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Benthic algal community structure and water quality of the Zapadna Morava River Basin near Cacak

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Abstract: Rivers provide their living world with a multitude of microhabitats, the mutual characteristic of which is a directed water flow. Other characteristics (water chemistry, size of the basin area, amount of water, flow rate, erosion, temperature and light regimes) are directly affected by the regions the rivers flow through.

The samples for algological investigations were collected and processed using standard methods (Kann after Schwoerbel 1970, Husted 1969 after Krammer Lange-Bertalot 1986, Vollenweider 1971). Determination of the water quality of the Zapadna Morava, Kamenica and the Cemernica rivers, based on algae as bioindicators, was made using methods after Pantle-Buck (1955), Zelinka, Marvan, Kubicek (1959) and after Zelinka, Marvan (1963).

Over the study period, at all the sites investigated, the presence of 145 taxa from 6 divisions was determined, the divisions being: *Cyanophyta, Pyrrophyta, Xanthophyta, Bacillariophyta, Euglenophyta* and *Chlorophyta*.

The water quality was much affected by general hydrologic conditions and it ranged from oligosaprobic (the Kamenica) to α-mesosaprobic (the Cemernica) zone.

Key words: algal floristic composition, community types, water quality

Introduction

The Zapadna Morava is a highland river type, particularly in its upper and middle streams. Its two left tributaries, the Kamenica and the Cemernica, are typical highland rivers. Part of the basin in the immediate vicinity of Cacak is a recipient of a large amount of various kinds of waste waters. It was a subject matter of a number of researches conducted within the framework of investigations

on the quality and care for the protection of water resources (Markovic et al. 1992; Djukic et al. 1994, 1997; Djukic 1996; Djurkovic et al. 1998; Jurisic and Kalinic 1998; Simovic and Markovic 1998; Jurisic et al. 1999; Tomasevic 2000). This paper is part of a detailed investigation conducted in 1996 for the master's degree thesis entitled: Floristic composition, dynamics of changes in the benthic algal communities structures and in the water quality of the part of the Zapadna Morava River Basin near Cacak (Jurisic, 2003). Of eight sites being investigated, four were at the Zapadna Morava and two at the Kamenica and the Cemernica each. The eight sites selected for the monitoring covered part of the Zapadna Morava stream 500 m below the dam in Medjuvrsje to the village of Stancici, 6 km downstream from Cacak. Polluters are present in this part of the stream - the industrial Cacak zone with its waste waters and municipal sewage effluent discharge. This is also where the Kamenica and the Cemernica tributaries flow into the Zapadna Morava. The sites included different types of substrates over which the river flows, different bottom types, as well as different types of vegetation.

Material and Methods

The paper used results of standard physico-chemical water sample analyses (Anonymous, 1990) made by the Chemical Laboratory of the Health Institute in Cacak.

The algal material was sampled during 1996 on a monthly basis.

At the sites investigated, using standard methods (Kann after Schwoerbel 1970, Vollenweider 1971), the samples for algological researches were collected from benthos and epiphyte communities (according to the living community division as presented in Round 1970) from all bottom types and immediately fixed with 4% formaldehyde.

The algal material was examined in the laboratories of the Department of Algology, Mycology and Lichenology, Botany Research Institute, Faculty of Biology, University of Belgrade. The algae were examined using a Reichert Diastar^{TM} microscope, with a digital camera Canon Power Shot S40, which filmed the algae directly from the sample.

While making permanent silicate algae preparations, part of each sample was tested by a standard procedure with concentrated sulphuric acid (Husted 1969 after Krammer Lange-Bertalot 1986) and then soaked in synthetic resin CEDAX.

Algal identification was done according to the keys:

Cyanophyta: Cvijan, Blazencic 1996; Gollerbah, Kosinskaja, Poljanski 1953; Elenkin 1938, 1949; Starmach 1966.

Pyrrophyta: Popovský, Pfiester 1990; Starmach 1972 b.

Xanthophyta: Ettl 1990.

Bacillariophyta: Kramer, Lange-Bertalot 1986, 1988, 1991a, 1991b

Euglenophyta: Starmach 1983; Gojdics 1953.

Chlorophyta: Hindák 1984, 1988, 1990; Huber-Pestalozzi, Komárek and Fott 1983; Krieger and Gerloff 1962; Pascher 1915; Ruzicka 1977; Starmach 1972a; Kosinskaja 1960; Palama – Mordvinceva 1982; Lind and Brook 1980.

The taxa were classified into divisions (according to the classification by Blazencic 1997), and into classes and orders respecting the taxonomic-evolutionary sequence. Lower taxonomic categories (species, varieties and forms) were arranged in alphabetical order. The families *Botryococcaceae* and *Coelastraceae* (*Chlorophyta*) were systematized according to Huber-Pestalozzi 1983.

Categorization of the benthic algal communities of the investigated rivers was made using the classification of benthic communities according to the substrate type (Round 1970).

As regards the taxa forming macroscopic aggregations on the bottom, coverage was determined with respect to relative values of the five-grade scale according to Braun-Blanquet (Jankovic 1979).

In terms of the coverage, the taxa covering more than 25 % of the bottom surface, of $2m^2$ size, were recognized as dominant ones. The number of the present taxa of the silicate algae in the samples investigated was determined according to the percentage of valves of each taxon compared to the total count of 500 valves on each permanent preparation (Round 1993). In terms of the total number, the taxa present with 25% and more compared to the total number of valves were found to be dominant.

Diversity of the silicate algae, (as main edificators of the benthic communities in the rivers investigated), was established according to the Shannon-Weaver diversity index (Shannon, Weaver 1949).

The taxa presence probability was estimated for easier interpretation and further comparison of the results on the silicate algae diversity (I) (Poole 1974).

Determination of the water quality of the Zapadna Morava, Kamenica and the Cemernica rivers in the research period, based on the algae as bioindicators, was done applying standard methods after Pantle-Buck (1955), Zelinka, Marvan, Kubicek (1959) and Zelinka, Marvan (1963) using the indicator organism list (www.ecograde.bio.msu.ru/opis4.htm).

Results and Discussion

Floristic algal composition

In the study period at all the investigated sites determination was made of the presence of 145 taxa from 6 divisions: *Cyanophyta, Pyrrophyta, Xanthophyta, Bacillariophyta, Euglenophyta* and *Chlorophyta* (Tab. 1).

Tab. 1 Floristic list of algae from the Zapadna Morava, Cemernica and the Kamenica rivers from January to December 1996

CYANOPHYTA
Class: Chroococcophyceae
Order: Chroococcales
Family: Merismopediaceae
Merismopedia tenuissima LEMM.

Class: Hormogoniophyceae
Order: Oscillatoriales
Family: Oscillatoriaceae
Lyngbya attenuata F. E. FRITSCH
Oscillatoria irrigua (KÜTZ) GOM.
Oscillatoria limosa AG.
Oscillatoria VAUSCH.*sp*.
Oscillatoria subtillissima KÜTZ.
Oscillatoria tenuis AG.
Phormidium favosum (BORY) GOM.
Spirulina major KÜTZ.
Spirulina subtilissima KÜTZ.

PYRROPHYTA
Class: Dinophyceae
Order: Peridiniales
Family: Peridiniaceae
Peridinium bipes SEIN
Peridinium EHR.*sp*.
Peridiniopsis oculatum (STEIN) BOURRELLY

XANTHOPHYTA
Class: Xantotrichophyceae
Order: Tribonematales
Family: Tribonemataceae
Tribonema minus (KLEBS) HAYEN

BACILLARIOPHYTA
Class: Centrophyceae
Order: Coscinodiscales
Family: Melosiraceae
Aulaceoseira granulata (EHR.) SIMONSEN
Melosira varians AGARDH
Family: Thalassiosiraceae
Cyclotella meneghiniana KÜTZ.
Class: Pennatophyceae
Order: Araphales
Family: Fragilariaceae
Diatoma mesodon (EHR.) KÜTZ.
Diatoma moniliformis KÜTZ.
Diatoma vulgaris BORY
Diatoma vulgaris var. capitulata GRUN.
Fragilaria arcus (EHR.) CLEVE

Fragilaria capucina var. vaucheriae (KÜTZ.) L.- B
Fragilaria parasitica var. subconstricta GRUN.
Fragilaria (NITZ) *sp.*
Fragilaria tenera (W. SMITH) L.-B.
Fragilaria ulna (NITZ) L.- B. Sippen *ulna* sensu L.- B.
Fragilaria ulna Sippen *acus* sensu L.- B.
Fragilaria ulna var. *oxyrinchus* (KÜTZ.) L.- B.
Meridion circulare (GREV.) AG.
Tabellaria flocculosa (ROTH.) KÜTZ.

Order: Monoraphales
Family: Achnanthaceae

Achnanthes lanceolata ssp. *lanceolata* (BRÉB.) GRUN.
Achnanthes minutissima KÜTZ. var. *minutissima* KÜTZ.
Achnanthes BORY *sp.*
Cocconeis pediculus EHR.
Cocconeis placentula var. *euglypta* (EHR.) GRUN.
Cocconeis placentula var. *lineata* (EHR.) VAN HEURCK
Cocconeis EHR.*sp.*

Order: Diraphales
Family: Naviculaceae

Amphora libyca EHR.
Amphora montana KRASSKE
*Amphora ovalis (*KÜTZ.) KÜTZ.
Amphora pediculus (KÜTZ.) GRUN.
Amphora veneta KÜTZ.
Caloneis amphisbaena (BORY) CLEVE
Caloneis macedonica HUST.
Caloneis silicula (EHR.) CLEVE
Cymbella affinis KÜTZ.
Cymbella austriaca GRUN.
Cymbella caespitosa (KÜTZ.) BRUN.
Cymbella cistula (EHR.) KIRCH.
Cymbella helvetica KÜTZ.
Cymbella lanceolata (EHR.) VAN HEURCK
Cymbella minuta HILSE
Cymbella prostrata (BERK.) CLEVE
Cymbella sinuata GREG.
Diploneis elliptica (KÜTZ.) CLEVE
Frustulia vulgaris (THWAIT.) DE TONI
Gomphonema acuminatum EHR.
Gomphonema augur EHR.
Gomphonema olivaceum (HORN) BRÉB var. *olivaceum*
Gomphonema parvulum KÜTZ.
Gomphonema truncatum EHR.
Gyrosigma acuminatum (KÜTZ.) RABH.
Gyrosigma attenuatum (KÜTZ.) RABH.

Navicula capitata EHR. var. *capitata*
Navicula capitatoradiata *GERMAIN*
Navicula cryptocephala KÜTZ.
Navicula cryptotenella L.-B.
Navicula cuspidata KÜTZ.
Navicula goeppertiana (BLEISCH) H. L.var. *goeppertiana*
Navicula gregaria DONKIN
Navicula halophila (GRUN.) CLEVE
Navicula laevissima KÜTZ. var. *laevissima*
Navicula lanceolata (C. AG.) EHR.
Navicula mutica KÜTZ.var. *ventricosa* (KÜTZ.) CLEVE & GRUN.
Navicula pupula KÜTZ.var. *pupula*
Navicula BORY *sp.*
Navicula tripunctata (O. F. MÜLL) BORY
Navicula viridula var. *rostelata* (KÜTZ.) CLEVE
Neidium dubium (EHR.) CLEVE
Pinnularia microstauron (EHR.) CLEVE var.*brebissonii* (KÜTZ.) MAYER
Pinnularia EHR. *sp.*
Rhoicosphenia abbreviata (AG.) L.-B.

Order: Aulonoraphales

Family: Bacillariaceae

Hantzschia amphioxys (EHR.) GRUN.
Nitzschia brevissima GRUN.
Nitzschia constricta (KÜTZ.) RALFS.
Nitzschia dissipata (KÜTZ.) GRUN.var. *dissipata*
Nitzschia fonticola GRUN.
Nitzschia frustulum (KÜTZ.) GRUN.
Nitrzschia linearis (AG.) W. SMITH
Nitzschia palea (KÜTZ.) W. SMITH
Nitzschia sigmoidea (NITZSCH.) W. SMITH
Nitzschia sinuata var. *tabellaria* (GRUN.) GRUN.
Nitzschia terestris (PETERSEN) HUST.
Nitzschia vermicularis (KÜTZ.) HANTZSCH

Family: Epithemiaceae

Epithemia turgida (EHR.) KÜTZ.
Epithemia turgida var. *westermanii* (EHR.) GRUN.
Rhopalodia O. Müller *sp.*

Family: Surirellaceae

Cymatopleura elliptica (BRÉB.) W. SMITH
Cymatopleura solea (BRÉB.) W. SMITH
Cymatopleura solea var. *apiculata* (W. SMITH) RALFS
Surirella angusta KÜTZ.
Surirella biseriata BRÉB.
Surirella brebissonii KRAMMER &LANGE- BERTALOT
Surirella brebissonii var. *kuetzinginii* KRAMMER &LANGE- BERTALOT

Surirella linearis W. SMITH
Surirella minuta BRÉB.
Surirella tenera GREG**.**

EUGLENOPHYTA
Class: Euglenophyceae
Order: Euglenales
Family: Euglenaceae
Euglena acus EHR.
Euglena pavlovskoensis (ELENKIN et POLJANSKIJ) POPOVA
Euglena EHR.sp.
Lepocinclis PERTY *sp.*
Phacus acuminatus STOKES
Phacus pleuronectes EHR. DUJ.
Family: Anisonemataceae
Peranema trichophorum EHR. LARSEN

CHLOROPHYTA
Class: Volvocophyceae
Order: Volvocales
Family: Volvocaceae
Pandorina morum (O. F. MÜLL) BORY
Class: Protococcophyceae
Order: Chlorococcales
Family: Hydrodictyaceae
Pediasrum boryanum (TURP.) MENEGH.
Pediastrum boryanum var. *brevicorne* A. BR.
Pediastrum boryanum var. *lonngicorne* REINSCH.
Pediastrum duplex var. *rugulosum* RACIB
Pediastrum (MEYEN) *sp.*
Pediasrum tetras (EHR.) RALFS
Family: Micratiniaceae
Micractinium pusillum FRES.
Family: Botryococcaceae
Subamily: Dictyosphaeroideae
Dictyosphaerium NÄG. *sp.*
Family: Oocystaceae
Kirchneriella irregularis (G. M. SMITH) KORŠ var. *irregularis*
Monoraphidium contortum THUR. KOM.-LEGN.
Monoraphidium KOM.-LEGN. *sp.*
Scenedesmus acutus MEYEN
Scenesedmus acutus MEYEN var. *acutus*
Scenedesmus dimorphus *(TURP.) KÜTZ.*
Scenedesmus obtusus MEYEN
Scenedesmus opoliensis P. RICHT.

Scenedesmus MEYEN sp.
Tetraedron minimum (A. BR.) HANSG.
Family: Coelastraceae
Coelastrum microporum NÄG. in A. BR.
Coelastrum microporum var. *octaedricum* (SKUJA) SODOMK.
Class: Ulotrichophyceae
Order: Chaetophorales
Family: Chaetophoraceae
Stigeoclonium tenue KÜTZ.
Order: Ulothrichales
Ulothrix KÜTZ. *sp.*
Class: Siphonophyceae
Order: Siphonocladales
Family: Cladophoraceae
Cladophora glomerata (L.) KÜTZ.
Class: Conjugatophyceae
Order: Zygnematales
Family: Spirogyraceae
Spirogyra LINK *sp.*
Order: Desmidiales
Family: Desmidiaceae
Closterium littorale GAY var. *littorale*
Closterium NITZSCH. *sp.*
Cosmarium laeve RABENH.
Cosmarium botrytis MENEG.
Cosmarium CORDA *sp.(difficile)*

In terms of the number of taxa, *Bacillariophyta* and *Chlorophyta* predominated with 94 taxa (64.82%) and 30 taxa (20.4%), respectively.

The share of all other divisions was 14.48%, 6.89% of which were *Cyanophyta* (Tab. 2).

The algal community structures are presented by the rivers, for each separate site, for the whole study period (tables 3, 4 and 5).

Tab. 2. The occurrence of algal divisions in the Zapadna Morava, Kamenica and the Cemernica

Division	Number of Taxa	*% Occurrence*
Cyanophyta	10	6.89
Pyrrophyta	3	2.06
Xanthophyta	1	0.68
Bacillariophyta	94	64.82
Euglenophyta	7	4.82
Chlorophyta	30	20.4
Total	145	100

Tab. 3. The algal community structure in the Zapadna Morava River by sites

Site	1. Medjuvrsje		2. Cacak		3. Konjevici		4. Stancici	
Division	No. of taxa	% share	No. of taxa	% share	No. of taxa	% share	No. of taxa	% share
Cyanophyta	7	8.5	8	8.9	6	5.8	5	5
Pyrrophyta	1	1.2	2	2.2	1	0.97	2	2
Xanthophyta	-	-	-	-	1	0.97	1	1
Bacillariophyta	66	80	64	71.9	79	76.7	70	70.7
Euglenophyta	2	2.4	3	3.3	3	2.9	3	3
Chlorophyta	6	7.3	12	13.4	13	12.6	18	18
Total	82	100	89	100	103	100	99	100

Tab. 4. The algal community structure in the Kamenica River by sites.

Site	5. Caganje		6. Prijevor	
	No. of taxa	% share	No. of taxa	% share
Division				
Cyanophyta	6	7.1	5	5.2
Pyrrophyta	-	-	1	1.0
Xanthophyta	1	1.2	-	-
Bacillariophyta	59	70.2	72	75.0
Euglenophyta	2	2.3	3	3.1
Chlorophyta	16	19	15	15.6
Total	84	100	96	100

Tab. 5. The algal community structure in the Cemernica River by sites

Site	7. Miokovci		8. Preljina	
Division	No. of taxa	% share	No. of taxa	% share
Cyanophyta	2	3.4	7	8.4
Pyrrophyta	-	-	-	-
Xanthophyta	-	-	-	-
Bacillariophyta	49	84.4	67	80.7
Euglenophyta	1	1.7	1	1.2
Chlorophyta	6	10.3	8	9.6
Total	58	100	83	100

There are numerous abiotic and biotic factors affecting formation and survival of the benthic algal community.

Temperature (Small, Constable 1991; Duncan, Blinn 1989), pH (Van Dam et al. 1994; Pan et al. 1996) but also the substrate type (Aboal 1989) and the presence of phosphates and nitrates (Van Dam, Mertens 1995; McCormick et al 1996) are major abiotic factors considerably affecting development and composition of algal communities. Invasive capability and spatial competition (Stevenson 1984; Stevenson, Peterson 1989; McCormick, Stevenson 1991), apart from other species interactions such as predatorship, allelopathy, parasitism, (Patrick 1976), are very important biotic factors.

Temperature regime of the investigated river water was dependent upon meteorological conditions and season. Minimal water temperatures of the three rivers were measured in January and they were: 3ºC of the Morava and 0ºC of the Kamenica and the Cemernica. Temperature maximum was reached during the summer, in August (Morava 22ºC, Kamenica 22.5ºC and Cemernica 19.5ºC).

During the year, pH was constantly slightly alkaline. The values measured in the Zapadna Morava ranged from 7.84 to 8.4, and somewhat higher values were recorded for the Kamenica and the Cemernica, being 8.25-8.83 and 8.22-8.76, respectively.

The taxa present in the investigated rivers were eurythermal, tolerating temperature variations of 20ºC or more. Furthermore, alkalophilous species predominated, some of which belonging to the genera *Amphora*, *Cocconeis* and *Diatoma* had high indicatory pH values (Tomasevic 2000). Data on the absence of the species from the *Eunotia* genus are in accordance with the previous investigations (Tomasevic 2000).

Of the total number of the determined taxa (145), *Bacillariophyta* were found to be absolutely predominating ones with 64.82% of all the identified taxa, the majority of which belonged to the genera *Navicula, Nitzschia, Cymbella* and *Fragilaria*. They are followed by *Chlorophyta* (20.4%) the most diverse genera of which were *Pediastrum* and *Scenedesmus*. Such relations in terms of the floristic diversity are a characteristic of all the three rivers (tab. 3, 4, and 5). The lowest diversity in terms of the number of taxa was registered with the Cemernica, where *Bacillariophyta* predominated, followed by Chlorophyta, and *Cyanophyta* which with 7 taxa (8.4%) had a greater share than in the previous two rivers. In terms of the floristic composition, the Zapadna Morava, Kamenica and the Cemernica rivers showed similarities with rivers having similar characteristics (Obuskovic, Kalafatic 1979; Obuskovic 1984, 1997; Martinovic-Vitanovic, Gucunski 1983; Martinovic-Vitanovic 1985).

The dominance of silicate algae in a benthic community depends on the characteristics of river habitats: type of habitat (Round 1993, Rönkko 1988, Cattaneo 1996), flow rate (Stevenson 1984, Biggs, Thomsen 1995), low water temperature (Patrick 1977, Kawecka 1980), nutrient availability and energetic mixing of water layers (Tryfon 1996), being factors favouring their development.

The following *Bacillariophyta* taxa are the most pronounced: *Achnanthes minutissima* var. *minutissima*, *Aulacoseira granulata, Cocconeis pediculus, C. placentula* var. *euglypta*, *Cymbella affinis*, *C. cistula*, *C. minuta*, *Diatoma moniliformis, D. vulgaris, Fragilaria ulna* var. *ulna*, *F. capucina* var. *vaucheriae*, *F. ulna* var. *acus*, *Gomphonema olivaceum* var. *olivaceum*, *Melosira varians, Navicula cryptocephala, N. cryptotenella, N. gregaria, N. lanceolata, N. mutica* var. *ventricosa*, *Nitzschia dissipata* var. *dissipata* and *Rhoicosphenia abbreviata*. These are the very taxa that are mentioned in literature (Aboal et al. 1996, Kawecka 1980, Krstic et al. 1994, Lausevic, Cvijan 1996, Lausevic 1997, Nikitovic, Lausevic 1995, Nikitovic 1998, Tomasevic 2000, Subakov 2001, Vis et al. 1998) as the ones most frequently found in different types of rivers. Apart from these, there appear other species, too, *Achnanthes lanceolata, Diatoma mesodon, Fragilaria arcus, Gomphonema parvulum, Meridion circulare* and *Tabellaria flocculosa*, frequently present in highland rivers, and occurring in the

Zapadna Morava, the Kamenica and the Cemernica, but not continually, nor in a significant number as the former ones are.

Diatoma mesodon, Gomphonema acuminatum, Navicula capitata var. *capitata, N. goepertiana* var. *goepertiana, N. viridula* var. *rostelata* were found only in the Zapadna Morava. *Caloneis macedonica, Nitzschia terestris, Surirella brebissonii* and *Tabellaria flocculosa* were present only in the Kamenica, and *Fragilaria parasitica* var. *subconstricta* and *Surirella tenera* occurred only in the Cemernica. The taxa found in both the Zapadna Morava and the Cemernica and absent from the Kamenica are: *Amphora veneta, Diatoma vulgaris* var. *capitulata, Gomphonema augur, Gyrosigma attenuatum, Navicula capita-toradiata, Nitzschia brevissima* and *N. vermicularis*. *Caloneis amphisbaena, Cymbella austriaca, Surirella brebissonii* var. *kuetzinginnii* are found in both the Kamenica and the Cemernica but are absent from the Zapadna Morava. Still, apart from these differences, we may say that there is a floristic similarity among the silicate algae in these three rivers.

An active response of the community to the stressful conditions in the habitat or to the activity of biotic factors such as competition, colonization or dying, can be seen through the presence or absence of a certain number of taxa or through a decreased possibility of their presence. A dynamic condition resulting from these processes can be monitored through the changes in the diversity index and the possibility of the presence of certain taxa in the community.

The diversity index values (H) for the benthic silicate algae of the Zapadna Morava ranged from 1.97 to 4.76 and accompanying values of a possible presence of certain taxa (I) varied from 0.58 to 0.95. Diversity index of the silicate algae of the Kamenica ranged from 1.67 to 4.45, and that in the Cemernica from 1.37 to 4.17. A possibility of finding a certain taxon in the Kamenica and the Cemernica rivers varied from 0.37 to 0.91, and 0.32 to 0.81, respectively. The values obtained conform to the literature data for similar habitats (Nikitovic 1998).

The benthic algal community of the Zapadna Morava, Kamenica and the Cemernica Rivers was characterized by a significant development of macroscopic aggregations covering a considerable bottom surface of these three rivers through the year. Their composition was uniform and the predominating ones were: *Cladophora glomerata, Ulothrix sp*. and *Phormidium favosum*. *Cladophora glomerata* formed two kinds of overgrowths depending on the flow rate (Parodi, Cáceres 1991 after Bergey 1995): light green branched forms developing on stone parts exposed to water beats and dark forms (the colour coming from a mass of epiphytic silicate algae), with short threads, in secluded parts. It was present during the major part of the year, dominating in summer months, as depicted in literature (Vis et al. 1998), when it was favoured by high light intensity, pH values higher than 7 and water hardness (Whitton 1970). A certain deviation was recorded in the Kamenica and the Cemernica rivers, where, depending on the site, it predominated in other periods of the year as well.

Macroscopic aggregations being developed in the Zapadna Morava by *Ulothrix sp*. were brown mucilaginous forms with short loosened threads. They more strongly developed in spring. This seasonal dynamics is depicted by Vis et al. 1998 and Kjeldsen et al. 1996 as well. In the Kamenica and the Cemernica rivers, the *Ulothrix sp*. aggregations developed from April to September,

probably due to the water flow rate. During the spring months the two rivers were very rapid. Namely, *Ulothrix sp*. does not develop in small mountain rivers with a high flow rate (Kawecka 1990).

Phormidium favosum formed blue-green leathery aggregations covering stone, their characteristic habitat, directly exposed to water beats (Lausevic 1992a; Simic 1995; Nikitovic 1998) but also in secluded sheltered parts. No regularity in their development during the year can be established in either of the investigated rivers, being in accordance with literature results (Kawecka 1981).

Brown-green flaky aggregations of *Spirogyra sp*. were present in the Zapadna Morava and the Kamenica as well. They developed in the summer months in the Zapadna Morava, and from April to October, depending on the site, in the Kamenica River. The presence of *Oscillatoria tenuis* in macroscopic aggregations of mucilaginous appearance and of dark blue or blue-green colour was more pronounced in the summer months.

A mucilaginous flaky overgrowth of *Lyngbya attenuata* developed in the Zapadna Morava in July, at the first two sites, but especially at the second one.

In July, in the Kamenica River, *Stigeoclonium tenue*, favoured by low river depth, and favourable nitrogen and phosphorus concentrations (this species can be used as an eutrophication indicator), formed macroscopic aggregations. In the spring months, under the conditions of high light intensity and low nutrient concentration, *Stigeoclonium tenue* was not sufficiently competitive (Rosemond, Brawley 1996). The mentioned taxa, constructors of macroscopic aggregations, are mentioned by other authors as well, as being particularly present in the rivers belonging to the Zapadna Morava basin (Obuskovic, Kalafatic 1979; Obuskovic 1984, 1997; Martinovic-Vitanovic 1985).

According to the type of substrate they inhabit, the algae are classified into: epilithic, epipelic, epipsamic, epiphytic and epizoic (Round 1970). The samples collected for the analysis contained different types of substrates (stone, gravel, silt and aquatic plants). The epilithic and epiphytic communities were dominant in the Kamenica and the Cemernica rivers, as well as at the first two sites at the Zapadna Morava. Besides these two communities, a well developed epipelic community is present at other two sites at the Zapadna Morava. The algae forming macroscopic aggregations (*Cladophora glomerata, Ulothrix sp., Phormidium favosum, Spirogyra sp., Stigeoclonium tenue* and *Oscillatoria sp*.) are typical constructors of epilithic communities. The silicate algae, primarily those adhering with the mucilaginous sheath to the stone, are epilithic, forming visible flaky coatings. The algae occurring as epilithic in the Zapadna Morava, Kamenica and the Cemernica rivers are the following: *Achnanthes minutissima var.minutissima, Cymbella affinis, C. minuta, C. prostrata, Diatoma vulgaris, Melosira varians* and *Navicula viridula*.

Owing to the well developed macroscopic aggregations of the epilithic algae, the epiphytic community inhabiting them was also well developed. The most frequent epiphytic algae in all the three investigated rivers belonged to the division Bacillariphyta, colonizers of *Cladophora glomerata* (*Cocconeis species, Epithaemia species, Gomphonema oivaceum, Rhoisosphaenia abbreviata*). The taxa present were *Meridion circulare, Achnanthes minutissima, A. lanceolata* and *Cocconeis placentula* that in waters abounding in lime develop on Fontinalis

(Round 1970). It is difficult to say whether the species like *Meridion circulare* and *Tabellaria flocculosa*, present in both communities, were authentically epilithic or whether they have secondarily come there.

The epipelic community is represented by a great number of taxa. Characteristic taxa are the species from the genera *Amphora, Caloneis, Cymatopleura, Gyrosigma, Navicula, Nitzschia, Surirella* and *Frustulia vulgaris*. It is not quite certain which taxa are contaminant due to which they are present secondarily in the epipelic community.

In the water layer between the parts of aquatic macrophytes and algal threads, and in the silt being retained there, during the summer months under favourable habitat conditions, particularly as regards water temperature, available nutrient amounts as well as lower flow rate, a community was developed termed by Cox (1990) as metaphyton. The community is represented by taxa of the orders Chlorococcales, Desmidiales, Peridiniales, as well as by the species from the genera: *Euglena* and *Phacus*.

Widely accepted manners of monitoring and evaluating water quality through physico-chemical and bacteriological parameters do not provide an insight into the effects the changes in these parameters have on biological communities (Vis et al. 1998). This aspect of water quality monitoring can be achieved by using saprobiologic methods and algae as bioindicators. Results of saprobiologic analyses after Pantle-Buck; Zelinka, Marvan, Kubicek, are presented. By comparison of the results on water saprobity an agreement of the results obtained using different methods is noted. The saprobity index obtained by the Pantle-Buck method was in the β-mesosaprobity zone, its values ranging from 1.7-2.4. The resulting saprobic valences obtained by the method after Zelinka, Marvna, Kubicek are in conformity with the saprobity index, with the domination of β-mesosaprobic indicators and a significant, occasionally predominating (August, October) participation of the α-mesosaprobic indicators. Later findings (Djukic et al. 1997) confirm that the water quality is in the β-mesosaprobity to α-mesosaprobity zone, with occasional numerous participation of α-mesosaprobic and polysaprobic zone indicators. Compared with the data obtained by Markovic (Markovic 1993), according to which the Zapadna Morava water shows a considerable degree of pollution, being particularly expressed in the presence of acute lethal ammonia concentrations, high BPK_5 values, in the presence of nitrates, heavy metals and continual or occasional phenol, detergent, pesticide and mineral oil loads, it should be stressed that in the year the investigation was conducted (1996) the water quality was improved. This was probably due to a decreased discharge of industrial waste waters and a reduced use of artificial fertilizers and pesticides in agriculture in the period following 1992 being covered by Markovic's research.

The results on the saprobiologic analyses in the Kamenica indicate that oligosaprobic and β-mesosaprobic zone indicators predominated. According to the saprobity index after the method of Pantle-Buck, the Kamenica water was oligosaprobic to β-mesosaprobic, the values ranging from 1.4-1.7. The resulting saprobic valences obtained by the method of Zelinka, Marvan, Kubicek were in the β-mesosaprobic zone, with a very pronounced participation of oligosaprobic zone indicators.

According to the saprobity index values the Cemernica water was β-mesosaprobic (1.6-2.1). The resulting saprobic valence was also β-mesosaprobic, except in August when there was a deviation in terms of quality deterioration and when the resulting saprobic valence was α-mesosaprobic. By comparing the data with the previous investigations (Markovic 1993; Tomasevic 2000) it can be said that the Cemernica had a better water quality, probably due to a decreased inflow of waste waters and reduced industrial and agricultural activities in the later period as well as due to the self-purifying process.

Conclusion

A total of 145 taxa and 6 algae divisions were determined: *Cyanophyta*, *Pyrrophyta*, *Xanthophyta*, *Bacillariophyta*, *Euglenophyta* and *Chlorophyta*. *Bacillariophyta* were absolutely dominant ones with 64% of all the identified taxa, the majority of which belonged to the genera *Navicula, Nitzschia, Cymbella* and *Fragilaria*. They are followed by *Chlorophyta* (20.5%) and its most diverse genera *Pediastrum* and *Scenedesmus*.

The Zapadna Morava, Kamenica and the Cemernica, in terms of the floristic composition, showed a mutual similarity, as well as a similarity with the rivers of similar characteristics. A dominant percental share in the silicate algae community was registered with: *Achnanthes minutissima* var. *minutissima, Cymbella affinis, C. minuta, Diatoma moniliformis, D. vlgaris, Gomphonema olivaceum* var. *olivaceum, Melosira varians, Navicula cryptocephala, N. lanceolata* and *Nittzschia dissipata* var. *dissipata*. Macroscopic agregations were formed by *Lyngbya attenuata, Oscillatoria spp., Phormidium favosum* (*Cyanophyta*), *Cladophora glomerata, Spirogyra sp., Stigeoclonium tenue* and *Ulothrix sp*. (*Chlorophyta*). The main constructors of the macroscopic aggregations in the Zapadna Morava, Kamenica and the Cemernica were: *Cladophora glomerata, Phormidium favosum* and *Ulotrix sp*. The epilithic and epiphytic communities predominated.

The diversity index values (H) of the benthic silicate algae in the Zapadna Morava varied from 1.97 to 4.76. The diversity index of the silicate algae in the Kamenica and the Cemernica ranged from 1.67 to 4.45, and from 1.37 to 4.17, respectively.

Saprobiologic analyses showed that the Zapadna Morava water was in the β-mesosaprobic zone. The oligo- and β-mesosaprobic indicators predominated, with an occasional significant participation of α-mesosaprobic and polysaprobic zone indicators. The results of the saprobiologic analyses in the Kamenica river showed that the water was of oligosaprobic to β-mesosaprobic quality. The Cemernica water quality, according to the saprobiologic indicators, was of the β-mesosaprobic to α-mesosaprobic zone.

The water quality was much affected by general hydrologic circumstances. The lowest saprobity level in the Zapadna Morava was registered in January, and that in the Kamenica and Cemernica rivers in April. The worst water quality in the Zapadna Morava, Kamenica and the Cemernica rivers was recorded in August, October and July and August, respectively.

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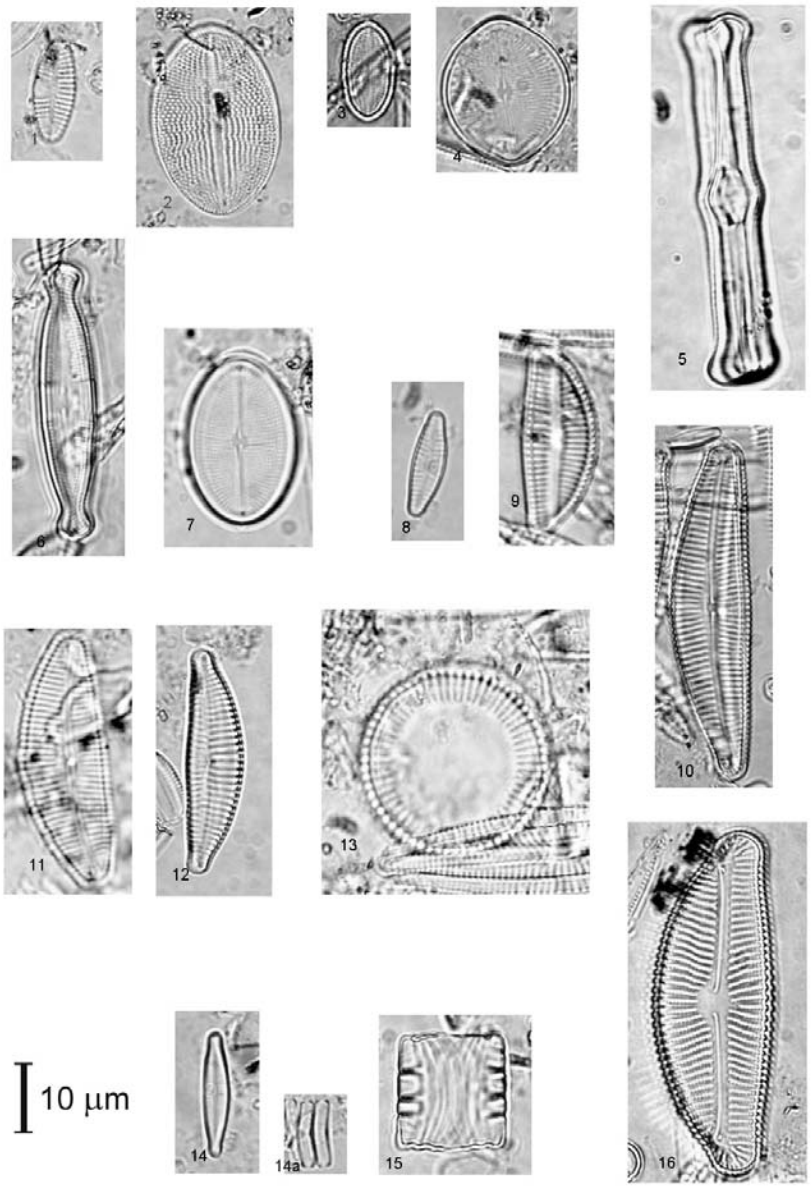
Appendix Some of the taxa of the silicate algae present in the investigated rivers

1.and 8. *Achnanthes lanceolata* ssp. *lanceolata* (BRÉBISSON) GRUN. (7752, 7753)
2. and 7. *Cocconeis placentula* var. *lineata* (EHR.) VAN HEURCK (7776,7777)
3. *Cocconeis placentula* var. *euglypta* (EHR.) GRUN. (7774)
4. *Cocconeis pediculus* EHR. (7773)
5. *Tabellaria flocculosa* (ROTH.) KÜTZ. (7940)
6. *Caloneis macedonica* HUSTEDT (7768)
9. *Cymbella caespitosa* (KÜTZ.) BRUN. (7799)
10. *Cymbella cistula* (EHR.) KIRCH. (7800)
11. *Cymbella austriaca* GRUN. (7798)
12.*Cymbella affinis* KÜTZ. (7797)
13. *Cyclotella meneghiniana* KÜTZ (7788)
14. and 14a *Achnanthes minutissima* KÜTZ. var. *minutissima* KÜTZ. (7755, 7754)
15. *Diatoma mesodon* (EHR.) KÜTZ. (7809)
16. *Cymbella prostrata* (BERK.) CLEVE (7806)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STRUKTURA ZAJEDNICA BENTOSNIH ALGI I KVALITET VODE SLIVA ZAPADNE MORAVE KOD ČAČKA

- skraćena verzija magistarskog rada -

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Rezime

Zapadna Morava je, posebno u svom gornjem i srednjem toku, reka brdsko-planinskog tipa. Njene dve leve pritoke Kamenica i Čemernica su tipične brdsko-planinske reke. Deo sliva koji se nalazi u neposrednoj blizini Čačka je recipijent velikog broja najrazličitijih otpadnih voda. Istraživanje je obuhvatilo osam lokaliteta, četiri na Zapadnoj Moravi i po dva na Kamenici i Čemernici. Osam lokaliteta odabranih za praćenje obuhvatali su deo toka Zapadne Morave 500 m ispod brane u Međuvršju do sela Stančići, 6 km nizvodno od Čačka. Na ovom delu toka nalaze se zagađivači – industrijska zona Čačka sa svojim otpadnim vodama i izliv gradskog kolektora. Takođe na ovom delu toka, u Zapadnu Moravu se ulivaju pritoke Kamenica i Čemernica. Obuhvaćeni su različiti tipovi podloge preko kojih reka protiče, različiti tipovi dna, kao i različiti tipovi vegetacije. Algološki materijal sakupljen je tokom 1996. godine, sa mesečnom dinamikom uzorkovanja. Utvrđeno je prisustvo 145 taksona i 6 razdela: *Cyanophyta*, *Pyrrophyta, Xanthophyta, , Euglenophyta* i *Chlorophyta*. U odnosu na broj taksona dominiraju *Bacillariophyta* sa94 taksona (64,82 %) i *Chlorophyta* sa 30 taksona (20,4 %). Svi ostali razdeli učestvuju sa 14,48 %, a od toga 6,89 su *Cyanophyta*. Taksoni prisutni u istraživanim rekama su euritermi, podnose variranja u temperaturi od 20^{o}C ili više.

Bentosna zajednica algi Zapadne Morave, Kamenice i Čemernice okarakteri-sana je značajnim razvojem makroskopskih agregacija koje tokom godine mogu pokrivati i znatnu površinu dna ovih triju reka. Može se reći da je njihov sastav uniforman, a kao dominantne se izdvajaju: *Cladophora glomerata*, *Ulotrix sp*. i *Phormidium favosum*. Kao epilitske u ovim rekama sreću se: *Achnanthes minutissima* var. *Minutissima*, *Cymbela affinis, C. minuta, C. prostrata, Diatoma vulgaris, Melosira variants, Navicula viridula*. Epifitna zajednica je dobro razvijena, grade je *Bacilariophyta*, kolonizatori *Cladophora glomerata*. Prisutni su i taksoni poput *Meridion circulare*, *Achnanthes minutissima, A. lanceolata, Cocconeis plancentula*. Epipelna zajednica je predstavljena velikim brojem taksona. Kao karakteristični mogu se označiti vrste iz rodova *Amphora, Caloneis, Cymatopleura, Gyrosigma, Navicula, Nitzschia, Surirella* i *Frustulia vulgaris*. Zajednica metafitona predstavljena je taksonima redova Chlorococcales, Desmidiales i Peridiniales, kao i vrstama iz rodova *Euglena* i *Phacus*.

Saprobiološke analize pokazuju da se voda Zapadne Morave nalazi u β-mezosaprobnoj zoni. Dominiraju indikatori oligo i β-mezosaprobnosti, ali uz povremeno značajno učešće indikatora α-mezosaprobne i polisaprobne zone. Rezultati saprobioloških analiza u Kamenici ukazuju da je voda oligosaprobna do β-mezosaprobnog kvaliteta. Kvalitet vode Čemernice, prema saprobiološkim pokazateljima, pripada β-mezosaprobnoj do α-mezosaprobne zone.