PASVIK PROGRAMME

SUMMARY REPORT

State of the Environment in the Norwegian, Finnish and Russian Border Area

Office of the Finnmark County Governor, Norway
Lapland Regional Environment Centre, Finland
Murmansk Department for Hydrometeorology and Environmental Monitoring, Russia

Office of the Finnmark County Governor
Department of Environmental Affairs
Report 1, 2008

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PHOTO: PEKKA RÄINÄ

Preface

The Pasvik Programme represents three years work by more than twenty research institutes and environmental authorities from Norway, Finland and Russia. This project, funded principally by the Interreg IIIA Kolarctic programme commenced in 2003 with the following aims:

- To develop and implement an environmental monitoring and assessment system in the joint Norwegian, Finnish and Russian border area during the period 2003-2006.
- To monitor and assess the cross-border area in response to the modernisation of the Pechenganikel mining and metallurgical complex on the Kola Peninsula in northwest Russia.
- To harmonise and standardise monitoring and assessment methodologies used by researchers and research institutes in all three countries.
- To produce integrated assessments of the state of the environment in the cross-border area, specifically the condition of the terrestrial ecosystems, the freshwater catchments and the atmospheric environment.
- To disseminate information to residents, municipalities and research institutes in the study area, informing them about the state of the environment in the Norwegian, Finnish and Russian border area.

In June 2007 the status report *State of the Environment in the Norwegian, Finnish and Russian Border Area* was published. This report describes the current environmental status of the Pasvik-Inari catchment area and the various changes that have taken place over a number of decades following the decline in emissions from the Petchenga mining and metallurgical plant. The complete scientific documentation, including quantitative results can be sourced from the appropriate research institute or the accompanying CD to the status report.

This report, known as the *Pasvik Programme Summary Report*, is a simplified, easy to follow version of the peer-reviewed and fully referenced status report. This summary report presents the main conclusions arising from the project regarding the current status of the environment; as well as recommending an ongoing trilateral monitoring and assessment programme jointly agreed upon for future assessments of the cross-border area.

A large number of experts from Norway, Finland and Russia have participated in this assessment, emphasising that multidisciplinary cooperation across three countries can be successful and can yield important, practical information regarding the management and monitoring of the environment, particularly in the unique Arctic regions.

The Pasvik Programme would like to express its appreciation to the many experts, research institutes and environmental authorities that have contributed their time, effort and data to this project. The main contributors are listed on the following page.

Special thanks are due to the Pasvik Programme co-ordinators Ilona Grekelä and Amund Beitnes for the countless hours of work and endless travelling that they have done to make this project possible. Special thanks are also due to the author of this report, Carolyn Symon, and to the graphic designer Hege Sjursen, for their work in producing this final report.

The excellent support and cooperation between Norway, Finland and Russia is the principal reason for the success of this project. Without this multidisciplinary, trilateral cooperation, environmental planning and decision-making at the regional, national and international levels would simply not be possible.

Bente Christiansen, Office of the Finnmark County Governor
Outi Mähönen, Lapland Regional Environment Office

Environmental bodies involved in the Pasvik Programme

Steering bodies
- *Office of the Finnmark County Governor, Norway*
- *Lapland Regional Environment Centre (LREC), Finland (lead body)*
- *Murmansk Department for Hydrometeorology and Environmental Monitoring (MUGMS), Russia*

Research institutes and environmental authorities
- *Norwegian Institute for Air Research (NILU)*
- *Geological Survey of Norway (NGU)*
- *Norwegian Institute of Water Research (NIVA)*
- *Akvaplan-NIVA, Norway*
- *Norwegian Institute for Nature Research (NINA)*
- *Norwegian College of Fisheries Science (NCFS)*
- *Forest Research Institute (Skogforsk), Norway*
- *Bioforsk Svanhovd Environment Centre, Norway*
- *Office of the Finnmark County Governor, Norway*

- *Finnish Forest Research Institute (METLA)*
- *Finnish Game and Fisheries Research Institute (RKTL)*
- *Finnish Meteorological Institute (FMI)*
- *Finnish Environment Institute (SYKE)*
- *Finnish Geological Survey of Finland (GTK)*
- *Lapland Regional Environment Centre (LREC)*

- *Institute of North Industrial Ecology Problems, KSC RAS (INEP), Russia*
- *Murmansk Department for Hydrometeorology and Environmental Monitoring (MUGMS), Russia*
- *Centre for Laboratory Analysis and Technical Measurement in Murmansk area, Russia*
- *Pasvik nature reserve, Russia*
- *All-Russian Scientific and Research Institute for Nature Conservation (VNIIPriroda)*
- *Institute of Global Climate and Ecology (IGCE), Russia*

Funding bodies
- *Interreg IIIA Kolarctic Programme*
- *Nordic Council of Ministers*
- *Barents Secretariat, Norway*
- *Ministry of the Environment, Norway*
- *Ministry of the Environment, Finland*

Additional contributors
- *Municipality of Sør-Varanger, Norway*
- *Municipality of Inari, Finland*
- *Pechenga District Administration, Russia*
- *Kola mining company, Russia*

Introduction

Almost nothing was known about the environmental devastation around and downwind of the Pechenganikel mining and metallurgical complex on the Kola Peninsula in northwest Russia until Russian border controls were relaxed in the 1980s. Until then it was very difficult for foreigners to enter Russia and despite the environmental damage around the smelters covering hundreds of square kilometres little was known about it outside the region. Environmental studies in the mid- to late 1980s showed that environmental damage in Finland and Norway near the Russian border was part of a continuum stretching outwards from the mining and metallurgical operations centred on Nikel and Zapolyarnyy. The studies also made it clear that this damage was a direct consequence of the vast quantities of sulphur dioxide, dust, and toxic heavy metals emitted into the atmosphere from the industrial activities at these sites.

Environmental quality in the Norwegian, Finnish and Russian border area has so far been monitored and assessed by Norway, Finland and Russian independently. This makes it difficult to get an overall picture of environmental quality in the terrestrial and freshwater ecosystems there and, more importantly, makes it difficult to use the results for environmental planning and decision-making, particularly at the regional level.

The aim of the Pasvik Programme was to develop and implement a trilateral environmental monitoring and assessment programme for the area affected by emissions from the Pechenganikel industrial complex. Scientists from over 20 Norwegian, Finnish and Russian research institutes and environmental authorities worked together during the three-year project to establish the current status of the environment in the border area, to understand the changes in the environment since the early 1990s, and to agree on a future monitoring and assessment programme that will harmonise the many national activities in the region. Harmonised methods for collecting and storing monitoring data should ensure that future data sets are reliable, comparable and easily available to experts and local people from the three countries. This will make it easier to explain improvements in environmental quality with regard to the ongoing and planned modernisation and emissions reduction programmes at the Pechenganikel industrial complex. The close co-operation that developed during this project between the environmental authorities and researchers in the three countries is expected to continue after the project.

The Pasvik-Inari Region

Along most of its length the River Pasvik represents the border between Norway and Russia. Its catchment area is characterized by a large number of lakes, streams and bogs, linked by fast flowing sections of river. Around 70% of the catchment area occurs in Finland, with 5% in Norway and 25% in Russia. The source of this river is Lake Inari.

Lake Inari, with its rocky and rugged shores, is Lapland's largest lake. Over half the lake is characterized by a labyrinth of more than 3000 islands.

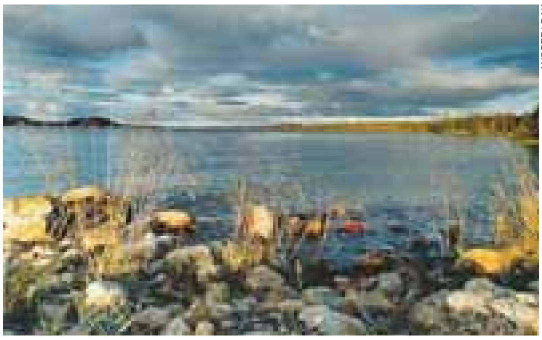
The Pasvik Programme study area is concentrated around the region where the Norwegian, Finnish and Russian borders meet

The Pasvik-Inari region extends across the borders of Norway, Finland and Russia. The River Pasvik valley is centred on the southward-pointing extension of Norway sandwiched between Finland and Russia. The study area covers around 20 000 square kilometres in total and marks the point where the north-western corner of the Euro-Siberian taiga meets the barren, tundra coast of the Barents Sea. This broad region of forests and lakes is very rich in natural resources.

Two principal water bodies dominate the region: the River Pasvik and Lake Inari. The region also has several smaller river systems as well as many tiny streams and lakes scattered through the upland forests and vegetation-free mountain areas.

Cool winters are typical in this region and the ground is usually snow covered from around mid-November to late May. Ice forms on the rivers and lakes in late autumn (October to November), breaking up earlier on the River Pasvik (April to


PEKKA RAINA


ANDRZEJ BAK

May) than on Lake Inari (June). The growing season is short despite relatively warm summers. Precipitation in the border area is low and around two to three times lower in winter than in summer.

The winds are mostly from the south and southwest during winter. As a result, the prevailing winds carry the majority of the Russian smelter emissions further into Russia, with pulses of air pollution carried south/ southwest into the study area only when the prevailing winds reverse direction. Wind direction is more variable during summer.

Growing season

The growing season is the period with days of average temperature above +5 °C. In the Pasvik–Inari region the growing season is between 110 and 120 days long.

In the valleys, on the lower hill slopes and in flat areas the soil material is up to several metres thick, with soil thickness gradually decreasing with increasing altitude to soil-free conditions on the fell tops. The soils reflect the underlying geology. In the border region the bedrock is mostly calcareous and except in small patches the soils are relatively resistant to acidification by depositing pollutants. Around 10% of the border area is covered by peat.

Owing to its geographical position the plants and animals of the border region are species at their northern limits of distribution, and eastern species at their western extremes. Towards the northern border of the extensive pine forests that characterise the region, there is a gradual change into sparse, birch-pine mixed forest, followed by fell birch forest, and finally treeless tundra.

The region contains several conservation areas: the Vätsäri Wilderness Area, the Pasvik Nature Reserve in Norway and the Pasvik Zapovednik in Russia, the Ovre Pasvik Landscape Protection Area, the Ovre Pasvik National Park and the Store Sametti-Skjelvatnet Nature Reserve. The Pasvik Nature Conservation Area has been designated as a Ramsar Area, which means it is recognised as an internationally important wetland area.


RAGNAR VÅGA PEDERSEN


DAN AAMLID


DAN AAMLID

The ground vegetation in the pine and birch forests is dominated by dwarf shrubs. Some commonly found species shown here include cowberry, crowberry and wild rosemary, other species often present include cloudberries, bilberries and various mosses and lichens.

Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (the "Ramsar Convention") is an intergovernmental treaty that came into force in 1975. The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international co-operation, as a contribution towards achieving sustainable development throughout the world.


RAGNAR VÅGA PEDERSEN

The extensive network of wetlands in the River Pasvik basin is an important nesting, resting and migration site for many bird species, including various wader birds.

Human Activities

The Pasvik-Inari area comprises three border municipalities: Pechenga in Russia, Sør-Varanger in Norway and Inari in Finland. The most populated of the three regions is Pechenga. This region has a strong industrial base and most of the working population is employed within the mining and metallurgical industry concentrated in the west near the border with Norway. Traditionally, the area has been home to the Saami people and reindeer herding, fishing and farming are still practised in rural areas.

Hydro-electric power

The seven hydro-electric power stations built between 1951 and 1978 on the Pasvik watercourse together generate enough power to supply 55 000 households. Despite four of these being built along the Norwegian-Russian border during the period of tense East-West relations immediately after the Second World War, there was close and effective co-operation between Norway and the former Soviet Union in the development and use of hydro-electric power in this area that is still evident today.

The mining and metallurgical industry

The Pechenganikel Mining and Metallurgical Combine is a large complex of mining and metal smelting activities focused on the north-west Russian border towns of Zapolyarnyy and Nikel. The industrial facilities at Zapolyarnyy and Nikel are approximately 30 km apart and approximately 15 and 5 km from the Norwegian border, respectively. The complex comprises one open-cast mine, two underground mines, an enrichment plant, a roasting plant, a smelting plant and sulphuric acid production. The main products are copper and nickel matte and sulphuric acid. The main pollutants emitted to the air are sulphur dioxide and heavy metals such as nickel and copper attached to small dust particles. Large quantities of heavy metals are also discharged into local water bodies in wastewaters.

HANS TØMMERVIK

The Pechenganikel smelter plant is located in the town of Nikel in north-west Russia, this photo taken on the Russian side of the border shows the three large chimney stacks towering over the otherwise barren landscape.

Industrial development in the Penchenga area

Industrial development in the Penchenga area began in the early 1930s with the discovery of nickel. The first smelter soon followed, built in Nikel in 1933 by a Canadian–Finnish enterprise. The Russians took over the nickel production in 1946 when that part of Finland's territory was ceded to the Soviet Union at the end of the Second World War. Gradually an intensive mining and metal processing industry developed on the western part of the Kola Peninsula. Initially the smelting activities at Nikel were based on copper and nickel ores mined locally, but in 1969 a rich ore with a much higher sulphur content began to be imported from Norilsk in Siberia. The result was a big increase in sulphur dioxide emissions and the beginnings of the environmental devastation seen near the smelters in the mid-1970s. Large quantities of dust containing a range of heavy metals were also emitted. Significant investments are now driving a modernisation programme at the Pechenganikel complex to reduce these emissions.

BARENTSPHOTO

Around 10 000 people are employed at the Pechenganikel Mining and Metallurgical Combine.

Copper and nickel production

In contrast to earlier times when large quantities of ore were imported from Norilsk in Siberia, copper and nickel production at the Pechenganikel complex is now based on ores mined locally. Large quantities of ore are obtained from the open-cast mine at Tsentralny near Zapolyarnyy. Open-cast mining extracts minerals that lie near the ground surface and as a by-product generates vast amounts of waste material that is usually dumped in mounds near the mines. These dumpsites are unsightly and can result in large quantities of dust being blown into the surrounding areas. Toxic substances leaching out of these waste materials can also contaminate local water courses.

Copper and nickel ore is processed in the concentrating plant at Zapolyarnyy. The concentrate is then transported to the roasting plant in Zapolyarnyy to manufacture hardened copper and nickel ore pellets or to the smelting plant in Nikel where the final products are copper and nickel matte blocks weighing around 14 tonnes. The roasting house and smelting plant are major sources of pollution, with large emissions of sulphur dioxide, toxic heavy metals and dust. Some of the sulphur dioxide released from the ore at high temperatures is recovered and used as a raw material for sulphuric acid production at a site in Nikel. Granulated slag formed during the smelting process is dumped at a site on the bank of the River Kolosjoki (see map on page 16).

BARENTSPHOTO

Tsentralny mine, Zapolyarnyy. Blasting and the excavation of vast amounts of rock and ore have considerably damaged the natural landscape.

Wastewaters

Activities at the Pechenganikel complex result in large quantities of wastewater. In 2005, around 26 million cubic metres of wastewater were discharged into surface waters, with around 8 million cubic metres discharged into the River Kolosjoki. Despite efforts to reduce the heavy metal levels in these waters, concentrations are still very high.

Sulphur dioxide emissions

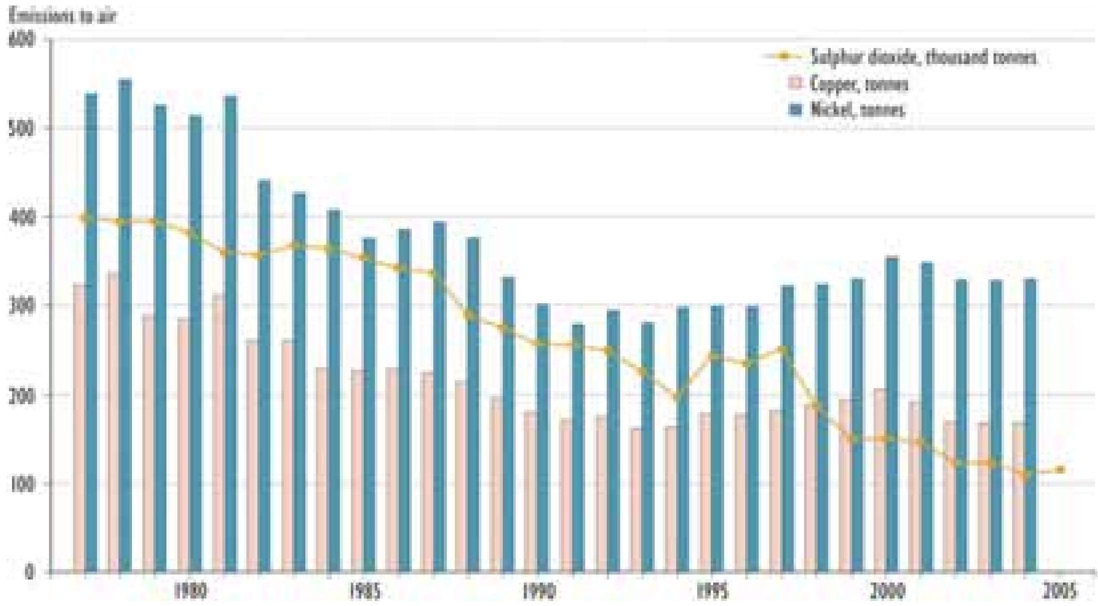
Copper and nickel production at the Pechenganikel complex has been responsible for large emissions of sulphur dioxide since operations first started in 1933. Emissions were around 100 000 tonnes a year for the first 30 years and then increased dramatically through the 1970s to peak at around 400 000 tonnes in 1979. This was due to a switch from local ore with a sulphur content of around 6.5% to ore brought in from Norilsk in Siberia with a sulphur content of around 30%. Emissions have since declined owing to lower production in the immediate post-Soviet era, to the greater use of local ore and to greater quantities of sulphur dioxide being recovered for sulphuric acid production.

Heavy metal emissions

Metals in their gas form condense on fine particles in the stacks before being released into the atmosphere. The main heavy metals released through production processes at the Pechenganikel complex are nickel and copper, although large quantities of cobalt and other toxic metals are also emitted. Copper and nickel emissions were greatest in the 1970s and then declined through the 1980s. Since then, copper and nickel emissions have been relatively stable although there is now some evidence of a recent slight increase in nickel emissions.

After the ore is extracted from the mines, it is crushed and ground to remove waste materials. An enriched ore or concentrate is then produced which is sent for smelting at the blast furnace. This ore is melted at high temperatures in the blast furnace producing a molten metal and slag. Once the molten metal cools a metal matte block is produced, this matte block represents the final stage in the smelting process.

ALL PHOTOS: NORILSK NIKEL



Although the total quantity of sulphur dioxide emitted from the smelters is now around 75% lower than when emissions peaked in the late 1970s, emissions are still high. For example, the total amount of sulphur dioxide emitted in 2004 from the combine was around four times higher than the sulphur dioxide emissions for the whole of Norway.

Further emissions reductions are planned

Norway and Russia have worked together for several years to reduce emissions from the Pechenganikel combine. The goal is to reduce emissions to 12 000 tonnes of sulphur dioxide per year and 300 tonnes per year for dust. These reductions are planned to be met by a new pelleting plant in Zapolyarnyy and a new smelter in Nikel, and by modernising the sulphuric acid plant in Nikel. Total costs are expected to be around US$ 93.5 million. The modernisation programme has been subject to some delays but it is hoped that completion will be achieved by 2010.

The environmental impact of non-industrial activities is low

Agriculture, fishing, forestry and reindeer herding are important occupations in rural areas of the Norwegian and Finnish parts of the region. Although the impact of these activities on environmental quality is extremely limited, intensive grazing by reindeer has reduced the lichen cover in some areas and may even have slowed the recovery of vegetation following the decline in sulphur dioxide emissions. Reindeer grazing has had no impact on the region's freshwaters.

Reliability of emissions data

The emissions data used in this report are based on mass balance calculations performed at the Pechenganikel Mining and Metallurgical Combine. Measured emissions data will only be available after the modernisation programme.


RAGNAR VÅGA PEDERSEN

Reindeer farming on both the Norwegian and Finnish sides of the border represents an important livelihood for many, with grazing areas in Norway and Finland carrying a substantial reindeer stock.

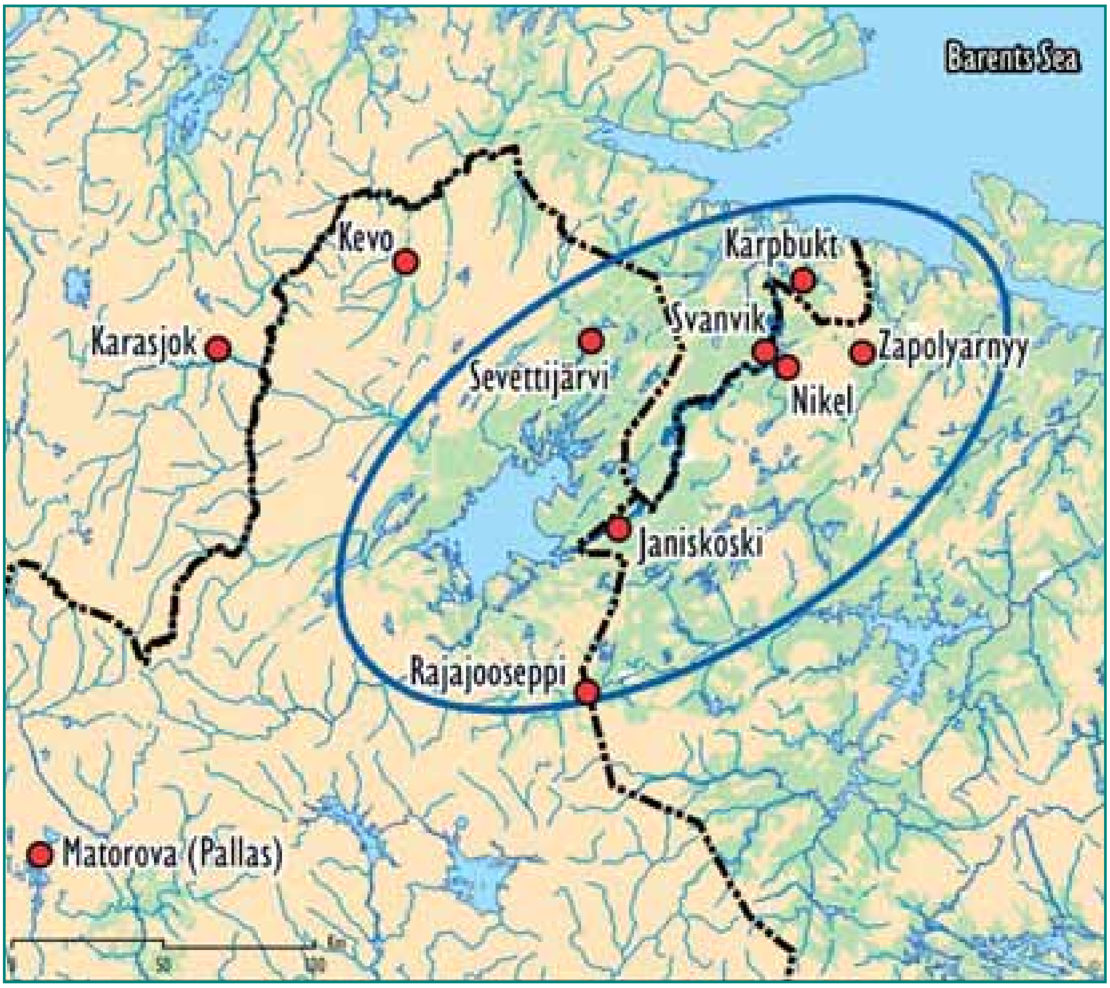
Air Quality

Air quality and environmental impacts have been monitored in the Pasvik-Inari area for several decades. Much of the monitoring has been undertaken through national programmes but there have also been several collaborative programmes. The first was a joint Norwegian–Russian baseline study of air pollution in 1988/90. This was followed by a study on air quality either side of the Norwegian–Russian border through the 1990s. The present project is the first to addresses air quality and environmental impacts in the joint Norwegian, Finnish and Russian border area.

Air quality is measured at purpose built stations

Atmospheric pollutants have been measured at purpose built monitoring stations across the border region for a number of decades. These stations range in proximity to the Pechenganikel complex from the Norwegian station at Svanik 9.2 kilometres west-northwest of Nikel, to the regional background station at Matorova (Pallas) in Finland around 300 kilometres southwest of Nikel. Some of the datasets recorded at these stations are long enough to show whether average concentrations are increasing, decreasing or staying the same over time. The longest dataset for sulphur dioxide concentrations in air has been recorded at Svanik and extends from 1974. For heavy metals, the longest dataset has also been recorded at Svanik and extends from 1988.

Since the breakdown of the Russian monitoring station in Maajavri in summer 2001 there has been no monitoring to the northeast of the smelter. This is likely to be the area most affected by the smelter emissions since it falls within the path of the prevailing winds.



Existing monitoring stations within Norway, Finland and Russia (red dots) were used to measure air quality in the border area during this study.

Regional background monitoring

The stations at Karasjok in Norway, Janiskoski in Russia, and Matorova (Pallas) in Finland are defined as regional background monitoring stations. Such stations are less affected by local air pollution and air quality at these sites reflects long-term trends in the composition of the atmosphere. Measurements at Karasjok, Janiskoski and Matorova/Pallas provide a baseline for determining changes in air quality due to local or regional sources.

Air quality is assessed differently by the three countries

Finland is a member of the European Union and so relates monitoring data to limit values and target values for human health and ecosystems set by the Air Quality Framework Directive and its various Daughter Directives.

Air Quality Framework Directive

In 1996, the European Council adopted Framework Directive 96/62/EC on ambient air quality assessment and management ("The Air Quality Framework Directive"). This introduced air quality standards for previously unregulated air pollutants and set the timetable for Daughter Directives on air quality limits and alert thresholds for a range of pollutants. The Daughter Directives aim to harmonise monitoring strategies, measuring methods, calibration and quality assessment methods throughout the European Union.

Limit values for sulphur dioxide

The limit values for concentrations of sulphur dioxide set in the first Daughter Directive (1999/30/EC) to the Air Quality Framework Directive are intended to avoid, prevent or reduce the harmful effects of sulphur dioxide on human health and the environment as a whole.

- *The daily limit value for the protection of human health is an average concentration of 125 g/m^3 over a period of 24 hours. This concentration is not to be exceeded more than three times a year.*
- *The limit value for the protection of ecosystems is a concentration of 20 g/m^3 averaged over a calendar year and winter (1 October to 31 March).*

Norway is a member of the European Economic Area (also known as the Europeiske økonomiske samarbeidsområde – EØS – in Norway) and uses the same standards to determine air quality. Russia determines air quality by comparing monitoring data with maximum permissible concentrations accepted by its Health Ministry. Despite the different approaches the limit values for sulphur dioxide used in Finland/ Norway and Russia are broadly similar.

Although there are no identifiable thresholds below which heavy metals (such as nickel) are not a risk to human health, the European Council has adopted target levels for heavy metals in the very small airborne dust particles with the aim of keeping harmful effects as a whole as low as possible.

Target values for other pollutants

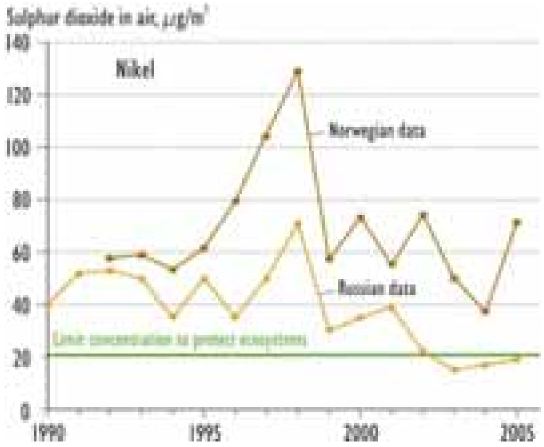
The fourth Daughter Directive (2004/107/EC) to the Air Quality Framework Directive sets target values for the concentration of arsenic, cadmium, nickel and benzo[a]pyrene in ambient air to avoid, prevent or reduce their harmful effects on human health and the environment as a whole. The target values are 6 ng/m^3 for arsenic, 5 ng/m^3 for cadmium, 20 ng/m^3 for nickel and 1 ng/m^3 for polycyclic aromatic hydrocarbons, represented by benzo[a]pyrene.

JUSSI PAATERO

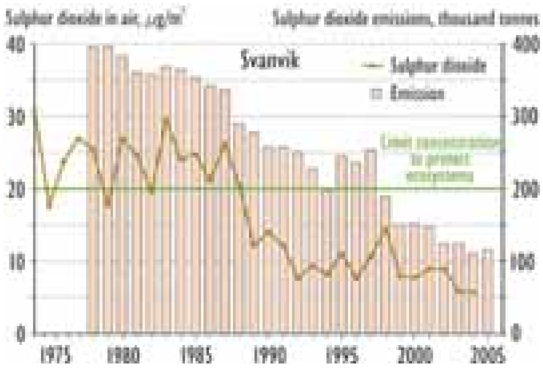
Regional background monitoring stations such as the one at Matorova (Pallas) are useful for studying trends in the amounts of pollutants transported into the Arctic from long-range sources. Such stations contribute data to EMEP (European Monitoring and Evaluation Programme) which is a scientifically-driven programme under the UN-ECE Convention on Longe-range Transboundary Air Pollution.

BJARNE SIVERTSEN

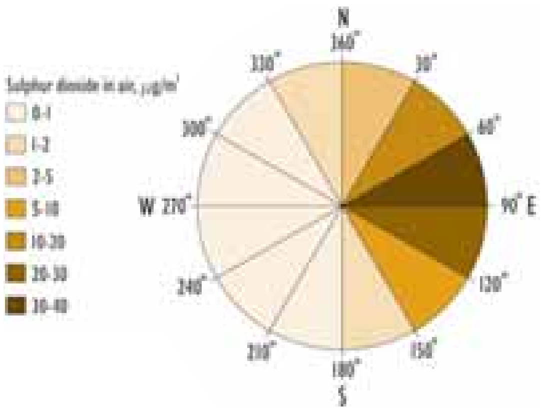
The air quality monitoring station at Nikel owned by NILU (photo) was one of the stations providing air quality data for the Pasvik Programme. Air quality monitoring at this station is still ongoing.



According to the Russian monitoring data, sulphur dioxide concentrations in Nikel have been at or below the limit value to protect ecosystems since 2002. In contrast, the Norwegian monitoring data indicate that sulphur dioxide concentrations in Nikel are over three times higher than the limit value. Studies are needed to resolve the reasons for this significant difference between the two data sets.



Annual average sulphur dioxide concentrations in air at Svanik appear to be decreasing in line with the progressive reduction in sulphur dioxide emissions from the smelters.



At Svanik, sulphur dioxide concentrations in air are highest when the winds are blowing from the smelters in the east. In winter 2005/06, winds from the east-northeast resulted in concentrations around 13 times higher than the winter average. These pulses of highly polluted air typically last for a few hours.

Sulphur dioxide levels in air are declining

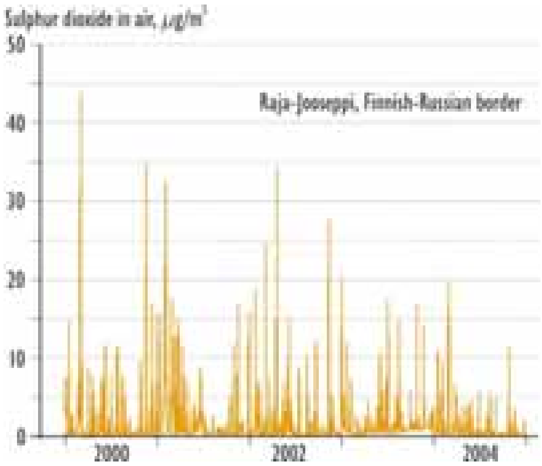
The air monitoring stations closest to the smelting plant are located in residential areas of Nikel: two operated by the Russian Murmansk Department for Hydrometeorology and Environmental Monitoring and a single station operated by the Norwegian Institute for Air Research. Sulphur dioxide levels in these urban areas are relatively high and due to diffuse emissions from the smelting operations. The highest concentrations occur when the winds are blowing from the smelter to the northeast.

Although the annual average sulphur dioxide levels based on the Norwegian data are consistently higher than those based on the Russian data, both data sets show the same basic pattern with concentrations in Nikel peaking in 1998 and then declining by at least 50%. The reasons for the difference between the Norwegian and Russian datasets are not clear but may include proximity to the diffuse emission sources, local meteorological conditions, and differences in the measurement procedures.

At Svanik, 9.2 kilometres west-northwest of Nikel, the annual average sulphur dioxide concentration in air exceeded the limit value for the protection of ecosystems a number of times during the 1970s and 1980s. Air concentrations at Svanik are now declining and the limit value has not been exceeded since 1989. Annual average sulphur dioxide concentrations in air are also below the limit value at the other air monitoring sites within the border region.

Peaks in sulphur dioxide concentration coincide with winds from the smelters

Although the average sulphur dioxide concentrations in air at the monitoring sites are generally low, many of the stations in the border region record short-term peaks that are well above the air quality guidelines. These peaks indicate periods of air pollution. Short periods of elevated sulphur dioxide concentration have been recorded at all the air monitoring stations, including Raja-Jooseppi on the Finnish–Russian border around 135 kilometres south-southwest of Nikel and at the regional background station in Matorova (Pallas) in western Lapland 300 kilometres to the southwest of Nikel.



The air monitoring station at Raja-Jooseppi on the Finnish-Russian border recorded 15 air pollution episodes in 2002. Peak concentrations as high as this are rare in industrial areas and are almost never seen in other background areas of Finland.

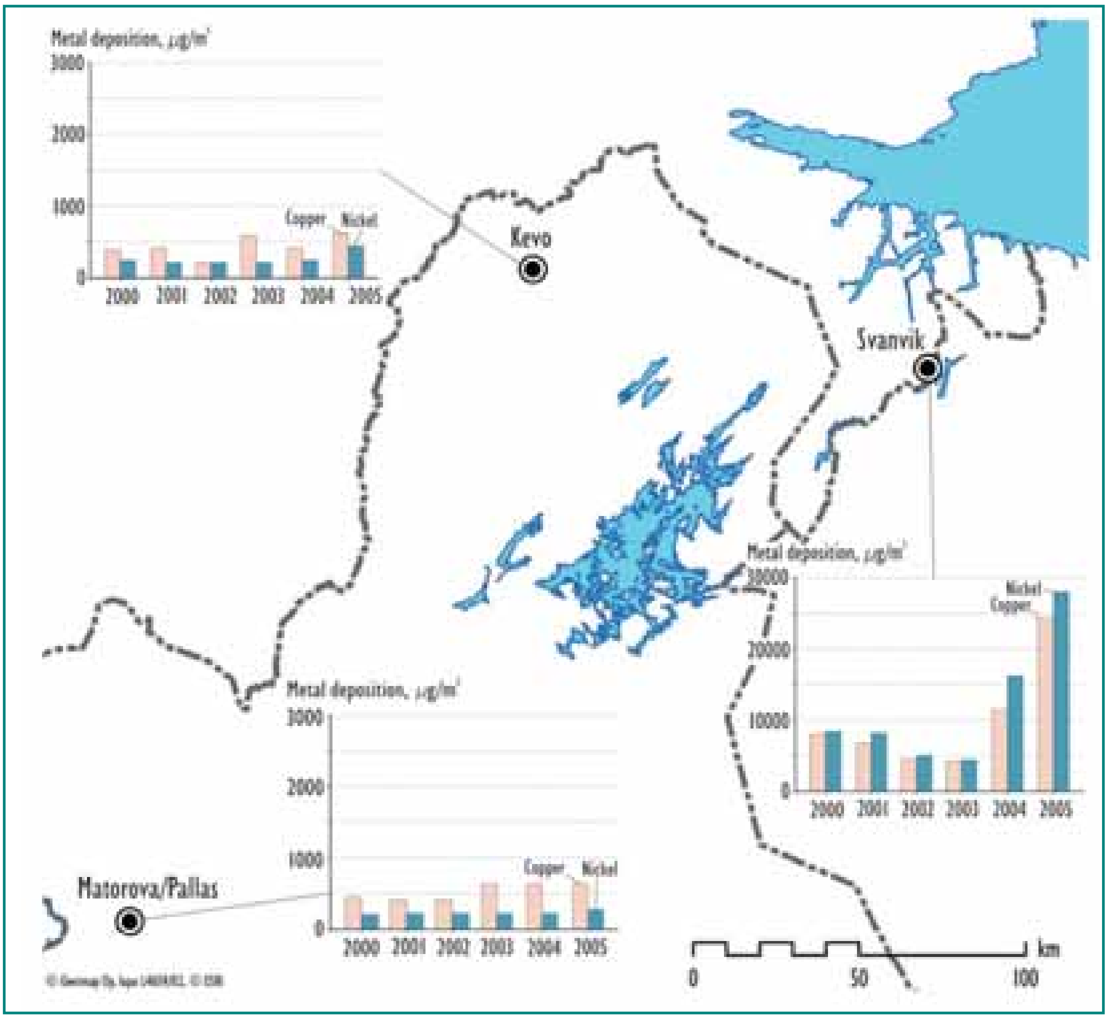
Heavy metal deposition decreases with increasing distance from the smelters

Levels of heavy metal deposition vary widely across the border region. Nevertheless, there is a clear trend of decreasing heavy metal deposition with increasing distance from the smelters, to the north, south and west of the smelters. There is no information about deposition to the east of the smelters. Sulphate deposition also decreases with distance from the smelters but the trend is less clear, probably due to the masking effect of sulphate from marine sources depositing onto sites near the Barents Sea coast.

For heavy metals and sulphate, the deposition is characterised by occasional peaks in concentration. These peaks are associated with winds arriving from the direction of the smelters. The prevailing winds normally carry the smelter emissions towards the northeast, away from the study area and further into Russia.

Heavy metal deposition is increasing

Copper and nickel deposition across the border region increased between 2000 and 2005. The reasons for this increase – which has occurred during a period of decreasing sulphur dioxide emissions and decreasing sulphur dioxide concentrations in air – are unclear and need resolving.



An increase in copper and nickel deposition since 2000 is apparent in the immediate vicinity of the smelters and at background stations as far away as Kevo.

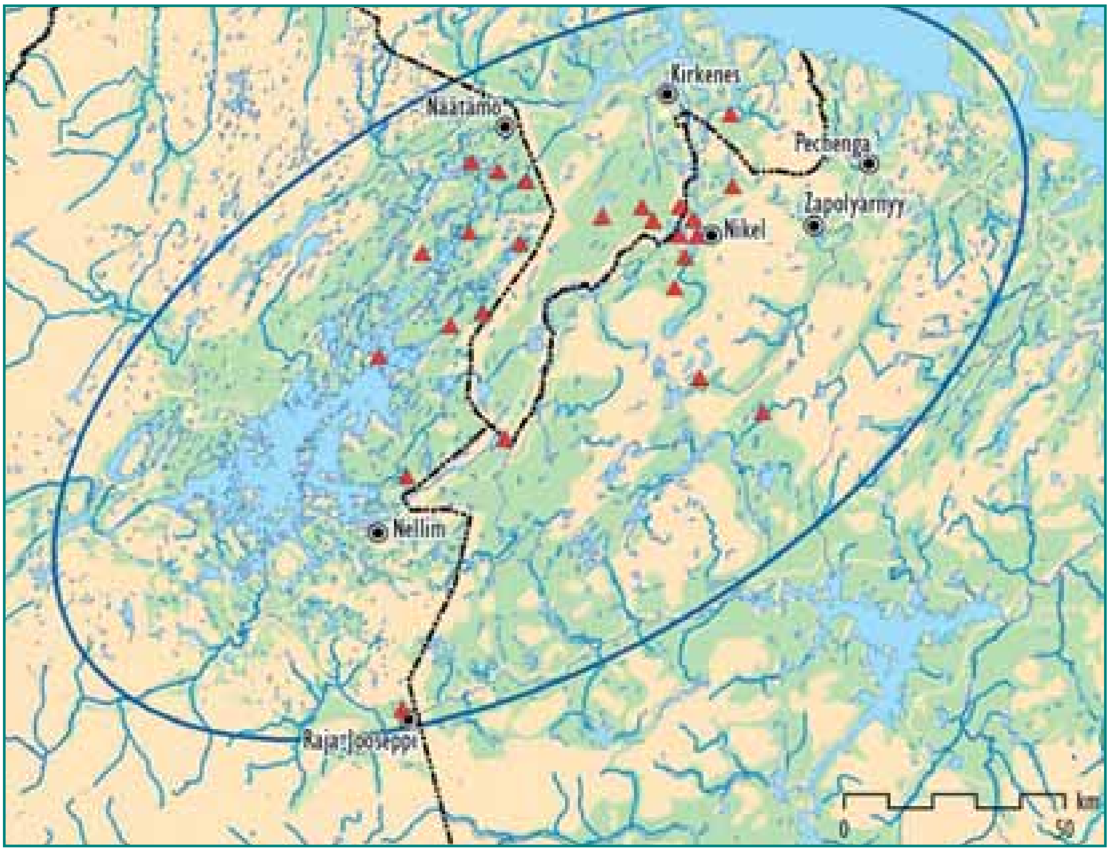
Terrestrial Ecosystems

Many monitoring activities have been carried out in the border area to assess the effects of emissions from the Pechenganikel complex on terrestrial ecosystems. The aim of this part of the project was to integrate and harmonise ongoing national activities in order to develop a sensitive and cost-effective trilateral programme. This has been achieved by establishing a Terrestrial Ecosystem Monitoring Network (TECM) based mainly on monitoring sites along transects to the north, west and south of the Pechenganikel complex. There are no plots to the east of the smelters and new plots could not be established during this project for various reasons.

A substantial amount of planning and effort was necessary in the early stages of the project to ensure that the data generated by the various groups of researchers would be directly comparable. Many scientists took part in field exercises and workshops and the three national laboratories responsible for the chemical analyses took part in inter-laboratory tests to establish the comparability of their data. Data handling and reporting procedures were also agreed.

Heavy metal levels in soils are unlikely to fall

Heavy metal concentrations in soils follow the same pattern as for atmospheric deposition, with soils nearest the smelters containing extremely high levels of many heavy metals and concentrations then decreasing with increasing distance from the smelters. These heavy metals have accumulated over the lifetime of the smelters and concentrations are unlikely to fall even if heavy metal emissions decline following the modernization programme. Although a large proportion of the metals are in an immobilized form, concentrations of plant-available metals are still very high and enough to prevent seedlings from establishing in the industrial barrens immediately around the smelters. Despite high emissions of sulphur dioxide, soils in the immediate vicinity of the smelters are not suffering from soil acidification. This is due to the protective effects of the calcareous geology in this region.



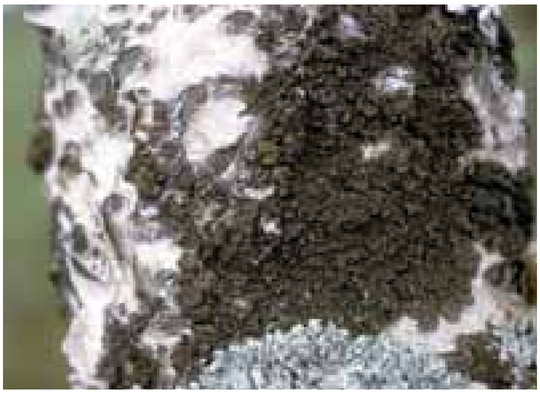
The monitoring sites are located in forested areas and are mostly based on plots from three large forest monitoring projects. The plots represent north-south and east-west gradients related to the mining and smelting complex centred on Nikel and Zapolyarnyy. The sites include heavily affected areas and undisturbed reference areas.

Bio-indicators confirm deposition measurements

Heavy metal concentrations in a range of mosses and lichens are highest near the smelters, decreasing with increasing distance from the smelters. The same pattern is also evident for sulphur in mosses and lichens, but the trend is not as clear as it is for metals.

Heavy metal concentrations in mosses growing nearest the smelters are now higher than a decade ago.

DAN AAMLID



DAN AAMLID

Lichens like this *Melanelia olivacea* (above) and mosses like this *Pleurozium schreberi* (below) depend on leaf surfaces rather than roots to take up nutrients and so accumulate high levels of atmospheric contaminants. Chemical analyses of mosses and lichens show the extent to which heavy metals emitted from the smelters on fine dust particles are depositing onto the ground surface. In contrast, mosses and lichens are not considered good bio-indicators for sulphur deposition.

Epiphytic lichens indicate recovery in the least polluted areas

Epiphytic lichens are sensitive indicators of air pollution and the extent of their presence on tree bark is a good measure of air pollution, especially for sulphur dioxide. The most heavily polluted area immediately around the smelters is an epiphytic lichen "desert". Epiphytic lichens increase westward from the smelters but are present only at the very ends of the northern and southern transects, 30 and 35 km from the smelters respectively.

Over the last decade, there has been a significant recovery in the extent of epiphytic lichens on trees in the least polluted plots to the west of the smelters.

Epiphyte

An epiphyte is a plant that grows on another plant for support or anchorage rather than for the supply of water or nutrients.

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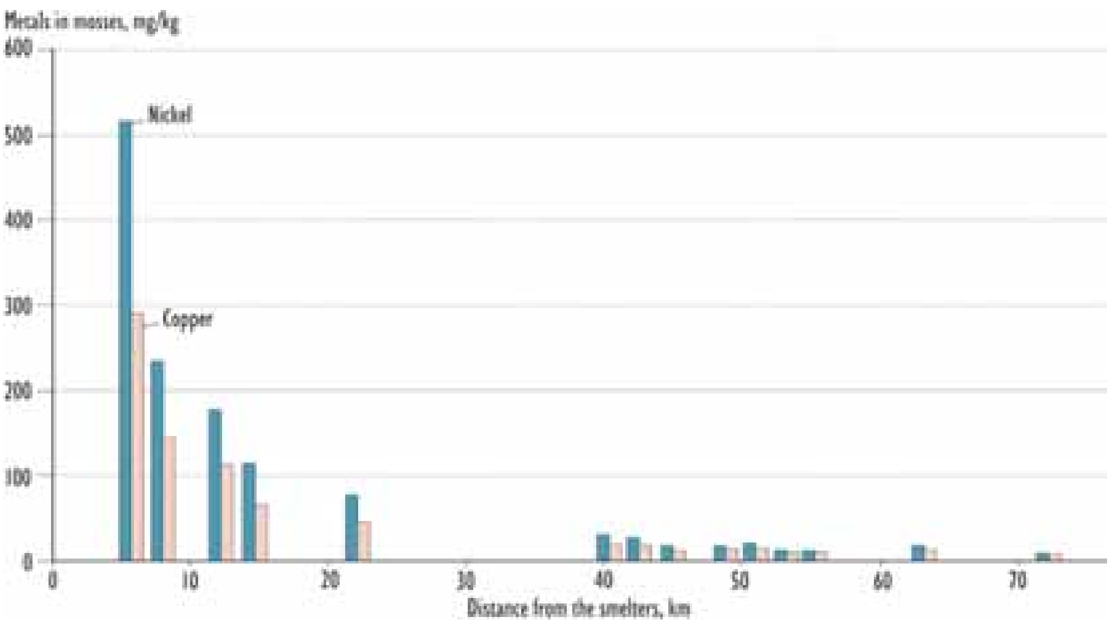
Epiphytic lichens are common on birch in unpolluted areas of the border region (left), but have been severely affected in areas exposed to air pollution (right).



The decrease in heavy metal concentrations with distance from the smelters is greatest within the first few kilometres.

Impacts of smelter emissions on trees are unclear

Despite large variations in the growth of Scots pine trees across the border region there are no indications that the smelter emissions have had a negative effect on tree growth, not even in the immediate vicinity of the smelters. However, smelter emissions do appear to have affected the condition of the trees. Scots pine trees are in better condition on moderately polluted sites in Norway than on the heavily polluted Russian sites. But this striking cross-border difference may reflect the combined effects of climate, soil conditions and pollution on the trees, rather than pollution alone, since there are Scots pine trees in poor condition in some background areas. Birch is less sensitive to pollutants than pine because it sheds its leaves in autumn. Although there are some indications that pollution has reduced the health of birch in the border area the data are not conclusive.

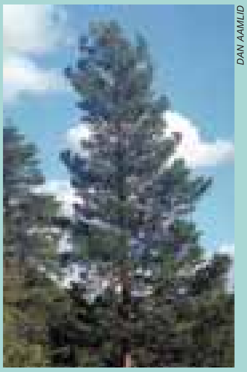
Ground vegetation near the smelters is still heavily affected

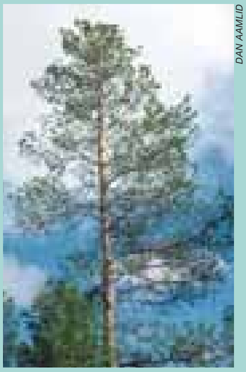
The ground vegetation in the border region follows a broad gradient from lichen-dominated communities in the unpolluted areas to communities dominated by dwarf shrubs in the heavily impacted areas. Many dwarf shrubs are relatively resistant to the effects of heavy metals and other pollutants. Reindeer lichens and the common forest mosses and liverworts, which are very sensitive to pollution, are completely absent near the smelters.

There have been major changes in the composition of the ground vegetation since the early 1970s, especially for lichen-dominated communities. Lichen cover was at its lowest in the early 1990s following the very high sulphur dioxide emissions of the 1980s. Although the ground vegetation near the smelters is still badly affected, there are indications that some species, especially pioneer species of mosses and lichens, are now recovering on some Russian plots.

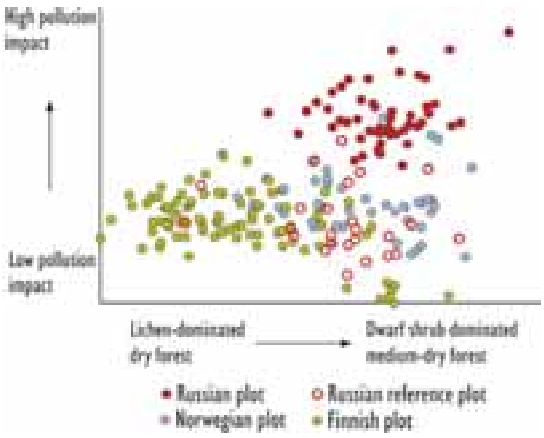
Crown condition

Crown condition is a term describing the overall vitality of a tree. One of the main components of crown condition is crown density. This refers to the percentage of needles or leaves present on a tree with respect to the "theoretical" amount on a "perfectly healthy" tree (i.e., 100%).





Crown density in Scots pine varies across the border region and is higher in some areas (left) than others (right)

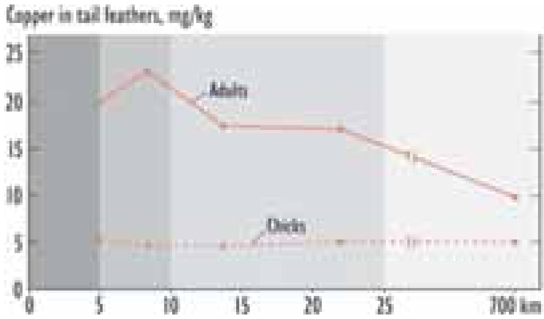


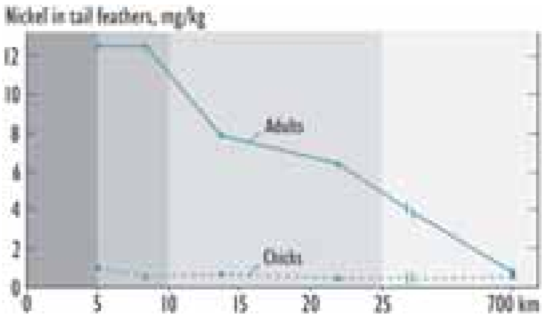
Changes in the structure of plant communities are common in polluted areas because plants differ in their tolerance to pollution. Lichens are particularly sensitive to sulphur dioxide and are replaced in heavily affected areas by dwarf shrubs such as crowberry.

Impacts on birds and small mammals are greatest near the smelters

The smelter emissions have had wide-ranging impacts on birds and small mammals. Heavy metal levels in pied flycatcher – an abundant hole nesting species in the border area – are higher near the smelters than in less affected areas. The pollutant load in the adults decreases with increasing distance from the smelters but is still much higher at a site 22 kilometres west of the smelters than in unpolluted areas. Breeding success in pied flycatcher is also lower in areas affected by the smelter emissions. This suggests that pied flycatchers breeding near the smelters are subject to considerable environmental stress.

There is some evidence of changes in small mammal populations near the smelters. Populations of grey-sided vole, ruddy vole, and common shrew are lower at a site 7 kilometres from Nikel than at a site 13 kilometres away. Also, at both sites there are around five times more grey-sided voles than ruddy voles. In unpolluted areas ruddy voles are usually more common.





Heavy metal levels in the tail feathers of adults decrease with distance from the smelters.

ALL PHOTOS: PAUL ASPHOLM

The weight of pied flycatcher chicks at fledging increases with distance from the smelter.

The shrew and pied flycatcher both represent the same trophic level, despite one being a small mammal and the other a bird. Shrews, like the pied flycatcher are likely to show signs of heavy metal accumulation due to their dietary habits.

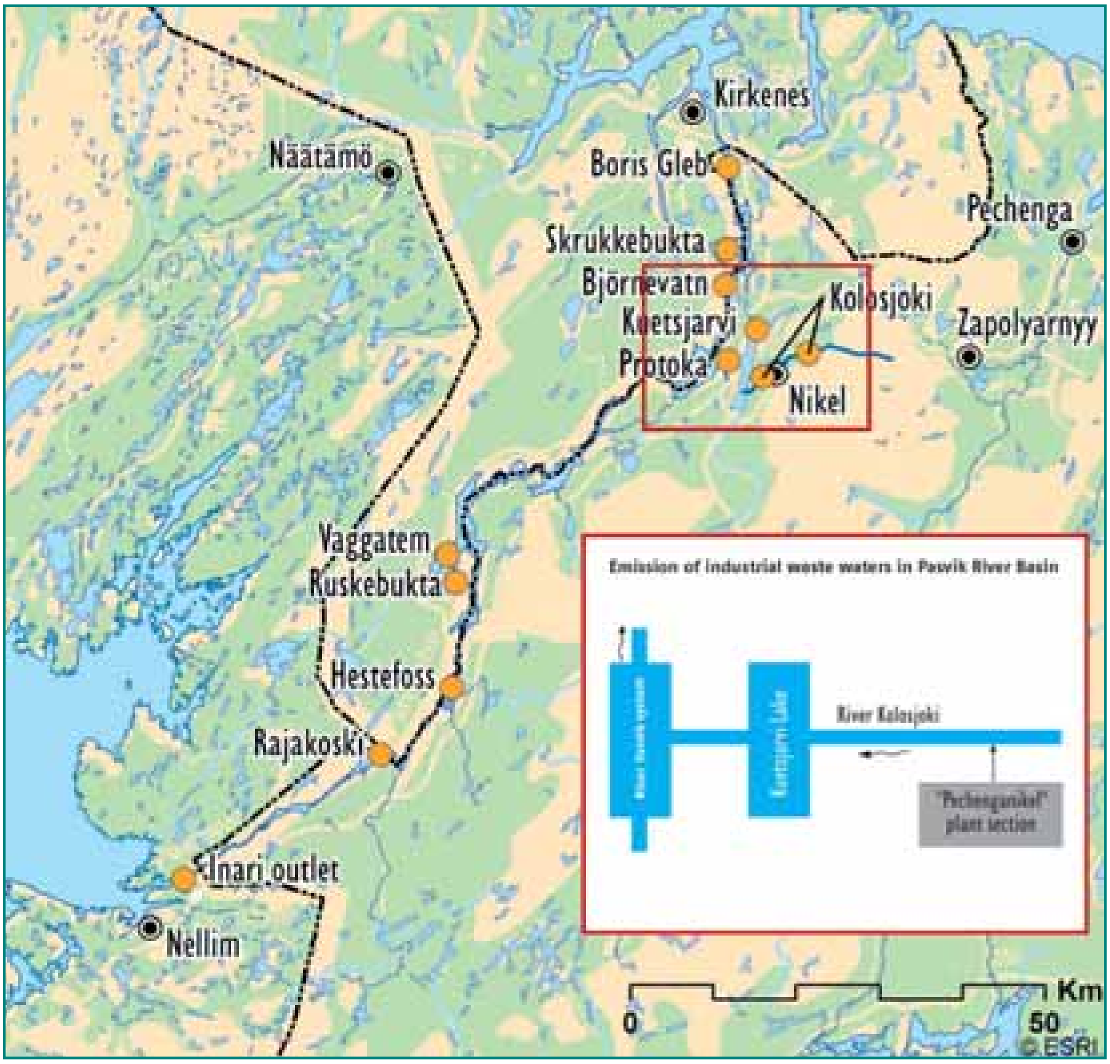
Freshwater Ecosystems

Many monitoring activities have been carried out in the border area to assess the effects of emissions from the Pechenganikel complex on freshwater ecosystems. Although there has been some bilateral co-operation between each of the three countries, most studies have been undertaken by Norway, Finland and Russia individually. The aim of this part of the project was to integrate and harmonise these ongoing national activities in order to develop a sensitive and cost-effective trilateral monitoring and assessment programme. Methodology used during this three-year project was in line with nationally or internationally agreed procedures. The comparability and quality of the chemical data were checked using inter-comparison exercises.

The extent to which freshwater bodies are or are not connected to the Pasvik watercourse affects the nature of their pollution

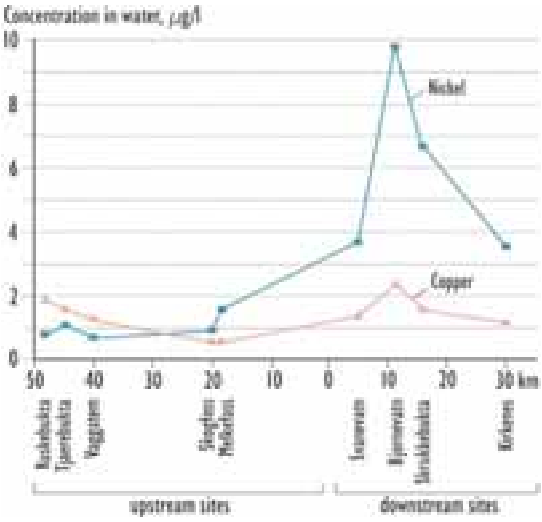
Freshwaters dominating the border area are of two types: those that are part of the vast interconnected network of rivers, lakes and streams making up the Pasvik watercourse and those that are not. The Pasvik watercourse receives pollutants via atmospheric deposition and via the wastewaters discharged into its lower sections through Lake Kuetsjärvi. Lakes and streams that are not directly linked to the Pasvik watercourse, as well as those upstream of Lake Kuetsjärvi, receive airborne pollutants only.

The Pasvik watercourse is made up of an interconnected network of rivers, lakes and streams. The schematic represents how the River Kolosjoki and Lake Kuetsjärvi flow from the site of the Pechenganikel plant into the River Pasvik system.



Parts of the Pasvik watercourse are extremely polluted

The environmental impact of the mining and metallurgical industry is clearly seen in the Pasvik watercourse, with high levels of heavy metals in water, sediments and fish in the immediate vicinity of the smelters. Concentrations upstream from the smelters are generally lower and similar to those in other parts of the border area.



Nickel concentrations in water vary little upstream of the Pechenganikel complex but increase sharply immediately downstream. The signal is much less clear for copper. This is because the nickel is mostly from the direct discharges, while the copper is mostly from the air. This results in a more even distribution of copper.

The same pattern occurs with organic pollutants in sediments, with concentrations highest in sediments from Lake Kuetsjärvi and progressively lower downstream. But unlike heavy metals, levels of many persistent organic pollutants and polyaromatic hydrocarbons in the Pasvik watercourse sediments are high relative to those in other parts of northern Norway.

Persistent organic pollutants

A common characteristic of most synthetic organic pollutants is that they break down very slowly. This allows them to persistent in the environment and, as most are fat-soluble, to accumulate in the fatty tissues of animals. Many persistent organic pollutants become increasingly concentrated at successive levels of the food chain and the highest levels are usually found in top predators.

Levels of some pollutants are increasing

Nickel concentrations in water have increased throughout the Pasvik watercourse since the mid-1990s, while copper levels have hardly changed. Higher concentrations of persistent organic pollutants in surface sediments than in slightly deeper sediments of Lake Kuetsjärvi show that levels of persistent organic pollutants have also increased over the last decade.

Impacts on fish are greatest near the smelters

Heavy metals in fish accumulate in different "target" organs. In whitefish, copper accumulates in liver while nickel levels are highest in kidney. High concentrations of heavy metals in internal organs can lead to problems such as kidney stones and other pathological changes. Many fish from Lake Kuetsjärvi have abnormalities in their tissues and internal organs. The frequency and severity of these problems within the Pasvik watercourse decrease with increasing distance from the smelters. This decrease in pathological abnormalities downstream from Nikel corresponds to the pattern for pollutant concentrations in fish.

PER-ARNE AMUNDSEN

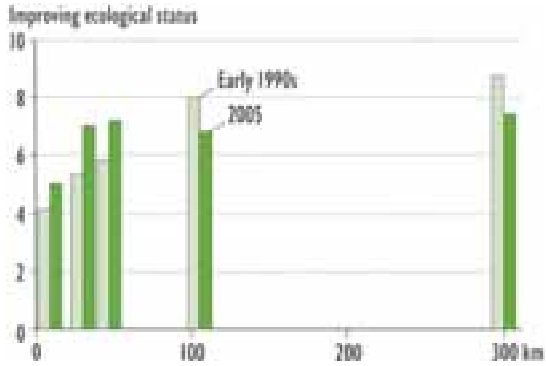
PER-ARNE AMUNDSEN

Researchers from Norway, Finland and Russia worked together during the three-year Pasvik Programme to investigate the accumulation of heavy metals in various species of fish. The photo shows Professor Per-Arne Amundsen from Norway (left) and Professor Yuri S. Reshetnikov from Russia (right) holding a whitefish caught in Lake Vaggatem. Whitefish is the dominant fish species in the small lakes near the smelters.

Other species found in the freshwaters of the border area include perch, pike and brown trout.

Some small lakes are showing signs of recovery from acidification

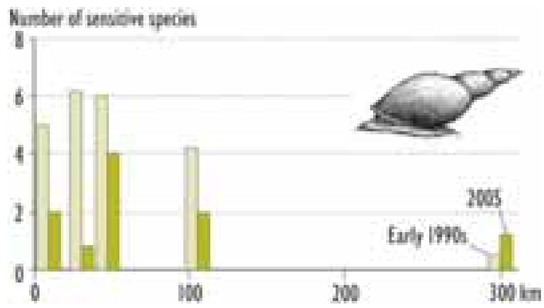
Although sulphur dioxide emissions are now much lower than at their peak in the late 1970s, sulphate levels in lakes near the smelters are still much higher than in other areas of Fennoscandia. However, most of these lakes show no signs of acidification due to the protective effects of the local geology and alkaline dust emitted from the smelters. The more weakly buffered lakes in the mountain areas of Jarfjord (to the north), Sør-Varanger (to the northwest) and Vätsäri (to the west of Nikel) have shown signs of acidification in the past. Although there appears to have been some recovery from acidification in these small lakes, almost certainly due to the lower emissions of sulphur dioxide, effects on acid-sensitive biota are still apparent.



Ecological quality, especially in those lakes nearest the smelters, has recovered significantly as sulphur emissions from the complex have declined.

Buffering capacity

Freshwaters vary in their ability to withstand acid inputs. The extent to which lakes can resist a change in pH and neutralise acid inputs – their buffering capacity – reflects the local geology and the amount of buffering material entering from the catchment. Fly ash emitted from the smelters and their associated power stations is an important source of alkaline material that helps to neutralize acidic deposition.



Despite the improvement in ecological quality, those lakes nearest the smelters show a clear fall in the numbers of pollution-sensitive species. The reasons for this apparent anomaly are unclear.

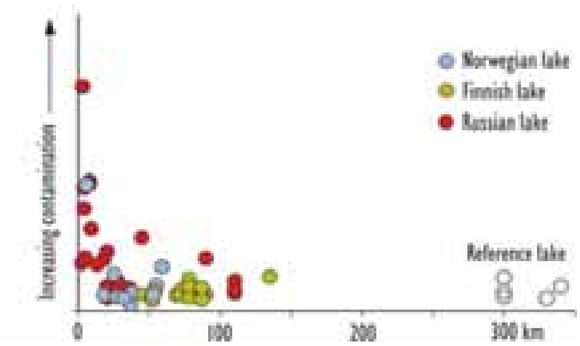
Community structures for acid-sensitive and pollution-sensitive invertebrates in lake sediments show a clear improvement in ecological status for lakes within 30 kilometres of the smelters, to the extent that there is now little difference compared to lakes in unpolluted areas. Although the signs of lake acidification seen in the early 1990s are now gone, there has been a dramatic decrease in the total number of sensitive species across most of the border area and the reasons for this are not clear.

In the late 1980s, acidification-induced damage was seen in fish populations in small lakes around 30 kilometres to the north of the smelters. Two decades later, the brown trout population in one of these, Lake Otervatn, has now almost completely recovered.

The strongest impacts concern heavy metals

Heavy metal concentrations in lakes are higher than background levels throughout the border region but are only a problem within 10 kilometres of the smelters. Concentrations of nickel and copper in this zone are several times higher than in other areas and in some lakes near the smelters are above the levels causing harmful effects in the lake biology. The highest concentrations occur in lakes between the smelters and several of these have lost all their fish. Levels in some lakes to the north of the smelters are at their highest since monitoring began in 1990.

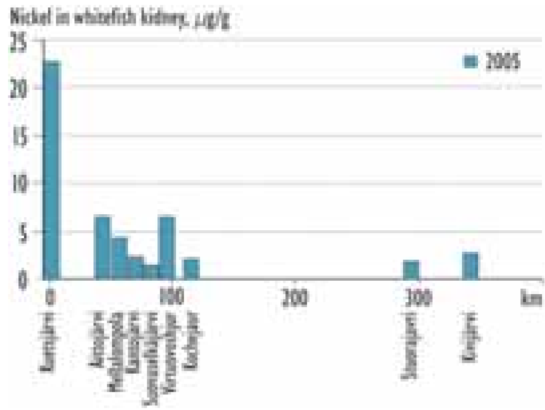
The upper centimetres of sediments at the bottom of lakes represent material that has settled out of the water over the last ten to twenty years. In the border area there is a clear relationship between the extent of surface sediment contamination and distance from the smelters. Sediment concentrations of nickel and copper in lakes within 10 kilometres of the smelters can be over a hundred times higher than the unpolluted levels, while concentrations in lakes 10 to 30 kilometres from the smelters are around five times higher. It is not until 50 kilometres or more from the smelters that concentrations reach background levels.



Lake sediments are most contaminated by heavy metals within 10 km of the smelting complex. Normal concentrations are not apparent until around 50 km from the smelters.


MARTTI SALMINEN

Nickel concentrations in whitefish kidney from some small lakes are similar to those in whitefish from the Pasvik watercourse upstream from the outlet of Lake Kuetsjärvi. Although there appears to be a slight decrease in nickel concentration with increasing distance from the smelters this is not the case for copper, possibly due to greater variability in the natural copper levels in the border area.



Nickel concentrations in whitefish kidney decrease rapidly with distance from the smelter, but appear to have doubled in the last three years at a site 100 km south of Nikel.

Groundwater

There is no evidence of anthropogenic pollutants in groundwater – water that has percolated through the surface soil into the bedrock – within the border area.

Human health

The Pasvik-Inari area has strong traditions in the exploitation of fish. This includes subsistence, recreational and commercial fishing and with an annual harvest ranging from 200 to 600 tonnes of fish over the past few decades. This project has revealed high levels of heavy metals in fish from some parts of the border area, and elevated levels of persistent organic pollutants in fish from Lake Kuetsjärvi. Although concentrations of persistent organic pollutants in fish from Lake Kuetsjärvi did not exceed the maximum permissible levels in fish for human consumption, little is known about the total body burden of pollutants in fish caught in this region and this needs more investigation.

A vertical sediment core from a lake is extruded into slices which correspond to discrete time intervals. Changes in the chemical composition of these slices make it possible to construct a historical record of pollution levels. Sediment from the deepest core layers (usually deeper than 20 cm) is several hundred years old, and predates industrial development in northern Fennoscandia. For lakes receiving airborne pollutants only, concentrations in the sediments help to identify the dispersal area for emissions.

Conclusions

• Sulphur dioxide emissions from the smelters are now about 75% lower than in the 1980s. This is supported by official emissions statistics, by measurements at air monitoring stations, and by the recovery of sensitive plants such as lichens. Sulphur dioxide concentrations at Svanvik have been below the critical level for the protection of ecosystems since 1989 but are still excessive in some areas. In the town of Nikel, sulphur dioxide concentrations are three times higher than the limit value and air pollution episodes are also expected downwind, to the northeast of the smelter.

• There are signs of a significant decrease in the acidification of some lakes that were previously severely affected by sulphur in the smelter emissions. Improvements are evident in the water quality and fish populations of lakes around 30 kilometres northwest of the smelters. Recent studies show that the brown trout population in one lake has almost completely recovered.

• A corresponding decrease in heavy metal emissions does not appear to have occurred. Air monitoring data show that heavy metal deposition is currently unacceptably high and that this has been the case for some years: nickel deposition even appears to have shown a recent increase. Heavy metal accumulation in mosses has increased over the past fifteen years and there has been no decrease in heavy metal levels in the Pasvik watercourse for the last six years.

• The area affected by the smelter emissions is strongly determined by prevailing wind directions. Lake and river sediments, soils and plants contain elevated heavy metal levels up to around 50 kilometres to the north, southwest and west of the smelters. There are no signs of soil acidification.

• There are clear gradients of decreasing heavy metal concentration with increasing distance from the smelters for many components of the terrestrial and freshwater ecosystems. However, these gradients are steep and short, extending for a few tens of kilometres only.

• The effects of heavy metal emissions from the smelters are apparent in the Pasvik watercourse. Pollutants enter the system via atmospheric deposition as well as through wastewater discharges. Concentrations are highest near the smelters, decreasing downriver and upstream of the inputs.

• There is little information on environmental quality to the east of the smelter complex.

• Fish contain high concentrations of heavy metals in some parts of the border area, especially in Lake Kuetsjärvi. The concentrations of persistent organic pollutants and polyaromatic hydrocarbons are highest in surface sediments, indicating that the levels have increased over the last ten years. The sediments in Lake Kuetsjärvi are classified as "markedly" to "strongly contaminated" by heavy metals, persistent organic pollutants and polyaromatic hydrocarbons.

Summary recommendations for future monitoring and assessment in the cross-border area *

The results of this project clearly show the need for a joint, trilateral monitoring programme to assess the effects of the modernisation process at the Pechenganikel combine and to assess the future state of the environment in the Norwegian, Finnish and Russian border area. The monitoring network will provide the means for carrying out this task. However, there are a number of issues and topics which still need to be addressed.

1 The joint monitoring programme should be implemented gradually. Sub-programmes that have been harmonized and tested during the project, and which are now ready for implementation, should be started in early 2007. Other components should be developed and included in the trilateral monitoring programme as soon as possible.

In order to assess the effects of the modernisation process on air quality in the border area, reliable emissions data and results from deposition models are essential to estimate the extent of the area affected by air pollution and to link air pollution to effects on terrestrial and aquatic ecosystems.

2 It is extremely important to guarantee continuation of the most important measurements (sulphur dioxide, meteorology, heavy metals in air and precipitation, other major components) using harmonized equipment at the existing key air-quality monitoring stations at Nikel in Russia, Svanvik in Norway and Sevettijärvi in Finland. An additional monitoring site should be established to the northeast or east of the smelter complex.

There are signs of a slight recovery in the condition of terrestrial and aquatic ecosystems in some parts of the border area. The ongoing modernization of the Pechenganikel smelter complex is very likely to lead to a further decrease in emissions. Monitoring the recovery and its biological effects are essential. On the other hand, concentrations of pollutants in many components of the ecosystems are still excessive and will continue to have a considerable effect on the environment in certain parts of the region.

3 Monitoring the selected range of attributes and parameters should be continued at predefined intervals on the network of plots employed in the terrestrial sub-project, and at the sampling locations in the aquatic subproject.

4 Integrated studies should be carried out in a number of catchment areas (e.g., lake and surrounding land area) in order to calculate input–output budgets for heavy metals and acidifying components.

Very little is known about the sources of organic pollutants (persistent organic pollutants and polyaromatic hydrocarbons) in the air and in terrestrial and aquatic ecosystems in the areas affected by the Pechenganikel industrial complex. The limited screening of organic pollutants, performed at a number of locations in the Pasvik-Inari watercourse during the project, suggests that the input of organic pollutants from local sources, possibly the Pechenganikel smelter complex, could be relatively high.

5 Extensive screening of persistent organic pollutants and polyaromatic hydrocarbons in the air and in terrestrial and freshwater ecosystems of the border area is strongly suggested in order to identify and map possible sources and to determine the levels of organic pollutants and the possible threat of accumulation in food chains.

Global climate change will undoubtedly affect the functioning of terrestrial and aquatic ecosystems and the sensitivity of species in the area. A future integrated assessment should take into account the combined effects of the modernization of the Pechenganikel smelter, the interactive effects of climate change, the long-range transport of pollutants from sources outside the area, and changes in land use in the Norwegian, Finnish and Russian border region.

6 An international research group (with representatives from governmental authorities) should be established to undertake the monitoring work as co-operation between the three countries, and to develop the monitoring programme in accordance with present and future challenges.

There is no information available on air quality, deposition and the state of terrestrial and aquatic ecosystems to the east of the smelters.

7 One new air quality monitoring and meteorological station, four new terrestrial ecosystem monitoring plots along a transect running eastward from Nikel, and a number of aquatic monitoring locations should be established to supply the missing information. The state of the environment should be established by assessing all information from these plots as soon as possible.

** The full recommendations arising from the Interreg IIIA Kolarctic project "Development and Implementation of an Environmental Monitoring and Assessment System in the joint Finnish, Norwegian and Russian Border Area" are published in full in the project report by Stebel et al. (2007).*

Stebel, K., Christensen, G., Derome, J. and Grekelä, I. (eds.), 2007. State of the Environment in the Norwegian, Finnish and Russian Border Area. The Finnish Environment 6/2007. 98 p. Jyväskylä.

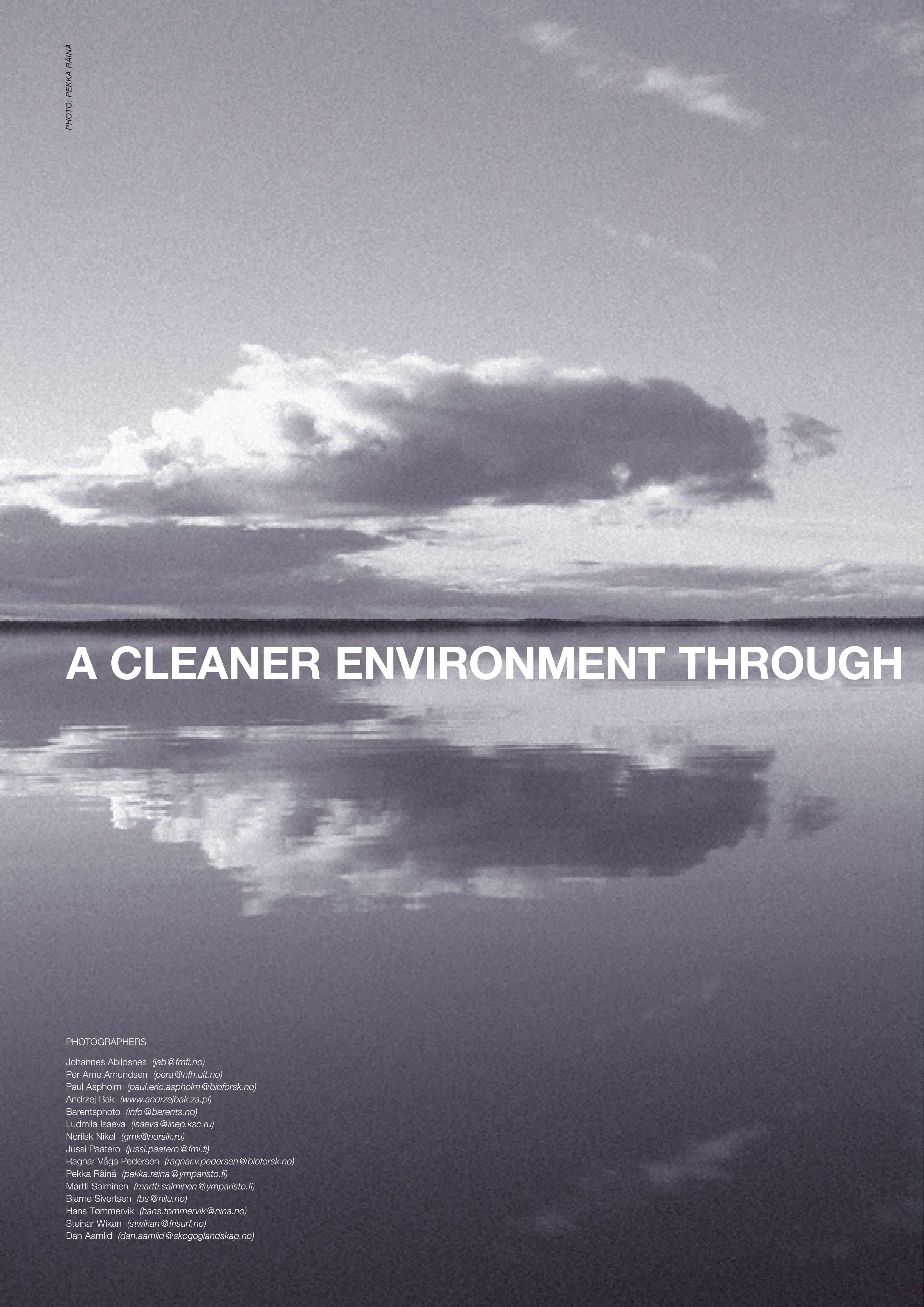


PHOTO: PEKKA RÄINÄ

A CLEANER ENVIRONMENT THROUGH

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CROSS-BORDER COOPERATION

COVER PHOTO: PER ARNE AMUNDSEN

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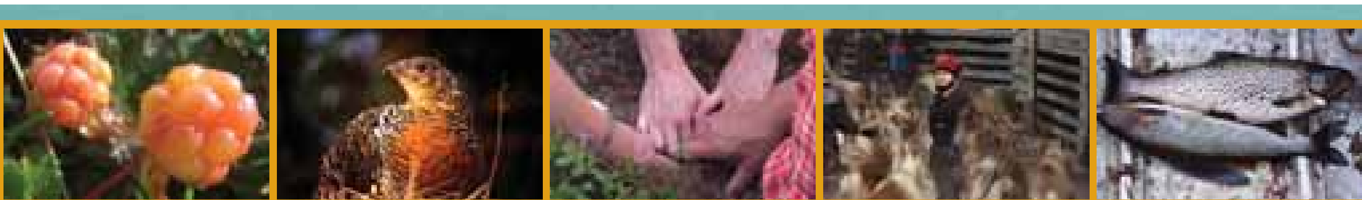

PHOTOS: LUDMILA ISAEVA, STEINAR WIKAN, HANS TØMMERVIK, RAGNAR VÅGA PEDERSEN, JOHANNES ABILDSNES

The Pasvik Programme – a trilateral environmental monitoring and assessment programme – was carried out by an international group of scientists representing more than twenty organisations in Norway, Finland and Russia.

This publication summarizes information on the current state of the environment in the Norwegian, Finnish and Russian border area and describes changes in environmental quality that have taken place over recent years. The major threat to the natural environment in this area is posed by the Pechenganikel mining and metallurgical complex on the Kola Peninsula in northwest Russia, where copper and nickel ores have been mined and processed for over 70 years.

Over the period 2003 to 2006, environmental authorities and researchers in the three countries worked together to draw up a long-term programme for environmental monitoring that will provide comprehensive information on future changes in environmental quality in the border area and which will make it possible to assess the effects of the modernization process at Pechenganikel.

This summary report is based on the comprehensive scientific status report *State of the Environment in the Norwegian, Finnish and Russian Border Area.*

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