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Article

Ecological state of watercourses in the Kizelovsky coal basin (Perm Krai, Russia) assessed by phytoplankton pharacteristics

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Abstract. The first data on the composition and quantitative development of phytoplankton is presented for the rivers of the Kizelovsky Coal Basin (Perm Krai, Russia) contaminated with acidic mine drainage. The studies were conducted in the summer of 2022 in the rivers Vil'va, Poludenniy Kizel, Vostochniy Kizel, and Bolshaya Gremyachaya. As a result of the unregulated mine discharge, the rivers have experienced significant acidification, high mineralization, and increased heavy metal content, caused by a relatively new type of anthropogenic impact in these areas. The study revealed that the phytoplankton structure and dominant species in these rivers differ significantly from those typical of river ecosystems in the Perm Cis-Urals. A significant decrease in phytoplankton species richness was observed at stations in the contaminated zone. The diatom species made the most of the phytoplankton diversity (33%), followed by green algae (17%), euglenoids (14%), and cyanoprokaryotes (13%). The phytoplankton similarity was low at different stations of the studied rivers. Cyanoprokaryotes dominated in phytoplankton by abundance (66–99% of the total abundance), microalgae of various divisions, by biomass. The dominant phytoplankton complex was represented by a small set of species specific to each river. High variability in total abundance and biomass was a characteristic feature of phytoplankton, indicating an unstable state of the communities.

Keywords: planktonic algae, polluted rivers, anthropogenic transformation, diversity, biomass, abundance, mine waters

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Научная статья

Экологическое состояние водотоков на территории Кизеловского угольного бассейна (Россия, Пермский край) по характеристикам фитопланктона

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Аннотация. В работе приводятся первые данные о составе и количественных показателях развития фитопланктона рек Кизеловского угольного бассейна (Пермский край, Россия), загрязненных кислыми шахтными водами. Исследования проводились летом 2022 г. в реках Вильва, Полуденный Кизел, Восточный Кизел и Большая Гремячая. В результате самоизлива шахтных вод в реках произошло значительное закисление, увеличение минерализации и содержания тяжелых металлов в воде, что стало относительно новым видом антропогенного воздействия на их акватории. В ходе исследования выявлено, что в этих реках структура фитопланктона и набор доминирующих видов значительно отличаются от типичных для речных экосистем Пермского Предуралья. На станциях в зоне загрязнения выявлено значительное снижение видового богатства фитопланктона. Установлено, что разнообразие фитопланктона рек определяли диатомовые (33% общего числа таксонов), зеленые (17%), эвгленовые водоросли (14%) и цианопрокариоты (13%). Сходство видового состава водорослей на разных станциях изученных рек невысокое. По численности в фитопланктоне преобладали цианопрокариоты (66–99% от общей численности), по биомассе – водоросли разных отделов. Доминантный комплекс фитопланктона представлен небольшим набором видов, специфичным для каждой реки. Характерной чертой развития фитопланктона была высокая изменчивость общей численности и биомассы, что свидетельствует о неустойчивом состоянии сообществ.

Ключевые слова: планктонные водоросли, загрязненные реки, антропогенная трансформация, разнообразие, биомасса, численность шахтные воды

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Introduction

The Kizelovsky Coal Basin (KCB) is the part of the West Ural Coal Basin. It stretches for 150 km from north to south (from Aleksandrovsk to Lysva), covering about 200 km^2. Coal seams occurred among terrigenous deposits of the Visean stage of the Lower Carboniferous, represented mainly by sandstones, siltstones, and mudstones. Here, coal was found as early as in 1783, the mining was started in 1797; the maximum amount of coal (12 million tons per year) was mined here in the late 1950s. In the late 1990s, due to unprofitability, the mines were being closed gradually (Imaikin, 2014; Maksimovich and Pyankov, 2018).

In the Perm Krai of Russia, the aftermath of coal mining operations in the Kizelovsky Basin is one of the most pressing environmental issues. The pollution of the riverine waters began as the coal production has been stopped, followed by the associated mine discharge in 2002. The average content of many heavy metals in KCB coals exceeds average concentrations for CIS coal deposits (Maksimovich and Pyankov, 2018). Therefore, in some cases, contamination of surface and groundwater with heavy metals makes them unsuitable for domestic and drinking water supply, sometimes, even for technical purposes. Currently, there are more than a dozen of sites, where mine water discharges to the surface. Mine water flows into 19 rivers, fifteen of which have been virtually withdrawn from water use (Imaikin and Imaikin, 2022; Maksimovich, 2004). Highly mineralized (up to 61.6 g/L) mine waters with low pH values (4–5) are characterized by abnormally high contents of sulfates (700–1400 mg/L), iron (250–430 mg /L), aluminum (29–54 mg/L), etc. (Maksimovich et al., 2006). Entering rivers, these runoffs both worsen water quality and increase the risk of degradation of river ecosystems. Acidic mine waters also increase the turbidity of river water and cause sedimentation in river beds. The surface water pollution starts from the fourth-order tributaries and reaches the Kama River, largest in the region. Even for big rivers, such as the Kos'va and Vil'va, high and extremely high levels of water pollution in terms of total iron concentration are constantly observed (Imaikin and Imaikin, 2022; Maksimovich, 2004). In the Vil'va River, total iron content in water exceeded 200 MAC, which corresponds to the level of extremely high pollution for the river of the fishery status (Maksimovich and Pyankov, 2018). The powerful influence of the mine discharge currently extends to the mouth of the Vil'va River and further along the left bank of the Us'va River, where the river water has a rusty tint, and the pebbles coated with rust are observed both for bottom and banks (Imaikin and Imaikin, 2022).

The taxonomic composition, diversity, and level of quantitative development of phytoplankton are the main indicators of the state of aquatic ecosystems. Due to both sensitivity of microalgae to environmental changes and their short generation time, phytoplankton is often used as an indicator of water quality (Busseni et al., 2019; Marvaetal et al., 2014; Niyogi et al., 2002; Parparov et al., 2015). However, no phytoplankton studies have been performed so far despite the pollution of small rivers (Poludenny Kizel, Vostochny Kizel, Bolshaya Gremyachaya) and medium-sized rivers (Vil'va) by man-made mine waters of the Kizelovsky Coal Basin.

The study aims to determine and to compare the taxonomic and quantitative characteristics of phytoplankton in some rivers located in the Kizelovsky Coal Basin in the zone affected by coal mine waters.

Materials and methods

The phytoplankton samples were collected in July 2022 during field studies at the middle reaches of the Vil'va River and at the small rivers Poludenny Kizel, Vostochny Kizel, and Bolshaya Gremyachaya; the areas located upstream (background) and downstream (polluted) the mine water discharges were considered (Figs. 1, 2, 3). At the sampling sites, the following were determined: water temperature and hydrogen index (pH) using an analyzer (Hanna 98127), current speed was measured using the "float" method, channel width was measured using a range finder, and depth was measured using direct measurements. Due to the shallow depths (0.2–0.7 m) and the lack of stratification of water masses in the studied rivers, 1-L phytoplankton samples were collected in coastal zones by scooping from the subsurface water layer. The samples were immediately fixed by Lugol's solution with added formalin. A total of 24 quantitative samples were obtained, six for each river: three samples from upstream and three ones from downstream of the mine water discharge site; the stations were located at 10-m distance from each other. The river sections for sampling were set based on their accessibility and the location of the mine water discharge sites. Samples were concentrated by filtration through Vladipor membrane filters (pore diameter of 1.2–3.0 μm).

The species composition of microalgae was determined using light microscope Zeiss (Axiostar Plus, Germany). The species identification was performed using a number of Russian and international taxonomic keys, listed in previous publication (Belyaeva, 2024). The species nomenclature is provided according to the international AlgaeBase database (Guiry and Guiry, 2023). Several representatives identified down to the genus level are included in the total number of taxa. The Sørensen-Czekanowski index was calculated to compare the degree of similarity of phytoplankton species composition (Magarran, 1992). Using this coefficient, data were clustered using Ward's method in Excel 2010, R package (Novakovsky, 2016).

Quantitative phytoplankton counting and cell size measuring were carried out in the Uchinskaya chamber (0.01-cm^3 volume). The biomass of microalgae was calculated using the standard volumetric-weight counting method (Metodika..., 1975). The species was considered dominant if its biomass or abundance exceeded 10% of the total biomass/abundance of all species in the phytoplankton community. The Shannon-Weaver species diversity index was calculated for each sample based both on the abundance and biomass of phytoplankton (Shitikov and Rosenberg, 2005).

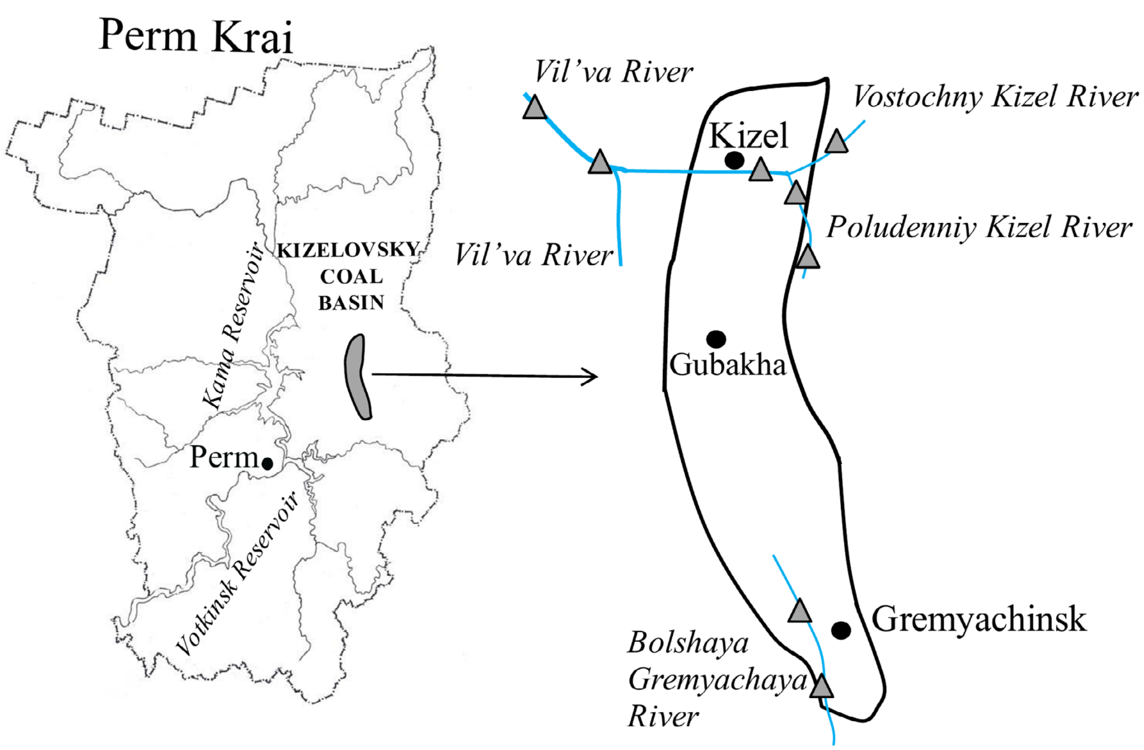

Fig. 1. Schematic map of the phytoplankton sampling in the rivers of the Kizelovsky Coal Basin.

Fig. 2. Mine water discharge sites nearby the Vostochnyi Kizel River

Fig. 3. Sampling sites at the rivers of the Kizelovsky Coal Basin, upstream and downstream the mine waters discharge sites. **A** – Bolshaya Gremyachaya River (mouth); **B** – Vilva River, downstream the confluence with the Poludenny Kizel River.

The ecological and geographical characteristics of algae are compiled according to the most recent systems accepted worldwide for the algae ecology and biogeography (Davydova, 1985; Marvan et al., 2005; Proshkina-Lavrenko, 1953; Sladeček, 1973).

The Pantle-Buck method, modified by Sladeček, was applied to assess the degree of organic pollution of waters (Pantle and Buck, 1955; Sladeček, 1973).

Results and discussion

During the study period, the water temperature at the sampling sites reached maximum in the Bolshaya Gremyachaya River (18.2–23.7 °C), in other rivers, it varied from 14.6 to 17.3 °C. The average current velocity in small rivers varied from 0.10 to 0.24 m/s, in the Vil'va River, 0.20–0.56 m/s. River width was 3 to 15 m at sampling sites. The pH and heavy metal content in the water varied significantly between the rivers (Table 1). The river banks are predominantly low, overgrown with forest or herbaceous and shrubby vegetation. The river soils are pebble and boulder-pebble with sand, clay, and plant debris.

In the studied rivers, the phytoplankton communities comprised 72 species and intraspecific taxa of algae (9 taxa identified to genus level), belonging to 47 genera, 33 families, 22 orders, 8 divisions. Cyanoprokaryota was represented by 9 species, Chrysophyta, 6, Bacillariophyta, 24, Xantophyta, 3, Dinophyta, 3, Euglenophyta,10, Chlorophyta, 12, and Charophyta (Desmidiales), by 5 species (Table 2, Fig. 4). The division Bacillariophyta was characterized by the greatest species richness, forming 33% of the total number of species and intraspecific taxa. The representatives of Chlorophyta, Euglenophyta, and Cyanoprokaryota accounted for 17, 14, and 13%, respectively, following diatoms in terms of species richness. The most diverse genera were *Monoraphidium*, *Euglena*, *Nitzschia* (5.5% each) and *Eunotia*, *Tribonema*, *Gomphonema*, *Navicula*, *Achnanthidium* and *Phacus* (4.1% each); they formed 41.7% of the total genera diversity.

In the river sections affected by mine waters, 13 taxa belonging to four divisions were found: Cyanoprokaryota (genera *Planktolyngbya*, *Anathece*, *Cyanodictyon*), Chlorophyta (*Stygeoclonium*, *Microspora*), Euglenophyta (*Euglena*, *Lepocinclis*, *Petalomonas*), and Xantophyta (*Tribonema*). Earlier, it was reported about a significant decrease in the phytoplankton diversity under the influence of mine waters from the coal industry (Luís et al., 2013, Valente et al., 2016; Verb and Vis, 2005). Phytoplankton was totally absent in the area of the mine water discharge in the Poludenny Kizel River and in the Vil'va River downstream the mine water discharge site.

Table 1. Morphometric and chemical parameters of the rivers of the Kizelovsky Coal Basin. * – data are given according to Maksimovich and Pyankov, 2018; ** – maximum permissible concentration for the river of the fishery status[1].

River	Basin area*, km^2	Length*, km	Width at the sampling point, m	Flow rate, m/s	pH	Heavy metal content in water*, mg/dm^3		
						Fe_{total} (0.3)**	Al (0.5)**	Mn (0.1)**
Bolshaya Gremyachaya	51.8	17	3–5	0.18–0.24	2.8–4.7	16.5–344	2.8–24.0	0.27–3.1
Poludenny Kizel	82.3	17	5–7	<0.1	2.1–4.7	59–105	4.4–5.9	1.3–16.0
Vostochny Kizel	218	24	7–10	0.17–0.22	3.2–5.4	8–233	1.0–50.0	0.15–5.5
Vil'va	1180	107	12–15	0.20–0.56	6.3–7.5	0.5–6.9	0.06–1.6	0.1–0.49

[1] Order of the Russian Ministry of Agriculture dated December 13, 2016 No. 552 "On approval of water quality standards for water bodies of fishery importance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fishery importance."

Table 2. Phytoplankton diversity in the rivers of the Kizelovsky Coal Basin.

Division	Order	Family	Genus	Species	Intra-specific taxa	Taxa identified to genus level	Total	% of total
Cyanoprokaryota	5	7	8	7	1	1	9	13
Chrysophyta	1	2	4	5	0	1	6	8
Bacillariophyta	8	11	13	21	1	2	24	33
Xantophyta	1	1	1	3	0	0	3	4
Euglenophyta	1	2	5	9	0	1	10	14
Chlorophyta	3	6	8	9	1	2	12	17
Charophyta	1	2	5	4	0	1	5	7
Dinophyta	2	2	3	2	0	1	3	4
Total	**22**	**33**	**47**	**60**	**3**	**9**	**72**	**100**

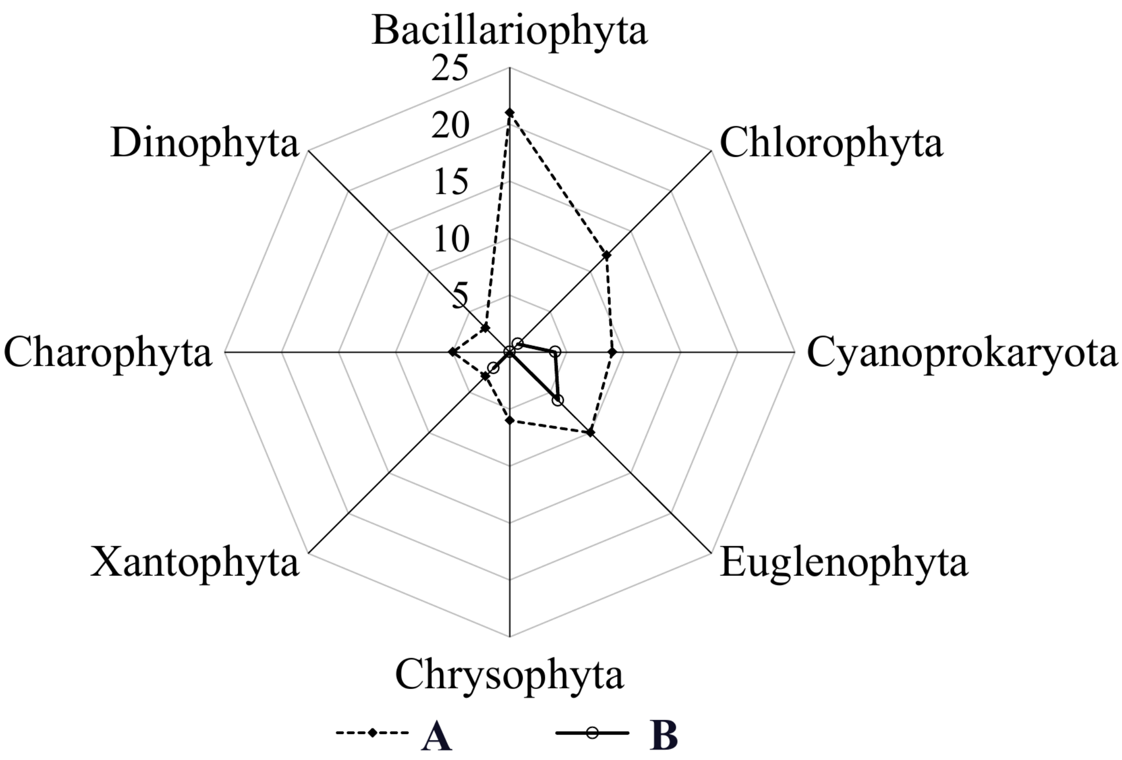

Fig. 4. Phytoplankton species composition in the background (**A**) and polluted (**B**) river sections of the Kizelovsky Coal Basin.

Relative species richness of phytoplankton (RSRP), i.e., the number of species in a sample, varied from 4 to 32 species and intraspecific taxa in the studied rivers. The RSRP was 26 ± 4 species in the river sections of the Vostochny and Poludenny Kizel rivers, located upstream of the mine discharge, being 3 times lower in the Bolshaya Gremyachaya River. The lowest RSRP is found at the stations located downstream of the mine discharge (5 ± 1 species).

Phytoplankton similarity coefficients were generally low (0.06–0.50) between sampling stations in the studied rivers. The highest similarity in phytoplankton species composition was observed between the polluted stations of the Vil'va and Bolshaya Gremyachaya rivers, the lowest, between the Vil'va River (polluted zone) and the Poludenny Kizel River (upstream the mine discharge site). The resulting dendrogram revealed two clusters, represented by the phytoplankton communities upstream and downstream the polluted area; these clusters were predetermined by the specificity of the phytoplankton species composition in the polluted sections of the rivers (Fig. 5).

The phytoplankton species diversity index ranged from 0.06 to 2.66 by abundance (on average, 1.51 ± 0.34) and from 0.20 to 3.90 by biomass (on average, 2.33 ± 0.35). The Shannon-Weaver index was significantly lower in the river sections polluted by mine discharges (0.74 and 1.72 by biomass and abundance, respectively) comparing to that in the background sections (2.28 and 2.94, respectively). The minimum index values in the Bolshaya Gremyachaya and Vil'va rivers downstream of the pollution sources were associated with a particularly strong technogenic load; this indicated a significant simplification of the phytoplankton community structure, numbering 2–4 representatives only (Table 3).

In the studied watercourses of KCB, non-heterocystous cyanoprokaryotes (*Anathece bachmannii* Komárková-Legnerová et G. Cronb., *Planktolyngbya limnetica* (Lemm.) J. Komárková-Legnerová & G. Cronb.) and diatoms (*Eunotia bilunaris* (Ehrenb.) Mills, *Achnanthidium affine* (Grun.) Czarnecki) were found at most sites located upstream the mine water discharge. The most frequently found were the diatoms *Eunotia exigua* (Bréb. ex Kütz.) Rabenh. (frequency of occurrence 85%), *Nitzschia sigma* (Kütz.) W. Smith (79%), *N. sublinearis* Hustedt (75%), and euglena *Euglena proxima* P.A. Dangeard

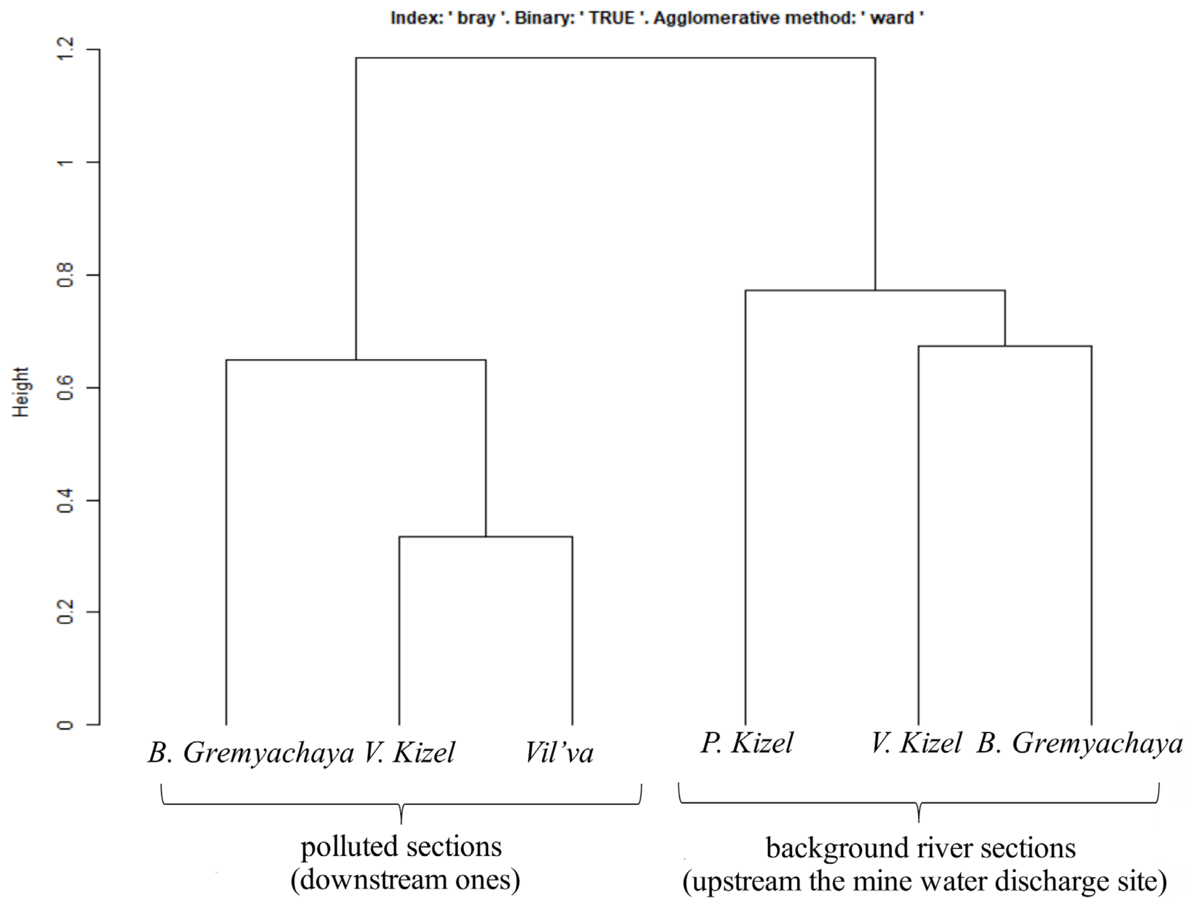

Fig. 5. Hierarchical clustering of phytoplankton species composition of the studied rivers in the Kizelovsky Coal Basin.

Table 3. Structural characteristics of phytoplankton communities in the rivers of the Kizelovsky Coal Basin. The values are given as mean and standard error; the values of indices are given for phytoplankton abundance (in the numerator) and biomass (in the denominator).

River		Abundance, million cells/L	Biomass, mg/L	Saprobity index	Shannon-Weaver index
Vil'va River	below the confluence of the P. Kizel River (pollution zone)	–	–	–	–
	middle reaches (pollution zone)	0.6 ± 0.20	0.02 ± <0.01	2.30 / 2.69	0.06 / 1.35
Vostochny Kizel River	upstream the mine water discharge site	0.4 ± 0.09	0.20 ± 0.07	1.70 / 2.03	2.66 / 2.14
	pollution zone	0.7 ± 0.12	0.06 ± 0.02	1.70 / 1.75	1.01 / 1.81
Poludenny Kizel River	upstream the mine water discharge site	6.0 ± 0.17	0.16 ± 0.10	1.73 / 2.03	2.04 / 3.90
	pollution zone	–	–	–	–
Bolshaya Gremyachaya River	upstream the mine water discharge site	10.2 ± 2.1	0.41 ± 0.09	1.56 / 0.96	2.14 / 2.78
	pollution zone	16.6 ± 2.9	25.31 ± 4.23	2.91 / 3.98	1.15 / 0.20

(83%). At the sites located downstream the mine water discharge, the yellow-green algae (*Tribonema viride* Pascher, *T. vulgare* Pascher, T. *ulotrichoides* Pascher), euglenoids (*Euglena proxima, E. deses* (O.F. Müll.) Ehrenb. and *Lepocinclis ovum* (Ehrenb.) Lemm.), and green algae (*Stygeoclonium* sp. and *Microspora* sp.) were usual. Apparently, the presence of these species was associated with their ability to develop at low pH values of 1–3 (Kelly, 1988; Verb and Vis, 2005; Vetrova, 1993), despite their optimal growth in a near-neutral environment (pH 7.0–7.8). In the Kizel River, *Euglena proxima* was noted as a numerous species as early as 1931 (Tauson, 1947). In the Krasny stream, representatives of the Xantophyta (*Tribonema vulgare, T. ulotrichoides*) and Euglenophyta (*Euglena* sp., *E. proxima*) were found 50 m downstream the mine waters discharge from the Bely Spoy mine shaft, pH = 3–4, mineralization of 0.1–0.2 g/L and high intensity of the water color (Belyaeva, 2022b).

Numerous studies of the impact of acid mine discharge on algal communities have demonstrated that some diatoms are good indicators of low pH environments (1.9–4.2) (Verb and Vis, 2005; Whitton et al., 2000; Zalack et al., 2010). The most frequently mentioned species are representatives of the genera *Eunotia* (*E. exigua* (acidobiont, the most common species in rivers polluted by mine waters of the coal industry), *E. tenella* (Grun.) Cl.*, E. septentrionalis* Østrup, *E. osoresanensis* Negoro, *E. arcus* Ehrenb., *E. glacialis* Meister, *E. pectinalis* (Dilwyn) Rabh.), *Pinnularia* (*P. subcapitata* Gregory, *P. acoricola* Hustedt, *P. acidophila* G. Hofmann & Krammer, *P. aljustrelica* A. Luís, S.F.P. Almeida & Ector, *P. obscura Krasske, P. braunii var. amphicephala* (Grun.) Cl., *P. subcapitata* Gregory, *P. terminitina (Ehrenb.) R.M. Patrick), Nitzschia* (*N. hantzschiana* Rabenh.*, N. subcapitella* Hustedt, *N. communis* Rabenh., *N. pusilla* Grun., *N. vasta* Hustedt), *and Achnanthidium minutissimum* Kütz. (Aguilera, 2013; Dong et al., 2015; Luís et al., 2013, 2016; Rivera et al., 2019; Urrea-Clos and Sabater, 2009; Valente et al., 2016; Zalack et al., 2010). Some researchers additionally indicate *Fragilaria capucina* Desmazières, and *F. rumpens* (Kütz.) G.W.F. Carlson, *Frustulia rhomboids* (Ehrenb.) De Toni, and *F. rhomboides* var. *saxonica* (Rabenh.) De Toni (Ferreira da Silva et al., 2009). In addition, most often mentioned algae are *Microspora* Thuret, *Euglena mutabilis* F. Schmitz, *E. proxima, Mougeotia* C. Agardh., *Klebsormidium flaccidum* (Kütz.) P.C. Silva, Mattox & W.H. Black *(*Amaral-Zettler et al., 2002; Verb and Vis, 2001).

In all studied sections of the KCB rivers, the phytoplankton is characterized by a predominance of planktonic (51%) and benthic (25%) species, most of which are eurybiont (85%) or boreal species (12%). Considering the pH of the environment, the most diverse are indifferent taxa (72%) with a high number of alkaliphiles (22%), the presence of latter is a consequence of the background slightly alkaline pH (7.8–8.8) of the rivers of the Perm Cis-Urals (Belyaeva, 2022b). Acidophiles make up 4%, represented by *Pinnularia borealis* Ehrenb., *Tabellaria flocculosa* (Roth) Kütz., *Eunotia bilunaris,* and *E. exigua.* Considering the water mineralization, indifferent species predominate (79%), followed by halophobes (9%). A small group (6% each) is formed by halophiles (*Planktolyngbya limnetica*, *Oscillatoria tenuis* C. Agardh ex Gomont, *Anathece clathrata* (West et G.S. West) Komárek, Kaštovský & Jezberová), and mesohalobes (*Nitzschia sigma*, *N. sublinearis*, *Euglena proxima*, *E. deses* (O.F. Müll.) Ehrenb., *E. viridis* (O.F. Müll.) Ehrenb., *Euglenaria caudata* (E.F.W. Hübner) Karnkowska-Ishikawa et E.W. Linton), sometimes reaching significant numbers and even being part of a complex of dominant species.

Non-heterocystous Cyanoprokaryotes dominated by abundance in the phytoplankton communities of the studied rivers, forming from 66% to 99% of the total abundance. The contribution of algae of different divisions to the total biomass varied: for most rivers, a predominance of euglenoids was noted (27–99%), in the areas located upstream the mine water discharge, diatoms were also presented in significant numbers in the phytoplankton (8–30%). In the Vostochny Kizel River, upstream the mine water discharge site, 65% of the biomass was formed by representatives of Charophyta, represented by desmid algae; downstream, filamentous green algae developed (61%); in the Poludenny Kizel River, species of the genus *Tribonema* formed 37% of the total biomass (Fig. 6). The total phytoplankton abundance and biomass varied significantly (Table 3). Minimum values of phytoplankton abundance and biomass were recorded in the Vil'va and Vostochny Kizel rivers, maximum, in the Bolshaya Gremyachaya River in the area downstream the discharge of mine waters due to the mass development of euglenoids. Significant fluctuations in phytoplankton abundance and biomass have also been described in the literature, both in watercourses polluted by mine waters (Kelly, 1988; Niyogi et al, 2002; Verb and Vis, 2005), and in watercourses of urbanized areas in general (Belyaeva, 2022a; Kadochnikova and Belyaeva, 2017; Turyanova, 2006; Umanskaya et al., 2018, etc.).

In the studied rivers, representatives of euglenoids, yellow-green algae, and cyanoprokaryotes dominated, while diatoms, generally characteristic of the rivers of the Cis-Urals, were absent among the dominant species even in the background areas located upstream the mine water discharge

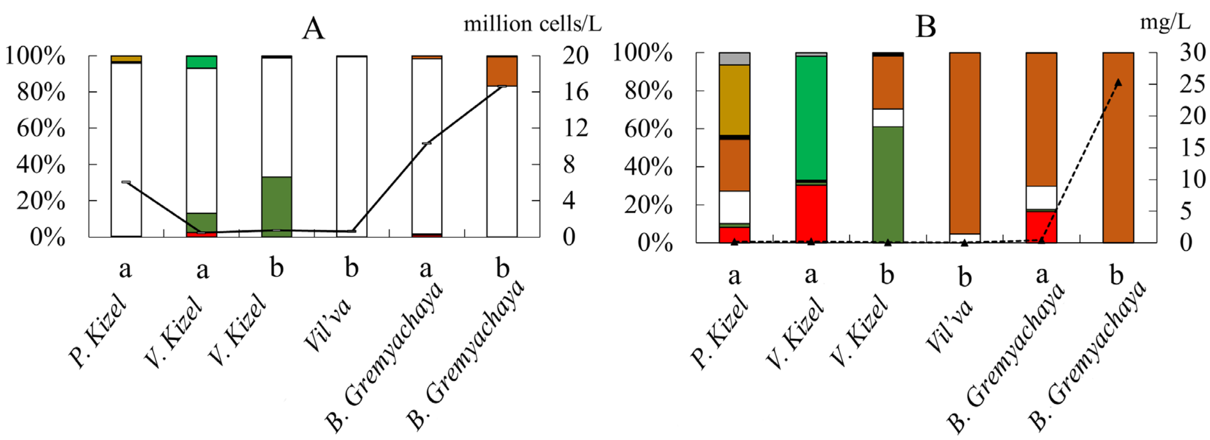

Fig. 6. Contribution of algal divisions to the phytoplankton community structure at different river sections in the Kizelovsky Coal Basin in July 2022. 1 – Bacillariophyta, 2 – Chlorophyta, 3 – Cyanoprokaryota, 4 – Euglenophyta, 5 – Chrysophyta, 6 – Xantophyta, 7 – Charophyta (Desmidiales), 8 – Dinophyta. **A** – phytoplankton abundance, solid line; **B** – phytoplankton biomass, dotted line. a – background river sections (upstream the mine water discharge site), b – polluted sections (downstream ones).

Table 4. Composition of dominant phytoplankton species in the rivers of the Kizelovsky Coal Basin. Values in the brackets are the species share (%) in total abundance / biomass.

River	Dominant species	
	By number	By biomass
Vil'va, below pollution zone	*Anathece clathrata* (89) *Planktolyngbya limnetica* (10)	*Lepocinclis ovum* (56) *Euglena deses* (36)
Vostochny Kizel, upstream the mine water discharge site	*Anathece clathrata* (40) *Planktolyngbya limnetica* (26) *Planktolyngbya contorta* (Lemm.) Anagn. et Komárek (13)	*Staurastrum striolatum* (Nägeli) W. Archer (63) *Pinnularia borealis* (12)
Vostochny Kizel, in the pollution zone	*Planktolyngbya limnetica* (66)	*Stigeoclonium* sp. (60) *Euglena proxima* (12)
Poludenny Kizel, upstream the mine water discharge site	*Anathece bachmannii* (57)	*Tribonema viride* (19) *T. vulgare* (11) *Trachelomonas planctonica* Svirenko (14)
Bolshaya Gremyachaya, upstream the mine water discharge site	*Cyanodictyon* sp. (36) *Anathece clathrata* (29) *Planktolyngbya contorta* (19) *Planktolyngbya limnetica* (11)	*Euglena proxima* (38) *Lepocinclis ovum* (30)
Bolshaya Gremyachaya, in the pollution zone	*Cyanodictyon* sp. (75)	*Lepocinclis ovum* (96)

(Table 4). When industrial and municipal wastewater enters small water bodies in the Perm Krai, both biomass and abundance of phytoplankton increase, as well as the proportion of non-heterocystous Cyanoprokaryotes. As the anthropogenic impact increases, the species characteristic of highly saprobic waters develop, and the role of euglenoids and green algae increases. With excessive anthropogenic impact, microalgae communities are suppressed, or they do not develop at all (Belyaeva, 2022b). Despite the high mineralization of mine waters (1.5–2.0 g/L), the water mineralization corresponds to waters with relatively high mineralization in the KCB rivers (up to 1.0 g/L), but cannot be considered extreme according to the classification of O.A. Alekin (1970). This is also noted by other researchers (Gorokhova and Zinchenko, 2014; Komulainen et al., 2021). In our studies, the absence of phytoplankton was noted exactly downstream the discharge of highly mineralized mine waters into the Poludenny Kizel River; no phytoplankton was found even at its confluence with the Vil'va River and further downstream for a considerable distance. Apparently, the lack of microalgae here was due to both chemical factors and the presence of large amounts of minerals and suspended solids, which significantly increased the water color and reduced transparency and illumination (Fig. 3). In addition, in the KCB watercourses, the development of microalgae was influenced by the water temperature: the correlation coefficients were 0.83 ($p \leq 0.01$) for phytoplankton abundance and 0.92 ($p \leq 0.004$) for biomass, respectively.

Conclusions

The data on phytoplankton communities of the streams within the Kizelovsky Coal Basin are presented for the first time. Analysis of the taxonomic composition, eco-geographic groups, and the quantitative phytoplankton parameters allowed us to identify river sections affected by anthropogenic impact to varying degrees. Phytoplankton communities had low species richness, which decreased as the pollution increased. Euglenoids, yellow-green algae, and non-heterocystous cyanoprokaryotes occupied a key position in the phytoplankton communities. Phytoplankton was characterized by high variability in total abundance and biomass. In river sections affected by mine waters, communities differed significantly from the background ones, the species adapted to low pH values developed abundantly. To obtain a more complete and accurate result, algological analysis should be accompanied by qualitative chemical analysis.

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