Analysis of the Family Solanaceae from Carl Studniczka's Herbarium

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We have analysed herbarium folder (fam. Solanaceae) which contain 36 herbarium sheets with 57 herbarium samples. Most plants were collected in Europe in the area of Austria. According to the affiliation to particular herbarium collections, the most representative plants are those from the collection Flora Dalmatiens. Most herbarium sheets were collected by Studniczka himeself (25). The oldest herbarium sheet dates from the year 1870 and the newest one is from 1902.

Key words: Studniczka's herbarium, Natural History Museum Split, Croatia

INTRODUCTION

As an amateur botanist, Carl Studniczka collected plants while he was traveling (1869–1904) and working as an officer (data are known from herbarium labels: wide surrounding area of Vienna and Wiener Neustadt in Austria, of Split in Croatia, of Celje in Slovenia, of Kotor in Montenegro, of Olomouc and Leitmeritz in the Czech Republic, of Przemysl in Poland and finally the wide surrounding area of Trieste in Italy). The analysis has shown that this herbarium contains samples of the plants which were collected and sent to Studniczka by many botanists or collectors of that time (compare with: Mitić et al., 2008 a,b; 2010-2011; 2011; 2012; 2013; Vladović et al., 2007 a,b; 2009 a,b; 2010 a,b; 2011; 2012; 2013 a,b,c; 2014 a,b,c; 2015; 2016; Vladović & Mitić 2016; Ževrnja et al., 2008 a,b; 2009 a,b,c; 2010 a,b; 2011; 2013 a,b,c; 2014; 2015 a,b,c).

MATERIAL AND METHODS

In this paper we have analysed the herbarium sheets from family Solanaceae. From the labels of the herbarium sheets first, we copied the Latin name of the genus and the species; then the date, month and year of collection; followed by the collector (**B**-Baenitz, **D**-Debeaux, **E**-Eggert, **F**-Freyn, **G**-Gandoger, **H**-Halácsy, **He**-Heiland, **K**-Kumlien, **R**-Ressmann i **S**-Studniczka) and the affiliation to the particular herbarium collection (BHE-Baenitz Herbarium Europaeum, EFA-E Flora Austriae inf., EHA-Eggert Herbarium Americanum, EHR-Ex herb. D.F.Ressmann Flora carniolica, FB-Flora Böhmens, FD-Flora Dalmatiens, FDB-Flora das Prz. Brandenburg, FGE-Flora Gallica exsiccata, FNO-Flora von N. Oesterreich, FOP-Flora von oesterr. Polen, FT-Flora von Triest, FWN-Flora von Wr Neustadt, HTP-Herb. Torre Pando). According to The Plant List and USDA Plants Database we have listed the name of the species in brackets; from the label we have copied the numerical sign, name of the place where the plant had been found, with altitude data if available, and have listed the number of herbarium samples in brackets.

RESULTS AND DISCUSSION

LIST OF SPECIES

1. *Atropa belladonna* L. 7.1876. **H** EFA (*A. belladonna* L.) in subalpinis mt. Schneeberg (2)
2. *A. belladonna* L. 28.6.1893. **S** FWN (*A. belladonna* L.) in Holzschlägen auf der Malleiten bei Fischau (1)
3. *Datura bullata Gdgr!* 16.9.1874. **G** FGE (*D. stramonium* L.) No 922 Hab. in ruderatis ad Arnas (1)
4. *D. stramonium* L. 9.10.1875. **S** FD (*D. stramonium* L.) Sturzengräben bei Salona (1)
5. *D. stramonium* L. 1897. **S** FWN (*D. stramonium* L.) wüste Plätze üm WrN. (1)
6. *D. tatula* L. 12.9.1870. **G** FGE (*D. stramonium* L.) No 347 Hab. in ruderatis ad Arnas (1)
7. *Hyoscyamus albus* L. 22.5.1875. **S** FD (*H. albus* L.) wüsten Plätzen und Mauern um Spalato (1)
8. *H. albus* L. 8.1877. **S** FD (*H. albus* L.) wüste Plätze auf der Insel St. Giorgio bei Perasto (2)
9. *H. niger* L. 20.8.1881. **S** FB (*H. niger* L.) wüste Plätze u. Schutthaufen in Theresienstadt (1)
10. *H. niger* L. 8.1885. **S** FOP (*H. niger* L.) wüste Plätze nächst den Zeughause (1)
11. . *Lycium chinense* Mill. 1.8.1874. **D** HTP (*L. chinense* Mill.) Habitat Perpignan-glacis des fortifications (2)
12. *L. barbarum* L. 6.1881. **S** FB (*L. barbarum* L.) Gesträuch bei Theresienstadt (2)
13. *Lycopersicum esculentum* 1875. **S** FD (*Lycopersicon esculentum* Mill.) bei Salona (1)
14. *L. esculentum* L. 7.1895. **S** FWN (*L. esculentum* Mill.) Garten in Neustasdt (1)
15. *Nicotiana affinis* ? 8.1896. **S** FWN (*N. alata* Link & Otto) botan Garten in Wr Neustadt (1)
16. *N. arborescens* ? 8.1875. **S** FD (*N. glauca* Graham) cult. u. verwildert in Ragusa; aüf bei Bodicelli nächst Spalato cult. (3)
17. *N. rustica* L. 20.10.1872. **S** FD (*N. rustica* L.) Garten und wüst. Plätzen in der Nähe derselben bei Punta d' Ostro (1)
18. *N. rustica* L. 8.1896. **S** FWN (*N. rustica* L.) botan Garten in Wr Neustadt (1)
19. *N. tabacum* L. 1897. **S** FWN (*N. tabacum* L.) cult. (2)
20. *Physalis alkekengi* L. 28.6.1893. **S** FWN (*P. alkekengi* L.) Wälder bei Fischau (3)
21. *P. alkekengi* L. 21.8.1902. **S** FT (*P. alkekengi* L.) zwischen Gestrüppen ober Barcola (3)
22. *P. pennsylvannica* L. 23.7.1875. **E** EHA (*P. cinerascens* (Dunal) Hitchc.) Blüffs eisenbachn in Ills. (2)
23. *P. viscosa* L. **K** (*P. viscosa* L.) Wisconsis (2)
24. *Scopolina hladnikiana* Biatz 4.1876. **R** EHR (*Scopolia carniolica* Jacq.) Gerlachstein b. Stein (2)
25. *Solanum dulcamara* L. 19.7.1876. **S** FD (*S. dulcamara* L.) wüsten Plätze bei Igala nächst CastelnuovO (1)
26. *S. dulcamara* L. 12.6.1885. **S** FOP (*S. dulcamara* L.) sumpfige Wiesen im Wald bei Lipowitza, an Mauern Przemysl (2)
27. *S. dulcamara* L. 18.8.1902. **S** FT (*S. dulcamara* L.) Bäche um Barcola (1)

28. *S. humile* Bernh. 8.10.1875. **B** BHE (*S. humile* Bernh.ex Willd.) Königsberg i. Pr.: In cultis ("Haufen") (2)
29. *S. humile* Bernh. 10.1875. **He** FPB (*S. humile* Bernh. ex Willd.) Lychen: Gastin üm kräut (2)
30. *S. miniatum* Bernh. 30.8.1874. **F** (*S. villosum* Mill.) Istrien. Umgebung von Pola Felsen am Meere Bodenunterlake kalk Seehöhe 15 m (1)
31. *S. miniatum* Bernh. 10.8.1902. **S** FT (*S. villosum* Mill.) längst der Miramarstrasse bei Barcola (2)
32. *S. nigrum* L. 1.10.1872. **S** FD (*S. nigrum* L.) wüsten Plätzen, Wegen der Halbinsel Punta d' Ostro (1)
33. *S. nigrum* L. 15.8.1881. **S** FB (*S. nigrum* L.) Schutthaufen um Theresienstadt (1)
34. *S. nigrum* L. 29.8.1893. **S** FNO (*S. nigrum* L.) Waldplätze Malleiten (2)
35. *S. reineggeri* Opiz. 9.8.1876. **G** FGE (*S. reineggeri* Opiz.) No 925 Hab. in ruderatis prope Arnas (1)
36. *S. tuberosum* L. 5.1893. **S** FNO (*S. tuberosum* L.) cult. üm Wien & Neustd. (3)

The total number of the herbarium sheets in the analysed family is 36 (with 57 samples of herbal plants). The majority of the plants were collected in Europe (34 herbarium sheets) and two sheets originate from North America.

Most of the herbarium samples were collected in the area of Austria (10 herbarium sheets) and distribution of remaining herbarium sheets from Ord. Solaneen in countries are shown in Fig. 1.

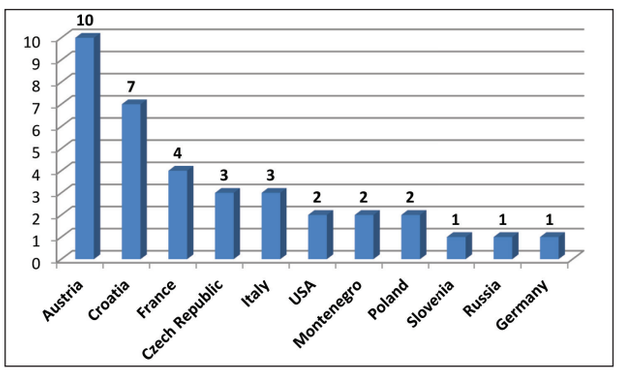

Figure 1. Distribution of herbarium sheets from Ord. Solaneen in countries
Slika 1. Raspodjela herbarskih listova u Ord. Solaneen po državama

According to the affiliation to a particular herbarium collection in the analysed family or their parts the most represented is Flora Dalmatiens with 8 herbarium sheets. This is followed by other collections such as: Flora von Wr. Neustadt (7), Flora Gallica exsiccata (3), Flora Böhmens (3), Flora von Triest (3), Flora von oesterr. Polen (2), Flora von N. Oesterreich (2), C. Baenitz Herbarium Europaeum (1), Eggert Herbarium Americanum (1), E Flora Austriae inf. (1), Ex herb. D.F.Ressmann Flora carniolica (1), Flora das Prz. Brandenburg (1) and Herb. Torre Pando (1). There are 2 herbarium sheets that are unmarked and therefore we do not know which herbarium collection they belong to.

Most of the samples of herbarium plants were collected by Studniczka himself (25 herbarium sheets), while other collectors and number of collected herbarium sheets are shown in Fig. 2.

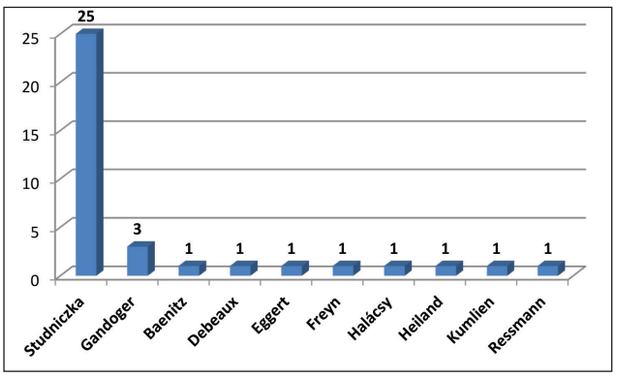

Figure 2. Collectors and number of collected herbarium sheets (Ord. Solaneen)
Slika 2. Sakupljači i broj sakupljenih herbarijskih listova (Ord. Solaneen)

The oldest herbarium sheet dates from 1870, whereas the latest date from 1902 (Fig. 3). The exact year of collection is missing from one herbarium label.

According to Studniczka, within 36 herbarium sheets (order Solaneen) there are 9 genera with 23 species.

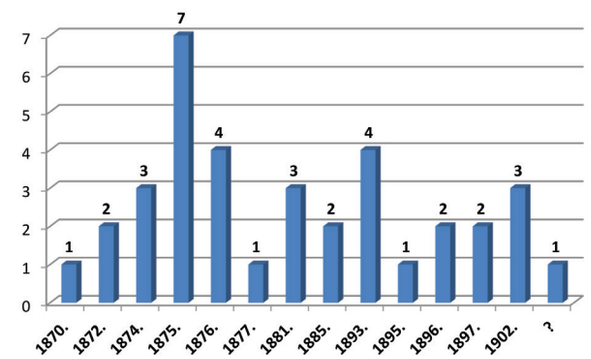

Figure 3. Number of herbarium sheets according to the year of collection (Ord. Solaneen)
Slika 3. Broj herbarijskih listova prema godinama sakupljanja (Ord. Solaneen)

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SAŽETAK

U radu je analiziran herbarijski biljni materijal iz porodice Solanaceae (Ord. Solaneen). Na 36 herbarijskih listova nalazi se 57 herbarijskih primjeraka. Najveći dio herbarijskog materijala sakupljen je u Europi. Najviše herbarijskog materijala sabrano je s područja današnje Austrije (10 herbarijskih listova). Prema pripadnosti pojedinim herbarijskim zbirkama najzastupljeniji su herbarijski listovi iz zbirke Flora Dalmatiens. Najviše herbarijskih listova sakupio je Studniczka (25). Najstariji herbarijski list je iz 1870. god., a najmlađi su iz 1902. god.

Ključne riječi: Herbarij C. Studniczke, Prirodoslovni muzej Split, Hrvatska

Comparison of Cyanobacteria and Algae Assemblages in Mine Pit Lakes of Different Origin in Bosnia And Herzegovina

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Research for this study was conducted from 2013 (21st July and 18th August) to 2014 (20th July, 9th August, 20th August and 13th September). Samples of cyanobacteria and algae were collected by scraping from the natural base, such as stone, mud or detritus. Epilithic samples were taken using a brush, while epipsamic samples were collected from the surface of mud and detritus substrates using plastic Pasteur pipettes. A total of 27 samples of phytobenthos were collected in the study. Identification and counting of diatoms was performed using a microscope BestScope BS2020. The relative abundance of diatoms was estimated by counting at least 400 valves of each taxa, while for the other cyanobacteria and algae assessment was carried out by assigning them numbers from 1 to 3 (1-rare, 2-frequent and 3-numerous). Ecological values for diatoms were arrived at using OMNIDIA ver. 5.3 software. Multivariate statistical analysis was performed using the PRIMER v6b software package. The aim of this paper was to analyse and compare cyanobacteria and algae assemblages in two mine pit lakes, in the municipalities of Kakanj (Lake Vrtlište) and Zenica (Lake Mošćanica). A comparison of the morphological, limnological, physical-chemical and biological characteristics of the lakes in question will yield criteria suitable for the ecological restoration of the mine pit lakes. A total of 183 species of cyanobacteria and algae were found in the qualitative and quantitative composition of phytobenthos of the mine pit lakes studied. The species identified belong to the following classes: ***Cyanophyceae*** (5), ***Chrysophyceae*** (1), ***Bacillariophyceae*** (166), ***Dinophyceae*** (1), ***Euglenophyceae*** (3), ***Chlorophyceae*** (3) and ***Conjugatophyceae*** (4). The most numerous class consists of ***Bacillarophyceae*** (166 species or 90.71%), while the other classes occur in somewhat smaller percentages. Dominant taxa were noted in both lakes: ***Achnanthidium minutissimum***, ***Brachysira microcephala***, ***Cyclotella meneghiniana***, ***Denticula kützingii***, ***Encyonopsis microcephala***, ***Navicula radiosa***, ***Nitzschia palea***, ***Nitzschia recta*** and ***Ulnaria ulna***. Multivariate statistical analysis established a clear distinction between the two mine pit lakes. By comparing the results with the data in reference works, it can be concluded that these mine pit lakes are in suitable condition particularly for the restoration and conservation of wetland biodiversity. These conditions have resulted in rapid colonization of the mine pit lakes studied and the establishment of a habitat for cyanobacteria and algae, as well as for other groups of organisms.

Key words: degradation, diversity, cyanobacteria and algae, mine pit lakes, restoration.

INTRODUCTION

Bosnia and Herzegovina is characterized by a great diversity of landscapes and ecosystems (Barudanović et al., 2015b; Kamberović et al., 2012; Barudanović et Kamberović, 2008; Redžić et al., /ed./ 2008).

However, due to intensive human activity over the past decade there has been a marked degradation of abiotic as well as biotic components of the ecosystem (Barudanović et Mašić, 2015a; Kamberović et al., 2012; Pehlić et al., 2008; Redžić et al., /ed./, 2008; Resulović, 1998; Knežićek et al., 2006).

Irrational and irresponsible use of natural resources in some areas has led to serious land, water and air pollution. Different anthropogenic pressures have led to the loss of biodiversity at the local as well as the global level (Barudanović et Mašić, 2015; Kljajić et al., 2012).

Mining activities are among the severe pressures affecting the configuration of the land, the geological base, climate, water, the fertile soil layer, and also the living world (Knežićek et al., 2006).

In Bosnia and Herzegovina, mining on active and abandoned mines alike has resulted in the formation of new, permanent bodies of water or mine pit lakes (Barudanović et Mašić, 2011, 2014, 2015a, 2015b, Kamberović et al., 2014, Nurić et al., 2014).

Mine pit lakes are a specific type of water accumulation, caused by the cessation of drainage or extraction, resulting in the final crater filling with water, or by damming the watercourse with mine tailings. Mine pit lakes may be formed by subsidence following underground mining (Barudanović et Mašić, 2011, 2014; Barudanović et al., 2014; Barudanović et al., 2013).

Once the new bodies of water are established as sterile structures, a natural process of wetland ecosystem progradation begins. The restoration of mine pit lakes and support for the natural process of progradation would facilitate the expansion of gravely endangered wetland species and habitats (Barudanović et al., 2013, 2014; Barudanović et Kamberović, 2008).

The ecological restoration of mine pit lakes is a very significant contribution to measures to mitigate the effects of climate change, primarily because of the possibility of increased uptake of CO2 from the atmosphere. At the same time, one should not ignore the potential for development of economic activities based on environmental grounds (Barudanović et Kamberović, 2008; Barudanović et Mašić, 2014, 2015b; Nurić et al., 2014).

In newly established mine pit lakes, cyanobacteria and algae form the basis for establishing a dynamic equilibrium in the ecosystem. Cyanobacteria and algae are especially prominent in number. In addition to being primary producers of organic matter and their importance in the food chain, they have the ability to react quickly to changes occurring in the environment (Kamberović et Barudanović, 2012).

Previous research has determined that mine pit lakes in Bosnia and Herzegovina are colonized by the cyanobacteria and algae, especially diatoms (Class *Bacillariophyceae*) (Barudanović et Mašić, 2015a; Kamberović et Barudanović, 2012).

Diatoms are sensitive to the many changes taking place in the ecosystem (changes in light intensity, humidity, temperature, oxygen concentration, salinity, pH value, concentration of mineral substances). They are good indicators that are now widely used in biomonitoring aquatic ecosystems, and mostly during the monitoring of acidification process, eutrophication, water pollution and climate change (Barudanović et Mašić, 2015a).

The aim of this paper was to analyse and compare cyanobacteria and algae assemblages in two mine pit lakes, in the municipalities of Kakanj (Lake Vrtlište) and Zenica (Lake Mošćanica). A comparison of the morphological, limnological, physical-chemical and biological characteristics of the lakes in question will yield criteria suitable for the ecological restoration of mine pit lakes.

MATERIAL AND METHODS

Research for this study was conducted in the period from 2013 (21st July and 18th August) to 2014 (20th July, 9th August, 20th August and 13th September).

Analysis of the basic physical and chemical parameters was performed in the Laboratory of the Department for Sanitary Chemistry and Bromatology of Cantonal Public Health Institute Zenica in Zenica. Instrumental and volumetric methods were used for the analysis of the basic physical and chemical parameters of the water. The analysis included water colour, turbidity, alkalinity, hardness, electric conductivity at 25 °C, evaporated residue, $KMnO_4$ consumption, pH value, calcium as CaO, magnesium as MgO, chlorides (Cl), sulphate (SO_4), ammonium (NH_4) , nitrite (NO_2), nitrate (NO_3) and iron (Fe).

Research methodology in the field of algology is based on the collection of phytobenthos samples, according to the methodology harmonized with the standards of the European Union Framework Directive (WFD, 200/60/EC).

Samples of cyanobacteria and algae were collected by scraping from natural base, such as stone, mud or detritus. Epilithic samples were taken using a brush, while epipsamic samples were collected from the surface of mud and detritus substrates using plastic Pasteur pipettes.

In all, 27 phytobenthos samples were collected. The samples were fixed in the field with 4% formaldehyde, labelled and transported to the Laboratory of Systematics of algae and fungi on the Faculty of Science, University of Sarajevo.

The analysis of cyanobacteria and algae was conducted in two phases. The first phase included the preparation and analysis of temporary slides. The second phase included the same procedure, but with permanent slides.

Permanent slides were prepared after chemical treatment of phytobenthos samples using sulphuric acid ($H2SO_4$), potassium permanganate ($KMnO_4$) and oxalic acid ($C_2H_2O_4$). After that the material was heated on cover glasses and mounted in Canada balsam diluted in xylene (Hustedt, 1930).

The identification and counting of diatoms was performed using a BestScope BS2020 microscope. Determination of the cyanobacteria and algae was performed by using specialized keys for determination: Hofman et al., 2013; Krammer, 2000, 2002, 2003; John et al., 2003; Lange-Bertalot, 2001; Krammer and Lange-Bertalot, 1986-1991.

The nomenclature of cyanobacteria and algae was harmonized with an online database (algabase) (Guiry, M.D. et Guiry, G.M., 2017).

The relative abundance of diatoms was estimated by counting at least 400 valves of each taxon, while for the other cyanobacteria and algae assessment was carried out by assigning them numbers from 1 to 3 (1-rare, 2-frequent and 3-numerous).

Indicator values of diatoms were analysed according to Van Dam et al., 1994, while the rare and endangered species were analysed according to Lange-Bertalot and Steindorf (1996), using OMNIDIA ver. 5.3 software.

In order to analyse the diversity of cyanobacteria and algae in the mine pit lakes α-diversity was selected, i.e. diversity within the investigated samples. α-diversity is expressed through the Shannon diversity index (H').

The Shannon diversity index is calculated according to the formula:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where: H' is median uncertainty per species for an infinite population composed of R species with known proportions of representation p1, p2, p3, ... writing. R and pi are the parameters of the population.

Multivariate statistical analysis was performed using PRIMER v6 software package. Cluster analysis was used to differentiate between the samples, and PCO analysis was used in order to understand the differentiation of phytobenthos community in relation to the gradient of the measured basic physical and chemical parameters.

The results of the research are presented in tables and graphs.

STUDY AREA

Research for this study was conducted in Vrtlište (Kakanj) and Mošćanica (Zenica) mine pit lakes. The rest of this paper presents the basic characteristics of the lakes studied.

1. CHARACTERISTICS OF THE VRTLIŠTE MINE PIT LAKE

The lake is situated at an altitude of 493 metres at the following coordinates: 44°08'09,73"N and 18°06'14,83"E, between the villages of Vrtlište, Stupe and Pope, about 3 km from the city centre.

The lake lies north (N) – south (S). The lake is 84.07 metres in length, with a maximum width (Bmax) 56.58 metres, and a minimum width (Bmin) of 34.50 metres. The coastline is 232.78 metres in length (L0), while the coastline length (L1) surrounding the coast line is 234.47 metres. The total area of the lake is 0.36 ha.

Vrtlište mine pit lake was caused by subsidence as a result of underground coal mining. The lake is fed by surface and rain waters. Water from the lake flows through the surface. There have been minor fluctuations of water over the years.

Macrophyte vegetation is well developed, including reed vegetation, reed beds and matting, as well as the vegetation of eutrophic standing waters. The dominant species of the first community is *Typha angustifolia* L. and of the second community, *Potamogeton natans* L.

Mud and detritus is present as a type of sediment.

The lake has been recognized by the local community as an important recreational area. It is used during the summer season for both swimming and fishing for different species of lake fish such as carp, tench, catfish and other species.

2. CHARACTERISTICS OF THE MOŠĆANICA MINE PIT LAKE

The lake is situated at an altitude of 672 metres and at the following coordinates: 44°10'11,16"N and 18°00'26,67"E, between the village of Krivići and Mošćanica, 5 km from the city centre. The lake lies east (E) – west (W). It is 200.66 metres in length, with a maximum width (Bmax) of 89.98 metres and a minimum width (Bmin) of 40.69 metres.The coastline is 548.39 metres in length (L0), while the coastline (L1) surrounding the coast line is 545 metres in length. The total area of the lake is 1.32 ha.

Mine pit lake Mošćanica was formed in the crater formed by open-cast coal mining. It is fed by surface and rain water. The east side of the lake flows into a small stream, which further feeds the lake water, while on the north-west side of the lake, water flows from the lower channel. There have been minor fluctuations of water over the years.

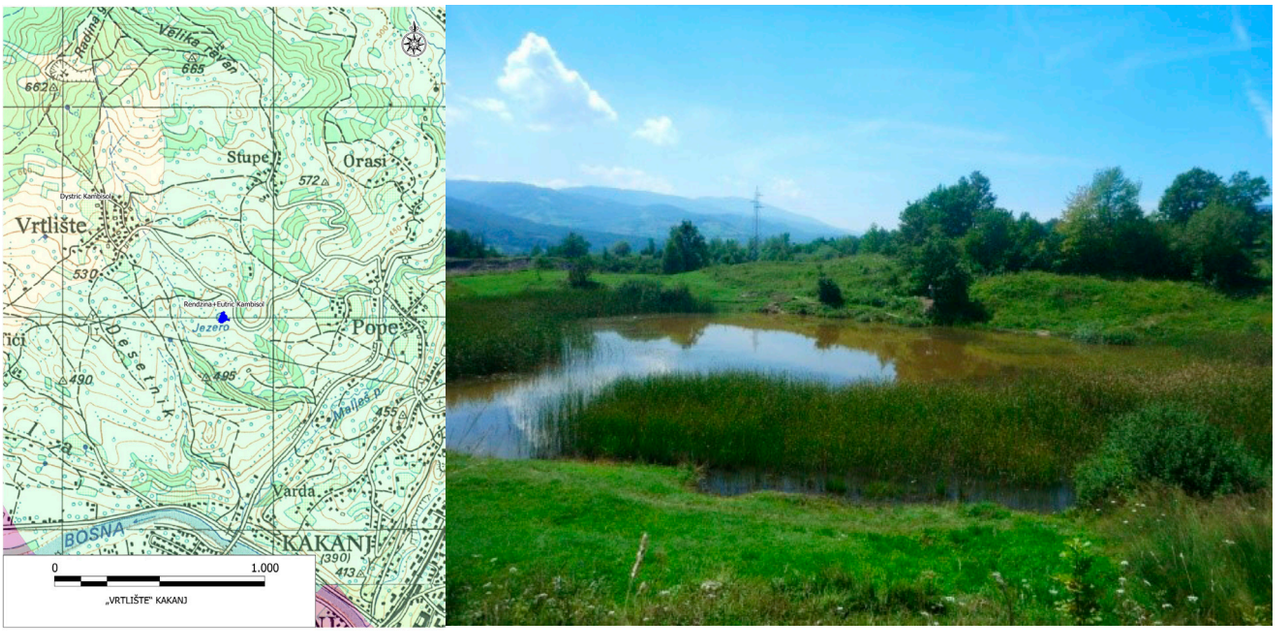

Figure 1 – Mine pit lake Vrtlište (Photo by Mašić, 2015)

Figure 2 - Mine pit lake Mošćanica (Photo by Mašić, 2015)

Macrophyte vegetation, of which the development is fragmentary, includes reeds, reed beds and matting, as well as the vegetation of eutrophic standing waters. The dominant species of the first community is *Phragmites communis* Trin., and of the second community, *Potamogeton natans* L.

Stone is present as a type of sediment.

The lake has been recognized by the local community as an important recreational area. It is used during the summer season for both swimming and fishing.

RESULTS

1. ANALYSIS OF THE PHYSICAL AND CHEMICAL PARAMETERS OF THE WATER

The results of measuring the physical and chemical parameters of the water in the mine pit lakes are shown in Table 1.

The measurement of the physical and chemical parameters of the water was carried out in 2013 (August) and 2014 (September). The physical and chemical parameters of the water revealed that

Vrtliše lake had an increased concentration of KMnO4 (9,28 mgl-1) consumption, pH (8.09), ammonia (0.329 mgl-1), nitrate (0.516 mgl-1) and iron (9.30 mgl-1), while Mošćanica lake had an increased concentration of electrical conductivity (1776 µScm-1), chloride (6.00 mgl-1) and sulphate (357.02 mgl-1).

Table 1. Results of measuring the physical and chemical parameters of the water

INDICATOR	Unit	Vrtliše	Vrtliše	Mošćanica	Mošćanica
Year		2013	2014	2013	2014
Water colour	°Pt-Co	20	20	5	0
Turbidity	NTU	0.10	2.29	2.25	1.81
Alkalinity	nj°	10.64	11.76	6.16	7.28
Total hardness	nj°	13.89	14.63	57.92	52.86
Electrical conductivity / 25°C	μScm^{-1}	493	487	1776	1563
Evaporated residues	mgl^{-1}	277.77	292.62	1158.37	1057.25
$KMnO_4$	mgl^{-1}	7.12	9.28	1.84	2.24
pH	-	8.09	7.32	7.95	7.76
CaO	mgl^{-1}	67.33	94.27	390.54	370.34
MgO	mgl^{-1}	51.11	37.17	134.74	113.06
Cl	mgl^{-1}	6.00	4.00	6.00	6.00
SO_4	mgl^{-1}	65.94	45.46	352.02	357.14
NH_4	mgl^{-1}	0.329	0.284	0.114	0.284
NO_2	mgl^{-1}	0.003	0.001	0.003	0.001
NO_3	mgl^{-1}	0.516	0.449	0.335	0.410
Fe	μgl^{-1}	7.364	9.30	8.837	6.40

A comparison of the physical and chemical parameters revealed the following:

- electrical conductivity values are lower than in Vrtliše lake than in Mošćanica lake, which can range from 1776 µScm-1 to 1563 µScm-1;
- lower values of $KMnO_4$ consumption were measured in Mošćanica lake than in Vrtliše lake, in which the values range from 7,24 mgl-1 to 9,28 mgl-1;
- the pH value of the water in the lakes is neutral to slightly alkaline;
- extremely high concentrations of sulphate were measured in Mošćanica lake (352,02 mgl-1 do 357,14 mgl-1) and
- a high concentration of ammonium and iron was measured in Vrtliše lake (Table 1).

2. DIVERSITY OF CYANOBACTERIA AND ALGAE IN THE MINE PIT LAKES

A total of 183 species of cyanobacteria and algae were found in the qualitative and quantitative composition of phytobenthos of the mine pit lakes.

The species identified belong to the following classes: *Cyanophyceae* (5), *Chrysophyceae* (1), *Bacillariophyceae* (166), *Dinophyceae* (1), *Euglenophyceae* (3), *Chlorophyceae* (3) and *Conjugatophyceae* (4). The most numerous class consists of *Bacillarophyceae* (166 species or 90.71%), while the other classes occur in somewhat smaller proportions.

There were 162 recorded taxa in the qualitative composition of phytobenthos of Vrtliše mine pit lake (Kakanj), while 87 taxa were recorded in Mošćanica mine pit lake.

Dominant taxa were recorded in both lakes: *Achnanthidium minutissimum* (Kützing) Czarnecki, *Brachysira microcephala* (Grunow) Compère, *Cyclotella meneghiniana* Kützing, *Denticula kuetzingii* Grunow, *Encyonopsis microcephala* (Grunow) Krammer, *Navicula radiosa* Kützing, *Nitzschia palea* (Kützing) W. Smith, *Nitzschia recta* Hantzsch ex Rabenhorst and *Ulnaria ulna* (Ehrenberg) Compère.

The differential species in the two lakes are *Spirulina* sp., *Dinobryon divergens* O.E. Imhof, *Epithemia adnata* (Kützing) Brébisson, *Rhopalodia gibba* (Ehr.) Otto Müller, *Caloneis silicula* (Ehrenberg) Cleve, *Sellaphora pupula* (Kützing) Mereschkowsky, *Diploneis ovalis* (Hilse) Cleve, *Gomphonema truncatum* Ehrenberg, *Eunotia bilunaris* (Ehrenberg) Schaarschmidt, *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, *Fallacia mitis* (Husted) D.G.Mann, *Euglena viridis* (O.F.Müller) Ehrenberg, *Pediastrum boryanum* (Turpin) Meneghini (Lake Vrtliše), *Merismopedia punctata* Meyen, *Phormidium* sp., *Euglena spirogyra* Ehrenberg, *Encyonopsis* sp., *Encyonema minutum* (Hilse) D.G. Mann, *Cymbopleura* sp., *Luticola* sp., *Surirella brebissoni* Krammer & Lange-Bertalot, *Tryblionela constricta* W.Gregory, *Peridinium bipes* Stein and *Oedogonium* sp. (Lake Mošćanica).

Rare and endangered species of diatoms (Lange-Bertalot and Steindor, 1996) were found in the mine pit lakes, as follows: *Cymbella aspera* (Ehrenberg) Cleve, *Diploneis oblongella* (Nägeli ex Kützing) Cleve-Euler, *Neidium affine* (Ehrenberg) Pfitzer, *Eunotia rhomboidea* Hustedt, *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg, *Cymbopleura amphicephala* (Nägeli) Krammer, *Pinnularia divergens* W. Smith, *Stauroneis anceps* Ehrenberg and *Ulnaria capitata* (Ehrenberg) Compère. The last five species also occur in Mošćanica lake.

A comparative overview of the diversity of cyanobacteria and algae of the two mine pit lakes is set out in tabular form (Table 2).

Table 2. Comparative overview of the diversity of cyanobacteria and algae of the mine pit lakes surveyed: Vrtlište (1-15) and Mošćanica (16-27)

Site Code	L1-V	L2-V	L3-V	L4-V	L5-V	L6-V	L7-V	L8-V	L9-V	L10-V	L11-V	L12-V	L13-V	L14-V	L15-V	L1-M	L2-M	L3-M	L4-M	L5-M	L6-M	L7-M	L8-M	L9-M	L10-M	L11-M	L12-M
Lake	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Vrtlište	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica	Mošćanica
Type of sediment	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	mud/detritus	detritus	mud/sand	mud/detritus	mud	stone	stone	stone	stone	stone	stone	stone	stone	detritus	stone	stone	stone
Vegetation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	±	±	±	±	±	±	±	±	±	±	±	±
Date	21/07/2013/	21/07/2013/	21/07/2013/	21/07/2013/	21/07/2013/	18/08/2013/	09/08/2014/	09/08/2014/	09/08/2014/	09/08/2014/	09/08/2014/	20/08/2014/	20/08/2014/	20/08/2014/	13/09/2014/	21/07/2013/	21/07/2013/	21/07/2013/	18/08/2013/	18/08/2013/	20/07/2014/	20/07/2014/	20/07/2014/	20/08/2014/	20/08/2014/	20/08/2014/	13/09/2014/
Species composition / Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
CYANOPHYTA																											
Cyanophyceae																											
Merismopedia punctata Meyen	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
Oscillatoria sp. 1	1	1	1	1	1	1	1	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	1	1	1	1
Oscillatoria princeps Vaucher ex Gomont	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	.	.	.	.	.	.	.
Spirulina sp. 1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phormidium sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
HETEROKONTOPHYTA																											
Chrysophyceae																											
Dinobryon divergens O.E.Imhof	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Bacillariophyceae																											
Achnanthidium minutissimum (Kützing) Czarnecki	2	1	3	3	2	1	3	3	4	4	4	3	4	4	2	3	2	1	2	2	6	1	1	2	3	2	1
Denticula kuetzingii Grunow	1	1	1	1	2	1	1	1	.	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	4	1	3
Navicula radiosa Kützing	1	1	1	1	1	1	1	1	.	1	1	1	1	1	1	3	3	2	4	1	1	3	3	4	1	4	3
Encyonopsis microcephala (Grunow) Krammer	1	1	1	1	1	1	1	1		1	2	1	1	1	1	2	1	1	1	2	2	1	1	.	1	1	2
Navicula sp. 1	.	.	.	1	.	1	3	2	1	2	1	.	1	1	1	3	3	3	3	1	1	1	1	2	1	3	2
Nitzschia recta Hantzsch ex Rabenhorst	.	1	.	1	1	1	1	.	1	1	1	1	1	1	1	1	1	.	1	2	1	5	3	1	.	1	.
Nitzschia palea (Kützing) W. Smith	.	1	1	1	1	1	1	.	.	.	1	.	1	1	1	1	1	1	1	1	1	.	.	1	1	1	1
Cyclotella meneghiniana Kützing	1	1	1	1	1	1	1	.	1	1	.	.	.	.	.	1	2	1	2	.	2	1	1	1	1	1	.
Ulnaria capitata (Ehrenberg) Compère	1	1	1	2	1	1	1	1	1	.	.	2	1	1	.	1	.	1	.	.	1	1	1	1	.	1	.
Brachysira microcephala (Grunow) Compère	1	1	.	1	1	.	.	.	.	1	.	1	.	.	.	3	3	6	3	4	2	1	2	3	4	3	5
Nitzschia sp. 1	1	1	1	1	.	1	2	2	1	1	1	1	1	1	3	.	1	.	.	.	.	.	.	.	1	1	1

Caloneis bacillum (Grunow) Cleve	1	1	1	1	1	1	1	1	1	1	1	.	1	.	.	1	.	1	1	.	.	.	.	.	1	1	.
Epithemia adnata (Kützing) Brébisson	1	1	2	1	1	1	1	3	2	2	1	1	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Rhopalodia gibba (Ehrenberg) Otto Müller	1	2	1	1	1	1	1	1	1	1	1	1	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.
Ulnaria delicatissima (W. Smith) Aboal &P.C.Silva	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	1	1	.	1	1	1	.	1	1	.	.	.
Pinnularia sp. 1	.	1	1	1	1	1	1	1	1	1	.	1	1	.	.	1	.	1	.	.	.	.	.	.	.	1	.
Hantzschia amphioxys (Ehrenberg) Grunow	.	1	1	1	.	1	1	1	1	1	2	3	1	2	.	1	.	.	.	.	.	.	.	.	.	1	.
Cymbopleura naviculiformis (Auerswald ex Heiberg) Krammer	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	1
Epithemia turgida (Ehrenberg) Kutzing	1	1	1	1	1	1	1	1	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Amphypleura pellucida(Kützing) Kützing	1	1	1	.	1	1	1	.	1	.	.	1	1	1	1	.	.	.	.	.	.	.	1	1	.	.	.
Cocconeis placentula Ehrenebrg	2	1	1	2	1	.	.	1	1	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Encyonema ventricosum (C.Agardh) Grunow	1	1	1	1	1	1	1	.	1	1	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Navicula lanceolata (Agardh) Ehrenberg	1	1	1	1	1	.	2	1	1	.	1	1	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.
Gyrosigma acuminatum (Kützing) Rabenhorst	1	.	.	.	1	1	1	.	.	.	.	1	.	.	.	1	1	.	1	.	1	1	1	1	.	.	.
Halamphora montana (Krasske) Levkov	.	2	1	.	1	1	.	.	3	2	4	.	.	1	1	.	1	.	.	.	1	.	.	.	.	1	.
Navicula trivialis Lange-Bertalot	.	1	.	.	1	.	2	1	1	1	1	1	2	1	.	.	.	.	.	.	.	1	.	.	.	1	.
Cymbopleura amphicephala (Nägeli) Krammer	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	2	1	1	1	1
Eucocconeis flexella (Kützing) Meister	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	1	1	1	1		1	1	1	1	1
Mastogloia sp. 1	2	1	1	1	2	1	1	.	1	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Nitzschia sigma (Kützing) W.M.Smith	1	1	1	.	1	1	1	.	.	.	.	.	.	.	.	1	1	1	.	1	.	.	.	1	.	.	.
Cymbella cistula (Ehrenberg) O. Kirchner	1	1	1	1	1	1	1	.	1	1	.	1		1		.	.	.	.	.	.	.	.	.	.	.	.
Anemoeoneis sphaerophora Pfitzer.	.	1	1	.	1	1	1	.	1	1	.	1	4	1	2	.	.	.	.	.	.	.	.	.	.	.	.
Stauroneis anceps Ehrenberg	.	1	1	.	1	1	1	.	.	.	.	.	1	.	1	.	1	1	.	.	.	.	.	1	.	1	.
Nitzschia commutata Grunow	.	.	.	1	1		1	4	1	1	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	1
Pinnularia major (Kützing) Rabenhorst	1	1	1	1	1	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	.	.	.	1	1
Navicula viridula (Kützing) Ehrenberg	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	1	1	1	1	1
Caloneis silicula (Ehrenberg) Cleve	1	1	1	1	1	1	1	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymbella affinis Kützing	1	1	1	.	1	1	.	1	.	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Ulnaria ulna (Nitzsch) Compère	1	1	1	2	1	1	.	1	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Gomphonema parvulum (Kützing) Kützing	.	1	1	1	.	.	1	1	.	1	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia borealis Ehrenberg	.	1	.	.	1	.	1	1	1	.	1	3	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.
Delicata delicatula (Kützing) Krammer	.	.	.	.	.	.	1	.	.	.	1	.	1	.	.	1	1	1	1	1	.	.	1	.	.	.	.
Gomphonema acuminatum Ehrenberg	1	1	1	1	1	1	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Sellaphora pupula (Kützing) Meresc-hkowksy	1	.	.	.	.	.	1	.	1	1	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia viridis (Nitzsch) Ehrenberg	.	1	1	1	1	1	.	1	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Navicula cryptocephala Kützing	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1	.	.	.	.	1	1	.	1	1	.
Frustulia vulgaris (Thwaites) De Toni	1	1	.	1	1	1	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.
Gomphonema sp. 1	1	1	.	1	1	1	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Denticula tenuis Kützing	1	1	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	1
Craticula ambigua (Ehrenberg) D.G. Mann	.	1	.	.	.	1	.	.	.	.	.	.	1		1	1		1		2	.	.	.	.	.	.	.

Placoneis sp. 1	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	1	.	.	.
Surirella angusta Kützing	.	.	.	.	.	1	1	1	1	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.
Luticola mutica (Kützing) D.G. Mann	.	.	.	.	.	.	1	1	.	1	.	1	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.
Craticula sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	2			1	2	1	1	
Rhopalodia paralella (Grunow) Otto Müller	1	1	1	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymbella aspera (Ehrenberg) Cleve	1	1	1	1	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Encyonopsis minuta Krammer & E.Reichardt	1	1	.	.	.	1	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.
Gomphonema vibrio Ehrenberg	1	1	.	.	.		.	.	1	1	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Diploneis ovalis (Hilse) Cleve	1	1	1	.	1	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymatopleura solea (Brébisson) W.Smith	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1	.	.	.	1	.
Gyrosigma attenuatum (Kützing) Rabenhorst	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	2	.	1	.	.
Gomphonema truncatum Ehrenberg	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mastogloia lacustris (Grunow) Grunow	1	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diploneis oblongella (Nägeli ex Kützing) Cleve-Euler	.	1	1	.	1	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Eunotia sp. 1	.	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Eunotia minor (Kützing) Grunow	.	1	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
Placoneis placentula (Ehrenberg) Mereschkowsky	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	.	.	.	.	1	.	.	.	.
Surirella sp. 1	.	1	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.
Fragilaria sp. 1	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cymbella cymbiformis C.Agardh	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Meridion circulare (Greville) C.Agardh	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mastogloia grevillei W.M. Smith	.	1	.		1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunotia bilunaris (Ehrenberg) Schaarschmidt	1		1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luticola ventricosa (Kützing) D.G. Mann	.	1	.	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Planothdium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nitzschia dissipata (Kützing) Rabenhorst	.	.	1	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Nitzschia sigmoidea (Nitzsch.) W. Smith	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.
Cocconeis placentula Ehrenebrg	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Pinnularia subrupestris Krammer	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Encyonopsis sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	1	.	.	.	.	1	.
Encyonema sp.1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Achnanthidium atomus (Hustedt) Monnier, Lange-Bertalot & Ector	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gomphonema clavatum Ehrenberg	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neidium affine (Ehrenberg) Pfitzer	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Cymbella sp. 1	.	.	1	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia grunowii Krammer	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diploneis sp. 1	.	.	.	1		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Gomphonema dichotomum Kützing	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Aneumastus sp. 1	.	.	.	.	1	.	.	.	.	.	.	.	1	1		.	.	.	.	.	.	.	.	.	.	.	
Nitzschia amphibia Grunow	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1

Luticola nivalis (Ehrenberg) D.G. Mann	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Encyonema minutum (Hilse) D.G. Mann	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.
Amphora copulata (Kützing) Schoeman &R.E.M.Archibald	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Encyonema silesiacum (Bleisch) D.G. Mann	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunotia arcus Ehrenberg	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia rupestris Hantzsch	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Cymbella excisa Kützing	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.
Cocconeis pediculus Ehrenberg	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Craticula cuspidata (Kützing) D.G.Mann	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gomphonema pala E.Reichard	.	1	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stauroneis sp. 1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia mesolepta (Ehrenberg) W.Smith	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia appendiculata (C.Agardh) Schaarchmidt	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Decussata hexagona (Torka) Lange-Bertalot	.	.	.	1		.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Neidium sp. 1	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Amphora ovalis (Kützing) Kützing	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Amphora sp. 1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fallacia sp. 1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gyrosigma sciotense (Sullivan & Wormley) Cleve	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tryblionella debilis Arnott ex O'Meara	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Pinnularia divergens W.Smith	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Nitzschia gracilis Hantzsch	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Mastogloia sp. 2.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Rhopalodia gibberula (Ehrenberg) Otto Müller	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Nitzschia linearis W. Smith	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Hantzschia sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.
Fallacia pygmea (Kützing) Stickle &D.G.Mann	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.
Cymbopleura sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Luticola sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Surirella brebissonii Krammer & Lange-Bertalot	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.
Tryblionella constricta W.Gregory	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.
Cyclotella sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		1		1	.	.	.
Staurosira construens Ehrenberg	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diploneis elliptica (Kützing) Cleve	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunotia arcubus Nörpel & Lange-Bertalot	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunotia rhomboidea Hustedt	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Navicula menisculus Schumann	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunotia tenella (Grunow) Husted	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fallachia sp. 1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Gyrosigma kuetzingii (Grunow) Cleve	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gyrosigma sp.1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Navicula sp. 1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia brebissonii (Kützing) Rabenhorst	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia rhombarea Krammer	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Placoneis paraelgiensis Lange-Bertalot	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymbella neocistula Krammer	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Surirella linearis W.M.Smith	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymbella neolanceolata W.Silva	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippodonta sp.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diploneis oculata (Brébisson) Cleve	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Encyonemasp. 1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tryblionella hungarica (Grunow) Frenguelli	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aneumastus tusculus (Ehrenberg) D.G. Mann & Stickle	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caloneis tenuis (W.Gregory) Krammer	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Halamphora veneta (Kützing) Levkov	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Navicula kotschyi Grunow	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neidium ampliatum (Ehrenbereg) Krammer	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia neomajor Krammer	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinnularia obscura Krasske	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brachysira brebissoni R.Ross	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hantzschia sp. 1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Navicula erifuga Lange-Bertalot	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diatoma moniliformis (Kützing) D.M.Williams	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclotella sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Nitzschia umbonata (Ehrenberg) Lange-Bertalot	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Caloneis fontinalis (Grunow) Cleve-Euler	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Craticula accomoda (Hustedt) D.G.Mann	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.
Pinnularia gibba Ehrenberg	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Brachysira procera Lange-Bertalot & Gerd Mosser	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Diadesmis contenta (Grunow) D.G.Mann	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Nitzschia inconspicua Grunow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Discostella stelligera (Cleve & Grun.) Houck & Klee	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Encyonopsis subminuta Krammer &E. Reichardt	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Achnanthes sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
DINOPHYTA																										
Dinophyceae																										

Peridinium bipes Stein	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1		1
EUGLENOPHYTA																											
Euglenophyceae																											
Euglena sp. 1	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euglena viridis (O.F.Müller) Ehrenberg	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Euglena spirogyra Ehrenberg	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
CHLOROPHYTA																											
Chlorophyceae																											
Pediastrum boryanum (Turpin) Meneghini	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.		.	.	.	.	.	.	.	.	.
Oedogonium sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Oocistis lacustris Chodat	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Conjugatophyceae																											
Closterium sp. 1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.
Mougeotia sp. 1	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	1	1
Cosmarium sp. 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	1
Spirogyra sp. 1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Number of taxa (n)	56	76	58	54	72	66	41	25	35	35	24	36	40	34	42	31	31	25	30	25	22	22	25	25	20	33	28
Shannon index (log^{10})	1,738	1,877	1,752	1,716	1,851	1,817	1,584	1,341	1,503	1,510	1,317	1,518	1,556	1,498	1,597	1,444	1,450	1,317	1,425	1,354	1,261	1,271	1,359	1,348	1,224	1,470	1,381

3. DIFFERENTIATION OF THE SURVEYED LAKES BASED ON THE DEGREE OF DIVERSITY AND INDICATOR VALUES OF CYANOBACTERIA AND ALGAE

In both mine pit lakes, diatoms (*Bacillarophyceae*) are dominant with a share of over 50%. Other representatives of cyanobacteria and algae occur in somewhat smaller proportions.

The Shannon diversity index was used to determine the degree of diversity in the mine pit lakes. The results set out in Table 2 show the variation in the diversity index. The diversity index values range from 1.224 (Mošćanica lake) to 1.877 (Vrtlište lake).

Indicator values were used (Van Dam et al., 1994) for the purpose of understanding the complex of environmental conditions.

The spectrum of indicator values of the diatoms is presented in tabular and graphical form (Table 3, Chart 1).

Table 3. Spectrum of indicator values of diatoms

	P	S_1	N	O	S_2	T	V
Vrtlište	3,75	2,00	1,91	1,41	2,00	5,79	2,94
Mošćanica	3,27	2,00	1,85	1,58	2,00	4,97	2,85

A comparison between the spectrum of indicator values of the two lakes reveals important differences, such as:

- Vrtlište lake is inhabited by alkalophilic species that mainly prefer pH>7, while Mošćanica lake is inhabited by circumneutral species that usually live in waters with pH=7;
- Vrtlište lake is found to have species that require a constant high concentration of oxygen, while Mošćanica lake is found to have species that need a moderately high concentration of oxygen;
- Vrtlište lake is found to have hypertrophic species, while Mošćanica lake is found to have mesotrophic and eutrophic species;
- there is no significant difference in respect of other indicator values.

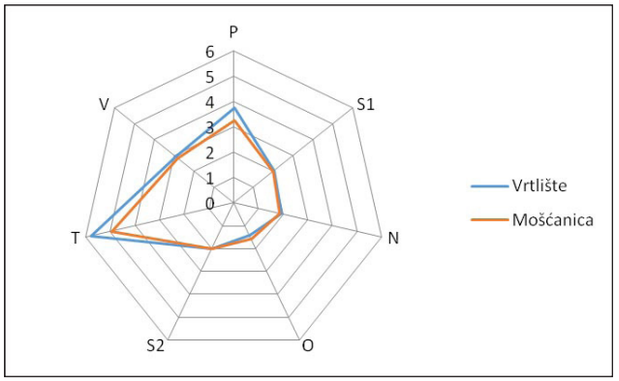

Chart 1 – Spectrum of indicator values of diatoms

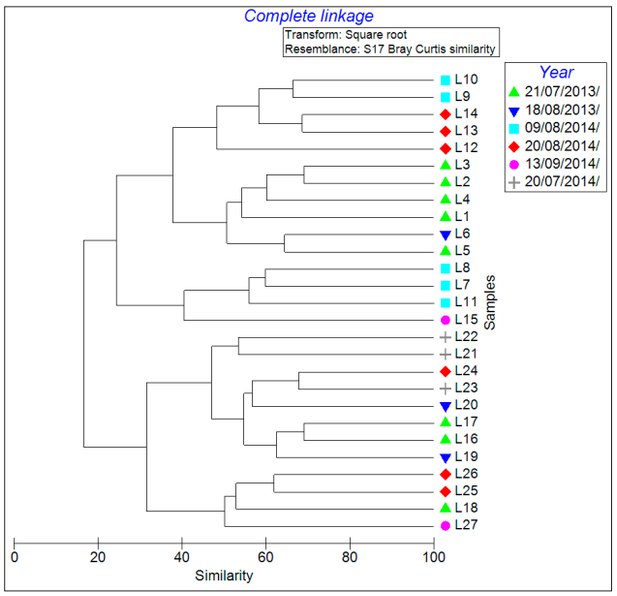

Chart 2 - Cluster analysis of phytobenthos samples within the investigated mine pit lakes

4. DIFFERENTIATION OF THE STUDIED LAKES ACCORDING TO THE COMPOSITION STRUCTURE OF PHYTOBENTHOS

Cluster analysis Bray-Curtis similarity) was used to differentiate the composition of phytobenthos. Chart 2 presents the clear differentiation of the phytobenthos community into two groups:

Group I (samples from Vrtlište lake) and

Group II (samples from Mošćanica lake).

The causes of differentiation of communities were investigated by means of PCO analysis *(Principal coordinates analysis),* which established their differentiation into three groups (Chart 3):

1st group consisting of L1, L2, L3, L4, L5 and L6 samples (Vrtlište, 2013);

2nd group consisting of L7, L8, L9, L10, L11, L12, L13, L14, L15 samples (Vrtlište, 2014) and

3rd group connsisting of L16, L17, L18, L19, L20, L21, L22, L23, L24, L25, L26, L27 samples (Mošćanica).

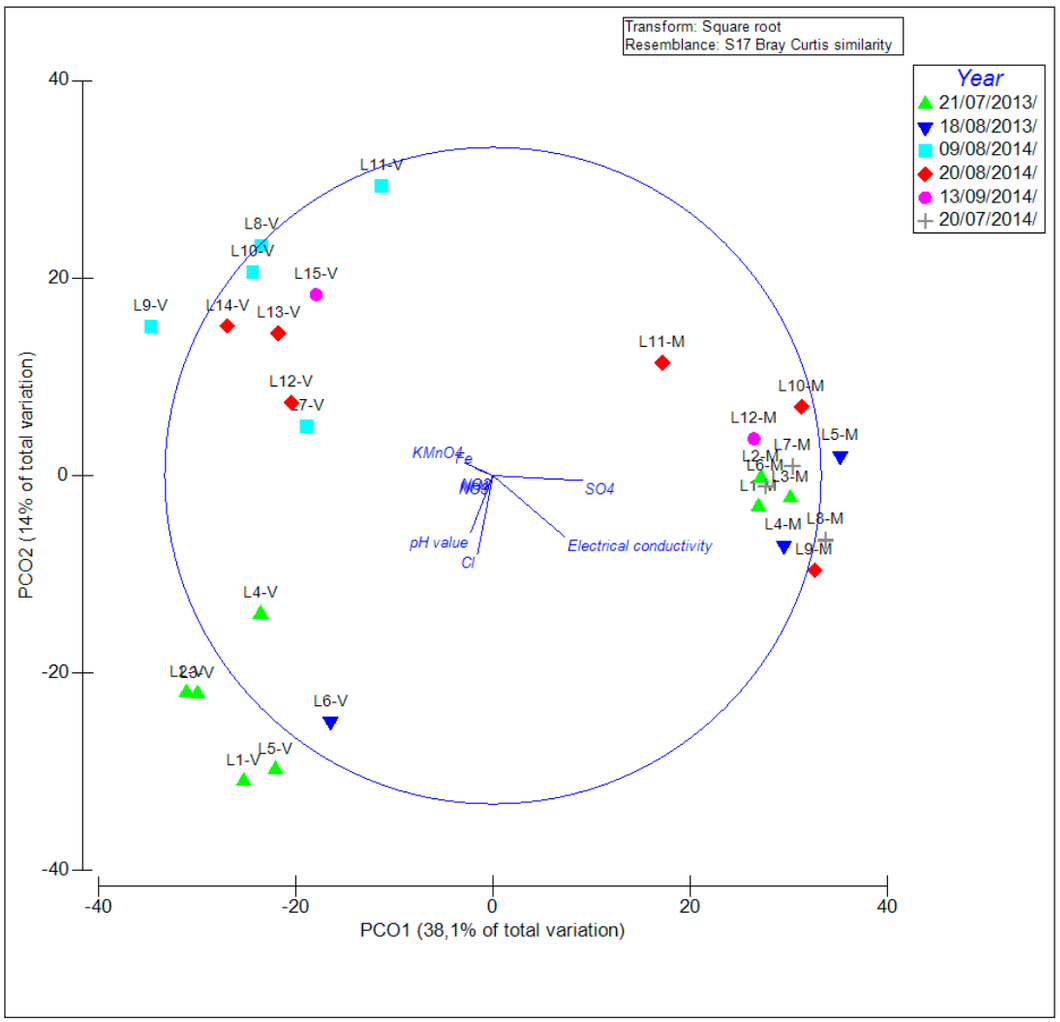

Chart 3 - PCO differentiation of the phytobenthos communities analysed

DISCUSSION

Multivariate statistical analysis established a clear distinction between the mine pit lakes at Vrtlište and Mošćanica. These differences are reflected in their morphometric, limnological, physical-chemical and biological characteristics.

Sample differentiation of phytobenthos into two groups (Chart 3) derives from the differences in the formation of the lake, the bed type and the presence of macrophytes.

Vrtlište mine pit lake was formed by subsidence caused by underground exploitation, while Mošćanica mine pit lake was formed in the crater formed by open-cast coal mining.

The verges of Vrtlište mine pit lake are colonized with macrophyte vegetation. A high concentration of KMnO4, ammonia and pH value was observed in the water, resulting from the high biomass production and decomposition of organic matter. Other environmental conditions prevail in Mošćanica mine pit lake. Macrophyte vegetation is sparsely developed as a result of the lack of a fertile soil layer and the steep coast. The poor biomass production is reflected in reduced decomposition of organic matter. A high concentration of sulphate was measure in Mošćanica mine pit lake. The main reason for the increased concentration of sulphate is that the water is in direct contact with the geological substrate rich in coal.

According to a reference work (Studija energetskog sektora u BiH, 2008), the brown coal in Mošćanica open-cast mine contains a higher total amount of sulphur (I-layer: 3,25% and II-layer: 3,27%). Table 4 sets out other parameters of the brown coal from Mošćanica open-cast mine (Zenica).

Table 4. Quality of coal from Mošćanica open-cast mine (Zenica)

Coal layers	Total moisture (%)	Ashes (%)	Evaporated residue (%)	Combustion residue (%)	C-fix (%)	Cocs (%)	Total amount of sulphur (%)
I	8,15	35,46	30,52	55,68	26,30	61,56	3,25
II	6,88	42,43	25,07	52,55	23,65	64,09	3,27

The reason for the differentiation of phytobenthos into three groups lies in the complex action of environmental factors. The increased number of rainy days and flooding that occurred in the course of the research are the most important factor for the differentiation of samples into three groups. The effects of the increased number of rainy days and flooding were felt on Vrtlište lake (2014), while such effects in Mošćanica lake are not considered significant (Chart 3). The effect of the increased number of rainy days and flooding was reflected in the structure and diversity of cyanobacteria and algae in Vrtlište mine pit lake. According to Chart 3, samples from 2014 (L7, L8, L9, L10, L11, L12, L13, L14 and L15) have less diversity than samples collected in 2013 (L1, L2, L3, L4, L5 and L6).

There have been few studies of mine pit lakes in Bosnia and Herzegovina. In recent years, however, thanks to their specific physical, chemical and biological characteristics, mine pit lakes have been increasingly the subject of research. It is especially important to mention study of mine pit lakes in Tuzla Canton (Kamberović et Barudanović, 2012).

By comparison with the Vrtlište and Mošćanica mine pit lakes, those of Tuzla Canton have higher values of consumption of KMnO4 (10,5-24,0 mgL-1), while no significant differences are observed in comparison to other physical and chemical parameters measured.

As regards the diversity of cyanobacteria and algae assemblages in neutral and slightly alkaline mine pit lakes in Bosnia and Herzegovina, Kamberović and Barudanović (2012) noted the presence of 73 taxa, among which the most numerous are algae from class *Bacillariophyceae* (48 taxa). They also noted the presence of representatives from the classes *Cyanophyceae* (11 taxa), *Zygnematophyceae* (10 taxa), *Chlorophyceae* (3 taxa) and *Dinophyceae* (1 taxon).

From a study of the current scientific literature it can be concluded that the hydrochemistry of mine pit lakes is the result of geology, hydrology, the sulphur content of the coal, and technology used (Blodau, 2006; Rolland et al., 2001; Wisotzky et al., Obermann, 2001).

Denimal et al., (2005) analysed three mine pit lakes formed in open-cast coal mines. These mine pit lakes are located in the north-eastern part of the Massif Central in France. The results show that the studied lakes were circumneutral. The sulphate concentration ranged from 500 mgL-1 to 1500 mgL-1. Iron concentrations were extremely low. Values ranged from 0.01 mgL-1 to 0.11 mgL-1 on the surface of the water, with significantly lower concentrations (0.06 mgL-1 to 0.3 mgL-1) at the lake bottom. Much the same was true of manganese concentration. Values ranged from 0.02 mgL-1 to 0.2 mgL-1 on the surface of the water, with higher concentrations of manganese (1.4 to 4.5 mgL-1) at the lake bottom.

The effects of certain physical and chemical parameters on the composition of phytoplankton and phytobenthos have been analysed in current scientific literature. The most common parameters monitored are pH value, concentration of phosphorus and some heavy metals.

The food chain in lakes with low pH values includes far fewer levels and species than in lakes with neutral or slightly alkaline pH values (Geller et al., [ed.], 2013).

Typical biocenoses of phytoplankton in mine pit lakes in the Lusatian region (Germany) belong to the genera

Ochromonas and *Chlamydomonas* (Lessemann et al., 2000; Nixdorf et al., 1998). Both groups of algae are widespread in acidic waters affected by acidic drainage waters (Geller et al., /ed./, 2013; Castendyk, D.N., Eary, L.E., 2009).

Rönicke et al. (2001) noted a slight increase in the diversity of phytoplankton species during chemical neutralisation. The most important species that were noted after remediation belong to the genera *Chlamydomonas*, *Ochromonas* and *Chrysococcus*. After a certain time the lake was inhabited by different groups of phytoplankton algae: *Chromulina* sp., *Synedra acus*, *Nitzschia acicularioides*, *Eunotia exigua*, *Cryptomonas ovata*, *Rhodomonas minuta* and *Peridinium umbonatum*. Cyanobacteria occur only when the water reaches neutral pH values.

In Grünwalder Lauch mine pit lake, 88 % of the lake bottom is covered with a coating several centimetres thick formed by the species *Zygogonium ericetorum* Kützing (Kleeberg et al., 2006), which occurs in great abundance at depths of between 5 and 6 metres. *Zygogonium ericetorum* is phosphorus-dependent, and has poor tolerance of a high concentration of iron (Nixdorf et al., 2003).

By comparing the results with the data given in reference works (Soni, et al., 2014; Geller et al., [ed.], 2013; Castendyk, D.N., Eary, L.E., 2009), it may be concluded that the mine pit lakes studied are in suitable condition in particular for the restoration and conservation of wetland biodiversity. Mine pit lakes in Bosnia and Herzegovina have neutral to slightly alkaline pH values and significantly lower concentrations of heavy metals in the water by comparison with other mine pit lakes in Europe. In this study of mine pit lakes, higher concentration of nutrients in the water, especially nitrites and nitrates, were observed. These conditions have resulted in the rapid colonization of the mine pit lakes and the establishment of habitats for cyanobacteria and algae, as well as for other groups of organisms.

CONCLUSIONS

The following conclusions may be adopted on the basis of the results of the survey:

- increased values of certain physical and chemical parameters, diversity of cyanobacteria, algae and macrophytes biocenoses are correlated with the type of lake formation;
- mine pit lakes that were formed as a result of subsidence are more rapidly colonised with cyanobacteria, algae and macrophytes than are lakes in open-cast craters;
- a prerequisite for the development of macrophytes is the inclination of the coastal area of the lake. Steep coasts inhibit colonization by macrophytes, whereas level coasts facilitate such colonization;
- the presence of macrophytes is correlated with the diversity of cyanobacteria and algae;
- the model of restoration of mine pit lakes formed as a result of subsidence should focus on the control of wetland vegetation, neutralization and reduction in the concentration of ammonia, $KMnO_4$ consumption and heavy metals. The restoration of mine pit lakes formed in open-cast craters should focus on the establishment of wetland vegetation and a reduction in the concentration of sulphate and heavy metals.

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SAŽETAK

Istraživanje za ovu studiju je provedeno u periodu od 2013. godine (21.07. i 18.08.) do 2014. godine (20.07., 09.08., 20.08. i 13.09). Uzorci cijanobakterija i algi su prikupljeni struganjem sa prirodne podloge, kao što je kamen, mulj i detritus. Uzorci sa kamena su prikupljeni struganjem četkicom, dok su uzorci sa pijeska i mulja prikupljeni Pasterovom pipetom. Za potrebe ovog rada prikupljeno je ukupno 27 uzoraka fitobentosa. Identifikacija i brojanje dijatomeja je izvršeno pomoću mikroskopa BestScope BS2020. Relativna brojnost dijatomeja je procijenjena brojanjem ukupno 400 valvi svakog taksona, dok je za ostale cijanobakterije i alge procjena izvršena dodavanjem brojeva od 1 do 3 (1-rijetka, 2-česta i 3-brojna). Ekološke karakteristike za dijatomeje su analizirane pomoću softvera OMNIDIA ver. 5.3. Multivarijantna statistička analiza je izvršena upotrebom programskog paketa PRIMER v.6. Cilj ovog rada je analiza i poređenje sastava cijanobakterija i algi u dva kopovska jezera, koja se nalaze u općinama Kakanj (jezero Vrtlište) i Zenica (jezero Mošćanica). Poređenjem morfoloških, limnoloških, fizičko-hemijskih i bioloških karakteristika istraživanih kopovskih jezera biće utvrđeni povoljni kriteriji za ekološku restauraciju. U kvalitativno-kvantitativnom sastavu fitobentosa istraživanih kopovskih jezera ukupno su konstatovana 183 taksona cijanobakterija i algi. Identifikovane vrste pripadaju sljedećim klasama: ***Cyanophyceae*** (5), ***Chyrsophyceae*** (1), ***Bacillariophyceae*** (166), ***Dinophyceae*** (1), ***Euglenophyceae*** (3), ***Chlorophyceae*** (3) i ***Conjugatophyceae*** (1). Najbrojnija klasa je ***Bacillariophyceae*** (166 vrsta ili 97,71 %), dok se ostale klase javljaju sa nešto manjom procentualnom zastupljenošću. Dominantni taksoni istraživanih kopovskih jezera su: ***Achnanthidium minutissimum***, ***Brachysira microcephala***, ***Cyclotella meneghiniana***, ***Denticula kützingii***, ***Encyonopsis microcephala***, ***Navicula radiosa***, ***Nitzschia palea***, ***Nitzschia recta*** i ***Ulnaria ulna***. Multivarijantnom statističkom analizom utvrđena je jasna razlika između istraživanih kopovskih jezera. Poređenjem dobivenih rezultata sa literaturnim podacima, može se zaključiti da istraživana kopovska jezera imaju povoljne uslove, naročito za restauraciju i konzervaciju močvarnog biodiverziteta. Ovi uslovi su rezultirali brzom kolonizacijom navedenih kopovskih jezera i stvaranjem staništa kako za cijanobakterije i alge, tako i za druge grupe organizama.

Ključne riječi: *degradacija, diverzitet, cijanobakterije i alge, kopovska jezera, restauracija.*