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Water Quality Assessment in the Ibër River Basin (Kosovo) Using Macroinvertebrate and Benthic Diatom Indices

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ABSTRACT

The freshwater ecosystems in Kosovo have undergone significant degradation in recent years due to various anthropogenic pressures, including sewage effluents, industrial discharge, water intakes, and riverbed degradation. Consequently, the populations of freshwater biota, including bioindicators, have been heavily impacted by these activities. This study provides a thorough evaluation of water quality in the main course and tributaries of the Ibër Basin, Kosovo, utilizing macroinvertebrates and benthic diatoms as bioindicators. The well-being of aquatic ecosystems is intricately tied to water quality, and these organisms serve as valuable indicators because of their sensitivity to environmental changes. Sampling of macroinvertebrates and diatoms was conducted at 20 stations in the basin. Diversity, abundance, and ecological indices obtained from macroinvertebrates and benthic diatoms were employed to assess the water quality status at various sampling sites. The findings indicate variations in macroinvertebrate and benthic diatom assemblages among different sites, reflecting anthropogenic impacts on water quality in most of the studies sites. The macrozoobenthos structure during this investigation consists of one class (Gastropoda), two subclasses (Hirudinea and Oligochaeta), eight orders (Diptera, Isopoda, Coleoptera, Amphipoda, Decapoda, Trichoptera, Ephemeroptera, and Plecoptera), and 26 families. The composition of diatoms includes 152 species, with the most diverse genera being *Nitzschia* Hassall 1845 (29 species), *Navicula* Bory, 1822 (18 species), and *Gomphonema* Ehrenberg, 1832 (9 species). The integration of biological and environmental data provides a holistic understanding of the ecological health of freshwater ecosystems of the Ibër Basin indicating severe deterioration at several of the study sites. The outcomes of this study can help develop informed water resource management strategies, facilitating targeted conservation and remediation efforts to improve and preserve the overall water quality in the basin. This research contributes to the broader field of freshwater ecology and underscores the significance of using bioindicators for effective water quality monitoring and management.

Keywords: water quality, bioindicators, ecological indices, environmental monitoring, water management.

INTRODUCTION

Water quality plays a pivotal role in the vitality and biodiversity of aquatic ecosystems, exerting direct influence on the health of rivers and their associated basins. Monitoring these ecosystems is essential for evaluating water quality and ecological well-being. The Water Framework Directive (WFD) offers guidelines for effective monitoring, placing particular emphasis on the assessment of macroinvertebrates and diatoms. As highlighted in various studies [e.g., Arle et al., 2016; Blinkova Donchevska et al., 2019], the environmental objectives of WFD aim to prevent degradation of water body status as well as safeguard, enhance, and restore all water bodies, striving for good ecological status or ecological potential and good chemical status for surface waters by 2027 at the latest. The Water Framework Directive has underscored the importance of biological parameters in assessing the condition of aquatic ecosystems. Annex V of the WFD specifies algae, macrophytes, macroinvertebrates, and fish fauna as pertinent biological quality elements (BQE) in monitoring studies. Within these BQEs, macroinvertebrates and diatoms hold particular significance, as they are integral components of aquatic ecosystems, serving as key indicators of the ecological health of water bodies. Understanding the composition of macroinvertebrates and diatoms provides valuable information on the status of a waterbody and helps in formulating appropriate management strategies [Stevenson et al., 2010; Castillejo et al., 2024].

WFD recommends regular monitoring based on macroinvertebrate sampling, as outlined in Annex V, Section 1.3.4. It suggests intervals of no more than three years, and selection of sampling frequencies should aim for an acceptable level of confidence and precision. This emphasizes the need for consistent and timely data collection to ensure accurate assessments of water quality over time. Within BQEs, macroinvertebrates are frequently utilized for assessing the structure and functioning of surface water ecosystems [Slavevska-Stamenković et al., 2011; Blinkova Donchevska et al., 2019]. Benthic macroinvertebrates are aquatic organisms that dwell on the bottom substrates of streams and lakes, typically small enough to be captured by a 200 – to 500-μm (0.01 – to 0.02 – inch) mesh, yet large enough to be easily collected. They encompass various taxa, including insects, worms, crayfish, snails, and freshwater clams, as well as inhabit diverse aquatic habitats. These organisms are highly valuable in biomonitoring due to several advantages: they serve as excellent indicators of localized conditions, integrate the impacts of short-term environmental fluctuations, and reflect detrimental events that have occurred in the aquatic environment at any stage of their life cycle [Slavevska-Stamenković et al., 2011; Blinkova Donchevska et al., 2019].

Biotic index systems have been devised to assign numerical scores to particular "indicator" organisms at specific taxonomic levels [Armitage et al., 1983]. These organisms exhibit distinct requirements concerning physical and chemical conditions. Alterations in their presence/absence, abundance, morphology, physiology, or behavior can signify that the physical and/or chemical conditions are beyond their preferred thresholds [Rosenber, Resh, 1993]. The prevalence of numerous families of highly tolerant organisms typically indicates poor water quality [Hynes, 1998]. WFD (2000/60/EC) mandates the monitoring of diatoms as a quality element for assessing the ecological status of freshwaters as well due to their particular sensitivity to various ecological conditions. This underscores the importance of considering both macroinvertebrates and diatoms in monitoring programs. By combining these assessments, a more comprehensive understanding of water quality and ecosystem health can be achieved.

With species-specific ecological tolerances and a high sensitivity to fluctuations in a wide array of environmental variables, diatoms are globally recognized as one of the most established biological indicators of water quality [Battarbee, 2001; Bennion et al., 2010; Stevenson et al., 2010]. Diatoms respond to environmental changes, particularly to variations in nutrient concentrations and pollutant levels, by alterations in 1) the species composition, 2) abundance and 3) morphology. The species richness is significantly declining due to eutrophication and pollution, with presence and high dominance of tolerant and highly tolerant species. On the other hand, the abundance of sensitive taxa is decreasing, which might cause extinction of such species in the community. Additionally, pollution can cause changes in valve morphology resulting in the presence of teratogenic forms [Laclereq, 2008].

The Ibër River located in the Northern part of Kosovo is facing increasing environmental pressures, with pollution being a significant concern. Therefore, the primary objective of this study was to employ a combined approach utilizing macroinvertebrates and diatoms to evaluate the ecological conditions of running waters in the northern part of Kosovo, specifically focusing on the Ibër Basin. The study further assessed the influence that urban areas and factories have on freshwater ecosystems in the northern part of Kosovo (Zubin Potok, Mitrovice, Mitrovice e Veriut, Zvecan, Leposaviq, and Vushtrri).

MATERIAL AND METHODS

Study site

The sampling was carried out in running waters belonging to the Ibër Basin (Kosovo), encompassing a total of 20 sites distributed along various levels of anthropogenic pressures across the basin.

Among these, fifteen monitoring sites were specifically situated along the Ibër River, 12 along the main course and additional three at the tributaries contributing to the Ibër River. Furthermore, two monitoring sites were located in the Sitnica River, and one in the Llap River, allowing for a comprehensive representation of the aquatic ecosystems within the broader Ibër Basin. This distribution of sampling sites was designed to capture the variability in water quality across different sections of the Ibër River and its tributaries.

Macroinvertebrate sampling and laboratory methods

Macroinvertebrate sampling followed the standards outlined in EN ISO 10870:2012 and EN 16150:2012 at all 20 sampling sites (Figure 1, Table 1). EN ISO 10870:2012 establishes the criteria for selecting sampling methods and devices (including operational and performance characteristics) for assessing benthic macroinvertebrate populations in freshwater environments such as rivers, canals, lakes, and reservoirs. The methods and devices described in this International Standard are appropriate for sampling all primary components of the benthic community. EN 16150:2012 provides guidance on the procedures for pro rata Multi-Habitat-Sampling (MHS) of benthic macroinvertebrates in wadeable rivers and streams. The pro rata MHS technique complements other techniques and is a fundamental component of certain multi-metric assessment approaches used to determine the ecological status of running waters. The methodology described in this document is one of several pro rata MHS techniques available. The MHS methodology draws from various sources, including Rapid Bioassessment Protocols, procedures from the Environment Agency for England and Wales, Austrian guidelines for the assessment of saprobiological Water Quality of rivers and streams, the AQEM sampling manual, the AQEM & STAR site protocol, EN 27828, Austrian Standards M 6232 and M 6119-2, German standard DIN 38410-1, and French standard XP T90-333.

Selection of the metrics for the assessment is based on the requirements of WFD. The most commonly utilized biotic indices or metrics, including the EPT taxa index (number of Ephemeroptera, Plecoptera, and Trichoptera taxa), BMWP (Biological Monitoring Working Party score), FBI (Family Biotic Index), ASPT (Average Score Per Taxon) and SWRC (Stroud Water Research

Table 1. Sampling stations in the Ibër Basin

Code	GPS	River	River typology	Type of area
L1	42.755328, 21.017058	Llap	Type-6	Urban area (including commercial pollution)
L2	42.797738, 20.990463	Sitnica	Type-6	Urban-agricultural area, downstream
L3	42.877966, 20.874643	Sitnica	Type-6	Urban-industrial area, downstream
L4	42.880230, 20.845268	Ibër	Type-6	Urban-agricultural and industrial area, downstream
L5	42.874545, 20.836446	Ibër	Type-6	Urban-agricultural area
L6	42.880208, 20.844914	Ibër	Type-6	Urban-agricultural area
L7	42.948183, 20.662839	Ibër sidestream	Type-2	Pristine area
L8	42.944307, 20.660598	Ibër	Type-5	Urban-agricultural area
L9	42.904329, 20.760732	Ibër	Type-5	Urban-agricultural area
L10	42.889235, 20.773936	Ibër	Type-2	Pristine area
L11	42.883120, 20.795099	Ibër	Type-6	Urban-agricultural area
L12	42.869505, 20.808954	Ibër	Type-5	Urban & agricultural area
L13	42.867067, 20.812066	Ibër	Type-5	Urban-agricultural area
L14	42.969427, 20.821421	Ibër	Type-6	Urban-agricultural and industrial area, downstream
L15	43.027946, 20.831557	Ibër sidestream	Type-2	Pristine area
L16	43.025761, 20.831541	Ibër	Type-6	Urban-agricultural and industrial area, downstream
L17	43.19222 20.71155	Ibër	Type-6	Urban & agricultural area, downstream
L18	43.143230, 20.769406	Ibër sidestream	Type-2	Pristine area
L19	43.083869, 20.805719	Ibër sidestream	Type-2	Pristine area
L20	43.084921, 20.806413	Ibër	Type-6	Urban-agricultural area, downstream

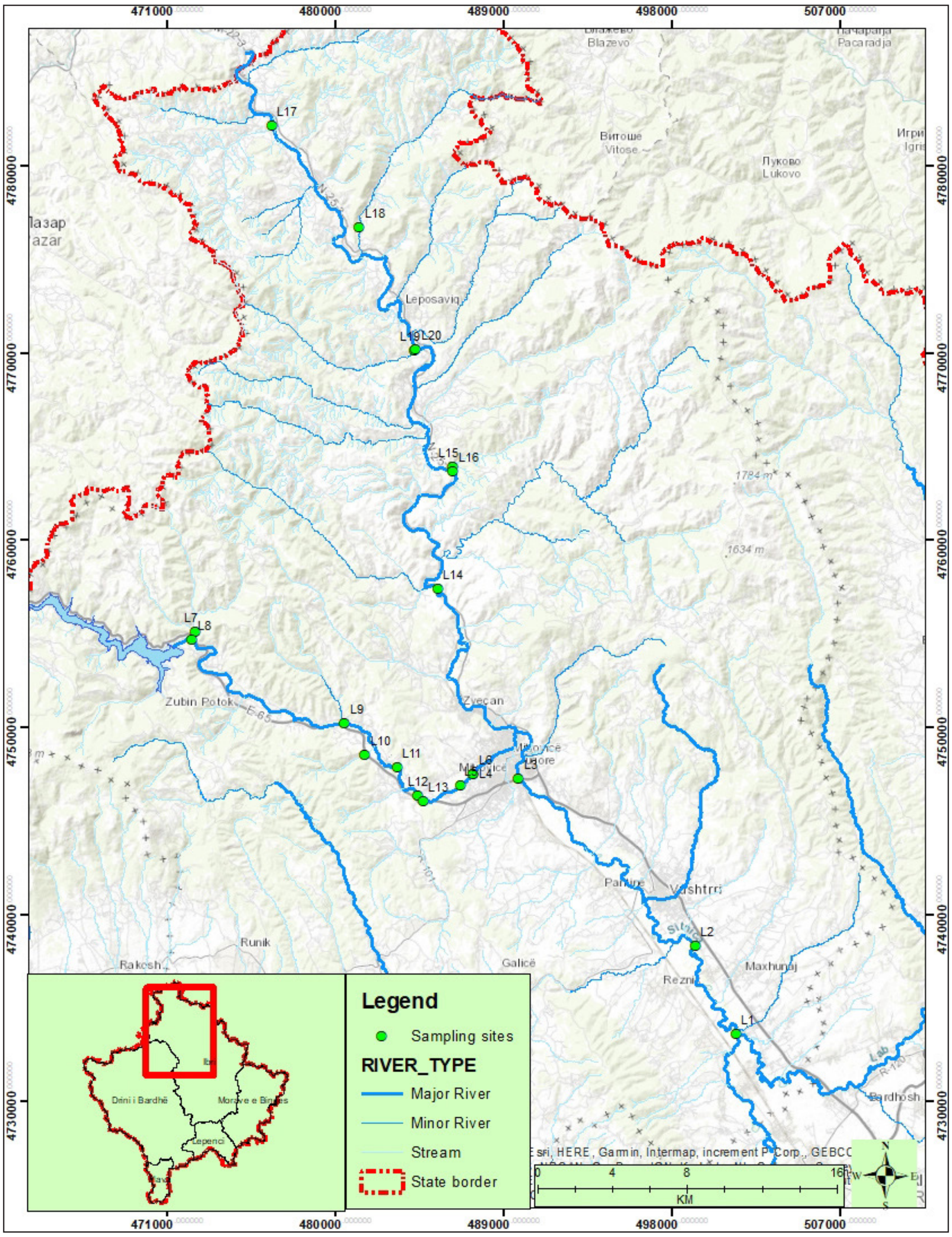

Figure 1. Sampling stations in the Ibër Basin

Center), are employed to assess the ecological status of river water bodies in Kosovo and will be utilized for this task as well. Identification of macroinvertebrate samples for this purpose, is done up to the family level. The indices were calculated by using R-package Macro Zoo Benthos Water A 0.1.0 [Geci et al., 2023].

Diatoms sampling and laboratory methods

Materials for the studies were collected from 20 study sites in the Ibar Basin (Figure 1, Table 1, from all available habitats: rocks, sediments and aquatic macroinvertebrates. In general, rocks are the most favorable substrate for diatom collection, because this type of substrate is stable and allows the development of diatom communities. The sample was transferred from the tray to the sample bottle. The details relevant to the sample were written on the sample bottles. The collected material was preserved in 4% formalin solution.

For light microscopy (LM) observations, diatom samples were prepared using materials fixed with 4% formalin. In the laboratory, they underwent treatment with $KMnO_4$ and 37% HCl, left overnight to remove carbonates. To oxidize organic matter, 37% HCl was added, and samples were boiled for 45 minutes at 80 °C. Following this, the samples were rinsed five times with distilled water and subsequently centrifuged. Diatom slides were mounted using Naphrax. LM observations were conducted using a Nikon Eclipse 80i microscope, under oil immersion at 1500 × magnification. Diatom images were captured using a Nikon Coolpix P6000 camera. Diatom counts were obtained by enumerating all species in randomly selected microscopic fields of view, up to a total of 400 valves.

RESULTS

The analysis of water monitoring in the Ibër River (Kosovo) is presented in the results chapter. The results from this investigation unveil a diverse array of benthic invertebrate communities, as well as diatoms included. These results offer a comprehensive insight into the overall ecological condition of the basin.

Macroinvertebrates composition

The presence of several families of macroinvertebrates in the study area was identified. These families belong to various groups of macroinvertebrates, including Diptera (Chironomidae, Simuliidae, Ceratopogonidae, Tipulidae), Isopoda (Asellidae), Coleoptera (Haliplidae, Dytiscidae), Hirudinea (Hirudinidae, Erpobdellidae), Amphipoda (Gammaridae), Decapoda (Astacidae), Oligochaeta (Tubificidae, Lumbricidae, Lumbriculidae), Gastropoda (Physidae), Trichoptera (Hydropsychidae, Rhyacophilidae, Limnephilidae, Hydroptilidae, Leptoceridae, Sericostomatidae), Ephemeroptera (Baetidae, Heptageniidae, Siphlonuridae, Ephemeridae), and Plecoptera (Nemouridae).

Most of the Ephemeroptera, Plecoptera and Trichoptera families intolerant to pollution were found at the upstream Ibër River tributaries, while most of the families tolerant to pollution and in high abundance were found around settlement areas. The dominance of families Nemouridae, Rhyacophilidae, Limnephilidae, Hydroptilidae, Leptoceridae, and Sericostomatidae, known for their sensitivity to environmental stress and as indicators of relatively clean river conditions, was observed at sampling sites L7, L10, L13, L15, L18, and L19. Conversely, at sampling sites L8, L9, L11, and L12, there was a decline in the number of EPT families in comparison to the aforementioned localities, with semi-tolerant families, such as Heptageniidae, Batidae, Siphlonuridae, Ephemeridae, Hydropsychidae, Gammaridae, and Tipulidae being more prevalent. Meanwhile, sampling sites L1 through L6, L14, L16, L17, and L20 were dominated by families tolerant to pollution, such as Chironomidae, Tubificidae, Asellidae, Hirudinidae, Erpobdellidae, Lumbricidae, and Lumbriculidae.

Diatoms composition

Light microscopy observations of permanent slides from 20 different sampling sites resulted in the identification of 152 diatom species. The most diverse genera have been *Nitzschia* Hassall 1845 with 29 species, *Navicula* Bory, 1822 with 18 species, and *Gomphonema* Ehrenberg, 1832 with 9 species. Only one species has not been completely identified (*Encyonema* sp.) from localities 6 and 10, but this species has been observed also in other reservoirs in Europe. The majority of the observed species are cosmopolitan and have wide distribution across freshwater habitats in Europe. Several species were frequently observed in the samples and in most cases these species are considered as tolerant to organic pollution, such as *Craticula subminuscula* (Manguin) C.E.Wetzel and Ector 2015, *Diatoma moniliformis* Kützing, 1833, *Gomphonella olivacea* (Horneman) Rabenhorst, 1853, *Gomphonema parvulum* (Kützing) Kützing, 1849, *Mayamaea permitis* (Hustedt) Bruder and Medlin, 2008, *Navicula lanceolata* (C. Agardh) Kützing, 1844, *Nitzschia palea* (Kützing) W. Smith, 1856 etc. In the areas with low anthropogenic pressure, few sensitive taxa were observed, such as *Cymbella affiniformis* Krammer, *Meridion circulare* (Greville) C.Agardh, *Nitzschia pura* Hustedt and *Odontidium mesodon* (Ehrenberg) Kützing. Also, these oligotrophic species are widely distributed in freshwater habitats in Europe.

Biotic indices

In this study, a comprehensive evaluation of water quality was undertaken, employing a multifaceted approach that integrated biotic indices, macroinvertebrates, and diatoms. Biotic indices, derived from macroinvertebrate data, include EPT, FBI, BMWP, ASPT, and SWRC. These indices serve as valuable indicators, reflecting the ecological health and pollution sensitivity of the

Table 2. The calculated values of benthic invertebrate indices in the 20 sampling sites of the Ibër River Basin during the May – December 2023 period

#	EPT	FBI	BMWP	ASPT	SWRC	Water quality status
L1	2	5.49	29	3.63	5.18	Poor
L2	0	7.76	10	2	8.00	Bad
L3	1	8.84	14	3.5	7.94	Bad
L4	2	7.78	31	3.88	7.63	Poor
L5	2	7.1	28	4	6.31	Poor
L6	3	6.37	60	4.61	5.96	Poor
L7	9	3.71	87	6.05	4.25	Good
L8	7	5	67	5.18	5.68	Moderate
L9	4	3.95	43	6.14	5.43	Moderate
L10	6	3.98	55	6.87	4.87	Good
L11	4	5.32	37	6.16	5.04	Moderate
L12	2	4.3	26	3.71	6.76	Moderate
L13	7	3.84	76	6.9	4.59	Good
L14	0	8	6	3	8	Bad
L15	7	3.64	91	8.06	5.05	Good
L16	2	6.48	21	4.2	6.82	Poor
L17	2	6.88	21	4.2	5.93	Poor
L18	6	4.11	57	7	4.75	Good
L19	6	4.16	67	6.7	4.69	Good
L20	2	5.96	36	4.5	6.05	Poor

Table 3. The calculated values of diatom indices for waterbodies in the Ibër Basin

#	IDAP	EPI-D	IBD	SID	TID	IPS	SLA	DES	CEE	Water quality status
L1	9.6	10.6	13.3	10.6	5.2	14.0	9.2	14.0	10.5	Moderate
L2	5.6	5.2	6.8	7.6	3.7	5.2	7.5	9.8	4.8	Poor
L3	7.3	10.9	13.7	10.6	6.1	12.6	9.4	8.5	7.8	Moderate
L4	9.9	12.2	16.9	12.7	8.2	14.6	10.4	15.2	11.5	Moderate
L5	13.6	12.4	20.0	13.5	8.3	15.8	11.4	18.0	14.1	Good
L6	11.2	12.6	16.7	14.5	7.6	13.6	10.9	16.4	13.9	Moderate
L7	13.1	16.1	20.0	14.8	10.9	17.3	13.4	17.4	15.3	Good
L8	11.5	16.9	20.0	16.1	12.3	18.3	12.8	18.5	17.3	Good
L9	14.7	13.9	20.0	15.2	11.7	15.6	12.6	19.4	15.1	Good
L10	14.1	14.5	16.7	13.0	8.0	16.0	11.5	17.0	13.9	Good
L11	17.1	14.9	20.0	14.2	11.8	16.1	13.2	18.5	14.9	Good
L12	13.4	13.8	18.9	14.3	9.0	16.2	12.6	16.1	15.4	Good
L13	13.4	12.5	18.7	13.2	10.2	14.2	10.6	19.3	13.4	Good
L14	10.3	12.9	18.6	14.2	9.4	14.8	11.3	16.8	12.0	Moderate
L15	9.2	14.6	20.0	14.7	11.9	16.6	13.9	15.5	13.9	Good
L16	6.0	5.7	8.8	6.4	5.6	9.8	6.4	11.9	7.3	Poor
L17	5.9	6.6	9.6	7.7	5.6	15.0	7.0	11.5	7.7	Poor
L18	7.3	10.4	14.5	12.1	7.4	16.8	10.1	14.9	6.9	Moderate
L19	11.2	10.9	13.2	11.7	6.0	14.2	9.4	13.1	9.2	Moderate
L20	7.0	8.4	12.9	10.3	6.6	12.7	7.7	11.7	8.2	Moderate

aquatic ecosystem. The assessment was further enriched by the inclusion of diatom indices, featuring IDAP, EPI-D, IBD, SID, TID, IPS, SLA, DES, and CEE. These diatom-related metrics contribute insights into water quality, providing information on pollution sensitivity, trophic status, and ecological integrity. By combining these diverse biological indicators, the study aimed to provide a comprehensive and detailed insight into the dynamics of water quality within the Ibër Basin.

DISCUSSION AND CONCLUSION

There exists a significant deficit in water quality assessment studies in Kosovo utilizing biotic indices of macroinvertebrates and diatoms [Berlajolli et al., 2019; Bilalli et al., 2022; Bytyqi et al., 2019; Etemi et al., 2020; Ibrahimi et al., 2021, 2007; Kashtanjeva et al., 2023]. While there have been numerous studies concerning freshwater ecosystems in Kosovo in recent years, they primarily focus on the taxonomy and ecology of specific groups [Bilalli et al., 2018, 2020, 2024a, b; Gashi 2016; Ibrahimi et al., 2014a, b, 2015, 2019a, b; Grapci et al., 2010, 2019, 2020; Musliu et al., 2020]. This expanding body of knowledge lays a critical foundation for advancing the assessment of freshwater quality in Kosovo. By integrating biotic indices of macroinvertebrates and diatoms into these studies, a more comprehensive understanding of water quality can be attained, thereby facilitating more effective environmental management and conservation efforts in the region.

Assessing the water quality in the Ibër Basin through macroinvertebrates and benthic diatoms assemblages is a vital component in comprehending the ecological health of the aquatic ecosystem. The identified compositions of macroinvertebrates and diatoms offer valuable insights into the ecological dynamics of the studied water bodies. The presence of diverse families of aquatic insects indicates the richness of the ecosystem. The composition of diatom species, including cosmopolitan and pollution-tolerant species, suggests variations in water quality across different sites. The observation of sensitive taxa in the areas with low anthropogenic impact highlights the importance of environmental conservation in maintaining biodiversity and water quality. The distribution patterns of oligotrophic species further emphasize the ecological significance of these freshwater habitats. These findings lay the groundwork for a comprehensive understanding of the ecological health and potential stressors in the Ibër Basin. The results of the biotic indices in the Ibër Basin provide valuable insights into the ecological health of the sampled sites. The EPT index in this investigation ranging from 0 to 9, indicates the presence of pollution-sensitive taxa. For example, at L7, where the EPT value is 9, the abundance of sensitive organisms suggests good water quality. Conversely, at L2, with an EPT value of 0, the absence of these taxa indicates poor water quality, aligning with the overall assessment of "Bad" ecological status.

The FBI values, ranging from 3.64 to 8, showcase the family composition of macroinvertebrates. In L13, where FBI is 3.84, the dominance of good and very good families aligns with the "Good" ecological status. On the other hand, at L14 with an FBI of 8, the prevalence of very poor families corresponds to the "Bad" ecological status. Similarly, the BMWP scores, ranging from 10 to 91, offer a numerical representation of macroinvertebrate diversity and pollution tolerance. L7 and L13, with BMWP scores of 87 and 76, respectively, reflect higher diversity and cleaner water, consistent with their "Good" ecological status. Contrastingly, L14, with a BMWP score of 6, indicates very poor diversity and severe pollution, aligning with the "Bad" ecological status.

The ASPT values, ranging from 2 to 8.06, provide an average score per taxon, offering a composite measure of macroinvertebrate health. For instance, at L15 with an ASPT of 3.64, the high average score contributes to the "Good" ecological status. In contrast, at L 14, the low ASPT of 8.06 reflects a compromised macroinvertebrate community and the "Poor" ecological status. The SWRC Biotic Index, reflecting overall community structure, varies from 4.25 to 8, corresponding to "Good" to "Bad" ecological statuses. L7, with a SWRC value of 4.25, signifies a well-structured community and clean water, aligning with the "Good" ecological status. Conversely, L2, with a SWRC value of 8, suggests a disrupted community structure and probable severe pollution, supporting the "Bad" ecological status.

The diatom indices provide valuable insights into the ecological condition of water bodies in the Ibër Basin. Examining specific values, variations are observed in the IDAP index, ranging from 5.6 to 17.1. For instance, at Location 16, the relatively low IDAP value of 6.0 indicates a poorer ecological status, aligning with the classification of “Poor.” Conversely, at Location 11, the higher IDAP value of 17.1 signifies a more favorable ecological status, corresponding to the classification of “Good.”

Similarly, the EPI-D values range from 5.2 to 16.1 across different locations. Notably, at Location 5, the EPI-D value of 8.3 suggests a relatively good ecological status, in agreement with the overall classification as “Good.” Conversely, at Location 2, the lower EPI-D value of 5.2 aligns with a poorer ecological status, categorized as “Poor.” Analyzing the IBD values, which vary from 6.8 to 20.0, provides further insights. Location 14, with an IBD value of 18.7, indicates a moderate ecological status, while Location 5, with an IBD value of 20.0, points to a good ecological status.

These specific values facilitate a detailed evaluation of the ecological condition at each location, contributing to a comprehensive understanding of water quality in the Ibër Basin based on diatom assemblages. This research indicates that the freshwater environments in the northern part of Kosovo face substantial pollution and are being negatively influenced by human actions, particularly in their middle and lower sections. The primary contributors to the degradation of their natural ecological state in these segments are the direct release of various forms of waste into rivers and streams, industrial effluents discharged into freshwater ecosystems, as well as the direct discharge of sewage into rivers and streams, water abstraction, fish farms, solid waste, mining and quarry, hydropower plants.

This study represents the initial efforts to assess the water bodies in the northern part of Kosovo using biological quality elements associated with macroinvertebrates and diatoms. While providing valuable environmental data for water quality evaluation, this research underscores the necessity for future investigations to incorporate more frequent monitoring and larger sets of biological indicator groups to attain a comprehensive understanding of the ecological status of these freshwater ecosystems. Additionally, it is imperative to identify and systematically study potential sites for reference conditions to gain a clearer understanding of the overall quality status.

These findings hold significant implications for policymakers and implementing institutions responsible for freshwater management in Kosovo. By highlighting the current state of freshwater ecosystems based on biological indicators, policymakers can make informed decisions regarding conservation and management strategies. Implementing institutions can utilize this information to prioritize areas for restoration efforts and develop targeted measures to safeguard water quality and biodiversity. Ultimately, this research contributes to the ongoing efforts to protect and sustainably manage freshwater resources in Kosovo, ensuring their long-term health and resilience.

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REFERENCES

1. Arle J., Mohaupt V., Kirst I. 2016. Monitoring of surface waters in Germany under the water framework direktive-a review of approaches, methods and results. Water, 8(6), 217.
2. Armitage P.D., Moss D., Wright J., Furse M. 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Research, 17(3), 333–347.
3. Battarbee R.W., Cameron N. G., Golding P., Brooks S.J., Switsur R., Harkness D., Appleby P.G., Oldfield F., Thompson R., Monteith D.T., McGovern A., 2001. Evidence for Holocene climate variability from the sediments of a Scottish remote mountain lake. Journal of Quaternary Science, 16, 339–346.
4. Bennion H., Battarbee R.W., Sayer C.D., Simpson G.L., Davidson, T.A., 2010. Defining reference conditions and restoration targets for lake ecosystems using palaeolimnology. Journal of Paleolimnology, https://doi.org/10.1007/s10933-010-9419-3
5. Berlajolli V., Płóciennik M., Antczak-Orlewska O., Pešić V. 2019. The optimal time for sampling macroinvertebrates and its implications for diversity indexing in rheocrenes – case study from the Prokletije Mountains. Knowledge and management of aquatic ecosystems, 420, 6.
6. Bilalli A., Ibrahimi H., Musliu, M., Geci, D. 2024a. Description of the hitherto unknown female of Rhyacophila siparantum Ibrahimi, Bilalli and Kučinić, 2021 (Trichoptera: Rhyacophilidae) from Kosovo. Ecologica Montenegrina, 71, 217–226. https://doi.org/10.37828/em.2024.71.22
7. Bilalli A., Ibrahimi H., Musliu M., Geci D., Grapci-Kotori L. 2024b. First record of Hydroptila ivisa

Malicky, 1972 (Trichoptera, Hydroptilidae) from the Ecoregion 6, Hellenic Western Balkans. Journal of the Entomological Research Society, 26(1), 137–145. https://doi.org/10.51963/jers.v26i1.2582

8. Bilalli A., Ibrahimi H., Musliu M., Grapci-Kotori L., Slavevska-Stamenkovič V., Hinič J., Geci D., Sivec I. 2023. New records and distribution data of stoneflies (Insecta: Plecoptera) from the Western Balkans. Natura Croatica, 32(2), 555–570. https://doi.org/10.20302/NC.2023.32.37
9. Bilalli A., Musliu M., Ibrahimi H., Sivec I. 2020. New records for the stonefly fauna (Insecta: Plecoptera) of Kosovo. Natura Croatica, 29(1), 29–36. https://doi.org/10.20302/NC.2020.29.4
10. Bilalli A., Ibrahimi H., Grapci-Kotori L., Musliu M., Geci D., Gashi, A. 2022. The Composition and Abundance of the Macroinvertebrate Fauna in the Leqinat Lake, National Park Bjeshkët e Nemuna, Kosovo. Ecological Engineering & Environmental Technology, 23(6), 173–177. https://doi.org/10.12912/27197050/152955
11. Bilalli A., Ibrahimi H., Musliu M. 2018. First records of the caddisfly fauna (Insecta: Trichoptera) from the Karadak Mountains, Western Balkans. Natura Croatica, 27(1), 143–151.
12. Blinkova Donchevska, M., Hinić, J., Mitić-Kopanja, D., Ristovska, M., Sekovski, D., Rebok, K., Slavevska-Stamenković, V. 2019. Ecological Status Assessment of the Strumica River Watershed Based on Macroinvertebrates–A Step Towards the Implementation of the EU Water Framework Directive in the Republic of North Macedonia. Water Research and Management, 9(3–4), 3–14.
13. Bytyçi P., Ymeri P., Czikkely M., Fetoshi O., Shala-Abazi A., Ismaili M., Millaku, F. 2019. The Application of Benthic Diatoms in Water Quality Assessment in Lepenci River Basin, Kosovo. Journal of Ecological Engineering, 20(11), 43–57. https://doi.org/10.12911/22998993/113409
14. Castillejo P., Ortiz S., Jijón G., Lobo E.A., Heinrich C., Ballesteros I., Rios-Touma, B. 2024. Response of macroinvertebrate and epilithic diatom communities to pollution gradients in Ecuadorian Andean rivers. Hydrobiologia, 851(2), 431–446.
15. Etemi F.Z., Bytyçi P., Ismaili M., Fetoshi O., Ymeri P., Shala-Abazi A., Muja-Bajraktari N., Czikkely, M. 2020. The use of macroinvertebrate based biotic indices and diversity indices to evaluate the water quality of Lepenci river basin in Kosovo. Journal of environmental science and health. Part A, Toxic/hazardous substances & environmental engineering, 55(6), 748–758. https://doi.org/10.1080/10934529.2020.1738172
16. European Parliament 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive).
17. Gashi A., Shabani E., Grapci-Kotori L., Bislimi K., Maxhuni Q., Ibrahimi H. 2016. Contribution to the knowledge of fish fauna of Kosovo with a special note on some invasive species, Turkish Journal of Zoology. 40, 64–72. 7.
18. Geci D., Bilalli A, Ibrahimi H, Musliu M, Grapci-Kotori L, Gashi A 2023. Macro Zoo Benthos Water A: Fresh Water Quality Analysis Based on Macro zoo benthos_. R package version 0.1.0, https://CRAN.R-project.org/package=MacroZooBenthosWaterA.
19. Grapci Kotori L., Zhushi Etemi F., Sahiti H., Gashi A., Škrijelj R., Ibrahimi H. 2010. The ichthyofauna of Drini i Bardhë River (Kosovo). Croatian Journal of Fisheries, 68, 149–158.
20. Grapci-Kotori L, Vavalidis T, Zogaris D, Šanda R, Vukić J, Geci D, Ibrahimi H, Bilalli A, Zogaris S. 2020. Fish distribution patterns in the White Drin (Drini i Bardhë) river, Kosovo. Knowledge and Management of Aquatic Ecosystems, 421, 29.
21. Grapci-Kotori L., Ibrahimi B., Bilalli A., Ibrahimi H., Musliu M. 2019. The Composition, Distribution and Abundance of Fish Species According to the Effects of Water Physicochemical Parameters in the Livoq Lake, Kosovo. Journal of Ecological Engineering, 20(5), 235–241. https://doi.org/10.12911/22998993/105358
22. Hynes K.E. 1998. Benthic Macroinvertebrate Diversity and Biotic Indices for Monitoring of 5 Urban and Urbanizing Lakes within the Halifax Regional Municipality (HRM), Nova Scotia, Canada. Project D-2, Soil & Water Conservation Society of Metro Halifax, 114.
23. Ibrahimi H., Bilalli A., Gashi A., Xërxa B., Grapci-Kotori L., Musliu M. 2021. The Impact of Inhabited Areas on the Quality of Streams and Rivers of a High Alpine Municipality in Southern Kosovo. Ecological Engineering & Environmental Technology, 22(3), 42–50. https://doi.org/10.12912/27197050/135449
24. Ibrahimi H., Dauti E., Gashi A., Trožić-Borovac S., Škrijelj R., Grapci-Kotori L. 2007. The impact of sewage effluents in water quality and benthic macroinvertebrate diversity of the Prishtina river (Kosova). Entomol. Rom., 12, 227–231.
25. Ibrahimi H., Gashi A., Bilalli A., Musliu M., Grapci Kotori L., Etemi-Zhushi F. 2014a. Three new country records from the genus Limnephilus Leach, 1815 (Trichoptera: Limnephilidae) from the Republic of Kosovo. Biodiversity Data Journal 2, e4140. https://doi.org/10.3897/BDJ.2.e4140
26. Ibrahimi H., Gashi A., Grapci-Kotori L., Zhushi-Etemi F., Bilalli A., Musliu M. 2015. New Distribution and Species Records of Caddisflies (Insecta: Trichoptera) from the Republic of Kosovo. Entomological News, 125(4), 229–238.
27. Ibrahimi H., Grapci-Kotori L., Bilalli A., Qamili

A., Schabetsberger R. 2019a. Contribution to the knowledge of the caddisfly fauna (Insecta: Trichoptera) of Leqinat lakes and adjacent streams in Bjeshkët e Nemuna (Kosovo). Natura Croatica, 28(1), 35–44.

28. Ibrahimi H., Kučinić M., Gashi A., Grapci-Kotori L. 2014b. Trichoptera Biodiversity of the Aegean and Adriatic Sea basins in Kosovo. Journal of Insect Science, 14(209), 1–8. https://doi.org/10.1093/jisesa/ieu071
29. Ibrahimi H., Kuçi R., Bilalli A., Musliu M., Vehapi V., Gashi A., Grapci–Kotori L., Geci D. 2019b. New additions to the caddisfly fauna (Insecta: Trichoptera) of the Sharr Mountains in Kosovo. Ecologica Montenegrina, 23, 40–46. https://doi.org/10.37828/em.2019.23.6
30. Ibrahimi H., Sejdiu N. 2018. The caddisfly fauna (Insecta: Trichoptera) of the Llap River catchment, Republic of Kosovo. Natura Croatica, 27(2), 293–304.
31. Ibrahimi H., Vehapi V. 2017. Contribution to the knowledge of the caddisfly fauna (Insecta: Trichoptera) of the Sharr Mountains in Kosovo. Journal of the Kansas Entomological Society, 90(4), 283
32. Kashtanjeva A., Vehapi I., Kurteshi K., Paçarizi M., Berisha A., Morina R. 2023. Assessment of Physico-Chemical, Microbiological Parameters and Diatom Algae of Badovc Lake, Kosovo. Polish Journal of Environmental Studies, 32(3), 2155–2169. https://doi.org/10.15244/pjoes/159122
33. Leudger-Laclereq 2008. IDSE Diatomic index of Saprobity-Eutrophication Conception.
34. Lecoinate,C., Coste M., Prygeil J. 1993. OMNIDA software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia, 269/270, 509–513. https://doi.org/10.1007/BF00028048
35. Musliu M., Ibrahimi H., Bilalli A., Slavevska-Stamenković V., Hinić J., Bozdogan H. 2020. New Records for the Caddisfly Fauna (Insecta: Trichoptera) of the Karadak Mountains, Western Balkans. Journal of the Entomological Research Society, 22(2), 153–162.
36. Rosenberg D.M., Resh V.H. 1993. Introduction to Freshwater Biomonitoring and Benthic Macroin vertebrates. In: Rosenberg, D.M., Resh, V.H., Eds., Freshwater Biomonitoring and Benthic Macroinver tebrates, Chapman & Hall, New York.
37. Slavevska-Stamenković V., Paunović M., Miljanović B., Kostov V., Ristovska M., Miteva, D. 2011. Water quality assessment based on the macroinvertebrate fauna-the Pcinja River case study. Water Research and Management, 1(2), 63–69.
38. Stevenson R.J., Pan Y., Vandam H. 2010. Assessing environmental conditions in rivers 1502 and streams with diatoms. In: Smol J.P., and Stoermer E.F., (2nd Eds.), The 1503 diatoms: applications for the environmental and earth sciences. Cambridge 1504 university press, London, 57–85.