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The Application of Benthic Diatoms in Water Quality Assessment in Lepenci River Basin, Kosovo

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ABSTRACT
During the study on the assessment of ecological status of the Lepenci river basin, epilithic diatoms were used. Via this methodology, the authors aimed to standardization the ecological assessment methodology and gradually make it applicable for all river basins of Kosovo. The authors relied on a hypothesis that the epilithic diatom communities can serve as a reliable ecological tool to evaluate the quality of flowing waters in Kosovo. Thirteen water quality indices (IBD, IPS, IDG, DESCY, SLA, IDSE, IDAP, EPID, CEE, WAT, TDI, IDP and SHE) were measured in eight sample-points. From the conducted qualitative analysis, the obtained results showed that the water quality varies from upper parts of the basin (SP1, SP2, SP3 & SP4) characterized with higher water quality towards the lower parts (SP5, SP6 & SP7) where water quality was of the 2nd class and finally in Hani i Elezit (SP8) where the index values showed that its water belongs to the 3rd class. The samples were taken in to 8 sampling sites, in river during year (2017), the *Navicula viridula* species was the most dominant, along with *Cocconeis placentula* var. *lineate* and *Diatoma vulgaris*. In turn, between August and end of September, the following species were dominant ones: *Craticula ambigua, Navicula hintzii, Navicula viridula* and *Rhoicosphenia abbreviata*.

Keywords: diatoms; bioindicators; Lepenci; Kosovo; environmental control

INTRODUCTION

As a diverse group of unicellular algae, aquatic diatoms are well-known as biological indicators with high sensitivity and narrow tolerance of their individual species towards the altering environmental parameters such as pH, salinity, nutrient availability as well as organic and inorganic pollution [Round 1993, Prygiel and Coste 1993, Soltanpour et al. 2011, Vasiljević 2014, Lobo et al. 2016, Antonelli et al. 2017]. In pursuit of correct manner to estimate the degradation of water bodies across the globe, scientists have developed several diatom-based indices such as IPS [Cemagref 1982], the TDI [Kelly et al. 1995] as well as BDI [Lenoir and Coste 1996]. The continuous and systematic use of these indices in all biomonitoring related programs in Europe within the European Water Framework Directive makes them very trustworthy and reliable for Kosovo (DKU 2000) and additionally points out that the biological indicators play an important role in the evaluation of the ecological status. Anyhow, large number of taxa that can be involved remains a problematic issue in using and analyzing diatoms as an biological indicator [Soltanpour et al. 2011, Dalu et al. 2016] that has been so far partially solved by using the indices that rely only on genera [Rumeau and Coste 1988, Rovira et al. 2012, Blanco et al. 2012]. Additionally, other authors [Àcs et al. 2004, Hassan and Shaawiat 2015, Srivastava et al. 2017, Bere and Tundisi 2010, Besse-Lototskaya et al. 2011, Jüttner et al. 2012] mention the required expertise on taxonomic treatment of this large and diverse group of aquatic organisms and their distributional patterns along streams that is directly interlinked with pH, temperature, substrate type and light availability [Toman et al. 2014, Kahlert and Rašić 2015, Trobajo and Sullivan 2010] among other factors. So far, in the biomonitoring studies in Kosovo concerning the water quality issues, the diatom flora has been neglected and has therefore received little attention or no attention at all, even though it is well-known that they, in particular the freshwater species, constitute a major group of algae. Via this study, the authors aimed at assessing the diatom flora of the Lepenci river basin, representing an important step towards the general overview and assessment of all freshwater rivers and basins of Kosovo.

Diatoms are an important component of ecosystems because they are in high correlation with the environmental characteristics [Hill, et al., 2001]. They are a specialized, systematic group of algae occurring in almost all water ecosystems and other damp habitats. Diatoms are valuable indicators of the stream ecosystem conditions because they are relatively simple to collect, respond rapidly and predictably to the changes in stream chemistry and habitat quality, taxonomically diverse, have short regeneration times, and are ubiquitous, which allows for comparisons across geographic regions [Round 1991, van Dam et al. 1994, Leland 1995].

They are a systematic group used in assessment of water quality [Noga et al., 2014]. These organisms constitute one of the main dominant groups of periphytic algae in lotic systems and efficient indicators of environmental changes, since they respond sensitively to the physical and chemical changes of water quality [Winter and Duthie, 2000; Lobo et al., 2002].

Diatoms have been recognized as good indicators of water quality [Stevenson, 2014], Maznah and Omar [2010] revealed that the use of algae as bioindicators is important to identify the alteration of water quality in the freshwater ecosystems.

Especially, algae have been shown as a good indicator for the environmental stress assessment caused by nutrient pollutants (substances containing nitrogen and phosphorus).

The research on the diversity of diatomic algae and the determination of surface water quality, with the help of these bioindicators in Kosovo Rivers to date has been scarce.

MATERIAL AND METHODS

The Lepenci River basin is the main water catchment in the southeastern part of the Republic of Kosovo. The hydrographic network that discharges water in the Lepenci River covers an area of 653 km^2 [KEPA, 2015], which is located in the territory of Kosovo, and which compared to the total area of Kosovo constitutes 5.98% thereof. The Lepenci River basin has its source in high mountainous areas at an altitude of 2212 m and is mainly fed by the water sources that flow into mountainous hills between the hydro-geologic formations in the upper permeable collector and watertight formations or floor hydro-geologic isolators at the bottom. The Lepenci River basin has a length of 50 km and average annual flow of 8.4 m^3/s [KEPA, 2015]; it has a river bed with many meanders forming in its entire length a river trench which continues outside the territory of Kosovo. The average annual precipitation in the Lepenci River area is 912 mm, whereas the effective precipitation is 469.8 mm with a coefficient of flow of 0.516 [KEPA, 2015].

The sampling was conducted during spring, summer and autumn, 2017, from 8 localities (S1-S8), along the River basin of Lepenci. (Figure 1).

The authors collected the benthic diatoms by scraping with a toothbrush, preserving the material in 4% formalin.

Preparation and cleaning of the diatoms followed the CEN methodology (prEN 13946:2002) with 30% cold hydrogen peroxide (H_2O_2), 37% hydrochloric acid (HCl) to oxidize organic matter and clean the diatom frustule. Microscopic identification and analysis was performed with mounted digital camera (MotiCam 5+ / 5.0 MP). The following literature sources for determining the diatom species:[Lange-Bertalot 1993, Lange-Bertalot 2001, Cantonati et al. 2017, Krammer

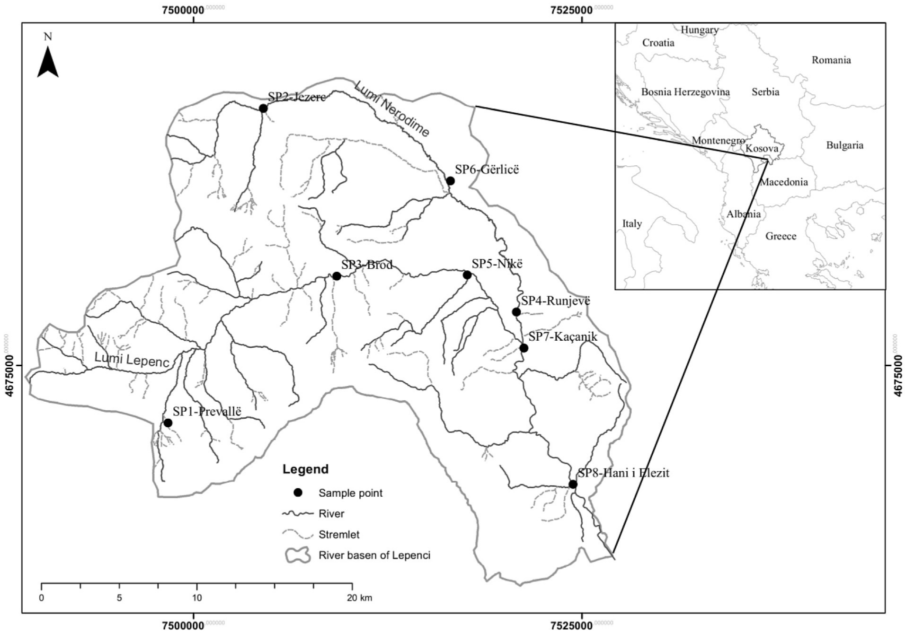

Figure 1. Location of investigated area

2010, 2012, 2013, Lange-Bertalot et al. 2011, Levkov et al. 2007, Levkov 2009, Levkov and Williams 2011, Levkov et al. 2016, Levkov et al. 2013, Pavlov et al. 2013]. Thirteen diatom indices, calculated based on the indicator values of the identified taxa using the OMNIDIA software [Lecointe et al. 1993] for the water quality assessment are: IBD [Prygiel and Coste 2000], IPS [Cemagref 1982], IDG [Prygiel and Coste 2000, Lecointe et al. 1993], Descy [Descy 1979], SLA [Sladecek 1986], IDSE [Leclercq and Lecointe 2008], IDAP [Prygiel et al. 2002], EPI-D [Dell' Uomo 2004], CEE [Descy and Coste 1991], WAT [Lecointe et al. 2003], TDI [Kelly et al. 1995], IDP [Gómez and Licursi 2001], SHE [Srivastava et al. 2017]. The scale values from 1 up to 20 were used.

Total species number, distribution and of species per locality, diversity of species – Shannon-Wiener diversity index (H), Simpson diversity index (D), Margalef index, Menhinick index, species richness estimator (SChao 1) (a species richness estimator estimate the total number of species present in a community and is based upon the number of rare species (singleton and doubleton) found in a sample [Chao, 1984] and similarity index (Jaccard's similarity index -Ja) were calculated using ComEcoPaC – Community Ecology Parameter Calculator, Version 1 [http://prf.osu.cz/kbe/dokumenty/sw/ ComEcoPaC/ComEcoPaC.xls].

The analyses of physicochemical parameters were performed based on the ISO 5667–6 standard, which determines the principles to be applied in designing the programs in sample collection, the techniques of sample collection and the treatment of water samples from rivers and flows for the physical and chemical assessment [ISO, 2014]. The samples for water quality analysis were collected at the same time as the diatom samples. Environmental factors, including water temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and total dissolved solids (TDS). The concentrations of silicate (SiO_2, $mg·L^{-1}$), nitrate (NO_3^-, $mg·L^{-1}$), orthophosphate (PO_4^{3-}, $mg·L^{-1}$), ammonium (NH_4^+, $mg·L^{-1}$), and sulfate (SO_4^{-2}, $mg·L^{-1}$).

RESULTS AND DISCUSSION

The results of water analysis are presented in Table 1. The variation of temperature ranged between 8.5°C in SP1 (autumn) to 20.7°C in SP4 (autumn), the average values in spring, summer and autumn were 10.80, 16.81 and 11.93°C, respectively, whereas the average value with standard deviation for the three seasons has been 13.18±3.73°C. The pH ranged from 6.9 in SP1 (autumn) to 8.7 in SP1 (spring). The average values in spring, summer and autumn were 8.375, 8.265 and 7.296, respectively, whereas the average value with standard deviation for the three seasons for pH was 7.98±0.55. The concentrations of nitrate ranged from 0.0.00 in

Table.1. Results of the water analysis during the study period. The first row represents mean ± SD and the second row represents the lowest and highest observed values

Sites / Symbol	S1	S2	S3	S4	S5	S6	S7	S8
T °C	9.16±0.70°C 8.5–9.9	12.5±1.35 11.2–13.9	13.3±2.26 11.4–15.8	14.3±5.71 9.7–20.7	14.86±3.64 12.1–19	10.08±3.50 9.1–15.7	14.26±5.46 9.9–20.4	13.93±5.56 10–20.3
pH	7.93±0.92 6.9–8.7	7.95±0.75 7.09–8.4	8.12±0.71 7.31–8.65	7.8±0.61 7.13–8.30	8.22±0.58 7.55–8.61	7.70±0.35 7.31–8.0	7.92±0.43 7.42–8.2	8.15±0.44 7.65–8.5
EC	69.93±31.04 41.4–103.0	135±20.81 123.7–159.9	232.2±78.84 145.7–300	596.3±169.0 411.0–742.0	252.2±87.11 155.7–325	553.6±180.9 356–711	522.3±112.3 400–621	384±93.1 285–470
TDS	35.16±15.86 20.5–52.0	67.9±10.0 62.0–79.5	116.3±39.3 73.1–150	298.0±74.78 205.0–371.0	126.8±42.3 80–162	276.8±90.45 178–355	261.3±56.4 200–311	192.3±46.36 143.0–235.0
O_2	8.11±1.82 6.7–10.2	8.75±1.62 6.95–10.1	9.06±3.12 6.67–12.6	6.88±1.67 5.71–8.8	8.53±3.16 6.05–12.1	5.43±3.11 1.9–7.8	7.39±1.62 5.5–8.6	7.96±1.79 5.9–9.2
COD	3.45±2.16 2.6–4.3	7.93±6.87 3.1–15.8	1.46±1.27 0.0–2.3	33.9±14.46 17.2–42.5	6.74±7.84 2.13–15.8	41.8±9.69 35.0–62.9	29.96±9.55 19.4–38.0	22.43±17.5 2.3–34.0
BOD	1.10±1.02 0.30–1.90	3.66±2.90 1.7–7.0	0.5±0.5 0.0–1.1	15.9±11.56 3.1–25.16	5.48±5.76 0.5–11.8	28.7±11.6 16–38.8	15.16±7.08 8.5–22.6	12.46±10.37 1.0–21.2
NO_3^-	1.23±1.12 0.0–2.2	0.53±0.66 0.15–1.3	3.9±3.7 0.13–7.60	4.43±3.26 1.0–7.5	3.85±3.72 0.16–7.6	0.76±1.15 0.10–2.10	3.43±3.49 0.5–7.3	9.56±9.25 1.8–19.8
NH_4^+	000±000 000–000	0.018±0.010 0.017–0.018	0.016±0.010 0.012–0.019	3.29±3.13 1.15–6.9	1.25±0.27 1.08–1.57	3.56±2.24 1.36–5.84	1.90±0.41 1.66–2.38	1.91±1.01 1.21–3.07
PO_4^{3-}	0.023±0.023 <0.02–0.023	0.025±0.014 0.025–0.025	0.036±0.021 0.036–0.036	0.81±1.31 0.05–2.32	0.033±0.015 0.024–0.050	0.92±1.07 0.11–2.14	0.86±1.27 0.06–2.33	0.31±0.34 0.049–0.70
SO_4^{2-}	3.33±3.21 1.0–7.0	4.0±1 3.0–5.0	4.66±2.51 2.0–7.0	12.66±2.88 11.0–16.0	5.0±3.6 1.0–8.0	16±9.84 8.0–27	12.33±5.13 8.0–18	10±2 8–12

S1 to 19.800 mg/L in S8. The variation of EC has been from 41.40 µS/cm in SP1 (spring) to 742.00 µS/cm in SP4 (summer). The average values in spring, summer and autumn were 239.813, 414.913 and 375.250 µS/cm, respectively, whereas the average value with standard deviation for the three seasons for EC reached 343.33±212.31 µS/cm. The values of TDS ranged from 20.50 mg/L in SP1 (spring) to 371.00 mg/L in SP4 (summer). The average values in spring, summer and autumn were 120.238, 207.438 and 187.875 mg/L, respectively, whereas the average value with standard deviation for the three seasons for TDS amounted to 171.85±106.04 mg/L. The value of COD ranged from 00.00 mg/L in SP3 (summer) to 52.90mg/L in SP6 (summer). The average values in spring, summer and autumn were 19.488, 12.329 and 23.150 mg/L, respectively, whereas the average value with standard deviation for the three seasons for COD reached 18.32±17.21mg/L. The variation of BOD_5 was from 00.00 mg/L in SP3 (summer) to 38.800mg/L in SP6 (summer). The average values in spring, summer and autumn were 8.513, 8.058 and 14.450mg/L respectively, whereas the average value with standard deviation for the three seasons for BOD_5 amounted to 10.34±11.24 mg/L. The value of NO_3^- was from 00.00 mg/L in SP1 (spring) to 19.800 mg/L in SP8 (summer). The average values in spring, summer and autumn were 1.205, 6.444 and 2.775 mg/L respectively, whereas the average value with standard deviation for the three seasons for NO_3^- reached 3.48±4.46 mg/L. The variation of NH_4^+ was from 0.010mg/L in several stations up to 6.900mg/L in SP4 (spring). The average values in spring, summer and autumn were 2.477, 0.815 and 1.198 mg/L respectively, while the average value with standard deviation for the three seasons for NH_4^+ amounted to 1.50±1.82 mg/L. The variation of PO_4^{3-} was from 0.020 mg/L at several stations (in different season) up to 2.335 mg/L at SP7 (summer). The average values in spring, summer and autumn were 0.129, 0.956 and 0.047 mg/L respectively, while the average value with standard deviation for the three seasons for PO_4^{3-} was 0.38±0.75 mg/L. The sulphates of SO_4^{2-} ranged from 1.000 mg/L in SP1 (summer) and SP5 (summer) up to 27.000 mg/L in SP6 (autumn).The average values in spring, summer and autumn were 7.250, 6.625 and 11.625 mg/L, respectively, while the average value with standard deviation for the three seasons for SO_4^{2-} was 8.50±6.00 mg/L.

Table 2 shows that during the research on the Lepenci River basin, there are 139 identified species of diatoms belonging to 8 families; the Naviculaceae familiy has the highest abundance and distribution, whereas the species with highest abundance corresponds to *Nitzschia dissipata*

Table 2. List of identified taxa in study river Lepenci basin.

CODE	Taxa	S1	S2	S3	S4	S5	S6	S7	S8
ADEG	*Achnanthidium exiguum*(Grunow) D. B. Czarnecki							+	
ADGL	*Achnanthidium gracillimum* (Meister) Lange-Bertalot	+							
ADMI	*Achnanthidium minutissimum* (Kützing) Czarnecki.							+	
ADPY	*Achnanthidium pyrenaicum* (Hustedt) Kobayasi							+	
ACOP	*Amphora copulata* (Kützing) Schoemann et Archibald			+					
AOVA	*Amphora ovalis* (Kützing) Kützing						+	+	
APED	*Amphora pediculus* (Kützing) Grunow	+							
AVEN	*Amphora veneta*Kützing		+						
ASPH	*Anomoeoneis sphaerophora* (Kützing) Pfitzer							+	
BPAR	*Bacillaria paradoxa* Gmelin	+		+		+		+	+
CAMP	*Caloneis amphisbaena* (Bory) Cleve						+	+	
CBAC	*Caloneis bacillum* (Grunow) Cleve							+	
CPED	*Cocconeis pediculus* Ehrenberg.		+	+			+	+	
CPEA	*Cocconeis placentula var. euglypta* (Ehrenberg) Cleve.	+	+	+	+				+
CPLM	*Cocconeis placentula var. lineata* (Ehrenberg) Cleve.	+	+	+	+		+	+	+
COPL	*Cocconeis pseudolineata* (Geitler) Lange-Bertalot.	+			+	+			
CAMB	*Craticula ambigua* (Ehrenberg) D. G. Mann.				+	+	+	+	+
CRBU	*Craticula buderi* (Hustedt) Lange-Bertalot		+			+		+	
CRCU	*Craticula cuspidata* (Kützing) D. G. Mann.	+	+		+	+		+	
CCMP	*Cymbella compacta* Østrup.	+		+					
CCYM	*Cymbella cymbiformis* Agardh		+	+			+		
CAEX	*Cymbella excisa* Kützing.			+	+	+			
CLAN	*Cymbella lanceolata* (Ehrenberg) Kirchner.	+	+	+					
CLBE	*Cymbella lange-bertalotii* Krammer		+	+			+		
CNCI	*Cymbella neocistula* Krammer	+	+						
CTUM	*Cymbella tumida* (Brébisson) Van Heurck	+	+	+	+	+	+		
DELO	*Diatoma elongatum* (Lyngb.)							+	
DHQU	*Diatoma hyemalis* (Roth) Heiberg.	+				+			+
DMES	*Diatoma mesodon* (Ehrenberg) Kützing.	+							
DMOF	*Diatoma moniliformis* Kützing.								+
DVUL	*Diatoma vulgaris* Bory.		+	+	+	+	+	+	+
DKRA	*Diploneis krammeri* Lange-Bertalot.	+			+			+	
ENMI	*Encyonema minutum* (Hilse) D. G. Mann.	+		+	+	+			+
EPRO	*Encyonema prostratum* (Berkeley) Kützing.	+	+	+					
ESLE	*Encyonema silesiacum* (Bleisch) D. G. Mann			+		+			+
EOMI	*Eolimna minima* (Hustedt)Lange-Bertalot	+			+		+	+	+
EGLA	*Eunotia glacialis* Meister.					+		+	+
EGRA	*Eunotia gracilis*(Eer.) Rabh.	+							
ELCA	*Eunotia lunaris* (Ehr) Grun.	+							
FHEL	*Fallacia helensis* (Schulz) D. G. Mann.							+	
FPYG	*Fallacia pygmaea* (Kützing) Stickle & Mann		+						
FBIC	*Fragilaria bicapitata* Mayer.	+						+	
FCCP	*Fragilaria capucina var. capitellata* (Kützing) Lange-Bertalot.	+							
VCVA	*Fragilaria capucina var. vaucheriae* (Kützing) Lange-Bertalot.						+	+	
FSAX	*Frustulia saxonica* Rabenhorst				+		+	+	
FVUL	*Frustulia vulgaris* (Thwaites) De Toni.	+					+		
KEDC	*Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin	+			+		+		
GAUG	*Gomphonema augur* Ehrenberg		+						
GCAP	*Gomphonema capitatum* Ehrenberg.	+							+
GCLA	*Gomphonema clavatum* Ehrenberg.	+	+	+			+	+	+
GEXL	*Gomphonema exilissimum* (Grunow) Lange-Bertalot & Reichardt.			+	+				
GGRA	*Gomphonema gracile* Ehrenberg	+				+			

Table 2. cont.

CODE	Taxa	S1	S2	S3	S4	S5	S6	S7	S8
GINT	*Gomphonema intricatum* Kützing						+		
GITA	*Gomphonema italicum* Kützing					+			
GMIC	*Gomphonema micropus* Kützing.	+			+	+	+	+	
GMIN	*Gomphonema minutum* (C. Agardh) C. Agardh.		+	+		+		+	
GOLI	*Gomphonema olivaceum* (Hornemann) Brébisson.		+	+		+	+		
GPAR	*Gomphonema parvulum* (Kützing) Kützing,				+				
GPUM	*Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot	+		+					
GROS	*Gomphonema rosenstockianum* Lange-Bertalot &Reichardt	+	+		+				
GSCL	*Gomphonema subclavatum* (Grunow) Grunow.	+	+	+		+	+	+	
GRSI	*Grunowia sinuata* Thwaites		+						
HARC	*Hannaea arcus* (Ehrenberg) Patrick	+	+						
HAHS	*Hantzschia amphioxys* (Ehrenberg) Grunow.				+				
HHUN	*Hippodonta hungarica* (Grunow) Lange-Bertalot Meltzeltin & Witkowski			+					
LGOE	*Luticola goeppertiana* (Bleish) D. G. Mann	+		+	+		+		
MVAR	*Melosira varians* Agardh.	+	+		+				
MCIR	*Meridion circulare* (Greville) C. A. Agardh	+	+				+		
NANT	*Navicula antonii* Lange-Bertalot.		+	+	+		+		
NCPR	*Navicula capitatoradiata* Germain.	+	+					+	
NAOT	*Navicula cf. antonii* Lange-Bertalot.							+	
NCBA	*Navicula confervacea* Kützing.							+	
NCTE	*Navicula cryptotenella* Lange-Bertalot.		+	+	+	+	+		+
NCUS	*Navicula cuspidata* Kützing							+	
NERI	*Navicula erifuga* Lange-Bertalot.		+	+			+		+
NGRE	*Navicula gregaria* Donkin		+		+			+	+
NHAL	*Navicula halophila* (Grun.)							+	
NHLV	*Navicula helvatica* Brun.				+			+	
NHIN	*Navicula hintzii* Lange-Bertalot.	+	+		+	+	+	+	+
NLAN	*Navicula lanceolata* (Agardh) Ehrenberg	+	+	+	+		+		
NOBL	*Navicula oblonga* Kützing.								+
NOLI	*Navicula oligotraphenta* Lange-Bertalot & Hofmann		+						
NPEP	*Navicula perpusilla* Grun.							+	
NPLT	*Navicula placenta* Ehr.						+		
NRAD	*Navicula radiosa* Kützing	+	+		+		+	+	+
NRCH	*Navicula reichardtiana* Lange-Bertalot							+	
NRHY	*Navicula rhynchocephala* Kützing	+	+					+	
NROS	*Navicula rostellata* Kützing				+		+		+
NSPD	*Navicula splendicula* Van Landingham			+				+	+
NSRH	*Navicula subrhynchocephala* Hustedt								+
NTPT	*Navicula tripunctata* Bory		+		+		+		
NVEN	*Navicula veneta* Kützing	+							
NVIR	*Navicula viridula* (Kützing) Ehrenberg	+	+	+	+	+	+	+	+
NACI	*Nitzschia acicularis* (Kützing) W. Smith				+	+			
NDIS	*Nitzschia dissipata* (Kützing) Grunow			+	+	+	+	+	+
NFON	*Nitzschia fonticola* Grunow					+			
NIFR	*Nitzschia frustulum* (Kützing) Grunow	+	+	+				+	+
NGDF	*Nitzschia gracilis* Hantzsch			+	+				
NLIN	*Nitzschia linearis* (Agardh) W. Smith		+			+		+	
NOBT	*Nitzschia obtusa* W. Sm.							+	+
NPLA	*Nitzschia palea* (Kützing) W. Smith	+		+	+				+
NREC	*Nitzschia recta* Hantzsch				+		+		
NSIG	*Nitzschia sigma* (Kützing) W. Smith		+	+					+
NSIO	*Nitzschia sigmoidea* (Nitzsch) W. Smith	+	+	+					+

Table 2. cont.

CODE	Taxa	S1	S2	S3	S4	S5	S6	S7	S8
NSOC	*Nitzschia sociabilis* Hustedt		+	+	+	+	+	+	
NZSB	*Nitzschia spectabilis* (Ehr) Ralfs.	+		+					
NVAG	*Nitzschia umbonata* (Ehrenberg) Lange-Bertalot							+	
NVAG	*Nitzschia vermicularis* (Kützing) Grunow	+					+		
PBOR	*Pinnularia borealis* Ehrenberg			+					
PMBR	*Pinnularia microstauron* (Kützing) Rabenhorst								+
PNEX	*Placoneis neoexigua* Lange-Bertalot & Miho							+	
PTLA	*Planothidium lanceolatum* (Brébisson) Lange-Bertalot	+					+		
RUNI	*Reimeria uniseriata Sala*, Guerrero & Ferrario.								+
RABB	*Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot	+	+		+	+	+	+	+
RGIB	*Rhopalodia gibba* (Ehrenberg) O. Müller	+	+						
SPUB	*Sellaphora pupula* (Kützing) Mereschowsky.	+							
SREC	*Sellaphora rectangularis* (Gregory) Lange-Bertalot & Metzeltin						+		
SPIN	*Staurosirella pinnata* (Ehrenberg) D. M. Williams & F. E. Round	+	+						
SBBI	*Surirella biseriata* Brébisson							+	
SBRE	*Surirella brebissonii* Krammer & Lange-Bertalot			+		+			
SBKU	*Surirella brebissonii var. kuetzingii* Krammer & Lange-Bertalot				+		+		+
SUCA	*Surirella capronii* Breb.					+			
SHEL	*Surirella helvetica* Brun.				+				
SLBK	*Surirella linearis* W. Sm.								+
SUMI	*Surirella minuta* Brébisson		+						
SOVI	*Surirella ovalis* Brébisson				+				
SOVA	*Surirella ovata*Kutz					+			
SOSA	*Surirella ovata var. salina* (W. Sm) Hust.								+
SURO	*Surirella robusta* Ehr.					+			+
SULN	*Synedra ulna* (Nitszch) Ehr.		+				+	+	
TBIN	*Tabellaria binalis* (Ehr.) Grun.	+							
TBLO	*Tabellaria flocculosa* (Roth) Kützing.	+							
TBSP	*Tabularia* spec						+		
TWEI	Thalassiosira weissflogii (Grunow) Fryxell & Hasle								+
TAPI	*Tryblionella apiculata* Gregory		+	+	+			+	
TCAL	*Tryblionella calida* (Grunow) D. G. Mann.	+							+
UACU	*Ulnaria acus* (Kützing) Aboal	+	+	+					
UBIC	*Ulnaria biceps* (Kützing) Compère	+		+		+			
UULN	*Ulnaria ulna* (Kützing) Compère.	+					+		

(Kützing) Grunow (4.69%), *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot (3.21%), *Diatoma vulgaris* Bory. (3.13%), *Cocconeis placentula* var. *lineata* (Ehrenberg) Cleve (2.62%), *Navicula viridula* (Kützing) Ehrenberg (2.46%), *Navicula hintzii* Lange-Bertalot (2.36%), *Nitzschia frustulum* (Kützing) Grunow (2.07%), *Navicula erifuga* Lange-Bertalot (2.04%), *Hannaea arcus* (Ehrenberg) Patrick (1.88%), *Navicula cryptotenella* Lange-Bertalot (1.85%), *Gomphonema clavatum* Ehrenberg (1.78%), *Navicula gregaria* Donkin (1.75%) dhe *Navicula capitatoradiata* Germain (1.75%) etc. The largest distribution species during the course of the Lepenci River Basin were *Navicula viridula* (Kützing) Ehrenberg, *Navicula hintzii* Lange-Bertalot, *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot, *Diatoma vulgaris* Bory, *Cocconeis placentula var. lineata* (Ehrenberg) Cleve.

In order to determine the ecological as well as trophic status of waters, thirteen indices were employed for Diatom survey, as shown in Table 3.

In SP1-Prevallë station, based on the indices calculated using the OMNIDIA software, it can be considered that the water quality is good and belongs to the second class while its trophic status is Oligo-Mesotroph. The analyzed indices were: IBD, IPS, IDG, SLA, IDSE, EPID, CEE, WAT, TDI and SHE, the same were used in all eight sampling plot analyses. Interestingly, based on

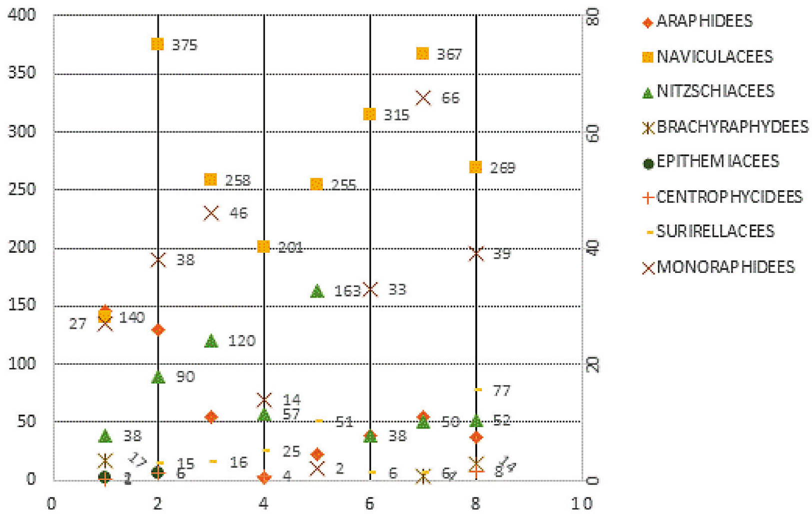

Figure 2. Distribution of taxa group based on the number of individuals

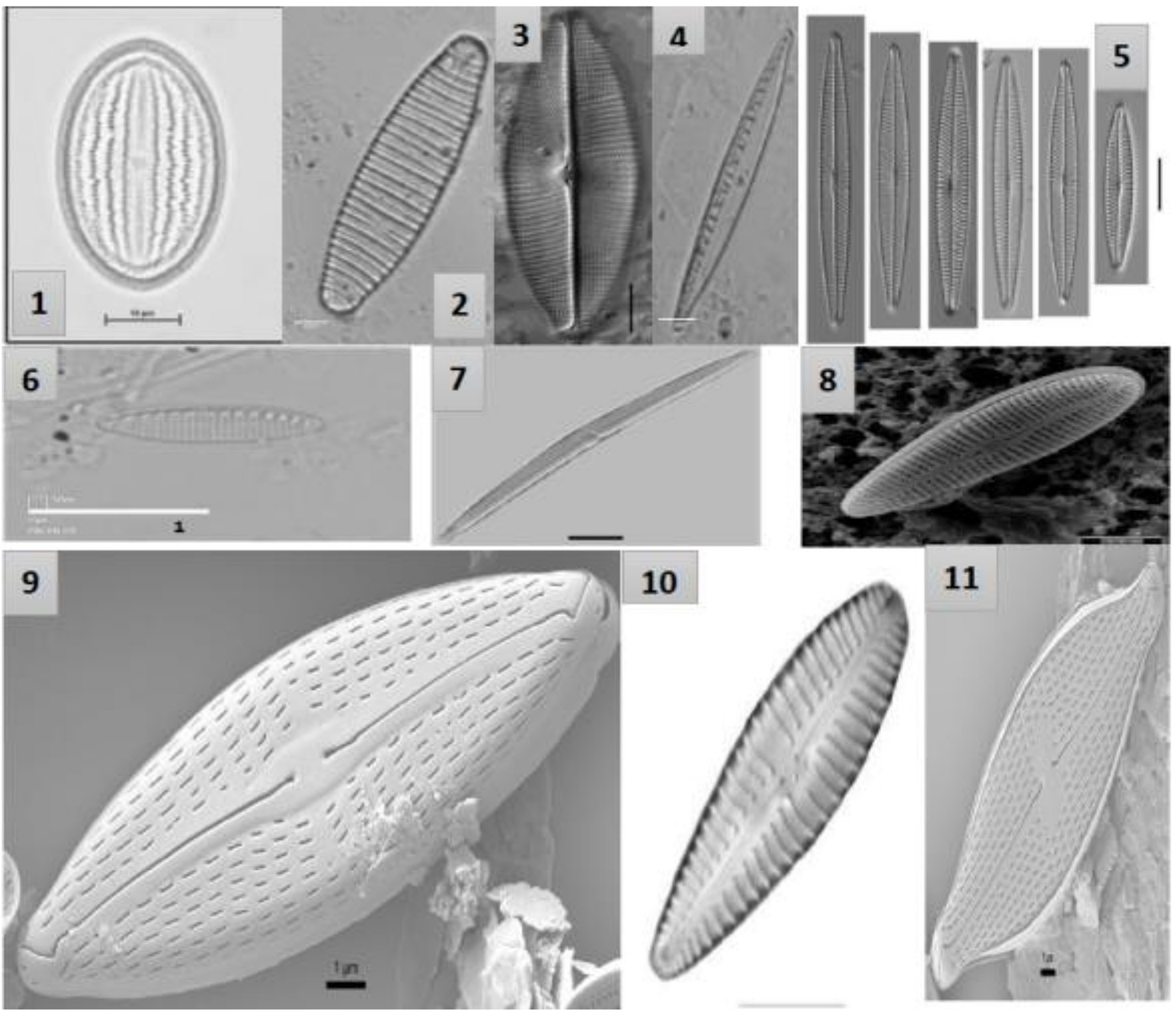

Figure 3. 1. *Cocconeis placentula var. lineata* (Ehrenberg) Cleve, 2. *Diatoma vulgaris* Bory, 3. *Navicula viridula* (Kützing) Ehrenberg, 4. *Nitzschia dissipata* (Kützing) Grunow, 5. *Navicula lanceolata* (Agardh) Ehrenberg, 6. *Nitzschia frustulum* (Kützing) Grunow, 7. *Hannaea arcus* (Ehrenberg) Patrick, 8. *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot, 9. *Navicula cryptotenella* Lange-Bertalot, 10. *Gomphonema clavatum* Ehrenberg, 11. *Navicula gregaria* Donkin

Table 3. Classes limit values for diatom indices

Water quality class	Ecological status	IPS, CEE, IBD, IDG, DESCY, SLA, IDSE, IDAP, EPID, WAT, TDI, IDP, SHE	Trophic status
I	High	17–20	Oligotrophic
II	Good	13–16	Oligo-mesotrophic
III	Moderate	9–12	Mesotrophic
IV	Poor	5–8	Eutrophic
V	Bad	1–4	Hypertrophic

the Descy index, the water quality is high which means that the water quality belongs to the first class (I) and trophic level is Oligotrophic. On the other hand, according to the IDAP & IDP indices, the water quality is moderate, and belongs to the third class (III) with Mesotrophic level.

In SP2-Jezerc station, according to the values of the IBD, Descy, IDSE, CEE and WAT indices, the quality of water is good and belongs to the second class (II), and the trophic status is Oligo-Mesotroph. Additionally, according to the IPS, IDG, SLA, ISAP, EPID, TDI, IDP and SHE indices, the water quality is moderate, and belongs to the third class (III) and trophic level is mesotrophic.

According to the values of the IBD, IDG, IDSE, IDAP, CEE, WAT, SHE indices, the quality of water is good and belongs to the second class (II), whereas the trophic status is Oligo-mesotrophic. In turn, based on the Descy index, the water quality is high which means that the water quality belongs to the first class (I) and trophic level is Oligotroph. According to the IPS, SLA, EPID, IDP indices, the water quality is moderate, and belongs to the third class (III) whereas the trophic level is mesotrophic. On the basis of the TDI index, the water is of poor quality, belongs to the fourth class (IV) and trophic level is Meso-eutrophic.

The obtained values for the diatom indices on the fourth monitoring station – SP4-Runjevë (Table 4) – indicate good water status and, which belongs to the second class (II) and the oligo-Mesotroph level. In turn, IPS, IDG, SLA, IDSE, IDAP, EPID, CEE, WAT, IDP and SHE indicate moderate status and the third class (III) as well as mesotrophic level. On the basis of the TDI index, the water is of poor quality, i.e. to the fourth classes (IV) and the trophic level is Meso-eutrophic.

For the fifth monitoring station, Nikë (Table 4), most of the diatom indices show moderate water status (IPS, IDG, SLA, IDSE, EPID, CEE, IDP) and its quality belongs to the third class (III) as well as Mesotrophic level. IBD, DESCY, IDAP, WAT and SHE indicate good status and second class (II) quality, with the trophic status being Oligo-mesotrophic while TID (poor status) belongs to the fourth class (IV), and Meso-eutrophic level.

Most of the scores for the diatom indices for the sixth monitoring station – Gërlicë – belong

Table 4. The values of diatom indices IBD, IPS, IDG, Descy, Sla, IDSE, IDAP, EPID, CEE, WAT, TDI, IDP, SHE, calculated for individual sites in the Lepenci River basin stream

Indices \ Sites	S1	S2	S3	S4	S5	S6	S7	S8
IBD	16.7	13.9	13.3	13.3	13.9	13.5	12.5	11.9
IPS	14.8	12.5	12.2	12.7	11.9	13.1	11.4	10.8
IDG	13.8	12.6	13.3	11.7	12.3	12.1	11.9	12.1
Descy	17.1	16.9	17.2	15.2	15.9	16.4	16.6	16
Sla	14.5	12	12.2	11.1	11.9	11.9	11.6	11.8
IDSE	14.5	13.1	13.3	12.1	12.6	13.9	12.9	13
IDAP	10.4	10.7	13.1	12.8	13	12.8	11.8	12.7
EPID	14.4	11.3	11.4	9.9	10.7	10.6	10.9	10.1
CEE	15.2	14.3	14.8	11.2	12.5	13.3	13.2	11.8
WAT	13.7	13.7	14.7	12.2	13.6	11	12.2	12.3
TDI	14.4	9.3	5.9	5.3	5.5	7.9	7.2	9.4
IDP	12	11.4	12.2	9.5	11.8	12.2	11.8	11.8
SHE	13	12.1	14.1	12.1	14	13.1	13.1	12.8

to the good or the lower limit of moderate status (table 4). The values obtained for IBD, IPS, DESCY, IDSE and SHE show that the quality of water is good and it belongs to the second class (II), with the Oligo-mesotroph status, while for IDG, SLA, IDAP, EPID, CEE, WAT, ISD show moderate status and the third class (III) as well as mesotrophic level; in turn, TID shows poor status and belongs to the four classes (IV) while the trophic level is Meso-eutrophic.

Most of the scores for the diatom indices for the seventh monitoring station – Kaçanik – belong to moderate status (Table 4). The values obtained for IBD, IPS, IDG, SLA, IDSE, IDAP, EPID, WAT, IDP are moderate and belong to the third class (III), the trophic level is mesotrophic; TID shows poor status and belongs to the fourth class (IV). The trophic level is Meso-eutrophic. In turn, DESCY,SHE have good status and belong to the second class (II), and the trophic status is Oligo-mesotrophic.

For the eighth monitoring station Hani i Elezit, most of the diatom indices show moderate status (IBD, IPS, IDG, SLA, IDAP, EPID, CEE, WAT, TDI, IDP, SHE) and belong to the third class (III) as well as Mesotrophic level (Table 4). On the other hand, DESCY and IDAP indices show it to have good status and the water quality belongs to the second class (II), while the trophic status is Oligo-mesotrophic. This study is the first attempt to uncover the taxonomic composition and distribution of diatoms in the Lepenci River basin. Nearly 139 taxa, belonging to 43 genera, were recorded (Table 2). The composition of the diatoms assemblage changed from site to site and different monitoring stations. At the upper sites source area (S1-S3), in S1, the dominant species were *Hannaea arcus* (Ehrenberg) Patrick 8.6%, *Diodoma mesodon* (Ehrenberg) Kützing 8.4%, *Ulnaria ulna* (Kützing) Compere 5.9%, *Ulnaria biceps* (Kützing) Compère 5.4%, *Diatoma hyemalis* (Roth.) Heiberg 4.9%. In S2, the dominant species included *Diatoma vulgaris* Bory 6.8%, *Nitzschia frustulum* (Kützing) Grunow 6.2%, *Hannaea arcus* (Ehrenberg) Patrick 5.9%, *Cymbella tumida* (Brébisson) Van Heurck 5.3% dhe *Navicula gregaria* Donkin 4.8%, and at S3 the monitoring station, the dominant species were *Nitzschia dissipata* (Kützing) Grunow 11.1%, *Cymbella tumida* (Brébisson) Van Heurck 8.7%, *Diatoma vulgaris*

Table 5. Calculation of statistical results with ECO pack by number of species

Symbol \ Sites	Prevallë	Jezerc	Brod	Runjevë	Nikë	Gërlicë	Kaçanik	Hani i Elezit
S	57	48	42	41	32	42	51	38
N	373	660	495	306	474	430	529	507
S_E	0	0	1	0	1	0	0	0
S_D	4	4	2	5	3	1	3	5
S_Sd	12	15	18	13	16	21	15	15
S_R	14	15	11	13	10	13	26	14
S_Sr	27	14	10	10	2	7	7	4
N_E	0	0	55	0	69	0	0	0
N_D	105	160	79	88	92	28	89	156
N_Sd	142	294	256	127	234	297	227	236
N_R	71	146	71	68	73	85	192	103
N_Sr	55	60	34	23	6	20	21	12
F_1	4	0	0	2	0	0	1	0
F_2	18	2	1	3	1	3	0	1
F_3	5	4	4	5	0	2	4	2
H’	5.219405	5.209322	4.951315	5.049589	4.641079	5.143133	5.406122	4.95428
E	0.894823	0.932741	0.918216	0.942518	0.928216	0.953789	0.953053	0.944045
E’	0.858996	0.92205	0.902788	0.924932	0.91706	0.943718	0.94319	0.934611
D	0.037109	0.033012	0.043159	0.03535	0.052573	0.032212	0.027762	0.037919
N2	26.94732	30.29207	23.17021	28.28882	19.021	31.04433	36.02021	26.37211
D_{Ma}	9.456938	7.239412	6.608045	6.988627	5.031481	6.761453	7.973225	5.940425
D_{Me}	2.951348	1.868397	1.88776	2.343814	1.469809	2.02542	2.217391	1.687639
S_{Chao1}	57.44444	48	42	41.66667	32	42	NA	38
Var(S_{Chao1})	0.652949	0	0	1.703704	0	0	NA	0

Bory 7.3%, *Navicula erifuga* Lange-Bertalot in Krammer & Lange-Bertalot 4.4%, *Cymbella excisa* Kützing 3.6%. Further downstream (S4 and S8), in S4, the dominant species were *Nitzschia dissipata* (Kützing) Grunow 6.9%, *Navicula tripunctata* (O. F. Müller) Bory 6.3%, *Navicula viridula* (Kützing) Ehrenberg 5.3%, *Navicula radiosa* Kützing 5.3%, *Gomphonema parvulum* (Kützing) Kützing 5.3%; in the S5 monitoring station, the dominant species were *Nitzschia dissipata* (Kützing) Grunow ssp. dissipata 14.6%, *Cymbella tumida* (Brebisson) Van Heurck 7.2%, *Craticula cuspidata* (Kützing) Mann 6.1%, *Surirella brebissonii* Krammer & Lange-Bertalot 6.1%, *Gomphonema micropus* Kützing 4.4%, in S6, the dominant species were *Frustulia saxonica* Rabenhorst 6.5%, *Navicula placenta* Ehrenberg 4.9%, *Eolimna minima* (Grunow) Lange-Bertalot in Moser & al. 4.7%, *Craticula ambigua* (Ehrenberg) Mann 4.4%, *Navicula lanceolata* (Agardh) Ehrenberg 4.4%, in S7 the dominant species were *Navicula hintzii* Lange-Bertalot 5.7%, *Navicula capitatoradiata* Germain 5.7%, *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 4.9%, *Caloneis amphisbaena* (Bory) Cleve 3.6%, *Cocconeis placentula var. lineata* (Ehr.)Van Heurck f. anormale 3.5% and in the S8 monitoring station the dominant species were *Surirella brebissonii var. kuetzingii* Krammer et Lange-Bertalot 7.9%, *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 6.7%, *Surirella linearis* W. Smith var. baikalensis Skvortzow 6.5%, *Navicula rostellata* Kützing 5.2%, *Craticula ambigua* (Ehrenberg) Mann 5.2%.

Referring to the data in Table 2 it was noticed that in the Lepenci River Basin, the largest number of Eudominant (SE) taxa was observed in the S3_Brod and S5_Nikë stations. The largest number of subdominant taxa (Ssd) in the Lepenci river basin was found in the S5 and S7 stations, while the lowest value – at the S6 station. The largest number of resident species (R) belongs to the S7_Nikë station 27, while the lowest number of resident species is at station S5_Nikë 10

The largest number of taxa with Sub-Resident (Ssr) frequency was found in the S1_Prevallë station with 27 taxa (families), and the lowest number in the S5_Nikë station with 2 taxa. The highest eudominant species (NE) abundance was observed at S5_Nikë 69 and S3_Brod 55. The largest dominant abundance (ND) was presented at S2_Jezerc (160) station while the lowest value was at S6_Gërlicë station (28). The abundance of resident species (NR) was the highest at the S7_Kaçanik station – 192, while the lowest was in the S4_Runjevë station – 68. The abundance of the sub-resident species (Nsr) as the highest at the S2_Jezerc station (60) while the lowest was at S5_Nikë station (6). The largest number of Sigletons (F1) and Doubletons (F2) was at the S1_Prevallë station. The largest number of Tripluses (F3) is displayed at the S1_Prevallë and S4_Runjevë stations.

Species richness estimator (Schao1) had the highest value at the S1_Prevallë station. Diversity index (Shannon-Wienner) and evenness index of epipelic diatom in river basin Lepenci are relatively high. Diversity index ranged from 4.64 up to 5.40, while the evenness index values – from 0.85 to 0.95, Margalef index 5.03 up to 9.45 and Menhinick index from 1.46 to 2.95 (Table 5). High diversity index reflects the stable ecosystem of Lepenci river basin downstream based on epipelic diatom community. Evenness index of epipelic diatom in Lepenci river basin downstream indicates the quite even of species distribution on these downstream rivers [Odum, 1993].

Table 6 shows that the greatest similarities in the composition of diatomic types were exhibited at between S2_Jezerc station with S3-Brod station, and S4_Runjevë and S6_Gërlicë station where Jacardi index is 0.36 or 36%, which implies that these localities have 36% of common types. The greatest differences were shown

Table. 6. Similarity in diatoms species composition between sampling sites (Jaccard ’s index)

Sites	Jezerc	Brod	Runjevë	Nikë	Gërlicë	Kaçanik	Hani i Elezit
Prevallë	0.3125	0.253165	0.240506	0.171053	0.222222	0.173913	0.202532
Jezerc		0.363636	0.253521	0.19403	0.304348	0.253165	0.194444
Brod			0.257576	0.254237	0.253731	0.1625	0.25
Runjevë				0.258621	0.360656	0.226667	0.253968
Nikë					0.193548	0.220588	0.22807
Gërlicë						0.256757	0.212121
Kaqanik							0.219178

Table. 7. Diatom Sorensen similarity index in river Lepenci basin

Sites	Jezerc	Brod	Runjevë	Nikë	Gërlicë	Kaçanik	Hani i Elezit
Prevallë	0.47619	0.40404	0.387755	0.292135	0.363636	0.296296	0.336842
Jezerc		0.533333	0.404494	0.325	0.466667	0.40404	0.325581
Brod			0.409639	0.405405	0.404762	0.27957	0.4
Runjevë				0.410959	0.53012	0.369565	0.405063
Nikë					0.324324	0.361446	0.371429
Gërlicë						0.408602	0.35
Kaqanik							0.359551

Table. 8. Pearson correlation coefficients between measured water quality variables and diatom indices

Indices / Symbol	H’	E	E_A	D	N2	D_{Ma}	D_{Me}	IBD	IPS	TDI
T, °C	-.412	.417	.492	.304	-.208	-.638	-.621	-.684	-.824*	-.654
pH	-.651	-.329	-.192	.742*	-.703	-.500	-.559	-.160	-.485	-.336
EC	.149	.843**	.759*	-.406	.450	-.227	-.083	-.636	-.372	-.328
TDS	.148	.843**	.760*	-.405	.449	-.228	-.085	-.637	-.374	-.329
O_2	-.312	-.602	-.478	.512	-.515	-.085	-.228	.154	-.156	-.072
COD	.324	.830*	.723*	-.586	.607	-.058	.048	-.486	-.188	-.090
BOD	.229	.809*	.721*	-.488	.515	-.145	-.048	-.433	-.150	-.157
NO_3^-	-.403	.241	.267	.241	-.268	-.481	-.392	-.668	-.702	-.170
NH_4^+	.023	.768*	.674	-.305	.326	-.264	-.066	-.458	-.198	-.178
PO_4^{3-}	.429	.777*	.660	-.629	.673	.069	.165	-.444	-.146	-.127
SO_4^{2-}	.273	.835**	.737*	-.532	.557	-.113	-.003	-.547	-.246	-.185

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

between S3_Brod station and S7_Kaçanik station where Jakard’s index is 0.17 or 17%.

This index is expressed in %, where the highest percentage also shows the highest similarity in the composition of two samples. Table 7 shows that the greatest similarity was obtained between the S2_Jezerc and S3_Brod stations, which have 53% of the types of common diatoms. The S3_Brod and S7_Kaçanik stations showed a similarity value of less than 27%.

Table 8 shows the correlations between the physical-chemical parameters and indices. The authors found that E index is significantly and strongly correlated with EC, TDS COD and BOD, NH_4^+, PO_4^{3-}, SO_4^{2-} parameters ($p<0.05$ and $p<0.01$). The E_A index is significantly and strongly correlated EC, TDS, COD and BOD, SO_4^{2-} ($p<0.05$). The D Index is significantly correlated only with pH and TDI is significantly correlated only with T°C. According to other indices, such as H, N2, D_{Ma}, D_{Me}, IBD and IPS, the level of correlation is high but not significant. All the samples are correlated with each other with strong and moderate correlations except D_{Ma} and D_{Me} indices, where weak correlations with physical-chemical parameters can be found.

The correlations ranged from 0.721–0.843 ($p<0.05$ and $p<0.01$), the weakest correlation was between D_{Me} and SO_4.

CONCLUSIONS

From eight monitoring stations in the Basin of Lepenci River, a diverse composition of 139 diatom species was obtained. It was observed that the upper part of the river stream was richer in species number. The monitoring stations located in the lower and middle part of the river stream were characterized with relatively smaller number of diatoms species present. On the basis of different indices (BD, IPS, IDG, Descy, Sla, IDSE, IDAP, EPID, CEE, WAT, TDI, IDP and SHE) that were taken into account, the best water quality was observed in monitoring stations of Prevallë (SP-1) and Jezerc (SP-2), where the water quality belongs to the first class. In other monitoring stations (SP-3 to SP-8) the water quality varied from the second (II) to the fourth (IV) class.

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