Current state of the surface water in Kostomuksha reservoir and surrounding territory

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Introduction

In 1977-1985 the town of Kostomuksha and the Kostomuksha Ore-dressing Mill were built in the northwest of Karelia. The town and the mill appeared in the northern taiga zone, where the natural resources practically had not been used and had stayed virgin. Upon completion of the building process when the mill started working the anthropogenic effect on the environment increased. It was connected with gaseous and solid emissions of the mill, domestic sewage waters disposal in the river Kontokki system (the river Kamennaya basin) and the technogenous waters in the river Kenti system (Lake Sredneye Kuito basin).

Before the natural resources development in this region in 1976-1980 a detailed study of surface waters of the Kostomuksha Ore-dressing Mill was conducted at the Northern Water Problems Institute of the Karelian Research Centre of the Russian Academy of Sciences. The state of water bodies and precipitation in the Kostomuksha region have been monitored since the onset of the works at the mill. Since 1992 these objects have been included in the monitoring program of the water environment of Karelia and monitored annually (Current state… 1998).

The joint hydrochemical investigation of lakes in the Kostomuksha reservoir was made by the Northern Water Problem Institute from Russia and Kainuu Regional Environment Centre from Finland. Lakes of Kalevala region, Kenti- and Kontokky lake-river systems were included too. The main anthropogenic factors, which have an impact on the surface water, are the emissions of Kostomuksha ore-dressing mill and sewage water (return system of the mill water supply and domestic sewage from the town Kostomuksha).

Objects and research methods

Since 1991 collaborative studies of the water bodies state and precipitation in the Kostomuksha region have been conducted at the Northern Water Problems Institute and the Kainuu Regional Environment Centre. The work is being done on the water bodies directly affected by anthropogenous factors (the rivers Kenti and Kontokki system, Lake Sredneye Kuito) and located in the air-pollution impact zone (the lakes of the Kostomuksha nature reserve and the Kalevala region).

Precipitation monitoring was conducted during maximum snow accumulation period (late March B early April). Snow samples were taken 3, 10, 24, 40, 60 km from the ore-dressing mill. The chemical analysis of water samples from surface water bodies and the analysis of melted snow were conducted by using the same methods.
The majority of chemical analyses were performed simultaneously in the Kainuu Regional Environment Centre and Northern Water Problems Institute. The Li, Al and heavy metals determination was conducted in Kainuu, and the determination of O$_2$\textsuperscript{-}, NO$_2$\textsuperscript{-}, BOD$_5$ (biochemical consumption of oxygen), oil and Fe$^{2+}$ in Petrozavodsk. For the majority of the components the results obtained in both the laboratories were highly comparable.

**Results and discussion**

One of the factors of anthropogenous influence on the water bodies in the Kostomuksha region is the chemical fallout of pollutants with precipitation due both to the local sources and transboundary transport. The basic source of air pollution in Kostomuksha is the ore-dressing mill, where the most part of emissions are represented by sulphur dioxide (53-38 thousand t) and solid matters (5.3-6.4 thousands t).

It should be mentioned that the greater part of the emissions of the dioxide of sulphur, as well as solid matters, starting from 1997 occur mostly in Kostomuksha in comparison with the other industrial centres of Karelia. At the same time, in comparison with such metallurgical plants as Severonickel and Pechenganickel, located in the Kola peninsula, the emission of SO$_2$ in Kostomuksha is only 20-30\% of the emission of each of the specified mills.

Gaseous and solid emissions of the Kostomuksha Ore-dressing Mill influence the chemical fallout of SO$_4$, K, Ca, and also Fe, Al, V and Ni, and their impact is substantial within the range of 10 km from their source. The fallout of strong acids in this area is insignificant. Over 10 km away from the mill the fallout of strong acids reaches 0.5 mmol m$^{-2}$ mth$^{-1}$, which is almost half of the mean values in Karelia (0.9 mmol m$^{-2}$ mth$^{-1}$) observed in 1989-1992 (Lozovik & Basova 1994).

**The lakes of the Kostomuksha nature reserve and the Kalevala region**

The study of the water bodies of the Kostomuksha nature reserve and the Kalevala region in the vicinity of the border suggested a character of the chemical composition of the water similar to the natural water characteristics for this region. The examination of the lakes of the Kostomuksha nature reserve and the neighbouring territory of the Kalevala region in the winter period 1997-1999 showed that the majority of the lakes was characterized by low mineralization and alkalinity (0.04-0.34 mmol l$^{-1}$). Judging by the organic matter content, 25 of the 46 lakes, which were examined, belong to the mesopolyhumic water class, 15 to mesohumic and 6 to oligohumic. 14 lakes can be classified as low acid (pH < 6.0, alkalinity 0.04-0.06 mmol l$^{-1}$). As a rule, they are characterized by a small watershed and a significant amount of atmospheric supply delivery. Lake Devitchia Lamba is characterized by a high acidity level. The values are close to those of the precipitation (pH 5.2). In comparison with similar water bodies of South Karelia the acidity level in the Kostomuksha region lakes is lower.

Oxygen supply in the surface waters of all the lakes is quite sufficient (60-90 \% in winter). At the same time in mesopolyhumic low acid neutral lakes the deficit of O$_2$ at the bottom level ranged from 70 to 100 \%, which is connected with the oxygen consumption by bottom sediments during the organic matter mineralization processes. Due to oxygen deficiency near the bottom high concentrations of Fe and Mn (Fe up to 3.3 mg l$^{-1}$, Mn up to 1.2 mg l$^{-1}$) were also observed, while on the surface their concentrations were 0.15-0.70 and 0.03-0.06 mg l$^{-1}$ accordingly).
The P\textsubscript{total} content in the majority of the lakes did not exceed 10-12 µg l\textsuperscript{-1}, which is characteristic for low productivity oligotrophic water bodies. A higher content of P\textsubscript{total} is observed in the lakes Latvajärvi, Srednyaya Vazha, Saarikkojärvi, Kovalampi and Lyttä (14-22 µg l\textsuperscript{-1}) and these lakes presumably belong to the mesotrophic type.

The content of all forms of nitrogen is rather low, and it is typical of small low productivity lakes, with a small drainage basin, particularly when there is no sewage waters inflow, and it actually characterizes the natural level of these lakes for the specified region with NH\textsubscript{4} - 0.015, NO\textsubscript{3} - 0.07, N\textsubscript{total} - 0.4 mg N l\textsuperscript{-1} on the average.

Trace elements concentration, including heavy metals, was rather low in all the lakes and its value corresponds to the background values:

- B 1.4-2.7, Cr < 0.1-0.9, Pb < 0.03-0.3, Ni 0.05-0.3, V 0.03-0.7, As 0.16-0.29, Li 0.34-1.2, Be < 0.15, Co 0.04-0.08, Sr 0.6-0.21, Sb 0.02-0.03, Ba 7.3-8.6, Cs < 0.04, Al 56-83, Cd < 0.03, Cu 0.3-0.8, Se < 0.4, and Zn 1.2-1.5 µg l\textsuperscript{-1}.

There are 6 types of geochemical classes according to the alkalinity of water and organic matter content. The most representative is the mesopolyhumic low acid neutral class of water (19 of the 46 lakes in the research). The number of the lakes belonging to each type is basically the same. The only lake of the acidic oligohumic type is Devitchia Lamba. According to the classification adopted in Finland, the water quality of the majority of the lakes is satisfactory (33 lakes), good (7), high (5) and poor (1) (Vesi-ja ympäristöhallitus 1988) (Fig. 1 and 2).

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Fig. 1. The Classification of Lake Water Quality in Kostamus in 1998.

Fig. 2. The Classification of Lake Water Quality in Kalevala in 1999.
The Kontokki-Nogeus river system

Domestic sewage waters of Kostomuksha (annual amount about 5 million m³) exert a negative influence on the Kontokki river, and it manifests itself mostly through the increase of nitrogen and phosphorus compounds concentration (N-NO₃ - 1200 µg l⁻¹, Ptot B 340 µg l⁻¹). The latter causes increased loads on the lower lakes Luvozero and Kimasozero and accelerates the eutrophication process, which is confirmed by the values of the mineral and organic substances, and nutrient content in the Nogeus river flowing out of Lake Kimasozero.

The Kenti lake-river system

Of all the water bodies of the Kostomuksha region the most significant anthropogenic changes have taken place in the Kenti lake-river system, due to the impact of the technogenous waters of the ore dressing mill. Since 1994, the water from the waste storage has been disposed in the lake B river system annually. Depending on the annual amount of water inflow their annual amount makes 9-22 million m³. Besides, drainage canal waters flow into the lakes Okuniovoye and Poppalijärvi. Technogenous waters composition differs considerably from that of natural waters of this particular region. In mine waters alongside with their high mineralization (about 1.5 g l⁻¹) there is a very high content of nitrous matters (NH₄ B 48 000, NO₃ B 64 000, Ntotal 100 000 µg N l⁻¹), manganese up to 3000 µg l⁻¹, nickel -140 µg l⁻¹. They are disposed directly in the waste storage and they are the main source of nitrogen compounds in its water alongside with the inflow from pulp in the course of ore processing.

The waste storage waters are characterized by very high potassium and sulphate content, and an abnormal ratio between potassium and the other main ions, which generally do no occur in natural waters. The filtration waters are close to the composition of the waste storage waters. They contain less nitrous matters, but more calcium and sulphates, what is connected with the leaching of gypsum from the lock. Drainage canal waters characteristics differ from those of the natural waters, and they also pollute the river Kenti system. In all technogenous waters, and first of all in mine water, the increased content of lithium, chromium, nickel and cobalt is observed in comparison with the natural waters. Technogenous waters inflow into the river Kenti system resulted in mineralization increase of 5 B 20 times from the lower lakes of the system to the upper ones, potassium concentration - 25-250 times and sulphates - 2-60 in comparison with the 70-s. Now a considerable increase of nitrates and N org concentration, exceeding the potassium concentration to a great extent, and also the decrease of oxygen content in water at the bottom in the winter period have become the other peculiar feature of the hydrochemical regime of the river Kenti system. Increased concentrations of Ni, Cr, Co, Mn and Li enter the lakes of the system with technogenous waters, and it shows in the excess of background values of these elements in the upper and central lakes Koivas and Kento, but the values observed do not exceed the maximum concentration limit for fish husbandry basins. In 1999 the concentration of lithium was: in Lake Poppalijärvi 19 mg l⁻¹, in Lake Koivas 12, 7.7 B in Lake Kento, 9 B in Lomozero and 6.6 in Lake Ylijärvi. The nickel content changed from 2.5 to 0.31 µg l⁻¹, and chromium from 3.0 to 0.42 µg l⁻¹.

Conclusion

On the whole, analyzing the water bodies state of the Kostomuksha region, it should be noted that beyond the area of the direct influence of the Kostomuksha Ore-dressing Mill technogenous waters no significant changes in the regime of the lakes were detected.
A slightly higher acidity level was observed in the lakes with a small watershed, which may be due both to the local emissions of sulphur dioxide from the ore-dressing mill, and the transboundary transport. The most significant changes are observed in the river Kenti system. The basic technogenic influence on its hydrochemical regime is the increase of mineralization, potassium and lithium concentration, and natural cations ratio disbalance. Nitrous matters pollution, nitrates first of all, deterioration of the oxygen regime in the winter period - all these factors exert a highly negative influence on the ecosystem of the lakes.

The eutrophication of the Kontokki river and the lower lakes Luvozero and Kimasozero is the consequence of domestic sewage waters disposal in Kostomuksha.

**Literature**

