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BENTHIC ALGAE AS BIOINDICATORS IN ASSESSING ECOLOGICAL STATUS OF ČEMERNICA AND DIČINA RIVERS

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Abstract: This study aimed to assess the ecological status/potential of the Čemernica and Dičina rivers (Zapadna Morava basin) based on epilithic diatoms and supporting physico-chemical parameters, as well as to explore indicative properties of the detected macroalgae. The sampling and analysis of benthic algae and measurement of physico-chemical parameters were carried out in August 2023. The ecological status/potential of the Čemernica River was poor to bad at all investigated sites (ČR1, ČR2, ČR3) based on diatom indices and physico-chemical parameters. Low diatom indices values and the presence of the macroalgae *Stigeoclonium tenue* indicated organic pollution. In the Dičina River, good ecological status was assessed at all sites (DR1-DR4) based on the diatom indices, while poor ecological status has been assessed at almost all sites (DR1, DR2, DR3) based on the physico-chemical parameters, except at DR4, where the ecological status was good. The high coverage of *Cladophora glomerata* in both rivers indicated nutrient loading, which aligned with the results of the physico-chemical parameters.

Keywords: water quality, diatom indices, macroalgae

Introduction

The Čemernica River and its longest left tributary, the Dičina River, are hilly-mountain rivers in southwestern Serbia within the Zapadna Morava River basin. The lower reaches of both rivers are indirectly polluted by industrial wastewater from Gornji Milanovac, which has led to several fish mortality events in the last two decades. In general, there is a lack of water quality studies of these rivers. The Čemernica River has only been investigated by Jurišić (2004), who explored the diversity of benthic algae and water saprobity. The monitoring program of the Serbian Environmental Protection Agency (SEPA)

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includes two sites on the Čemernica River and one site on the Dičina River. In addition, the Public Health Institute Čačak conducts monthly measurements of physico-chemical parameters at a single site on the Čemernica River.

The aim of this study was to assess the ecological status/potential of the Čemernica and Dičina rivers in accordance with the WFD (2000) (*Water Framework Directive*) based on the phytobenthos (epilithic diatoms) and supporting physico-chemical parameters, as well as to explore indicative properties of detected macroalgae.

Materials and methods

The field research was carried out in August 2023 and included three sites on the Čemernica River: ČR1 (43⁰58'55.3" N, 20⁰15'51.1" E, altitude 308 m), ČR2 (43⁰55'39.9" N, 20⁰19'29.8" E, alt. 260 m), ČR3 (43⁰54'45.2" N, 20⁰24'12.8" E, alt. 234 m) and four sites on the Dičina River: DR1 (44°06'15.4" N, 20°15'54.2" E, alt. 485 m), DR2 (44°03'44.6" N, 20°18'49.7" E, alt. 385 m), DR3 (44°02'43.6" N, 20°22'15.8" E, alt. 350 m), DR4 (44°01'31.8" N, 20°21'30.9" E, alt. 339 m).

The sampling of benthic algae, their qualitative and quantitative analysis, the measurement of physico-chemical parameters and ecological status assessment were carried out using the equipment, standard methods and regulations described in the study by Simić et al. (2018).

Results and discussion

During the research in August 2023, a total of 46 algal taxa were recorded in the Čemernica River: Cyanobacteria (1), Bacillariophyta (38), Chlorophyta (4), Charophyta (2), and Euglenophyta (1). A total of 35 taxa were recorded in the Dičina River: Cyanobacteria (1), Rhodophyta (2), Heterokontophyta (1), Bacillariophyta (27), Chlorophyta (2), Charophyta (1), and Euglenophyta (1).

The results of the quantitative analysis of the epilithic diatoms at the investigated sites are presented in Table 1.

Table 1. Quantitative analysis of epilithic diatoms in the Čemernica (ČR1, ČR2, ČR3) and Dičina (DR1, DR2, DR3, DR4) rivers - August 2023

Taxa / Site	**ČR1**	**ČR2**	**ČR3**	**DR1**	**DR2**	**DR3**	**DR4**
				%			
Achnanthidium minutissimum (Kütz.) Czarn.							2.75
Achnanthidium sp.	2.25						

Amphora ovalis (Kütz.) Kütz.	0.25	1	5.75			4.5	3.5
Amphora sp.			2				0.75
Cocconeis pediculus Ehrenb.	1	11.25	2.5		**76.5**	12.75	8
Cocconeis placentula Ehrenb.	11	1	3	**67.6**	3.5	10.5	3
Craticula cuspidata (Kütz.) Mann			0.5				
Cymbella affinis Kütz.	15	14.5	0.25	4		0.25	1
Cymbella aspera (Ehrenb.) Cleve	2	2.25		1.6			0.75
Cymbella compacta Østrup		0.5					
Cymbella neocistula Krammer	0.75	1.75					
Cymbella perparva Krammer		0.75					
Cymbella subcistula Krammer	0.25						
Cymbella tumida (Bréb. ex Kütz.) Van Heurck			0.5				
Diatoma vulgaris Bory	0.25	1	1.25	8		0.5	3.75
Encyonema leibleinii (Aga.) Silva							1.75
Encyonema minutum (Hil.) Mann	3.75	6.25	0.75	4			0.25
Encyonopsis minuta Krammer	1	0.25					
Gomphonema truncatum Ehrenb.	0.25					0.75	
Gyrosigma acuminatum (Kütz.) Rabenh.				0.8			1
Gyrosigma attenuatum (Kütz.) Rabenh.			1.75				0.75
Melosira varians Aga.			**46.5**	1.6	9	**35**	**44**
Navicula capitoradiata Germ. ex Gasse						13.25	12
Navicula cryptocephaloides Hust.			3.25				
Navicula radiosa Kütz.	0.75		0.75				
Navicula sp.						0.5	
Navicula subrhynchocephala Hust.	1.75	1.25					
Navicula tripunctata (Müll.) Bory	0.75		1.5			11.75	14
Navicula viridula (Kütz.) Ehrenb.			2.5			2.5	0.25
Nitzschia brevissima Grunow		0.5					
Nitzschia communis Rabenh.	0.75						
Nitzschia denticula Grunow	1.75	1.25					
Nitzschia dissipata (Kütz.) Rabenh.	1.75						
Nitzschia linearis (Aga.) Smith	1.5	0.25	0.25		7.5	1	0.75
Nitzschia palea (Kütz.) Smith	**43.25**	**42.75**	13				
Nitzschia sp.							0.25
Rhoicosphenia abbreviata (Aga.) Lange-Bert.	4	0.5	5	12.4	2	4.5	0.5

Stauroneis kriegeri Patrick						0.25	
Stauroneis sp.	0.25						
Surirella lacrimula English			0.25				
Surirella librile (Ehrenb.) Ehrenb.			4.5				
Surirella tenera Gregory			1.25			1	
Surirella undulata Ehrenb.			0.25			0.25	0.25
Ulnaria ulna (Nitzsch) Compère	5.75	13	0.75		0.5	0.75	0.75
Ulnaria ulna var. *contracta* (Østrup) Morales			0.75		1		

The following benthic macroalgae were detected: *Cladophora glomerata* (L.) Kütz. (ČR1- 95%; ČR2- 10%; ČR3- 30%; DR2- 40%; DR3- 90%; DR4- 40%), *Stigeoclonium tenue* (Agardh) Kütz. (ČR1- 1%), *Hildenbrandia rivularis* (Liebmann) Agardh (DR1- 10%), *Audouinella pygmaea* (Kütz.) Weber Bosse (DR2 and DR3- 1%), *Microcoleus autumnalis* (Gomont) Strunecký et al. (DR3- 1%), and *Tribonema regulare* Pascher (DR4- 5%). The physico-chemical parameters measured at the sites of the Čemernica and Dičina rivers are listed in Table 2.

Table 2. Measured physico-chemical parameters at the investigated sites of Čemernica (ČR1, ČR2, ČR3) and Dičina (DR1, DR2, DR3, DR4) rivers

Parameter / Site	**ČR1**	**ĆR2**	**ČR3**	**DR1**	**DR2**	**DR3**	**DR4**
pH	7.9	8.12	8.11	7.4	6.7	6.7	7.5
Oxygen conc. (mg/L)	7.67	8.79	8.76	9.46	13.10	9.56	11.69
BOD (mg/L)	1.9	3.8	4.25	1.3	1.9	1.25	1.95
PO_4-P (mg/L)	0.36	0.58	1.18	0.16	0.38	0.47	0.09
TP (mg/L)	0.12	0.19	0.38	0.05	0.12	0.15	0.03
NO_3-N (mg/L)	<4	12	14	9	8	8	<4
NH_4-N (mg/L)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

Based on the diatom indices, the ecological status of the Čemernica River was assessed as bad at ČR1 (IPS=7; CEE=5.6) and ČR2 (IPS=7.2; CEE=4.8), while poor ecological potential was assessed at ČR3 (IPS=10.9). At all sites of the Dičina River, the ecological status was assessed as good based on the diatom indices (IPS=15.5, CEE=13.8; IPS=14.8, CEE=12.2; IPS=14.2, CEE=12.2; IPS=14.6, CEE=12.6; respectively). Considering that the IPS and CEE indices are primarily indicative of organic pollution (Cemagref, 1982; Descy and Coste, 1991), it can be concluded that the Čemernica River, unlike the Dičina River, was impacted by organic matter. Based on physico-chemical parameters, a poor (ČR1) to bad (ČR2) ecological status and a bad ecological potential (ČR3) were assessed

along the Čemernica River, while the Dičina River sites exhibited a good (DR4) to poor (DR1, DR2, DR3) ecological status. Jurišić (2004) determined that the water of the Čemernica River is β- to α-mesosaprobic based on the presence of benthic algae. SEPA monitoring in 2012/13 determined moderate ecological potential for ČR2 and poor ecological status for ČR3 based on physico-chemical parameters, while both sites exhibited moderate ecological status/potential based on diatom indices (Denić et al., 2015). The results of the Public Health Institute Čačak in August 2023 show a moderate ecological status based on physico-chemical parameters (Anonymous, 2023). Our results suggest a deterioration in water quality compared to all previous studies.

Although macroalgae were not used in the assessment of ecological status in Serbia, their usage is recommended by the WFD (2000) due to their indicative properties. The green alga *Cladophora glomerata* tends to cover entire riverbeds at high nutrient concentrations (Michalak and Messyasz, 2020), which was observed in ČR1 and DR3. *Stigeoclonium tenue*, detected in ČR1, is known to indicate organic pollution (Jafari and Gunale, 2006) and is associated with poor to bad water quality (Carmoma-Jimenez et al., 2022), which is consistent with our results. The red alga *Hildenbrandia rivularis*, previously known as an indicator of oligotrophic waters, is considered a species resistant to inorganic pollution according to recent data (Jakubas-Krzak et al., 2023). This is confirmed by the discovery of this species at the DR1 site, where high nitrate concentrations were detected.

Conclusion

The Čemernica River exhibits a poor to bad ecological status/potential at all surveyed sites (ČR1, ČR2, ČR3), based on diatom indices and physico-chemical parameters. At all sites of the Dičina River, based on the diatom indices, good ecological status was assessed, while based on physico-chemical parameters it ranged from good (DR4) to poor (DR1, DR2, DR3). Some of the identified species of macroalgae have proven to be good indicators of inorganic and organic pollution in these rivers.

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