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Article

Response of communities of aquatic organisms to the anthropogenically-driven changes in water mineralization of a small stream (the White Sea basin, Republic of Karelia, Russia)

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Abstract. An increase in water mineralization in the Kenti River has occurred as a result of mining at the Kostomuksha iron ore deposit (Republic of Karelia, north-west of the European part of Russia); it has become a relatively new type of anthropogenic impact. Meantime, the total mineralization of water in the upper reaches of the Kenti River reached 800 mg/L. The species composition, abundance and biomass of phytoplankton, phytoperiphyton, zooplankton, and zoobenthos were analyzed. The influence of natural and anthropogenic factors on the chemical composition and formation of the structure of aquatic biocoenoses was assessed. The trophic status of the river, its saprobity, and the significance of particular communities and biotic indices for bioindication of the ecological state was studied. Dominant complex of the Kenti River was represented by a small number of species that were resistant to the dynamic load of water. The abundance and biomass of phytoplankton, phytoperiphyton, zooplankton, and zoobenthos made it possible to conclude on rather high degree of their development in river, as well as on their vital activity and flexibility. It was then reported on the ability of the river ecosystem to restore.

Keywords: Kenti River, chemical composition, aquatic biocoenoses, taxonomy, ecology.

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Introduction

Hydrobiological studies on the freshwater tributaries of the White Sea began much later than the first researches performed in the sea itself. This was due to the lack of large-scale economic activities of the local population, whose density has always been low. Nowadays, only 72 thousand people live on the territory of the Karelian coast, which is 67100 km^2, i.e. slightly more than 1 person per km^2; 76% of population live in four regional centers (Kem', Belomorsk, Loukhi, and Kalevala). In general, high urbanization with a low population density in the rest of the territory is also typical for the entire Republic of Karelia. The state of the environment in the region has been assessed as stable in recent years (Gosudarstvennyi Doklad..., 2020). Cases of extremely high pollution of watercourses, leading to a noticeable decrease in water quality and mass mortality of aquatic organisms, were not registered. This is due to the fact that most of the large settlements with developed industry are located along the shores of the White Sea. Therefore, all river ecosystems, except the Kem' River, are exposed to anthropogenic impact only in the estuaries.

The research in the White Sea watershed area has become regular only from late 1970s; in particular, these were the studies in the Kem' River and its main tributary, the Kenti River (Vliyanie..., 1995; Sostoyanie..., 2007). This was due to the construction of the Kostomuksha mining and processing plant (GOK) in the upper reaches of the Kenti River. This plant is the largest in the north-west of Russia; along with the city of Kostomuksha, it is still the main source of anthropogenic impact in the region today. However, the structure of natural communities, except that of phytoperiphyton (Komulaynen, 1995, 2019), has been mainly studied in the lakes belonging to the Kenti River stream.

Chemical analysis of water in drainage lakes evidences that the upstream system of the Kenti River is exposed to anthropogenic impact (Lozovik and Galakhina, 2017). However, the lakes belonging to the Kenti River system differ markedly in their morphometry. The largest of the lakes, Lake Kento, has an area of 28.1 km^2, a water volume of 0.103 km^3, and a maximum depth of 23.5 m. The smallest Lake Okunevoe has an area of 0.3 km^2, a water volume of about 0.001 km^3, and a maximum depth of 5.6 m. Undoubtedly, such differences affect structure of aquatic biocoenoses. Meantime, the formation of communities of aquatic organisms in the watercourses full of rapids occurs under similar conditions (depth, flow rate, and substrate). We suggest that searching for the influence of anthropogenic factors may be much easier here than in other types of water bodies.

The study aims:

(1) to assess the influence of anthropogenic increase in mineralization on the structure of aquatic biocoenoses and to search for the peculiarities of their formation;

(2) to obtain data on the indicator significance of the communities of aquatic organisms;

(3) to analyze the ability of river ecosystems to recover after disturbances caused by this type of anthropogenic impact (i.e., water mineralization).

Materials and methods

The watershed area of the Kenti River locates on the Karelian (western) coast of the White Sea; it is a swampy plain (the so-called Belomorskaya Lowland) with relative heights of up to 20 m, one of the most climatically unfavorable regions of the Republic of Karelia with a long winter and a short growing season.

Hydrobiological and hydrochemical studies were carried out in August 2019. At the Kenti River, two sites were studied. The first site (station no. 1) is located 100 m downstream from the runoff from the tailing dump of the Kostomuksha GOK, the second site (station no. 2), 10 km downstream, in 100 m from the confluence of the river into the Lake Koyvas. In order to obtain comparative data, simultaneous studies were carried out in the Lakhna River (station no. 3), where no economic activity has being performed currently.

The headstream of the Kenti River is located in the northeastern part of the Lake Kostomukshskoe (N 64°42′09″ E 30°53′34″) with an area of 5.4 km^2, converted into a tailing pond; the river flows into the Lake Yulijärvi (N 65°02′02″ E 31°07′57″). The headstream of the Lakhna River is located 8 km from the headstream of the Kenti River (N 64°39′09″ E 31°03′11″); it flows into the Lake Pushtos'-Järvi (N 64°46′34″ E 31°58′05″). The catchments of both rivers have a mostly flat, sometimes swampy relief. The main characteristics of rivers and their catchments are given in Table 1.

When controlling the chemical composition of water, indirect parameters of the organic matter content (CW – color of water; PV – permanganate value) and the content of biogenic elements (BE) were determined, as well as the electrical conductivity (æ) and pH of water (Rukovodstvo..., 2009).

Sampling of phytoplankton, phytoperiphyton, zooplankton, and zoobenthos, their processing in the laboratory and analysis of the qualitative composition and quantitative development of particular species were carried out according to the methods worked out by the authors (Komulaynen et al., 1989; Komulaynen, 2003; Rukovodstvo..., 1983). Species, which relative abundance exceeded 10%, were classified as dominants. The ecological group of algae was defined according to S.S. Barinova et al. (2006).

The quality of river water was assessed by the composition of indicator species in accordance to the Pantle-Buck saprobity index (P&B) as modified by Sládeček (Sládeček, 1967); in addition, the diatom index (TDI) was calculated for phytoperiphyton (Kelly and Whitton, 1995).

The concentration of heavy metals in water, sediments, filamentous algae, and mollusks was determined by atomic absorption spectrometry with flame atomization (AA-7000 Shimadzu spectrophotometer, Japan) using equipment from the “Analytical Laboratory” Center for Collective Use of the Forest Research Institute, Karelian Research Centre, Russian Academy of Sciences.

Results and discussion

The wastewater releases from the tailing dump, on average 13.1 million m^3/year, had the greatest impact on the chemical composition of water in the Kenti River. Their influx into the river led to an increase in mineralization, in particular, in the content of potassium, sulfates, and nitrates (Lozovik and Galakhina, 2017). There were two trends found in accordance to the obtained hydrochemical information (Table 2).

- when moving from station no. 1 to station no. 2, there is a decrease in the total mineralization in terms of electrical conductivity, the content of hydrocarbonates and chlorides, as well as of the pH value. This is due to the gradual dilution of highly mineralized man-made waters of Karelskiy Okatysh JSC coming from the tailing dump to the Kenti River. A simultaneous decrease in the concentration of total nitrogen present in the industrial waters due to the large amount of nitrates also occurs as a result of natural dilution.
- the water is being enriched with allochthonous organic matter coming from the catchment area. As a result, there is an increase in both CW and PV. The low content of total phosphorus (7–9 μg/L) corresponds to the natural oligotrophic state of water bodies of the lake-river system of the Kenti River.

At the station no. 3, low mineralization of water, high concentration of organic matter, weakly acidic reaction, and high CW in the Lakhna River are preconditioned by the high swampiness of its catchment area (Lozovik, 2013).

The algae flora of plankton in the studied areas of the Kenti and Lakhna rivers comprise 46 taxa, and 6 more forms are identified down to the genus level. Diatoms and green algae are the most diverse groups, comprising together 78.3% of the total number of species (Table 3). In general, this is a characteristic feature of the phytoplankton communities of the rivers of the Republic of Karelia (Komulaynen et al., 2006).

Planktonic diatoms (*Aulacoseira islandica*), along with Dinophyta (*Peridiniopsis penardii, Peridinium cinctum,* and *P. inconspicuum*) and green algae (*Phacotus lenticularis*), dominate by biomass (Table 4). In terms of abundance, the dominant complex includes also diatoms (*Aulacoseira islandica* and *Eunotia pectinalis*) and green algae (*Botryococcus neglectus*) in addition to the listed species. The average abundance and biomass of planktonic algae in the Kenti and Lakhna rivers are generally close to those previously noted in other watercourses of the Karelian coast (Komulaynen et al., 2006).

Eurybiont species prevail (83–94%) in all studied phytoplankton communities. The pH-indifferent spe-

Table 1. Characteristics of the studied rivers and their catchments. L is the length of the river; S, the catchment area; SWL, swampiness; SL, lake percentage (Resursy..., 1972).

River	L, km	Stream gradient, m/km	S, km^2	SWL, %	SL, %	Discharge rate, m^3/s
Kenti	75	1.4	934	18.1	11.9	16.7
Lakhna	51	1.8	346	21.7	5.1	13.1

Table 2. Results of chemical analysis of the water samples from the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3).

Station	æ, μSm/cm	pH	HCO_3^-, mg/L	Cl^-, mg/L	Suspended matter, mg/L	$N_{общ}$, mg/L	$P_{общ}$, mg/L	PV, mg O^2/L	CW, Pt-Co degrees
st. 1	896	7.8	91.2	16.2	20.1	1.76	9	1.1	17
st 2	563	7.6	58.7	8.4	17.1	1.47	7	7.1	30
st. 3.	13	6.4	1.9	1.8	25.3	0.47	7	8.7	110

Table 3. Species composition of phytoplankton of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Dn is the species dominating by abundance, Db, by biomass.

Taxon	St. 1	St. 2	St. 3
Cyanophyta			
Anabaena sp.	+	+	−
Merismopedia punctata Meyen	+	+	+
Oscillatoria limosa Agardh ex Gomont	+	+	−
Bacillariophyta			
Amphora ovalis (Kützing) Kützing	+	+	−
Aulacoseira islandica (O. Müller) Simonsen	Dn, Db	+	Dn
Aulacoseira italica (Ehrenberg) Simonsen	+	+	−
Cyclotella stelligera Cleve & Grunow	+	+	+
Cyclotella radiosa (Grunow) Lemmermann	+	+	+
Diploneis elliptica (Kützing) Cleve	+	−	−
Eunotia pectinalis (Kützing) Ehrenberg	+	−	Dn
Eunotia praerupta Ehrenberg	+	−	+
Fragilaria capucina Desmazieres	−	+	+
Fragilaria ulna (Nitzsch) Lange-Bertalot	+	+	+
Gomphonema acuminatum Ehrenberg	−	+	+
Meridion circulare (Greville) Agardh	+	−	−
Navicula campllanata (Grunow) Grunow	−	+	−
Navicula cryptotenella Lange-Bertalot	+	−	−
Navicula sp.	−	+	−
Navicula trivialis Lange-Bertalot	+	+	+
Nitzschia acicularis (Kützing) W. Smith	+	+	−
Pinnularia constricta O'Meara	−	+	−
Pinnularia interrupta W. Smith	+	+	+
Surirella robusta Ehrenberg	+	−	−
Chrysophyta			
Chrysococcus rufescens Klebs	−	+	−
Dinobryon divergens Imhof	−	+	+
Kephyrion baciliforme Conrad	+	+	−
Cryptophyta			
Cryptomonas sp.	+	+	−
Chlorophyta			
Actinochloris sphaerica Korschikov	−	+	−
Botryococcus neglectus (West & G.S. West) J. Komárek & P. Marvan	Dn	Dn	+
Chlamydomonas sp.	+	+	−
Chlorococcales sp.	−	+	−
Closterium gracile Brébisson ex Ralfs	−	+	+
Cosmarium humile Nordstedt ex De Toni	−	+	+

Taxon	St. 1	St. 2	St. 3
Cylindrocystis crassa De Bar	−	+	−
Didymocystis bicellularis (Chodat) Komárek	−	+	−
Elakatothrix gelatinosa Wille	+	+	−
Oocystis lacustris Chodat	+	+	−
Oocystis solitaria Wittrock in Wittrock & Nordstedt	−	+	−
Pandorina morum (O.F. Müller) Bory	+	+	−
Pediastrum boryanum (Turpin) Meneghini	−	+	+
Pediastrum duplex Meyen	+	+	+
Phacotus lenticularis (Ehrenberg) Diesing	Db	+	−
Planctococcus sphaerocystiformis Korshikov	+	−	−
Planktosphaeria gelatinosa G.M. Smith	+	+	−
Scenedesmus obtusus Meyen	−	+	−
Scenedesmus quadricauda (Turpin) Brébisson	−	+	−
Westella sp.	+	−	−
Dinophyta			
Peridiniopsis penardii (Lemmermann) Bourrelly	Db	−	+
Peridinium cinctum (O.F. Müller) Ehrenberg	+	Db	Db
Peridinium inconspicuum Lemmermann	+	−	−
Euglenophyta			
Trachelomonas rugulosa F. Stein	−	+	+
Trachelomonas volvocina (Ehrenberg) Ehrenberg	+	−	+

Table 4. The main indicators of phytoplankton of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Sp is the number of species; N, abundance; B, biomass.

Station	Sp	N, 10^3 cells/L	Dominants by abundance	B, mg/m^3	Dominants by biomass
st. 1	33	609.9	*Aulacoseira islandica* *Botryococcus neglectus*	0.26 (0.1–0.92)	*Aulacoseira islandica* *Phacotus lenticularis* *Peridiniopsis penardii*
st. 2	38	890.6	*Botryococcus neglectus*	0.31 (0.1–0.64)	*Peridinium cinctum*
st. 3	21	972.8	*Aulacoseira islandica* *Eunotia pectinalis*	0.37 (0.1–0.81)	*Aulacoseira islandica* *Peridinium inconspicuum*

cies are the most diverse group (40–47%), followed by acidophiles (20–26%). The presence of latter is a consequence of the inflow of bog waters from the catchment into watercourses.

Algae flora of riverine periphyton (65 species in total) is also mainly represented by diatoms (39 species); euperiphyton forms of the genera *Tabellaria, Eunotia,* and *Achnanthes* have been found the most frequently. This complex of dominant species usually determines the structure of algal fouling in rivers. Green algae, represented by *Bulbochaete* sp., *Zygnema* sp. and *Mougeotia* sp., have been the main species forming the coenose. Red algae are represented by only one taxon (*Batrachospermum gelatinosum*); however, it is presented fairly constant and dominates in all studied areas.

The species dominating by abundance are represented by 13.3% of the total number of species. However, the structure of phytoperiphyton in rivers is determined by an even more limited number of species, contributing each more than 10% of the total abundance and biomass of phytoperiphyton at certain stations (Table 5).

The dominant complex of species in fouling algal coenoses is presented mostly by both obligate and facultative rheophiles. In relation to the total mineralization of water, most of the species are oligohalobes. The pH-indifferent species prevail, which is common for humified waters, but the group of acidophiles is also quite numerous. In fouling algal coenoses, they are represented by diatoms of the genus *Eunotia* and green algae of the order Desmidiales.

A sufficiently high similarity of taxonomic composition at different stations is accompanied by the differences in the structure of the dominant complex and noticeable fluctuations in the abundance of the formed groups (Table 6).

In total, 26 species of planktonic crustaceans and rotifers are identified in the zooplankton communities of the studied sites (Table 7).

The zooplankton abundance and biomass in the studied sites differ markedly, which may be explained not only by the influence of runoff from the drainage lakes, but also by a change in the level of anthropogenic load. There are only five zooplankton species dominating by abundance and biomass at some study sites (Table 8).

The macrozoobenthos is presented by 58 taxa of macroinvertebrates, 77% of them are insects (Table 9).

The representatives of Oligochaeta, Bivalvia, Ephemeroptera, Trichoptera, Plecoptera, and Diptera form the basis of macrozoobenthos community. The quantitative characteristics of benthic communities generally correspond to those previously identified in the rivers of the northern part of the Republic of Karelia (Baryshev, 2015; Baryshev and Khrennikov, 2016). Despite high species richness and taxonomic diversity, the composition of the dominant complex is quite stable and includes species that are typical for litreophilous biotopes of the Karelian rivers (Table 10).

In total, 112 saprobity indicator species are found in the studied communities of aquatic organisms. The most diverse are β-mesosaprobes and oligosaprobes (Table 11). That is why the values of the Pantle – Buck index calculated for phytoplankton, phytoperiphyton, zooplankton, and zoobenthos of the Kenti and Lakhna rivers are characteristic of the oligosaprobic zone (Table 12), these values are lower comparing that in the polluted rivers of the Northern European Russia (Komulaynen, 2002, 2004b).

Therefore, the structure of all studied communities and the list of dominant species are typical for river ecosystems in the Republic of Karelia (Biotic diversity of Karelia..., 2003). They are preconditioned by geographic location, landscape and topography of river catchments. All the identified species are present in various proportions in the groups of aquatic organisms in the watercourses of the region. However, in the upper reaches of the Kenti River (station no. 1), a number of specific features, which cannot be explained by natural factors only, are noted in the structure of communities.

It is natural that an increase of the density of the precipitated mineral matter on the surface of a solid substrate in the upper reaches of the Kenti River (station no. 1) reduces the possibility for the formation of a “real” periphyton (Komulaynen, 2004a) and leads to an increase in the abundance and diversity of benthic forms typical of microphytobenthos (Algal ecology..., 1996). Here, mesohalobes and halophiles are the most diverse groups in plankton and periphyton, i.e. the species preferring waters with increased mineralization. In phytoplankton, the dominance of small-sized species of green algae (up to 70%) is observed, which explains the maximum values of the total abundance. Meantime, the number of zooplankton and macrozoobenthos species decreases.

A comparison of aquatic biocoenoses of the Kenti and Lakhna rivers also brings indicative results. The phytoplankton and phytoperiphyton of the Lakhna River are characterized by a greater diversity and abundance of acidophilic forms, characteristic of water bodies with swampy catchments, and by the absence of halophilic species, which are common in the algae flora of the Kenti River, especially in its upper reaches. These differences, as well as the general impoverishment of the species composition and simplification of the structure of algal coenoses of the periphyton of the Kenti River, can only be explained by the increased water mineralization, since the hydrological regime in the studied areas is similar.

A decrease of the abundance and biomass is also noted for zooplankton in the zone of industrial wastewater intake. Meantime, no significant differences in the abundance of macrozoobenthos at the surveyed stations have been found in both rivers, Kenti and Lakhna.

Table 5. Species composition of phytoperiphyton of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Dn is the species dominating by abundance, Db, by biomass.

Taxon	St. 1	St. 2	St. 3
Cyanophyta			
Dichothrix gypsophila (Kützing) Bornet et Flahault	−	+	−
Hapalosiphon pumilus Kützing ex Bornet et Flahault	−	−	+
Oscillatoria limosa Agardh ex Gomont	+	−	−
Planktothrix agardhii (Gomont) Anagnostidis et Komarek	+	−	−
Scytonema crispum Bornet ex De Toni	−	−	+
Stigonema mamillosum (Lyngb.) Ag.	−	+	+
Tolypothrix distorta Kützing ex Bornet et Flahault	−	+	+
Tolypothrix elenkinii Hollerbach	−	+	+
Dinophyta			
Peridinium cinctum (O.F. Müller) Ehrenberg	−	+	−
Chrysophyta			
Dinobryon divergens Imhof	−	+	−
Bacillariophyta			
Achnanthes linearis (W. Smith) Grunow	−	+	−
Achnanthes minutissima Kützing	Dn	Dn	Dn
Amphora ovalis (Kützing) Kützing	−	+	−
Anomoeoneis exilis (Kützing) Cleve	+	−	−
Aulacoseira distans (Ehrenberg) Simonsen	−	+	+
Aulacoseira islandica (O. Müller) Simonsen	−	+	+
Aulacoseira italica (Ehrenberg) Simonsen	+	+	+
Cocconeis placentula Ehrenberg	+	−	+
Cyclotella radiosa (Grunow) Lemmermann	+	+	−
Cymbella cessatii (Rabenhorst) Grunow	−	+	−
Cymbella silesiaca Blesch in Rabenhorst	−	+	+
Diatoma tenuis Aghard	Dn	+	−
Epithemia adnata (Kützing) Brébisson	+	−	−
Eunotia bilunaris (Ehrenberg) Mills	−	−	+
Eunotia pectinalis (Kützing) Ehrenberg	+	Dn, Db	Dn, Db
Eunotia praerupta Ehrenberg	−	+	+
Eunotia sudetica O. Müller	−	+	+
Fragilaria capucina Desmazieres	−	−	+
Fragilaria ulna (Nitzsch) Lange-Bertalot	−	+	+
Frustulia rhomboides (Ehrenberg) De Toni	+	+	+

Taxon	St. 1	St. 2	St. 3
Gomphonema acuminatum Ehrenberg	−	+	−
Gomphonema angustatum (Kützing) Rabenhorst	−	+	+
Gomphonema clavatum Ehrenberg	−	+	−
Gomphonema gracile Ehrenberg	−	+	−
Gomphonema parvulum (Kützing) Kützing	−	+	+
Navicula radiosa Kützing	+	−	−
Navicula rhynchocephala Kützing	+	−	−
Navicula trivialis Lange-Bertalot	+	−	+
Nitzschia linearis (Agardh) W. Smith	+	−	−
Pinnularia gibba (Ehrenberg) Ehrenberg	+	−	+
Pinnularia major(Kützing) Rabenhorst	+	−	−
Pinnularia microstauron (Ehrenberg) Cleve	+	−	+
Pinnularia viridis (Nitzsch) Ehrenberg	+	+	+
Rhopalodia gibba (Ehrenberg) O. Müller	+	−	−
Rhopalodia musculus (Kützing) O. Müller	+	+	−
Stauroneis anceps Ehrenberg	+	−	+
Surirella robusta Ehrenberg			
Tabellaria fenestrata (Lyngbye) Kützing	+	Dn	+
Tabellaria flocculosa (Roth) Kützing	+	−	Db
Chlorophyta			
Bulbochaete sp.	+	−	+
Chaetophora elegans (Roth) C. Agardh	+	−	−
Cosmarium formosulum Hoff	−	+	−
Cosmarium humile Nordstedt ex De Toni	−	+	−
Cosmarium ornatum Ralfs ex Ralfs	−	+	−
Cosmarium punctulatum Brébisson	−	+	+
Microspora amoena (Kützing) Rabenhorst	Dn	−	+
Mougeotia sp.	−	−	+
Oedogonium sp.	+	Db	Db
Pediastrum boryanum (Turpin) Meneghini	−	+	−
Pleurotaenium minutum var. *elongatum* (West) Cedergren	−	+	−
Staurastrum muticum Brébisson ex Ralfs	−	+	−
Ulothrix zonata (F. Weber & Mohr) Kützing	+	−	−
Zygnema sp.	+	+	+
Rhodophyta			
Batrachospermum gelatinosum (Linnaeus) De Candolle	Dn, Db	Db	Dn, Db

Table 6. The main indicators of phytoperiphyton of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Sp is the number of species; N, abundance; B, biomass.

Station	Sp	N, 10^4 cells/cm^2	Dominants by abundance	B, µg/cm^2	Dominants by biomass
st. 1	31	0.1–1500.0	*Achnanthes minutissima* *Batrachospermum gelatinosum*	0.1–25.7	*Diatoma tenuis* *Batrachospermum gelatinosum*
st. 2	41	4.8–288.0	*Achnanthes minutissima* *Eunotia pectinalis* *Zygnema* sp. *Batrachospermum gelatinosum*	0.3–47.9	*Oedogonium* sp. *Batrachospermum gelatinosum*
st. 3	34	1.8–1360.0	*Tabellaria flocculosa* *Achnanthes minutissima* *Microspora amoena* *Batrachospermum gelatinosum*	0.5–55.7	*Aulacoseira italica* *Tabellaria flocculosa* *Microspora amoena* *Bulbochaete* sp.

The relatively high biomass of macrozoobenthos is probably a consequence of river runoff. It is known that zooplankton entering rivers from lakes causes an increase in the biomass of river macrozoobenthos (Kruglova and Baryshev, 2011).

The concentration of heavy metals in various environments is also an indicator of the level of anthropogenic load. Concentrations of heavy metals in the upper reaches of the Kenti River (station no. 1) turned out to be higher than at the other two sites (Table 13).

However, it should be noted that the concentrations of heavy metals at the studied sites of the Kenti River is significantly lower than those noted for anthropogenically disturbed aquatic ecosystems in the Republic of Karelia and the Murmansk Oblast (Komulaynen and Morozov, 2007, 2010).

Conclusions

The hydrochemical conditions developed in the Kenti River make it possible to observe the response of various aquatic communities to the changes in the ionic composition of the environment typical for the region. Meantime, it should be taken into account that an increase of water mineralization up to 800 mg/L cannot be regarded as catastrophic; once observed in the upper reaches of the Kenti River, these values correspond to fresh waters according to Alekin classification (1970). Most of autotrophic and heterotrophic organisms living in fresh waters must and can stand such changes without significant loss of species diversity and abundance. Regard should be paid then to the change in the amount of the suspended matter, which may reduce transparency, illumination, and thus lowers indirectly the activity of plankton and periphyton autotrophs.

An analysis of the taxonomic composition, the ratio of the ecological-geographical groups of aquatic organisms, and the abundance of these groups makes it possible to distinguish two sections of the river, affected by anthropogenic load differently. In the upper section, an increase in water mineralization affects the formation of aquatic biocoenoses. An increase in the proportion of mesohalobic and halophilic algal species is observed in the algal flora of the periphyton and plankton. Similar changes in the algal flora, as well as a decrease in the productivity of algocenoses, are observed in the water bodies with an increased water mineralization (Ermolaev, 1989). A similar pattern of changes in the algal flora of the periphyton has been noted in river estuaries; it has been also considered as a result of an increase in water mineralization (Elliott and Whitfield, 2011). In the lower section of river, the communities of aquatic organisms and their structure are typical for the pristine watercourses of the region. The latter are characterized by high stability of the structure of the dominant complex, taxonomic homogeneity of groups of organisms, lack of blow-up development of indicator species of pollution and eutrophication.

All identified species are presented in the groups in different proportions; they are constantly found in the rivers of the eastern Fennoscandia, which indicates the decisive role of climate in the formation of aquatic biocoenoses. Meantime, short period of our observations does not allow us to consider the list of species as sufficiently complete. The further detailed studies will help to expand the species list and to reveal the seasonal dynamics of the species structure, abundance and biomass of aquatic organisms.

Although the observed changes in the structure of phytoplankton, phytoperiphyton, zooplankton, and zoobenthos in the studied areas of the Kenti River are not of a “catastrophic” nature; they require further detailed analysis of all parameters of the ecosystem. This is all the more important, since the results of “background” monitoring of rivers that are minimally exposed to anthropogenic impact can be used to

Table 7. Species composition of zooplankton the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Dn is the species dominating by abundance, Db, by biomass.

Taxon	St. 1	St. 2	St. 3
Rotifera			
Kellicottia longispina (Kellicott,1879)	–	Dn	–
Keratella cochlearis (Gosse, 1851)	–	+	–
K. quadrata (Müller,1786)	+	+	–
Asplanchna priodonta Gosse, 1850	–	+	–
Bipalpus hudsoni (Imhof, 1891)	–	+	–
Brachionus angularis Gosse, 1851	Dn	+	–
Trichocerca capucina (Wierzejski et Zacharias, 1893)	–	+	–
Euchlanis lyra Hudson, 1886	–	–	Dn
Euchlanis triquetra Ehrenberg, 1838	–	–	+
Euchlanis sp.	–	+	–
Cladocera			
Limnosida frontosa Sars, 1862	–	+	–
Daphnia (Daphnia) cristata Sars, 1862	Db	Dn, Db	–
D. (Daphnia) longispina O.F. Müller, 1785	–	+	–
D. (Daphnia) cucullata Sars, 1862	–	+	–
Bosmina (Bosmina) longirostris (O.F. Müller, 1785)	–	+	–
Bosmina (Eubosmina) coregoni Baird,1857	–	+	–
B. (Eubosmina) cf. *thersites* Poppe,1887	Dn, Db	Db	–
B. (Eubosmina) cf. *gibbera* Schoedler, 1863	+	+	–
Alona quadrangularis (O.F. Müller, 1785)	–	+	–
Alonopsis elongatus Sars, 1862	–	–	Dn, Db
Chydorus sphaericus (O.F. Müller, 1785)	–	–	+
Copepoda			
Eudiaptomus gracilis (Sars, 1863)	–	+	–
Acanthocyclops capillatus (Sars, 1863)	–	+	–
Thermocyclops oithonoides (Sars, 1863)	+	+	–
Macrocyclops albidus (Jurine, 1820)	–	–	+
Mesocyclops leuckarti (Claus, 1857)	–	+	–

Table 8. The main indicators of zooplankton of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Sp is the number of species; N, abundance; B, biomass.

Station	Sp	N, ind./m^3	Dominants by abundance	B, mg/m^3	Dominants by biomass
st. 1	5	180	*Bosmina gibbera* *Brachionus angularis*	4.38	*Bosmina gibbera* *Daphnia cristata*
st. 2	21	1230	*Kellicottia longispina* *Daphnia cristata*	51.09	*Bosmina gibbera* *Daphnia cristata*
st. 3	5	190	*Alonopsis elongatus*	8.4	*Alonopsis elongatus*

Table 9. Species composition of macrozoobenthos in the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Dn is the species dominating by abundance, Db, by biomass.

Taxon	St. 1	St. 2	St. 3
Oligochaeta			
Cognettia glandulosa (Michaelsen, 1888)	+	+	+
Eiseniella tetraedra (Savigny, 1826)	+	−	+
Enchytraeidae sp.	−	+	−
Lumbriculus variegatus (Müller, 1774)	+	+	−
Oligochaeta spp.	−	−	+
Hirudinea			
Glossiphonia complanata (Linnaeus, 1758)	+	−	−
Bivalvia			
Euglesa sp.	Db	+	+
Pisidium sp.	+	+	−
Sphaerium sp.	Db	Db	−
Gastropoda			
Bathyomphalus sp.	+	+	−
Arthropoda			
Arachnida			
Hydracarina spp.	+	—	—
Insecta			
Coleoptera			
Elmis maugetii Latreille, 1802	+	+	+
Oulimnius tuberculatus (Müller, 1806)	+	—	+
Ephemeroptera			
Baetis fuscatus (Linnaeus, 1761)	+	—	—
Baetis rhodani (Pictet, 1843)	Dn	+	+
Baetis vernus Curtis, 1834	+	+	+
Heptagenia fuscogrisea (Retzius, 1783)	+	—	—
Heptagenia sulphurea (Müller, 1776)	+	—	—
Nigrobaetis digitatus (Bengtsson, 1912)	+	+	—
Paraleptophlebia submarginata (Stephens, 1835)	—	—	+
Serratella ignita (Poda, 1761)	+	+	—
Plecoptera			
Diura bicaudata (Linnaeus 1758)	+	—	—
Diura nanseni (Kempny, 1900)	+	—	+
Isoperla difformis (Klapalek, 1909)	—	—	+
Leuctra fusca (Linnaeus, 1758)	+	+	+
Leuctra sp.	+	—	—
Taeniopteryx nebulosa (Linnaeus, 1758)	—	+	+
Trichoptera			
Arctopsyche ladogensis (Kolenati, 1859)	—	—	+

Taxon	St. 1	St. 2	St. 3
Cheumatopsyche lepida (Pictet, 1834)	–	+	–
Hydropsyche pellucidula (Curtis, 1834)	+	Dn, Db	–
Ithytrichia lamellaris Eaton, 1873	+	–	+
Lepidostoma hirtum (Fabricius, 1775)	–	–	+
Neureclipsis bimaculata (Linnaeus, 1758)	–	+	Dn
Oxyethira sp.	–	–	+
Polycentropus flavomaculatus (Pictet, 1834)	–	–	+
Polycentropus irroratus Curtis, 1835	+	+	–
Rhyacophila fasciata Hagen, 1859	–	–	+
Rhyacophila nubila Zetterstedt, 1840	+	Db	+
Diptera			
Ceratopogonidae spp.	+	+	–
Chelifera sp.	+	–	–
Dicranota bimaculata (Schummel, 1829)	–	+	–
Prionocera turcica (Fabricius, 1787)	–	–	Db
Simuliidae			
Odagmia sp.	+	–	–
Simulium (*Archesimulium*) *polare* (Rubzov, 1940)	–	–	+
Simulium (*Eusimulium) angustipes* Edwards, 1915	+	–	–
Simulium sp.	+	–	–
Chironomidae			
Cricotopus sp.	+	+	–
Eukiefferiella sp.	+	–	–
Procladius (*Holotanypus*) sp.	+	+	–
Rheocricotopus sp.	–	+	–
Orthocladiinae sp.	+	–	Dn
Tanypodinae sp.	–	–	+
Chironominae sp.	+	+	+

Table 10. The main indicators of zoobenthos of the Kenti River (stations nos. 1 and 2) and the Lakhna River (station no. 3). Sp is the number of species; N, abundance; B, biomass.

Station	Sp	N, 10^3 ind./m^2	Dominants by abundance	B, g/m^2	Dominants by biomass
st. 1	36	1.9–2.3	Baetis rhodani	3.3–9.7	*Euglesa* sp. *Sphaerium* sp.
st. 2	25	2.4–5.6	Hydropsyche pellucidula	2.6–23.6	*Sphaerium* sp. *Hydropsyche pellucidula* *Rhyacophila nubila*
st. 3	36	2.5–7.0	Neureclipsis bimaculata	34.5–91.2	*Prionocera turcica* Orthocladiinae spp.

Table 11. Indicator species in the studied communities of aquatic organisms. χ – xenosaprobic species; χo – xeno-oligosaprobic; β – betamezosaprobic; o-β – oligo-beta-mesosaprobic; o – oligosaprobic; α-β – alphabetamezosaprobic; α – alphamesosaprobic species.

Community	Number of species							
	χ	χo	β	o-β	o	α-β	α	Total
Phytoplankton	0	0	11	1	5	1	1	19
Phytoperiphyton	1	0	15	3	9	1	1	30
Zooplankton	0	0	12	2	3	2	1	20
Zoobenthos	2	1	20	1	16	1	2	43
Total	3	1	58	7	33	5	5	112
% of total number of species	2.7	0.9	51.8	6.3	29.5	4.5	4.5	100.0

Table 12. Saprobity indices, calculated by number of indicator species, in the studied areas.

Community	Index	st. 1	st. 2	st. 3
Phytoplankton	P&B	1.47	1.6	0.92
Phytoperiphyton	P&B	1.15	0.77	0.81
	TDI	2.12	1.52	1.49
Zooplankton	P&B	1.68	1.,28	0.81
Zoobenthos	P&B	1.83	1.88	1.67

Table 13. Average concentrations of heavy metals (mg/kg) in the Kenti and Lakhna rivers.

Station	Analyzed object	K	Fe	Zn	Cu	Cd	Pb
st. 1.	sediments	6090	41226	74.2	6.4	0.7	3.3
	caddis flies	5851	8028	72.4	7.3	0.8	1.9
	mollusks	1486	1952	18.9	2.1	0.3	0.4
	phytoperiphyton	15231	22266	36.0	3.2	1.6	2.1
st. 2	sediments	297	5963	5.3	2.3	0.1	0.7
	caddis flies	4283	2095	47.1	4.9	0.5	0.3
	mollusks	308	294	9.3	1.3	0.4	0.3
	phytoperiphyton	6666	10295	45.0	2.6	0.7	1.5
st. 3	phytoperiphyton	4601	7601	31.7	2.3	0.2	1.6

assess the degree of impact on other watercourses in the region. It should be borne in mind that the structure of plankton communities in the river depends on the presence of drainage lakes, the benthos and periphyton communities are highly dependent on the nature of the bottom sediments and substrate.

Our results evidence that the studies of even one watercourse, including those of the structure of river biocenoses along with detailed hydrochemical analysis, provide additional data for solving fundamental problems of hydrobiology. Meantime, our knowledge on the biodiversity of aquatic organisms and the potential bioresources of watercourses is expanding, much factual material is accumulating nowadays in order to identify the main approaches for assessing the water quality.

The communities of aquatic organisms are highly useful for biological indication. Obviously, both the structure of aquatic biocoenoses and the calculated indices reflect the trophic status of rivers. Data on particular ecological groups of aquatic organisms complement each other, increasing the objectivity of the conclusions. However, the hydrobiological analysis must be accompanied by a qualitative chemical analysis in order to obtain correct results and overall pattern. We consider the analysis of aquatic biocoenoses typical for inland water bodies must be included in the monitoring program of aquatic ecosystems. This is even more relevant if one considers the environmental regulatory documents (Federal Standard of the Russian Federation, GOST 17.1.3.07-82), which regulate determining of a number of biotic indicators, along with traditional abiotic ones, on a legal background.

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