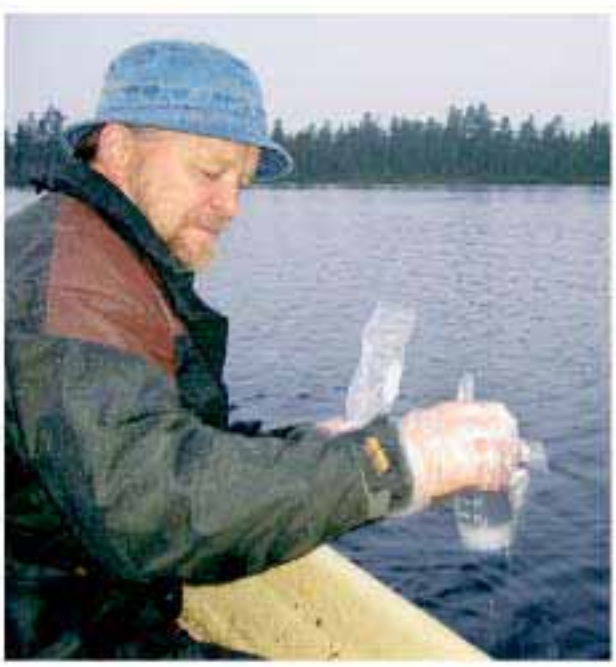
Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area – Implementation Guidelines

Annukka Puro-Tahvanainen, Ilona Grekelä, John Derome and Kerstin Stebel (editors)



Lapland Regional Environment Centre, Finland
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Rovaniemi 2008

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1. General about the programme

This programme is the main outcome of the two international projects Interreg III Kolarctic "Development and implementation of an environmental monitoring and assessment programme in the joint Finnish, Norwegian and Russian border area", carried out during 2003 – 2006 and 2007-2008.

An international group of scientists from more than twenty research institutes and environmental authorities of three countries participated in the process of creating of a long-term monitoring programme.

Participating organizations:

1. Lapland Regional Environment Centre (LREC), Finland
2. Office of the Finnmark County Governor, Norway
3. Murmansk Department for Hydrometeorology and Environmental Monitoring (MUGMS), Rosgidromet, Russia
4. Norwegian Institute for Air Research (NILU)
5. Finnish Meteorological Institute (FMI)
6. Institute of North Industrial Ecology Problems (INEP), Kola Science Centre, RAS, Russia
7. Finnish Forest Research Institute (METLA)
8. Norwegian Institute for Nature Research (NINA)
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12. Svanhovd Environment Centre, Norway
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18. Pasvik Nature Reserve, Russia
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23. Centre for Laboratory Analysis and Technical Measurement in Murmansk area, Russia
24. Lapland Biosphere Reserve, Russia
25. University of Ryazan, Russia
26. OJSC Kola Mining and Metallurgical Company (Kola MMC), Russia
27. Municipality of Sør-Varanger, Norway
28. Municipality of Inari, Finland
29. Municipality of Pechenga, Russia

1.1 Objectives of the programme

The primary objective of the monitoring programme is to provide scientifically robust, up-to-date information on the environment and its changes in the joint border area of Norway, Finland and Russia.

The main reason for carrying out the programme is the impact of the large, copper-nickel smelter complex (Pechenganikel enterprise) on the Kola Peninsula, in the immediate vicinity of the Russian-Norwegian border. The complex is one of the world's largest plants for processing non-ferrous metals. During the 70 years' lifetime of the plant, large amounts of sulphur dioxide (SO_2) and heavy metals have been emitted into the atmosphere. Sulphur dioxide emissions cause acidification of surface waters, especially in small lakes with a weak buffering capacity. Heavy metals accumulate in organisms, soil and the bottom sediments of surface waters. The Paz watercourse is impacted by the direct input of pollutants (discharges) and by atmospheric pollutants, while the lakes and streams in the headwater areas of the Paz watercourse only receive atmospheric pollutants. The planned renovation of the plant by 2010 is expected to result in a considerable reduction in the emissions of sulphur compounds and heavy metals. This programme will allow the monitoring of environmental changes in response to reduced emissions from the Petchenganickel complex.

The monitoring area covers a large part of the Paz catchment, which is divided between the three countries. The countries differ with respect to their environmental legislation, relation to the EU, and structure and content of the existing monitoring systems. One of the goals of the joint monitoring programme is to exploit existing national monitoring networks in order to obtain more complete information about the condition of the environment in the region.

The environment monitoring programme is based on existing national monitoring systems, supplemented where necessary with additional monitoring points and attributes, and takes into account the specific characteristics of the area.

1.2 Connections with other programmes

The Pasvik monitoring program is related to several national and international environmental monitoring programs.

Air quality

The measurements at Svanvik, Norway, are included in the European Monitoring and Evaluation Program (EMEP) coordinated by the UN/ECE (http://www.emep.int/). In Finland, the sulphur dioxide measurements at Sevettijärvi are a part of the national background area monitoring program. The stations in Zapoliarny and Nikel, Russia, monitor atmospheric air pollution in industrial towns within the national monitoring program.

Water quality

In Finland, the national monitoring program for airborne pollution and climate change includes several lakes in the Vätsäri region. The water quality of Lake Inari is also monitored within a number of national programs. In Norway, continuous water quality monitoring is conducted in the Jarfjord region. In the Russian border area,

surface water quality monitoring for 42 chemical parameters covers the watercourses of the Paz and Kolosjoki rivers, which receive direct loading of pollutants from the Pechenganikel smelters.

Terrestrial ecosystems

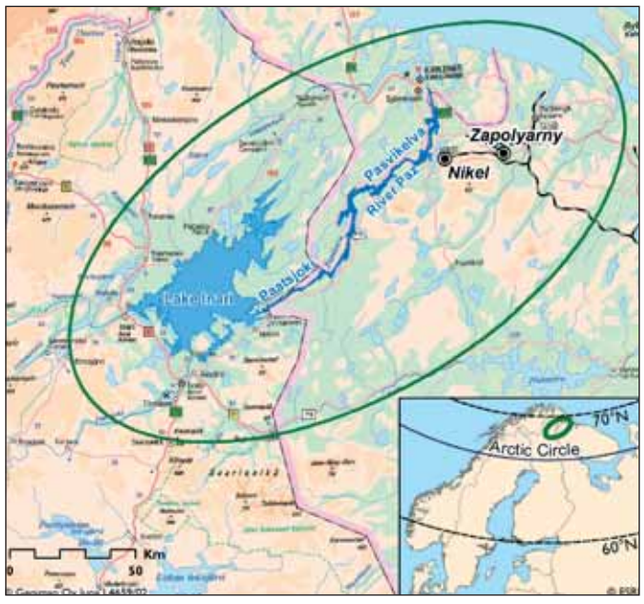
The terrestrial monitoring network consists of plots selected from three earlier forest monitoring projects:

1. The Finnish Lapland Forest Damage Project monitoring network, established in 1990-1995 (Tikkanen and Niemelä, 1995)
2. The Skogforsk-NINA-VNIIPRIRODA-IGCE monitoring network with eight plots along a transect from the Pechenganikel smelter towards Norway, established in 1994-1998 (Aamlid et al. 2000)
3. The NINA-NGU-INEP-METLA monitoring network with 31 plots along a north-south and a west-east transect running through the Nikel area, established in 2000-2001 (Yoccoz et al. 2001)

The monitoring plot at Sevettijärvi in Finland is a part of the trans-European ICP Forests monitoring programme (http://www.icp-forests.org/)

The gathered data are also utilized by the Arctic Monitoring and Assessment Program (http://www.amap.no).

1.3 Target area



The joint environmental monitoring network includes the Paz River basin, which covers areas in Norway, Finland and Russia, and the basins of the Jakobs (Norway) and Näätämö (Finland) rivers.

The ecosystems of Northern Fennoscandia and the Kola Peninsula have a naturally low resistance and tolerance to pollution due to the low temperatures and short growing period. These factors are characteristic of all Arctic ecosystems. The Arctic region of Northern Fennoscandia has unique geological, geographical and climatic qualities, combined with a moderately high level of industrial development. The joint border area of Norway, Finland and Russia lies within Key area number 1 of the Arctic Monitoring and Assessment Programme (AMAP), working under the Arctic Council.

1.4 Structure of the programme

The Pasvik joint monitoring programme consists of three parts:

- Air quality and deposition
- Water quality and aquatic ecosystems
- Terrestrial ecosystems

The programme is based on the recommendations of an international team of research and environmental authorities in Norway, Finland and Russia. The recommendations are set forth in the Final Report of the project Interreg III Kolarctic "Development and implementation of an environmental monitoring and assessment programme in the joint Finnish, Norwegian and Russian border area"
(http://www.ymparisto.fi/publications)

1.5 Reporting

A joint report of the State of the Environment including air quality and deposition, water quality and aquatic ecosystems as well as state of the terrestrial ecosystems in the border area should be published in 5-6 years period.

2. Implementation guidelines for the monitoring of air quality and deposition

2.1 National monitoring networks, measured parameters and frequencies

Figure 2.1
Map showing the location of large non-ferreous metal production sites (Nikel, Zapolyarny) and the main air monitoring sites in the border area of Finland, Norway and Russia.

The results of the project clearly show that there is a need for a joint, trilateral monitoring programme to follow up the effects of the modernisation process at the Petchenganickel combine and to assess the future state of the environment in the Paz River region. The proposed monitoring network will provide the means for carrying out this task.

The existing key stations in the area are Nikel in Russia, Svanvik in Norway and Sevettijärvi in Finland (see Figure 1). Measurements made at regional background stations Karpbukt/Karasjok (Norway), Jäniskovski (Russia) and Raja-Joseppi/Matorova (Finland) are essential for comparison.

The following measurements are the most important ones. Comparable equipment that is fully inter-calibrated would need to be used at all sites.

a. Continuous SO_2 and meteorological measurements
b. Measurement of precipitation quality: heavy metals, amount of precipitation, pH, and the main ionic components
c. Measurement of heavy metals in fine and coarse particles in the air

Measured parameter and frequencies of the proposed monitoring programme are outlined in Table 2.1. Heavy metal measurements include e.g. Cu, Ni, Co, Cd, Pb, Cr, Zn and As (Fe, Mn, and V).

Today, national monitoring covers only parts of the above outlined program. These measurements are marked in green in Table 2.1. In Norway the national monitoring program cover SO_2 and meteorological measurements in Svanvik as well as measurements the heavy metal in precipitation at the same site. In Finland SO_2 measurements at Sevettijärvi are part of the national background area-monitoring program. The Russian measurements, marked in yellow, are "one-time samples", which is the standard monitoring technique in Russia.

Additional monitoring measurements (marked in light orange in Table 2.1) and sites (marked in dark orange in Table 2.1) are important to follow the development of air quality and deposition during the renovation process of the Pechenganikel smelter. This includes continuous SO_2 and meteorological measurements in Nikel as well as measurement of main components and heavy metal deposition at three key sites. In particular additional measurements of heavy metals are considered important.

In particular, the integration of additional Russian monitoring site is essential for a future joint monitoring system. The re-establishment of an air quality monitoring site in the main wind direction at the smelter (around NE), where high levels of pollutions are expected, is required.

Station	Air				Precipitation		
	continuous		weekly	monthly	weekly	monthly	
	Met	SO_2	heavy metal	PM_{10}, $PM_{2.5}$	heavy metals	heavy metals	main comp.
Svanvik	x	x	x		x		x
Nikel	x	x	x		x		x
NE station, Zapolyarny	x	x	x			x	x
Sevettijärvi	x	x	x	x		x	x

Table 2.1
Air quality monitoring program proposed for border area of Finland, Norway and Russia.

Ongoing monitoring, included into the joint monitoring programme

Russian measurements, not included into the joint monitoring programme

Additional monitoring measurements, proposed for the joint monitoring programme

Additional monitoring sites, proposed for the joint monitoring programme

2.2 Used methods

Methods used need to follow EU/EOS regulations and recommendations made by international entities like WMO/GAW and EMEP. A in detail description of recommended methods to be used is, for example, given in the EMEP manual for sampling and chemical analysis (available in English, Russian and Chinese) (see http://www.nilu.no/projects/ccc/manual/index.html). Russian measurements are preferred to as "one-time sampling", which is the standard monitoring technique in Russia.

2.3 Quality assurance and quality control, error estimation

The participating laboratories, FMI and NILU perform air quality monitoring for National and international authorities, which assures the quality of the monitoring programmed, including measures of quality assurance and quality control. In 2001, NILU has been pointed out by the Norwegian Pollution Control Authority (SFT) to be the Norwegian National Reference Laboratory for air.

Laboratory ring test are one important measure to check the data quality. NILU and FMI regularly take part in international field and laboratory comparison of analytical methods arranged by for example EMEP and WMO. QA/QC, including error estiamtes and data flagging, are performed in each of the laboratories.

Further harmonization between methods used in Russia on one site and the EU/EOS countries is essential for the establishement of a joint tri-lateral monitoring programme. This may include specific harmonization excercises, ring test or additional field-intercomparisons.

2.4 Reporting and data updating

The reporting of the state of the atmosphere and deposition is performed via yearly reports to National authorities in Norway. A joined monitoring programme result will be a combined assessment report, based on the tri-lateral monitoring activities and model results. This should be implemented on a bi-annual to tri-annual bases, at times when the National reports have been submitted to the authorities.

The air quality information system is established through links from the joint monitoring programmme web pages (www.pasvikmonitoring.org) to the web-sites of the National actors, who carry out the measurements in commission for their respective national pollution authorities: NILU (www.nilu.no), FMI (www.fmi.fi) and Murmansk Hydromet (www.kolgimet.ru). A future joined monitoring programme would link the available data and information together via a joined project web sites.

2.5 Future evaluation and development of programme

As very little is currently known about the sources and presence of organic pollutants (POPs and PAHs) in the air in the area affected by the Pechenganickel smelter, the screening of these pollutants is recommended.

A future integrated assessment should take into account the combined effects of the modernization of the Pechenganikel smelter and the expected effects of climate change, the long-range transportation of pollutants from sources outside the area, as well as changes in land use in the Norwegian/Russian and Finnish border region.

3. Implementation guidelines for the monitoring of water quality and aquatic ecosystems

3.1 Common description

The main purpose of the programme is to monitor the state of and change in freshwater ecosystems. As a consequence of the renovation of the Pechenganikel smelters, emissions could be expected to decrease. However, increasing deposition of Cu and Ni has been recorded in recent years, and the Cu and Ni concentrations in the Jarfjord lakes have also been increasing. A change in the global climate change may also have an effect on the functioning of aquatic ecosystems and the sensitivity of individual species. In the changing situation, monitoring should be focused on the indicators found to be the most sensitive in the project "Development and implementation of an environmental monitoring and assessment programme in the joint Finnish, Norwegian and Russian border area", referred to in the following as the Pasvik-Pechenga Project. The monitoring programme must be based, as far as possible, on the ongoing monitoring and studies in the area. It should also take into account the demands of the EU Water Framework Directive (WFD). However, the main point is to monitor the effects of emissions. The monitoring programme should be cost-effective, and there should be a limited number of monitoring sites. Furthermore, the sampling frequency must also be reasonable, and it is recommended that the frequency fits in with the timetable of the WFD, wherever appropriate.

Freshwater ecosystems are focal points for pollution because they receive airborne pollution both directly through atmospheric deposition and via runoff water from the catchment. Especially lakes act as sinks for environmental contaminants. The surface waters of the Pasvik border area consist of two different types of system: the large-sized Lake Inari – River Paz watercourse (Paz watercourse) and the numerous small-sized lakes and streams in the catchment area. These two water systems are influenced by different kinds of emissions. The lower parts of the Paz watercourse are impacted by both atmospheric pollution and direct wastewater discharge from the Pechenganikel smelter and the town of Nikel. The upper parts of the watercourse, and the small lakes and streams which are not directly linked to the Paz watercourse, only receive atmospheric pollution. Emissions from the smelters contain varying amounts of a range of compounds and element, including sulphur dioxide (SO_2), metals (Ni, Cu, Cd, Cr, As etc.) and persistent organic pollutants (POPs).

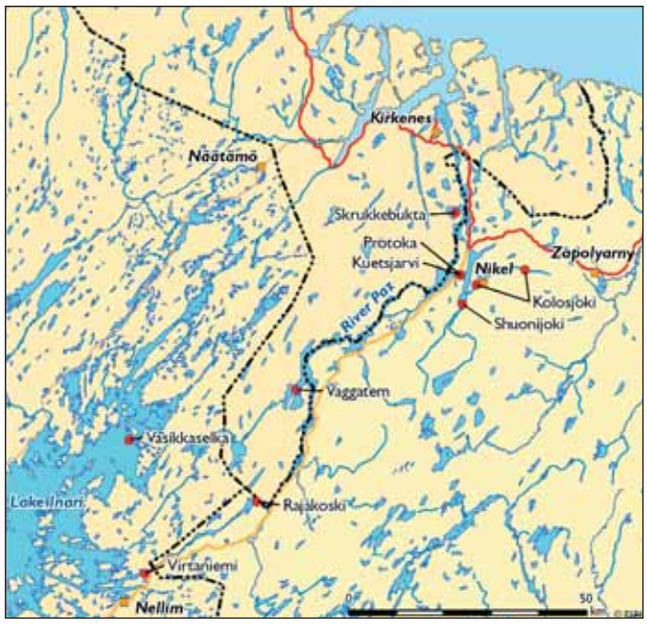
According to previous investigations and the results of the Pasvik-Pechenga Project, the effects of the Pechenganikel smelters on the Paz watercourse are most clearly seen as high heavy metal concentrations in water and sediments in the vicinity of the smelters. A number of pathological modifications have been found in fish organs and tissue in this area, especially in Lake Kuetsjarvi which directly receives wastewater from the smelter. The incidence of pathological disorders decreased with increasing distance to the smelters, exhibiting a strong correlation with the contamination levels of most heavy metals, thereby suggesting a causal relationship between fish pathology and heavy metal pollution. Fish are also used for human consumption especially in the Paz watercourse, and the monitoring of fish in the Paz watercourse with respect to heavy metal contamination, population ecology and fish pathology, is therefore very important.

The Pechenganikel smelters have increased the acidification of small lakes and streams in the region due to high sulphur dioxide emissions. The lakes located near the Pechenganikel smelters have a good buffering capacity, but many small lakes and

streams in the Jarfjord – Sør-Varanger and Vätsäri areas especially are very acid-sensitive and are affected by acidic precipitation. The sulphur dioxide emissions have decreased in recent years and it is expected that the modernization of the smelters will decrease the emissions even more. Although small, acidified lakes are recovering from acidification, monitoring this change and its biological effects is necessary. Small lakes near the smelters are also affected by heavy metal pollution, and elevated levels of POPs have been documented in lake sediments in the Sør-Varanger area.

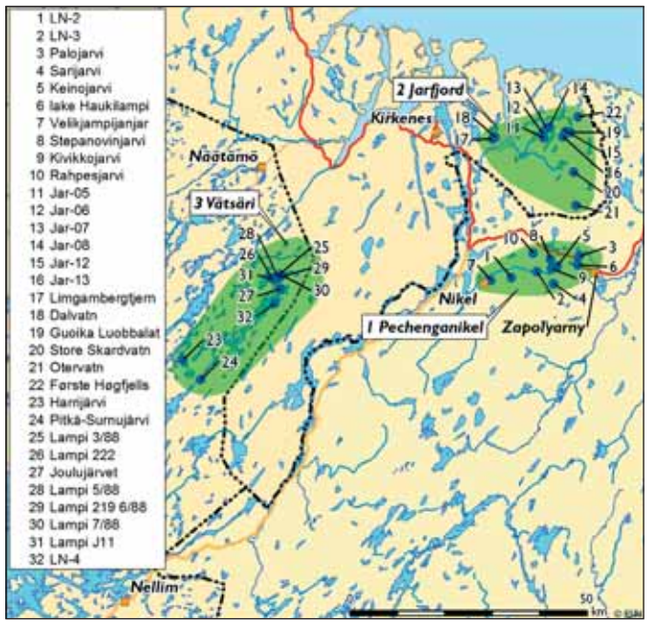
3.2 Target areas

A. Paz watercourse including the Lake Inari – River Paz watercourse and lakes directly connected to it (e.g. Lake Kuetsjarvi, **Fig. 3.1**).



B. Small lakes that are not directly connected to the Paz watercourse and which receive only atmospheric pollution. The monitoring of small lakes is to be concentrated in three main areas (**Fig. 3.2**):

1. Pechenganikel area
2. Jarfjord - Sør-Varanger area
3. Vätsäri area



3.3 Existing national monitoring programmes

A. The Paz watercourse

Water quality

- Water quality of the Paz watercourse is monitored regularly by the Finnish and Russian authorities (LREC and MUGMS). In Finland, the monitoring of Lake Inari and the River Paz belongs to national monitoring programmes.

Sediments

- Currently there is no regular monitoring of sediments, but sediments in Lake Inari and Lake Kuetsjarvi, as well as the reservoir lakes connected to the Paz watercourse (Vaggetem, Björnevatn, Skrukkebukta) were studied during the Pasvik-Pechenga Project.

Biological monitoring

- In Lake Inari, phytoplankton and fish populations are monitored from the point of view of fishery management every year. The zoobenthos has also been monitored regularly. The effects of regulation on littoral ecosystems (marcophytes and zoobenthos) have also been monitored.
- In the River Paz, the Russian MUGMS is monitoring phytoplankton, zooplankton, zoobenthos and bakterioplankton regularly. Fish studies in Paz watercourse have been conducted by research institutes (INEP and the University of Tromsø), but there has been no "official" fish monitoring programme in the River Paz. A screening of POP levels in fish was carried out during the Pasvik-Pechenga Project.

B. Small lakes

Water quality

- There are national monitoring programmes focusing on the effects of acidification, airborne pollution and climate change on lakes both in Norway and in Finland. In Norway, a total of 33 lakes in the Sør-Varanger municipality are included in this programme. In Finland, 4 lakes from the Vätsäri area and 2 lakes from both Raja-Jooseppi and Pallas are included in the national program. However, this monitoring does not include heavy metal analyses.

Sediments

- There is an ongoing national monitoring programme for sediment contaminant concentrations in Norway. It is mainly focusing on heavy metals, and it is carried out every 10 years. POPs and PAHs have also been analyzed in some of the lakes. The last study was carried out in 2006. The lakes studied in Norway are included in the AMAP programme.
- In Finland, a few lakes in Vätsäri and Pallas are also included in the AMAP programme and, according to the programme, heavy metals and some POPs are analyzed in lake sediments at intervals of ca. 20 years.

Biological monitoring

- In Norway, zooplankton, zoobenthos and fish populations are monitored in 3 lakes in Sør-Varanger as a part of a national monitoring programme.
- In Finland, littoral fish populations in 10-20 lakes and streams in the Vätsäri area have been monitored once in 5-10 years.

C. Ground water

There are two groundwater monitoring sites in the border area:
- Svanvik, Sørvaranger municipality, within the Baccavæjåkka,
- Nellim, Inari municipality, near the outlet of the Paz watercourse.

Groundwater monitoring at Svanvik is a part of the Norwegian National groundwater monitoring network (LGN). Groundwater monitoring at Nellim is a part of the Finnish National groundwater monitoring network .

3.4 Methods, frequencies and parameters to be measured

A summary of sub-programmes and tentative responsible institutes for carrying out the monitoring are presented in Table 3.1. Because this is a joint monitoring programme for three countries, the main principle is that there should be at least two countries represented in each sub-programme.

A. The Paz watercourse

Sub-programme	**Frequency**	**Responsible organizations/ institutes**
Water quality	Every year	LREC/SYKE + MUGMS + NIVA/APN
Sediments: metals and POPs	Every 6 years	INEP + APN/NIVA + LREC/SYKE
Fish monitoring: populations + pathology + metals and POPs in fish + biomarkers	Every 3 years	NCFS + INEP + APN/NIVA + RKTL + LREC/SYKE

B. Small lakes

Sub-programme	**Frequency**	**Responsible organizations/ institutes**
Water quality	1-3 year interval	APN/NIVA + LRECP/SYKE + INEP
Metals in lake sediments	6 – 12 years interval	INEP + APN/NIVA + LRECP/SYKE

Table 3.1
Summary of the sub-programmes and tentative responsible institutes.

C. Sub-programmes that require further development before being included in the monitoring programme (see chapter 3.7)

Sub-programme	Frequency	Responsible organizations/ institutes
Sedimentation	Samples collected every year, analyzed every 6 years	LREC/SYKE + INEP + APN/ NIVA
Zoobenthos in small lakes	Every 6 years	INEP + LREC + NINA
Fish populations and indicators in small lakes	Every 6 – 12 years	RKTL + NINA + INEP

APN = Akvaplan-niva
MUGMS = Murmansk Department for Hydrometeorology and Environmental Monitoring, Rosgidromet
RKTL = Finnish Game and Fisheries Research Institute
INEP = Institute of North Industrial Ecology Problems, Kola Science Centre
LREC = Lapland Regional Environment Centre
NCFS = Norwegian College of Fishery Science, University of Tromsø
NINA = Norwegian Institute for Nature Research
NIVA = Norwegian Institute for Water Research
SYKE = Finnish Environment Institute

3.4.1 The Paz watercourse

Monitoring of the Paz watercourse is focused on heavy metals and the effects of high heavy metal concentrations on fish populations. Suggested monitoring stations and frequencies are presented in more details in Appendix 3.1.

3.4.1.1 Water quality

Water quality is a basic element in monitoring and assessing the effects of decreasing emissions on aqueous ecosystems. It represents the chemical environment in which aqueous organisms live. It is also a relatively cheap and precise parameter to monitor and it provides data for detecting changes and trends.

Methods:

Water samples are taken with the type of water samplers generally in use. It is recommended that samples are taken with a cylindrical open-top type (e.g. Limnos) sampler, made of materials such as teflon, polypropylene and polyethylene. Samples for heavy metal analyses are taken carefully to avoid contamination either directly into a bottle or with a sampler that contains no metal. Bottles used for sample collection or storage must be cleaned using procedures specified for the analyses in question. Samples from river stations are usually taken at a depth of 1 m or, in shallow stations, of 0.5 m. In the case of lakes, samples are taken at depths of 1 m, 5 m, h and 2h-1 m, where h = maximum depth/2. It is recommended to use international standard methods such as ISO/CEN in analyzing the water samples. If this is not possible, then national standard methods can be used.

Frequency and time of sampling:

Water samples from the Paz watercourse should be taken every year. Samples from river stations (Appendix 3.1) should be taken at least four times per year during the main hydrological phases in March, May, August and in September-October. Samples from lakes and reservoir lakes should be taken at least twice per year in May–early June and in September-October during autumn overturn of the water masses.

Variables:

Parameter	Variable
General water quality	**Conductivity**, turbidity, **colour**, O_2, CODMn, **TOC**, **tot-P**, **tot-N**, SiO_2, **NO_3**, **NH_4**, **PO_4**
Acidification	**pH**, **Alkalinity**, **Ca**, **Mg**, **Na**, **K**, **Cl**, **SO_4**
Metals	**Fe**, **Mn**, **Al**, **As**, **Cd**, **Cu**, **Cr**, **Ni**, **Pb**, **Zn**, **Hg**

Table 3.2 *Mandatory (in bold) and optional variables (normal text) in water quality monitoring of the Paz watercourse.*

3.4.1.2 Sediments

Many heavy metals and other polluting substances accumulate in sediments, and therefore undisturbed sediments can be considered to represent a historical record of lake ecosystems. Sediment studies allow the determination of background levels and historical trends of air-borne pollutants. In the case of changing physical and chemical conditions (e.g. pH, Eh, O_2), harmful compounds accumulated in the sediments can dissolve in the water column, enter the food web and have secondary effects.

Methods:

There are some differences in sediment sampling and sample preparation methods between the countries (Appendix 3.4), and these require further comparison and harmonization (see chapters 3.5.5 and 3.7).

Sediment samples are taken from the deepest part of lakes with a gravity corer and divided into horizontal layers in order to facilitate the analyses. The coordinates of each sample station are determined with a GPS device. Sediment samples for metal analyses are placed in polyethylene containers and transported to the laboratory, stored at a temperature of +4 ˚C up until analysis. Sediment samples are first dried and homogenized, then extracted with nitric acid, and the concentrations of metals determined by atomic absorption spectrophotometry. Mercury is determined by cold vapour atomic absorption spectrophotometry. Sample preparation for the analysis of POPs includes freezing, homogenization and drying. Extraction and analysis of POPs are performed using methods specific for the individual organic pollutants.

Freguency and time of sampling:

Sediment samples from lakes or reservoir lakes in the Pasvik watercourse are taken every 6 years. The time of sampling is not so important in sediment sampling because sediments are usually relatively stable throughout most of the year.

Variables:

Parameter	Variable
General	**water content**, **loss of ignition**, Ca, Mg, Na, K, P
Metals	**Ni**, **Cu**, **Co**, **Zn**, **Cd**, **Pb**, Sr, Mn, Fe, **Al**, **As**, **Hg**
POPs	PCBs, pesticides, Brominated flame retardants, PAHs, Dioxins

Table 3.3
Mandatory (in bold) and optional variables (normal text) of sediment studies in the Paz watercourse.

3.4.1.3 Fish monitoring

Monitoring fish populations in the Paz watercourse is important because freshwater fish are important resources for recreational and subsistence exploitation and human consumption in the watercourse. Fish are also sensitive and conspicuous indicators of environment quality and serious impacts of the metallurgical industry on fish populations have been reported.

Methods:

It is recommended that the methods employed in the Pasvik- Pechenga Project are used in the monitoring programme (see Kashulin et al 2006). Fish sampling is performed in the littoral (< 8 m), profundal (> 10 m) and pelagic habitats (0-6 m) using gillnets. It is recommended to use 40 m-long gillnets containing eight 5 m sections with mesh sizes of 10, 12.5, 15, 18.5, 22, 26, 35 and 45 mm (knot to knot). Fish are identified to the species level, and each fish is measured for length and weight, and the sex and stage of maturation recorded. For age determination, otholiths are sampled from whitefish, vendace, Artic charr and trout, and opercula from perch.

It is important to analyze pollutants (fish pathology and metal and POP concentrations) on the same fish species (target species) in all the sub-programmes. This will make it possible to investigate the total body burden of pollutants in fish, and to evaluate the synergetic effects of different pollutants. It is especially important to analyze the same fish species at the same trophic level each period when monitoring POP concentrations, because POP levels increase on moving up the food web.

Tissue samples for the analysis of heavy metals are collected from muscle, liver and kidney from a minimum of 10-20 specimens of whitefish, perch and pike. Tissue samples for heavy metal analyses must be handled with care in order to avoid contamination. It is recommended to use sterile tools made of glass or stainless steel (scalpel), and the tissue samples are placed in plastic sachets and frozen. Laboratory analyses are conducted with standard methods preferably in one laboratory to reduce variance. For the analysis of POPs, muscle samples (20 gram) are taken from the same fish as for the metal analyses. The samples are wrapped in pre-burned aluminium foil and packed in a zip-lock plastic bag. Samples are stored frozen in the field and transported frozen to the laboratory for analysis.

Fish individuals used for pathological analysis should be fresh (just caught). It is important to use the same fish as the one sampled for metal and POP analyses. The following pathological conditions of fish organs and tissues are diagnosed:

- Outward appearance (depigmentation of skin, depigmentation of skull)
- Gills (warped, split and clavate rakers, irregular row and partial absence of rakers, necrotic disorders of gills (anaemic ring)
- Gonads (anisochronous and asymmetric maturation, strangulated and twisted gonads)
- Liver (degeneration of tissue, hyperemia, focal necrosis resulting in changes of colour and stretching)
- Kidney (hyperemia, hemorrhages, necrosis focuses, dystrophic changes of epithelium of tubules and granulation). The most frequent disease of kidneys – connective tissue expansions in the shape of white bands in the tail.

Frequency and time of sampling:

Fish population parameters, pathological studies, metal and POPs concentrations as well as biomarkers should be monitored every third year. Fish sampling should be performed during August-September.

Variables:

Table 3.4
Recommended variables of fish studies in the Paz watercourse.

Sub-programme	Target media/species	Variable
Fish populations	Whitefish, vendace, perch	Fish species composition, population structure (target species), somatic growth, sexual maturation
Pathological studies	Whitefish, perch, pike	Gonads, gills, kidney and liver
Heavy metals in fish	Whitefish, perch, pike: muscle, liver, kidney	Ni, Cu, Co, Zn, Al, As, Cd, Pb, Hg, Mn, Sr
POPs in fish	Whitefish, perch, pike and trout: muscle	PCB, pesticides, Brominated flame retardants, Hg
Biomarkers in fish	Whitefish, perch, pike: bile, liver	Cytochrome P-450, Bile acids

3.4.2 Small lakes

The monitoring of small lakes will be focused on trends and the effects of acidifying pollutants. Small lakes in the Pechenganikel area are also affected by heavy metals. Small headwater lakes are considered to be the most sensitive to airborne pollution. Therefore, the monitoring network should concentrate on lakes smaller than 1 km2 which are not subjected to any direct human impact. In the Pasvik-Pechenga Project the individual sub-programmes mainly used different lakes, and therefore it is difficult to select small lakes that are suitable for all the sub-programmes. In the first stage of the monitoring programme about 10 lakes per area will be included and screened in order to find a limited number of lakes in which biological monitoring especially could be focused (Appendix 3.2).

3.4.2.1 Water quality

Water quality is a basic element in monitoring and assessing the effects of changes in emission levels on aqueous ecosystems. It more directly reflects changes in acidic deposition than the deposition of metals, because the concentrations of metals are more dependent on the bedrock geology, pH and the total organic carbon (TOC) concentration in the soil and surface water.

Methods:

Because most of the small lakes are not accessible by car or boat (not at least in Vätsäri), water samples can be taken directly from a helicopter or hydroplane or by foot at the outlet of the lake. Water samples are taken with the type of water samplers generally in use. It is recommended that samples are taken with A cylindrical open-top type sampler (e.g. Limnos), made of materials such as teflon, polypropene and polyethylene. Samples for heavy metal analyses are taken carefully in order to avoid contamination either directly into a bottle or with aq sampler that contains no metal. It is recommended to use international standard methods such as ISO/CEN in analyzing the water samples. If this is not possible, then national standard methods can be used.

Frequency and time of sampling:

Water quality should be monitored in the most representative lakes (about 5 per area) every year in order to obtain sufficient data for statistical analyses and the detection of trends. Water quality could be monitored every third year in additional lakes (see Appendix 3.2). Samples should be taken during autumn overturn when the water is circulating. This helps to reduce the variance within the lake, between years, and also between lakes, because sampling all the lakes during a period of several weeks allows the lakes to be sampled under similar conditions.

Variables:

Parameter	**Variable**
General water quality	**Temperature, conductivity,** turbidity, **colour**, CODMn, **TOC**, **tot-P**, tot-N, SiO_2, **NO_3, NH_4**
Acidification	**pH, Alkalinity, Ca, Mg, Na, K, Cl, SO_4**
Metals	**Fe, Mn, Al, As, Cd, Cu, Cr, Ni, Pb, Zn**

Table 3.5
Mandatory (in bold) and optional variables (normal text) in the water quality monitoring of small lakes.

The dynamic acidification model MAGIC will be used in analysing the data. The MAGIC model is widely applied in modelling surface water acidification. The outputs from the MAGIC model can contribute to policy decision making related to emission reductions, as the model predicts future chemistry as a response to changes in deposition levels. The model results can hence support policy making by providing information about when a given water quality improvement can be expected under different scenarios for emission reduction measures.

3.4.2.2 Lake sediments

Sediment studies allow the determination of background levels and historical trends in air-borne pollutants. However, especially in northern lakes with an extremely small sedimentation rate (even < 1 mm/yr) and possible bioturbation, it is practically impossible to determine the annual variation in a sediment core, with or without dating methods. Therefore, sediment core analysis can be repeated after a relatively long period of 10 -15 years.

Methods:

There are some differences in the sediment sampling and sample preparation procedures used in the three countries (Appendix 3.4), and further comparison and harmonization are therefore required (see chapters 3.5.5 and 3.7).

Sediment samples are taken from the deepest part of the lakes with a gravity corer, and divided into horizontal layers in order to facilitate the analysis. The coordinates of each sample station are determined with a GPS device. Sediment samples are placed in polyethylene containers and transported to the laboratory, stored at a temperature of +4 ˚C up until the analysis. Sediment samples are first dried, then extracted with nitric acid, and the metal concentrations determined by atomic absorption spectrophotometry. Mercury is determined by cold vapour atomic absorption spectrophotometry.

Frequency and time of sampling:

Metal analyses on sediments could be performed more frequently (every 6 years) in some lakes especially in the most polluted area near Pechenganikel. However, in most of the lakes the sediment analyses should be performed every 12 years (Appendix 3.2).

Variables:

Table 3.6
Mandatory (in bold) and optional variables (normal text) of sediment studies in small lakes.

Parameter	**Variable**
General	**water content, loss on ignition,** Ca, Mg, Na, K, P
Metals	**Ni, Cu, Co, Zn, Cd, Pb**, Sr, Mn, Fe, **Al, As, Hg**

3.4.3 Groundwater monitoring

3.4.3.1 Common description of the groundwater monitoring

As the investigations carried out during the Pasvik-Pechenga Project did not show any clear indications of anthropogenic contamination in ground water on the Norwegian side of the border and the long-term monitoring shows good quality of the groundwater on the Finnish side of the border, the groundwater monitoring in Norway and Finland will be continued as a part of the requirements of the Water Framework Directive with respect to groundwater monitoring in trans-boundary aquifers.

There are two groundwater monitoring sites in the border area:
- Svanvik, Sørvaranger municipality, within the Baccavæjåkka,
- Nellim, Inari municipality, near the outlet of the Paz watercourse.

If there are signs that the groundwater quality is deteriorating, then the environment authorities will inform the authorities on the other side of the border about this. Data on ground water quality based on monitoring at the Svanvik and Nellim sites are available to the environment authorities on both sides of the border. The groundwater quality data from the Nellim station could, when required, be integrated with the corresponding data from the Svanvik monitoring station through co-operation between LREC and NGU.

3.4.3.2 Methods, frequency and time of sampling

Groundwater monitoring at Svanvik is a part of the Norwegian national groundwater monitoring network (LGN). A summary of the Norwegian national groundwater monitoring programme is given in Appendix 3.3.

Groundwater monitoring at Nellim is a part of the Finnish national groundwater monitoring network. The Nellim station, established in quarternary sediment deposits, has been used as a monitoring station for groundwater for 20 years. Groundwater sampling for chemical analysis is carried out 6 times a year from wells, and 5 times a year from lysimeters. In addition, snow sampling is carried out once a year in early spring. A summary of the groundwater monitoring programme at Nellim station is given in Appendix 3.3.

3.5 Quality assurance, quality control and error estimation

3.5.1 General

The general objective of a co-operative international programme for monitoring the effects of air pollution on ecosystems requires that all the data generated by the individual participants should be comparable on an objective basis. It is very important to have good quality data that are consistent over both time (in order to assess trends) and space (for comparison between different areas). To achieve such comparability, the methods employed in sampling and analysis must be thoroughly documented. A quality assurance programme must be carried out to demonstrate that results of adequate accuracy are being obtained. Only through objective control is it possible to draw a reliable distinction between natural variability and anthropogenic effects. The quality assurance (QA) and quality control (QC) procedures should include all parts of the activities performed at the site and in the laboratory.

3.5.2 Quality assurance routines in the field and in sampling

Traditionally, the most attention in QA programmes is paid to laboratory procedures. However, a significant source of error is related to field sampling, transportation, and sample preparation.
Field sampling must be performed by trained personnel. The prevention of sample

contamination or mix-up of the samples during sampling or storage is critical for obtaining accurate measurements. All sampling equipment, containers and bottles used for sample collection or storage must be cleaned using procedures specific for the analyses in question. The containers and bottles must also be made of material that will neither absorb nor release measurable quantities of the determinant.

It is important that water sample bottles are protected from light and kept cool during and after sampling. Biological material should be preserved and stored according to uniform, widely established practices. Samples should be transported to the laboratory as soon as possible and, if necessary, cooled during transport.

3.5.3 Quality assurance and quality control

In this monitoring programme field blanks (blank samples of distilled water) and parallel samples are taken to ensure that:

- The chemicals used for the fixation of samples do not contain impurities
- Sampling equipment, containers and bottles are not contaminated
- Any other systematic or incidental errors in sampling are identified and pre vented

Field blanks and parallel samples should be used regularly, at least once per weekly sampling occasion. For field blanks, the sampling bottles are filled with deionized water in the laboratory and fixation chemicals are added to the bottles in the field. The contamination of sampling equipment can be tested by pouring deionized water into the sample collector after it has been washed/rinsed in the field. The blank samples should be subjected to the same procedure as the ordinary water samples. Parallel samples are taken as separate samples at the same sampling station.

3.5.4 Laboratory practices

The basic prerequisite for environmental studies and laboratory analyses is that the results are fully comparable with each other. This goal can be reached through laboratory quality assurance management. Laboratory quality assurance can be divided into two parts: external quality assurance and internal quality assurance. Both parts of the quality management programme should be fulfilled in order to achieve reliable laboratory results. The whole analysis chain from sampling and suitable sample pre-treatment procedures to reporting must be controlled and documented.

External quality assurance:

- The laboratories should have a quality management system according to the EN ISO/IEC 17025 standard.
- The laboratories participating in the monitoring programme should partici pate regularly in an international inter-comparison test
- External audits should be performed annually by qualified persons.

Internal quality assurance:

- **Quality handbook**
  - The quality handbook is needed in order to obtain exact results and methods of high quality. The quality system and its documentation are to be written in the quality handbook. Requirements for the quality handbook are written in the EN ISO/IEC 17025 standard.

- **Standard methods**
  - In general, standard methods must be used. It is recommended to use international standard methods such as ISO/CEN in analysing water samples. If this is not possible, then national standard methods can be used.
  - Possible in-house methods should be verified through validation and inter-comparison tests.

- **Method validation**
  - Validation of the analyses is performed on all analysis methods included in the monitoring programme. At a minimum, the detection limit, uncertainty, range and calibrations are to be defined. This is accomplished with the help of control charts, inter-comparison tests and statistical methods.

- **Routine quality control**
  - The laboratory is to have a continuous method for the intra-laboratory quality control (control samples and charts). A continuous control method is to be used in every sample series. (http://www.nordicinnovation.net/nordtestfiler/tec569_ed_2.pdf).

- **Audits**
  - The laboratory is to carry out internal audits once a year. All activities and analyses conducted in the laboratory are to be inspected in the audits.

- **Reporting**
  - The laboratory results are to be reported using a specific form, which includes the following information at least: name of the laboratory, identification of the analysis method and uncertainty, analysis date, sampling date and place, unit of measurements and signature of the person authorizing the analysis report. All the reports must be archived.

3.5.5 Quality assurance in sediment studies

During the Pasvik-Pechenga Project the techniques used in sediment investigations in Russia (INEP) and in Finland (LREC) were compared, and the techniques used in sediment sampling and chemical analyses proved to be almost the same (see Appendix 2). There were differences in sample preparation, but the results of chemical analyses were comparable. Norway did not participate in this inter-comparison test.

Sediment sampling and chemical analysis of heavy metals require further comparison and harmonization of the methods used in the three countries. In addition, all the laboratories from the responsible institutes in the three countries that carry out the sediment studies should participate in inter-comparison tests.

3.5.6 Quality assurance in zoobenthos studies

In order to maintain the comparability of the results between the countries and sampling periods, it is important to harmonize the sampling methods, taxonomy analyses, statistical analyses, data storage and data exchange. Joint meetings and training in sampling, processing of samples and identification of animals would contribute to ensuring that the acquired data are reliable. Identification guides and keys should also be introduced and exchanged between the researchers in order to harmonize the species identification.

The laboratory practices and used taxonomy are nowadays relatively similar in the three countries. However, differences in the taxonomic level in species identification and reporting, which arise from differences in national practices, standards and legislation, are greater problems. A commonly agreed minimum level of identification is therefore needed. One solution could be the use of the species list employed in national benthic inventories in Sweden (Riksinventering). A similar list is currently being developed also in Finland and it should fulfil the needs of the EU Water Framework Directive.

In the small lakes, future surveys (especially the extensive studies every 12th year) should be conducted using the methods as in the Pasvik-Pechenga Project in order to ensure comparability of the results. Additional samples using the methods of WFD monitoring should be collected in the lakes included in more intensive monitoring (every 6th year) programme. This would enable comparison of different sampling methods and act as a step towards the harmonization of methods. In order to ensure the comparability of the results and to reduce costs, it is recommended that zoobenthos monitoring should be performed by the same research group or institute, and consist of members from at least two countries.

3.5.7 Quality assurance in fish studies

Fish studies in the Paz watercourse were conducted by one research group, and it is recommended that the same methods are used in the monitoring programme. This will ensure comparability of the results.

There has been more variability in the methods used in studies on fish populations in small lakes. To ensure better comparability of the results, it is recommended to develop and harmonize methods in the future monitoring programme (see chapter 3.7).

Because there was very much variation in the results of the heavy metal analyses made on fish samples, inter-comparison tests for biological materials should be continued. There were differences especially in sample preparation, which should be compared and harmonized. It is recommended that heavy metal analyses on fish and other biological material should be carried out in one analytical laboratory, which has internal quality assurance and quality control with reference material. Furthermore, tissue samples for heavy metal analysis should be taken carefully in order to avoid contamination of the samples (see chapter 3.4.1.3).

3.6 Reporting and data updating

Monitoring data on water quality, sediment analysis, zoobenthos and fish studies will be collated on pre-determined forms in Excel files. Each organization responsible for reporting a sub-programme will make suggestions for the Excel table(s) in which data are collated. The regional environmental authorities (LREC, Gidromet, Office of the Finnmark County Governor) should confirm that data will be available for a joint information system and reporting of the monitoring programme. Water quality data from stations monitored every year should be delivered annually to the other participants and a progress report delivered to the Finnish-Norwegian Border Commission. Data from the previous year should be delivered by the end of June during the next year.

A short report of water quality in the Paz watercourse and in small lakes will be prepared after every 3 years. A joint assessment report of water quality, sediment studies, zoobenthos and fish monitoring studies will be prepared after every 6 years. A more extensive assessment report of the state of and effects on freshwater ecosystems will be prepared after 12 years. The monitoring programme will be evaluated and, if necessary revised, after 6 years, and a more thorough evaluation of the whole monitoring programme will be carried out after 12 years.

It is recommended that the monitoring programme should be started in the beginning of 2007 such that the responsible organizations in each country would take responsibility for water quality monitoring. The first report on water quality would be ready in 2010.

A. The Paz watercourse

Sub-programme	Frequency	Responsible organizations
Water quality	3-year interval (first in 2010)	MUGMS + NIVA/APN + LREC
Sediments: metals and POPs	6-year interval (first in 2013)	INEP + APN/NIVA
Fish monitoring: populations + pathology + biomarkers + metals and POPs in fish	6-year interval (first in 2013)	NCFS + INEP + APN/NIVA + RKTL

B. Small lakes

Sub-programme	Frequency	Responsible organizations
Water quality	3-year interval (first in 2010)	LREC + APN/NIVA + INEP
Metals in lake sediments	6-year interval (first in 2013)	INEP + APN/NIVA + LREC/SYKE
Joint assessment report	6-year interval (first in 2013)	LREC, Gidromet, Office of the Finnmark County Governor

Table 3.7
Proposed reporting frequency and organizations responsible for the reporting.

The organizations responsible for preparing the sub-programme reports will draw up a short summary including the most important findings concerning trends and assessment of the effects of emissions from the smelters on the specific part of the freshwater ecosystems. The monitoring results of sub-programmes will be included in the joint assessment report.

3.7 Further evaluation and development of the programme

During the Pasvik-Pechenga Project, inter-comparison exercises were carried out on water quality analyses, sediment investigations and heavy metal analyses on biological samples, but harmonization of the monitoring methods was not completely fulfilled. Especially fish studies in small lakes require further comparison and harmonization of the methods, as well as assessment of the sensitivity of different indicators. The selection of lakes that are suitable for the individual sub-programmes requires further screening and focusing (Table 3.8). During the Pasvik-Pechenga Project it became clearly evident that there was a need for further studies or screening. Recommendations for monitoring, and the frequency of monitoring, will be made on the basis of these results (Table 3.9).

It is recommended that the monitoring programme be started in the beginning of 2007 such that the responsible organizations in each country would take responsibility for the monitoring activities. The monitoring programme will be evaluated and, if necessary revised, after 6 years, and a more thorough evaluation of the whole monitoring programme will be carried out after 12 years. Sub-programmes that require further development before they can be included in the monitoring programme, and monitoring recommendations based on these results, should be ready before the first check in 2013.

Table 3.8
Parts of the programme that require further development before inclusion in the monitoring programme.

Sub-programme	Frequency	Responsible organizations/ institutes
Sedimentation	Samples collected every year, analysed every 6 years	LREC/SYKE + INEP + APN/ NIVA?
Zoobenthos in small lakes	Every 6 years	INEP + LREC + NINA
Fish populations and indicators in small lakes and streams	Every 6 – 12 years	RKTL + NINA + INEP

Metals in lake sediments:

The sediment sampling and sample preparation methods used in the individual countries require further comparison and harmonization. For example, the optimum thickness of sampled and analysed horizontal section of sediment (0,5 or 1,0 cm) has to be tested in practice. It is important that all three countries should participate in the inter-comparison tests.

Sedimentation in small lakes:

Annual sedimentation samples collected in six Finnish lakes between 1988 - 2005 were analysed during the Pasvik-Pechenga Project. In Finland the sedimentation traps had been sampled annually in late autumn before freezing-over. The sedimentation method gave good correlation between the accumulation rate of heavy metals and annual emissions from the Pechenganikel smelters. However, this method needs further development and harmonization between the countries before it can be recommended for future monitoring.

Zoobenthos in small lakes:

It is recommended that the future monitoring of small lakes should be conducted using the same methods as in the Pasvik-Pechenga Project in order to ensure comparability of the results. However, additional samples should be collected from the lakes using the WFD monitoring methods. This would enable the comparison of different sampling methods and act as a step towards the harmonization of methods in the future. In order to compare and harmonize different methods and to focus biological monitoring as far as possible on the same lakes, it is recommended that the zoobenthos monitoring should be further developed before it is included in the monitoring programme.

Fish populations and indicators in small lakes:

Two different basic methods were used in the investigations on fish populations in small lakes. Littoral fish populations of extremely small lakes and brooks were monitored by the electrofishing method, which is a standardized procedure in the EU. In slightly larger lakes fish populations were studied using gillnets. In the Jarfjord lakes fish sampling was carried out using Nordic multimesh gillnets (30 m long and 1,5 m deep) with 12 different mesh sizes of between 5 – 55 mm. INEP has carried out sampling with gillnets (25 m long and 1,5 m deep) with mesh sizes of 16, 20, 31, 36 and 40 mm. The Nordic multimesh gillnet will be a standard method in the EU, and the possibilities of using this method in monitoring have to be studied.

There is also a need to compare and harmonize the different indicators and target species used in the fish studies. The sensitivity of different indicators has to be evaluated further. Furthermore, the selection of lakes that are suitable for the individual sub-programmes needs further screening and focusing.

Methods for heavy metal analysis on fish samples need to be compared and harmonized. There are differences in sample preparation especially, and these should be harmonized. Inter-comparison exercises for biological materials should be continued.

Cause and effects of the pH decline in stream water during spring melt runoff	Modelling and evaluation of biological effects	LREC/SYKE + APN/NIVA? +
POPs in small lakes	Evaluation of results from 2006 -> decision on further screening or monitoring	APN
Synergetic effects of heavy metals, POPs and Hg on fish and biomarkers in fish in the Paz watercourse -> human health	Investigation -> decision on monitoring and frequency	APN/NIVA, NCFS + INEP + LREC/ SYKE

Table 3.9
Requirements for further studies before a decision can be made on monitoring and frequency.

Cause and effects of the pH decline in stream water during spring melt runoff in the border area:

In a study on water quality in small lakes and streams, an episodic decline of about 0,5 – 1,0 pH units was recorded in one stream in the Vätsäri area during the spring flood. The lowest pH value was under 6, and some elevated total Al concentrations were recorded at the same time. In the border area the SO_4* deposition load during winter seems to have an influence on the spring water pH decline, but separating and quanti-

fying the individual components needs modelling. We also lack information about the biological effects of the spring pH decline.

POPs in small lakes:

During the Pasvik-Pechenga Project a screening study was carried out on POPs in lake sediments in the Paz watercourse, and elevated levels of POPs was detected. A corresponding screening study on sediment in small lakes was not performed. However, Norway has a national, long-range transport monitoring programme for determining pollutants in lake sediments. In this programme approximately 40 lakes in Finnmark County are investigated for heavy metals, and 20 of them also for POPs and/or PAHs. These lakes were sampled in 2006, and the results will be reported during 2007. The results of this study and similar studies performed 10 years ago will provide a good indication of the trends in POP and PAH concentrations in the sediments of small lakes in Finnmark and in the border region. These results will be useful in evaluating the need for further screening of POPs and PAHs in small lakes in the region, and the relevance of including POPs and PAHs in the monitoring programme of small lakes influenced by emissions from the Nikel smelters.

Synergetic effects of heavy metals, POPs and Hg on fish in the Paz watercourse:

Heavy metals have been the main subject of pollution studies on freshwater biota in the border area, and there is only limited information available on the levels of POPs and other toxic compounds in biological samples. However, the screening studies on POPs in fish and sediment indicated elevated levels of PCB and PAH in parts of the Paz watercourse. Furthermore, the pathology studies carried out in the Paz watercourse clearly indicated that fish in the areas with higher levels of pollution are more affected than fish in less polluted areas. The screening of biomarkers in fish in the Paz watercourse also showed that selected biomarkers can be used as an assessment tool for evaluating the impact of pollutants on fish, and as early warning diagnostic tools. Therefore it is strongly recommended to include biomarkers, pathology, heavy metal concentrations, POP concentrations, PAH concentrations and population studies on fish in the new monitoring programme for the Paz watercourse.

It is well documented that different pollutants have different effects on biota, but very little is known about the possible synergistic or antagonistic effects that can occur when animals are exposed to a cocktail of different pollutants. Fish from the Paz watercourse would be an ideal subject for carrying out a more detailed study on the synergetic/antagonistic effects of pollutants on fish populations.

Another part of this project will be related to food safety. In the Paz watercourse fish are an important resource for human consumption. We know from the Pasvik-Pechenga Project that levels of one or several pollutants are high in fish in certain areas. Food safety is often related to toxicity equivalents that are calculated on the basis of the levels of individual pollutants and their toxicity to humans. Analysis of a wide range of pollutants in fish that are used for human consumption will make it possible to calculate more accurate toxicity equivalents. Based on these values, it will be possible for the Food Safety Authorities to issue guidelines for the consumption of fish from the Paz watercourse.

The result of these studies will be useful for developing and evaluating future environmental monitoring programmes.

4. Implementation guidelines for the monitoring of terrestrial ecosystems

4.1 Background and aims

The future monitoring programme should take full advantage of the experience gained in the present project with respect to the most appropriate monitoring activities (i.e. parameters and attributes), spatial resolution of the monitoring plots, as well as the utilization of human and other resources and the harmonisation of monitoring methods.

The present project has provided valuable reference data on the current state of the environment prior to the remodernization of the smelter complexes in Nikel and Zapoljarny. At the same time this project constitutes a combination and a continuation of earlier monitoring programmes carried out in the border area. The acquisition of new data means that a number of invaluable time series have been extended.

Primary aims of the future monitoring programme:

- to detect changes in the concentrations and spatial distribution of heavy metal and SO_2 emissions from the smelter complexes,
- to detect changes in the species composition and coverage of the ground vegetation,
- to detect changes in the main vegetation cover types on the landscape/regional level using remote sensing,
- to detect changes in forest condition (growth and health of birch and Scots pine stands),
- to detect changes in the distribution and condition of sensitive bioindicators (e.g. epiphytic lichens),
- to detect changes in the mobility of heavy metals accumulated in the forest soil during the lifetime of the smelters,
- to detect changes in the distribution and effects of heavy metal accumulation in the bird and small mammal population, and
- to evaluate the potential health threat to the local human population posed by the accumulation of heavy metals and organic pollutants (POPs, PAHs) in wild berries (cloudberries, bilberries and cowberries) and edible forest mushrooms.

4.2 Monitoring plot network

The locations of the plots to be monitored in the terrestrial part of the programme are shown in Fig. 4.1, and background information about the plots in Table 4.1. The plots at Kessi (F-10) and Raja-jooseppi (F-11) in Finland, which so far have only been used for monitoring deposition, should be included in the monitoring programme and all the parameters and attributes monitored on the other plots should be assessed as soon as possible. Birds and small mammals should only be monitored on the plots listed in Table 4.2.

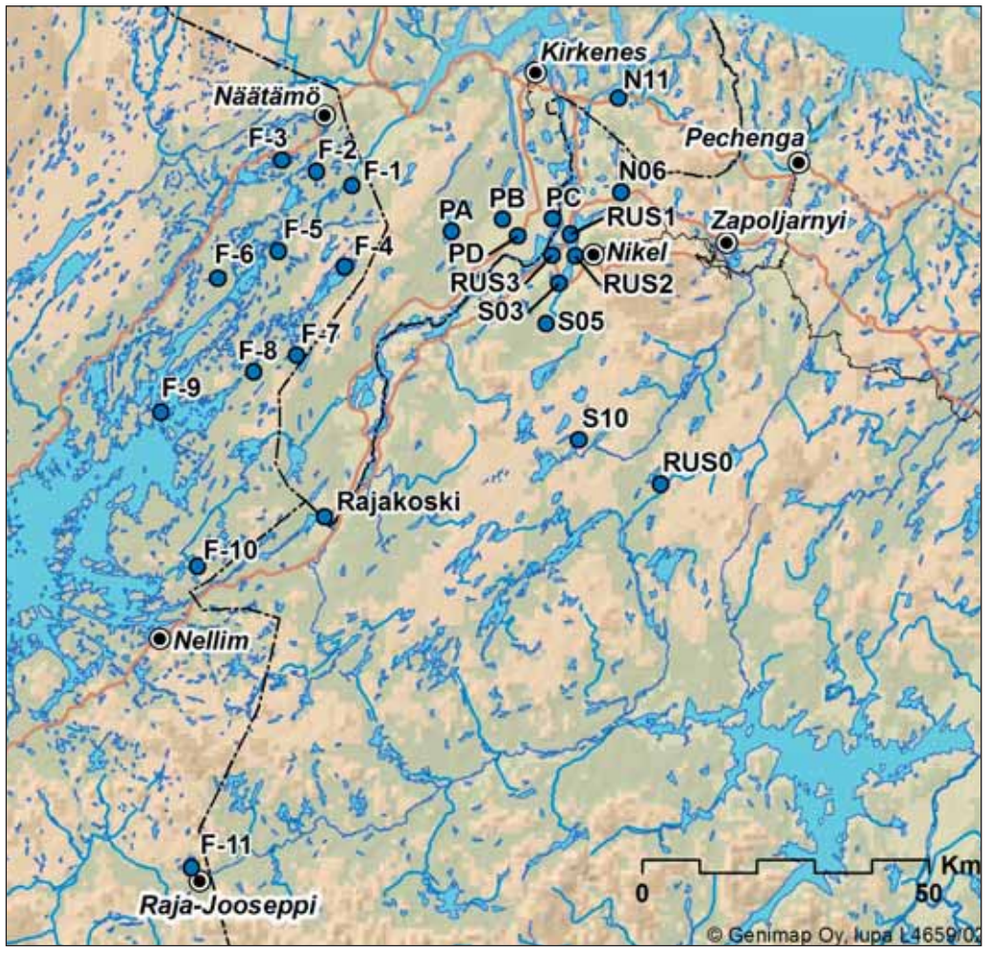


Figure 4.1
The terrestrial ecosystem monitoring network showing the location of the plots in Finland, Russia and Norway. The numbers refer to the code number of the plots used in the terrestrial final report.

Plot	Tree species
Russia	
RUS0	birch
RUS1	Scots pine
RUS2	Scots pine
RUS3	Scots pine
S03	birch
S05	birch
S10	birch
N6	birch
Norway	
N11	birch
PA	Scots pine
PB	Scots pine
PC	Scots pine
PD	Scots pine
Finland	
F-1	Scots pine
F-2	Scots pine
F-3	Scots pine
F-4	Scots pine
F-5	Scots pine
F-6	Scots pine
F-7	Scots pine
F-8	Scots pine
F-9	Scots pine
F-10	Scots pine
F-11	Scots pine

Table 4.1
List of plots to be used in the terrestrial ecosystem monitoring network in Russia, Norway and Finland. The assessment of birds and small mammals is to be carried out on a restricted number of plots.

The monitoring network covers the area affected by heavy metal and sulphur deposition to the south, west and north of the Nikel smelter, but not to the east. At least four plots, at distances of 2, 5, 20 and 50 km, should be established to the east of Nikel in order to complete the west-east transect. According to the prevailing wind pattern, this area receives the highest deposition load. These plots should be established using the same design as for the plots running along the transect to the west of Nikel (cf. Aamlid et al. 2000).

Two of the new plots (preferably the ones at 20 and 50 km distance) should be established as a part of integrated (terrestrial, aquatic and atmospheric) studies to be carried out in two small catchment areas (e.g. lake and surrounding land area) in order to calculate input-output budgets for heavy metals, organic pollutants and acidifying components. The location of the plots should be decided on between the parties responsible for carrying out the terrestrial, aquatic and atmospheric monitoring sub-programmes.

	Plot
Birds: pied flycatcher (*Ficedula hypoleuca*)	RUS2, RUS3, Rajakoski, N1, N2, N3, N4, Lakselvdalen-Troms
Small mammals: rodents (*Clethrionomys rufocanus, Cl. Rutilus, Microtus agrestis, M. oeconomus*) shrews *(Sorex araneus, S. caecutiens, S. minutus*)	N2, N3 and Kalkoupä (N 69°16'38" E 29°23'00"). Reference point in Lakselvdalen, Troms.

Table 4.2
Birds and small mammals to be monitored and the monitoring plots.

A snowpack survey should be carried out during the winter on a systematic grid (e.g. 8 x 8 km) in order to more precisely identify the emission point sources (primarily of POPs and PAHs), and to estimate the distribution and extent of heavy metal, organic pollutant and acidifying compound deposition over the whole area.

A survey of heavy metal and organic pollutant concentrations in forest berries (cloudberries, bilberries, cowberries and crowberries) and edible wild mushrooms should be carried out on the same systematic grid as for the snowpack survey in order to assess the potential threat to the health of the local population who consume these products.

4.3 Parameters and attributes to be monitored

The parameters and attributes to be monitored are listed in Table 4.3, and the reference methods to be used in the monitoring work in Table 4.4. International standardised methods are available for most of the parameters and attributes. In the case of parameters and attributes not covered by such standard methods, references are given to published articles in which the methods are described in detail.

Parameter or attribute	Species (if applicable)	Annually	2 years	4 years	10 years
Deposition (snow)	**snowpack survey**		**X**		
Deposition (bulk deposition and stand throughfall)	**1 new plot in Russia to the east of Nikel, 1 existing plot in Norway nd 1 existing plot in Finland**	**X**			
Crown condition	Scots pine, birch	X			
Stand growth	Scots pine			X	
Ground vegetation	all species within quadrats, additional species within plot			X	
Epiphytic lichens	birch, Scots pine			X	
Photosynthetic efficiency	birch, bilberry			X	
Plant chemistry	pine needles, birch leaves, mosses, bilberry, crowberry, cowberry, cloudberry, grasses, lichens			X*	
Wild berries and edible mushrooms (systematic e.g. 8 x 8 km grid covering the whole area)	**cloudberry (Rubus chamaemorus) bilberry (Vaccinium myrtillus) cowberry (V. vitis-idaea) crowberry (Empetrum hermaphoditrum)**		**X**		
Birds	Pied fly catcher	Biological parameters		Metals, organic pollutants	
Small mammals	rodents, shrews	Population numbers		Metals, organic pollutants	
Soil	litter, humus, mineral soil				X
Satellite imagery		MODIS		Landsat (or similar)	
POPs and PAHs	**all components**			**X**	

Table 4.3
The individual parameters and attributes to be monitored, and the sampling interval. The parameters/attributes marked in "bold" are new activities that require development and testing in the field, as well as the development of suitable analytical procedures.

* Moss samples should be taken at 5-year intervals (next sampling in 2010 in connection with the pan-European ICP Vegetation heavy metal moss survey)

Parameter or attribute		Standard, manual or scientific article
Deposition	snowpack survey	Lindroos, A-J., Derome, J. & Niska, K. 1995. Snowpack quality as an indicator of air pollution in Finnish Lapland and the Kola Peninsula, NW Russia. Water, Air and Soil Pollution, 85:2185-2190
Deposition	bulk deposition and stand throughfall	ICP Forests, Manual, Part VI, Measurement of deposition (http://www.icp-forests.org/Manual.htm)
Crown condition	Scots pine, birch	ICP Forests, Manual, Part II, Visual assessment of crown condition and submanual on visual assessment of crown condition on intensive monitoring plots (http://www.icp-forests.org/Manual.htm)
Stand growth	Scots pine	ICP Forests, Manual, Part V, Measurement of growth and yeild (http://www.icp-forests.org/Manual.htm)
Ground vegetation	all species within quadrats, additional species within plot	See Appendix 1
Epiphytic lichens	birch, Scots pine	Aamlid, D. et al. 2000. Ecosystem monitoring in the border areas between Norway and Russia. Boreal and Environmental Research 5: 257-278. Aamlid D. & Skogheim I. 2001. The occurrence of *Hypogymnia physodes* and *Melanlia olovacea* lichens on birch stems in northern boreal forests influenced by local air pollution. Norw. J. Geogr. 55: 94-98. Bjerke W.B., Tømmervik H., Finne T.E., Jensen H., Lukina N. and Bakkestuen V. 2006. Epiphytic lichen distribution and plant leaf heavy metal concentrations in the Russian-Norwegian boreal forests influenced by air pollution from nickel-copper smelters. *Boreal Env. Res.* 11: 441-450.
Photosynthetic efficiency	birch, bilberry	Odasz-Albrigtsen, A.M., Tømmervik, H., & Murphy, P. 2000. Decreased photosynthetic efficiency in plant species exposed to multiple airborne pollutants along the Russian-Norwegian Border. Canadian Journal of Botany, 78: 1021-1033.
Plant chemistry	pine needles, birch leaves	ICP Forests, Manual, Part IV, Sampling and analysis of needles and leaves (http://www.icp-forests.org/Manual.htm)
Plant chemistry	mosses, lichens	ICP Vegetation (http://icpvegetation.ceh.ac.uk/Moss_monitoring_%20manual/UNECEHEAVYMETALSMOSSMANUAL2005.pdf)
Plant chemistry	bilberry, crowberry, cowberry, grasses,	Aamlid, D. et al. 2000. Ecosystem monitoring in the border areas between Norway and Russia. Boreal and Environmental Research 5: 257-278.
Wild berries and edible mushrooms	cloudberry (*Rubus chamaemorus*) bilberry (V*accinium myrtillus*) cowberry (V. vitis-idaea crowberry (*Empetrum hermaphoditrum*)	Aamlid, D. and Skogheim, I. 1993. Nickel, copper and other metals in berries of cloudberries (Rubus chamemorous) and bilberry (Vaccinium mytillus) from South Varanger, north-east Norway, 1992. Research paper of Skogforsk 14/93.
Birds	Pied fly catcher	Framstad, E. (ed.) 2003. Monitoring programme for terrestrial ecosystems. Ground vegetation, epiphytes, small rodents and birds in monitoring sites, 2002. – NINA Oppdragsmelding 793. 62 pp.
Small mammals	Rodents, shrews	Framstad, E. (ed.) 2003. Monitoring programme for terrestrial ecosystems. Ground vegetation, epiphytes, small rodents and birds in monitoring sites, 2002. – NINA Oppdragsmelding 793. 62 pp.
Soil	Litter, humus, mineral soil	ICP Forests, Manual, Part I11, Sampling and analysis of soil and submanual on soil collection and analysis (http://www.icp-forests.org/Manual.htm)
Remote sensing		Tømmervik, H., Høgda, K.A., & Solheim, I. 2003. Monitoring vegetation changes in Pasvik (Norway) and Pechenga in Kola Peninsula (Russia) using multi-temporal Landsat MSS/TM data. Remote Sensing of Environment, 85: 370-388.
POPs and PAHs	All components	MAP Assessment 2002 - Persistent Organic Pollutants in the Arctic (http://www.amap.no/)

Table 4.4
The internationally standardised methods (or literature references in which the methods are described) for the individual parameters and attributes to be monitored.

4.4 Monitoring timetable

The timetable for the monitoring activities is given in Table 4.1.

4.5 Data quality, validation and storage

Achieving fully comparable monitoring results, collected independently by different organizations in the three countries, presupposes that all the fieldwork and chemical analyses are carried out in accordance with harmonised, internationally approved manuals (e.g. ICP Forests, ICP Vegetation). Joint field exercises should always be carried out prior to making assessments and measurements of the selected range of parameters and attributes, and participation in international inter-calibration courses is also highly recommended. Strict quality assurance and control procedures covering sampling, sample transport and chemical analyses in the laboratory, should also always be employed. The laboratories responsible for carrying out the chemical analyses should participate regularly in national and international inter-calibration exercises, and especially before starting analyses that are not carried out every year. The laboratories responsible for carrying out the analyses should also participate in so-called working ring tests, in which standard samples (e.g. plant and soil samples) from the monitoring area are analysed.

The results of the assessments and measurements made in the field, as well as the results of the chemical analyses, should be stored in the appropriate data files in the terrestrial databank maintained by the Rovaniemi Research Unit, Metla.

4.6 Reporting

A report of the state of the terrestrial ecosystems in the area should be published by the end of the year 2010.

4.7 Development of the monitoring programme

During the course of the project a number of gaps in information were identified. There is an urgent need to carry out planning and development work on these missing parameters and attributes before they can be incorporated into the future monitoring programme. The main gaps in information can be addressed by implementing the following:

1. At least four plots, at distances of 2, 5, 20 and 50 km, should be established to the east of Nikel in order to complete the west-east transect.
2. Two of the existing plots (one in Norway and one in Finland), and one of the new plots (either at 20 and 50 km distance) in Russia to the east of Nikel, should be established as a part of integrated (terrestrial, aquatic and atmospheric) studies to be carried out in two small catchment areas (e.g. lake and surrounding land area) in order to calculate input-output budgets for heavy metals, organic pollutants and acidifying components.

3. A snowpack survey should be carried out during the winter on a systematic grid (e.g. 8 x 8 km) in order to more precisely identify the emission point sources (primarily of POPs and PAHs), and to estimate the distribution and extent of heavy metal, organic pollutant and acidifying compound deposition over the whole area.
4. A survey of heavy metal and organic pollutant concentrations in forest berries (cloudberries, bilberries, cowberries and crowberries) and edible wild mushrooms should be carried out on the same systematic grid as for the snowpack survey in order to assess the potential threat to the health of the local population who consume these products.

References

Aamlid, D., Vassilieva, N., Aarrestad, P.A., Gytarsky, M., Lindmo, S., Karaban, R., Korotkov, V., Rindal, T., Kusmicheva, V. and Venn, K. 2000. Ecosystem monitoring in the border areas between Norway and Russia. Boreal and Environmental Research 5.

Appendix 3.1

Join monitoring programme for the Paz watercourse

Monitoring stations	Location Nikel	Distance from smelter	Country	Frequency X = every year x = every 3th year Water quality (general)
Inarijärvi Vasikkaselkä 151	Upstream	100	Finland	X
Paatsjoki Virtaniemi 14400	Upstream	80	Finland	X
Rajakoski	Upstream	60	Russia, MUGMS	X
Vaggetem	Upstream	40	Norway	X
Kolosjoki (14,7 km)	Upstream	15	Russia, MUGMS	X
Shuonijoki	Upstream	5	Russia, INEP	X
Pechenganikel plant		0		
Kolosjoki	Downstream	2	Russia, MUGMS	X
Lake Kuetsjarvi	Downstream	0-6	Russia, INEP	X
Protoka stream (Kuetsjärvi-Salmijärvi)	Downstream	5	Russia, MUGMS	X
Skrukkebukta	Downstream	16	Norway	X

Existing programme

	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
	X = every year	**X = every 6th year**	**X = every 6th year**	**X = every 3th year**	**X = every 3th year**	**XX = every year**	**X = every 3th year**
	x = every 3th year					**X = every 3th year**	
	Water quality (metals)	**Sedi-ments (metals)**	**Sediments POPs**	**Fish popu-lations**	**Fish pa-thology**	**Fish metals**	**Fish POPs**
		X	X	X	X	X	X
	X						
	X						
	X	X	X	X	X	X	X
	X						
	X						
	X						
	X	X	X	X	X	XX	X
	X						
	X	X	X	X	X	XX	X

Appendix 3.2

Join monitoring programme for lakes in the Norwegian, Finnish And Russian Border Area

Area	Area number (on map)	Lake name	Size (km²)	Country	Frequency X = every year x = every 3th year Water quality (general)	Frequency X = every year x = every 3th year Water quality (metals)
Main monitoring areas:						
Pechenganikel	1	Palojärvi	0,64	Russia	X	X
	1	LN-2	0,11	Russia	X	X
	1	LN-3	0,05	Russia	X	X
	1	Haukilampi	0,24	Russia	X	X
	1	Stepanovinjarvi	<0.5 km2	Russia	x	x
	1	Velikjampijanjarvi	0,09	Russia	X	X
	1	Sarijarvi	0,08	Russia	X	X
	1	Kivikkojarvi	<0.5 km2	Russia	x	x
	1	Rahpesjarvi	<0.5 km2	Russia	x	x
	1	Keinojarvi	0,19	Russia	x	x
Jarfjord	2	JAR5	<0.5 km2	Norway	X	X
	2	JAR6	<0.5 km2	Norway	X	X
	2	JAR7	<0.5 km2	Norway	X	X
	2	JAR8	<0.5 km2	Norway	X	X
	2	JAR12	<0.5 km2	Norway	X	X
	2	JAR13	<0.5 km2	Norway	X	X
	2	Dalvatn	0,245	Norway	X	X
	2	Første Høgfjellsvatn	0,159	Norway	X	X
	2	Otervatnet	0,185	Norway	X	X
	2	Store Skardvatnet	0,598	Norway	X	X
	2	Guoika Luobbalat	0,118	Norway	x	x
	2	Limgambergtjern	0,13	Norway	x	x
Sør-Varanger	2	Brannflället 145m	<0.5 km2	Norway	x	x
	2	Sametfjället 114m	<0.5 km2	Norway	x	x
	2	Sametfjället 120m	<0.5 km2	Norway	x	x
	2	Sametfjället 152 m	<0.5 km2	Norway	x	x
Vätsäri	3	Lampi 222	0,26	Finland	X	X
	3	Joulujärvet V1	0,36	Finland	x	x
	3	Lampi 3/88	0,05	Finland	X	X
	3	Lampi 5/88	0,017	Finland	X	X
	3	Lampi 219 6/88	0,07	Finland	X	X
	3	Lampi 7/88	0,026	Finland	X	X
	3	Lampi J11	0,046	Finland	X	X
	3	Harrijärvi H62	0,95	Finland	x	x
	3	Pitkä-Surnujärvi V6	0,75	Finland	x	x
	3	Surnujärvi V4	4,59	Finland	x	x
	3	Mellalompolo	2,27	Finland	x	x
	3	K. Aittojärvi	0,57	Finland	x	x

Existing monitoring (part of national programme)

Part of the program that are planned to be developed and included into program later

	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
	X = every 6th year	X = every 6th year	annual samples	X = every 6th year	XX = every 3th year	X = every 6th year	X = every 6th year	X = every 6th year
	x = every 12th year	x = every 12th year	analyzed every 6 years	x = every 12th year	X = every 6th year			x = every 12th year
					x = every 12th year			
	Sediments (metals)	Sediments POPs	Sedimentation (metals)	Zoobenthos	Fish populations L = littoral, P = pelagic	Fish pathology	Fish metals	Fish POPs
	X	X						
	X	X		X	L, x			
	X	X			L, x			
					L, x			
				X				
	x	x		X	L, x			
					L, x			
					L, x			
				x				
	x	x						
	x	x						
	x	x						
	X	X	X	X	P, XX	X	X	X
	x	x		X		X	X	X
	X	X	X	X	P, XX	X	X	X
	x			X	P, XX			
				X				
				x				
					L, x			
					L, x			
					L, x			
					L, x			
	X	X	X	x				
				X				
	x	x		X	L, x			
					L, x			
					L, x			
					L, x			
					L, x			
	x	x		x				
	x	x		X				
	X	X	X					
	x				P, X	X	X	X
	x				P, X	X	X	X

Appendix 3.3

Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area – Implementation Guidelines for the Groundwater Monitoring

Common description of the groundwater monitoring

As the investigations carried out during the Pasvik-Pechenga project didn't show clear indication on anthropogenic contamination in ground water on the Norwegian side of the border and the long-term monitoring shows good quality of groundwater on the Finnish side of the border, the groundwater monitoring in Norway and Finland will be continued as a part of the requirements of the WFD regarding groundwater monitoring in transboundary aquifers.

There are two groundwater monitoring sites in the border area:
- Svanvik, Sørvaranger municipality, within the Baccavæjåkka,
- Nellim, Inari municipality, near the outlet of the Paz watercourse.

If there will be any signs that groundwater quality is deteriorating the environment authorities will inform the other side about this fact. The data of the ground water quality based on the monitoring in Svanvik and Nellim sites is available for the environment authorities on the both sides of the border. The groundwater quality data from the Nellim station could be integrated with groundwater quality data from the Svanvik monitoring station when needed through co-operation between LREC and NGU.

Used methods, frequency and time of sampling

Groundwater monitoring at Svanvik is a part of the Norwegian National groundwater monitoring network (LGN).

SUMMARY OF LGN QUALITATIVE MONITORING PROGRAM

Subject	Activity	Parameter/measurement	Instruments	Detection limit
Monitoring program	Sampling (after purging the wells)	500 ml raw-water sample for analysis of physical parameters	HDPE bottle	
		100 ml filtered 5 µm sample for anion analysis	Polyeten bottle	
		50 ml filtered 0.45 µm sample for analysis of cations	LDPE bottle	
	Field measurements	Temperature & EC	WTW, LF92	
		pH	ISFET pH meter, model IQ125	
		Dissolved O_2	Oxi 315i meter	0.1 mg/l
		Alkalinity	Merck, 1.11 109.0001 alkalinity field kit	
		Groundwater level (Not for springs)	Water level meter	
	Laboratory analyses	Partial/ total alkalinity	Radiometer Titralab 94/ Glass-electrode pHC 2701-8 "Red Rod"	0.04mmol/l
		pH	Radiometer Titralab 94/ Glass-electrode pHC 2701-8 "Red Rod"	
		Electrical conductivity, Temperature	Radiometer Titralab 94 / CDM 210 cond. meter	0.07mS/m
		Colour	SHIMADZU UV-1201 spectrophotometer	1.4
		Turbidity	Hach 2100 A turbidity meter	0.05 FTU
		Anions (F, Cl, NO2, Br, NO_3, PO_4, SO_4	Ion chromatography (IC)	See attachment
		Cations (Si, Al, Fe, Ti, Mg, Ca, Na, K, Mn, P, Cu, Zn, Pb, Ni, Co, V, Mo, Cd, Cr, Ba, Sr, Zr, Ag, B, Be, Li, Sc, Ce, La, Y, As, Sb)	Inductively coupled plasma-atomic emission spectrometry (ICP-AES)	See attachment
		Cations (Al, B, Be, Cd, Ce, Co, Cr, La, Mo, NI, Pb, Rb, As, Se, Sb, Ag, Bi, Cs, Cu, Ga, Ce, Ho, I, In, K, Li, Mn, Nb, Nd, P, Sm, Ta, Th, Tl, U, V, W, Y, Yb, Zn, Zr)	Inductively coupled plasma-mass spectrometry (ICP-MS)	See attachment
	Sampling frequency	Southern Norway	Twice/year - Spring & Autumn	
		Northern Norway	Up to and including 2006: Once/ year- Autumn Starting in 2007 same frequency as for Southern Norway	

Sub-ject	Activity	Type	Description
Data	Data collection	Field data	Data manually recorded on standard field form
		Laboratory data	Digital and hard copy from laboratory (Digital data mostly used)
	Data processing		NGU's Standard for geographic positioning of locatities and for sample format Check for anomalies in Excel, Check internal consistency in AQUA / AQUACHEM Format data in Excel for input into GRANADA database

Sub-ject	Type	Description
Docu-men-tation	Protocols	Groundwater sampling protocol
		Protocol for quality control (in prep)
	Publications	Summary report: Øvervåkning av grunnvann 1 (2003)
		Annual reports 1991-1999, 2005 - (see also www.grunnvann.no)
		Miscell. reports and articles
	Databases	Oracle GRANADA (www.ngu.no/kart/granada)

Groundwater monitoring at Nellim is a part of the Finnish National groundwater monitoring network .

The Nellim station, established in Quarternary sediment deposits, has been used as a monitoring station for groundwater for 20 years. Groundwater sampling for chemical analysis is carried 6 times per year from wells, and 5 times per year from lysimeters. In addition, snow sampling is carried out once a year in early spring.

SUMMARY OF THE GROUND WATER MONITORING PROGRAM AT THE NELLIM STATION

Subject	Activity	Parameter/measurement	Instruments	Detection limit
Monitoring program	**Sampling**	1000 ml sample	Polyeten bottle	
		250 ml sample for anion analysis	Polyeten bottle	
		500 ml sample for mercury	Glass bottle	
		100 ml sample for TOC	Polyeten bottle	
		500 ml sample for AOX	Glass bottle	
		250 ml sample for Fe,Mn,CODMn	Polyeten bottle	
		100 ml sample for anlysis of oxygen	Glass bottle	
		150 ml sample for analysis of cations	LDPE bottle	
	Field measurements	Temperature	Mercury thermometer	
		Amount of filtrate , ground water level, thickness of snow and frost	Lysimeter, frost tube, snow line	
	Laboratory analyses	Partial/ total alkalinity	Metrohm Titrando Autom. analycer	0.007mmol/l
		pH	Radiometer PHM 62/ Glas-selectrode RedHod	
		Electrical conductivity	Metrohm 712 / PL100/B/2	
		Colour	Lovibond DAYLIGHT 2000 UNIT	5
		Turbidity	Hach 18900 turbidity meter	0,05FTU
		Fe, Mn	Spektrofotometer	5ug, 10ug
		CODMn	Metrohm Titrnado Autom. analyzer	0,5
		Anions (F, Cl, SO4)	Ion chromatography (IC)	
		Cations (Si, Al, Ag, Cu, Zn, Pb, Ni, Co, V, Mo, Cd, Cr, Ba, Sr, B, Be, Li, Sc, Ce, La, As, Sb, Ni, Pb, Rb, Se, Bi, Cs, L, Nb, Nd,Ta, Th, Ti, U, Zn, Zr)	Inductively coupled plasma-atomic emission spectrometry (ICP-AES,IC-OES)	
		Na, K, Ca, Mg	AAS-F	0,1 mg/l
		Hg	AFD	0,002 ug/l
		AOX	Titrimetric- method	
		NO3-N, N-tot, NH4-N, P-tot. PO4-P,	Lachat- autom.analyzer	2ug/l, 30ug/l, 5ug/l, 3ug/l, 2ug/l
	Sampling frequency	NELLIM lähde	Four times /year	
		Nellim lysimeter	Once in autumn and in spring	
		Nellim snow	Once a year in early spring	

Subject	Activity	Type	Description
Data	**Data collection**	Field data	
		Laboratory data	Digital and hard copy from laboratory. Digital copy in the national ground water registerPOVET
	Data base		National ground water registerPOVET, www.ymparisto.fi

Appendix 3.4

Intercomparison of technique of the sediment investigation

Technique of the sediment sampling

Russian scientists (INEP). Sediment samples from the different lakes and stations of the Pasvik River watersheds on the Finnish, Russian and Norwegian sites were taken from the deepest area of lakes with the Skogheim (1979) gravity corer and divided into 1-cm thick horizontal layers to facilitate the analysis. Sediment samples have been placed in polyethylene containers and sent in laboratory for the analysis where they were stored at temperature 4˚C up to the analysis.

Finnish scientists (Lapland Regional Environment Centre). Sediment samples were taken by the same technique, but the difference was only the division of the sediment cores – the first 10 cm of the sediment cores were divided into 1-cm thick horizontal layers, and then the layers of 18-20, 28-30 cm and so on.

Technique of sediment chemical analyses

Russian scientists (INEP). Samples (approximately 5 g) have been dried up in a drying case at temperature 105˚C during 6 h, and humidity of a sample (Håkanson, 1980) was determined. Then samples were ignited in muffle furnaces at temperature 450-500˚C during 4 h for definition of losses on ignition (LOI) as indirect index of the contents of organic substance. Samples then were pounded in jasper mortar and kept at temperature 4˚C up to the chemical analysis.

To determine the total concentrations of metals, the sediment sample of 0.4 g was extracted by 4 ml of the concentrated nitric acid (HNO_3) in an autoclave with the teflon loose leaf at temperature 140˚C during 4 h. Contents of an autoclave were then cooled up to a room temperature, and 2 ml of aliquot moved to 60 ml plastic botle and were diluted by deionized water up to volume of 25 ml. The resulting solution was analyzed by the atomic absorption spectrophotometer (Perkin-Elmer-5100) in air - propane (Ni, Cu, Co, Zn, Cd, Pb, Mn, Fe, Na, K), air - acethylene (Mg, Ca) and protoxide of nitrogen – acethylene flame (Al). Hg was determined utilizing cold vapour atomic absorption.

Finnish scientists (Lapland Regional Environment Centre). A representative sediment sample of up to 0.5 g is extracted and dissolved in 10 ml concentrated nitric acid, for 10 minutes using microwave heating with a suitable laboratory microwave unit. The sample and acid are placed in a fluorocarbon polymer (PFA or TFM) or quartz microwave vessel or vessel liner. The vessel is sealed and heated in the microwave unit. After cooling, the vessel contents are filtered, centrifuged, or allowed to settle and then diluted to volume and analyzed by the abovementioned determinative method.

Results and conclusions

The technique of sediment sampling and chemical analyses by INEP and LREC were almost the same. The insignificant difference was only in sample preparation – INEP for that uses the autoclave with the teflon loose leaf, and LREC microwave heating. This similarity and accurate works of the chemists of the both laboratories allows to secure perfectly comparable results of the chemical analyses. Mistake of the determination of the concentrations of analysed elements mainly was in range of 10%, very seldom up to 20-30%.

Appendix 3.5

Variables and methods of the Lapland Regional Environment Centre (LREC) and other laboratories in the Finnish environment administration, Finland

Monitoring measures	Parameters
Water quality	pH, Conductivity, Alkalinity, Turbidity, Colour, O_2, K, Ca, Mg, Na, SO_4, SiO_2, Cl, CODMn, TOC
Nutrients	tot-P, tot-N, PO_4-P, NO_{2+3}-N, NH_4-N
Heavy metals	Ni, Cd, Cr, Cu, Pb, Zn, As, Hg, Mn, Al, Fe

Parameters	Methods
pH	Electrometry
Conductivity	Electrometry
Alkalinity	Titrimetry
Turbidity	Nephelometry
Colour	Comparator method
O_2	Redox titration (Winkeler)
K	FAAS
Ca	FAAS
Mg	FAAS
Na	FAAS
SO_4	IC
SiO_2	Spectrophotometry, FIA
Cl	Titrimetric
CODMn	Oxidation with KMnO4, + titrimetry
TOC	IR
tot-P	Peroxodisulfate oxidation, Spectrophotometry, FIA
tot-N	Peroxodisulfate oxidation, Spectrophotometry, FIA
PO_4-P	Spectrophotometry, FIA
NO_3-N	Spectrophotometry, FIA
NH_4-N	Spectrophotometry
Ni	ICP-MS or ICP-AES
Cd	ICP-MS or ICP-AES
Cr	ICP-MS or ICP-AES
Cu	ICP-MS or ICP-AES
Pb	ICP-MS or ICP-AES
Zn	ICP-MS or ICP-AES
As	ICP-MS or ICP-AES
Hg	AAS (1995-2001), Atom fluorescence (2001->)
Mn	Peroxodisulfate oxidation, Spectrophotometry
Al	ICP-MS or ICP-AES
Fe	Peroxodisulfate oxidation, Spectrophotometry

Appendix 3.6

Variables and methods of the Norwegian Institute of Water Research (NIVA), Norway

Monitoring measures	Variables
Water quality	pH, Conductivity, Alkalinity, Turbidity, Color, O_2, K, Ca, Mg, Na, SO_4, SiO_2, Cl, CODMn, TOC
Nutrients	tot-P, tot-N, PO_4-P, NO_2-N, NO_3-N, NH_4-N
Heavy metals	Ni, Cd, Cr, Cu, Pb, Zn, As, Hg, Mn, Al, Fe

Variables	Methods
pH	Electrometry
Conductivity	Electrometry
Alkalinity	Titrimetry
Turbidity	Nephelometry
Color	Spectrophotometry
O_2	Redox titration (Winkeler)
K	Ion chromatography
Ca	Ion chromatography
Mg	Ion chromatography
Na	Ion chromatography
SO_4	Ion chromatography
SiO_2	ICP-MS or ICP-AES
Cl	Ion chromatography
CODMn	Oxidation with KMnO4, + titrimetry
TOC	UV/peroxodisulfate oxidation, or cathalytic combustion at 680 °C
tot-P	Spectrophotometry, automated
tot-N	Peroxodisulfate oxidation + spectroph.
PO4-P	Peroxodisulfate oxidation + spectroph.
NO_2-N	Ion chromatography
NO_3-N	Ion chromatography
NH_4-N	Ion chromatography
Ni	ICP-MS or ICP-AES
Cd	ICP-MS or ICP-AES
Cr	ICP-MS or ICP-AES
Cu	ICP-MS or ICP-AES
Pb	ICP-MS or ICP-AES
Zn	ICP-MS or ICP-AES
As	ICP-MS or ICP-AES
Hg	Cold vapour Atomic absorption
Mn	ICP-MS or ICP-AES
Al	ICP-MS or ICP-AES
Fe	ICP-MS or ICP-AES

Appendix 3.7

Variables and methods of the Murmansk Department for Hydrometeorology and Environment Monitoring (MUGMS), Russia

Monitoring measures	Parameters
Water quality	pH, Conductivity, Alkalinity, Turbidity, Color, O_2, K, Ca, Mg, Na, SO4, SiO_2, Cl, CODMn, TOC
Nutrients	tot-P, tot-N, PO_4-P, NO_2-N, NO_3-N, NH_4-N
Heavy metals	Ni, Cd, Cr, Cu, Pb, Zn, As, Hg, Mn, Al, Fe

Parameters	Methods	Notes
pH	electrometric	pH-meter
Conductivity	electrometric	conuctometer
Alkalinity	potentiometric	PH-meter+titrator
Turbidity	-	
Color	spectrofotometric	
O_2	TitrimetricWink	
K	Flamephotometry	
Ca	TitrimetricEDTA	
Mg	TitrometricEDTA	
Na	Flamephotometry	
SO_4	Turbidimetric	
SiO2	spectrofotometric	
Cl	mercurimetric	
CODCr	Titrimetric2Cr	
TOC	-	
tot-P	photometric	
tot-N	-	
PO_4-P	photometric	
NO_2-N	Spectrofotometric Griss	
NO_3-N	photometricCdRe	
NH_4-N	photometricIndo	
Ni	GFAAS	
Cd	GFAAS	
Cr	GFAAS	
Cu	FAAS	
Pb	GFAAS	
Zn	FAAS	
As	GFAAS	
Hg	AAS	
Mn	FAAS	
Al	FAAS	
Fe	FAAS	

Appendix 3.8

Variables and methods of the Institute of North Ecological Industrial Problems (INEP), Russia

Monitoring measures	Variables
Water quality	pH, Conductivity, Alkalinity, Turbidity, Color, O_2, K, Ca, Mg, Na, SO_4, SiO_2, Cl, CODMn, TOC
Nutrients	tot-P, tot-N, PO_4-P, NO_2-N, NO_3-N, NH_4-N
Heavy metals	Ni, Cd, Cr, Cu, Pb, Zn, As, Hg, Mn, Al, Fe

Variables	Methods	Notes
pH	Potentiometry; pH-meter M-82, Radiometer, Copenhagen	pH-meter
Conductivity	Conductometry; Conductometer 660, Metrohm (Switzerland)	conuctometer
Alkalinity	Potentiometric titration; Gran's method	PH-meter+titrator
Turbidity	-	
Color	spectrofotometry	
O_2	-	
K	Flame AES; AAS 460, Perkin-Elmer	
Ca	FAAS; AAS-360, Perkin-Elmer	
Mg	FAAS;AAS-360, Perkin-Elmer	
Na	Flame AES; AAS 460, Perkin-Elmer	
SO_4	Ion chromatography	
SiO_2	Spectrophotometry	
Cl	Ion chromatography	
CODMn	Titrimetry	
TOC	converting: CODMn*0.764 + 1.55	
tot-P	Digestion with peroxodisulfate and spectrofotometric determination of blue phospho-molybdate complex (using ascorbic acid)	
tot-N	Spectrophotometric determination of nitrogen content of water after oxydation by peroxodisulphate	
PO_4-P	Spectrofotometric determination of blue phospho-molybdate complex (using ascorbic acid)	
NO_2-N	Spectrophotometric determination of nitrogen content after reduction of nitrate to nitrite by passage of the digest through a copperized cadmium column	
NO_3-N	Spectrophotometric determination of nitrogen content after reduction of nitrate to nitrite by passage of the digest through a copperized cadmium column	
NH_4-N	Phenol-hypochlorite method	
Ni	AAS; Perkin-Elmer-5000 with graphite atomizer HGA-400	
Cd	AAS; AAnalyst-800 with Zeeman-effect background correction	
Cr	AAS; AAnalyst-800 with Zeeman-effect background correction	
Cu	AAS; Perkin-Elmer-5000 with graphite atomizer HGA-400	
Pb	AAS; AAnalyst-800 with Zeeman-effect background correction	
Zn	AAS Perkin-Elmer-5000 with Graphite Furnace HGA-400	
As	AAS; AAnalyst-800 with Zeeman-effect background correction	
Hg	Mercury atomizer FIMS-100 (Perkin-Elmer)	
Mn	AAS; Perkin-Elmer-5000 with graphite atomizer HGA-400	
Al	AAS; Perkin-Elmer-5000 with graphite atomizer HGA-400	
Fe	AAS; Perkin-Elmer-5000 with graphite atomizer HGA-400	

Apppendix 4.1

Assessment of ground vegetation

The ground vegetation is defined as all lichens, bryophytes and vascular plants (for woody species only those with a height below 50 cm) growing on the ground.

The main objectives for assessing the ground vegetation in the Pasvik monitoring programme are:

1. To characterize the current state of the forest ecosystem on the basis of the plant species composition
2. To monitor the vegetation changes attributable to natural and anthropogenic environmental factors, especially the effects of changes in air pollution levels, by repeated measurements over time

The methods for assessing the ground vegetation have been developed by harmonizing the methods from the three different monitoring networks. The methods are also comparable with the ICP Forests manual on assessing ground vegetation (ICP Forests, Manual, Part VIII, Assessment of ground vegetation (http://www.icp-forests.org/Manual.htm) and the Norwegian national monitoring programme TOV (Framstad 2002). The methods should be used to monitor the species abundances and composition, the structure of different vegetation layers, and the cover of bare soil, litter, stone and dead plants on the ground.

Sampling design

The common sample unit for the assessment of the species composition and abundance of the ground vegetation is a 1 x 1 m quadrat which should either be randomly or systematically distributed within the monitoring plots. The quadrats should not be located less than 1 meter from each other and they should not fall on large stems, stumps or large stones. All quadrats should be permanently marked with aluminium sticks in each corner and wooden sticks in opposite corners at points immediately outside the square. The number of quadrats should be 20 on all the monitoring plots, and the total plot area at each site should be approximately 1000 m^2. It should be possible to calculate plotwise averages for the cover and number of plant species.

Information about topography, abundance of bare soil, litter, stone and dead plants

The aspect of the 1 x 1m quadrats should be measured with a compass, and the slope of the ground in degrees with a clinometer. The proportion of bare soil, litter, stones and dead plants within the quadrats should be estimated in percentage cover of the ground.

Recording of height and percentage cover of vegetation layers

The average height and percentage cover of different vertical vegetation strata should be recorded in the field for each the 1 x 1m quadrats:

A: Tree layer (tree species and *Salix* spp., 2 m or higher)
B1: Shrub layer (tree species and *Salix* spp. below 2 m)
B2: Dwarf shrub/heather layer (*Vaccinium spp., Calluna vulgaris, Empetrum nigrum, Ledum palustre*)
C1: Herb layer (all vascular plants except woody species)
C2: Grass layer (grasses and sedges)
D: Ground layer (bryophytes and lichens)

The strata B2, C1 and C2 can be combined into a measurement of the field layer.

Species monitored and taxonomy

All vascular plants (Pteridophyta and Spermatophyta), bryophytes (Bryophyta) including liverworts (Anthocerotopsida and Hepaticopsida) and mosses (Bryopsida), and macrolichens growing on the soil should be recorded. Species not verified in field should be collected for later identification in laboratory. In general, species should be identified to the species level, if not possible then to the genus level. A number of species that are difficult to identify separately have earlier been recorded in groups of taxa: Lophozia ventricosa coll. includes *L. excisa, L. ventricosa,* and *L.* spp. *Cladonia arbuscula* coll. includes *C. arbuscula* and *C. mitis*. *Cladonia chlorophaea* coll. includes *Cladonia* species with broad, regular cups and brown apothecia, such as *Cladonia chlorophaea, C. fimbriata* and *C. pyxidata*. The mosses *Dicranum flexicaule* and *D. fuscescens* have not been identified separately and are assessed as one taxa. The same has been done with *Barbilophozia lycopodioides* and *B. hatcheri*, with *Cladonia coccifera* and *D. pleurota*, with *Cladonia deformis* and *C. sulphurina*, and with *Cladonia gracilis* and *C. cornuta*. This grouping of difficult taxa should continue in future.

National floras can be used to identify plants. However it is important to use the same taxonomic nomenclature, especially for collation in a common database and in the analysis of changes in species composition. We recommend that the taxonomic nomenclature follows Lid & Lid (2005) or Mossberg & Stenberg (2003) for vascular plants, Frisvoll et al. (1995) for bryophytes, and Santesson et al. (2004) for lichens. However, the nomenclature should always be updated to the latest versions following the International Code of Botanical Nomenclature (ICBN). Joint training course on species identification is recommended.

Measuring species abundance and species composition

The abundance of all species of lichens, bryophytes and vascular plants (for tree and shrub species only individuals below 0.5 m height) covering the 1 x 1 m plot, regardless of whether they are rooted inside or outside the quadrat, shall be recorded. Species growing directly on stones, litter, dead wood or stumps shall not be recorded unless there is a humus layer lying on top of the substrate. Joint training on estimating the percentage cover of the species should be performed prior to the assessments.

A 1 x 1 m frame should be used to assess the abundance of each species within the quadrats using two different abundance methods:

1. **Percentage cover of species** should be subjectively estimated for each species using a percentage cover scale from 1-100%. Finer scales below 1% should be used equally on all plots, e.g. covering less than 0.01%, 0.01% - 0.1% and 0.1 - 1%. The field personnel performing the estimations should be trained as regards accuracy and common estimations before the recordings.

2. **Frequency of species** should be recorded by dividing the 1 x 1 m frame into 16 equal sub-plots of 25 x 25 cm. In each sub-plot the species should be recorded as either present or absent, regardless of whether they are growing inside or outside the sub-plots. In addition, the occurrence of each species within the 16 sub-plots should be recorded as either 1) one individual, 2) covering less than 50%, or 3) covering 50% or more.

Species diversity measurements

Species richness of the plots should be calculated on the basis of the species occurring within the 1 x 1 m quadrats and additional species within the plot area. The additional species should be assessed with an approximately percentage cover abundance value for the total plot area.

Photo documentation

The 1 x 1 m vegetation quadrats should be photographed with a digital camera before performing the vegetation analysis. Such photos are useful for quality control and they can also be used in computer programs for estimating changes in species composition and abundance over time. Photos should also be taken of each plot at fixed positions in order to describe the present structure of the forest vegetation.

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

This programme is the main outcome of the two international projects Interreg III Kolarctic "Development and implementation of an environmental monitoring and assessment programme in the joint Finnish, Norwegian and Russian border area", carried out during 2003 – 2006 and 2007-2008.

The environmental authorities and researchers in the three countries have created long-term environmental monitoring programme for getting comprehensive and current information on changes taking place under the varying anthropogenic load in the border area. The main reason for carrying out the programme is the impact of the Pechenganikel industrial complex, where copper and nickel ore has been mined and processed for over 70 years. The monitoring area covers a large part of the Paz catchment, which is divided between the three countries. The countries differ with respect to their environmental legislation, relation to the EU, and structure and content of the existing monitoring systems. One of the goals of the joint monitoring programme is to exploit existing national monitoring networks in order to obtain more complete information about the condition of the environment in the region.

The programme is based on the outputs of the monitoring, research, evaluation and development activities carried out by an international group of scientists presenting more than twenty organizations.

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

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