FI0000015

STUK-A166 August 1999

General characterisation of study area and definition of experimental protocols

WP 1 in the project 'Effect of industrial pollution on the distribution dynamics of radionuclides in boreal understorey ecosystems'

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RADIATION AND NUCLEAR SAFETY AUTHORITY

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ISBN 951-712-328-0
ISSN 0781-1705

Oy Edita Ab, Helsinki 1999

Sold by:
STUK • Radiation and Nuclear Safety Authority
P.O. Box 14 FIN-00881 HELSINKI Finland
Tel. +358 9 759 881

RAHOLA, Tua, ALBERS, Bert, BERGMAN, Ronny, BUNZL, Kurt, JAAKKOLA, Timo, NIKONOV, Vyacheslav, PAVLOV, Vladimir, RISSANEN, Kristina, SCHIMMACK, Wolfgang, STEINNES, Eiliv, SUOMELA, Matti, TILLANDER, Michael and ÄYRÄS, Matti. General characterisation of study area and definition of experimental protocols. WP 1 in the project, Effect of industrial pollution of the distribution dynamics of radionuclides in boreal understorey ecosystems. STUK-A 166, Helsinki 1999, 37 pp.

ISBN 951-712-328-0
ISSN 0781-1705

Keywords industrial pollution, heavy metals, radionuclides, boreal ecosystems

ABSTRACT

The research project EPORA (Effects of Industrial Pollution on the Distribution Dynamics of Radionuclides in Boreal Understorey Ecosystems) is part of the EU Nuclear Fission Safety Programme 1994 - 1998. The main purpose of EPORA is to study the influence of strong chemical pollution on the behaviour of artificial radionuclides (^{137}Cs, ^{90}Sr, $^{239,240}Pu$) in a northern boreal ecosystem and subsequently to assess the significance of the findings to the radiation exposure of the population in such areas. The present report is a documentation of the selection of study areas based on the assessment of available information on pollution in the Kola Peninsula and Northern Fennoscandia and of sampling and analysing methods.

RAHOLA, Tua, ALBERS, Bert, BERGMAN, Ronny, BUNZL, Kurt, JAAKKOLA, Timo, NIKONOV, Vyacheslav, PAVLOV, Vladimir, RISSANEN, Kristina, SCHIMMACK, Wolfgang, STEINNES, Eiliv, SUOMELA, Matti, TILLANDER, Michael and ÄYRÄS, Matti. Tutkitun alueen karakterisointi ja kokeellisten menetelmien kuvaus. WP 1 projektissa Effect of industrial pollution of the distribution dynamics of radionuclides in boreal understorey ecosystems eli Teollisten saasteiden vaikutus radionuklidien jakautumiseen ja kulkeutumiseen pohjoisten metsien aluskasvillisuuden muodostamassa kasvuympäristössä. STUK-A 166, Helsinki 1999, 37 s.

ISBN 951-712-328-0
ISSN 0781-1705

Avainsanat teollinen saastuminen, raskasmetallit, radionuklidit, metsäympäristö

TIIVISTELMÄ

Projekti EPORA (Effect of Industrial Pollution on the Distribution Dynamics of Radionuclides in Boreal Understorey Ecosystems) eli teollisten saasteiden vaikutus radionuklidien jakautumiseen ja kulkeutumiseen pohjoisten metsien aluskasvillisuuden muodostamassa kasvuympäristössä on osa EU:n säteily- ja ydinturvallisuuden (Nuclear Fission Safety) vuosien 1994-1998 tutkimusohjelmaa.

Projektissa tutkitaan kemiallisten saasteiden vaikutusta radionuklidien ^{137}Cs, ^{90}Sr ja $^{239,240}Pu$ kulkeutumiseen pohjoisten alueiden metsäympäristössä. Tulosten perusteella arvioidaan saasteiden aiheuttamien muutosten merkitystä alueen väestön säteilyannoksiin. Tässä julkaisussa on esitetty tutkimusalueiden valinta ja ominaisuudet. Valintaperusteena on käytetty Kuolan niemimaalta ja Suomen, Ruotsin ja Norjan pohjoisosista käytettävissä olleita saasteiden levinneisyystietoja. Julkaisussa myös esitetään tutkimuksessa käytetyt näytteenkeräys- sekä mittaus- ja analyysimenetelmät.

CONTENTS

1 INTRODUCTION

In the Kola Peninsula, the most northern region of the European region of the Russian Federation, there are two big smelter complexes. At the end of the 1980's it was realised that the sulphur and heavy metal discharges from these smelters also polluted the northern parts of Finland and Norway. The areas adjacent to the smelters exhibit severe effects of pollution. The operating smelters released industrial pollution annually about 700 000 tons before 1991 and still about 580 000 tons in 1994. The most important industrial pollutants are S, Cu, Ni, Cd and Cr. Some studies have already been done or are performed based on the content of certain stable elements present in the atmospheric discharges – e.g. nickel and copper in sampling areas along pollution gradients from Nickel and Monchegorsk to various sites in Finland and Norway. (Kismul et al. 1992, Kozlov et al. 1993, Mäkinen, 1994, Reimann et al. 1994). However, the studies have so far not yet considered the potential of concomitant measurement of fallout radionuclides – particularly ^{137}Cs, ^{90}Sr and $^{239,240}Pu$ - and heavy metals in the same samples as a means to describe and analyse consequences of industrial pollution. Measurements done by Radiation and Nuclear Safety Authority (STUK) and University of Helsinki, Radiochemical Laboratory (HYRL) show that the radioactive fallout in Northern Fennoscandia mainly originates from the atmospheric nuclear weapons tests and the Chernobyl accident. (Doudarev et al. 1995, Paatero et al. 1994, Strand et al. 1997). An overview of Arctic pollution issues was also presented by AMAP, the Arctic Monitoring and Assessment Programme. (AMAP, 1997).

The research project EPORA(Effects of Industrial Pollution on the Distribution Dynamics of Radionuclides in Boreal Understorey Ecosystems) is a part of the EU Nuclear Fission Safety Programme 1994 - 1998. The main purpose of EPORA is to study the influence of strong chemical pollution on the turnover of artificial radionuclides (^{137}Cs, ^{90}Sr,$^{239,240}Pu$) in a northern boreal ecosystem, and subsequently to assess the significance of the findings to the radiation exposure of the population in such areas. The present report is a documentation of the selection of study areas based on the assessment of available current information on pollution in the Kola Peninsula and Northern Fennoscandia as well as of sampling and measurement methods and the planning of sampling.

2 ASSESSMENT OF CURRENT INFORMATION ON POLLUTION IN THE KOLA PENINSULA AND IN NORTHERN FENNOSCANDIA

Nearly all of the Kola Peninsula as well as Finnish Lapland belongs to the cool temperature zone where the mean annual temperature varies between - 1°C and + 1°C. The air temperature is characterised by sharp seasonal variations. The temperature passes below zero during all months and the thermal growing season (day mean temperature is higher than + 5°C) is short, only about 120 days. In the northern taiga sub-zone the total amount of precipitation is 500 - 600 mm throughout the year. The precipitation is highest in the summer and autumn period. The monthly rainfall in Monchegorsk varies from less than 20 mm in March to almost 70 mm in August. The duration of snow fall period is 6 - 6.5 months (from the middle of October to the end of May). (Mäkinen 1994, Reimann et al. 1998)

Shallow frozen layer - up to 50 - 100 cm characterises the podzolic sandy soil that prevails in coniferous forests in the Kola Peninsula. This is a result of mild winters and thick snow cover (60 - 100 cm). In the growing period the "active" temperatures (higher than + 10°C) are observed from the end of June -middle of July to the beginning or end of August, that is, the duration of the period of "active" temperatures is 1 - 1.5 months. In relatively cold years the "active" temperatures have been found only in the organic horizon (thickness of layer up to 10 cm). In moderate or relatively warm years (air temperature) the "active" temperatures can be observed significantly deeper (15 - 20 cm and 40 - 50 cm respectively). The same climatic pattern can be seen in Finland. In the winter period (October to May) south-westerly winds are predominant but in summertime northerly and north-easterly winds are more common than during the winter. (Mäkinen. 1994, Reimann et al. 1998).

Information on chemical pollution problems in the Kola Peninsula has been gathered from the scientific literature and from other recent research and monitoring programmes carried out in this region of Russia, with particular emphasis on the Monchegorsk region. (Derome (ed.). 1993, Kozlov et al. 1993, Lukina et al. 1996, Mäkinen, 1994, Nylén et al. 1995, Reimann et al.1994). The subjects particularly focused on are acidic and heavy metal deposition. Most of the information stems from work carried out during the last 10 years. Among the sources examined the following were found to contain particularly useful information:

1. The project "Biogeochemical cycles in the Northern forests subjected to air pollution", carried out by Kola Science Centre, Apatity. The precipitation chemistry of selected pollutants and the impact of these pollutants on soil and vegetation were studied in a series of forest plots situated at increasing distances from the Monchegorsk smelter. Some of these plots appeared to be suitable also for the work to be carried out in EPORA. The data previously gathered for these plots form a particularly useful basis for the present project, and the responsible scientists from Kola Science Centre participate in parts of EPORA. (Lukina et al. 1996).

2. The "Kola Ecogeochemistry Project", a large-scale monitoring project co-ordinated by the Geological Survey of Norway and carried out in collaboration with the Geological Survey of Finland and Central Kola Geological Expedition. In that project samples of mosses, surface soils and other media were collected in 1995 according to a dense network in most of the Kola Peninsula and analysed for 40 elements, including those of interest in the present work. Moreover the input/output of acidity and heavy metals was studied over a period of one year in eight catchments with varying pollution load. (Reimann et al. 1994).

3. The "Lapland Forest Damage Project", a project carried out during the period 1990-1994 as a collaboration between a number of research institutions in Finland and the Kola Peninsula and co-ordinated by the Finnish Forest Research Institute. An important part of that project was a detailed study of forest damage along three gradients from the Monchegorsk smelter: in the easterly, westerly, and south-westerly directions, using a combination of field observations, chemical analyses of soils and plants, and satellite data. (Derome (ed.), 1993).

4. The European heavy metal deposition program 1995 based on moss analysis, including the whole of Fennoscandia. The leader of WP 2 in EPORA is one of the co-ordinators of that program. (Ruhling et al 1995.)

In the Kola Peninsula there are four important sources for chemical pollution: mining, energy, other industrial production and traffic. The main sources of pollution are the Cu-Ni smelters Severonikel at Monchegorsk and Pechenganikel at Nikel. The proportion of their emissions out of the total emissions is 70 %. In 1987 to 1991 the total emissions of pollution were about 700 000 tons per year. The amount decreased to 578 000 tons per year in 1994. The composition of emissions is multicomponent. About 70 % of the emissions is SO_2 .In the period 1987 - 1991 the emission of Ni was 3700 and that of Cu 2600 tons per year. In 1996 the corresponding amounts were 1300 and 700 tons per year respectively. Most of the Ni and Cu originate from the smelter at Monchegorsk.

There are two main sources for radioactive contamination, the atmospheric nuclear weapons tests in the 1950's and 1960's and the Chernobyl accident in 1986. The possible releases from other nuclear facilities are of minor importance. The long-lived radionuclides ^{137}Cs, ^{90}Sr and $^{239,240}Pu$ are the most important when considering the long-term risks from internal radiation. In the case of external radiation the main contributor among the gamma emitting nuclides is ^{137}Cs. The radionuclide deposition originating in the nuclear weapons tests was rather evenly distributed in contrast to the deposition from Chernobyl. The accumulated deposition of ^{137}Cs before the end of 1985 was in Finland 1 800, of ^{90}Sr 1 100 and of $^{239,240}Pu$ 37 Bq per m^2 respectively. (Paatero et al. 1994, Saxén et al. 1987). The fallout from Chernobyl was very unevenly deposited. The mean surface ^{137}Cs activity was 10 000 Bq per m^2 on October 1, 1986 as mean for Finland, but in northern Lapland only 1 000 to 2 000 Bq per m^2. In all of Finland the ^{90}Sr deposition was much smaller, only a few percent of that of ^{137}Cs and also small compared to the earlier deposition from the nuclear weapons tests. Also in Lapland the ^{90}Sr deposition was small, only a few percents of the ^{137}Cs deposition. The $^{239,240}Pu$ deposition follows the same pattern, the deposition in Finland being about 1 Bq per m^2 and in Lapland 0,1 Bq per m^2. A Finnish-Russian study showed that the concentration of ^{137}Cs in lichen samples collected in Inari, Finnish Lapland, and in Lovozero, Kola Peninsula, 1960 - 1994, was about the same; only after the Chernobyl accident somewhat more ^{137}Cs was found on the Finnish side. (Doudarev et al. 1995). Also another publication confirms this finding (Rissanen et al. 1994). The collected information was found well documented and suitable as the base for the choice of study area.

3 SELECTION OF STUDY AREAS (REFERENCE AREAS AND FOUR DAMAGED AREAS ALONG THE POLLUTION GRADIENT)

The data presented above were considered when selecting the study areas for EPORA. Moreover they will form a basis for estimation of the long-term exposure of chemical pollutants to the sites selected in EPORA.

The Severonikel smelter complex in Monchegorsk was chosen as the release source producing a pollution gradient suitable for the aims of the EPORA project. The criteria for selection of sampling sites included investigation of visible damage of vegetation and water to be available from runoff at an adjacent catchment area. At distances from the release source where the pollution level is small or insignificant the vegetation at the growing sites is still unchanged. When approaching the release source the original characteristics of the vegetation are gradually changing into an ultimate state that may be classified as an industrial desert. At some intermediate stage it is expected to exist growing sites where the moss and lichen carpet is currently subjected to disintegration. At such sites the ground cover may have been substituted to a large extent by dwarf shrubs and grass.

The study areas described below fulfil the criteria chosen. The ecosystems to be investigated are open areas in spruce forests (*Piceetum fruticuloso-hylocomiosum*) with an old tree stand (> 100 years). Four sample sites (A, B, C, D, co-ordinates given in Table 1) will be established to the south of the Severonikel smelter complex at points subjected to varying levels of pollution by sulphur, nickel and copper compounds. The comparison reference site (REF) was selected at a sufficient distance from the industrial complex at Naruska in Finland 152 km from the smelter.

3.1 Vegetation

The spatial distribution of biomass of understorey species is far from even. The major factor responsible for spatial distribution of ground vegetation biomass is the tree layer. Tree plants regulate light, temperature, and hydrological and nutrient regimes in the forests. They also regulate intensity of element fluxes, including pollutants and acid forming substances, in forest ecosystems. The mass of *Pleurozium schreberi* below the crowns, particularly below the edge of the crowns, is comparable to that of between the crowns. The mass of *Hylocomium splendens* between the crowns is significantly higher than that below the crowns. *Empetrum* biomass below the crowns, particularly in the cases of tree groups, is significantly lower.

Reference sampling site

According to the detailed descriptions done in the 1930's the pollution-transformed spruce forests were originally of the fruticuloso - hylocomiosum type as at the reference site (REF) in Finland. In the primary *Piceetum fruticuloso - hylocomiosum* type forests *Hylocomium splendens* and *Pleurosium schreberi* were the dominant among understorey species and *Dicranum* spp. were also found. The proportion of green mosses out of the total above ground biomass was approximately equal to that of *Empetrum nigrum spp hermaphroditum* and *Vaccinium vitis-ideae* taken together. Solitary specimens of *Vaccinium uliginosum*, *Lycopodium annotinum*, *Cornus suecicum*, *Linnea borealis*, *Solidago lapponica*, and of the lichens *Nephroma arcticum*, *Cladina stellaris*, *Cladina mitis* and *Cladina rangiferina* were found.

The proportions of *Empetrum nigrum* out of the total above ground biomass between the crowns varied from 6 % to 55 %, whereas this proportion between the crowns did not exceed 35 %. In contrast, *V.vitis-ideae* biomass below the crowns is higher. The proportion of bilberry out of the aboveground phytomass below the crowns may reach 35 %, whereas this proportion is only 4 % between the crowns. The highest biomass of *Deschampsia flexuosa* is found between the crowns. The proportions of *Deschampsia flexuosa* out of the total aboveground phytomass below the crowns varied from 0.2 % to 4 % and between the crowns did not exceed 5 %.

Since the biomass of predominant species such as green mosses and crowberry between the crowns are significantly higher than below the crowns, total biomass of ground vegetation here is also higher. But it should be emphasized that the spatial distribution of ground vegetation as a whole is much more even than for individual species. On the basis of primary productivity parameters four significantly different degradation stages of the *Piceetum fruticuloso - hylocomiosum* subjected to air pollution in the Kola Peninsula were identified: 1) *P. fruticulosum*; 2) *P. graminoso-fruticulosum*; 3) *sparse Piceetum empetrosum*; 4) industrial barrens. One of our sampling sites presents the first stage of degradation - *Piceetum fruticulosum* (sample site D), two sampling sites (C, B) present the second stage of degradation - *Piceetum graminoso-fruticulosum* and sample site A presents the third stage - sparse *Piceetum Empetrosum*.

Sample site D

The total biomass of ground vegetation below the crowns of trees of different states and in the sites between the crowns decreased significantly in comparison with the reference values. The main reason for the lower biomass is the lack of green mosses. Biomass of hair grass (*Deschampsia flexuosa*), particularly below the edge of the crowns, increased significantly. The proportion of this species biomass out of aboveground biomass below the crowns varied from 0 to 70 %. The proportion of crowberry varied from 0 to 84 %. The proportions of these species between the crowns in comparison with the background values increased to 9 and 50 % respectively. The spatial distribution of ground vegetation biomass is much more heterogeneous than in the reference area. This heterogeneity results from lack of green mosses and from the beginning of colonization of an area by hair grasses and crowberry. The important reason is also that the state of trees, which are responsible for distribution of understorey species, is very different: from defoliating (with different extent of defoliation and crown thinning) to dead.

Sample sites C and B

The total biomass of ground vegetation is lower than in the reference area but significantly higher than the previous sample site D. The main reason is an increase in biomass of crowberry and hair grass. Crowberry formed individual microgoups on fallen trees and stumps. Hair grass also formed microgroups, containing preferentially this species, particularly below the edges of crowns. The proportions of crowberry and hair grass out of the total aboveground biomass can reach 100 and 60 % respectively. The proportions of these species between the crowns in comparison with the reference values increased to 13 and 50 % respectively. The spatial distribution of ground vegetation phytomass is less heterogeneous than in the previous sample plot owing to the more even distribution of crowberry and hair grass, particularly below the crowns of the trees of different states.

Sample site A

This sample site presents the third stage of spruce forest degradation - Sparse *Piceetum Empetrosum.* In this stage the area not covered by vegetation, so called industrial barrens, is increasing. The major part of the area is occupied by crowberry. Hair grass formed individual microgroups. The biomass of crowberry and hair grass reached maximal values. Total aboveground biomass is comparable to that of the reference area owing to the significantly higher biomass of *Empetrum* and *Deschampsia.* The proportions of these species out of the aboveground biomass in the open sites can reach 90 and 70 % respectively.

3.2 Description of catchment areas

Catchment area RI

General features: No trees; stumps cut off, so trees have been felled. Traces also of forest fire. Other vegetation also very sparse (Betula spp.). Considerable erosion of organic layers, probably also by wind. From the tree stumps it can be seen that the organic soil layer had in the past been up to 0.5 m thicker. In place sand visible, in other spots accumulation of humus to considerable thickness. There are boulders and stones. About 200 m from start of stream a dump of gravel with access road of very inferior quality. Truck of CKE could be driven slowly over the terrain. The gravel dump was about 500 m east of the M10 main road.

Stream: Starts "from nothing", possibly artesian. Runs approximately NW to SE and ultimately discharges into L. Imandra. Runs in ravine 5 - 10 m deep and 100 m wide, somewhat meandering. Banks steep and soft. Debris and humus have accumulated in the ravine, which is overgrown by bushes and grass (Cyperaceae). Tussocks of grass in stream bed.

Catchment area RII

General: This site is on the border of the "Lapland natural park", and is much less affected by acid fallout than site A. Mixed forest (spruce, pine, birch) with normal understorey vegetation including berries (blueberry, lingonberry, cloudberry) and mushrooms. The ground rises on both sides of the stream, more steeply to the east with the bedrock visible between the stream and the road bank. A road runs west from the M10 into the natural park. It fords the stream and water samples will be taken just upstream of the ford.

Stream: The stream runs roughly from north to south, parallel to the M10 main road and about 500 m west of it. Below the ford the stream runs into a bog, but upstream the terrain is less peaty with firm ground along the stream and tussocks of grass along it. 800 m upstream from the ford there is a ridge of rock across the stream, about one-meter high, and above this ridge is a small circular swamp which cannot be crossed on foot.

Reference catchment area RIII

General: The landscape is more hilly than on the Russian sites, and undisturbed by acid fallout. On the south side of the stream, up to the hill Jaltakkilautoiva, there has been extensive logging, and furrows have been plowed downhill. Spruce has been planted along the furrows but has not yet grown over 50 cm. A rough track crosses the stream at the water sampling point and runs along the south bank of the ravine east and west of the crossing point. Mixed forest with normal understorey vegetation except where the trees have been felled. Ground is very stony gravel with a thin organic cover.

Stream: Alimmainen Nuolusoja runs from W to E in a ravine, which is steeper on the south side. Abundant, clear water. Trees grow right to the edge of the stream, and in some places the growth has formed "islands" in mid-stream.

3.3 Soil

For description of the geology of the selected sites data from the following references were used. Juopperi, 1994, Radchenko (ed.). 1994, Reimann et al. 1998, Zaizevsky (ed.), 1994.

Lithology

The rocks in central part of Kola Peninsula and in eastern part of Finland are Archean in age. In the Kola Peninsula, the supracrustal rocks include felsic gneisses, iron quartzites and amphibolites, and in eastern Finland felsic gneisses and tonalites. In the study area there are also several intrusive complexes, mainly gabbros.

South of the town Monchegorsk, study sites A and B, the main rock types present are basic - gabbro, gabbro-norite and both amphibolite and metabasalt. At site C the bedrock belongs to the Imandra massif, in which the rocks are gabbros and gabbro-norites and are also as at sites A and B mainly basic. At site D the rocks are somewhat more acidic, biotite gneisses, biotite-amphibole gneisses (tonalitic).

On the Finnish side, the reference site REF , Aitatsivaara, near Naruska, the rocks are acidic, mainly tonalitic gneisses originating sedimentary. The typical rocks are quartz-feldspar gneisses and mica gneisses. To the west of study site, there the rocks are amphibolites, originally volcanic.

Quaternary deposits

The area, where the study sites are, is part of the glaciated terrain of Northern Europe. The area was entirely covered by ice during the Pleistocene, which began 2 - 3 million years ago. During this period, Northern Europe was glaciated and deglaciated at least three times. The main Quaternary deposit is till, which consists of an unsorted mixture of rock and mineral fragments from boulders to clay size, and the material in the till is mainly of local origin. The Quaternary overburden in the study sites are mainly basal till.

The predominant soils at the study area are podzolic Al-Fe soils. Podzolic Al-Fe-humus soils are characterised by high acidity and low base saturation. Organic horizons are the most acidic. In these horizons the cation exchange capacity is maximum. These soils are featured by the following characteristics:

- low thickness (less than 40 - 50 cm) and single type of the mineral profile composition,
- upper rough-humus organic horizon,
- bleached layer under organic horizon,
- water-soluble fulvic humus is predominant among humus compounds,
- illuvial humus, consisting mainly of fulvic humus being concentrated under horizon E2,
- free inner drainage, aerobic regime, lack of stable moistening and gleization is explained by high proportion of coarse material,
- lack of permafrost and developed cryogenic processes.

At site A the overburden is meltout till, hummocky moraine. The area of the site is almost technogenic desert, almost all of the vegetation is destroyed and visible changes are found in drift, too. The organic layer is almost totally absent and the samples of organic layer are litter samples in practice. The E-layers, eluvial layers, are very thin, instead the B-layers, illuvial layers, are thick. The parent soil is yellowish green till.

The area of site B is also almost totally destroyed. The overburden is very stony, the organic layer is thin and includes a lot of roots and is poorly decomposed. The thickness of the E-layers is variable. The B-layers are thick, compact and partly cemented. The parent soil is grey till.

At site C the humus-layer is thin, the thickness of the E-layers varies greatly and the B-layers are very stony. The parent soil is grey till.

At site D the thickness of the organic layer varies in general from 3 to 4 cm. Also the E-layers are very thick, from 4 to 10 cm, though the variability is great. The thickness of B-layers is more than 10 cm. The parent soil is grey till.

At the reference site REF, in eastern Finland, the podzol profile is well developed. The top layer, organic, is not well decomposed, whereas the lower parts represents the more decomposed organic material. The E-layer is from 4 to 7 cm thick and the B-layer quite thick. The parent soil material is brownish till.

4 STANDARDISATION AND INTERCOMPARISON OF THE SAMPLING AND MEASUREMENT METHODS

The sampling methods to be used were routine methods used in the laboratories of the partners slightly modified to fit the EPORA project. Only the method for treatment of the water samples was developed for this project as described in annex 3 of this report. Also the measurement methods were well established in the organisations of the partners. All methods have been intercompared in a number of international intercomparison exercises. Since the same methods were not used in all the laboratories this method of intercomparison was found satisfactory, but if a need arises during the experimental work the matter will be reconsidered. The sampling and measurement methods are described in Appedices 1 - 5.

4.1 Measurement methods

Chemical properties of soil, heavy metals (Ni, Cu), nutrients (Ca, Mg, K, Zn, Mn) and stable Sr are determined. The methods used are standardised methods. Speciation of heavy metals by sequential extractions is done according to the Tessier scheme, which is described more closely in Annex 5.

To estimate also the experimental error of the procedure, each extraction of ^{137}Cs and $^{239+240}$Pu will be performed in duplicate after each storage period.

The measurement methods used for determination of ^{90}Sr and ^{137}Cs are described in two STUK reports (Ikäheimonen et al. 1995, Rantavaara et al.. 1994). The ^{229,240}Pu analyses are done according to the description by Hakanen and Jaakkola (1977).

All participating partners work at well-established institutions with quality assurance programmes of their own. All quality assurance programmes are specially created for each establishment. During the experimental part of the EPORA project the quality assurance programmes of the partners institutes will guarantee the quality.

5 DEFINITION OF EXPERIMENTAL PROTOCOLS AND PLANNING OF SAMPLING PROGRAMMES

For sample coding a system with a combination of letters and numbers was designed to be used during field work; the system is presented in Appendix 4. The sampling protocol used in the field is presented in Appendix 6.

The sampling programme is planned to include two field trips in 1997, one to Finland to the reference or background area (REF) and another to the Kola Peninsula (A, B, C, D). Corresponding samples will be collected at the five selected sites.

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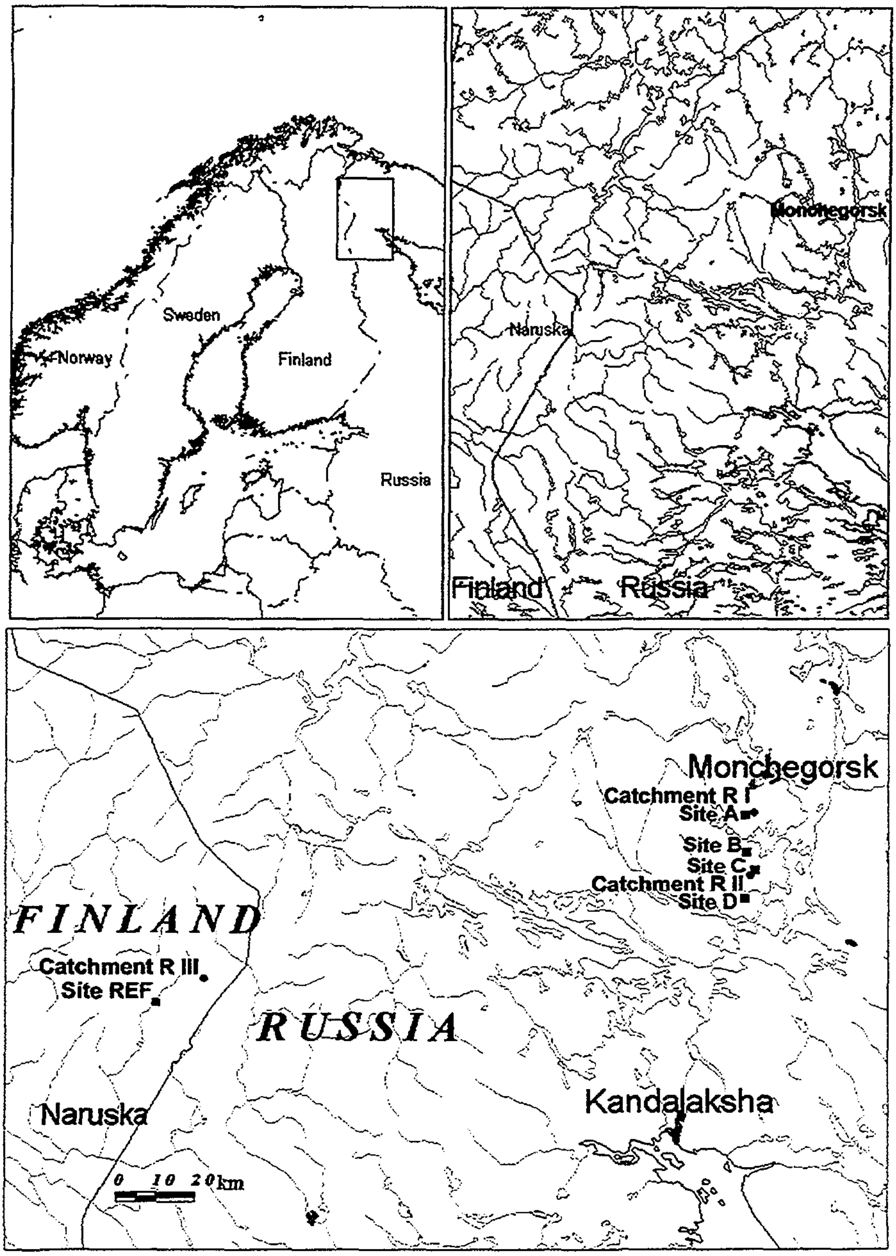

Fig. 1. Map of study area – Kola peninsula, Russia and Finnish Lapland.

Table I. Location of sample sites and catchment areas.

Sample site		Latitude	Longitude	Distance from smelter
Russia	Monchegorsk (site A)	67°51'	32°48'	7 km
	Vitta (site B)	67°46'	32°48'	16 km
	Kurka (site C)	67°44'	32°51'	21 km
	Apatity (site D)	67°40'	32°47'	28 km
	Catchment RI	67°51'	32°50'	6 km
	Catchment RII	67°43'	32°49'	21 km
Finland	Naruska (site REF)	67°26'	29°27'	152 km
	Catchment RIII	67°29'	29°46'	137 km

Table 2. Overview of the bedrock and Quaternary deposits characteristics (Monchegorsk gradient).

Site	Distance from Monchegorsk smelter	Geological Units	Bedrock (lithology)	Surface cover
A	7 km	Glavny hrebet (Gla M)	gabbro, gabbro-anortosites	Meltout till (Hummocky moraine)
B	16 km	Vitebugskay svita (Vt)	amphibolites and metabasalts	basal till
C	21 km	Imandra massif (Ima M)	gabbro, gabbro-norite	basal till
D	28 km	Kislogubskay svita (Ks)	Biotite-, Biotite-amphibol gneiss (tonalitic gneiss) with amphibolite interlayers	basal till

Appendix 1

Description of the soil sampling and pretreatment procedure (EPORA)

The sampling sites are chosen in a typical spruce forest. The 5 plots (1x1 m) will be arranged at the corners of a 10x10 m square with one plot in the middle of the square (Fig 1, left graph). The aboveground vegetation will be carefully cut using scissors and later sorted according to the different species. To carry out soil sampling, the square meter will be divided into two parts. First two strips of about 25 cm x 100 cm at the peripheral of the m^2 at the reference site in Finland and of about 50cm x 100 cm at the Russian sites A - D were used to sample the organic layer. The second one (a 50cm x 100 cm area in the middle) will be needed to collect the samples from the mineral horizons (Fig 1, right graph).

The organic layer will be divided in pieces of about 25x25 cm using a sharp spade and then carefully put down on a plastic film. Attached mineral soil will be scraped off from the organic layer using a knife. After this procedure, the organic layer will be divided into two parts by hand according to their natural constitution. The top layer consists of not well decomposed material, fibric soil material and roots, whereas the second layer (about 1.5 to 2 cm thick) represents the more decomposed organic material (sapric soil material). Both layers can be well separated from each other because of a weak zone between them.

To sample the mineral horizons, the organic layer will be removed without destroying the first cm of the E-horizon. Samples will be taken from a defined area (about 35 cm x 35 cm) inside the plot. The E-horizon will be divided into two layers: The first 2 cm will be collected separately, whereas the second layer will be taken according to there natural thickness down to the B-horizon (about 2 - 5 cm). The same procedure will also be carried out with the B-horizon, but in contrast the first layer consists of 5 cm.

In conclusion six different soil samples will be collected: Two from the organic layer (Of and Oh), two from the E-horizon (E1 and E2) and two from the B-horizon (B1 and B2). The soil samples will be taken to the GTK laboratory in Rovaniemi to be dried at + 40°C and after that to be sieved with a mesh size of 2 mm.

Soil samples will also be taken with a corer with an inner diameter of 10.3 cm and with a depth of about 22 cm.(Fig.2) These samples are much smaller and planned to be used if needed.

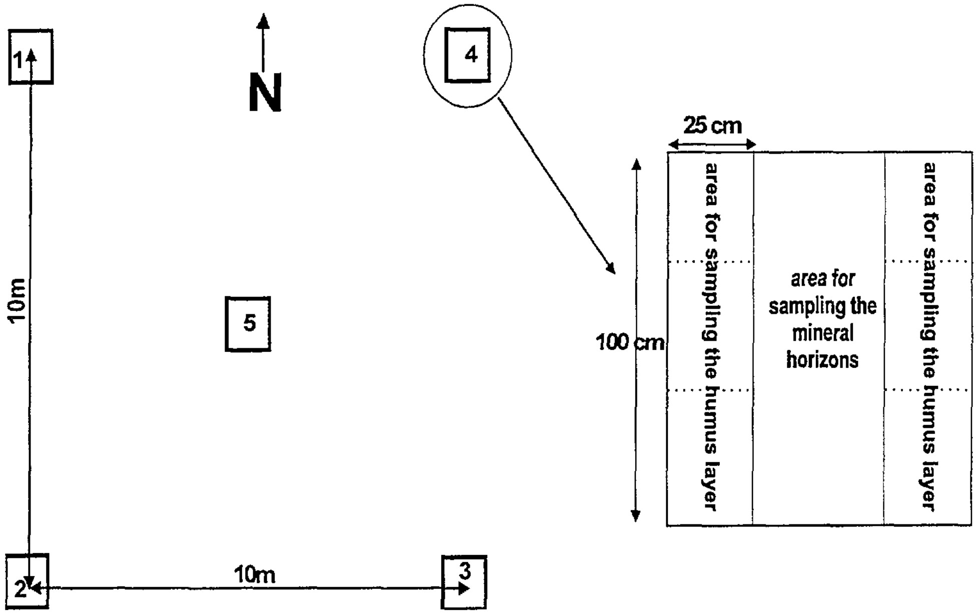

Fig. 1. Schematic layout illustrating the arrangement of the plots 1 - 5 on the selected study area.

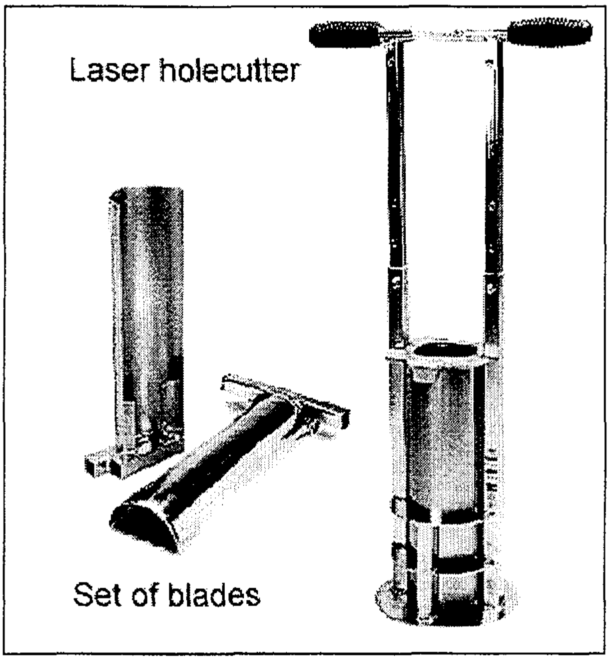

Fig. 2. Corer sampling device.

Appendix 2

Sampling of vegetation

The areal surface vegetation and the litter layer above the organic layer is to be sampled quantitatively. The size of the sampling plots is 1 m x 1 m = 1 m^2 at the Finnish reference plots and 1 m x 1.5 m = 1.5 m^2 at the plots in Russia. Samples from the five plots at each site are to be collected , the distance between the plots 10 - 20 m.

Additional large samples of the main scrubs crowberry (*Empetrum nigrum*), bilberry (*Vaccinium myrtillus*), cowberry/lingonberry (*Vaccinium vitis-idaea*) and of the forest hairgrass (*Deschampsia flexuosa*) will be collected by the Russian botanists around the sampling plots A-D from which quantitative samples are taken.

In addition to these vegetation samples, when available berries of bilberry and crowberry will also be collected at all five sampling sites.

Sampling of the surface vegetation and the litter

The surface vegetation will be collected by cutting the stems of the plants with scissors near the soil surface. At the Finnish reference site with the thick moss layer the collection will resemble the shearing of a lamb. The remaining plants will be cut separately and the small amount of litter collected by hand. In the Russian sites without moss carpet the vegetation will also be cut by scissors and then stored in plastic bags.

The vegetation and litter samples will be collected in 25 l thick plastic. The sample code (e.g. SRUSD1) will be marked on cards which are placed in tight Minigrip bags and thereafter inside the 25 l plastic bag with the samples from the individual sampling plots.

The vegetation samples collected at the Finnish site will be transported within two days to STUK's Rovaniemi laboratory and stored in + 4°C temperature. The samples collected in Russia will be transported as soon as possible to Rovaniemi but delays will probably be unavoidable.

Drying and homogenization of the samples

All the vegetation and litter samples will be dried at 105°C temperature in large drying ovens. The samples will be separated with a Mylar film from the metallic trays or cages to avoid contamination. The large plant and litter samples will be homogenized in a Palman mill, small plant samples in a Waring blendor homogenizer.

Appendix 3

Sampling of runoff water and connected soil samples

Sampling and preconcentration of runoff water samples

Two parallell samples of 200 litres water from each site will be taken, since concentrations of the radionuclides under study (^{137}Cs and ^{90}Sr) are low. To avoid transporting these large water samples preconcentration with selective ion exchangers will have to be done.

Sampling of soil from the runoff water area

The primary objective of the sampling of soil is to get an estimation of the mean level of ^{137}Cs remaining in the catchment, and of the variability. For that purpose area defined samples will be taken of a) the whole organic layer 25x25 cm^2 and b) 15 cm of the underlying mineral soil 12.5x25 cm^2. In all, ten sets of organic and mineral soil will be taken, five on each side upstream of the water sampling point within a distance of 2 km. The coordinates for each sampling plot will determined using GPS.

The coordinates for the catchment areas are given in Table 1.

Preconcentration of run off water

For preconcentration two plastic containers of 200 litres with outlets at the bottom will be used. It is planned to use the very specific ion exchangers Cs-Treat® and Sr-Treat® (manufactured by Selion OY, Finland), or : natural clinoptilolite, a zeolite mineral.

The columns prepared for preconcentration are made from poly(methyl metacrylate) plastic and have an inner diameter of 60 mm and a length of 180 mm. 400 millilitres of exchanger will be used for each run. The flow rate will be adjusted with a screw clamp to 15 liters /hour at the beginning of each run. The water will run through the columns by hydrostatic pressure. At Naruska this can be done on site, but in Russia the water samples will be taken to a laboratory in Monchegorsk.

Appendix 4

System for sample coding during field work - soils and vegetation

The sample code is a combination of letters and numbers as follows:

1. A letter defining whether the sample is from a soil/plant site (S) or a runoff site (R) or is a separate plant sample (P).

2. Three letters defining the site (e.g. FIN = background site in Finland is the reference site REF) and a letter (A - D) separating the different sites in Russia (e.g. RUSA) and an extra R for the three runoff sites (e.g. RI,RII, RIII).

3. A number (1 - 5) defining the plot.

In a soil/plant site 5 plots are selected for soil sampling. Plots 1 - 4 form the corner points of a square, plot 5 is near the center point of that square. The distance between the corner plots is 10 - 20 metres. The corner plots are numbered clockwise, starting with the northern-most point as shown in Fig.1.

4. Two letters characterizing the sample. The following combinations are used:

Soils: Organic horizon: Of, Oh, - -
Eluvial horizon: E1, E2, - -
Illuvial horizon: B1, B2, - -

The number of layers within each horizon is normally two, but may vary between plots and sites. The average thickness of each layer and the area sampled for that layer is recorded in the field.

Plants: VM = Vaccinium myrtillis
VI = Vaccinium vitis ideae
EH = Empetrum nigrum (spp.hermaphroditum)
DF = Deschampsia flexuosa

The plant samples will be collected as composite samples at each site. Only the green parts of the plants are collected.

Appendix 5

The extraction scheme (Tessier) is as follows:

Fraction 1: Readily exchangeable (Extraction with 1 M CH_3COONH_4),

Fraction 2: Bound to iron and manganese oxides (Extraction with 0.04 M $NH_2OH.HCl$ in 25 vol.-% HAc at pH 2),

Fraction 3: Bound to organic matter (Extraction with H_2O_2 (30%), adjusted to pH 2),

Fraction 4: Persistently bound cesium (Extraction with 7 M HNO_3),

Fraction 5: Residual (Complete digestion or gamma spectrometry).

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Appendix 6

EPORA 1997 SAMPLING PROTOCOL

Serial number	Date	Location coordinates	Sample Code				Sampling method	Remarks	Collected by
			Code	Area cm x cm	Depth cm	Size			

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ISBN 951-712-328-0
ISSN 0781-1705

Oy Edita Ab, Helsinki 1999