to III of the ecological status.

Conclusions

The purpose of this research was to determine the physical, chemical and biological quality of water in Lake Badovc. The findings of this investigation show that some of the physico-chemical and heavy metal parameters had light exceedances compared to the limit values set by WHO and EPA. The increase in the number of bacteria during rainy seasons, such as January, indicates the need for rigorous monitoring during rainy seasons to avoid or mitigate the risk of numerous water-borne diseases, as Lake Badovc, in addition to being used, is used for water supply of beverage, also used for fishing and bathing. Examination of diatomaceous algae using diatomaceous earth indices revealed that they have a favorable ecological status, ie their water quality is in the second (II) class, but also average in the third (III) class, and their status trophic varies from oligo-mesotrophic to mesotrophic. Consequently, in order to protect this aquatic environment, frequent and finding-based monitoring should be done, as well as necessary actions to improve the water quality in the lake studied in this paper.

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Conflict of interest

The authors declare that they have no conflict of interest.

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