Assessment of water quality and the impact of mining and smelting activities on the water courses of the Paz river basin

Project Ka 00 72 Interreg III Kolarctic/ Final report
Development and implementation of an environmental monitoring and assessment programme in the joint Finnish, Norwegian and Russian border area, 2003 - 2006

The mouth of the River Paz. Photograph: Pekka Räinä

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Preface

Investigations on the ecological status and improvements in the condition of the environment in the Paz river basin are of great importance for Norway, Russia and Finland because the basin extends over the territory of the three countries. The River Paz, together with Lake Inari, is a major water system in Northern Fennoscandia. Anthropogenic pollutants passing into the water-courses in the area mainly consist of heavy metal and sulphur emissions and discharges from the Pechenganikel mining and smelter complex on the Kola Peninsula, as well as sewage from settlements located in the river basin. In addition, the River Paz is regulated by a series of hydro-electric power stations along the border between Russia and Norway. The purpose of this study was to determine the spatial and temporal variation in the water quality of the River Paz, and to estimate the effect of anthropogenic pollution sources on water quality.

1. Description of the study area

The Paz River and Lake Inari form the basin of the Paz River which flows into the Barents Sea. The River Paz starts from Lake Inari, Finland, and flows into the Bekfjord, Norway, which is part of the Varanger-fjord on the Barents Sea. The river and lake form a river-and-lake system typical of the Kola North. Its total catchment area is 18325 km^2. The hydrographic network of the Paz river basin is characterized by a large number of lakes, wetlands and rivers with rapids. The river-and-lake system also includes Lake Salmijarvi, which is connected by the Protoka stream to Lake Kuetsjarvi, through which the River Kolosjoki flows.

Lake Inari is located at an altitude of 119 m above sea level, and is located in an extensive downturn of tectonic-glacial origin. The area of the lake is 1043 km^2, with a maximum depth of over 90 m. The shoreline is fragmented and extensively paludified, and the lake contains about 3,000 islands.

The water conditions in the River Paz are representative of Eastern European rivers. The annual fluctuation in the water level is characterized by a high spring flood, increased autumn flow, and periods of low water in summer/autumn and autumn/winter. The rivers are mostly charged by snowmelt, with a considerable proportion of rainwater and ground water flow. The length of the river from source to mouth is 147 km, with an overall drop of 119 m. The river is 100 to 500 m wide, and up to several kilometres broad in lake extensions. The depth of the river in the rapids is 1 to 2 m, and in the stretches between rapids up to 8 m. The bottom of the river consists of sand with pebbles or exposed bedrock. The river originally had a large number of rapids (before construction of the hydro-electric power plants) and islands. The river bed and hydrological characteristics of the river changed significantly after 5 power plants were built in Russian territory and 2 in Norwegian territory.

The River Kolosjoki flows into Lake Kuetsjarvi. It is a small river with a small catchment area. The length of the river is 22 km, and the catchment area 133 km^2. The surrounding area is hilly, with a vegetation cover consisting of mixed forest and bushes. The river valley is trapezoidal. The left slope is flat and blends in smoothly with the landscape, while the right slope is moderately steep. The valley slopes continue into the slopes of adjacent hills. The floodplain of the river is 30 to 70 m wide, and the riverbed is slightly winding. The banks consist of sandy-loam, and the riverbed of silt or deposited waste from the Pechenganikel industrial complex (in the mouth). The bank is high and flow-resistant.

The Stream Protoka (running from Lake Kuetsjarvi to Lake Salmijarvi) is 2.7 km long and the catchment area 679 km^2. The monitoring site is surrounded by large hills 300 to 500 m high. The tops and slopes are covered with mixed forest, and the lower areas are wetlands. Protoka stream is characterized by a distinct flood period in the spring (May/June), low-water during summer/autumn with occasional rain flooding, and low water during winter (December-April).

2. Analytical methods and sampling

The samples collected in the River Paz were analysed in the laboratories of the Murmansk Department for Hydrometeorology and Environmental Monitoring, Rosgidromet (MUGMS), Institute of North Industrial Ecology Problems, KSC RAS (INEP) and Lapland Regional Environment Centre (LREC) using standard analytical methods. Since 1996 the laboratories have regularly participated in inter-calibration exercises. However, the variation in the analysis results due to the use of different methodology in the individual laboratories, as well as to the modernization and improvement of the methodology over time, means that the data cannot in all cases be combined.

The water samples were taken at the monitoring sites at the surface level at depths of 0.1 - 0.3 m from the surface. Water temperature, pH and the 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 preserved with chloroform and transported to the laboratory usually within 1 - 2 days. The analyses were performed by spectrophotometry:

- Samples for determining the ionic composition were preserved with chloroform.
- Calcium and magnesium ions were analysed by chelatometry (titration with B Trilon), chlo ride by mercurimetry, bicarbonate by potentiometry, and sulphate-ion by turbidometry.
- Suspended matter was determined by gravimetry on samples preserved with chloroform.
- Biological oxygen demand (BOD) was determined on the sampling day by the “light and dark bottle” method.
- Chemical oxygen demand (COD - Cr) was determined by titrometry with Mohr's salt.
- Oil products were determined by infrared spectrometry and fluorometry on unpre served samples.

3. Pollution sources in the Paz River basin

The mining activities and copper and nickel ore-processing plants are the major environmental polluter in the area. The Pechenganikel complex of the Kola GMK Public Corporation is a subsidiary company of the Russian Joint Stock Company Norilsky Nikel, which produces non-ferrous and precious metals. At the present time the plant uses local sulphide copper and nickel ore, but during 1970 to 1990 ore was also shipped from Norilsky GMK in NW Siberia. The plants of the Pechenganikel complex is located in the immediate vicinity of the towns of Zapolyarny and Nikel, north-west Kola Peninsula, close to the Norwegian border. According to the long-term weather statistics, the prevailing winds are from the south (31 %), but in summer northerly winds are more frequent. The average temperature in the hottest month of the year is +17.6 ºC, and in the coldest month of the year -11.6 ºC. The major activities of the Pechenganikel complex are to extract and process copper and nickel ore, and to process them into converter matte for the production of nickel, copper and cobalt. Converter matte, as well as the sulphuric acid produced from the smelter gases, are the final products. The pollution load on the water courses is variable, and consists of the emission of air pollutants an the direct discharge of pollutants. The main pollutants in the water courses are Cu and Ni. The water supply for the production plants and the town of Nikel is obtained from Lake Kuetsjarvi, River Kolosjoki and Lake Luchlumpolo. Wastewater from the plant passes to the treatment facilities at Nikel, and industrial wastewater is discharged into the watercourses of the Pas river basin (see Figure 1). The main discharge sources are:

1. Industrial wastewater from the main production plants passes for treatment to sedimentation pond No 1, from where the recycled water supply of the plants is obtained. The amount of recycled water utilised in slag suspension transport is 17,436,000 m^3/year. The outflow from sedimentation pond No 1 is 3,600,000 m^3/year, and it is discharged at a distance of 20.5 km from the source of the River Kolosjoki.

2. The outflow from the Kaula-Kotselvaara ore deposits is discharged at a distance of 14 km from the source of the River Kolosjoki.

3. The mining wastewater from the Kaula-Kotselvaara mine is discharged into the source of Laskipuro stream (90 % of the water in Laskipuro stream is mining water) and suspended matter is removed by sedimentation in sedimentation pond No 2 on the slag disposal site.

After filtration in the sedimentation pond the mining water is discharged into the River Kolosjoki or, during high water, through overflow from the sedimentation pond. The discharge from the Kotselvaara ore deposit is flood-related, and depends on the time of year. In recent years filtration through the pond has amounted to 700,000 m^3/year, with overflow from the pond of 2,500,000 m^3/year. The discharge point is located at a distance of 19 m from the source of the river.

4. Discharge from the biological treatment facilities in the town of Nikel. Household sewage from the plant and the town of Nikel passes to the biological treatment works at a distance of 0.6 km from the mouth of the River Kolosjoki.

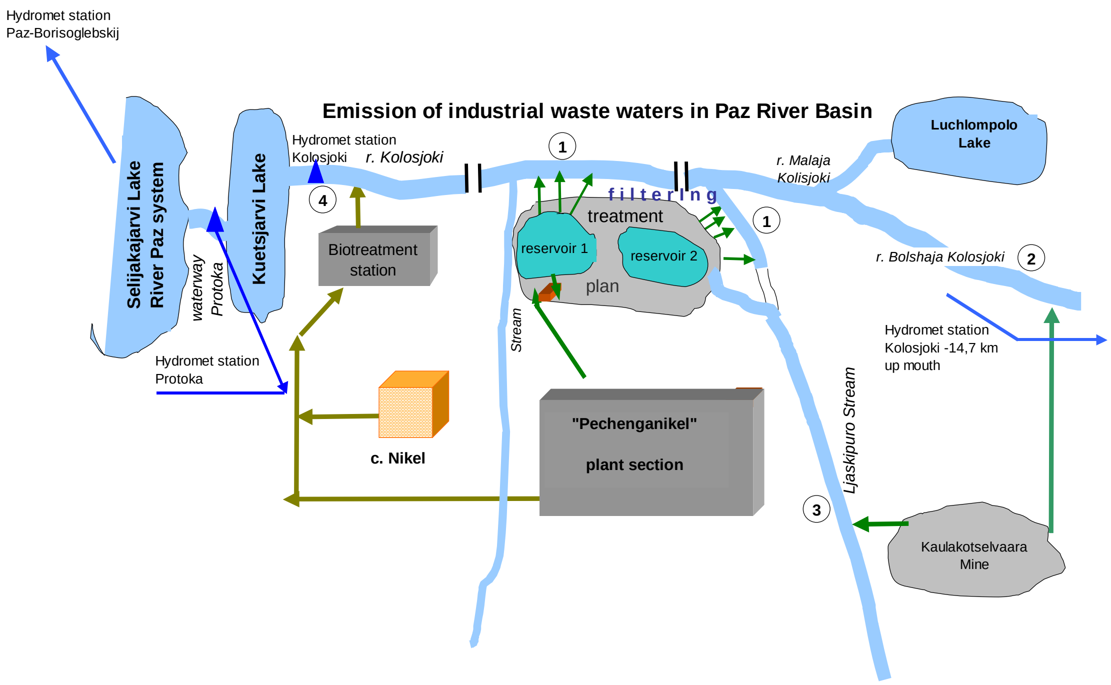

Figure 1. Wastewater discharge into the watercourses of the Paz river basin.

During 1980 - 1988 discharges and emissions from the industrial complex fluctuated strongly, with a maximum in 1983 (45.1 million m^3). During 1989 - 1996 the discharge of wastewater stabilized. In 1997 discharges decreased primarily due to the drop in production and a reduction in the proportion of high-sulphur ore (from Norilsk). In 2004 the Pechenganikel complex discharged 26.3 million.m^3 of wastewater into the surface waters. Of this amount, 16.6 million m^3 was mining wastewater and 8.4million m^3 was discharged into the River Kolosjoki. In 2005 the corresponding amounts were 25.9, 17.1 and 7.8 million m^3. The hydro-electric power plants along the River Paz discharge wastewater into the river. The discharges amount to tens of thousands of tonnes a year, with a decreasing trend in recent years. The discharge water is clean according to the standards, and contains only low concentrations of suspended, organic and other matter (Fig. 2 and 3).

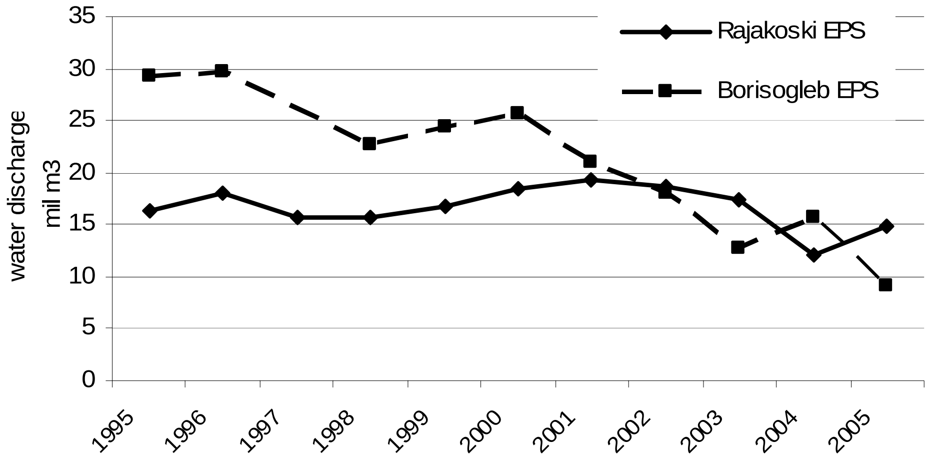

Figure 2. Amount of wastewater discharge from the Pechenganikel complex.

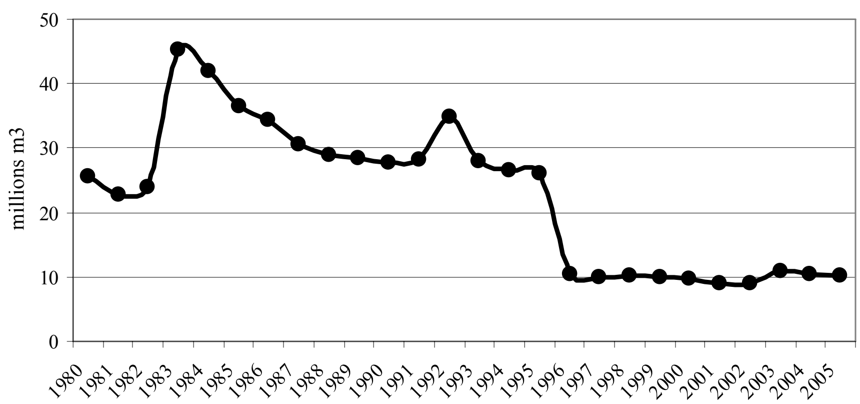

Figure 3. Amount of water discharged from the hydro-electric power plants along the River Paz.

4. The water quality monitoring network

Water quality assessment was carried out by the partner authorities at the following stations:

On the Lake Inari:

Inarijarvi-Nellim - LREC 1965 - 2005
Inarijärvi-Vasikkas - LREC 1965 - 2005

At the source and upstream of the River Paz:

Paz-Inari outlet - INEP 2004
Paz-Virtaniemi - LREC 1965 - 2005

In the middle course of the River Paz:

Paz-Kaitakoski - MUGMS 2001 - 2005
Paz-Janiskoski - INEP 1993, 1994, 2002
Paz-Janiskoski - MUGMS 2001 - 2005
Paz-Rajakoski - INEP 1993, 1994, 2002, 2004
Paz-Rajakoski - MUGMS 2001 - 2005
Paz-Hevaskoski - MUGMS 2001 - 2005
Paz-Jordanfossen - INEP 2002, 2003, 2005
Paz-Ruskebukta - INEP 2002 - 2005
Paz-Tjerebukta - INEP 2003 - 2005
Paz Vaggatem - INEP 1996 - 1998, 2002 - 2005
Paz-Hestefoss - INEP 1993, 2002
Paz-Skogfoss - INEP 1993 - 1994, 1996 - 1998
Paz-Melkefoss - INEP 2002,2005
Paz-Svanevatn - INEP 1994, 1996 - 1998, 2003, 2005
Paz-Bjornevatn - INEP 1994, 1996 - 1998, 2002 - 2003
Paz-Skrukkebukta - INEP 2002 - 2005

In the downstream of the River Paz:

Paz-Borisoglebski - MUGMS 2001 - 2005
Paz-Kirkines - INEP 1993

On the lakes Kuetsjarvi and Salmijarvi

Stream Protoka - MUGMS 1975 - 2005 .

On the River Kolosjoki:

Kolosjoki - 14,7 up from the town of Nikel - MUGMS 1975 - 2005
Kolosjoki - MUGMS 1975 - 2005

Monitoring at the Paz-Virtaniemi station (LREC) was carried out during 1965 - 2005.
Monitoring at the INEP stations was carried out 1993 to 2005. The monitoring period was July to September.

The MUGMS stations on the Paz River are all (except Kajtakoski) 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 Paz 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.

5. Water Quality

5.1 Water Quality in the Lake Inari

The Inari Lake is oligotrophic with a low humus concentration. Different zones can be identi-fied on the basis of the colour and transparency of the water in the lake. The water colour decreases towards the north: in the central part of the lake it is 10 - 15 Pt mg/l, and in the northern part about 10 Pt mg/l. The higher colour values (25 - 35 Pt mg/l) in the river estuaries in the southern part of the lake are due to the presence of organic substances entering the lake in river water. Respectively the water transparency increases from 4 m in the river estuaries up to 7 meters in the northern parts of the lake, with a maximum of up to 10 m (Marttunen et al 1997).

The low nutrient reserves are reflected in the low nitrogen and phosphorus concentrations. The phosphate concentration did not exceed 1.5 - 2 µg/l, and the nitrate concentration 40 - 50 µg/l. There were clear seasonal fluctuations in the concentrations, with a peak during the winter period and a minimum in the summer. The total phosphorus concentration during open water was 4 - 5 µg/l, and the total nitrogen concentration 150 - 200 gµ/l. The total phosphorus concentration remained relatively constant throughout the monitoring period, and but there was a clear decreasing trend in the total nitrogen concentration (Fig. 4).

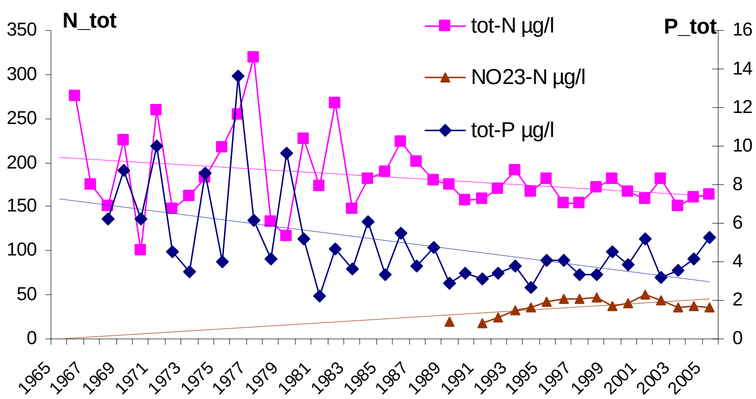

Figure 4. Total phosphorus and total nitrogen concentrations in Lake Inari.

Pollution sources near Lake Inari are the sewage treatment plants of settlements (Ivalo, Inari, Saariselkä) and also 2 fish-breeding plants. The main sources of pollution in the region are the scattered settlements, as well as agriculture and forestry. The contribution of pollution to the nutrient load of the basin is relatively insignificant, because more than 90 % of the nutrient input is through the natural leaching of the surrounding soil. In areas with settlements and agriculture the contribution can be higher. Near Lake Inari 40 % of the phosphate load and more than 50 % of the nitrogen load input is derived from deposition.

The organic matter concentration in the lake is currently 2 - 3 mg/l. The higher concentrations. The organic matter concentration in the lake is currently 2 - 3 mg/l. The higher concentrations of nutrients and organic substances observed at the end of the 1970s and beginning of the 1980s years may have been influenced by the intensification of forestry in the middle of the 1970s (Fig. 5).

The mineralization of the water was very low, with a conductivity not exceeding 3 - 3.5 µS/cm, the concentrations of the main ions were very low: Ca 2 - 3 mg/l, Mg ca. 1 mg/l, sulphate 2.5 - 3.0 mg/l (1977 - 1978, 1989), and alkalinity 0.16 - 0.18 mmol/l (Fig. 6).

Changes in the water quality of Lake Inari that were associated with possible acidification processes caused by the atmospheric deposition of sulphate, were visible. According to the data, sulphate concentration was first increasing and alkalinity decreasing until the middle of 1980s, and after that the trend turned reverse. The reversal of acidification processes in the middle of the 1980s was most probably due to the reduction in sulphur emissions in Finland and on the Kola Peninsula, starting at the beginning of the 1980s. The concentrations of heavy metals in the lake during 2003 - 2005 were lower than 1 µg/l.

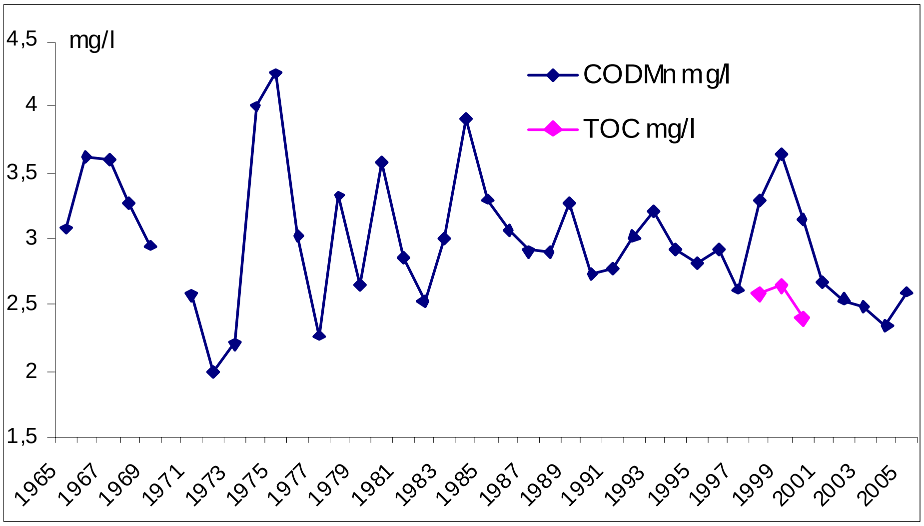

Figure 5. Organic matter concentration in Lake Inari.

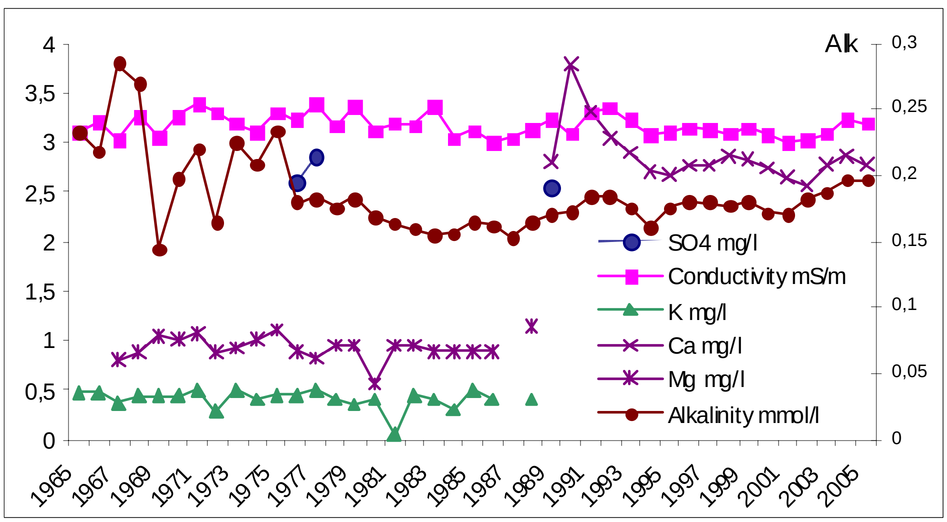

Figure 6. Conductivity and concentrations of the main ions.

5.2 Water Quality in the Paz watercourse

5.2.1 Ionic composition of the water

The hydrochemical properties are influenced by the bedrock, terrain of the river valley and, especially, by the source of the water. As a typical northern river, the ion input to the River Paz is primarily determined by atmospheric deposition, melting snow and summer/autumn rain-water. Owing to the excessive moisture and low weathering intensity of the heavily out-washed quaternary deposits and the predominance of acidic podzolic soils, the surface runoff is of low ionic strength. The ionic concentration is around 40 mg/l, and the electrical conductivity 21 - 41 µS/cm. Based on the ratio of the major ions in the water, the rivers are classified as hydro-carbonate/calcium waters type (Fig. 7).

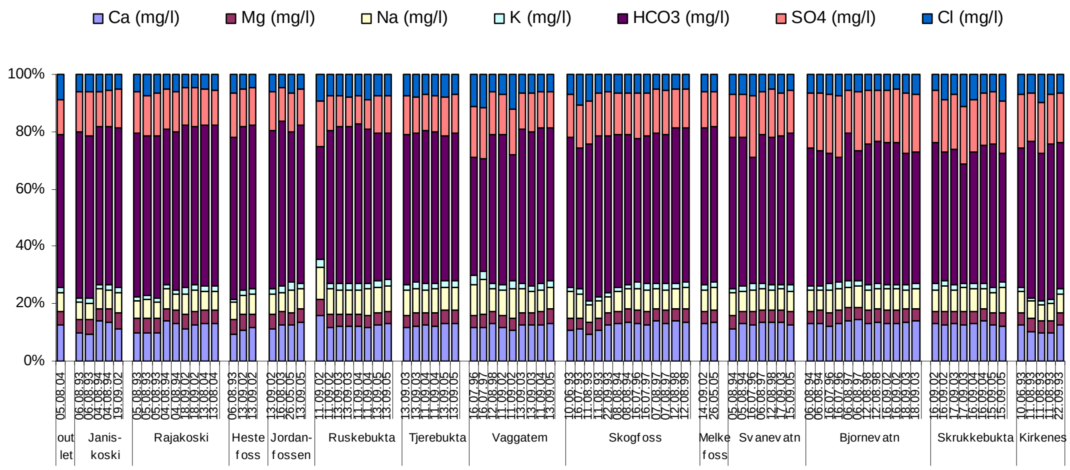

Figure 7. The ratio of main ions in the River Paz.

One characteristic feature of the ionic composition of the river water is the large variation in the sulphate concentration due to the sulphate load on the catchment area in the region. The sulphate concentration in the section of river above the discharge point of polluted water from Lake Kuetsjarvi was below 2 - 3mg/l (INEP, Hydromet, 1993 - 2005), while there was an increase in the sulphate concentration to up to 3 – 6 mg/l in the area closest to the industrial complex. Downriver from the Borisoglebskaya power plant, the sulphate-ion concentration was even higher, 4 - 9 mg/l (INEP, Hydromet, 2001 - 2005). The chloride concentration also increased toward the mouth of the river: from 0.8 - 2.2 mg/l in the upstream and middle section to up to 1.2 - 3.0 mg/l (INEP, Hydromet) (Fig. 8)

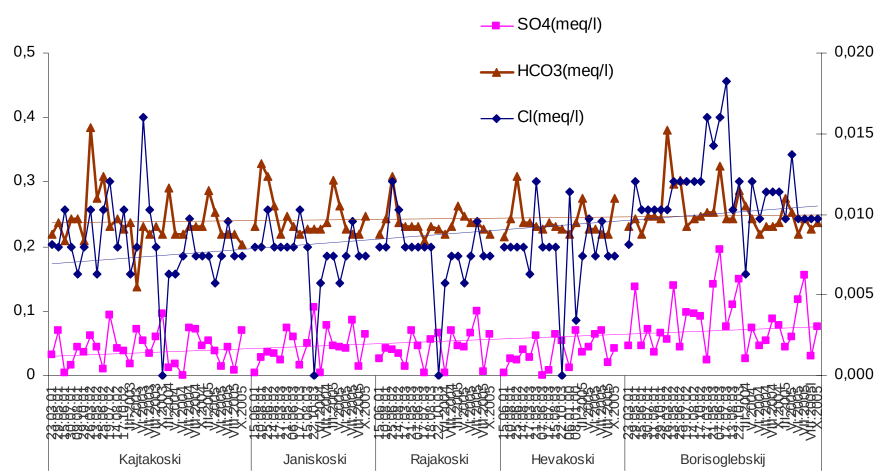

Figure 8. Distribution dynamics of anions in the River Paz.

The alkalinity of the water was relatively constant throughout the whole river, and varied from 0.086 - 0.200 meq/l (INEP). At the monitoring stations near the Paz hydro-electric power plants the bicarbonate concentration was somewhat higher, but from Kajtakoski to Borisoglebsky the variation was low, 0.150 - 0.300 meq/l.

The pH in the river water varied from 6.17 - 7.18 (INEP), and close to the power plants it was somewhat higher, 6.65 - 7.80 (Hydromet). There was a clear seasonal variation in the pH and ionic composition in the upstream part of the river (Virtaniemi, LREC) (Fig.9).

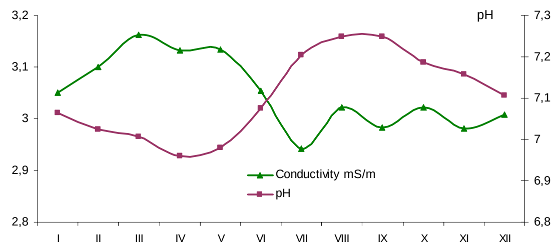

Figure 9. Seasonal dynamics upstream in the River Paz.

Calcium is the predominant cation in the river water. The calcium concentration was 1.4 - 3.0 mg/l in the upstream and middle section, and 1.9 - 3.6 mg/l in the mouth of the river, due to the influence of the sea. Similarly, the magnesium concentration was 0.5 - 1.0 and 0.8 - 1.2 mg/l, respectively. The total calcium and magnesium concentration throughout the River Paz, including the stations near the hydro-electric power plants (Hydromet), amounted to 0.16 - 0.33 meq/l. There was a slight increase in the sodium concentration from 1 - 1.9 to 1.2 - 2.3, respectively (INEP). The potassium concentration was relatively constant throughout the river, 0.2 - 0.7.

5.2.2 Nutrient and organic matter concentrations

Low concentrations of organic matter and nutrients are characteristic of surface waters in sub-arctic regions.

The organic carbon concentration in the River Paz varied from 2.51 - 6.64 mgC/l. The organic matter in the river contained about 50 % carbon. The organic carbon concentration was higher in the lake section of the watercourse. The distribution of the phosphorus and iron concentrations also indicated a connection between the chemical composition of the river water and the distribution of wetlands in the catchment area. The peak in concentrations in the river mouth is of anthropogenic origin, i.e. the load from the industrial complex (Fig. 10).

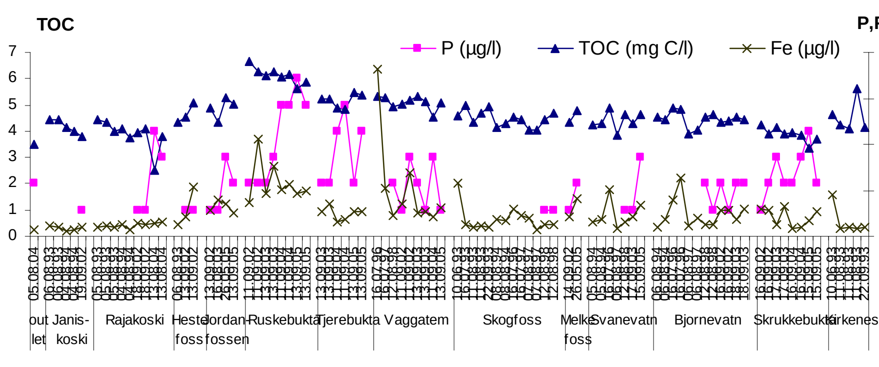

Figure 10. Distribution of the organic matter, iron and phosphorus concentrations.

The concentration of easy-oxidable organic matter was low: 0.1 - 1.7 mg/l for BOD_5, and 5 - 17 mgO/l for COD_{Cr} . The water colour in the river was within 10 - 50 degrees on Pt-Co chart (Fig. 11).

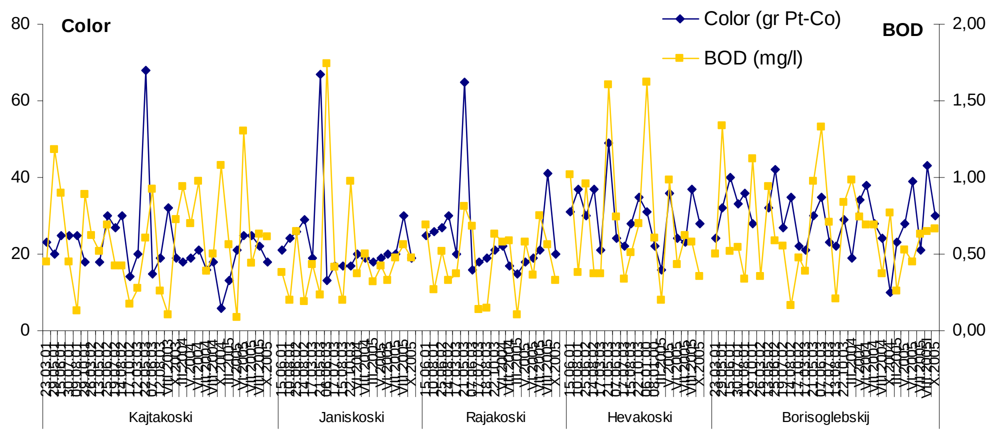

Figure 11. Color of water and concentration of easy-oxidable organic matter according to BOD_5.

The nutrient concentrations are closely connected with the processes involved in the decomposition of organic matter in the water. The nitrate concentration in the River Paz was 0 - 130 µgN/l , and the nitrite concentration lower than 1 µgN/l. The ammonium concentration varied from 0 to 115 µ/l. The concentration of non-organic phosphorus compounds was 1 - 20 µ/l, and the silicon concentration 0 - 2.9 mg/l (Fig.12).

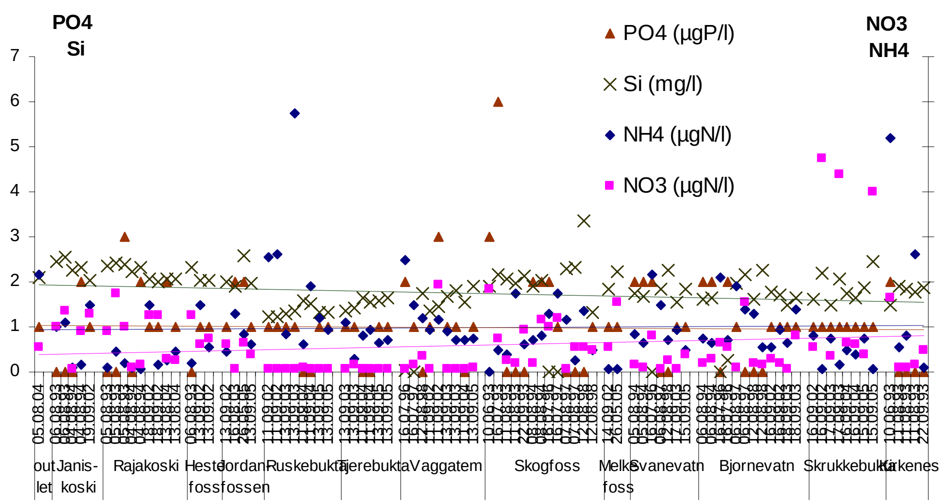

Figure 12. Distribution dynamics of the nutrient concentrations.

The seasonal variation in nutrient concentrations is illustrated on the basis of the results for the Paz-Virtaniemi monitoring station (LREC). The nitrate concentration decreases in spring but, during the growing period with minimum concentration in August. In the autumn the nitrate concentration increases and reaches a maximum by the end of the northern winter period. The seasonal variation in the phosphate concentrations is smaller. The iron concentration increases during the low flow period due to the ground water flow (Fig. 13).

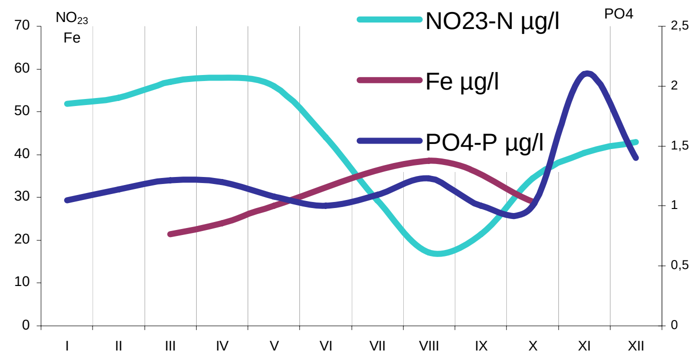

Figure 13. Seasonal distribution in nutrient concentrations at the Paz-Virtaniemi monitoring station.

Overall, the organic matter and nutrient concentrations corresponded to the oligotrophic water conditions typical of the natural conditions in the sub-arctic regions.

Most of the polluted wastewater from the Pechenganikel complex is discharged into the River Paz watercourse via the River Kolosjoki. The River Kolosjoki runs into Lake Kuetsjarvi which, in practice, is used as a sedimentation basin by the mining and smelting complex. The sediments are the most polluted. The polluted water passes into the Paz River and lake system through the stream interconnecting Lake Kuetsjarvi and Lake Salmijarvi.

5.2.3 Pollutant concentrations

Copper and nickel, derived from the wastewater discharges and atmospheric emissions from the mining and smelting industries, are the major pollutants in freshwater ecosystems on the Kola Peninsula. Assessment of the environmental impacts of the mining and smelting activities is one of the most important issues in modern geochemistry and ecology. Many metals become extremely toxic to the environment after they have been extracted and processed. Excessive contamination of surface waters by metals through their direct discharge in wastewater from metallurgical plants, changes in the geochemical cycles in catchment areas as a result of mining activities, atmospheric deposition and leaching by acidic deposition, considerably increase the threat to the environment and reduce the quality of water resources (Bokris 1982, Grushko 1979).

Contamination of the River Paz with metals was clearly evident throughout the monitoring period, and their distribution in the watercourse unequivocally demonstrated the impact of the smelters. The concentrations of copper and nickel were higher in the downstream Kuetsjarvi. There were also high concentrations in the River Kolosjoki. At the monitoring station situated 14.7 km up from the mouth of the River Kolosjoki, which is outside the direct influence of the wastewater discharged from the Pechenganikel complex, the copper (5 – 8 µg/l) and nickel (15 – 20 µg/l) concentrations were of course lower than those in the mouth, but higher than the background levels for natural water and higher than the maximum permissible level for watercourses used for fishing. This was due to the deposition of heavy metals, as well as to the leaching by rain and snowmelt from the surrounding soil that is heavily polluted by many years of atmospheric deposition.

There were high concentrations of copper and nickel in the mouth of the River Kolosjoki throughout the monitoring period (starting in 1964). From 1978 to 2002, the nickel concentrations varied from 317 to 819 µg/l, and the copper concentrations from 6 to 44 µg/l. The maximum concentrations occurred in 19781980. The seasonal variation was characterized by a reduction in concentrations during flood periods. The average annual sulphate concentration in the River Kolosjoki varied between 116 and 281 mg/l.

The river flows into Lake Kuetsjarvi. The pollution levels in the lake were close to the concentrations recorded in the stream connecting Lake Kuetsjarvi and Lake Salmijarvi, and considerably lower than in the River Kolosjoki. From 1980 to 1990 the nickel concentration in the stream varied between 48 and 84 µg/l. Since 1991, there has been a gradual increase in nickel concentrations in the stream, reaching 120 µg/l in 2005. The copper concentration varied between 3 and 74 µg/l, and the sulphate concentration between 32.1 and 50.6 µg/l (Fig.14).

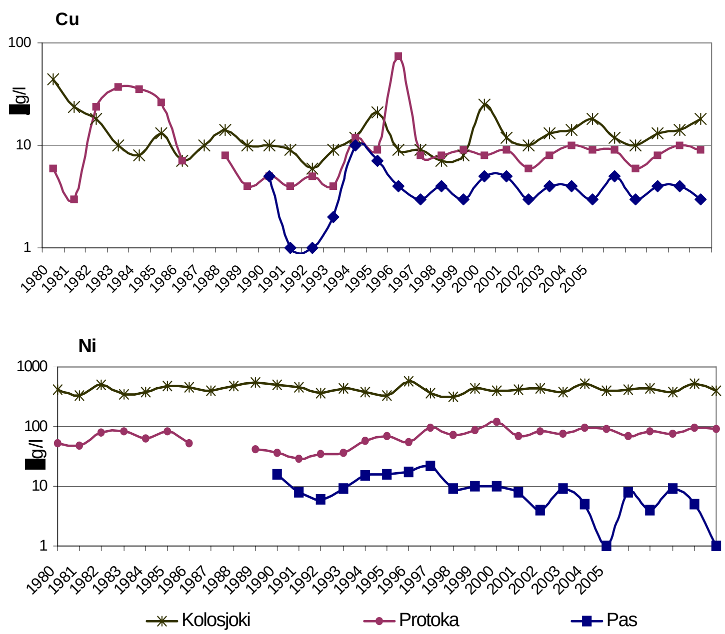

Figure 14. Distribution of pollutants in the Paz river basin

The average annual metal concentrations in the River Paz have been falling since 2001. In 2001 the nickel concentration was 4.7 µg/l, whereas in 2005 it was 1.0 µg/l, and the copper concentration was 4.6 and 2 µg/l, respectively (Fig. 14). The nickel concentration was the highest in the mouth of the River Kolosjoki, considerably lower in the stream, and did not exceed 10 - 12 µg/l in the River Paz. The highest copper concentration also occurred in the mouth of the River Kolosjoki, but its distribution in the other watercourses was more even. The differences in the distribution of these two metals indicate that they follow different pollutant pathways. Nickel is primarily (about 80 %) derived from industrial wastewater discharges, whereas copper (up to 90 %) is distributed over the catchment area through atmospheric emissions, thus causing more widespread pollution in the area. In addition, copper occurs naturally in non-polluted waters on the Kola Peninsula, thus contributing to the relatively even distribution of copper in the watercourses. At the monitoring station on the River Paz, below the Borisoglebskaya hydro-electric power station, the metal concentrations were lower than those in the watercourses directly affected by the Pechenganikel mining and smelting complex. However, the copper concentration exceeded the maximum permissible limits for fishing (Fig. 15 and 16).

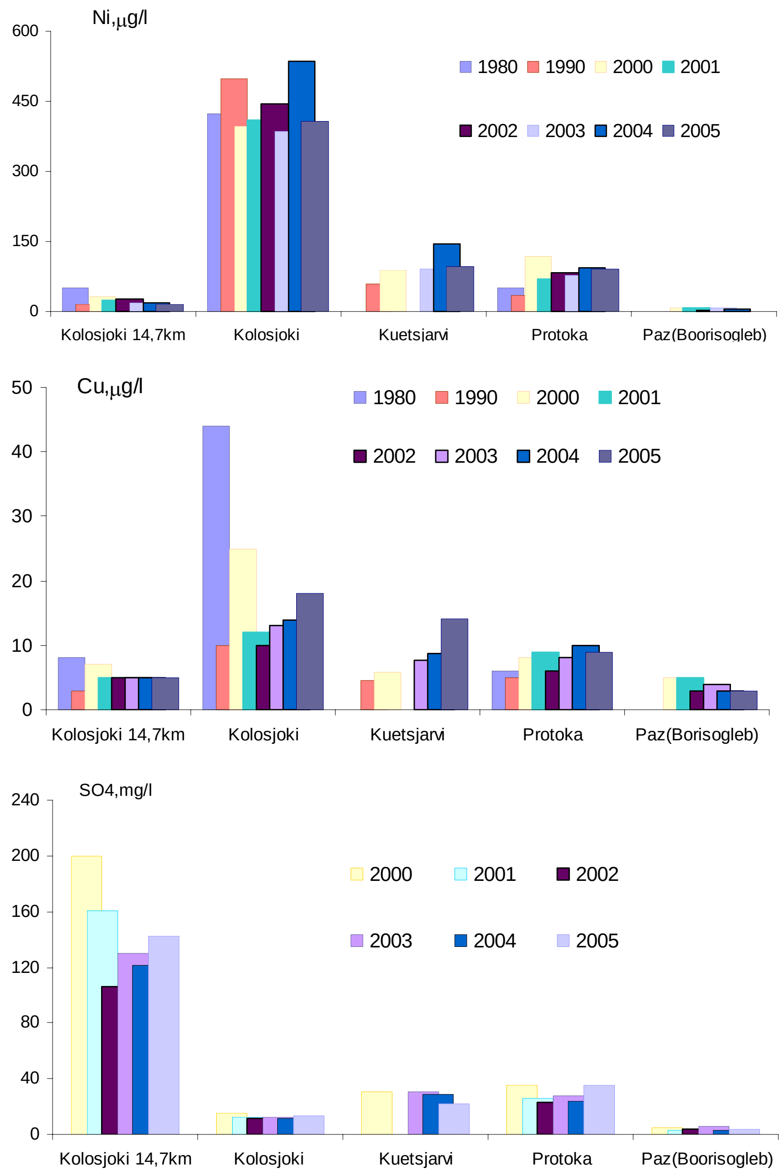

Figure 15. Distribution of metals and sulphate in the watercourses direct affected by the Pechenganikel mining and smelting complex and in the lower reaches of the River Paz watercourse (Borisgleb).
 * Kolosjoki, 14.7 km upstream from the town of Nikel

Other metals and elements were also present in the River Paz. The zinc concentration was 1 - 28 µg/l, manganese 1 - 37 µg/l, chromium 0.1 - 3 µg/l, cadmium 0.01 - 0.5 µg/l, and strontium 8 - 24 µg/l. The concentrations of these elements were relatively even throughout the whole watercourse, clearly demonstrating the considerable impact of atmospheric deposition and leacing of pollutants from the catchment area.

Hydrocarbons were present in the river in very small concentrations of up to 0.08 mg/l.

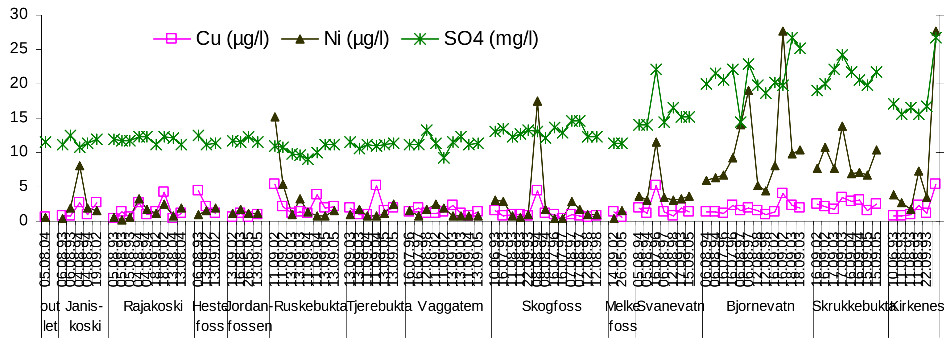

Figure 16. Distribution of metals and sulphates in the River Paz watercourse

6. Conclusions

The issue of surface water contamination by metals through their direct discharge into the watercourses along with wastewater from the metal-processing plants, changes in the geochemical cycle in the catchment areas caused by mining, atmospheric deposition and leaching by acidic deposition, is one of the most serious problems affecting the conservation of water resources in the Arctic basin.

1. Polluted wastewater discharged by industry into the water bodies of the Arctic basin repre sent a serious environmental threat to water resources despite the fact that the discharges are relatively localised.
2. The activities of the mining and smelting industry on the Kola Peninsula have resulted in elevated metal concentrations in the water. The metals are derived from both dust emissions and wastewater discharge.
3. Excessive contamination of surface waters by metals has considerably increased the envi ronmental risks and reduced the quality of the water resources.
4. Lake Inari is oligotrophic, with clean water and low nutrient concentrations. The main sources of pollution are settlements, fish-breeding facilities, and also agriculture and for estry. However, the proportion of anthropogenic loading is very low. Organic matter concentrations in the lake were low, and the ionic concentrations were also low. There have been some changes in lake water quality, most probably connected to acidification process caused by the deposition of sulphate. The concentrations of heavy metals and other ele ments in the lake were, according to the monitoring data for 2003 - 2005, relatively low.
5. The water of the River Paz has a low ionic concentrations and is classified as the carbonate/calcium type. The concentrations of nutrients and organic matter were relatively low, and their distribution down the river is influenced by morphological and landscape charac teristics. Seasonal variability is typical of rivers in the north and especially in rivers with recharge of this type.
6. The mining and smelting complex has a negative impact on the aquatic environment in the basin. The River Kolosjoki is the most polluted river in the basin, directly receiving dis charges of polluted wastewater from Pechenganikel GMK.
7. The impact of discharges from the complex on the River Paz ?are reflected/? in the down stream Kolosjoki. In this part of the watercourse the concentrations of copper, nickel and sulphate were higher than in the middle and upper part of the river.
8. Despite of the reduction in emissions and discharges by Pechenganikel GMK, the metal concentrations in the River Kolosjoki and stream have remained high, especially of copper

and nickel. The reason for this is leaching from the soil surface by runoff, and the secondary leaching of metals from the polluted sediments.

10. The main source of water pollution by nickel is the discharge of wastewater, whereas cop per, zinc, manganese, lead and strontium are mainly derived from dust emissions.

The watercourses directly receiving wastewater discharges are the most seriously affected by the mining and smelting complex. These watercourses are the River Kolosjoki and Lake Kuetsjarvi, and in the lake the sediments are the most polluted. Further along the stream (running from Lake Kuetsjarvi to Lake Salmijarvi) the pollutants pass into the Paz river system, where the concentrations of heavy metals are higher than those upstream of Lake Kuetsjarvi.

It is difficult to identify a clear gradient in metal concentrations in the individual lakes of the Paz River basin because atmospheric deposition plays an important role in the distribution of pollutants in the area.

The heavy metal concentrations, as well as those of the major ions, in the areas subjected to direct discharges of wastewater from the complex should be monitored continuously in order to identify possible increases in discharge levels or hazardous situations. In the more remote areas of the basin, in addition to monitoring the condition of the aqueous environment, methods should be used for determining the impact of the atmospheric distribution of pollutants, for example, analysis of pollutant concentrations in the snow cover and in the soil.

7. Recommendations for the future monitoring programme

It is necessary to continue monitoring the watercourse of the Paz river basin under the standard programme of Murmansk Gidromet as this will permit observation of the inter-annual changes in the concentrations of pollutants (monitoring has already been carried out for more than 25 years), variation in the concentrations of pollutants in the different hydrological phases (sampling 4 times a year), and the distribution and fate of the pollutants discharged into the River Kolosjoki up to the mouth of the River Paz (4 sampling points along the pollution gradient).

1. Compulsory monitoring stations: the mouth of the River Kolosjoki (0.6 km upstream from the mouth), Lake Kuetsjarvi, the stream running between Lake Kuetsjarvi and Lake Salmi jarvi, and three locations in the upper, middle and lower parts of the River Paz.
2. The main elements to be monitored: copper, nickel and sulphate.
3. Frequency: four times a year during the main hydrological phases.
4. Extensive monitoring, once a year in summer/autumn:
5. Determination of the hydrobiological parameters of the aquatic ecosystems affecting the con dition of phytoplankton, zooplankton, and zoobenthos
6. Determination of the concentrations of the main ions.

8. References

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