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Centre for Economic Development, Transport and the Environment

Pasvik Water Quality Report

Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area

Annukka Puro-Tahvanainen, Marina Zueva, Nikolay Kashulin,
Sergey Sandimirov, Guttorm N. Christensen and Ilona Grekelä

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Contents

Acknowledgements 5
Introduction 7
Pechenganikel reconstruction 8
- Mining 8
- Smelting Industry 8
- Construction of Briquetting Shop 9
- Renovation of smelting production 10

Water quality in the Pasvik watercourse 11
Description of the study area 12
Analysis methods and sampling 13
Pollution sources in the Pasvik River basin 14
The water quality monitoring network 16
Water Quality in the Pasvik watercourse 17
- Organic matter 17
- Phosphates and phosphorus in general 18
- Nitrogen 19
- Salinity balance of water 20
- Alkalinity and pH factor 20
- Copper and nikel 22

Conclusions 26

Water quality in the Lake Kuetsjarvi 27
Water Quality in the Lake Kuetsjarvi 29
- Organic matter 29
- Total phosphorus and phosphates 29
- Nitrogen 30
- Salinity balance of water 30
- Alkalinity and pH-factor 32
- Copper and nickel 32

Conclusions 34

Water quality of small lakes and streams in the Norwegian, Finnish and Russian border area 35
Introduction 36
Materials and methods 36
Results 38
- Overall water quality 38
- Acidification 39
- Metals 41

Discussion and conclusions 44
Recommendations 45
References 46
Documentation page 47
Kuvailulehti 48
страница документации 49
Kolofonside 50

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- Institute of North Industrial Ecology Problems (INEP), Russia
- Bioforsk Soil and Environment, Svanhovd, Norway
- Akvaplan-niva AS, Norway
- University of Tromsø, Norwegian College of Fisheries Science (NCFS), Norway
- Finnish Environment Institute, Finland

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Introduction

This Report details the results of trilateral water quality monitoring during past three years in the border area of Norway, Finland and Russia. Water quality monitoring is a part of the Pasvik Programme created by the environmental authorities and researchers for obtaining comprehensive and current information on the changes taking place under the varying anthropogenic load in the joint border area of the three nations.

The main threat to aquatic environments in the border area is the neighbouring Pechenganikel industrial complex, located on the Kola Peninsula in northwest Russia. Emissions from the complex comprise high levels of sulphur dioxide, and particulate material containing a wide range of toxic metals, primarily copper and nickel. Sulphur dioxide emissions cause acidification of surface waters, especially in small lakes with weak buffering capacity. Heavy metals accumulate in organisms, soil and the bottom sediments of surface waters. The Pasvik watercourse is impacted by the direct input of pollutants (discharges) and by atmospheric pollutants.

The monitoring area covers a large part of the Pasvik catchment, which is divided between the three countries. The trilateral water quality monitoring programme is based on existing national monitoring systems, supplemented where necessary with additional monitoring points and attributes, and takes into account the specific characteristics of the area.

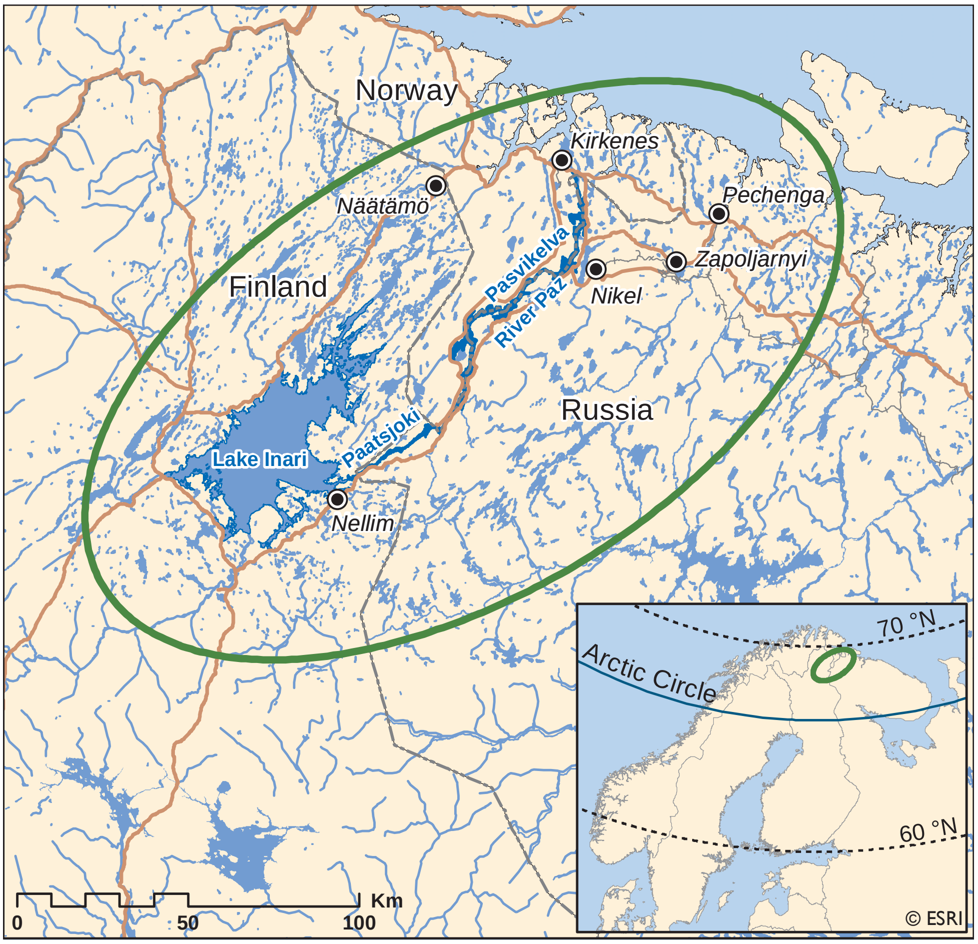


Figure 1. The area covered by the Pasvik Programme.

Pechenganikel Reconstruction

The Pechenganikel Mining and Metallurgical Combinine the Russian border towns of Nikel and Zapolyarny is a part of the OJSC Kola GMK, a subsidiary of MMC Norilsk Nickel Group.

Mining

Presently, the Kola GMK is operating eight deposits of copper-and-nickel ores. Each deposit is located within the limits of the Pechenga Ore Field and grouped into two ore clusters – the Western Cluster near the settlement of Nikel, and the Eastern Cluster near the town of Zapoliarny.

The Western Ore Cluster comprises the fields of Kotselvaara-Kammikivi and Semiletka. The Eastern Ore Cluster comprises the fields of Zhdanovskoye, Zapoliarnoye, Bystrinskoe, Tundrovoe, Verkhnee, and Sputnik. Mining activities are ongoing at four of these fields: Zhdanovskoye, Zapoliarnoye Kotselvaara-Kammikivi and Semiletka. The fields Sputnik, Bystrinskoe, Tundrovoe, and Verkhnee are kept in reserve.

According to plans, in 2011 ore extraction at the Severny-Gluboky and Kaula-Koselvaara mines will increase by 10% compared to the previous year.

The construction of the Severny-Gluboky Mine near the town of Zapoliarny is one of the Norilsky Nikel Company's important investment projects. Its main objective is to renew the raw material base and maintain the achieved level of commercial nickel production from the Company's own raw materials on a long-term basis. In December 2010, the mine reached the design capacity of ore production – 6 million tons per year. The proven reserves of the Severny-Gluboky mine are sufficient for at least 30 years; the activities aimed at expansion of the Company's ore supplies are ongoing.

The construction of the Severny-Gluboky Mine began in July 2008. Its first startup complex (one of four) was commissioned only four years later. Today, the Severny-Gluboky Mine is a true underground town. It reaches as deep as over one kilometre with a length around 200 km. Up to 600 employees of Kola GMK are permanently operating underground, with over 100 units of mobile mining equipment. In 2011, the fourth startup complex is expected to be commissioned. The overall investment into mine construction will amount to 360 million euros.

Activities aimed at reduction of sewage discharge into surface water sources are underway at the Severny and Severny Gluboky mines.

Thus, presently the following actions are being implemented:

- Construction of water treatment plants involving ion-exchange technologies for pit water treatment at the Severny and Severny Gluboky mines.
- Cleaning of settling ponds. Compared to 2008, in 2010 a reduction of nickel concentrations from 0,04 mgl^{-1} to 0,036 mgl^{-1} took place; copper from 0,012 mgl^{-1} to 0,009 mgl^{-1}, and iron from 0,18 mgl^{-1} to 0,125 mgl^{-1} as a result of the decrease in discharge quantities.
- Completion of mining activities in the pits to conduct quarry water into the underground openings of the Severny Mine. As the quarry water flows into the underground openings, the discharge of pollutants with quarry water decreases.
- Utilization of post-treated quarry water in the system of recycling water supply for production needs of the Severny Mine. Compared to 2009, in 2010 a discharge of 563,0 thousand cubic metres of quarry water into the Seliakka-Joki River (tributary of the Pechenga River) was prevented. As the result, the quantity of discharge was reduced:
  - oil products, dry residue, nickel, nitrites, nitrates, and sulphates – twofold;
  - iron, BOD, and copper – threefold.

At the Kaula-Koselvaara Mine in 2010, the rock skip shaft was deepened, which improved the productivity of the mine.

Smelting Industry

Over the latest three years, the emission level of the principle atmospheric pollutant – sulphur dioxide SO_2 – has amounted to 100 000 tons per year. Over the course of 15 years, these emissions have decreased by 2.5 times.

The fall in SO_2 emissions at the smelting production facilities of Zapoliarny and Nickel resulted from the following technical activities:

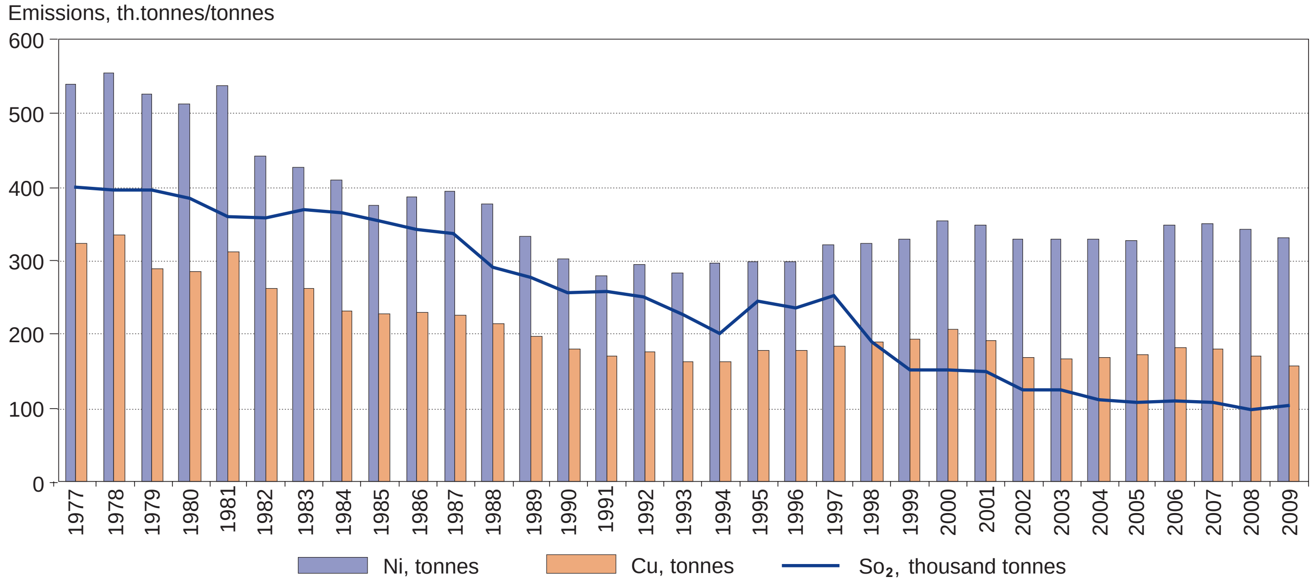


Figure 2. Emissions of sulphur dioxide (SO_2), nickel (Ni) and copper (Cu) compounds at the Pechenganikel Plant (Zapoliarny Production Area of Kola GMK).

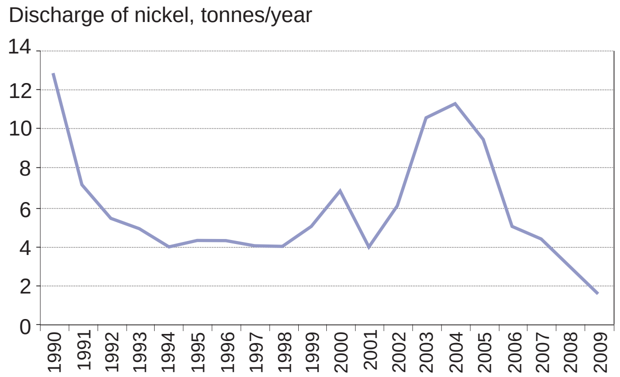


Figure 3 . Nickel (Ni) discharge at the Pechenganikel Plant (Zapoliarny Production Area of Kola GMK).

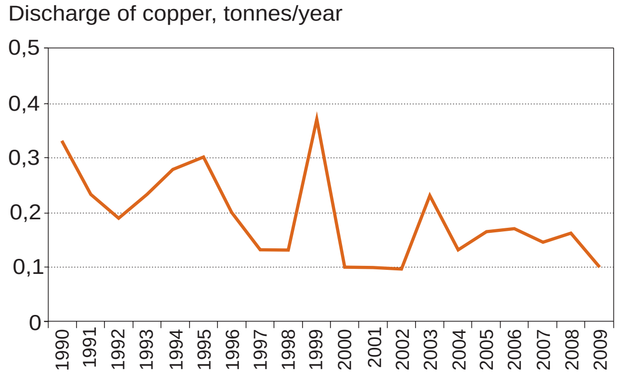


Figure 4. Copper (Cu) discharge at the Pechenganikel Plant (Zapoliarny Production Area of Kola GMK).

Renovation of the concentrating plant has allowed production of concentrate with a higher content of nickel and, consequently, more sulphur in the form of sulphide minerals which are inert substances in relation to the environment; these are transported to the tailings storage of the concentration plant and are not used in the follow-up metallurgic processing. The number of metallurgic units engaged in the activities has decreased. In the smelting shop, only two furnaces are currently permanently operating instead of six in the past. Consequently, the reduction of the proportion of sulphur in the matter and the reduction in the amount of matter were achieved using only two converters in the Nikel smelting shop instead of the previous four to five. Sulphuric acid production has also been renovated, which has allowed increasing the degree of SO_2 utilization from the converter gases into sulphuric acid. In total OJSC Kola GMK has spent over 48 million euros of its own assets on hese activities.

Construction of Briquetting Shop

OJSC Kola GMK is currently concluding the implementation of the first part of the renovation programme – construction of briquetting shop at the concentration plant in Zapoliarny.

The Briquetting Shop project in Zapoliarny is expected to be completed in 2011. The construction project for the Briquetting Shop is a part of the Metallurgic Production Renovation Programme being implemented by OJSC Kola Kolskaya GMK to reduce emissions of sulphur and heavy metals dust/waste. The overall cost of the project is 52,6 million euros. The so-called briquetting shop will mark the end of the use of technology that has been used for over a century. Today's metal production technology implies concentrate filtration and burning to produce pellets for follow-up smelting. The burning process uses non-utilizable gases SO_2 which are emitted into the atmosphere. In the new shop, a new process chain will be used (filtration–drying–briquetting) which will exclude the environmentally unfriendly burning process. The filtration equipment is designed to dewater the ore copper-and-nickel concentrate from the concentrating plant. Furthermore, the filtrated concentrate will be delivered for drying and briquetting. The equipment to be used is made in Germany and Finland. Briquetting is expected to facilitate enormous reductions of hazardous emissions from the Zapoliarny production area: from today's 40 thousand tons down to less than 1,4 thousand tons per year. The process will be fully automated; the bin type will help avoid dust becoming airborne during unloading and loading.

Installation of the first briquette-press reached completion in the end of December 2010. The experimental start-up of the filtration area with production of filter cake was performed in summer. Setup of equipment for drying and briquetting is currently underway. The briquetting shop is scheduled for reaching full design capacity during the fourth quarter of 2011.

Renovation of smelting production

Presently, two ore heat-treatment furnaces operate in the smelting shop. Thorough repairs of one furnace were performed in 2010. The second furnace is to be repaired in autumn 2011. This scheduled repair will ensure stable and continuous operation for two years. Following this, the next thorough repair is scheduled.

According to preliminary estimations made by OJSC Kola Kolskaya GMK, the renovation of the smelting shop in Nikel will cost around 134 million euros. The metallurgic production renovation programme includes a transition for using a double-chamber smelting furnace. Testing of the Vanyukov double-chamber furnace showed that the furnace will not be able to provide the expected process results. The design technical solutions did not prove to be correct. Based on the testing, Kola GMK has carried out revisions and a re-evaluation of the design. The new design performed by the Gipronikel Institute showed that the entire metallurgic production renovation program will cost a minimum of 290 million euros. Tests have shown that regardless of spending this sum on the programme, it is impossible to achieve the values of SO_2 emissions as planned: 10,5 thousand tons from the smelting plant in the settlement of Nikel.

At the smelting shop's sulphuric acid production area, measures have been taken to improve the degree of utilization of sulphuric gases. The ongoing work is one of the stages of the smelting shop preparation for processing of high-sulphur copper-and-nickel briquettes; it will allow an increase in the amount of utilizable sulphuric gases by 7 000 Nm³/hour without reduction of the utilization degree.

This publication presents information on renovation of Pechenganikel Plant based on the official website of Kola GMK www.kolagmk.ru.

Figure 5. Smelting plant, Nikel.
Photograph: Sergey Sandimirov.

Water quality in the Pasvik watercourse

– monitoring report on 2000–2009

Marina Zueva

Photograph: Sergei Kotov.

Description of the study area

The study of the Pasvik watercourse remains an important ecological task for the three countries sharing the catchment area of the river basin. In the lower course of the watercourse, the load on the basin is formed by the sewage and discharge impact of the Kola GMK Pechenganikel industrial complex. Both Russian and Norwegian hydro-power plants are situated on the water course and their operation also has an impact on the condition of the river. Continuous monitoring of the water quality of the watercourse and detection of variability in the quality parameters are necessary for the assessment of the condition, its dynamics, and ultimately for the measures to be taken to reduce the negative impact and to improve the state of the environment in present day conditions.

This publication continues the basin water quality study; it provides an assessment of today's status and changes over the latest ten years.

Pasvik watercourse flows out of Lake Inari in Finland and flows into the Bekfjord of the Varanger fjord, the Barents Sea in Norway. The basin has a total area of 18 325 km^2 and includes a large number of lakes and wetlands, constituting a river-and-lake system rather typical for the Kola Peninsula. The lower course of the river includes the Salmijarvi (Svanevatn) Lake linked via a stream with the Kuetjarvi Lake which in turn is in the course of the Kolosjoki River that is affected by direct discharge of sewage from the smelter.

Figures 1–3. Pasvik watercourse. Photograph: Sergei Kotov.

Analysis methods and sampling

The samples collected in the Pasvik watercourse were analyzed in the laboratories of the Murmansk Department for Hydrometeorology and Environmental Monitoring (MUGMS), Institute of North Industrial Ecology Problems, KSC RAS (INEP) and LAP ELY using standard analytical methods. Since 1996, the laboratories have regularly participated in intercalibration exercises. However, the variation in the analysis results was due to the use of different methodology in the individual laboratories and the modernization and improvement of the methodology over time, meaning that the data cannot be combined in all cases.

The water samples were taken at the monitoring sites at the surface level at depths of 0,1–0,3 metres from the surface.Water temperature, pH and dissolved oxygen concentration were measured immediately during sampling.

Samples for determining metal concentration were filtered through a 0,45 µm membrane filter, preserved with nitric acid and transported to the laboratory. Metals and other elements were determined by flame and flameless atomic absorption spectrophotometry.

Samples for analysing nutrients were analysed using the spectrophotometry or ionic chromatography method.

Samples for determining ionic composition were analysed using the titrimetric or ionic chromatography method.

Biological oxygen demand (BOD) was determined on the sampling day using the “light and dark bottle” method.

Figure 4. The analytical results of the laboratories participating in the monitoring programme are fully comparable with each other. Photograph: Ilona Grekelä.

Pollution sources in the Pasvik River basin

The pollution load on the water sources of the River Pasvik basin is formed of industrial pollution transferred by air and direct inflow of the sewage from the Pechenganikel industrial complex – an enterprise within the mining and smelting Group OJSC Kola GMK processing copper and nickel ores.

The Kolosjoki River serves as the main collector of insufficiently treated run-off from the smelter waste piles, mining waters from the plant and domestic sewage from the settlement of Nikel. The discharge of industrial and domestic sewage is released 1,4 km upstream from the river mouth.

Since 1997, the discharge quantities have decreased primarily due to a reduction in the use of high-sulphur Norilsk ore in the smelter. Since then, the volume of loading has been on a constant level, but in recent years (2008–2009) there has been a decreasing trend (Figure 5).

The Kola GMK enterprises are taking active measures to reduce the negative impact on the environment.

A number of industrial facilities are included in the environmental "Hot Spots" list and the list of Murmansk Region priority projects developed by the Nordic Environment Finance Corporation (NEFCO) and Arctic Monitoring and Assessment Programme (AMAP) in 2003. The list includes projects for the reduction of pollutant emissions from OJSC Kola GMK. These projects were announced as priorities at the meeting of the BEAC Working Group on Environment in October 2008 and were included in the list of priority environmental projects ("hot spots") of Murmansk Region for 2009–2013. International cooperation in this area will continue in future.

OJSC Kola GMK is working steadily to renovate and modernize the process and improve the systems of quality management and environment protection. In 2001, the governments of the Russian Federation and the Kingdom of Norway signed an agreement for renovation of OJSC Kola GMK. The purpose of the agreement was to refurbish the company's

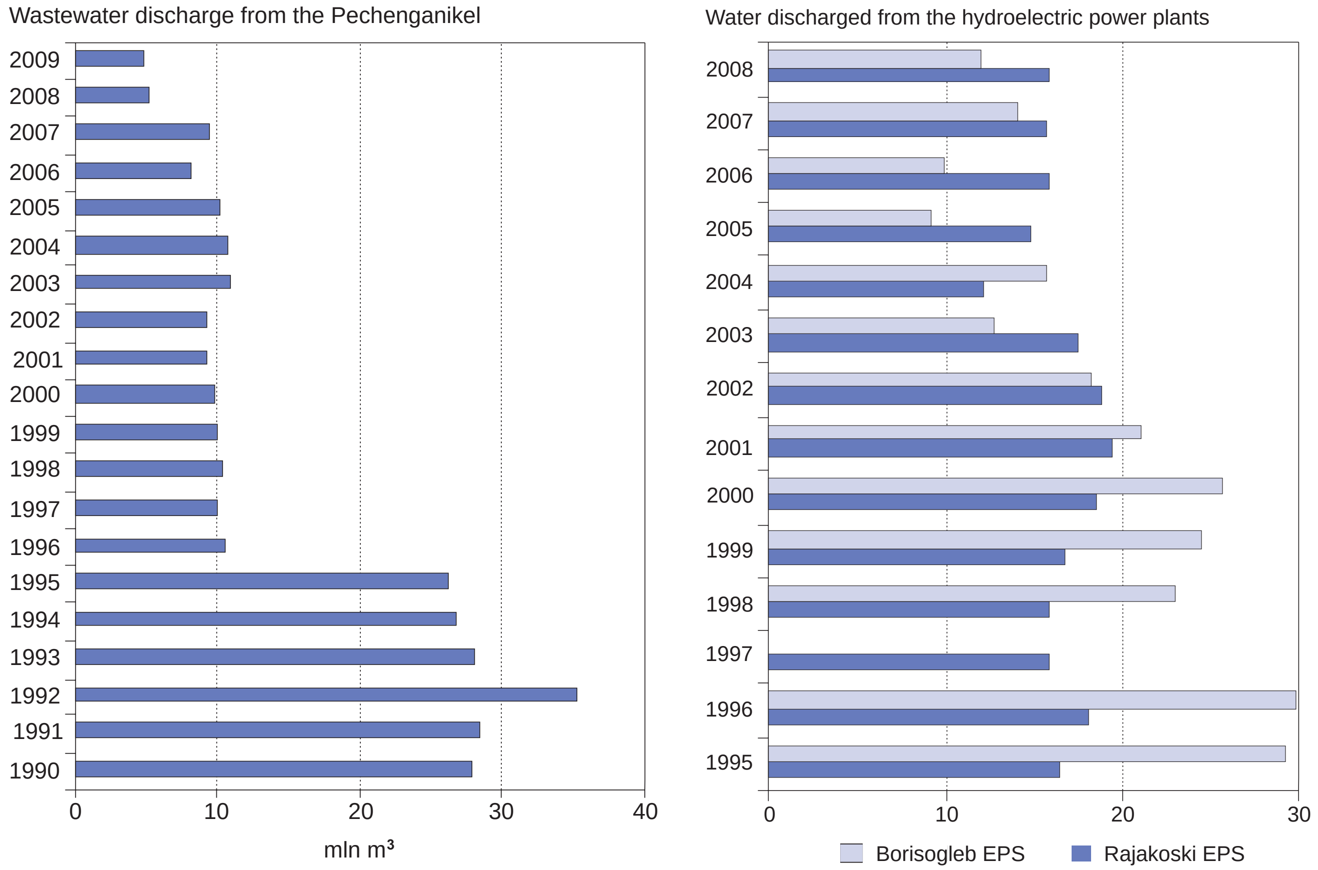


Figure 5. Discharge from GMK Pechenganikel and the Paz HPP.

equipment to reduce the emissions of sulphur and heavy metals. The agreement is effective until 2011. The project is funded by a Nordic Investment Bank grant and OJSC Kola GMK's own resources.

OJSC Kola GMK is continuing the implementation of the Programme for modernization of smelting process. The programme comprises two large investment packages, one of which is renovation of the incinerator building at the industrial facility in Zapoliarny to reduce the sulfur dioxide (SO_2) emission from 42 000 to 686 tons per annum (design data) through replacement of the existing "palletizing – burning" technology with briquetting technology.

The general reduction of sewage volume and the amount of pollutants in the sewage is associated with the annual implementation of the Allowable Discharge Standards Programme. This programme's aims are the more rational use of fresh water and arrangement of new recycling water supply systems. The OJSC Kola GMK Pechenganikel smelter's expenses on the measures targeted at achieving the allowable discharge standards, reduction of water consumption and water supply system in 2007, totalling up to 5,02 million roubles.

The modernization of the smelting processes (construction of Vanyukov double-chamber furnace with renovation of the sulphuric acid and oxygen shop) targeted at reducing SO_2 and heavy metal dust emissions from the facility in Nikel. The project is targeted at improving the treatment of gas from smelting equipment at the OJSC Kola GMK Pechenganikel smelter and reduction of SO_2 emission from 60 000 tons to 10 500 tons per annum.

Industrial sewage from the electric power plants of Paz HPP (Hydro Power Plant Cascade) is dischar. ged along the course of the Pazvik River. The discharge amounts to tens of thousand of tons per annum with a declining trend over the past few years. The discharged water is clean according to the standards; containing small concentrations of suspended, organic and other matter.

As examinations of many HPP water reservoirs show, their impact is generally positive. However, there are negative issues as well. For example, the creation of small HPP water reservoirs causes river run-off alterations depending on the regulation mode. Evaporation loss from the reservoirs represents natural water flow balance. The unevenness of the run-off has an impact on the hydro-chemical regime of the small rivers. As the flood run-off stays in a small river for only a short time – for several days or even hours, there is insufficient time for the river to self-clean from pollution in the course of natural biological and chemical processes. It is especially important during the low-water periods (periods of seepage flow). This may mean that pollution in small rivers exceeds the permissible levels, even with relatively low amounts of incoming pollutants.

The water quality monitoring network

Water quality assessment was carried out by the partner authorities at the following stations (Figure 6):

- Inari, Vasikkaselkä – LAP ELY 2001–2009
- Pasvik, Virtaniemi – LAP ELY 2001–2009
- Pasvik, Kaitakoski – MUGMS 2001–2009
- Pasvik, Janiskoski – MUGMS 2001–2009
- Pasvik, Rajakoski – MUGMS 2001–2009
- Pasvik, Hevaskoski – MUGMS 2001–2009
- Pasvik, Jordanfossen – FMFI/Bioforsk/INEP 2002, 2003, 2005, 2008
- Pasvik, Ruskebukta – FMFI/Bioforsk/INEP 2002–2005, 2008–2009
- Pasvik, Tjerebukta – FMFI/Bioforsk/INEP 2003–2005, 2007–2008
- Pasvik, Vaggatem, FMFI/Bioforsk/INEP 2002–2005, 2008–2009
- Pasvik, Melkefoss – FMFI/Bioforsk/INEP 2002, 2005, 2008
- Pasvik, Salmijarvi (Svanevatn) – FMFI/Bioforsk/ INEP 2003, 2005, 2008
- Pasvik, Bjornevatn – FMFI/Bioforsk/INEP 2003, 2005, 2008
- Pasvik, Skrukkebukta – FMFI/Bioforsk/INEP 2002–2005, 2007–2009
- Pasvik, Borisoglebski – MUGMS 2001–2009
- Stream Protoka (between the lakes Kuetsjarvi and Salmijarvi) – MUGMS 2001–2009 .
- Kolosjoki , 14,7 up from the town of Nikel – MUGMS 2001–2009
- Kolosjoki – MUGMS 2005–2009.

The MUGMS stations on the Pasvik watercoure are all (except Kaitakoski) located below the hydro-electric power plants, and therefore the activities of the power plants have some impact on water quality at the sampling stations. Sampling on the River Pasvik was performed 6 times a year: March, May, June, July, August and October. Monitoring was carried out monthly on the River Kolosjoki and the Stream Protoka.

Monitoring at the Inari, Vasikkaselkä and Pasvik, Virtaniemi stations (LAP ELY) was carried out 7–12 times a year. Monitoring at the INEP stations was carried out 2–7 times a year.

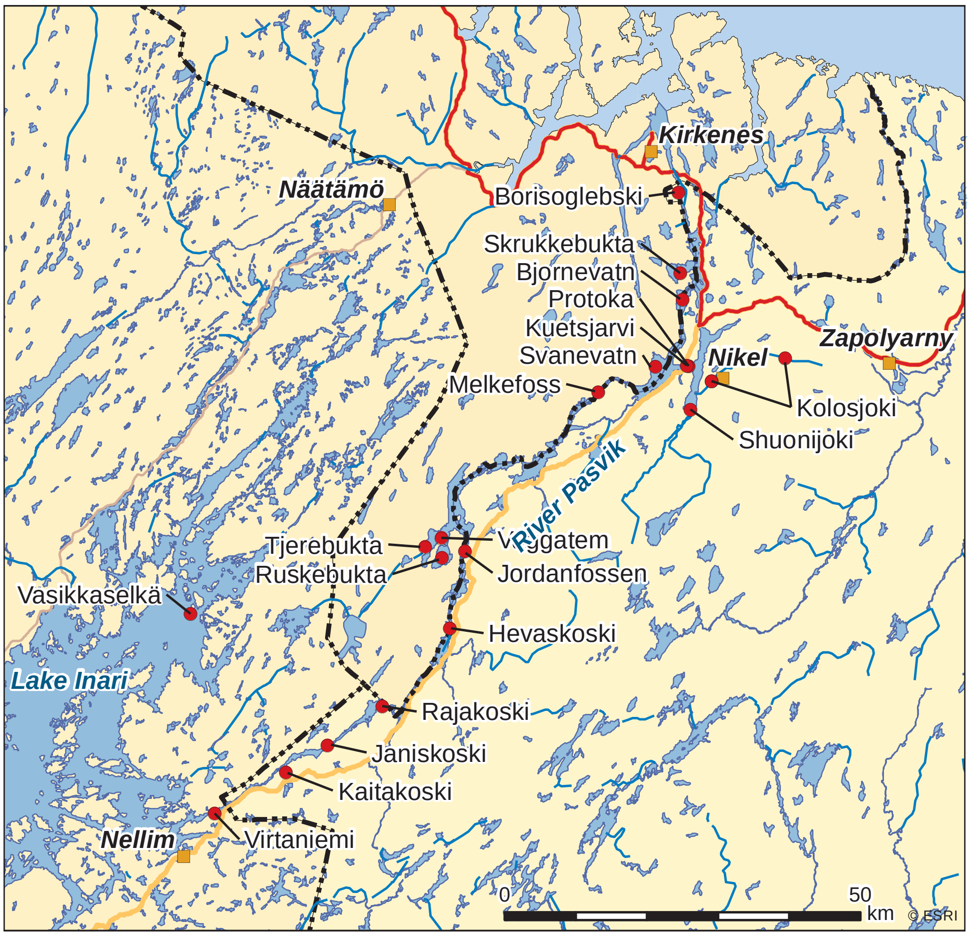


Figure 6. Monitoring of water quality in the Pasvik watercourse is cooperation between six different organizations.

Water Quality in the Pasvik watercourse

The chemical composition of the Pasvik River surface water is determined by the substratum properties of the river and its drainage, precipitation (predominantly from snow with a considerable share of rain) and terrestrial run-off. The industrial impact is composed of air transmission and direct emissions from pollutant sources. The industrial impacts are more obvious on the river course closer to the location of the Pechenganikel smelter.

The report presents the description of the watercourse water quality concerning the concentrations of organic matter, nitrogen and phosphorus compounds, principal ions and metals, and shows the diagrams of indicator distribution in the river and the dynamics of their changes.

Organic matter

In terms of organic matter concentration, the Pasvik watercourse is considered an oligotrophic water source. The concentration of organic carbon in the area Pasvik, Virtaniemi (LAP ELY) did not exceed 3 $mgCl^{-1}$, in the locations monitored by INEP the figure was 4–6 $mgCl^{-1}$, decreasing in the area of impact from the smelter's sewage. The concentration of easily oxidisable organic matter in the area of the Pazvik Cascade of hydro power plants (MUGMS) amounted to 6–8 mgl^{-1} according to chemical oxygen demand (COD) (Figure 7).

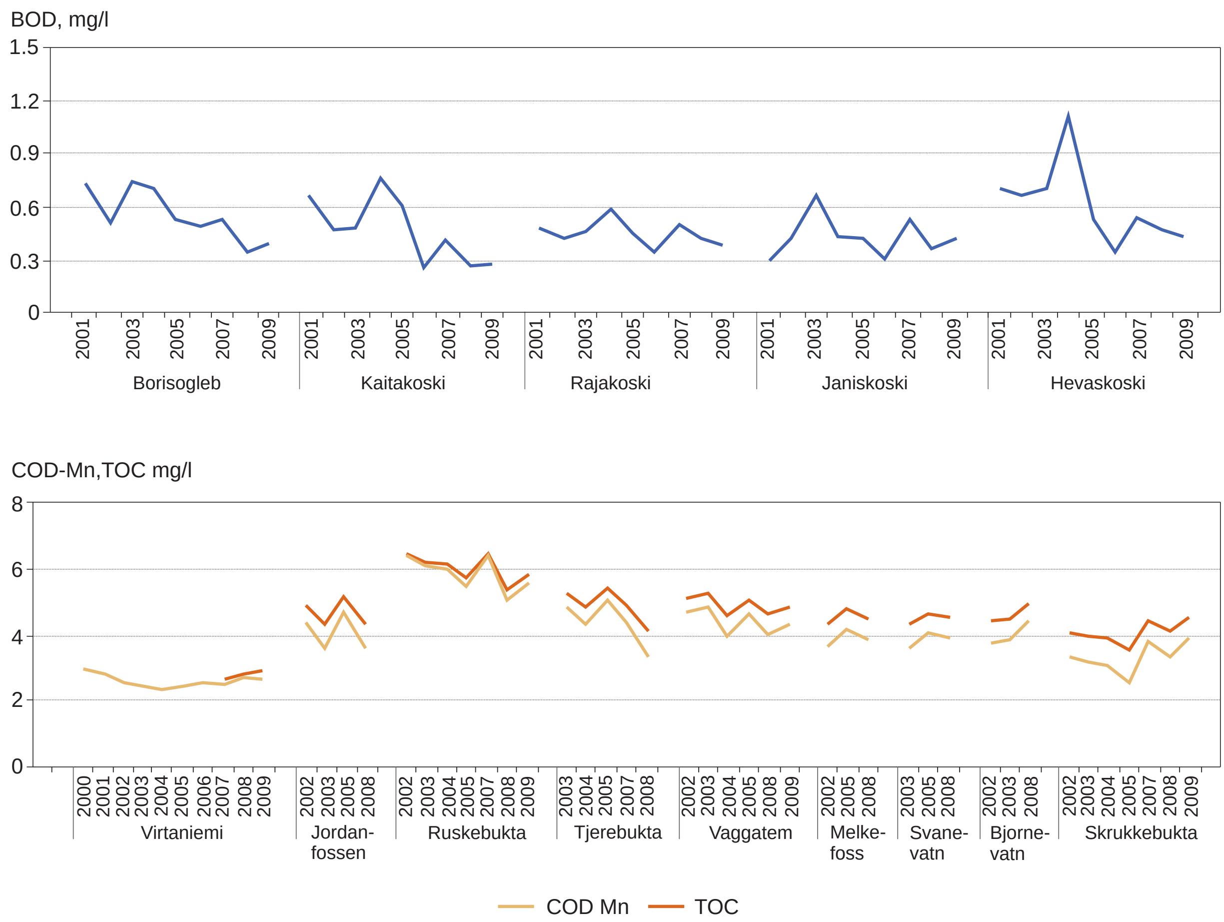


Figure 7. Organic matter distribution in the Pasvik River.

Phosphates and phosphorus in general

The average concentration of total phosphorus in the Pasvik River at the locations of INEP sampling, varied between 7–10 µgl^{-1}, with the highest values at the Ruskebukta station (19–23 µgl^{-1} in 2007–2009). During this period, increased concentrations of organic matter (TOC) were also observed, Figure 8. At the location Pazvik, Virtaniemi, the phosphorus concentration was between 3–5 µgl^{-1} during the monitoring period.

Phosphate concentration varied between 0–5 µgl^{-1}. The highest concentrations were observed in the locations at HPP Cascade (MUGMS) (up to 8–10 µgl^{-1}).

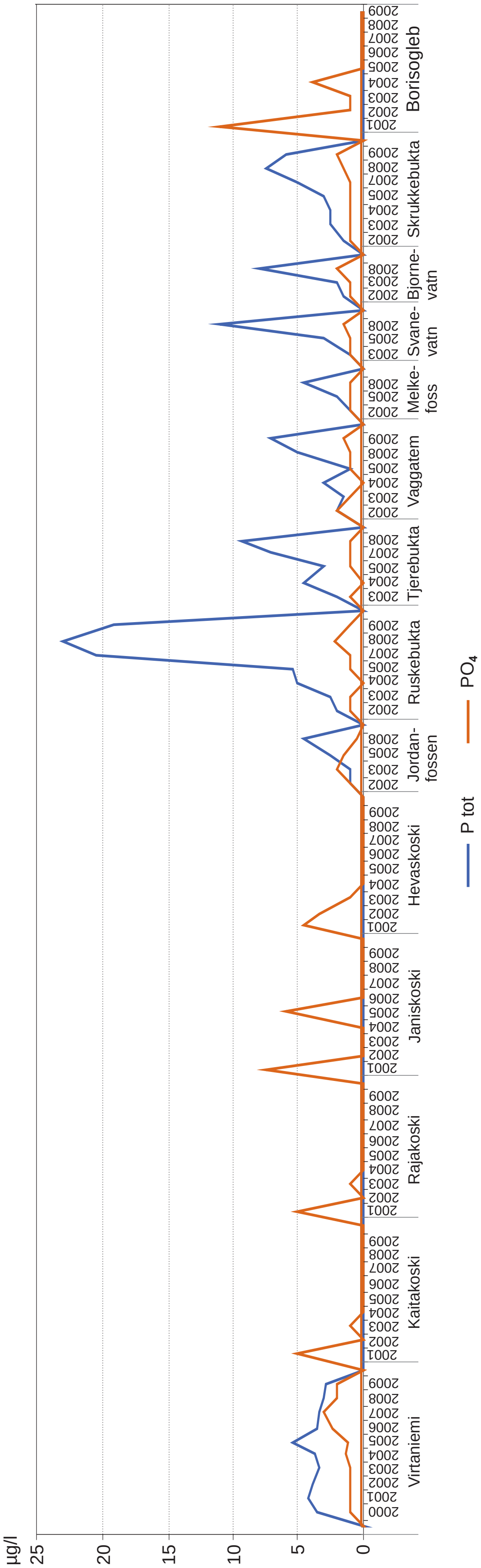


Figure 8. Distribution of phosphorus in general and phosphates.

Nitrogen

Total nitrogen (Ntot) ranged from concentrations 160–180 µgl^{-1} in the upstream areas (Virtaniemi, LREC and Jordanfossen, INEP) to higher concentrations of 400–500 in the Ruskebukta–Vaggatem area (INEP) in the midstream. This is determined by the concentration of organic matter in this location (Figure 9). The average concentrations of nitrates (NO_3) in the river are 30–60 µgl^{-1}. The concentration of ammonia nitrogen (NO_4) is not high, generally reaching a level of 20–40 µgl^{-1} and only in several cases exceeding 100 µgl^{-1}.

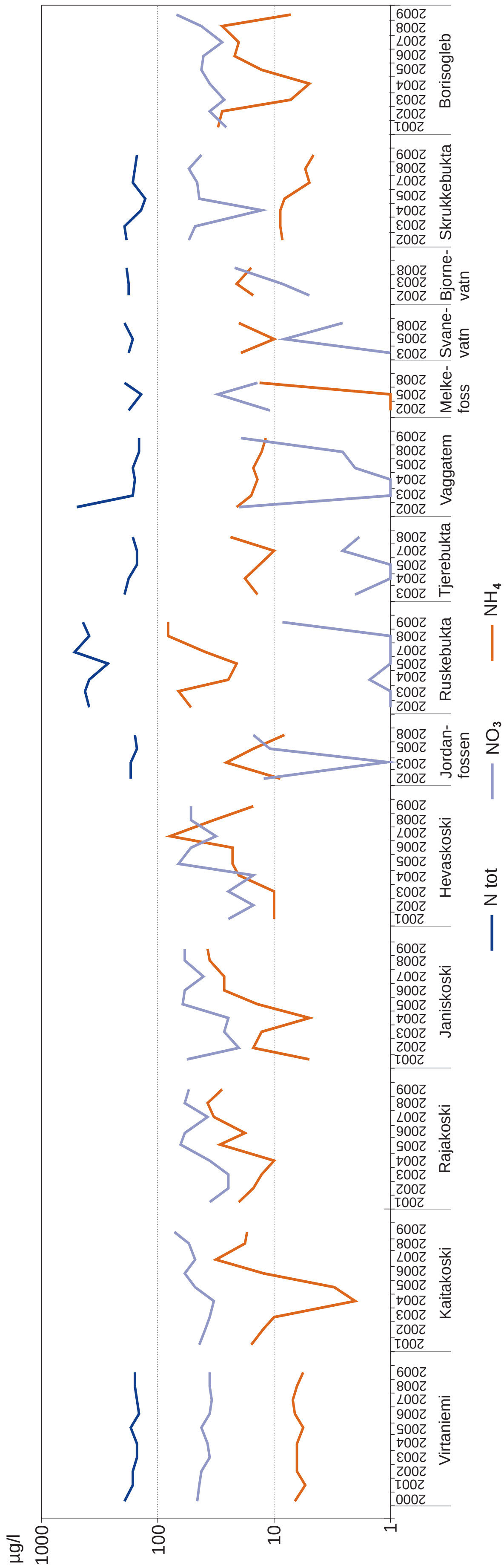


Figure 9. Distribution of nitrogen compounds.

Salinity balance of water

The content of minerals in the river water is low. The average concentration of principal cations in the river amounts to 20 mgl^{-1}, with higher concentrations reaching 30 mgl^{-1}. Calcium is the prevailing cation reaching as much as 50% of cation compositions (Figure 10).

Water hardness is generally 20–25 μeql^{-1} and stays under 40 μeql^{-1} which is a normal parameter for river water.

Increased concentrations of cations, mainly Na and Ca, are observed in the smelter's impact area.

The anion concentration is also increased in the impact area; in particular, the concentration of sulphates is twice as high compared to the upper reaches of the river, reaching up to 6 mgl^{-1} (INEP, MUGMS). The share of sulphates (SO_4) among anions is 15–20% reaching up to 30% and even more in the impact area (Figure 11).

Due to the load from industrial sulphates, the natural water salinity balance is disturbed causing changes in transparency, electrical conductivity, and salinity.

Alkalinity and pH factor

The water alkalinity in the river varies from 17 to 23 μeql^{-1}. The average pH value is 7,0–7,3. No fall in the alkalinity value was observed, which means there is no acidification (Figure 12).

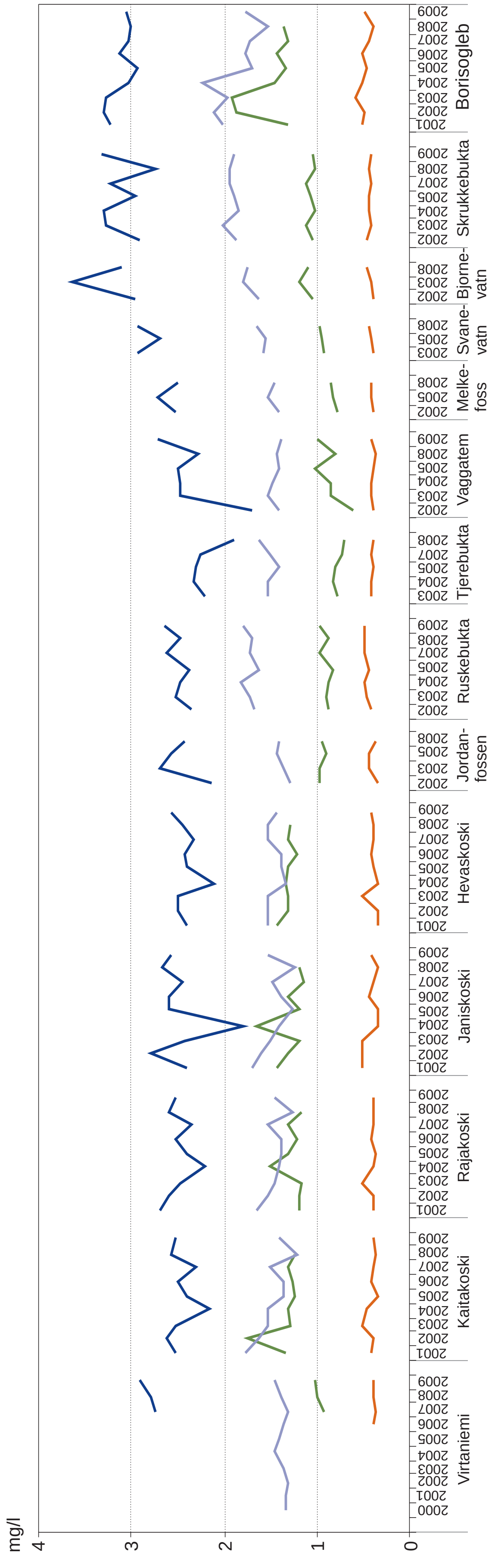


Figure 10. Distribution of cations in the river.

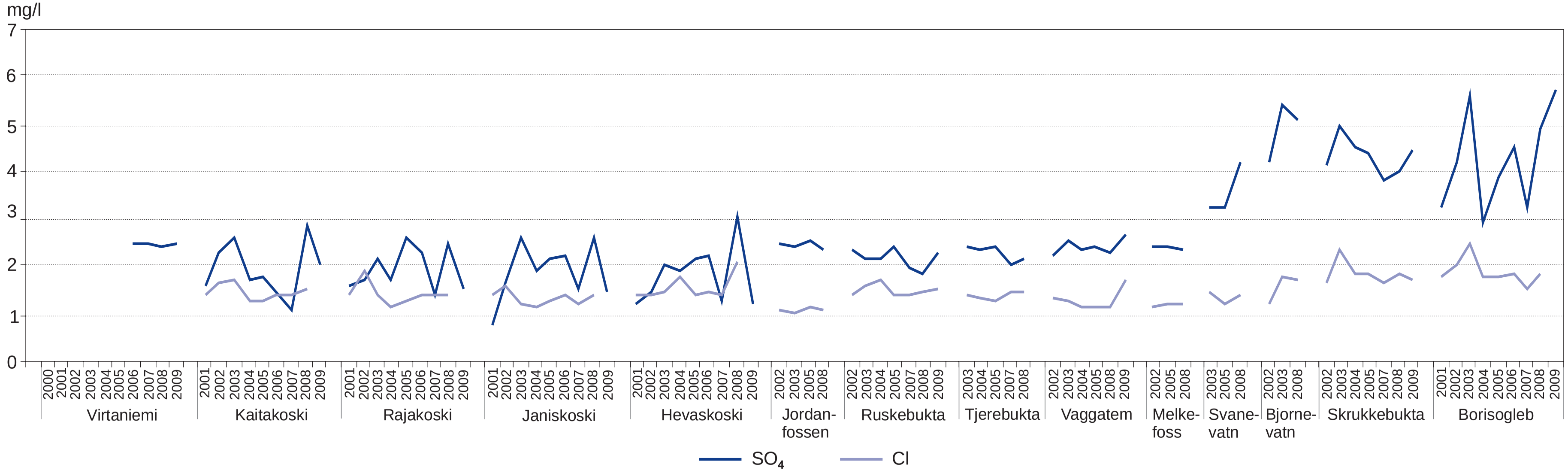


Figure 11. Distribution of sulphate- and chloride-ions.

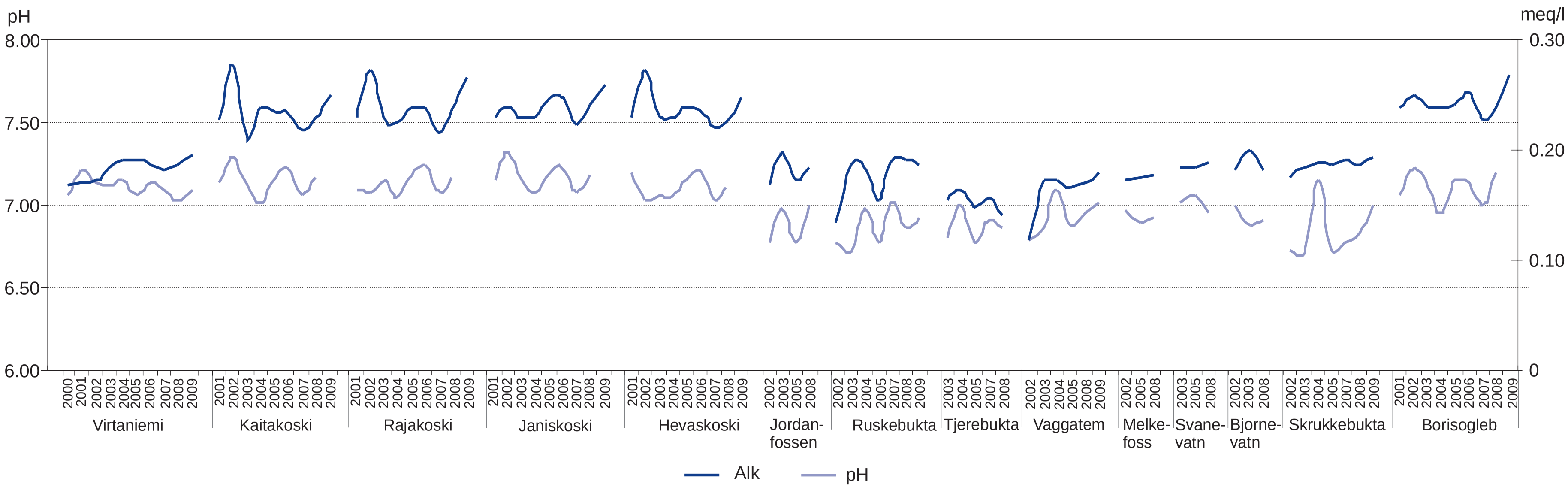


Figure 12. pH and alkalinity.

Copper and nickel

The smelter's impact can be seen in the distribution of copper (Cu) and especially nickel (Ni) concentrations in the Pasvik watercourse (Figure 13).

The concentration of nickel in the river upstream from the Kuetsjarvi Lake polluted by the smelter's sewage varies from the minimal detectable concentrations to 2 µgl^{-1}, which may be considered as background values for the river. Concentration considerably increases downstream from the lake inflow: up to 6–8 µgl^{-1} at the Bjornevatn, Skrukkebukta and Borisogleb stations with maximum concentrations exceeding 10 µgl^{-1} (Tjerebukta, Skrukke-bukt, Borisogleb) and even 20 µgl^{-1} (Bjornevatn). Similarly, the concentration of copper upstream in the sewage inflow is 1–3 µgl^{-1}, later increasing to 5–6 µgl^{-1}.

The concentrations of other metals remain within background levels. The input of these with the sewage is rather insignificant (Figure 14).

The dynamics of organic matter, nitrogen and phosphorus concentrations in the river are shown in Figure 15. The results confirm stable hydro-chemical regime in the river over the last 10 years. The average concentration of principal ions is also rather stable in respect to time. In respect of the monitoring stations, concentrations are higher in the lower course which is under the smelter's influence (Skrukkebukta INEP, Borisgleb MUGMS, Figure 16).

Concentrations of metals in the river are more variable in time as well as by stations, as these elements are more mobile and dependent on loading.

Metals, especially copper and nickel (Figure 17), together with sulphates serve as indicators of the smelter's negative impact and distribution of loading in the river basin. Loading coming from the Kolosjoki River polluted with the smelter's discharge eventually pollute the water of River Pasvik. Pollutant concentrations in the mouth cross-sections of the River Pasvik, although considerably lower than those in the polluted water sources, are still somewhat higher than those in the background cross-section of the Kolosjoki River and at the stations upstream in the Pasvik watercourse (Figure 18).

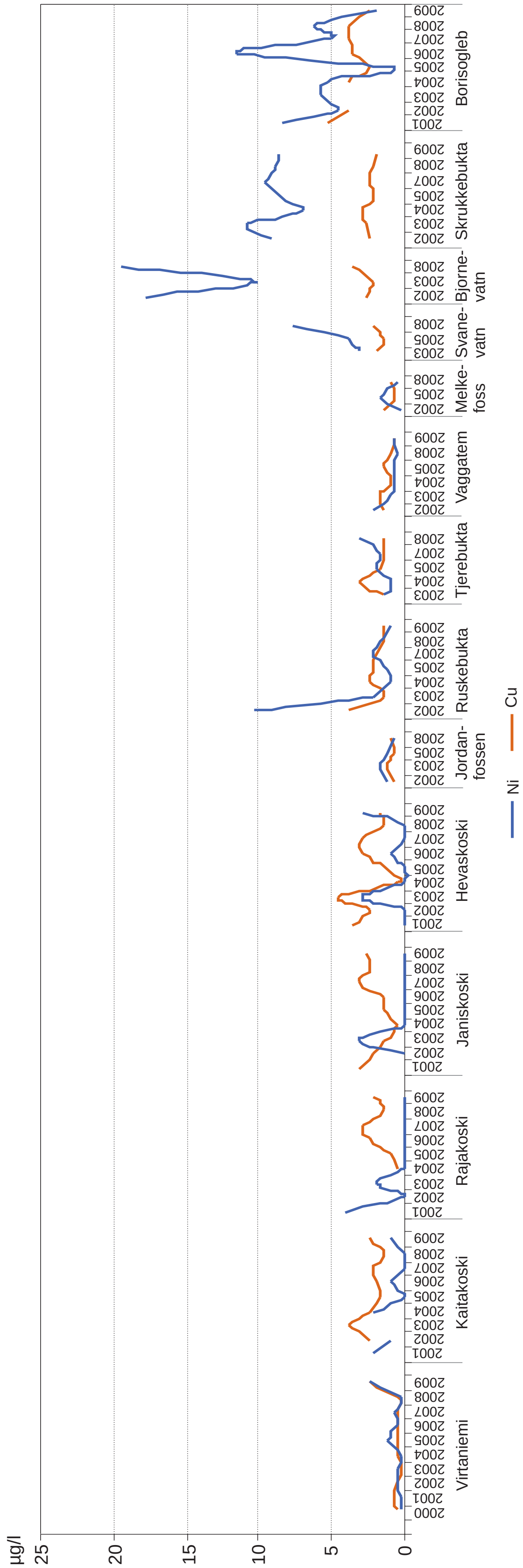


Figure 13. Distribution of copper and nickel.

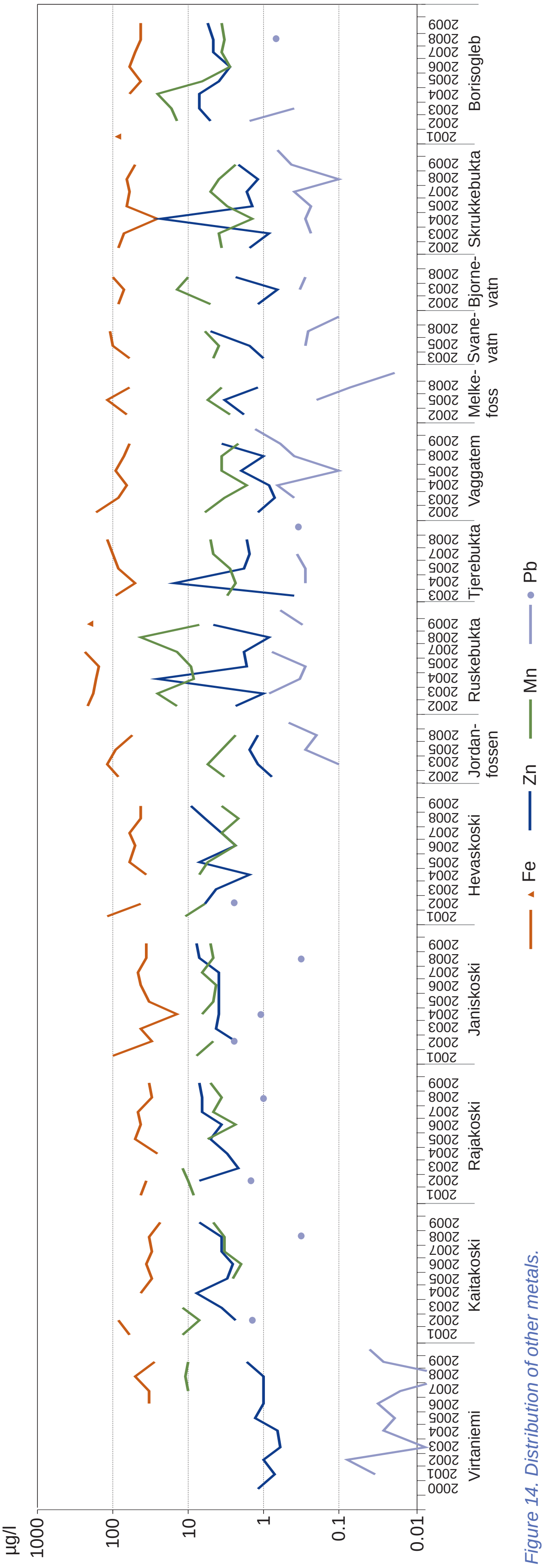


Figure 14. Distribution of other metals.

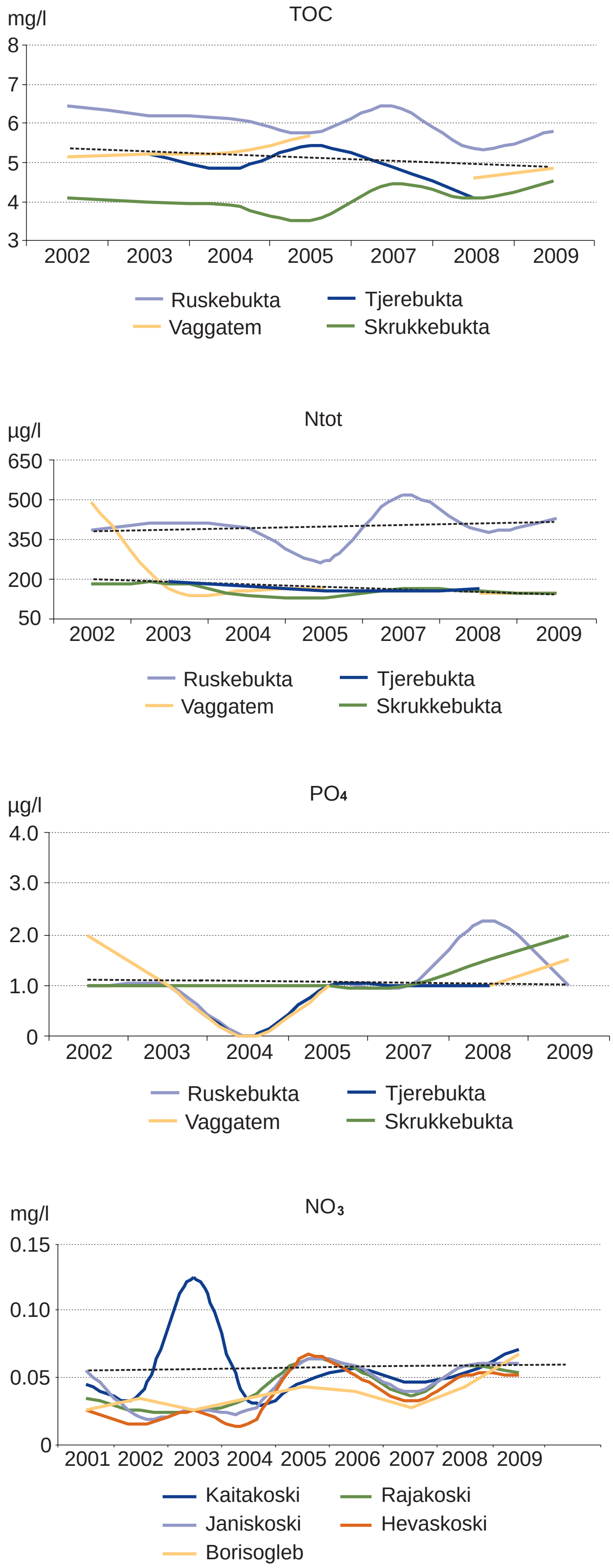
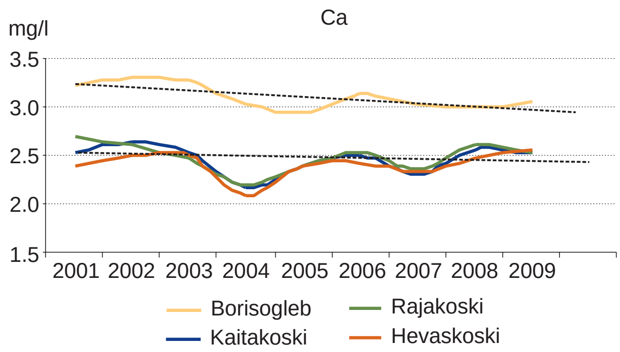
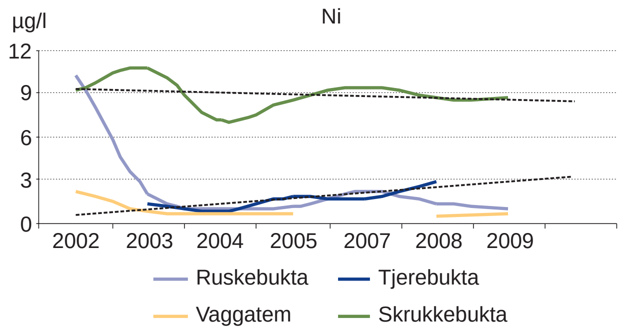
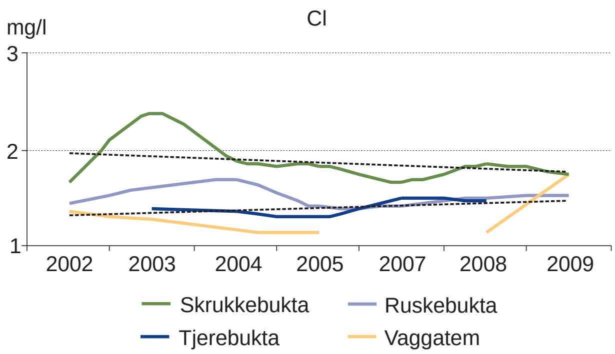


Figure 15. Dynamics of organic and biogenic matter.







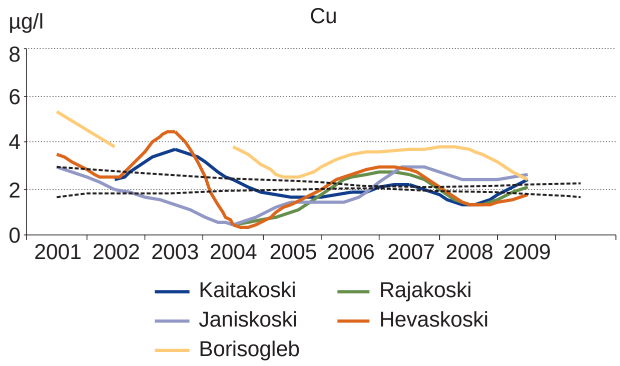
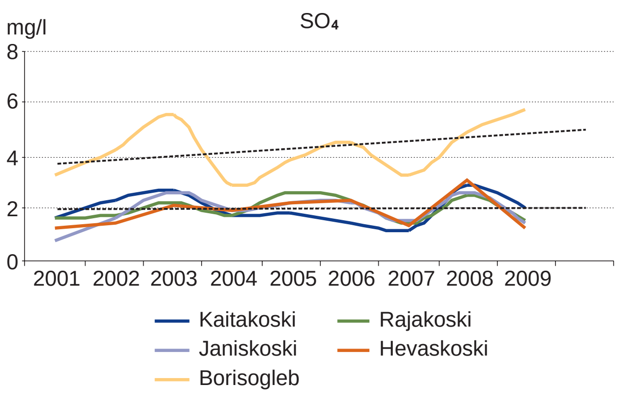


Figure 17. Dynamics of copper and nickel.



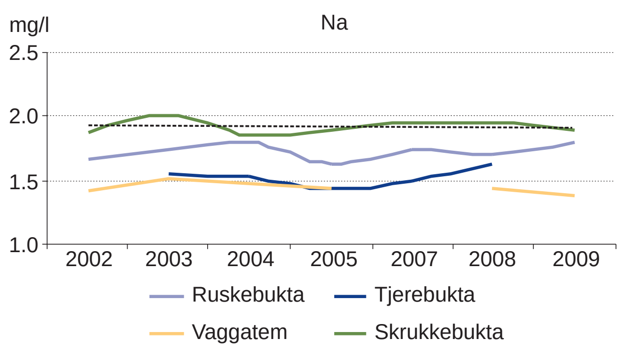


Figure 16. Dynamics of principal ions.

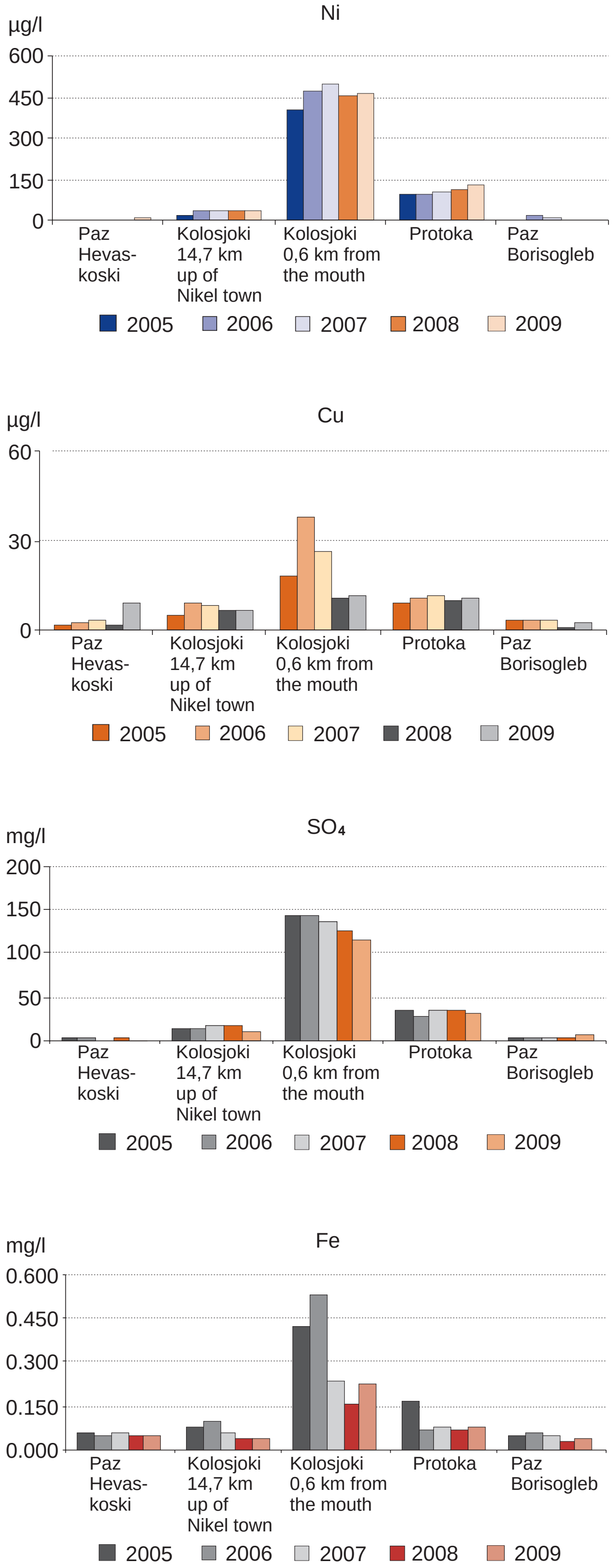


Figure 18. Impact from the sources on the Pasvik watercourse pollution.

Conclusions

The report is made based on the monitoring results of 2000–2009.

The study of the Pasvik watercourse status continues. Regular monitoring of the river's pollution indicators – organic and biogenic matter, ion composition and concentrations of metals and microelements – is carried out at 20 sampling stations by six organisation from three countries: MUGMS and INEP (Russia), FMFI, NCFS and Bioforsk Svanhovd (Norway) and LAP ELY, Finland). The samples were analyzed in the laboratories of MUGMS, INEP and LAP ELY.

Based on the water monitoring results obtained through this period, one can speak of the stabilization of the hydro-chemical regime of the river and basin including the level of pollutants concentrations.

The data obtained also confirms the ongoing pollution of the river and water system of the basin with pollutants originating from sewage as well as from Pechenganickel's emissions transferred by air.

Copper, nickel and sulphates are the main pollution components.

The most polluted water sources of the basin are the Kolosjoki River, as it directly receives the sewage discharge from the smelters and the stream connecting the Lakes Salmijarvi and Kuetsjarvi.

The concentrations of metals and sulphates in the Pasvik watercourse are higher downstream from the Lake Kuetsjarvi.

According to the Kola GMK, there is a decreasing trend in pollutant loading into the rivers of the basin.

Regular monitoring of the Pasvik River basin ecology needs to be continued; the summarized results of monitoring give impartial assessment of the status of the water systems and facilitate decision making in respect of improving the condition of water systems and rehabilitation of the natural environment in general.

Figure 19. Pasvik watercourse downstream from the Janiskoski power plant. Photograph: Sergei Kotov.

Water quality in the Lake Kuetsjarvi

- monitoring report for 2000–2009

Nikolay Kashulin and Sergey Sandimirov

Photograph: Sergey Sandimirov.

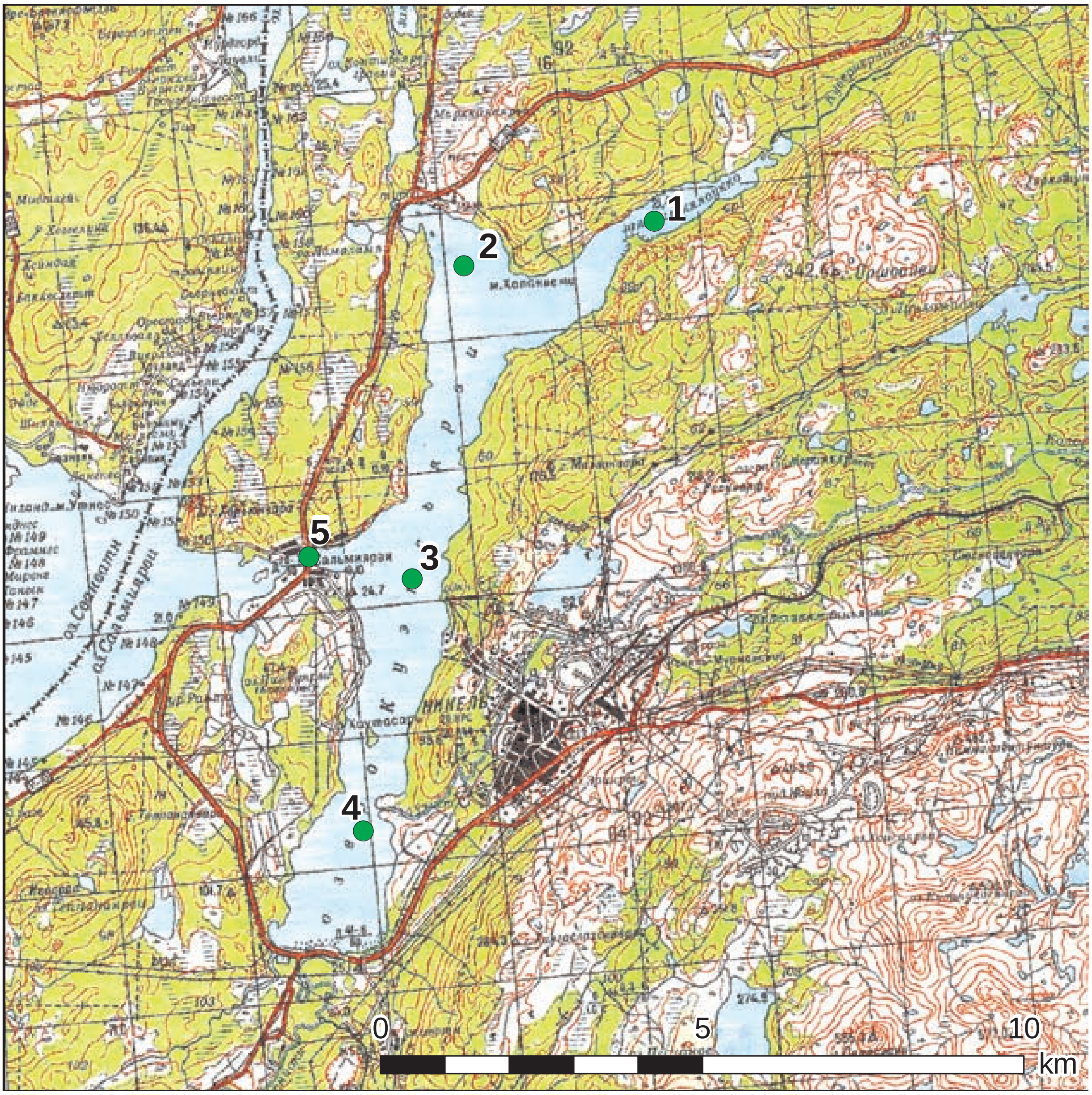


Figure 1. Map of the Lake Kuetsjarvi with monitoring stations:

1. White stone
2. Golfsream
3. Salmijarvi
4. Kolosjoki
5. Lake outlet

The Lake Kuetsjarvi is located in the vicinity of the Pechenganickel metallurgic enterprises. Airborne contamination and sewage of Pechenganikel enterprise as well as residential waste waters directed into the Lake Kuetsjarvi have strong impact on the lake. The Lake Kuetsjarvi linked via a stream with the Salmijarvi (Svanevatn) Lake wich is in the course of Pasvik River. Contamination affects also the Lake Salmijarvi (Svanvatn) and all water bodies downstream the Pasvik watercourse.

Water Quality in the Lake Kuetsjarvi

This report describes the Lake water quality concerning the concentrations of organic matter, nitrogen and phosphorus compounds, principal ions and metals, and shows the diagrams of the distribution of indicators in the lake and the dynamics of their changes. The results confirm the existence of a stable hydro-chemical regime in the lake for over 10 years (2000–2009).

Organic matter

A sufficiently permanent value of chemical oxygen demand, which varies little across the water area, is characteristic (3,2–7,1 mgl^{-1}) of the Lake Kuetsjarvi. The average content of organic carbon in the study period of 2000–2009 was 5,0 mgl^{-1} (Figure 2). No considerable seasonal changes have been found in the content of organic carbon. In the springtime, the content of organic carbon is 6,1 mgl^{-1}, while in the summer-autumn period the figure is 4,8 mgl^{-1}. The biggest differences are seen in the receiving area of Pechenganikel smelter waste water discharges (River Kolosjoki). During the study period, the content of organic carbon in various years alternately increased and decreased by 1–2 mgl^{-1}. At present, its content over the entire Lake Kuetsjarvi has increased to reach the 2005–2007 levels (Figure 2).

The colour of water has sufficiently low values (12–36° Pt), making on average 19°Pt. Higher values can be observed in the summertime near River Kolosjoki, Lake Salmijarvi and the lake outlet. Before the commencement of studies in 1990–2000, the colour of water near Lake Salmijarvi reached an average of 39°Pt.

Total phosphorus and phosphates

The analysis of data concerning the total phosphorus content in Kuetsjarvi Lake shows that at present, the content of this element corresponds to the natural content across the entire lake (Figure 3).

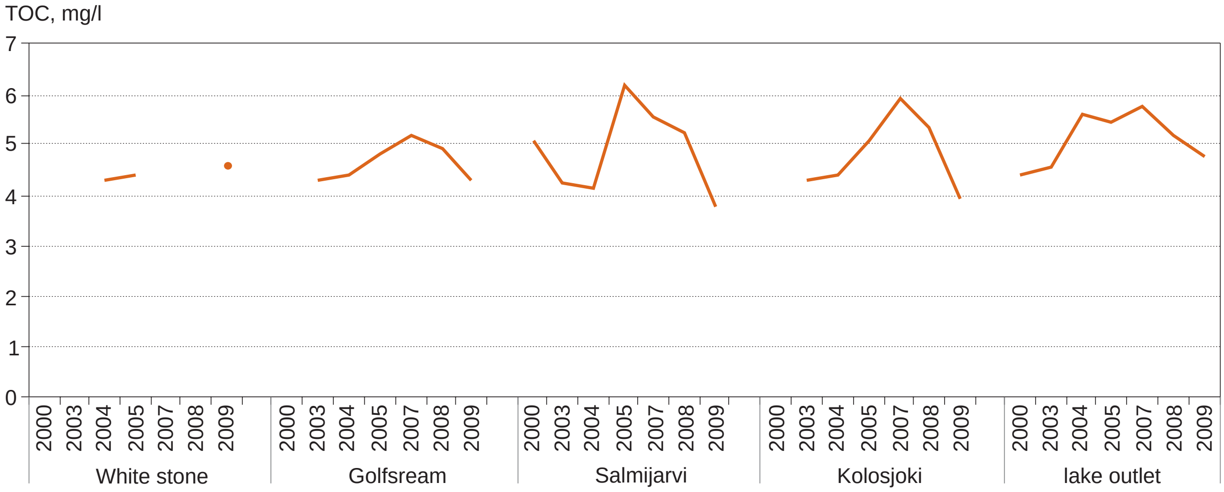


Figure 2. Distribution of organic carbon in the Lake Kuetsjarvi.

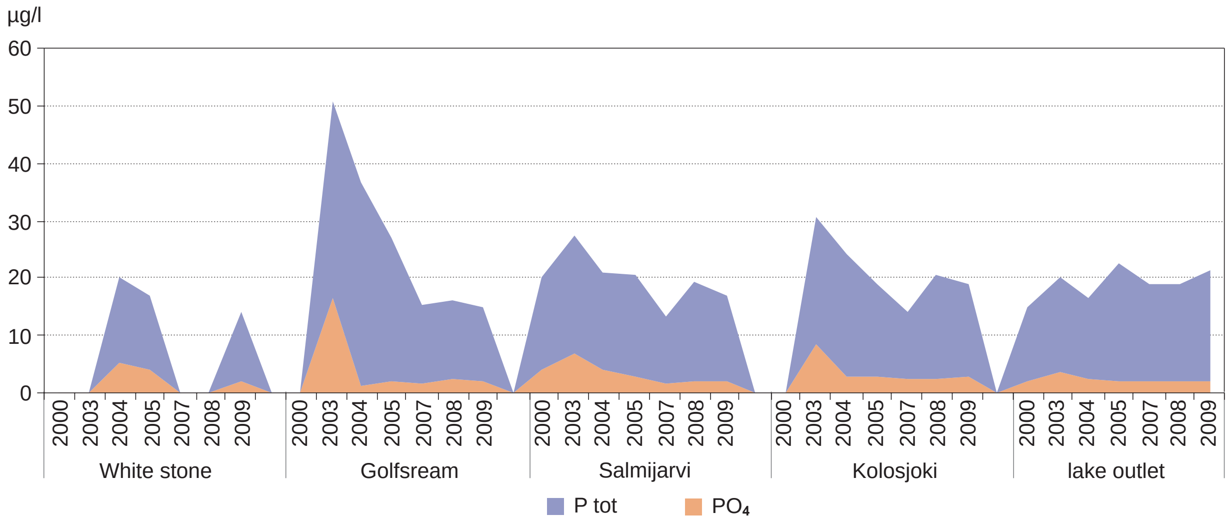


Figure 3. Distribution of total phosphorus and phosphates.

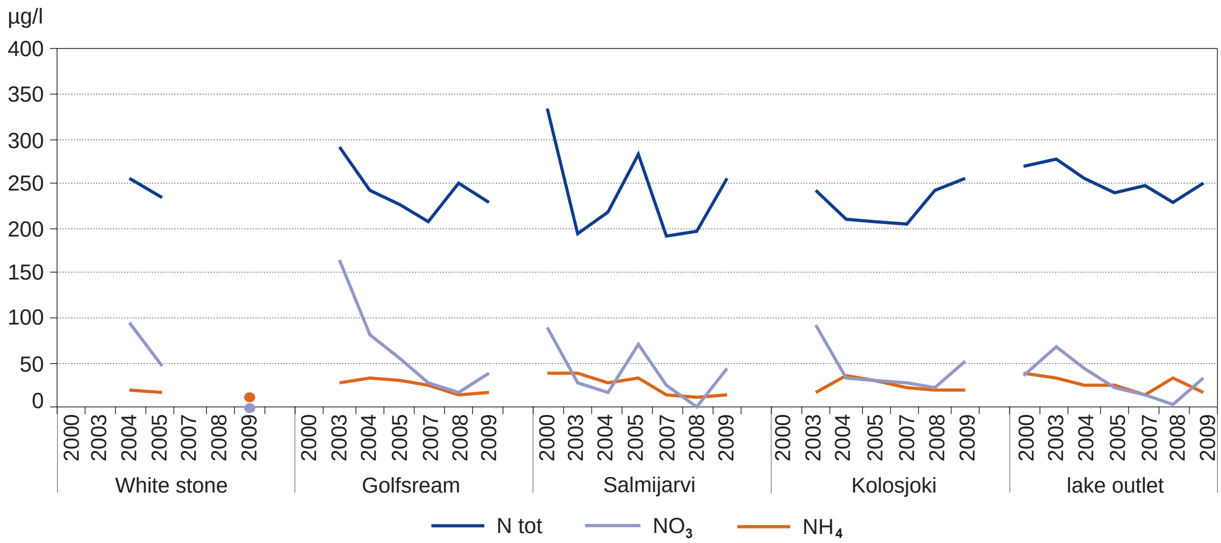


Figure 4. Distribution of nitrogen compounds.

The concentration of total phosphorus in the bottom and surface layers of the lake varies within the limits of 4–60 µgPl^{-1}, making an average of 16–17 µgPl^{-1} during last two decades (1990–2009). In 2003, the content of total phosphorus in the bottom layers of the Gulf Stream water area located in the northern part of the lake reached 55 µgPl^{-1}. At present concentrations of total phosphorus are practically equal and at a constant level over the entire Lake Kuetsjarvi.

The concentration of phosphates in the Kuetsjarvi Lake varies between 1–26 µgPl^{-1}, with the average being 3 µgPl^{-1}.

Nitrogen

For oligotrophic water bodies, the content of total nitrogen is usually within the limits of 300–700 µgNl^{-1}. Average concentrations of total nitrogen in the Lake Kuetsjarvi vary within the limits of 134–390 µgNl^{-1}, making on average 229 µgNl^{-1} (Figure 4). The highest concentrations of total nitrogen are seen in the bottom layers and are now uniformly distributed over the entire water area of the lake. During the last two years from 2008 to 2009, the average concentration of total nitrogen over the entire Lake Kuetsjarvi increased from 230 to 280 µgNl^{-1}.

The weighted average in depths and nitroge concentrations in various water areas of the lake amount to 26–95 µgNl^{-1}. In the southern parts of the lake (River Kolosjoki, Lake Salmijarvi, lake outlet) the average concentration of nitrates is 26–38 µgNl^{-1}. The highest concentrations were registered in the bottom layers of the northern part of the lake (sampling stations White stone, Gulf Stream) – 174 and 320 µgNl^{-1} respectively.

Concentrations of ammonium ions are lower, varying between 3–70 µgNl^{-1}, making an average of 23 µgNl^{-1}.

Salinity balance of water

The distribution of the principle ions over the entire water area of the Kuetsjarvi lake corresponds to the order: SO_4^{2-} > HCO_3^- > Cl^-; Ca^{2+} > Na^+ > Mg^{2+} > K^+ and belongs to the class of sulphates. The comparison of contents of cations shows that during all sampling occasions, calcium was the prevailing cation, making 52–57% in cation composition (Figure 5). The content of sulphates in water is directly associated with the operation of the Pechenganikel smelter. Sulphates are introduced to the lake with emissions and waste water from the smelter via the Kolosjoki River, therefore, the distribution of these over the water area is uniform. In anion composition, sulphates account for 52–61% (Figure 6). We should also note that during the period of research from 2003 to 2009, this ratio remained at the same level, changing only during some years by an average of 2–3%. During the last ten years, no significant changes in the content of basic ions have occurred. It was only in 2005 that a short-period decrease in sulphate concentrations took place, however the content of these in the water increased once more following this period. The total mineralization in the Kuetsjarvi Lake averages 69,2 mgl^{-1}, slightly varying throughout the water area of the lake from 43,8 to 90,5 mgl^{-1}.

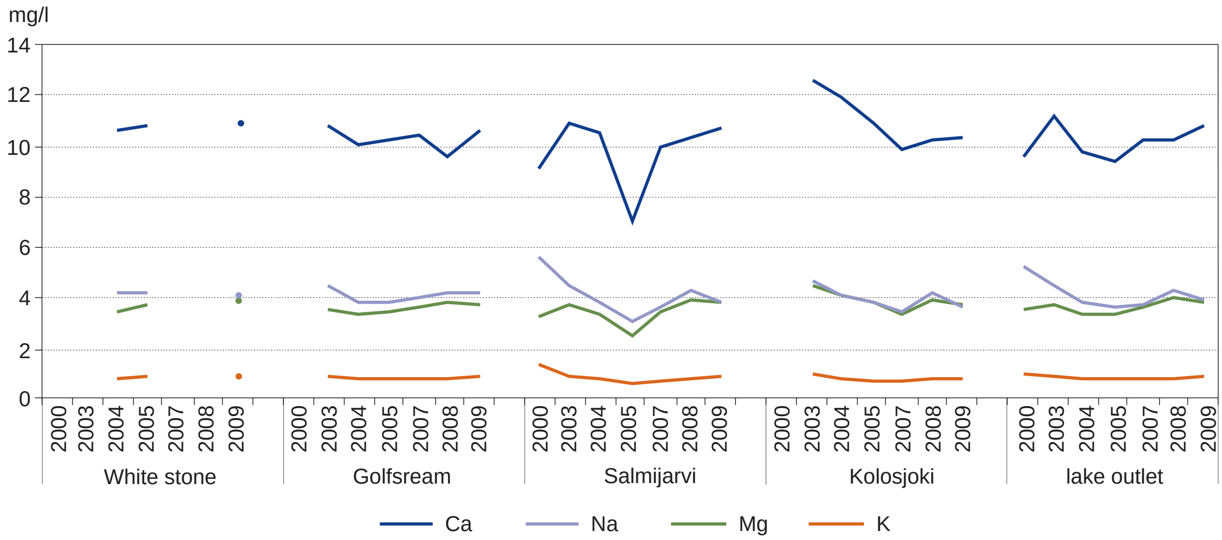


Figure 5. Distribution of cations.

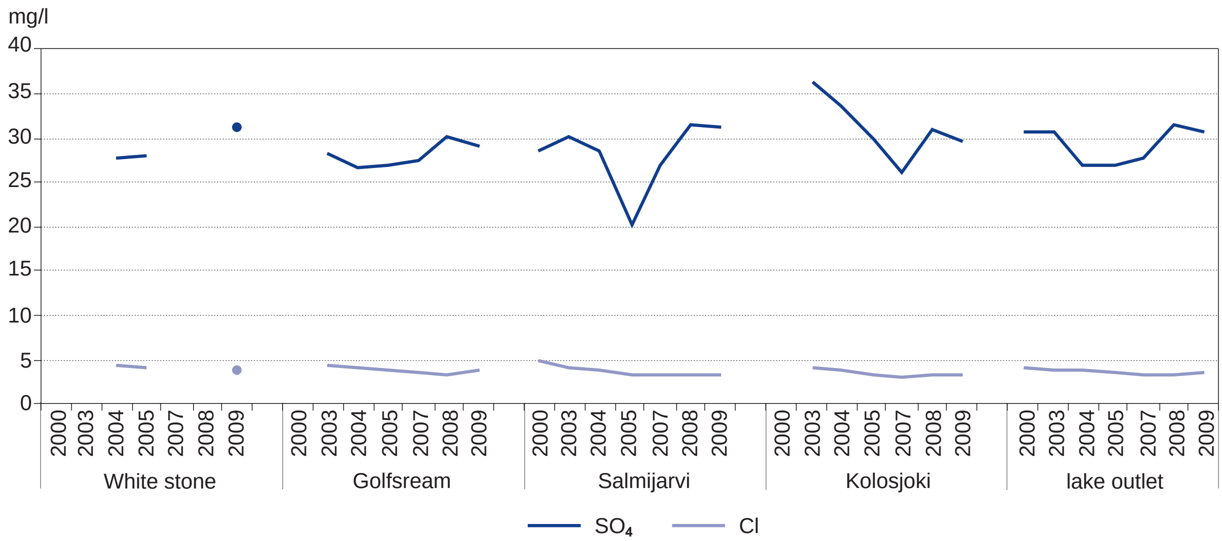


Figure 6. Distribution of anions.

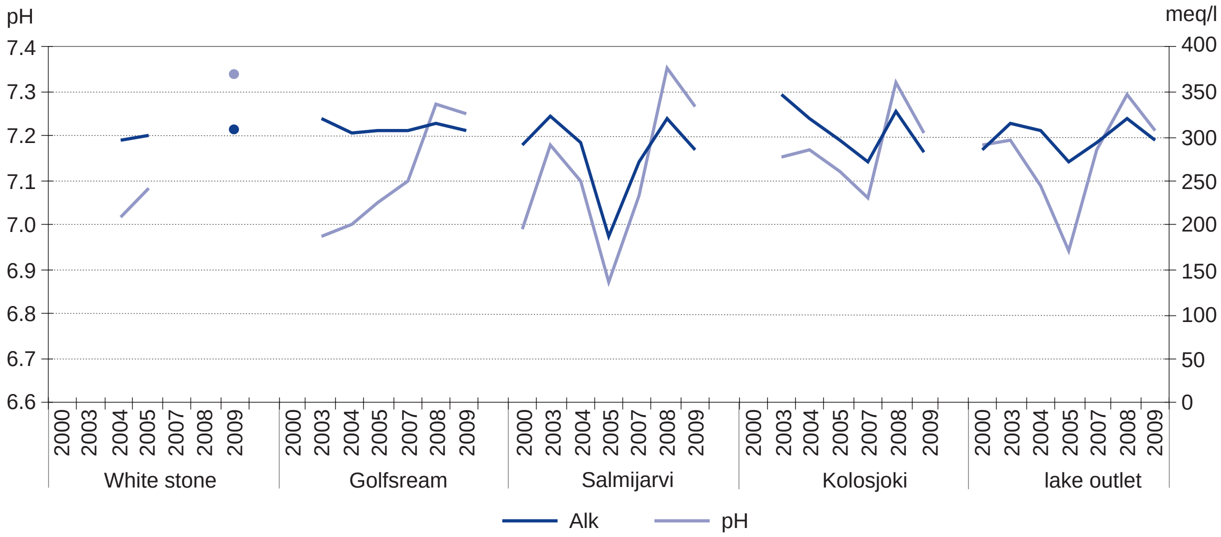


Figure 7. pH and alkalinity.

Alkalinity and pH-factor

The Kuetsjarvi Lake water belongs to a neutral water type, changing during the entire period of observations within the limits of 6,71–7,42, and averaging 7,13 units. No regularities of change in pH factor over the water area of the lake or by hydrological seasons have been observed (Figure 7). A decrease in average yearly values of pH in 2005 and in 2009 occurred due to water sampling during flooding, when pH values decrease on average to 6,71 units. During this period, acidified melt water accesses the lake from all over the catchment area. Alkalinity in the lake varies within the limits of 180–359 µeql^{-1} (Figure 7).

Copper and nickel

The discharge of the waste water of industrial companies, containing considerable amounts of pollutants, led to the fact that currently the content of these elements in the Kuetsjarvi Lake exceeds the accepted conventional background values.

Copper and nickel are the basic components of waste water of the copper-nickel smelter of Pechenganikel. The waste water from this company access the Lake Kuetsjarvi, which is located in the lower reaches of the Pasvik watercourse. From there, the polluting substances are taken further along the river water area by river currents.

The maximum concentrations of Cu acceptable in Russia for fishery waters is 1 µgl^{-1}. The average concentration of Cu in the Kuetsjarvi Lake exceeds this limit (MACfishery). During the study conducted in 2003–2009, the concentration of Cu in various parts of the lake varied from 6,3 to 18,1 µgl^{-1}, making an average of 10,0 µgl^{-1} (Figure 8). Concentrations of Cu throughout the lake do not differ significantly due to the atmospheric input.

The maximum concentration of Ni for fishery waters is 10 µgl^{-1}. The highest concentrations of this element in the Lake Kuetsjarvi are observed in the bottom layers – up to 182 µgl^{-1}. Higher values in the spring-time are stipulated by the increase of pollutants with melt water during the flooding period. As a whole for the entire lake, the content of Ni currently varies within the limits of 74–182 µgl^{-1} (Figure 8), making on average 120 µgl^{-1}, which significantly exceeds the MACfishery. The content of Ni in the discharge from the Lake Kuetsjarvi varies within the limits of 77–180 µgl^{-1}, averaging 115 µg/l. Compared to the 1990s, the current (2009) average yearly concentrations of Ni in Lake Kuetsjarvi have increased from 70 to 132 µgl^{-1}, i.e. almost doubling.

The content of Fe in the spring period exceeds the MACfishery valid in Russia (100 µgl^{-1}) due to significant increase of Fe from the catchment area, up to 520 µgl^{-1}. In the summer-autumn period the distribution of Fe over the lake averages 82 µgl^{-1}. The concentrations of other metals remain within back-ground levels. The input of these in the waste water discharge is rather insignificant (Figure 9).

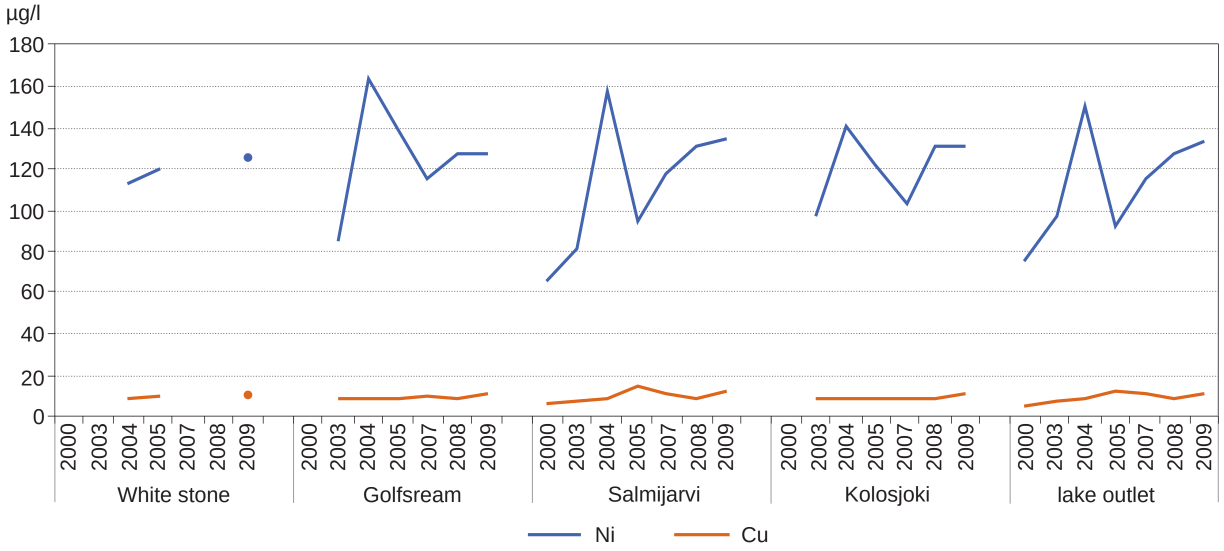


Figure 8. Distribution trends of copper and nickel.

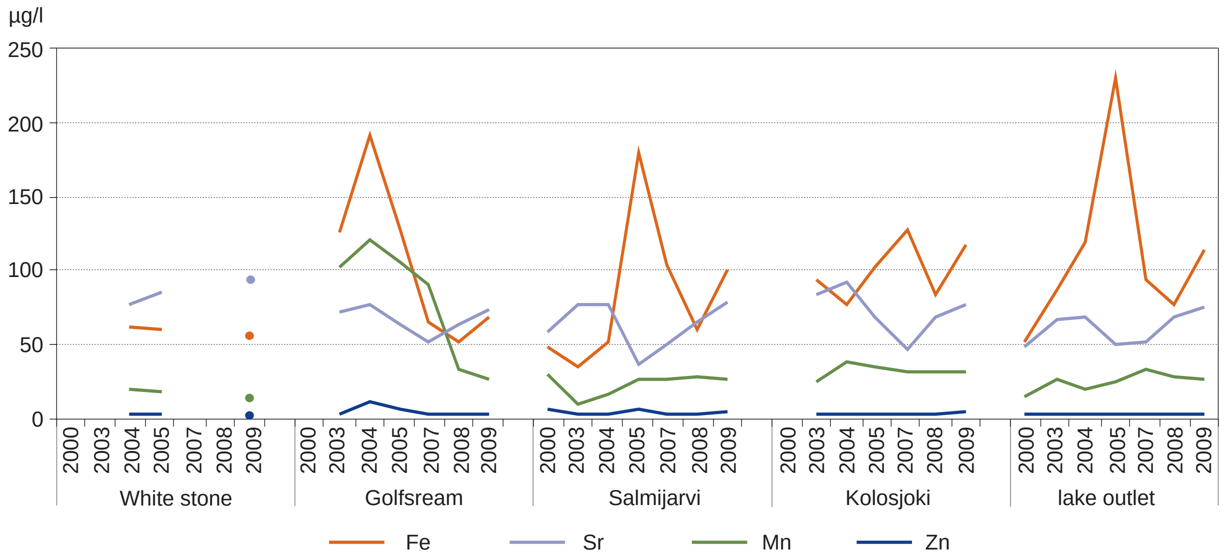


Figure 9. Distribution of other metals.

Conclusions

The presentation is the continuation of work started in 1990 and is based on the monitoring results of 2000–2009. Regular monitoring of the lake's pollution indicators – organic and biogenic matter, ion composition and concentrations of metals and microelements – is carried out at the lake stations by the laboratories of INEP and MUGMS.

Based on the water monitoring results obtained through this period, one can speak of stabilization of the lake and hydro-chemical regime of the basin including the level of pollutant concentrations. The data obtained also confirms the ongoing pollution of the lake and water system of the basin with pollutants originating from waste water discharge as well as from Pechenganickel's airborne emissions. Copper, nickel and sulphates are the main pollution components. The most polluted water source of the basin is the Kolosjoki River, as it directly receives smelter waste water discharge and the stream connecting to the Lake Kuetsjarvi.

Water quality of small lakes and streams in the Norwegian, Finnish and Russian border area

- monitoring report for 2000–2009

Annukka Puro-Tahvanainen

Photograph: Petri Liljaniemi

Introduction

Water quality of small lakes and streams in the Finnish, Norwegian and Russian border area was previously examined on the basis of the data collected during 2000–2005 (Puro-Tahvanainen & Luokkanen 2007). In that study data from altogether 103 small lakes and streams from three countries was compiled and examined the effects of airborne pollution from the Pechenganickel smelters on the water quality of small lakes and streams. On the basis of the results a joint monitoring programme on small lakes was established (Puro-Tahvanainen et al. 2008). In that report it was recommended that water quality of 5–10 small lakes should be monitored in each country in the areas of Pechenganickel, Jarfjord and Vätsäri. In this report temporal trends in water chemistry during 2000–2009 are examined on the basis of the data gathered from those three areas (Figure 3). Analysis is focused on the parameters which are connected to acidification and atmospheric deposition from Pechenganickel smelters.

Figure 1. Lake Joulujärvet in Vätsäri area. Photograph: Antti Lappalainen.

Figure 2. The Jarfjordmountain, the highest point along the road. Photograph: Paul E. Aspholm.

Materials and methods

In the monitoring programme of small lakes (Puro-Tahvanainen et al. 2008) it was recommended that monitoring should concentrate on lakes smaller that 1 km^2 which are not subjected to any direct human impact. It was also recommended that about 5 lakes per area should be monitored every year in order to get sufficient data for statistical analyses and the detection of trends. Samples should be taken during autumn overturn when the water is circulating. This helps to reduce the variance between years and between lakes, because sampling all the lakes during a period of several weeks allows the lakes to be sampled under similar conditions.

Data and analyses

Data for this study were obtained from NIVA in Norway, from the Centre for Economic Development, Transport and the Environment for Lapland (LAP ELY) in Finland and INEP in Russia. In analysis international or national standard methods has been used.

The monitoring has fulfilled best in Norway, where 10 small lakes in Jarfjord area include in national monitoring program (Figure 3) and they have been monitored every year with only few missing results. Total phosphorus has been analysed from 2004 onwards and metals have been analysed from 6 lakes. From Vätsäri area also 10 small lakes have been monitored in 2000–2009, but only two of them have been monitored every year and most of the lakes have been monitored in 5–7 years. So, the number of lakes monitored each year varies. From Pechenganickel area data was available from three small lakes and one large lake and two rivers from years 2003–2005 and 2007–2009 with some exceptions.

In this study temporal trends in water chemistry during 2000–2009 are examined. From some monitoring stations there were a couple of samples taken per year, and in such cases the yearly mean water quality was calculated on the basis of the late summer and autumn (July–October) values. Only surface (≤1 m) samples from lakes were included. The parameters used in this study are listed in Table 1. Yearly median values for every region was calculated to show the areal trends. Yearly median values could be calculated if there were results at least from two sites available. In the case that concentration was under the reliable detection limit, the value used in calculations is the reliable detection limit divided in two.

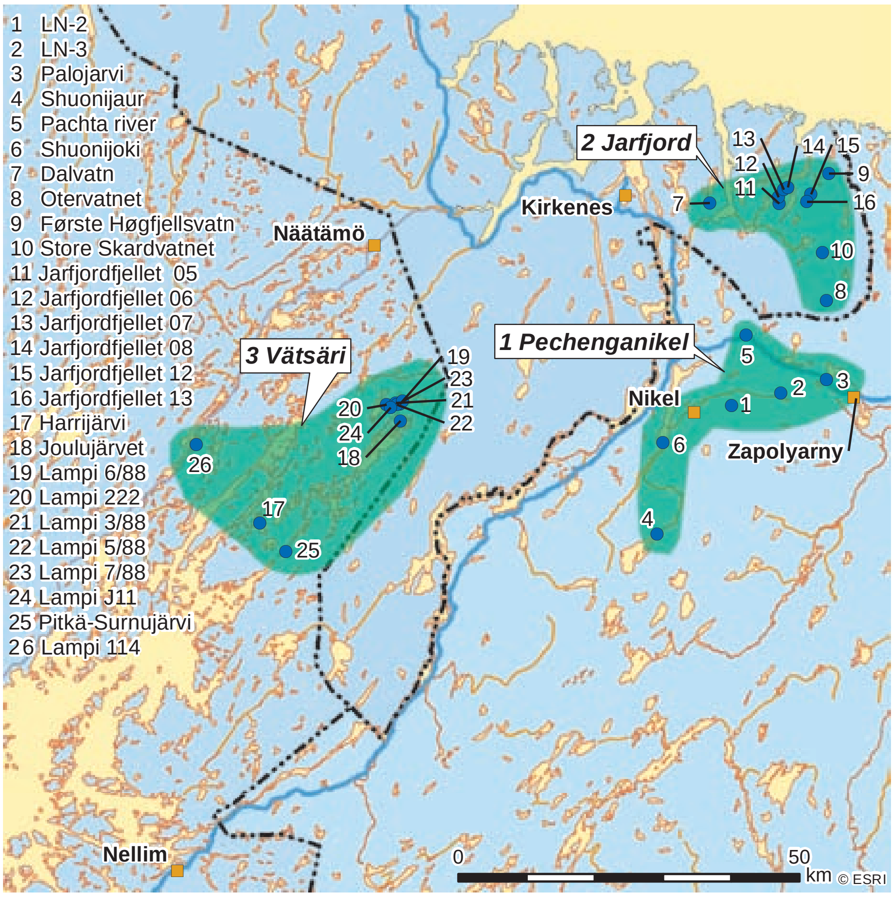


Figure 3 Location of the monitored lakes and rivers, and the three sub-areas.

Table 1. Variables used in the water quality study.

Variable	Abbreviation	Unit
Total organic carbon	TOC	mg l^{-1}
Total phosphorus	Ptot	µg l^{-1}
Total nitrogen	Ntot	µg l^{-1}
Alkalinity	Alk	µeq l^{-1}
Acid neutralizing capacity	ANC[1)]	µeq l^{-1}
pH		
Non-marine base cations	BC* = Ca*+Mg*+Na*+K*	µeq l^{-1}
Non-marine sulphate	SO_4*	µeq l^{-1}
Total aluminium	Al	µg l^{-1}
Labile Al	Lab Al	µg l^{-1}
Arsenic	As	µg l^{-1}
Cadmium	Cd	µg l^{-1}
Cobalt	CO	µg l^{-1}
Chromium	Cr	µg l^{-1}
Copper	Cu	µg l^{-1}
Nickel	Ni	µg l^{-1}
Lead	Pb	µg l^{-1}
Zinc	Zn	µg l^{-1}

1) ANC = $([Ca^{2+}] + [Mg^{2+}] + [Na^{+}] + [K^{+}] + [NH_4^{+}]) - ([Cl^{-}] + [SO_4^{2-}] + [NO_3^{-}])$

Trends for each lake and each variable were analysed using the non-parametric Mann-Kendall trend test and the Theil slope estimator. Trend slopes for each region were calculated using the same test, but in this case each lake was treated as a 'season' (Skjelkvåle et al. 2006). The results give the direction of the trend from the trend slope. The detected trends are monotonic, so they proceed in only one direction.

Results

Overall water quality

The overall water quality in years 2000–2009 is examined using the yearly areal median concentrations of total organic carbon, total phosphorus and total nitrogen and regional trend tests. Also, some diagrams with yearly mean values in each lake are shown as an example to point out the variance between lakes and continuity of the data.

Total organic carbon (TOC)

The TOC concentrations are, on the average, higher in Pechenganickel area than lakes in Jarfjord or Vätsäri (Figure 4), where median TOC concentrations are about 1 mgl^{-1} and 2–3 mgl^{-1} respectively. There are no trends detected in TOC concentrations in Jarfjord or Vätsäri area, but in Pechenganickel area there is a gentle increasing trend in TOC concentrations (Table 2). In Jarfjord area the small lakes situated up in the fell (Jarfjordfjellet) have very small amount of organic carbon, but a little bit larger lakes in the area have slightly higher concentrations of organic carbon (Figure 5).

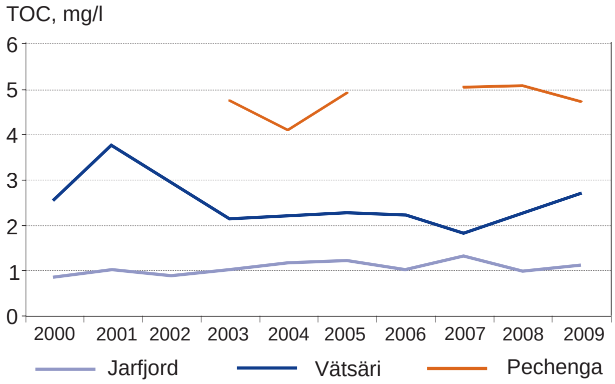


Figure 4. Median total organic carbon (TOC) in three monitoring areas in years 2000–2010.

Table 2. Areal trends for TOC, Ptot and Ntot in years 2000–2009. Values are median slopes with significant results (<0,05) in italic.

	n	TOC mg/l			Ptot µg/l			Ntot µg/l		
		p	Sign	Area Theilslope	p	Sign	Theilslope	p	Sign	Theilslope
Jarfjord	10	0,1	+	0,02	0,7	-	0	0,2	-	-0,53
Vätsäri	10	0,6	-	-0,01	0,3	-	0	0,9	-	0
Pechenga	6	*0,04*	+	*0,01*	0,1	-	-0,5	0,9	+	-0,5

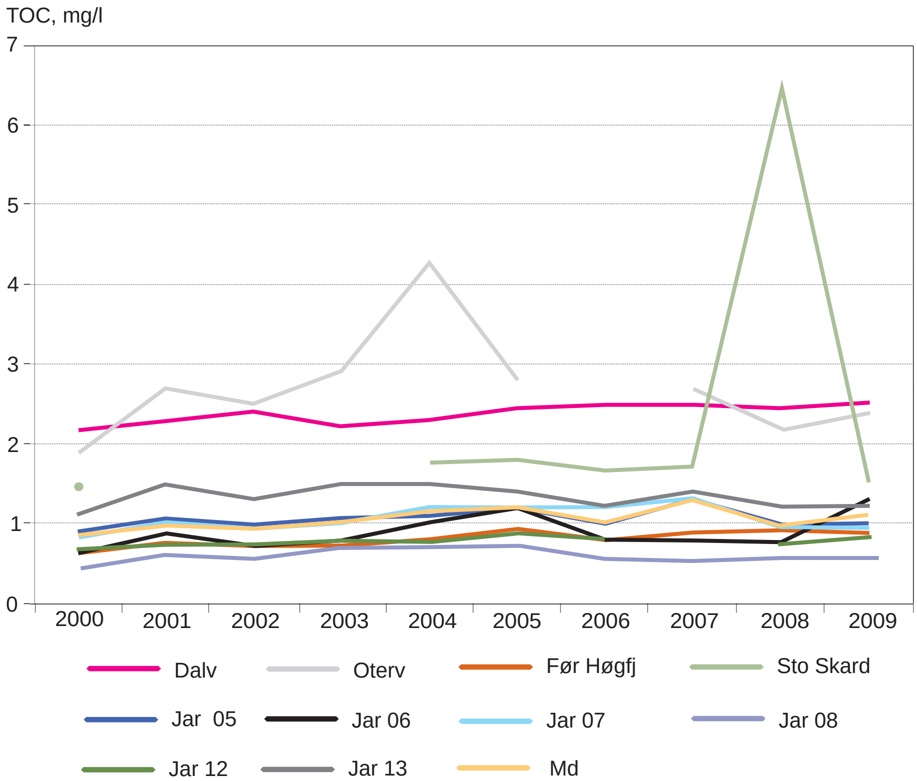


Figure 5. Yearly mean total organic carbon (TOC) concentrations in lakes monitored in Jarfjord area.

Total phosphorus (Ptot) and total nitrogen (Ntot)

Lakes and rivers in the three monitoring areas are in general oligotrophic, with median Ptot concentrations less than 10 µg l^{-1}, and median Ntot concentration less than 200 µg l^{-1} (Figures 6 and 7). The Ptot concentration is usually related to the TOC concentration, because the transport of phosphorus is associated with the dissolution of humus material in the catchment, especially in northern areas where fertilized agricultural soils are rare. A similar relationship is found in the lakes and rivers of this study (Figure 8), although Ptot concentrations are relatively low in most of the sites despite the somewhat elevated TOC concentrations.

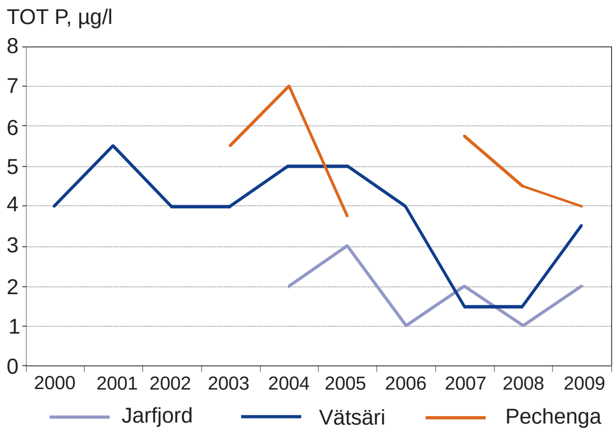


Figure 6. Median total phosphorus (Ptot) concentrations in three monitoring areas in years 2000–2010.

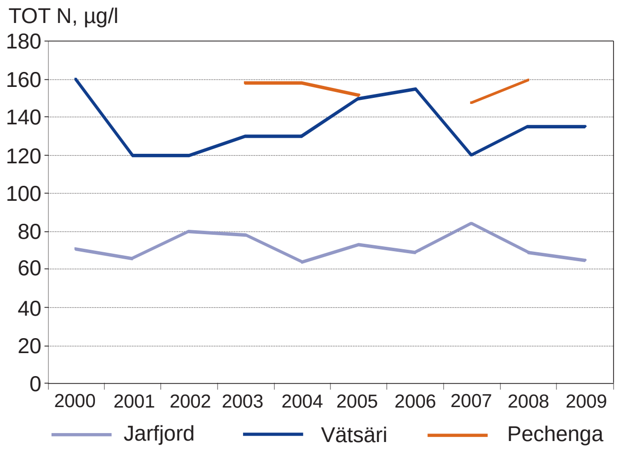


Figure 7. Median total nitrogen (Ntot) concentrations in three monitoring areas in years 2000–2010.

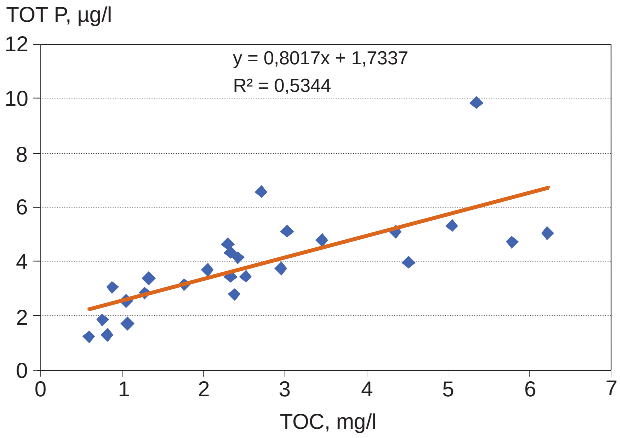


Figure 8. Correlation between total organic carbon (TOC) and total phosphorus (Ptot) concentrations.

Acidification

Alkalinity and pH

Alkalinity is a measure of buffering capacity of waters, or a measure of the water's ability to resist change in pH and to neutralize acid inputs (Skjelkvåle et. al. 2006). The buffering capacity of natural waters is usually determined as the bicarbonate ($HCO3^-$) concentration in waters. Alkalinity is closely related to the properties of the soil in catchments, in particular to the weathering and ion-exchange processes, in which base cations and bicarbonate are released. The alkalinity of surface waters is also influenced by acidic deposition and humic acids (anions of weak organic acids).

Waters with low alkalinity (<20 µeql^{-1}) are very susceptible to changes in pH. Most natural waters fall within the pH range of 6 to 8. pH 6 is a threshold value below which at least the most sensitive species or developmental phases are affected by acidification. Lakes in Jarfjord area are most acidic with mean pH values in single lakes ranging from 5,0 to 7,0 (Figure 9) and median pH for all lakes from 5,5 to 6,0 (Figure 10). Lakes in Jarfjord and Vätsäri areas have increasing trends in pH values with average trend slope of +0,03 in Jarfjord and +0,02 in Vätsäri (Table 3).

An extremely acid sensitive lake typically has an alkalinity of <20 µeql^{-1} and a less sensitive lake from 20 to 50 µeql^{-1} (Skjelkvåle et al. 2006). Lakes in Jarfjord and Vätsäri are in general quite sensitive to acidification with median alkalinity ranging from 20 to 50 µeql^{-1} (Figure 11). Monitored sites in Pechenga-nickel area have better buffering capacity against acidification. In Jarfjord and Vätsäri areas the buffering capacity of lakes has improved during 2000-decade with average trend slope of +1 µeql^{-1}yr-1 in Jarfjord and +1,1 µeql^{-1}yr-1 in Vätsäri.

Table 3 Areal trends for alkalinity, pH, ANC, $SO_4{}^*$ and BC in years 2000–2009. Values are median slopes with significant results (<0,05) in italic.*

	n	Alkalinity µeq/l			pH			ANC			$SO_4{}^*$			BC*		
		p	Sign	Theil-slope	p	Sign	Theil-slope	p	Sign	Theil-slope	p	Sign	Theil-slope	p	Sign	Theil-slope
Jarfjord	10	*0,005*	+	*1*	*0,005*	+	*0,03*	0,1	+	0,77	*0,01*	-	*-1,32*	0,5	-	-0,38
Vätsäri	10	*0,01*	+	*1,09*	*0,02*	+	*0,02*	0,3	-	-0,76	*0,04*	-	*-0,44*	0,2	-	-0,37
Pechenga	6	0,9	+	0	0,9	-	-0,005	0,6	+	1,23	0,7	+	0,71	0,2	+	1,79

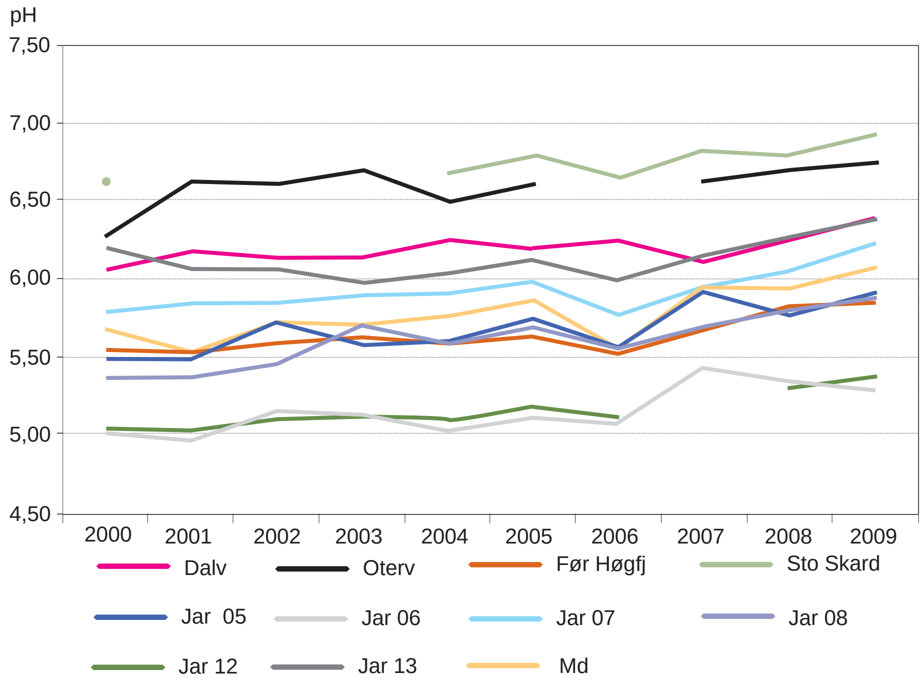


Figure 9. Yearly mean pH in lakes monitored in Jarfjord area.

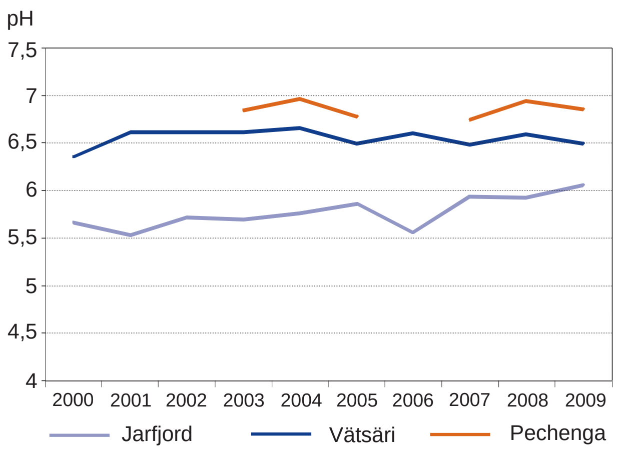


Figure 10. Median pH in three monitoring areas in years 2000–2010.

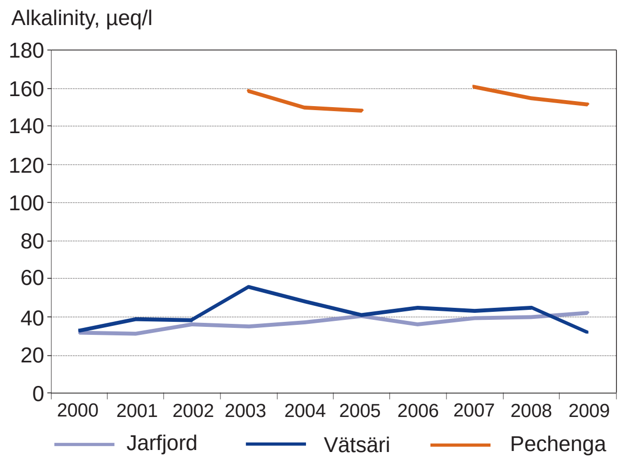


Figure 11 Median alkalinity in three monitoring areas in years 2000–2010.

Acid neutralizing capacity (ANC)

Calculated acid neutralizing capacity (ANC) is an equivalent to measured alkalinity. ANC in even more integrative and robust parameter than alkalinity in establishing good dose/response relationship between water chemistry and damage to the biological community (Skjelkvåle et al. 2006). On the basis of the calculated ANC values there is even more pronounced difference between sensitivity to acidification: lakes in Jarfjord area are most sensitive (ANC <20 $\mu eq l^{-1}$) and monitoring sites in Pechenganickel less sensitive (Figure 12).

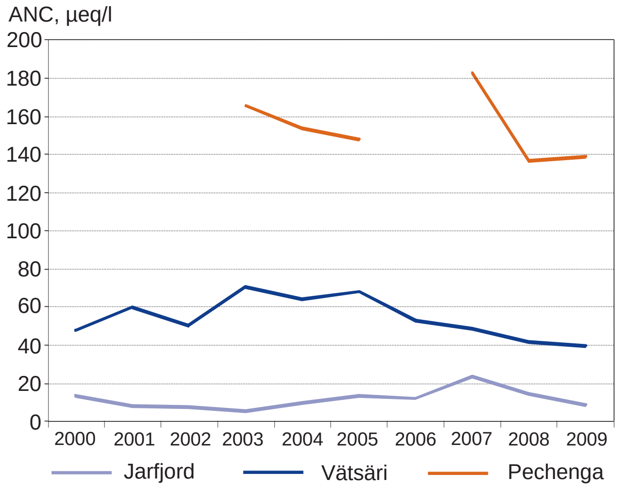


Figure 12. Median acid neutralizing capacity (ANC) in three monitoring areas in years 2000–2010.

Sulphate (SO_4*)

In Pechenganickel area one monitored lake, lake LN-2, has over ten times higher non-marine sulphate concentrations than other monitored sites. On the average, the highest sulphate concentrations are found in Pechenganickel area and the lowest alues on the Finnish side (Figure 13). Sulphate is, in general,

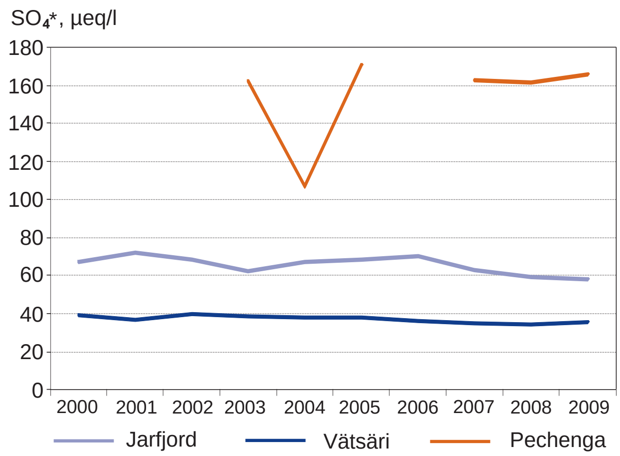


Figure 13. Median non-marine sulphate (SO_4) concentrations in three monitoring areas in years 2000–2010.*

a relatively mobile anion, which means that almost all of the sulphate in deposition is transported through catchments. Lakes in Jarfjord and Vätsäri areas have significant decreasing trend of SO4* with average trend slope of -1,3 $\mu eq l^{-1} yr^{-1}$ for Jarfjord and -0,4 $\mu eq l^{-1} yr^{-1}$ for Vätsäri.

Base cations (BC*)

Lake LN-2 has also approximately ten times higher non-marine base cations concentrations than other monitored sites. In general, monitoring sites in Pechenganickel area have moderate sensitivity to acidification while lakes in Jarfjord and Vätsäri areas are sensitive to acidic atmospheric inputs (Figure 14). There are no trends in BC* concentrations in any of three monitoring areas (table 3).

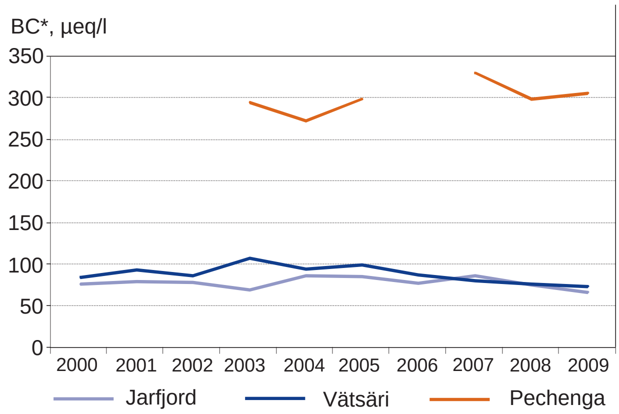


Figure 14. Median non-marine base cations (BC) concentrations in three monitoring areas in years 2000 –2010.*

Metals

In this study temporal trends of total aluminium (Al), labile aluminium (Lab Al), arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) was examined. Increasing trend for Ni was found for all three areas and increasing trend for Cu in Jarfjord and Pechenganickel. In addition to this some increasing or decreasing trends was found for labile Al, Cd and Pb (Table 4). Metals with detected trends are discussed in more detail below.

Table 4. Areal trends for metals in years 2000–2009. Values are median slopes with significant results (<0,05) in italic.

Area		Jarfjord	Vätsäri	Petchenga
n		6	10	6
Al	p Sign Theilslope		0,05 - -2,09	0,6 - -0,3
Lab Al	p Sign Theilslope	*0,02* - *-1,25*		
As	p Sign Theilslope	0,8 + 0	0,06 - -0,002	
Cd	p Sign Theilslope	*0,03* + *0,001*	*0,03* - *-0,001*	0,8 + 0
Co	p Sign Theilslope	0,5 + 0,002		0,4 + 0
Cr	p Sign Theilslope	0,05 + 0	0,1 - 0	0,8 - 0
Cu	p Sign Theilslope	*0,02* + *0,10*	0,2 + 0,02	*0,02* + *0,5*
Ni	p Sign Theilslope	*0,004* + *0,7*	*0,04* + *0,05*	*0,01* + *4,5*
Pb	p Sign Theilslope	*0,01* - *-0,01*	*0,02* - *-0,005*	0,7 + 0,045
Zn	p Sign Theilslope	0,3 - -0,04		0,9 + 0

Aluminium

The total Al concentration has been measured in lakes and rivers in Pechenganickel and Vätsäri areas, and in Jarfjord different forms of Al including labile Al has been analysed. The toxicity of Al is directly related to the pH value. This metal is soluble and biologically available in acidic (pH <5,5) soils and waters, but relatively non-toxic in circumneutral (pH 5,5–7,5) conditions. The biological activity and toxicity vary depending on the Al species formed (Sparling and Lowe 1996). According to field studies in Norway (Rosseland et al. 1990), the toxic level of labile Al has been defined as 25–75 $\mu g l^{-1}$, depending on other environmental factors such as pH, and the specific organisms and their development state (Wilander 1999).

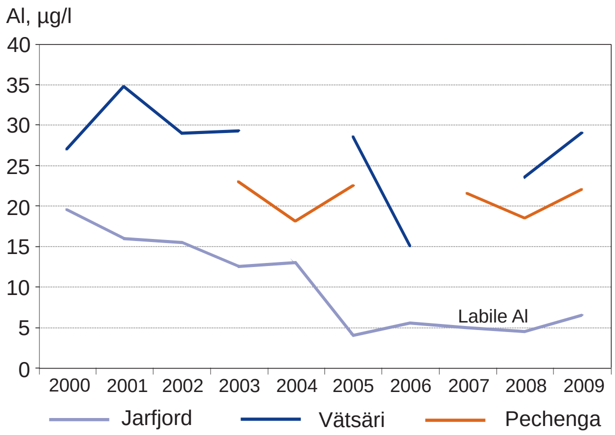


Figure 15. Median total aluminium (Al: Pechenganickel, Vätsäri) and labile aluminium (Labile Al: Jarfjord) concentrations in years 2000–2010.

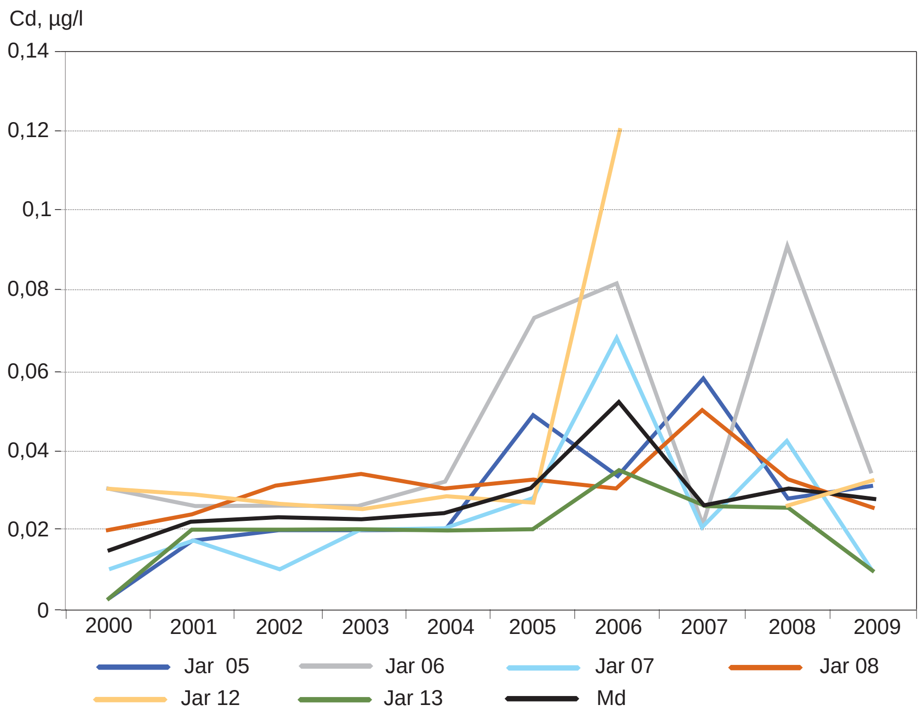


Figure 16. Yearly mean Cd concentrations in lakes monitored in Jarfjord area.

Total Al concentrations in Pechanganickel and Vätsäri areas are relatively low: median values fluctuate between 15–35 µgl^{-1} (Figure 15). Labile Al concentrations in Jarfjord lakes have been decreased from around 20 µgl^{-1} in year 2000 to about 5 µgl^{-1} in 2009.

Cadmium

There is a gentle increasing trend in Cd concentration in Jarfjord area (Figure 16) and a gentle decreasing trend in Vätsäri area (Tabel 4). In Vätsäri area the Cd concentrations have usually been near or under the reliable detection limit. Up to year 2003 the reliable detection limit has been 0,030 µgl^{-1} and after that 0,010 µgl^{-1}. So, the change in reliable detection limit has affected in appearing the ”trend”.

Copper

The impact of the Pechenganickel smelters is clearly evident in the Cu concentrations (Figure 17) the highest concentrations being in Pechenganickel area and the lowest values in Vätsäri. There is an increasing trend of Cu concentrations in lakes and rivers of Pechenganickel area and lakes in Jarfjord (table 4).

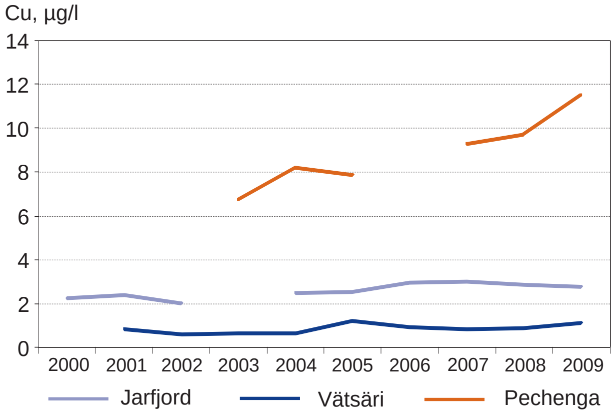


Figure 17. Median Cu concentrations in three monitoring areas in years 2000–2010.

Nickel

Also the Ni concentrations are significantly higher in the Pechenganickel area compared to Jarfjord or Vätsäri areas (Figure 18). Concentrations in Jarfjord lakes are clearly higher than natural background levels and even in Vätsäri lakes concentrations are a bit elevated. In all three areas there is an increasing trend for Ni between years 2000–2009 (table 4). Cu and Ni concentrations are also dependent on the chemical composition of the bedrock, which is the major regulating factor in areas that are not influenced by the direct atmospheric deposition of heavy metals (Skjekvåle et al. 1999).

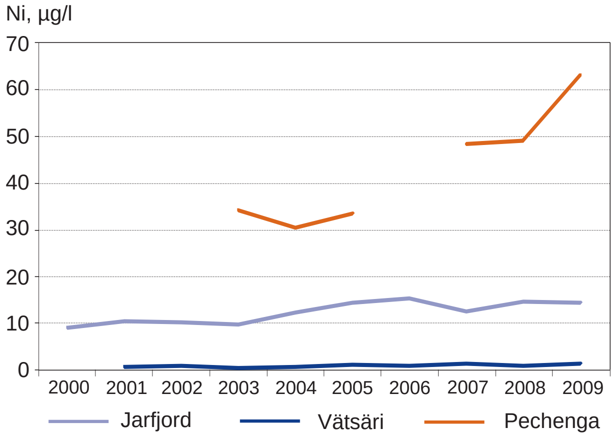


Figure 18. Median Ni concentrations in three monitoring areas in years 2000–2010.

Lead

There is a decreasing trend of Pb both in Jarfjord and Vätsäri areas (Table 4). Probably the regulation or banning of Pb containing products (e.g. gasoline additives, paint) has reduced emissions to the environment and hence the anthropogenic deposition.

Discussion and conclusions

There is still seen ongoing recovery from acidification in small lakes of Jarfjord and Vätsäri areas during 2000-decade. Buffering capacity of these lakes has become better and pH has increased. The reason for this recovery is that sulphate deposition has decreased, which is also seen in water quality. In Pechenganickel area monitored lakes and rivers are not sensitive to acidification although sulphate concentrations of these sites are higher than in other areas.

According to Pietilä et al. (2006), the bedrock in the Pechenganickel area is basic and contains relatively high amounts of base cations. Thus, despite the high sulphur deposition, there have been enough base cations in the catchment to prevent acidification. This can be seen in the water quality: lakes with high sulphate concentrations also have high concentrations of base cations and alkalinity. Another explanation for the high base cation concentrations and buffering capacity near the smelters is that the smelters have ineffective control of particle emissions, which has led to the deposition of alkaline ash (Moiseenko 1995, Reinman et al 1999). Dust from the local mining activities may also be a source of base cations (Kashulina et al 2003).

However, concentrations of some metals, especially Ni and Cu has increased during 2000-decade. Ni concentrations have increased in all three areas and Cu concentrations in Pechenganickel and Jarfjord areas, which are located closer to the smelters. In earlier, more extensive report (Puro-Tahvanainen & Luokkanen 2007) it was noticed that the areas with high Cu and Ni concentrations were located within a distance of less than 30 km around the smelters.

According to the Swedish water quality criteria, harmful biological effects may occur in sensitive waters if the Cu concentration exceeds 3 $\mu g l^{-1}$ or the Ni concentration exceeds 15 $\mu g l^{-1}$ (Alm et al 1999). In Jarfjord lakes the median values are close to these critical limits. Accumulation of metals in the organs and tissues of fish and abnormal fish pathologies have been reported close to the smelters, and this has been attributed to high metal emissions, especially Cu and Ni (Moiseenko et. al. 1995, Moiseenko and Kudryatseva 2001 and Lukin et al 2003). Moiseenko et. al. (1995) presented critical levels for Ni and Cu concentrations in lake waters based on the occurrence of fish diseases. The critical levels in well-buffered waters (ANC>200 $\mu eq l^{-1}$) were 8 $\mu g l^{-1}$ for Cu and 20 $\mu g l^{-1}$ for Ni. In this study the median concentrations of 3 monitored sites out of 6 in Pechenganickel area exceeded the critical levels for Cu, and all but one for Ni.

Figure 19. Vätsäri area. Photograph Petri Liljaniemi.

Recommendations

In joint monitoring programme (Puro-Tahvanainen et al. 2008) it was recommended that the monitoring of small lakes should concentrate on headwater or closed lakes smaller than 0,5 or 1 km^2 which are not directly influenced by human impacts. Water quality of a few (about 5 per area) representative lakes should be monitored every year in order to obtain sufficient data for statistical analyses and detection of trends. Additional lakes could be monitored every third year. It was also recommended that samples should be taken during autumn overturn when the water is circulating. This reduces the variance within the lake (circulation period), both year-to-year and lake-to-lake, because sampling over a period of several weeks enables the lakes to be sampled in similar conditions (Mannio 2001).

The monitoring programme has fulfilled best in Norway, where 10 small lakes in Jarfjord area include in national monitoring program and they have been monitored every year with only few missing results. In Vätsäri area also 10 small lakes have been monitored in 2000–2009, but only two of them have been monitored every year and most of the lakes have been monitored in 5–7 years. Because the number of lakes monitored each year varies and there is discontinuity in data, it makes the detection of trends more difficult. From Pechenganickel area data was available from three small lakes and one large lake and two rivers from years 2003–2005 and 2007–2009 with some exceptions. Only three small lakes were the same that was suggested in monitoring program and one of them, LN-2, had extremely high values of SO4* and BC*. That also makes comparisons and detection of trends more difficult.

It is still recommended that monitoring should concentrate on small, preferably headwater or closed lakes which are not directly influenced by human impacts. There should be at least 5 representative lakes in every area that are monitored every autumn in order to obtain sufficient data for statistical analyses and detection of trends. Representativeness means also that there should not be too much heterogeneity between monitored lakes.

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Abstract
The Pasvik monitoring programme was created in 2006 as a result of the trilateral cooperation, and with the intention of following changes in the environment under variable pollution levels. Water quality is one of the basic elements of the Programme when assessing the effects of the emissions from the Pechenganikel mining and metallurgical industry (Kola GMK).

The Metallurgic Production Renovation Programme was implemented by OJSC Kola GMK to reduce emissions of sulphur and heavy metal concentrated dust. However, the expectations for the reduction in emissions from the smelter in the settlement Nikel were not realized. Nevertheless, Kola GMK has found that the modernization programme's measures do not provide the planned reductions of sulfur dioxide emissions.

In this report, temporal trends in water chemistry during 2000–2009 are examined on the basis of the data gathered from Lake Inari, River Pasvik and directly connected lakes, as well as from 26 small lakes in three areas: Pechenganikel (Russia), Jarfjord (Norway) and Vätsäri (Finland). The lower parts of the Pasvik watercourse are impacted by both atmospheric pollution and direct wastewater discharge from the Pechenganikel smelter and the settlement of Nikel. The upper section of the watercourse, and the small lakes and streams which are not directly linked to the Pasvik watercourse, only receive atmospheric pollution.

The data obtained confirms the ongoing pollution of the river and water system. Copper (Cu), nickel (Ni) and sulphates are the main pollution components. The highest levels were observed close to the smelters. The most polluted water source of the basin is the River Kolosjoki, as it directly receives the sewage discharge from the smelters and the stream connecting the Lakes Salmijarvi and Kuetsjarvi. The concentrations of metals and sulphates in the River Pasvik are higher downstream from the Kuetsjarvi Lake. There has been no fall in the concentrations of pollutants in Pasvik watercourse over the last 10 years.

Ongoing recovery from acidification has been evident in the small lakes of the Jarfjord and Vätsäri areas during the 2000s. The buffering capacity of these lakes has improved and the pH has increased. The reason for this recovery is that sulphate deposition has decreased, which is also evident in the water quality. However, concentrations of some metals, especially Ni and Cu, have risen during the 2000s. Ni concentrations have increased in all three areas, and Cu concentrations in the Pechenganickel and Jarfjord areas, which are located closer to the smelters. Emission levels of Ni and Cu did not fall during 2000s. In fact, the emission levels of Ni compounds even increased compared to the 1990s.

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Pasvik Water Quality Report

Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area

(Ympäristönseurantaohjelma Norjan, Suomen ja Venäjän raja-alueella)

Tiivistelmä

Paatsjoen seuranta-ohjelma perustettiin vuonna 2006 kolmenvälisestä yhteistyöstä, jotta voidaan seurata ympäristön muutoksia päästötasojen vaihdellessa. Vedenlaatu on yksi ohjelman peruselementtejä arvioitaessa Petšenganikelin kaivos- ja metalliteollisuuden päästöjen vaikutusta ympäristöön.

OJSC Kola GMK toteuttaa Petšenganikelin uudistamisohjelmaa vähentääkseen rikki- ja raskasmetallipäästöjä. Odotukset Nikelin sulaton päästöjen vähentämisestä eivät kuitenkaan toteudu. Kola GMK:n tekemissä tutkimuksissa ilmeni, että Nikelin sulaton uudistaminen maksaa paljon arvioitua enemmän, ja suunniteltua rikkidioksidin päästötasoa ei silti pystytä saavuttamaan.

Tässä raportissa tarkastellaan Inarinjärven, Paatsjoen ja siihen liittyvien järvien sekä myös Petšenganikelin, Jarfjordin ja Vätsärin alueella sijaitsevien 26 pienen järven vedenlaadun kehitystä vuosina 2000–2009. Paatsjoen alajuoksun tilaan vaikuttavat sekä ilmansaasteet että suorat jätevesipäästöt Petšenganikelin sulatosta sekä Nikel-taajamasta. Paatsjoen yläjuoksu sekä järvet ja purot, jotka eivät suoraan liity jokeen, kärsivät vain ilmansaasteista.

Saatujen tietojen perusteella päästöt kuormittavat vesistöjä edelleen. Kupari (Cu), nikkeli (Ni) ja sulfaatit ovat keskeisimmät haitta-aineet. Suurimmat pitoisuudet mitattiin sulaton läheltä. Alueen eniten kuormittuneet vesistöt ovat Kolosjoki, joka vastaanottaa sulaton jätevedet sekä salmi, joka yhdistää Salmijärven ja Kuetsjärven. Kupari-, nikkeli- ja sulfaattipitoisuudet Paatsjoessa ovat korkeimpia Kuetsjärven jälkeisessä alavirrassa. Haitta-ainepitoisuudet Paatsjoen vesistössä eivät ole laskeneet viimeiseen kymmeneen vuoteen.

Pienissä järvissä Jarfjordin ja Vätsärin alueilla on havaittu toipumista happamoitumisesta 2000-luvulla. Näiden järvien puskurikyky on parantunut ja pH on noussut. Syynä tähän elpymiseen on, että sulfaattilaskeuma on vähentynyt, mikä näkyy myös veden laadussa. Kuitenkin joidenkin metallien, erityisesti nikkelin ja kuparin pitoisuudet ovat kasvaneet 2000-luvulla. Ni-pitoisuudet ovat kasvaneet kaikilla kolmella alueilla and Cu-pitoisuudet Petšenganickelin ja Jarfjordin alueilla, jotka sijaitsevat lähempänä sulattoa. Nikkelin ja kuparin päästötasot eivät laskeneet 2000-luvulla. Oikeastaan nikkelipäästöt ovat jopa lisääntyneet 1990-luvulta.

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Название публикации

Pasvik Water Quality Report
Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area
(Отчёт по качеству воды Пасвик
Программа мониторинга окружающей среды в приграничном районе Норвегии, Финляндии и России)

Резюме

Программа мониторинга «Пасвик» разработана в 2006 году в рамках трехстороннего сотрудничества, с целью наблюдения за изменениями окружающей среды при различных уровнях загрязнения. Качество воды является одним из ключевых элементов программы и показателем воздействия выбросов горно-металлургического комбината «Печенганикель».

ОАО «Кольская ГМК» реализует программу модернизации металлургического производства для снижения выбросов серы и соединений тяжелых металлов. Вопреки ожиданиям, снижение выбросов комбината в поселке Никель не произошло. «Кольская ГМК» сообщила о том, что снижения выбросов диоксида серы до ранее ожидаемого уровня достичь невозможно, даже вложив намного больше денег, чем было запланировано.

В настоящем отчете представлены тенденции изменения химического состава вод озера Инари, реки Паз и озер, непосредственно с ней соединенных, а также 26 малых озер в трех районах: вблизи комбината «Печенганикель» (Россия), в районах Йарфьорд (Норвегия) и Вятсяри (Финляндия) в 2000–2009 гг. В нижнем течении река Паз находится под влиянием как атмосферных выпадений, так и непосредственного сброса сточных вод комбината «Печенганикель» и поселка Никель. Верхняя часть реки, малые озера и ручьи, не связанные непосредственно с рекой Паз, загрязняются только атмосферными выбросами.

Полученные данные подтверждают продолжающееся загрязнение реки и водной системы. Главные компоненты загрязнения – медь, никель и сульфаты. Наиболее высокие показатели обнаружены вблизи комбината. Наиболее загрязненные водоемы бассейна – река Колосйоки (поскольку в нее непосредственно сбрасываются стоки комбината) и протока, соединяющая озера Салмиярви и Куетсъярви. Более высокое содержание металлов и сульфатов в реке Паз наблюдается вниз по течению от озера Куетсъярви. За последние 10 лет содержание загрязняющих веществ в реке Паз не снижается.

В первое десятилетие XXI века наблюдается процесс понижения кислотности малых озер районов Йарфьорд и Вятсяри. Буферная способность этих озер возросла, уровень pH повысился. Причиной этого восстановления является уменьшение загрязнения соединениями серы, что отражается на качестве воды. Однако, содержание некоторых металлов, особенно никеля и меди, за 2000–2009 гг возросло. Содержание никеля повысилось в водоёмах всех трех районов, а содержание меди увеличилось в районах комбината «Печенганикель» и Йарфьорд, расположенных ближе к комбинату. Уровень выбросов никеля и меди за 2000-2009 гг не снизился. Фактически, уровень выбросов соединений никеля даже повысился по сравнению с периодом 1990–1999 гг.

Ключевые слова
Окружающая среда, мониторинг, качество воды

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Sammendrag

Overvåkingsprogrammet for Pasvikområdet ble etablert i 2006 som et resultat av de tre berørte lands samarbeid innen miljøovervåking. Programmet skal avdekke endringer i miljøet under vekslende forurensningsbelastninger. Overvåking av vannkvaliteten er et av de grunnleggende elementer i programmet for å vurdere effektene av utslipp fra Petsjenganikel kombinatets gruvedrift og metallurgiske industri (Kola GMK).

Kola GMK iverksatte et moderniseringsprogram for å redusere utslippene av svovel og tungmetaller. Dette har imidlertid ikke gitt de forventede utslippsreduksjoner fra smelteverket i Nikel. Kola GMK har erfart at moderniseringsprogrammets tiltak ikke gir de planlagte kuttene av sulfur dioxide utslippene.

Rapporten angir tidsbestemte trender i vannkjemien for årene 2000 - 2009 med bakgrunn i data innsamlet fra Enaresjøen, Pasvikelva og innsjøer i direkte tilknytting til den, samt 26 små innsjøer i følgende tre områder: Petsjenga (Russland), Jarfjord (Norge) og Vätsäri (Finland). De nedre delene av Pasvikvassdraget er påvirket av både luftbåren forurensing, av direkte utslipp fra smelteverket og av avløp fra Nikel by. De øvre delene av Pasvikvassdraget, de små innsjøene og bekker som ikke er direkte tilknyttet Pasvikelva mottar forurensingen via luft og nedbør.

De innhentede data bekrefter den pågående forurensingen av elva og vannsystemene. Kobber (Cu), nikkel (Ni) og sulfater er de sentrale forurensingskomponentene. De høyeste nivåene ble funnet nærmest smelteverkene Elven Kolosjoki, som kobler sammen innsjøene Salmijarvi og Kuetsjarvi er den mest forurensede ettersom den mottar direkte utslipp fra både smelteverket og avløp fra byen. Konsentrasjonene av metaller og sulfater i Pasvikelva er høyere nedstrøms innsjøen Kuetsjarvi enn oppstrøms. Det har ikke vært noen reduksjon i forurensingsnivået i Pasvikvassdraget gjennom de siste 10 årene.

Gjennom de siste ti årene ser man en forbedring i forsuringssituasjonen i de undersøkte små innsjøene i Jarfjord og Vätsäri området. Bufferkapasiteten i disse innsjøene har blitt bedre og pH har økt. Grunnen til dette er minkende sulfatinnhold i nedbøren, dette ses også i vannkvaliteten. Imidlertid har konsentrasjonene av enkelte metaller, spesielt nikkel og kobber økt i løpet av de siste ti årene. Nikkel konsentrasjonen har økt i alle de tre undersøkte områdene og kobber konsentrasjonen har økt i Petsjenga og i Jarfjord, som er områder som ligger nærmest smelteverket. Utslippsnivået for nikkel og kobber er ikke redusert i løpet av det siste ti-året. Faktisk ser man en jevn økning av utslippsnivået for nikkel-forbindelser, sammenlignet med 1990-årene.

Emneord				
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