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RESPONSE OF ALGAL COMMUNITIES TO ANTHROPOGENIC CHANGES IN MINERALIZATION

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Abstract

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A relatively new type of impact of human activities on lake-river system has resulted from mining operations in the Kostomuksha iron deposit, Karelia, NW Russia. Lake Kostumus was isolated by a dam and has since acted as a waste accumulator for ore-dressing production. The total mineral content of the water has reached 400 mg l^{-1}. Comparative analysis of the structural organization and functioning of phytoperiphyton and phytoplankton in the Kenti lake-river system and subject to anthropogenic load resulting from urbanization is presented. The algal communities influenced by mineralized mining mill wastes were analysed in terms of species richness, species diversity, species ecology values, biomass and chlorophyll *a* concentration. When the anthropogenic load is minimized, the natural structure of algal assemblages quickly restores. This is most typical of lake-river systems with alternations of lakes and rivers, rapids and pools, playing the role of natural water treatment facilities. The possibility of using algal assemblages as an indicator of the ecological state of lake-river ecosystems is analysed.

Keywords: rivers, phytoplankton, phytoperiphyton, monitoring, Northwest Russia.

INTRODUCTION

Human-induced transformation of ecosystems has become a widespread phenomenon and one of the most acute problems. According to the data of numerous observations (Wetzel, 2001; Stevenson & Sabater, 2010), the state of water bodies and organisms inhabiting them largely depends on anthropogenic load on the catchments area.

The algal flora is one of the most sensitive constituents of aquatic ecosystems and is responsible for the structure and functioning of its components (Round, 1981). The advantage of using algae to monitor aquatic ecosystems is due to their short life cycle, enabling not only the assessment of the present state of a water body during short-term observations, but also prediction of possible changes (Round, 1981; Wetzel, 2001).

The Republic of Karelia (NW Russia) does not have a high population density. The total territory is 172.000 km^2 with a population about 700.000 people, giving an average density of only 4 people per square km (Karelia, 2007). Rivers in Karelia have many lakes along their course and the stream sections act as connections within the landscape mosaic of lakes. As a result, complex lake-river systems are formed (Vodogrecki, 1972). The water bodies are largely natural in character and with little disturbance by human activity. However, the situation is starting to change, therefore, a biomonitoring approach has been developed (Komulaynen, 2002, 2004a) to assess the influence of land-use patterns on the structure of algae communities in this region.

The Kostomuksha industrial centre is at present one of the largest in the north-western part of Karelia. Development of the city, ore-dressing mill (ODM) and related industries inevitably told on the status of water resources. Anthropogenic load on water ecosystems is constituted by gaseous and dust emissions from ODM, industrial and domestic sewage discharges.

Elevation of total dissolved salts of waters due to a variety of man-induced activities and natural processes is one of the major ecological disturbances on a global scale (Silva et al., 2000). In spite of many publications, in which the mineralization of water bodies is assessed, its effect on the structure of algal communities is not yet fully understood. It has been shown (Biggs & Price, 1987; Hill & Webster, 1982) that as mineralization increases from 10 to 50‰, the phytoperiphyton production level remains unchanged. However, some authors have noted that a rise in salinity induces the suppression of photosynthesis as a result of the increase of osmotic pressure (Bierhuizen & Prepas, 1985; Carpenter et al., 1991). The authors of the relevant publications commonly assess the response of communities to the extreme increase of mineralization, for example, in the estuary zone (McLusky, 1989; Cloern, 1997; Popovich et al., 2008).

Phytoperiphyton and phytoplankton can be helpful for assessing changes in river and lake ecosystems (Whitton et al., 1991; Whitton & Rott, 1996; Prygiel et al., 1999) such as those associated with eutrophication, river management, changes in land use at the scale of the watershed and in last years for monitoring in NW Russian rivers (Komulaynen, 2002, 2004a).

It should be noted, however, that algae can withstand a wide mineralization range and that the salt concentrations estimated in the Kenti River system are much lower than the upper limits tolerated by algae (Genter, 1996; Blinn & Bailey, 2001).

The main objectives of this study were to describe the spatial distributions of phytoplankton and phytoperiphyton in water bodies affected by human activity.

MATERIALS AND METHODS

The algological investigations were carried out in 1987, 1993, 1994, 1995, 2007 and 2008. Phytoplankton and phytoperiphyton samples were collected once a year during a late summer low-water discharge period. A total of 17 locations were sampled (Fig. 1), of which 11 were located in the Kenti River (sites 1, 2, 4, 5, 7, 9, 10, 12, 13, 15, 17) and six (sites 3, 6, 8, 11, 14, 16) in the flowing lakes.

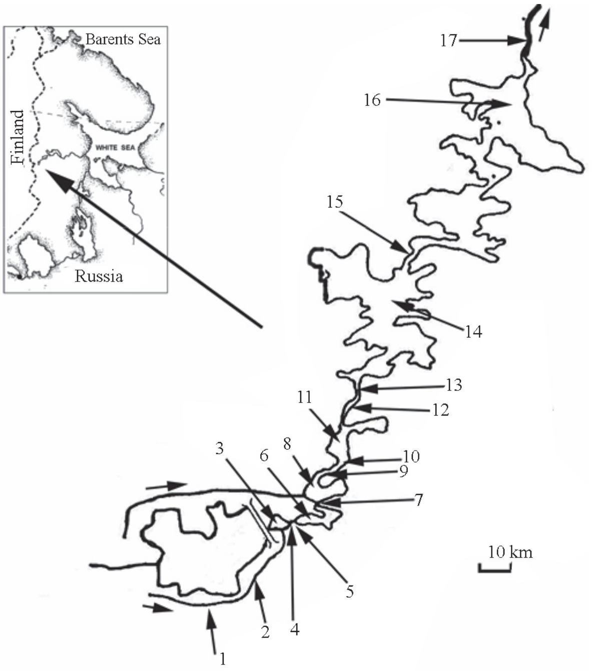

Fig. 1. The study area and sampling locations are indicated by arrows

Net samples for phytoplankton studies were taken in flowing lakes with a Ruttner water sampler (2 litres) from standard depths 0, 2, 5 and 10 m and 1 m from the bottom. Primary production was determined by the O_2-method (Vollenweider, 1969).

Sampling procedures for phytoperiphyton developed from the methodology previously described (Wetzel, 1979, 1983a, b; Jarlman et al., 1996) were used. The methods used are comparable to the CEN standard (CEN, 2005). The term periphyton adopted here follows the definition after Wetzel (1983a): “a complex community of microbiota (fungi, bacteria, animals, inorganic and organic detritus) that is attached to substrata. The substrata are inorganic or organic, living or dead.” The prefix phyto- is added to indicate that of the whole biocoenoses only phototrophs are considered in this study. For taxonomy investigation, the samples were collected in the Kenti River by scraping or brushing the surface of rocks, stones and pebbles with a knife, scalpel or nylon-bristled nailbrush, by squeezing mosses or by scraping the surface of stems and leaves of vascular plants.

To assess the anthropogenic effect and exclude the influence of substratum and variations in hydrological regime, phytoperiphyton samples were collected in rapids, in an open-canopy area from a rock 20–30 cm in size at a depth of 20–30 cm and where current velocity was in the range 20–30 cm s^{-1}. Our general observations indicate that such conditions are optimum for phytoperiphyton formation, at least in this region (Komulaynen, 2004b). The scarped material was washed off the brush and rock with 200–500 ml of filtered (pore diameter 0.9–1.0 µrn) river water and then homogenized in a blender. Three subsamples, which were kept unpreserved, were then taken for chlorophyll *a* analysis. Another subsamples were preserved with formalin (2–4% depending on the amount of material) and examined microscopically for types and numbers of algae.

In the laboratory, the phytoperiphyton samples were studied in two steps. First, filamentous algae were analysed using the counting chamber technique at a magnification of ×150. The relative abundance of each phytoperiphyton element is estimated as a degree of coverage, i.e. percentage of bottom surface that is covered by the element.

Diatoms were treated for identification by boiling in acid mixture (concentrated nitric acid and sulphuric acid in a 2:1 ratio, boiling time 2–4 h). Diatom slides were mounted in Pleurax. Identifications were made at ×1000 upon oil immersion (Olympus CX31). At least 200 valves per slide were identified and counted. Species, showing a relative abundance of ≥ 10% in the algal flora of a particular location, were considered dominant.

Algal cells biovolume was calculated using the table after Kuzmin (1984), and 10^{12} μm^3 were understood as equal to 1 g of biomass (Guseva, 1956).

Data on the geographic distribution of algae were borrowed from floristic guides (Raspopov, 1971; Getsen, 1985; Levadnaya, 1986). The environmental characteristics of algae were used from Omnidia 2 software (Lecointe et al., 1993). The Omnidia 2 software was used to calculate the trophic diatom index – TDI (Kelly & Whitton, 1995). This index reflects better the water quality differences in humic waters (Eloranta, 1999). The Sládeček index was calculated (Sládeček, 1973).

Cell counts were used to calculate the Shannon-Weaver diversity index – natural logarithm (Shannon & Weaver, 1963). Chlorophyll *a* was determined spectrophotometrically (Strickland & Parsons, 1972).

Water chemistry data were obtained from the Northern Water Problems Institute of the Karelian Research Centre, RAS, which indicated the nutrient concentration at sites corresponding with our phytoplankton and phytoperiphyton sampling (Lozovik et al., 2007) by standard methods (APHA, 1989). The metal concentrations were determined with an atomic absorption spectrophotometer (Shimadzu AA-6800). An air-acetylene flame and graphite furnace were used to determine the metal concentrations (Suomen Standardisoimisliitto, 1990).

The taxonomy of diatoms follows Gleser et al. (1988, 1992), and of other groups – Gollerbah (1951–1983).

Cluster analysis was based upon relative abundance of algal species in the phytoperiphyton and carried out using the Statistica software (Ward's method, Euclidean distance).

General condition of the habitat

The catchment of the Kenti River is located in the northwest of Karelia Republic (NW Russia), from 64° 40′ N to 65° 50′ N and from 30° 40′ E to 31° 20′ E (Fig. 1). The climate is continental with relatively warm summers, but cold winters: all lakes are covered with ice and snow for some 200 days each year. The Kenti River is flowing to the Kem River, the White Sea. The length of the Kenti River is 75 km, and it passes through a number of lakes. The rivers consist predominantly of numerous rapids and have gradient 1.4%.

The river channels are poorly incised, their valleys are poorly developed and the longitudinal profile shows a stepwise pattern formed by alternating rapids and pools, which expand into lake-like water bodies and lakes. The streambed is stony and deposition of silt and sand is at a minimum. The Kenti River was approximately 15–25 m wide with maximum depths ranging from 1 to 2 m. In all rivers the highest level was observed during the spring flood caused by snowmelt, the minimum in August.

The Kenti River has many lakes along its course and the stream sections act as connections within the landscape mosaic of lakes and mires. As a result, the complex lake-river systems are formed. The percentage of lakes in the drainage basin area is 12%. Mires account 18% and drainage areas cover 930 km^2.

All the numerous lakes of the lake-river system of the Kenti River are lakes with a short residence time, the area of which varies from 0.3 (Lake Okunevo – site 3) to 20 km^2 (Lake Koivas – site 14), and the volume from 0.003 (Lake Okunevo) to 0.103 km^3 (Lake Kento – site 15). These lakes are mostly shallow. Their average depth is from 2.5 to 4 m, the maximum – 21 m in Lake Koivas.

Based on pH value, the river waters are classified as transition from slightly acid to slightly alkaline (pH 6.5–7.5). Phosphorus concentrations are low in most locations in all rivers, indicating oligotrophic conditions. High concentration of nutrients were observed in a limited zone in Lake Okunevo and reached 7.00–14.90 µg l^{-1} of total phosphorus and 0.90–6.59 mg l^{-1} of nitrate-N (Lozovik et al., 2007).

Since 1994 water from the tailings dump has been discharged to the lake-river system. Its annual volume is from 9 to 22 10^6 m^3 depending on precipitation amounts. Furthermore, lakes Okunevo (site 3) and Poppalijarvi (site 8) receive water from discharge canals. The composition of industry water differs considerably from that of the natural water in the area. Mining (quarry) water, alongside with high mineralization reaching about 1.5 g l^{-1}, has very high content of nitrogen compounds (NH_4 – 48, NO_3 – 64, N_{tot} – 100 mg N l^{-1}).

Supply of industry water to the Kenti River system caused mineralization from the downstream to the upstream lakes of the system to grow 5–20 times, potassium concentration – 25–250 times and sulphates – 2–60 times as compared to the 1970s (Lozovik et al., 2007).

Industry water brings raised concentrations of heavy metals Ni, Cr, Co that accompany iron and Li. As a result, their concentrations in the upstream and central lakes has increased, but has remained relatively low in absolutely all lakes: Ni – 0.05–0.30, Cr – < 0.17–0.98, Co – 0.04–0.76, Li – 0.34–1.2 µg l^{-1}.

RESULTS AND DISCUSSION

Phytoplankton

During the qualitative investigations of phytoplankton, a total of 177 taxa were identified in the lakes (Komulaynen et al., 2006). The largest group in number of species like in previous years (Kalugin, 1991) was *Bacillariophyta* (68, 16% of the total number of taxa) followed by *Chlorophyta* (41, 23%), *Chrysophyta* (28, 16%), *Cyanophyta* (12, 7%), *Euglenophyta* (11, 6%), *Cryptophyta* (8, 5%), *Dinophyta* (8, 5%) and *Xanthophyta* (2, 1%). Such a correlation is characteristic of the planktonic algal flora of Karelian lakes and rivers and the water bodies of boreal and subarctica territories in Russia and Fennoscandia (Johansson, 1982; Eloranta, 1986, 2004; Lepisto, 1999; Kauppila & Lepisto, 2001). The number of taxa per quantitative sample varied between 1 and 44.

The number of algal species in phytoplankton increases from upstream lakes (Okunevo, Poppalijarvi – 65–82 taxa), which are exposed to human impact, to water bodies (Kojvas, Kento – 91–104 taxa) the furthest from the pollution source. Species diversity (Shannon index) varies in a similar manner: Okunevo – 2.87 ± 0.28, Poppalijarvi – 2.59 ± 0.62; Kojvas – 2.99 ± 0.18, Kento – 3.24 ± 0.29.

The algal flora of lakes is typically dominated by widespread cosmopolitan forms (85%), which is characteristic of the natural phytoplanktonic communities that inhabit taiga-zone water bodies (Getsen, 1985). The cold-loving pattern of the lake flora is emphasized by substantial percentages of arctalpine (8.5% of the total number of taxa) and boreal (6.5%) species and a low diversity of cyanophytes. Indifferent species (76%) and alkaliphilous (18%) as well as acidophilous (6%) forms are differentiated based on their environmental pH. The presence of the latter is considered to result from the supply of bog water from the catchment area to the water bodies. Up to 85% of the algal species found were classified as pelagic and littoral forms of plankton. Bottom species and encrusting organisms made up 15%. The largest number of halophilous forms (*Diatoma elongatum* (Lyngb.) C.Agardh, *Nitzschia palea* (Kütz.) W.Sm., *N. sigma* (Kütz.) W.Sm., *Navicula radiosa* Kütz.) were revealed in plankton from Lake Okunevo (Komulaynen et al., 2006). The water mineralization of the lake was the highest.

An increase in human impact also affects the size structure of phytoplankton. In 1993–2008, the percentage of small-sized species of green algae was observed to increase from 20% to 70% in Lake Okunevo and from 25% to 90% in Lake Poppalijarvi. Lake Okunevo was dominated by algal species of the *Chlorococcales* (*Monoraphidium mirabilis* (W. et G.S.West) Lemmerm., *M. contortum* (Thur.) Komárk.-Legn., *M. komarkovae* Nygaard) and Lake Poppalijarvi by those of the *Volvocales* (*Phacotus coccifer* Korschikov).

Annual variations in the abundance and biomass of phytoplankton are small. Over the 20-year monitoring period (1987–2008), the abundance of phytoplankton in the lakes of the river system was not more than 700 10^3 cell l^{-1} and the biomass was 1 g m^{-3}, which shows that the lakes are oligotrophic. Higher index values reported from Lake Poppalijarvi in 1987 (1.4 million cell l^{-1}; 1.0 g m^{-3}) were an exception. They result chiefly from the evolution of diatoms (genus *Aulacoseira*) also in 2008 (2.5 million cell l^{-1}, 1.9 g m^{-3}) and the intense vegetation of algae of *Volvocaceae* (*Phacotus coccifer*) and *Dinophyceae* (*Glenodinium*, *Peridinium*).

Seventy per cent of saprobity-indicator species are oligosaprobic, oligo-β-mesosaprobic and β-mesosaprobic forms (*Coelosphaerium kuetzingianum* Nägeli, *Ceratium hirundinella* (O.Müll.) Dujard., *Dinobryon divergens* Imhof, *Aulacoseira islandica* (O.Müll.) Simonsen., *A. italica* (Kütz.) Simonsen., *Tabellaria fenestrata* (Lyngb.) Kütz., *Asterionella formosa* Hassall, *Fragilaria capucina* Desm.). High saprobity (26%) is indicated by β-α-saprobic, α-saprobic and ρ-α-saprobic species that evolve in lakes contaminated by organic substances: *Pseudanabaena catenata* Lauterborn, *Oscillatoria tenuis* C.Agardh, *Cryptomonas erosa* Ehrenb., *C. ovata* Ehrenb., *Stephanodiscus hantzschii* Grunow, *Nitzschia acicularis* (Kütz.) W.Sm., *N. palea* (?), *N. sigma* (?). The saprobity index (Sládeček, 1973) values were found to decrease gradually from the river source (2.1–2.3) to the river mouth (1.5–1.7).

Based on phytoplankton analysis, water bodies were subdivided into two groups. Group I consists of two upper lakes of the system (Okunevo and Poppalijarvi). Group II is composed of the lakes farthest from the source of contamination. The average abundance of phytoplankton in group I was twice as high as in group II, 116.0 ± 55.5 and 56.3 ± 18.2 10^3 cell l^{-1}, respectively. The average biomass in group I was also twice as high as phytoplankton biomass in the lakes of group II. The abundance of dinoflagellates was 2.3 times, green algae –7, blue-green algae – 9 and euglenophytes – 3.5 times higher in the lakes of group I. Conversely, the abundance of diatoms and yellow-green algae for the lakes of group I was 1.5–2 times lower. The lakes of the two groups of water bodies also differ in the abundance of *Nitzschia acicularis*. The abundance and biomass of this indicator species is about three times higher in the lakes that are closer to the source of contamination.

The chlorophyll *a* values (0.3–2.2 µg m^{-3}) in the reference lakes are compatible with those in other oligotrophic lakes in the region (Rask et al., 1998). In the impacted lakes Poppalijarvi and Okunevo, the chlorophyll *a* content were doubled by the high density of small-sized species. The daily phytoplankton production also decreases in water bodies that are far from the source of contamination: Okunevo – 0.29, Poppalijarvi – 0.19, Kojvas – 0.11, Kento – 0.05 g O_2 m^{-3} day^{-1}. Based on biomass, chlorophyll *a* concentration and daily phytoplankton production, the lakes studied are classified as an oligotrophic type.

Phytoperiphyton

A total of 136 species from five divisions were identified in phytoperiphyton samples collected: *Cyanophyta* – 22, *Bacillariophyta* – 89, *Chlorophyta* – 23, *Pyrrophyta* – 1, *Rhodophyta* –1 (Komulaynen et al., 2006).

Phytoperiphyton assemblages in the Kenti River contained diverse algal floras with indifferent, stenotopic, euperiphytic species adapted to high flow. The most common and frequent species were diatoms *Achnanthes minutissima* Kütz., *Cocconeis placentula* Ehrenb., *Cymbella affinis* Kütz., *C. ventricosa* Kütz., *Didymosphenia geminata* (Lyngb.) M.Schmidt., *Eunotia pectinalis* Kütz., *Frustulia rhomboides* (Ehrenb.) De Toni, *Gomphonema angustatum* (Kütz.) Rabenh., *G. constrictum* Ehrenb., *Hannaea arcus* (Ehrenb.) R.M.Patrick, *Melosira varians* C.Agardh and *Tabellaria flocculosa* (Roth) Kütz. These species contributed the majority of diatoms counted for every sampling period. Green algae were occasionally abundant in upstream location. The most frequent of these was *Zygnema*. In locations with well-developed riparian vegetation, attached algal communities consisted predominantly of diatom films. It should be noted that such natural phytoperiphyton structure is characteristic of most of the rivers of NW Russia (Komulaynen, 2004b, 2008, 2009; Komulaynen et al., 2006).

Most of these taxa were also frequent in upstream stretches (sites 1, 2, 4, 5, 7), but the common rheophilous χ-saprobic diatoms (*Achnanthes minutissima*, *Eunotia pectinalis* and *Cymbella affinis*) were observed to drop out, and *Tabellaria flocculosa* became less important. *Diatoma elongatum*, *Gomphonema angustatum, Nitzschia acicularis, N. frustulum* (Kütz.) Grunow, *Pinnularia major* (Kütz.) Rabenh=, *Navicula cryptocephala* Kütz. and *N. rhynchocephala* Kütz. were more abundant in these locations.

Analysis of dendrograms (Fig. 2) showing the similarity of species composition has added to the evidence of anthropogenic influence. The dendrograms typically fall into two clusters (Komulaynen, 2004b). The first combines the sites immediately downstream of the flowing lakes; the second combines sites in the middle stretches of rivers away from the lakes. For the Kenti River this scheme has broken down. Two clusters differ according to the presence or abundance of species, which react to the level of mineralization. The first cluster (A) combines upstream sites near the outfall and is dominated by halophilic species (*Synedra pulchella* (Ralfs.) Kütz., *S. tabulata* (C.Agardh) Kütz., *Navicula peregrina* (Ehrenb.) Kütz., *N. salinarum* Grunow, *Rhopalodia musculus* Kütz., *Nitzschia sigma*). The second cluster (B) combines downstream sections, where a variety of acidophilic forms, algal communities characteristic of bogs, has increased. The increased abundance of species of *Eunotia* (*E. exigua* (Breb.) Rabenh., *E. lunaris* (Ehrenb.) Grunow, *E. pectinalis*, *E. praerupta* Ehrenb.), which replace *Navicula peregrina, N. rhynchocephala, Gomphonema angustatum* and *Achnanthes minutissima*, is related to a reduction in the human influence.

In addition to variations in species composition, there were changes in the ecological and geographic spectra of algal flora. Arctic-alpine species (*Tabellaria flocculosa, Hannaea arcus Eunotia pectinalis, Frustulia rhomboides*) remained dominant, but the ratio of groups changed in favour of boreal and cosmopolitan species. Accumulation of organic and inorganic sludge may be another important reason for changes in the phytoperiphyton composition and result in an increase of a number of benthic (motile, especially *Naviculaceae*) and alkaliphilous forms in the algal assemblages (Fig. 3).

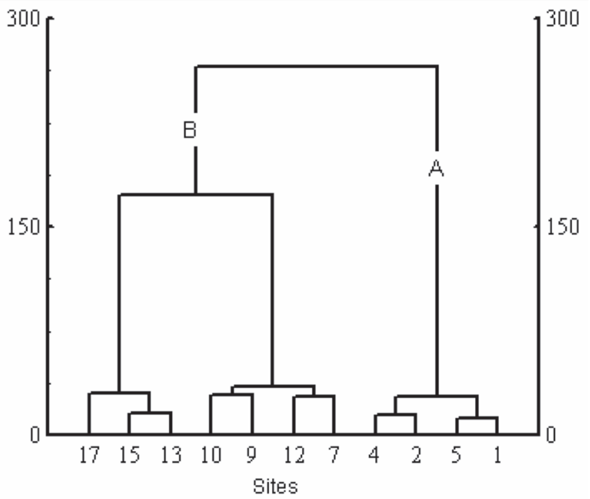

Fig. 2. Dendrograms based on cluster analyses of phytoperiphyton communities formed in different sites of the Kenti River

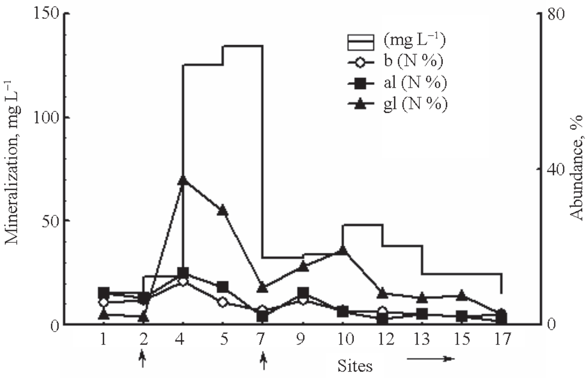

Fig. 3. Relative abundance of some ecological forms in periphyton communities for different sites on the Kenti River: b – benthic, al – alkaliphilic, gl – halophilic; vertical arrows indicate sites of sludge introduction

Substantial changes in phytoperiphyton structure were often caused by an enhanced mechanical impact due to storm runoff retarding colonisation. The burial of algae by sand and silt resulted in decreases in the number of species recorded and their abundance. Turbulence decreases rapidly in locations with sewage waters input and the presence of even loosely aggregated organic and inorganic sediment increased the sedimentation of algae. In addition to variations in species composition, there were changes in the ecological spectra of algal flora. The data obtained demonstrate that the flora here is enriched by eubenthic (unattached, motile) forms (Fig. 3) such as *Navicula* and *Pinnularia*.

The phytoperiphyton biomass in the river ranged from 0.3 to 25.7 mg cm^{-2} and chlorophyll *a* – from 1.1 to 37.2 µg cm^{-2}. Phytoperiphyton biomass and chlorophyll *a* concentration was the highest in downstream sites (sites 12, 13, 16, 17), where attached algal communities were composed of macroscopic green filamentous mats of *Zygnema* and *Mougeotia*, whereas in upstream sites (sites 1, 2, 4, 5), the phytoperiphyton consisted predominantly of thin diatom films.

Comparative analyses of phytoperiphyton in the Kenti and Lahna Rivers were made (Fig. 4).

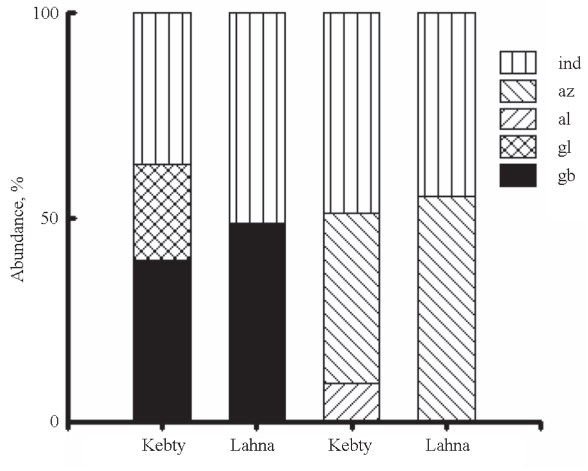

Fig. 4. Relative abundance of some ecological forms in periphyton communities for the Kenti and Lahna Rivers: al – alkaliphilic, az – acidophilic, gl – halophilic, gb – halophobic, ind – indifferent

The rivers, draining similar landscapes, had fundamentally similar physical, chemical and biological properties (Vodogrecki, 1972). The Lahna River and its tributaries are more natural and less impacted by human activity. Acidophilous forms characteristic of water bodies with high percentage of mires in the catchments are abundant and diverse in the phytoperiphyton of the River Lahna, but no halophilic species, which prevail in the Kenti River, were reported (Komulaynen et al., 2006).

The analysis of the saprobiological structure of phytoperiphyton has shown that β-mesosaprobic forms are most widely spread in the Kenti River, their share varying from 25 to 40% of the total number of indicator species. However, at most of the observation locations, χ-, χ-oligo and oligosaprobic alga species form the core of the dominant complex. Therefore, there is no wonder that the values of the Sládeček Index and the Trophic Diatom Index, calculated for algaflora on the whole, varied from 0.56 to 1.51 and from 1.03 to 2.79, respectively. This allows us to classify the water in the Kenti River as oligosaprobic (conventionally clean). The highest values of saprobility indices are found in the up-stream within urban areas.

CONCLUSIONS

The taxonomic diversity of phytoplankton and phytoperiphyton in the Kenti lake-river system reflects the geographical location and landscape characteristics of the region. Most of the dominant algae species found are typical of cold, oligotrophic water bodies (Komulaynen, 2007). The phytoplankton and phytoperiphyton in the studied water bodies are characteristic of the boreal type. The taxonomic structure of the algae flora shows a tendency for taxa to be concentrated in a small number of genera and families. A high similarity of floristic lists indicates the dominant contribution of zonal conditions to the formation of the species composition of lacustrine algal flora relative to anthropogenic and other factors. To sum up, over the 20-year monitoring period the species composition of the phytoplankton and phytoperiphyton of the Kenti River system has not changed considerably.

Human-induced mineralization and eutrophication causes structural changes, but the differences in nutrient concentration are not big enough to be seen in all index values, because χ-saprobic species remain fairly abundant. A rise in potassium, nitrogen and, to a lesser extent, phosphorus concentrations in the water bodies of the Kenti River is rather the improvement of the nutrient supply of algal communities. In small streams it is extremely difficult to interpret changes in the phytoperiphyton communities in terms of water quality changes at a given site. The community sampled at one site is the result of physical, chemical and biological determinants, which interact in separate stretches.

The share of mesohalobous and halophilic species in the periphyton of the upper reaches of the river and in the phytoplankton of lakes Okunevoe and Poppalijärvi was observed to increase. The share of attached forms in the periphyton has decreased. The share, abundance and biomass of small-sized species in the phytoplankton of the lakes in the upper reaches have increased.

When anthropogenic load is minimized and the hydrological regime stabilizes, the natural structure of algal assemblages quickly restores. This is most typical of lake-river systems with alternations of lakes and rivers, rapids and pools, playing the role of natural water treatment facilities (Komulaynen, 2004b).

According to diatom indices, the Kenti River is of a good quality. This may be because the diatom taxa, which dominate in the polyhumic brown waters with low pH and conductivity common in Northwest Russia, are, in general, classified as xeno- to oligosaprobic. As a result, diatom indices do not reflect the differences in nutrient content in unpolluted rivers in all cases.

Undoubtedly, algae are suitable in a large number of situations for monitoring. However, an attempt to apply one method or data analyses, one concept or theory, leads to errors, especially in lake-river systems, where the diversity of algal communities is maintained by the asynchronism in succession (Komulaynen, 2007). Monitoring should be more complete and include hydrobiological and chemical analyses as well as the study of potentially sensitive organisms from other trophic levels, combining standardized methods and the use of local ones.

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DUMBLIŲ BENDRIJŲ ATSAKAS Į ANTROPOGENINĖS MINERALIZACIJOS POKYČIUS

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Santrauka

Darbe tirtas žmogaus veiklos, susijusios su Kostomuksha (Karelija, ŠV Rusija) geležies rūdų kasykla, poveikis upės ir jos ežerų sistemai. Kostumus ežeras buvo dirbtinai sukurtas pastatant užtvanką ir tarnauja kaip geležies rūdos gavybos atliekų saugykla. Bendra vandens mineralizacija ežere siekia 400 mg l^{-1}. Fitoperifitono ir fitoplanktono bendrijų struktūros palyginamoji analizė atlikta Kenti upės ir jos ežerų sistemoje įvertinant antropogeninį poveikį, susijusį su kasybos pramonės veikla. Gamyklos išleidžiamo mineralizuoto vandens poveikis dumblių bendrijai atskleidžiamas aptariant rūšių skaičių ir įvairovę, indikatorines rūšis bei dumblių biomasės ir chlorofilo *a* reikšmes. Tyrimai atskleidė, kad antropogeniniam poveikiui sumažėjus iki minimalaus, dumblių bendrijos greitai atsistato. Taigi upės-ežerų sistema, kurią sudaro besikeisdami upės vaga, kriokliai, duburiai ir ežerai, tarnauja kaip natūrali vandens apsivalymo sistema. Darbe aptariama galimybė dumblių bendrijas taikyti ekologinės upės-ežerų sistemos būklės įvertinimui.