

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

Kristina Markeljić¹, Aleksandra Rakonjac², Nevena Đorđević³, Duško Brković¹,
Snežana Simić³

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)

¹University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, Čačak, Serbia (kristina.markeljic@kg.ac.rs)

²Institute for Vegetable Crops, Karađorđeva 71, Smederevska Palanka, Serbia

³University of Kragujevac, Faculty of Science, Radoja Domanovića 12, Kragujevac, Serbia

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 (43°58'55.3" N, 20°15'51.1" E, altitude 308 m), ČR2 (43°55'39.9" N, 20°19'29.8" E, alt. 260 m), ČR3 (43°54'45.2" N, 20°24'12.8" 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
%								
<i>Achnantheidium minutissimum</i> (Kütz.) Czarn.								2.75
<i>Achnantheidium</i> sp.		2.25						

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

<i>Stauroneis kriegeri</i> Patrick						0.25	
<i>Stauroneis</i> sp.	0.25						
<i>Surirella lacrimula</i> English			0.25				
<i>Surirella librile</i> (Ehrenb.) Ehrenb.			4.5				
<i>Surirella tenera</i> Gregory			1.25			1	
<i>Surirella undulata</i> Ehrenb.			0.25			0.25	0.25
<i>Ulnaria ulna</i> (Nitzsch) Compère	5.75	13	0.75		0.5	0.75	0.75
<i>Ulnaria ulna</i> var. <i>contracta</i> (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) Strunický 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	ČR2	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.

Acknowledgement

Work on this paper was supported by Ministry of Education, Science and Technological Development of Republic of Serbia (451-03-66/2024-03/200088, 451-03-65/2024-03/200122, 451-03-66/2024-03/200216).

References

- Anonymous (2023). Rezultati ispitivanja kvaliteta površinskih voda na području grada Čačka u 2023. godini. Available: <https://www.zdravljecacak.org/korisne-informacije>.
- Carmoma-Jiménez J., Salinas-Camarillo V., Caro-Borrero A. (2022). The Macroalgae Ecological Quality Index (MEQI) in the Basin of Mexico: a proposal of aquatic bioindicators for peri-urban rivers. *Revista Mexicana de Biodiversidad*, 93 (1): 13.
- Cemagref C. (1982). Étude des méthodes biologiques quantitative d'appréciation de la qualité des eaux. Rapport Division Qualité des Eaux Lyon—Agence financière de Bassin Rhône-Méditerranée-Corse, Pierre-Bénite, 218 pp.
- Denić Lj., Čađo S., Đurković A., Novaković B., Dopuđa-Glišić T., Veljković N., Stojanović Z., Milovanović J., Domanović M. (2015). Status površinskih voda Srbije, Analize i elementi za projektovanje monitoringa. Ministarstvo poljoprivrede i zaštite životne sredine, Agencija za zaštitu životne sredine, Beograd, 232 pp.
- Descy J., Coste M. (1991). A test of methods for assessing water quality based on diatoms. *Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen*, 24 (4): 2112-2116.
- Jafari N., Gunale V. (2006). Hydrobiological study of algae of an urban freshwater river. *Journal of Applied Sciences and Environmental Management*, 10 (2): 153-158.
- Jakubas-Krzak E., Gąbka M., Panek P., Kowalski W., Lisek D., Smoczyk M., Rybak A. (2023). The red alga *Hildenbrandia rivularis* is a weak indicator of the good ecological status of riverine habitats. *Ecological Indicators*, 147, 109918.
- Jurišić I. (2004). Benthic algal community structure and water quality of the Zapadna Morava River basin near Čačak. *Acta Agriculturae Serbica*, 9 (18): 13-33.
- Michalak I., Messyasz B. (2021). Concise review of *Cladophora* spp.: macroalgae of commercial interest. *Journal of Applied Phycology*, 33 (1): 133-166.
- Simić S., Petrović A., Đorđević N., Vasiljević B., Radojković N., Mitrović A., Janković M. (2018). Indicative ecological status assessment of the Despotovica River. *Kragujevac Journal of Science*, 40: 227-242.
- WFD (2000). Water Framework Directive - Directive of European Parliament and of the Council 2000/60/EC.