CORRELATION BETWEEN WATER QUALITY AND THE DIVERSITY INDEX OF THE BOSNA RIVER IN THE ZENICA REGION (BOSNIA AND HERZEGOVINA)

Sanela BEGANOVIĆ *, *Avdul ADROVIĆ* ** (c.a.),
Halim PRCANOVIĆ *** and *Mirnes DURAKOVIĆ* ****

*, ***, **** Institute "Kemal Kapetanović", Univerzitety of Zenica, Zenica, Travnička Street 10, Bosnia and Herzegovina, BA-72000, beganovic.sanela@yahoo.com, ORCID: 0000-0002-1236-5096, halim.prcanovic@ikk.unze.ba, ORCID:0000-0001-5822-5948, mirnes.durakovic@ikk.unze.ba, ORCID:0009-0002-8550-7857.
** University of Tuzla, Faculty of Natural Sciences and Mathematics, Urfeta Vejzagića Street 4, Tuzla, Bosnia and Herzegovina, BA-75000, avdul.adrovic@untz.ba, ORCID: 0000-0002-6429-4509.

DOI: 10.2478/trser-2023-0016

KEYWORDS: water quality, Spearman corelation coefficient, index of diversity, Bosnia and Herzegovina, Riwer Bosna.

ABSTRACT

Using the Shannon-Weaver index (H'), the link between the physical and chemical components of the biological component in the Bosnia River was examined. The results showed that pH and H' had a strong link (rs = 0.59), while total nitrogen and H' had a poor relationship (rs = 0.44), and COD-Cr had a weak relationship (rs = 0.34). KPK-Cr (I water class) had the lowest parameter concentrations, whereas electrical conductivity (IV-V water class) showed the highest. The values of the biological elements range from a poor 0.267 to a high state of 2.26.

ZUSAMMENFASSUNG: Korrelation zwishen waserquälitetselmenten und diversitäsindex des flusses Bosna in der gegend Zenica (Bosnien und Herzegowina).

Die Beziehung zwischen den physik-chemischen Elementen der biologischen Komponente im Bosnien-Fluss wurde mithilfe des Shannon-Weaver-Index (H') analysiert. Es wurde eine starke Beziehung zwischen pH-Wert und H' (rs = 0,59) und eine schwache Beziehung zwischen Gesamtstickstoff und H' (rs = 0,44) und CSB-Cr mit H' (rs = 0,34) gefunden. Die höchsten Parameterkonzentrationen wurden für die elektrische Leitfähigkeit (IV-V-Wasserklasse) und die niedrigsten für KPK-Cr (I-Wasserklasse) beobachtet. Die Werte der biologischen Elemente reichen von einem schlechten 0,267 bis zu einem hohen Zustand von 2,26.

REZUMAT: Corelația dintre calitatea apei și Indicele de Diversitate al râului Bosna din regiunea Zenica (Bosnia și Herțegovina).

Folosind indicele Shannon-Weaver (H'), a fost examinată legătura dintre componentele fizice și chimice ale componentei biologice din din râul Bosna. Rezultatele au arătat că pH-ul și H' au avut o legătură puternică (rs = 0,59), în timp ce azotul total și H' au avut o relație slabă (rs = 0,44), iar COD-Cr a avut o relație slabă (rs = 0,34). KPK-Cr (clasa I de apă) a avut cele mai scăzute concentrații de parametri, în timp ce conectivitatea electrică (clasa de apă IV-V) a arătat cea mai mare. Valorile elementelor biologice variază de la o stare slabă de 0,267 la o stare ridicată de 2,26.

INTRODUCTION

Many stresses substantially impact freshwater, which is why ongoing technique development, evaluations, and monitoring are crucial (Bănăduc et al., 2022). The largest watercourse in the Zenica area, in Bosnia and Herzegovina, is the Bosna River, which flows from Drivuša through the city. The Bosna River flows through the fields of Sarajevo, Visoko, Kakanj, and Zenica on its upper course. The Bosna River flows through the Zenica region and is around 32 kilometers long. The Kočeva, Babina, and Gračanička rivers are in addition to the Bosna River; the latter only reaches the area under investigation at its confluence. Zenica is categorized as a heavy industrial city that has unreasonably contaminated and deteriorated the environment. The construction of industry and the city in the conditions of a closed basin, with little space for both, creates anthropogenic climate factors that, in their extremity, modify the climate. The northern region of the Zenica basin is home to all industries, with the Arcelor Mittal Zenica company taking up the most space in the industrial zone.

Due to its population density and development, the Bosna River is most exposed to anthropogenic influences, significantly compromising water quality. This condition results from both industrial activities and the influence of the local population. Extensive industrial production processes, such as those in steel mills, must be viewed as sources of complete interaction with the environment. Environmental incidents are becoming more and more noticeable in the Bosna River in the Zenica region. These occurrences show themselves as mass mortality of fish populations, changes in water color noticed by visual inspection, and disagreeable scents. This is the outcome of adding non-native materials to the watercourse, upsetting the natural equilibrium.

Certain freshwater organisms larger than 0.5 mm are known as macroinvertebrate benthos and live on the bottom of aquatic environments. Due to their relatively long lifespan and limited mobility, changes in environmental conditions, alterations in physical water properties (water flow rate, temperature, and light), chemical water properties (nutrient levels, oxygen, and carbon dioxide), as well as seasonal and daily changes in water flow regimes, result in modifications to the qualitative and quantitative structure of the macroinvertebrate community. Under the influence of organic pollution, there is a reduction in species diversity, accompanied by an increase in the number of individuals within the same species. In contrast, clean waters support a greater variety of species but with lower individual abundance (Rosenberg et al., 1993). Consequently, it is possible to evaluate the decline of aquatic ecosystems from one or more causes using the taxonomic makeup of macroinvertebrates.

According to WFD 2000/60/EC, the quality of surface water is determined based on the assessment of its “ecological status”, which encompasses the study of physicochemical elements (thermal conditions, oxygen regime, acidification, nutrients, and specific pollutants), hydro-morphological elements (flow, hydrological regime, river continuity, and morphological conditions) that accompany biological elements (composition and richness of benthic macroinvertebrate fauna). The outcomes form the foundation of future management plans that involve taking all required steps to attain good status

In the rivers Una, Vrbas, Bosna, Drina, and Neretva with Trebišnjica, the research led by Blagojević (1984) showed that the correlations between saprobic parameters and water oxygen content, oxygen saturation, and BOD_5 vary with watercourses biogeographical, regional-hydrographic, and seasonal conditions. Physicochemical parameters, commonly determined in routine monitoring, can be compared with various ecological parameters derived from biomass, diversity, and saprobic index. Furthermore, studies on the relationships between saprobic conditions and chemical factors relevant to the Miljacka River’s oxygen regime have shown no agreement among individual results of measured parameters.

MATERIAL AND METHODS

Twenty samples were collected at five sites along the Bosna River during seasonal aspects, except for total nitrogen, for which 15 samples were taken. The parameters used for assessing water status through intercorrelations are presented in table 1.

Table 1: The applied elements for the analysis of intercorrelations

Hidromorfological elements	River flow Q (m^3/s)
Physico-chemical elements	
Thermal conditions	Water temperature (°C)
Acidification	pH
Oxygen regime	BPK_5 (mg/O_2l) KPK-Cr (mg/O_2l)
–	Electrical conductivity Total suspended solids
Nutrients	Ammonium ion (μg/l) Total nitrogen (μg/l) Total phosphorus (μg/l)
Biological elements	Shannon-Weaver index of diversity (H')

Table 2 shows the chemical techniques used to test the specified parameters. Air temperature was measured in the field using a glass thermometer, while water temperature was measured using a multifunctional environmental meter – PCE-222 type device.

Water quality assessment is determined by comparing physicochemical parameters with the limit values of substances in current legal regulations. The pH, BOD_5, COD-Cr, and total suspended solids are compared with the maximum permitted concentrations of specific hazardous and harmful substances in surface waters by the Regulation (Official Gazette of the Socialist Republic of Bosnia and Herzegovina, 19/80).

Table 2: Chemical methods for testing water parameters.

Order nr.	Parameter	Measurement unit	Standard-Technique
1.	pH	–	JUS H.Z1.111 – Potenciometric
2.	BPK_5	mg O_2/l	JUS H.Z1.136 – Titrimetric
3.	KPK-Cr	mg O_2/l	JUS H.Z1.165 – Titrimetric
4.	Electrical conductivity	μS/cm	JUS H.Z1.112 – Conductometric
5.	Total suspended solids	mg/l	JUS H.Z1.160 – Gravimetric
6.	Total phosphorus	μg/l	ICP* – Spectrophotometric
7.	NH_4-amonium ion	μg/l	MERCK ** – UV VIS – Spectrophotometric
8.	Total nitrogen	μg/l	MERCK ** – Kjeldahl method

* PERKIN ELMER Analytical Methods for OES-ICP.

** The testing of Water.

Ammonium ion and total phosphorus are compared with the provisions of the Regulation (Official Gazette of the Federation of Bosnia and Herzegovina, 43/07). In contrast, electrical conductivity and total nitrogen are classified according to the Regulation (Official Gazette of the Republic of Srpska, 3/97, 3/98, and 29/00). These comparisons will determine whether there is an environmental burden associated with individual parameters and possible causes of elevated concentrations. The biological elements (Shannon-Weaver index – H') for Type 3 are compared according to the Decision (Official Gazette of the Federation of Bosnia and Herzegovina, 1/14).

The research of the relationship between water quality elements was conducted using statistical tools in the Excel program. The association of variations in the values of two or more variables is called correlation. By applying the correlation coefficient, we aim to determine whether measured physico-chemical parameters can serve as a basis for biological indicators or vice versa.

A complete correlation or functional relationship exists when there is a one-to-one correspondence between every value in variables x and y. When there is a partial correlation, several values of variable y correlate to a given value of variable x. The lower the correlation, the greater the variability of values of variable y that appear with a specific value of variable x.

The relationship between two continuous variables is depicted graphically through a scatter plot of pairs of values of the two continuous variables. Each point on the scatter plot represents a pair of data from one statistical unit. The scatter plot suggests the shape of the relationship between the two variables (Figs. 3-8). A linear relationship between two variables exists if the straight line drawn through the center of the points on the scatter plot best fits the given observations. The correlation coefficient measures the closeness of points to the straight line.

The Spearman rank correlation coefficient, a nonparametric equivalent to the Pearson correlation coefficient, is calculated when one or more of the following conditions is true:

At least one of the variables, x or y, is measured on an ordinal scale;

Neither x nor y follows a normal distribution;

The sample size is small.

We need a measure of association between two variables when this association is not linear.

To estimate the population value of the Spearman coefficient, we use its value calculated on the sample, denoted as rs: we arrange the values of x in ascending order starting from the smallest value and assign successive ranks (numbers 1, 2, 3, ..., n) to them, with identical values receiving the average rank of the values they would take if they were not identical. We assign ranks to the values of variable y in the same manner. rs is the Pearson coefficient between the ranks of x and y.

$$r_s = 1 - \frac{6\sum d_i^{\,2}}{n(n^2-1)}$$

as it is: d_i – difference of ranges, n – number of samples.

Characteristics of the Spearman correlation coefficient: it shares the same features as the Pearson correlation coefficient, denoted as rs, providing a measure of association, not necessarily linear, between variables x and y. rs^2 is not calculated since it does not represent the proportion of total variation in one variable that could be attributed to its linear relationship with others.

Table 3 provides interpretations of linear correlation coefficients, based on which conclusions about the strength and nature of the relationship between the observed variables are drawn. The strength of the association (interpretation) is the same for negative values of the correlation coefficient.

Table 3: Criterion of the strength of the linear relationship between ranked variables expressed through the values of the Spearman correlation coefficient.

Correlation coefficient			Strength of the relationship between variables
1			Total
0.80 ≤	r	< 1	Strong
0.50 ≤	r	< 0.8	Medium strong
0.20 ≤	r	< 0.5	Weak
0.0 ≤	r	< 0.2	Slightly
0			Totally absent

The diversity of macroinvertebrate communities will be represented by the Shannon–Weaver diversity index (H) (Shannon et al., 1949), which utilizes the relative abundance of individual taxa:

$$H^{'} = -\sum P_i \log_2 P_i \ \text{ as it is } \ P_i = \frac{ni}{N};$$

as it is: H' – value of the diversity index, Pi – the relative representation of that taxon in the sample and $\log_2(x) = \log(x)/\log2$

This index starts at zero if only one species is present in the sample, and as the number of species increases, the index value also increases, reflecting an increase in evenness.

RESULTS AND DISCUSSION

Data on the Bosna River's water level and flow values at the Raspotočje gauge station were provided by the Agency for the Water Area of the Sava River Basin - Sarajevo database, covering the period from January 2014 to April 2015. During the investigated period, fluctuations in the water level of the Bosna River triggered by heavy rainfall and floods were observed. High water levels were recorded, reaching around 520 cm in May 2014 and approximately 320 cm in January 2015, causing widespread flooding (Figs. 1 and 2).

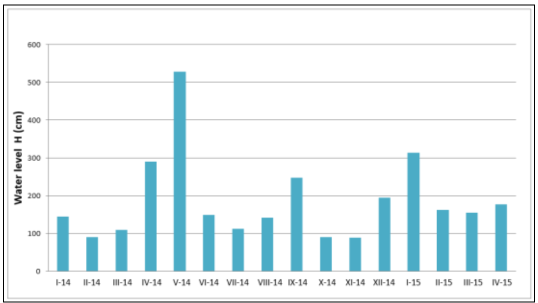

Figure 1: The maximum water levels of the Bosna River.

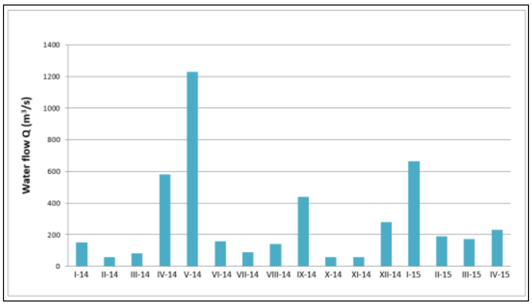

Figure 2: The maximum water flow of the Bosna River.

In the following tables 4, 5, 6, 7, and 8, the values of the studied elements for assessing the water category are presented for five sampling sites collected in annual periods.

Table 4: The values of hydromorphological, physico-chemical, and biological elements of the Drivuša site.

Parameters	08.10. 2014	15.01. 2015	06.05. 2015	23.06. 2015
The flow rates of the Bosna River Q (m^3/s)	27.25	39.10	27.89	15.22
Water temeperature (°C)	12.1	2.6	13.9	12.3
Air temperature (°C)	14.2	3	26.4	22.7
pH	7.6	7.3	7.5	7.4
BPK_5 (mg/O_2l)	1.95	0.35	1.33	1.29
KPK-Cr (mg/O_2l)	4.61	0.78	1.90	1.84
Electrical conductivity (µS/cm)	1,109	1,058.6	970.1	1,258.9
Total suspended solids (mg/l)	8	50	24	34
Amonium ion (µg/l)	2,180	14,010	1,400	1,400
Total nitrogen (µg/l)	–	15.410	2,800	2,800
Total phosphorus (µg/l)	74	76	88.5	107.8
Shannon-Weaver index of diversity (H’)	1.39	1.15	1.86	0.627

Table 5: The values of hydromorphological, physico-chemical, and biological elements of the Raspotočje site.

Parameters	08.10. 2014	15.01. 2015	06.05. 2015	23.06. 2015
Flows of Bosna River Q (m^3/s)	27.42	39.80	28.21	15.63
Water temeperature (°C)	13	1.5	14.7	16.5
Air temperature (°C)	14.25	3.3	30.1	25.3
pH	7.8	7.3	7.5	7.5
BPK_5 (mg/O_2l)	1.73	0.37	0.89	1.29
KPK-Cr (mg/O_2l)	4.10	0.78	1.27	1.84
Electrical conductivity (µS/cm)	1,136	1058.6	931.6	1225.8
Total suspended solids (mg/l)	12	65	18	25
Amonium ion (µg/l)	2,180	16,810	1,400	1,400
Total nitrogen (µg/l)	–	18,210	2,800	2,800
Total phosphorus (µg/l)	74	72	84.0	113.4
Shannon-Weaver index of diversity (H’)	2.11	0.92	1.89	0,267

Table 6: The values of hydromorphological, physico-chemical, and biological elements of the Hotel Metalurg site.

Parameters	08.10. 2014	15.01. 2015	06.05. 2015	23.06. 2015
Flows of Bosna River Q (m^3/s)	28.92	41.30	29.71	17.13
Water temeperature (°C)	12.6	3.9	16.2	17.3
Air temperature (°C)	15.5	3.7	30.4	23.2
pH	7.8	7.2	7.8	7.7
BPK_5 (mg/O_2l)	0.68	0.71	2.67	0.86
KPK-Cr (mg/O_2l)	1.57	1.96	3.81	1.23
Electrical conductivity (µS/cm)	1,136	1,012.6	950.6	1194.3
Total suspended solids (mg/l)	18	28	27	37
Amonium ion (µg/l)	2,800	11,210	1,400	2,800
Total nitrogen (µg/l)	–	12,610	2,800	2,800
Total phosphorus (µg/l)	650	63	79.1	101.2
Shannon-Weaver index of diversity (H’)	1.48	0.92	1.26	0.794

Table 7: The values of hydromorphological, physico-chemical, and biological elements of the Coastal Channel of the Ironworks site.

Parameters	08.10. 2014	15.01. 2015	06.05. 2015	23.06. 2015
Flows of Bosnia river Q (m^3/s)	29.10	41.50	30.10	17.53
Water temeperature (°C)	14.5	3.6	18.2	20.6
Air temperature (°C)	19.2	3.8	32.7	24.3
pH	7.7	7.2	7.7	7.7
BPK_5 (mg/O_2l)	0.95	0.70	3.59	0.86
KPK-Cr (mg/O_2l)	2.35	1.96	5.08	1.23
Electrical conductivity (µS/cm)	1,606	1,083.2	991.1	1,293.9
Total suspended solids (mg/l)	51	34	67	39
Amonium ion (µg/l)	6,550	19,610	2,800	5,600
Total nitrogen (µg/l)	21,010	15,410	7,000	
Total phosphorus (µg/l)	790	77	90.0	146.4
Shannon-Weaver index of diversity (H’)	2.08	0.97	1.52	2.075

Table 8: The values of hydromorphological, physico-chemical, and biological elements of the Banlozi-Jelina site.

Parameters	08.10. 2014	15.01. 2015	06.05. 2015	23.06. 2015
Flows of Bosna River Q (m^3/s)	30.20	42.40	31.21	18.60
Water temeperature (°C)	13.6	2.3	16.6	17.6
Air temperature (°C)	16.5	1.1	30.9	27.2
pH	7.7	8.5	8.0	7.6
BPK_5 (mg/O_2l)	0.71	1.80	1.78	2.24
KPK-Cr (mg/O_2l)	1.57	4.70	2.54	3.20
Electrical conductivity (µS/cm)	1,194	1,035.1	1,013.0	1,330.8
Total suspended solids (mg/l)	36	65	24	33
Amonium ion (µg/l)	5,600	15,410	3,200	4,200
Total nitrogen (µg/l)		16,810	4,200	5,600
Ukupni fosfor (µg/l)	800	69	91.1	121.2
Shannon-Weaver index of diversity (H')	0.92	1.91	2.26	0.809

The studied river Bosna in the Zenica region increases its flow downstream through its entire course, mitigating anthropogenic influences and resulting in the partial flushing of sediment containing different harmful substances. Due to a more prominent food source, this condition leads to a slightly higher diversity of macroinvertebrates at the lower river sites (Tabs. 4-8). In January, the highest flows were recorded at 42.40 m^3/s, leading to significant water levels.

During the study period, the lowest air temperature occurred in January (1.1°C) and the highest in May (32.7°C). Water temperature is directly dependent on air temperature. Lower water temperatures were observed at the upper Bosna River sites. In comparison, higher temperatures were recorded at the lower sites, as expected, due to more prolonged exposure to sunlight, causing downstream water warming (Tabs. 4-8).

The water is weak to moderately basic, ranging from 7.2 to 8.5 (Tabs. 4-8). The pH value fluctuates slightly over the observed period, consistently falling within Class I of water quality. The higher pH values are likely a result of a significant reduction in water quantity, leading to increased concentrations of detergents, which are strongly basic substances (Duran et al., 2000-2001).

BOD_5 values ranged between the values of 0.71 mg/O_2l to 3.59 mg/O_2l, classified as Class II of water quality (Tabs. 4-8). COD-Cr values ranged from 0.78 mg/O_2l to 5.8 mg/O_2l, meeting the requirements of Class I of water quality. There is no evidence of significant organic pollution due to relatively low BOD_5 and COD-Cr values during the observed period. Variations in daily chemical oxygen demand may be attributed to sampling at different times when the quantity of municipal wastewater changes throughout the day (Duran et al., 2000-2001).

In contrast to the oxygen regime, electrical conductivity reached high values from 991.1 µS/cm to 1,606 µS/cm (Tabs. 4-8). It can be classified as Class IV-V of water quality, indicating significant pollution. Increased conductivity values suggest a higher concentration of salts in the water, a result of wastewater discharge accumulating in sediment, adversely affecting aquatic life. Conductivity values are influenced by temperature, pH value, and, to some extent, dissolved carbon dioxide (Trožić-Borovac, 2001).

Total suspended solids (TSS) concentrations ranged between the values of 8 mg/l to 67 mg/l (Tabs. 4-8), falling within the limits for Class II-III of water quality. Determining and analyzing this parameter in water is very important due to the fact that it leads to forming sediment deposits, favoring the creation of anaerobic conditions at the bottom of the aquatic ecosystem.

Ammonium ion concentrations ranged from 1400 µg/l to 19610 µg/l (Tabs. 4-8), exceeding Class IV of water quality limits. Oscillations in ammonium content indicate that sewage and industrial wastewater significantly affect the studied river's water quality. Ammonium is commonly considered an indicator of fresh fecal pollution. Still, increased concentrations can also result from applying fertilizers near the river and wastewater rich in mineral and organic materials. High ammonium values are likely due to the high water levels of the river, leading to flooding of areas around the river and causing increased nutrient concentrations through leaching and accumulation of organic matter from the surrounding vegetation.

Total nitrogen varied during the observed period, ranging from 2,800 µg/l to 21,010 µg/l (Tabs. 4-8), categorized as Class II to IV of water quality. Nitrogen content in water is considered an indicator of water pollution due to insufficiently treated wastewater and excessive fertilizer use.

Total phosphorus levels ranged from 72 µg/l to 800 µg/l (Tabs. 4-8), falling into Class I-II to III-IV of water quality. Phosphorus is an indicator of water pollution, indicating the presence of sewage and artificial fertilizers

The biological diversity index fluctuated from poor at 0.267 at the Raspotočje site (Tab. 5) to high at 2.26 at the Banlozi site (Tab. 8). Differences in diversity and abundance of individuals were observed between seasons. Considering consistent physico-chemical analyses at the sites, variations in diversity index values should be sought in other potential significant influences. Flooding events in 2014 led to changes in hydromorphological elements of water quality, mainly in substrate structure and homogeneity, affecting the composition and structure of macroinvertebrates and other biological communities (Novaković et al., 2015). Specifically, during high water levels in May 2014, a portion of benthic macroinvertebrates was washed away, directly related to increased water levels, as the flow velocity increases with rising water levels (Figs. 1-2), making it difficult for some organisms to resist. After heavy rainfall or floods, drift occurs, the passive transport of macroinvertebrates when the water quantity in the riverbed rises, carrying insects downstream. In this study, the highest number of taxa, individuals, and diversity index values were detected downstream at the Banlozi site of the Bosna River.

Table 9: Comparison of correlation coefficients for the considered relationships between elements.

Orderer nr.	Considered relationships between elements	Spearman's correlation coefficient and the strength of the relationship between variables
1.	Q – H'	0.24 – weak and positive
2.	T – H'	0.13 – minor and positive
3.	pH – H'	0.59 – medium strong and positive
4.	BPK5 – H'	0.24 – weak and positive
5.	KPK-Cr – H'	0.34 – weak and positive
6.	Electrical conductivity – H'	– 0.24 – weak and negative
7.	Total suspended solids – H'	– 0.11 – minor and negative
8.	Amonium ion – H'	0.13 – minor and positive
9.	Total nitrogen – H'	0.44 – weak and positive
10.	Total phosphorus – H'	– 0.02 – totally absent

The correlation between elements is weak (Tab. 9), except for the established correlation with a moderately strong relationship between pH and H' (rs = 0.59) (Fig. 3). Within the achieved weak connection, we highlight the total nitrogen – H' correlation (rs = 0.44) (Fig. 4) and KPK-Cr – H' correlation (rs = 0.34) (Fig. 5). The same correlation value (rs = 0.24) is achieved for flow (Fig. 6) and BPK_5. Therefore, a statistically significant connection between elements exists for pH and the Shannon-Weaver diversity index, meaning that the most critical influence on H values is the pH. Also, it can be concluded that there is a connection between total nitrogen and KPK-Cr with H'. The low correlation coefficients for temperature (rs = 0.13) indicate that its influence is insignificant for H'. Achieved negative values for electrical conductivity (Fig. 7) and total suspended solids (Tab. 9) imply that H' increases as the value of these elements decreases. A negative value is observed for total phosphorus and a complete absence of correlation with H' (Fig. 8).

In the study (Imamović, 2005) on the water quality of the Bosna River, the best correlation was found with the saprobic index for nitrates (r = 0.52), temperature, and pH (r = 0.42). Examining the quality of the Sava River (Ćuk et al., 2014), it was observed that, in addition to physico-chemical indicators, the highest number of taxa is directly connected with the diversity of dominant substrate with a higher proportion of rocks and gravel. The smallest number of taxa inhabits habitats with a proportion of sand and mud without large substrate fractions. Williams and Williams (1998), determined that the composition of the riverbed (size and heterogeneity) and the presence of aquatic vegetation play a dominant role in the composition of macroinvertebrate communities.

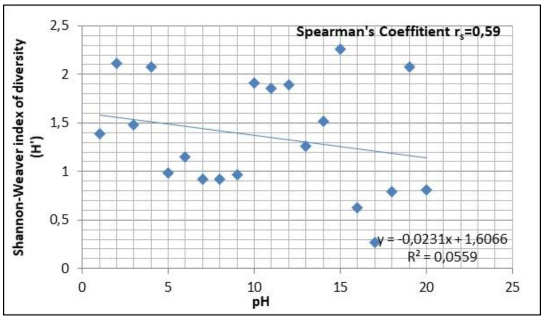

Figure 3: Connection pH – H'.

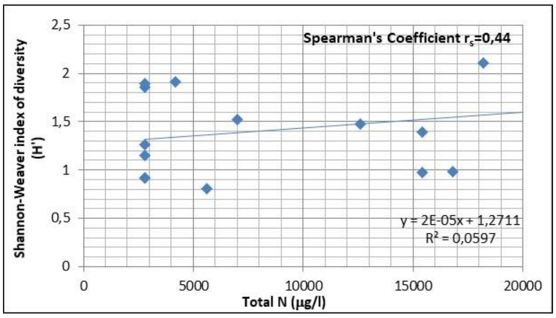

Figure 4: Connection of total N – H'.

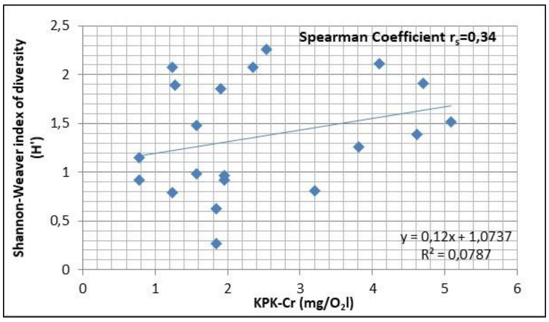

Figure 5: Connection KPK-Cr – H'.

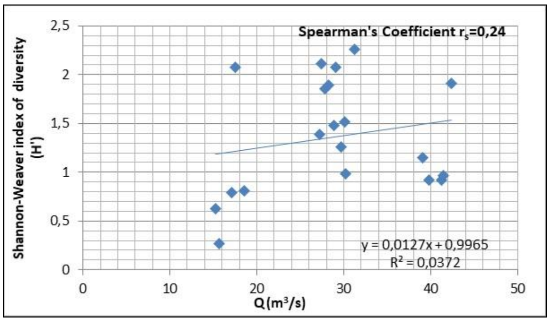

Figure 6: Connection Q – H'.

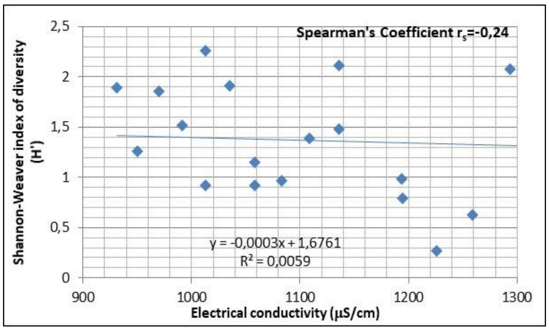

Figure 7: Connection electric conductivity – H'.

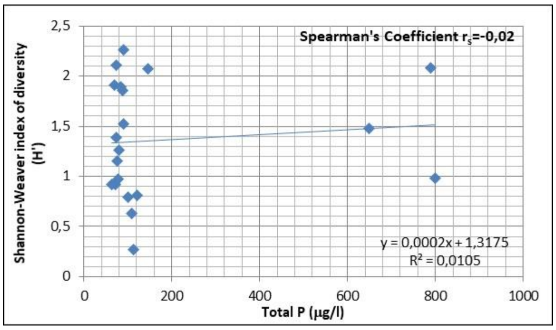

Figure 8: Connection total phosphorus – H'.

As this analysis revealed a significant dispersion of results and negative outcomes, it is necessary to increase the number of sites in further research, analyzing a greater number of samples over a longer period of approximately three years. This is aimed at obtaining more efficient data that would provide a better correlation between ecological parameters.

CONCLUSIONS

Based on the results of the water quality assessment, which included analyses of essential physico-chemical and biological elements of the Bosna River in the Zenica area from October 2014 to June 2015, it can be concluded that multivariate analysis demonstrated the interconnection of water quality elements using the dependent variable with the Shannon-Weaver Diversity Index.

A statistically significant correlation of moderate strength was achieved between pH and the Shannon-Weaver Diversity Index (rs = 0.59). Additionally, there is a connection between total nitrogen and KPK-Cr with the diversity index. In further research, it is necessary to increase the number of sites with a more significant number of samples over a more extended period in different seasonal conditions of watercourses to have more effective data that would provide a better correlation between elements determining water quality. Continuous monitoring of the Bosna River's quality is essential not only for pollution assessment and implementing preventive and practical protection measures but also for more specific requirements to polluters to introduce and implement protective measures preventing or reducing water pollution within permitted concentrations.

REFERENCES

1. Barbour M. T., Gerritsen J., Snyder B. D. and Stribling J. B., 1999 – Rapid bioassessment protocols for use in streams and wadable rivers: periphyton, benthic macroinvertebrates and fish, 2nd edition, EPA 841-B-99-002, Washington D. C., 337.
2. Bănăduc D., Simić V., Cianfaglione K., Barinova S., Afanasyev S., Öktener A., McCall G., Simić S. and Curtean-Bănăduc A., 2022 – Freshwater as a sustainable resource and generator of secondary resources in the 21st century: stressors, threats, risks, management and protection strategies, and conservation approaches, *International Journal of Environmental Research and Public Health*, 19, 16570, 1-30, 10.3390/ijerph192416570.
3. Blagojević S., Dizdarević M. and Pavlović B., 1984 – Odnosi između nekih bioloških i fizičko hemijskih parametara kvaliteta vode u tekućicama Bosne i Hercegovine, Univerziteta u Sarajevu, Godišnjak Biološkog instituta Univezriteta u Sarajevu, 37, 23-30. (in Bosnian)
4. Ćuk R., Tomas D. and Vučković I., 2014 – Kakvoća rijeke Save u 2012, godini, Hrvatske Vode, 88, 97-106. (in Croatian)
5. Duran F. and Salkić A., 2000-2001 – Izvještaji o kontinuiranim mjerenjima zagađenosti zraka i vodotoka u Zenici za 2000-2001 godina, Mjerenja i izvještaj o zagađenosti zraka i vodotoka, Metalurški institut Kemal Kapetanović, Izvještaji broj 005/2000-09/2000, 150. (in Bosnian)
6. EU Water Framework Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy 2000.
7. Giller P. S. and Malmquist B., 1998 – The Biology of Streams and Rivers, Oxford University Press, Oxford, 256.
8. Imamović A., 2005 – Analiza korelacija ekoloških parametara kvaliteta voda na rijeci Bosni, Javno preduzeće za "Vodno područje slivova rijeka Save", *Voda*, 84, 24-34. (in Bosnian)
9. Novaković B., 2015 – Poplave u Srbiji tokom 2014. godine – Uticaj na zajednice akvatičnih makroinvertebrata, 44 konferencija o aktuelnim problemima korišćenja i zaštite voda, *Voda*, 41-44. (in Bosnian)
10. Odluka o karakterizaciji površinskih i podzemnih voda, referentnim uslovima i parametrima za ocjenu stanja voda i monitoring voda, Službene novine FBiH, br. 1/14, 78. (in Bosnian)
11. Rosenberg D. and Resh V. H., 1993 – Freshwater biomonitoring and benthic macroinvertebrates, Champan Hall, New York, 488.
12. Shanon C. E. and Weaver W., 1949 – The mathematical theori of commucation, The University of Illinois Press, Urbana, I, 11, 19-21, 82-83, 104-107.
13. Trožić-Borovac S., 2001 – Istraživanje makroinvertebrata bentosa rijeke Bosne i pritoka u ocjeni kvaliteta vode, Doktorska disertacija, Prirodno-matematički fakultet Univerzitet u Sarajevu, 260. (in Bosnian)
14. Uredba o klasifikaciji voda i voda obalnog mora Jugoslavije u granicama SR BiH, Službeni list SR BiH, broj 19/80, 374-377. (in Bosnian)
15. Uredba o opasnim i štetnim materijama u vodama, Službeni list Federacije BiH, broj 43/07, 4117-4120. (in Bosnian)
16. Uredba o klasifikaciji voda i kategorizaciji vodotoka, Službeni glasnik Republike Srpske, broj 3/97, 1-16, 3/98 1-2 i 29/00, 1-2, 16 pp). (in Bosnian)
17. Williams D. and Williams N. E., 1998 – Invertebrate communites from freshwater springs what can they contribute to pure applied ecology, U: Studies in Crenobiology. The biology of springs and springbooks, Bachuys Publishers, Leiden, 251-261.