REPORT SNO 3543-96

Heavy metals from the Nikel area

Investigations in Kolosjoki river 1995, Kola peninsula, Russia.

In cooperation with

Institute of the North Industrial Ecology Problems

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Abstract

A cooperative project between INEP, MUGMS and NIVA to identify the main sources of heavy metals pollution in the Nikel area has been performed. The assessment of pollution load on the river system from mine drainage and from industrial discharges was also an objective. Data from field work in 1995 combined with data from MUGMS have shown that the main pollution comes from industrial sites within Nikel. The significance of drainage from mines has been documented, and it is also shown that airborne deposition gives a contribution to the load of heavy metals. Concentrations of nickel in the main river vary between 20 and 1000 µg/l. Transport of nickel in Kolosjoki river downstream the town of Nikel is about 40 tons/year.

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Heavy metals from the Nikel area

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Preface

This investigation of heavy metal pollution from the Nikel area has been a cooperative project between Institute of the North Industrial Ecology Problems (INEP, Apatity), Murmansk Area Department for Hydrometeorology and Environment Monitoring (MUGMS, Murmansk) and Norwegian Institute for Water Research (NIVA, Oslo). The project contractor has been The Norwegian Ministry of Environment. Brita Slettemark, responsible for this project in the Ministry has been cooperative and helpful, and it has been possible to complete the study according to the original ideas.
We will also take the opportunity to thank Victor Tatarinskij, vice-mayor of Nikel, for his good-will and cooperation, making the field work possible.

Oslo, September 1, 1996

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1. Summary

In 1993 NIVA and INEP made a preliminary study to propose a programme for investigations to identify the relevant sources of heavy metals and estimate their individual importance related to the water quality in Kolosjoki and Kuetsjarvi. The study was reported in a status report in January 1994.

On this background work was started in May/June in 1995 with field work in Nikel. The project has included:

- Meeting and discussions in the city of Murmansk with Murmansk Area Department for Hydrometeorology and Environment Monitoring (MUGMS), in Nikel with the local authorities and in Apatity with Institute of the North Industrial Ecology Problems (INEP).
- Cooperative field work in the Nikel area where MUGMS, Murmansk, INEP and NIVA participated.
- Meeting and discussions in Oslo starting the necessary work for the report, e.g. site descriptions, data transfer and processing etc.

The objectives have been:

- To identify the main sources of heavy metal pollution in the area and give an estimate of their significance.
- To assess the pollution load on the water river system from mine drainage and discharges and run off from industrial areas and wastes.

From a visual inspection in the field five different possible sources of pollution were identified, in addition to airborne pollution.

- Waste water from the nickel smelter and connected activities.
- Run-off from waste-rock dumps in the mining area.
- Mine-water pumped from the mines around Nikel.
- Run-off from the tailings dam.
- Run-off from piles of slag near the smelter.

In a cooperative work INEP and NIVA have made field investigations in the Nikel-area. Water samples have been taken from more than twenty different places in the watershed of Kuetsjarvi (Figure 1). During the summer 1995 INEP has taken samples from about 15 different stations during June, August and September. In addition to the sampling done by NIVA and INEP, MUGMS has a monitoring programme for the area, and relevant data from this programme have been incorporated in the study.

There are some discrepancies between the results obtained at different laboratories (NILU, INEP, MUGMS) The differences are not important for the conclusions in this study, but parallel analyses should be made if the cooperative work is to be continued.

The nickel and copper concentrations are quite high at all stations. In the main river nickel concentrations vary between 20 and 1000 µg/l, while the concentration of copper varies between 10 and 150 µg/l. The deposition from airborne pollution seems to influence the water quality more near the smelter than further away.

The annual transport of heavy metals in Kolosjoki downstream Nikel is estimated to 40 tons of nickel and 2.8 tons of copper. The transport from Kuetsjarvi to Pasvik is a little less, 27 tons of nickel and 1.3 tons of copper. The reduction is probably due to precipitation of insoluble compounds, adsorption on particles and immobilisation due to biological processes.

The most important sources, apart from airborne deposition, are found in the industrial area in the town of Nikel, but drainage from mines outside this area is also contributing significantly to the pollution.With reasonable certainty the water quality have been characterised and the sources of pollution within the catchment area of Kolosjoki have been located. It is not possible, with the existing data, to link the pollution load within the industrial site in Nikel to specific areas or activities. The possibilities are discharge of mine water, process water from ore dressing or smelter and drainage from mine sites and tailing pond. To locate these individual sources of pollution, it is necessary to perform a special study within the industrial area in Nikel.

To make cost effective measures against the pollution in the area, it is necessary to have more details about the sources. This calls for a more extensive programme for investigations. This investigation may be accomplished through a cooperative project between INEP, MUGMS and NIVA and will require participation from the "Pechenganickel" company and local athorities.

2. Background

2.1 The project

As a part of the work in the Water Group under the Joint Norwegian - Russian Commission for Environmental Co-operation, investigations of heavy metal load from the Nikel area on the environment has been performed. In a report published in June 1994 (Moiseenko *et al.*) the pollution impacts and ecological responses in the Pasvik river were discussed. The importance of the "Pechenganickel" company as a source of heavy metal pollution was described. The actual sources and their individual importance was not described in the report. In the same report a general description of the area and the river system was given.

The Pasvik river receives substantial amounts of heavy metals from the Nikel area, partly airborne and partly through runoff from mine sites and industry directly to the local recipient, the Kolosjoki/Kutsjarvi river system.

The emission from the smelter and the deposition from airborne pollution of heavy metals have been estimated. There have been, however, little information or the sources and the load of pollution directly to the river system.

In the report the following abbreviations have been used:

INEP	Institute of North Industrial Ecology Problems, Apatiti
NILU	Norwegian Institute for Air Research
NIVA	Norwegian Institute for Water Research
MUGMS	Murmansk Area Department for Hydrometeorology and Environment Monitoring

In 1993 NIVA proposed a prefeasibility study to make a programme for a study to identify the relevant sources and estimate their individual importance related to the water quality in Kolosjoki and Kutsjarvi.

The prefeasibility study was made in 1993 and reported in a status report in January 1994. The work done was described in the status report, and details of the practical work will not be repeated here. The results obtained will, however, be used.

The allocation of funds for the next second step in the study was not made until end of September 1994, too late to start the field work that year.

The work in 1995 was started in May/June with field work in Nikel. The work in 1995 has been:

- Meeting and discussions in the city of Murmansk with MUGMS, division Murmansk, in Nikel with the local authorities and in Apatity with INEP.

- Cooperative field work in the Nikel area where MUGMS, Murmansk, INEP and NIVA participated.

- Meeting and discussions in Oslo starting the necessary work for the report, e.g. site descriptions, data transfer and processing etc.

In the work performed in 1995/96, the following persons have been involved:

- Tatjana Moiseenko, Ljuba Kudryavtseva and Juri Tereshko - INEP

- Head of department Anatoly Semenov and Olga Makrotovarova - MUGMS, Murmansk

- Victor Tatarinskij vice-mayor in the Town of Nikel

- Tor Traaen and Rolf Tore Arnesen - NIVA

2.1.1 Formalities

During the days 31. May and 1. June 1995 the fieldwork in Nikel was performed and the meeting with the local authorities was arranged during those days. The purpose of the trip was to visually inspect the area and to take water samples according to the programme made from the experiences made in the feasibility study. During the stay in Russia an agreement on a programme for future work with sampling and data handling was made with INEP and MUGMS, Murmansk.

2.1.2 Objectives

The objectives for the project have been:

- To identify the main sources of heavy metal pollution in the area and give an estimate of their significance.

- To assess the pollution load on the water river system from mine drainage and discharges and run off from industrial areas and wastes.

The results from the common field work in Nikel and earlier work by MUGMS and INEP were discussed and evaluated during a workshop in Oslo, 13. - 18. December 1995. Participants of the workshop were Olga Makrotovarova, MUGMS, Murmansk, Ljuba Kudryavtseva, INEP and Rolf Tore Arnesen and Tor Traaen from NIVA.

2.2 The area

2.2.1 General

For a more general description of the area we refer to the report (Moiseenko *et al.* 1994) already mentioned.

A simplified map of the area is shown in figure 1.

From a visual inspection in the field five different possible sources of pollution were identified, in addition to airborne pollution.

- Waste water from the nickel smelter and connected activities.
- Run-off from waste-rock dumps in the mining area.
- Mine-water pumped from the mines around Nikel.
- Run-off from the tailings dam.
- Run-off from piles of slag near the smelter.

There may also be some diffuse pollution from the industrialised part of Nikel due to storage and spills of raw ore.

2.2.2 Industry

The "Pechenganickel" company is one of the biggest metallurgical enterprises in the northern part of Fennoscandia. It is situated near the Norwegian-Russian border and has been operating since 1940, with activities including open pit and underground mining, ore dressing and smelter. Until 1971 the Pechenganickel company used an ore with low sulphur contents. After 1971, high-sulphur copper-nickel ore from Norilsk in Siberia has been used. The content of sulphur in this ore has been about 30%. Ore from Norilsk in Siberia and from 4 local mines constitute the resource base of Pechenga-Nickel. Production and production capacity of the local mines are given in the table 1. During the last years the use of Norilsk ore has been substantially reduced.

Figure 1 shows a simplified map of the "Pechenganickel" mining area. Mineral deposit, which was formed mostly by nickel-copper ores, are exploited from underground and open pit mines. The main bulk of ores, however, are transported from the Norilsk mines to Murmansk by ship, and by train to Nikel. The ore from Pechenga mining is dressed by flotation at the factory, and smelted in the Nikel smelter. Tailings from the Nikel dressing plant (after flotation), are deposited in a tailings pond (fig. 1). Water from the pond is recirculatetd to the factory. In the last 5 years economical crises in Russia have lead to a decrease in the production and consequently to a decrease of the pollution.

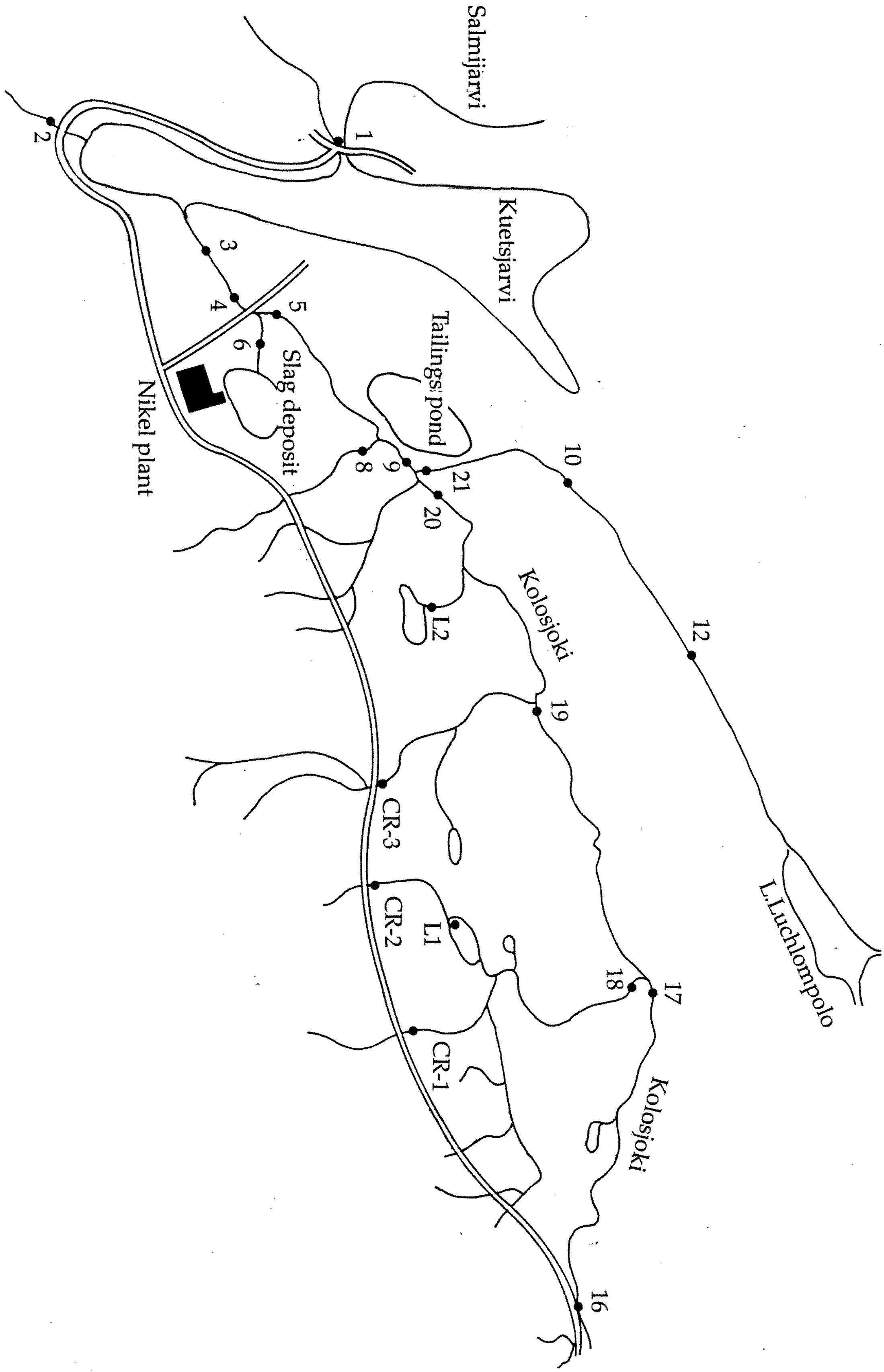

Figure 1. Simplified map of the Nikel-area and the Kulosjoki river system.

Table 1. Production and production capacity of the local mines in the Nikel-area

Mine	Capacity	Production	
		1985	1990
	mill. tons/year	mill. tons/year	
Centralny mine	5	3.95	4.5
Zapadny mine	1	1.55	1.5
Severny mine	0.5	0.6	0.5
Kaula-Kotselvaara	1.7	1.66	1.5
Total	8.2	7.76	8

In the Nikel smelter, 1.3 mil. tons of ore were processed in 1990. Some 105.000 tons of high-grade feinstein were also produced. The production process for smelting of high-grade matte consists of two stages; electric smelting of the charge and partial conversion to Ni-Cu-matte.

The emission of flue gases and heavy metals from the Pechenga-Nickel (Nikel and Zapolyarny) plants in 1990 and 1991 were reported as listed in table 2.

Table 2. Emission of pollutants to the air from the Pechenga-Nikel smelters.

Component	Nickel, tons/year	
	1990	1991
Sulphur dioxide	190,100	189,800
Carbon dioxide	250	250
Nitrogen dioxide	150	150
Dust etc. of which:	3,880	3,870
Nickel	165	131
Copper	92	88
Cobalt	5	5

At the metallurgical works of Pechenga-Nickel, 97.000 tonnes of sulphur dioxide gas were used in the production of sulphuric acid in 1991.

(Evaluation of key environmental impact of Petchenga-Nickel modernisation project. Volume 1. Final report, Kola Science Centre, Russia; Ekono Environmental Technology, Finland; 3E Economics, Norway; May 1992)

3. The Catchment area

3.1 Geology

The central part of the Pechenga-area includes the so-called Petsamo-formation, consisting of eruptive and sedimentary rocks which are easily weathered and more nutrient/calcium-rich than the much harder and infertile gneissic and granitic bedrock that dominates to the south and north (Lieungh, 1990). Calcium-rich bedrock is covering large areas south of the Kolosjoki river catchment. Most of the area is covered with morainic till, with the thickest deposition south and north of the Petsamo mountains (layer-thickness 1-20 m), near the cost the cover with till is thinner and patchy (layer-thickness 0-2 m).

3.2 Vegetation and soil

The major part of the Kolosjoki river catchment is bare and bogged, hilly country (m.a.s.l. 120-450 m). This ecosystem are stretching to the lower part where it gradually are replaced by birch forests of Vaccinium or gras/herb rich type. The soil normally consists of podzolic illuvial-humus (podzolic Al-Fe-humus), thin-solum soil. The thickness of the soil-layer in the upper part of the water catchment does not exceed 30 cm. On the hills with rock outcrops the thickness of the soil profile is 0-5 cm. The strong airborne pollution load is the reason of terrestrial ecosystem degradation.

3.3 Climate

The climate in the Pechenga area is continental, with cold winters, fairly high summer temperatures and low annual precipitation. An average annual precipitation (1961-1990) was 463 mm. The year average temperature for the area is -1.1°C. An average temperature for July is 13.7 °C, while the temperatures for January/February are -15.4 °C. Average values of meteorological parameters for "Nickel" area are given in table 3.

Table 3. Annual mean values of meteorological parameters.

Air temp.	Rel. humidity	Wind velocity	Precipitation	Total days with snow cover
°C	%	m/s	mm	
-0.1 (-40 - +34)	76	3.8	463	203

3.4 Hydrology

To estimate the runoff from separate parts of the catchment area of Kolosjoki, it is necessary either to have measurements from each part, or to have measurements at one or a few main stations and calculate the values for each part from area relative to the main station. In table 4 chatcment area and the coefficient for each station is listed.

The heavy metals (nickel and copper) in the runoff from the industrial areas, originates from the handling of ore in the mine, in the ore dressing plant or in the smelter. This heavy metals pollution runs into the Kolosjoki which is running into Kuetsjarvi lake and through a channel into the Salmijarvi lake to the Pasvik river.

Table 4. Area of catchment area above the different stations in the Kolosjoki river. The coefficient is the area relative to the area at station N 3/ N 4.

Station	Area km^2	Coefficient
N16	39.94	0.29
N17	50.69	0.36
N18	15.56	0.11
N19	76.31	0.55
N20	89.56	0.64
N21	31.5	0.23
N22	7.81	0.06
N23	4.81	0.03
N12	23.31	0.17
N9	125.87	0.90
N5	134.06	0.96
N6	$\approx$ 5.34	0.04
N4		1.00

The Nikel branch of the "Pechenganickel" company is situated in catchment area of the Kolosjoki river, which passes through the industrial site. The river Kolosjoki is 25 km long, and the catchment area to the outlet in the Kuetsjarvi is 140.4 km^2. According to MUGMS data, the average monthly water flow, at a point downstream Nikel, is varying from 0.85 to 7.7 m^3/sec.

The monthly average the runoff in 1995 is given in table 5.

Table 5. Monthly average water flow in the Kolosjoki downstream the town of Nikel in 1995.

Month	Water flow m^3/s
January	1.11
March	1.06
May	7.93
June	5.29
July	5.94
August	4.24
September	2.94
October	3.02

4. Practical work

4.1 Sampling and analysis of samples

In cooperation with INEP, NIVA has made two field investigations in the Nikel-area. The first time in August 1993 and the second time in May 1995. In connection with these investigations, water samples have been taken from more than twenty different places in the watershed of Kuetsjarvi (Figure 1). During the summer 1995 INEP has also taken samples from about 15 different stations in the months June, August and September. Many of the stations were the same during all samplings. In addition to the sampling done by NIVA and INEP, MUGMS, Murmansk has a monitoring programme for the area, and relevant data from this programme have been incorporated in this study. The different stations are marked in the map in figure 1. Some photos and a description of the stations (table 13) are found in appendix A.

During the two cooperative field trips, there were taken parallel samples at most stations, one taken to NIVA and the other to INEP for chemical analysis. The samples taken by INEP have all been analysed at the laboratory of INEP in Apatity. The samples analysed in Norway were sent to NILU and analysed by ICP-MS technique. The samples taken by MUGMS, have all been analysed by MUGMS. The analytical method used by both laboratories in Russia was atomic absorption.

Table 6. Results from the cooperative sampling in August 1993 and May 1995. Samples analysed both at NILU and at INEP.

Sample	NILU	INEP	NILU	INEP	NILU	INEP
	Sulphate		Nickel		Copper	
Year-no.	mg/l		µg/l		µg/l	
93-1	54.6	54.8	720	800	11.9	6.9
93-2	501	500	690	600	9.6	6.6
93-3	157.8	137	527	450	7.2	5.5
93-4	441	420	242	150	32.2	6.9
93-5	144.3	134	522	500	8.3	6.6
93-6	51.3	47.8	338	350	4.3	6.5
93-7	190.2	184	457	300	6.1	4.3
93-8	14.1	13.5	27	30.9	3	1.7
93-11	14.4	12.6	19	20.8	0.05	2.3
93-12	35.7	34.5	77	61	0.05	4.1
95-1		34.4	57	88	4.5	6.3
95-2		7.6	19.5	24	3.7	3.8
95-3		53	200	235	7.7	17
95-4		81	215	255	6	11.2
95-5		49	220	250	7.3	18
95-6		282	220	280	2.2	37
95-7		31	25	160	4.3	12.2
95-Cr-1		30	74	89	5.1	7.7
95-Cr-2		304	1530	1230	3.6	17
95-Cr-3		116	245	260	3.2	7
L-1		194	730	760	4.8	19
L-2		29	295	300	29.5	53

In table 6 results from the cooperative sampling in are listed. There may seem to be some difference between the results obtained by the two laboratories. Especially the difference between the copper values are for some samples quite large. A paired statistical comparison on a confidence level of 95 % shows no significant difference between the results from the two laboratories. The variance in the difference is, however, quite high. If cooperative work including heavy metal analysis, is to be continued, parallel analysis of samples should be performed.

The rest of this report is based on the results from INEP and MUGMS, Murmansk

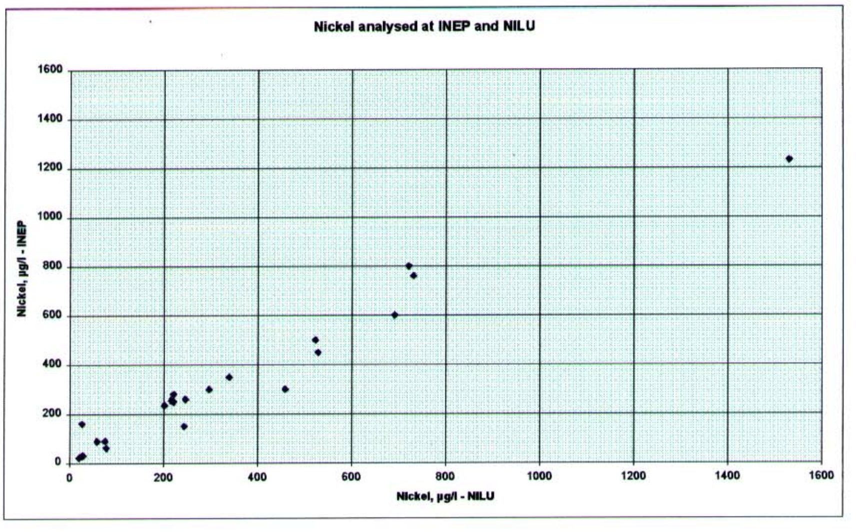

Figure 2. Results of parallel sampling in the Nikel-area. Samples analysed for nickel at NILU and INEP.

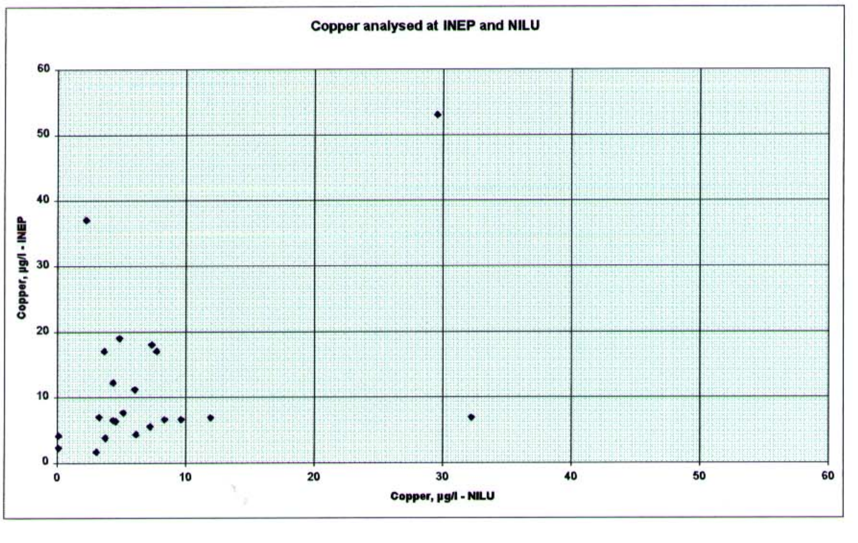

Figure 3. Results of parallel sampling in the Nikel-area. Samples analysed for copper at NILU and INEP.

To illustrate the variance in the difference between the results obtained at INEP and NILU, parallel total copper and nickel values from the two laboratories are shown graphically in figure 2 and figure 3.

4.2 Presentation of results

The results of sampling and chemical analysis of the samples taken in the Nikel area by INEP in 1995 are presented in table 7. This table includes only the total concentrations of the most important pollutants for this study. In table 14 in appendix B all results from INEP may be found.

The laboratory at INEP has analysed both dissolved and total concentrations of many different chemical constituents. Within the frames of this project, it has not been possible to use all this information. At NIVA we usually use total values for the determination of transport of pollutants, and to identify the most important sources. To discuss the toxicity of different constituents, it is necessary to have information of the speciation of the heavy metals. May be it will be possible to use this information in a future project in the area. The main pollutants in the area are nickel, copper and sulphate. Nickel is the most characteristic for the situation, and our discussion is mainly based on the total nickel concentrations.

Table 7. Chemical analysis of samples taken in the Nikel area 1995. Analysed by INEP. Other parameters have been determined, complete list in Appendix B.

(Continued)

Station no.	**Date**	**pH**	**Conductivity µS/cm**	**Sulphate mg/l**	**Copper µg/l**	**Nickel µg/l**	**Cobalt µg/l**
16	01.06.95	6.65	37	8.4	4.8	29	< 0.5
	07.06.95	6.87	35	7.6	14	31	< 0..5
	02.08.95	7.24	54	12.8	5.2	24	< 0.5
	21.09.95	6.97	61	14.4	2.1	23	< 0.5
	Average	6.93	47	10.8	6.5	27	< 0.5
17	07.06.95	6.88	37	7.9	7.3	39	< 0.5
	02.08.95	7.33	55	12.1	4	23	< 0.5
	21.09.95	7.08	62	14.8	1.9	24	< 0.5
	Average	7.10	51	11.6	4.4	29	< 0.5
Cr-1	01.06.95	6.79	86	30	7.7	89	1.4
Cr-2	01.06.95	7.32	603	304	17	1230	17.5
L-1	01.06.95	6.83	390	194	19	760	9.2
18	07.06.95	7.16	113	39	11.5	110	0.8
	02.08.95	7.10	164	62.2	6.3	170	0.8
	21.09.95	6.92	160	53	4.6	135	0.5
	Average	7.06	146	51.4	7.5	138	0.7
19	07.06.95	6.90	67	19.8	9	86	0.6
	02.08.95	7.24	74	17.9	4	38	< 0.5
	21.09.95	6.92	106	30.6	5.7	75	< 0.5
	Average	7.02	82	22.8	6.2	66	0.6
Cr-3	01.06.95	7.33	318	116	7	260	2.6
L-2	01.06.95	7.34	111	29	53	300	6.6

Table 7. Chemical analysis of samples taken in the Nikel area 1995. Analysed by INEP. Other parameters have been determined, complete list in Appendix B.

(Continued)

Station no.	Date	pH	Conductivity µS/cm	Sulphate mg/l	Copper µg/l	Nickel µg/l	Cobalt µg/l
20	07.06.95	7.00	69	20.5	29	102	1.6
	02.08.95	7.50	119	36.4	7.9	173	2
	21.09.95	7.21	164	53	7.2	270	3.3
	Average	7.24	117	36.6	14.7	182	2.3
12	01.06.95	7.22	75	14.6	10.1	80	< 0.5
	07.06.95	7.44	86	18.8	30	105	1
	02.08.95	7.74	95	18.3	10.2	92	0.5
	21.09.95	7.45	103	19.7	6.3	103	0.5
	Average	7.46	90	17.9	14.2	95	
10	17.03.95	7.48	210	44.5	55	390	8.5
	19.04.95	7.36	117	28.4	60	330	7
	09.05.95	7.28	94	21	35	210	2.5
	01.06.95	7.22	76	17	18	130	< 0.5
	Average	7.34	124	27.7	42.0	265	6.0
21	07.06.95	7.44	92	20.3	25	110	3.5
	02.08.95	7.72	99	21.1	12.9	103	0.6
	21.09.95	7.38	113	23.8	18.6	120	0.8
	Average	7.51	101	21.7	18.8	111	1.6
9	17.03.95	7.43	143	36.7	39	330	5.6
	19.04.95	7.13	136	38.7	130	850	21
	09.05.95	7.27	132	35.4	37	420	7.3
	01.06.95	7.03	82	24	13	130	1.1
	07.06.95	6.63	83	25	24	125	1.5
	02.08.95	7.59	124	35.4	7.1	175	1.9
	21.09.95	7.40	167	52	5.6	220	3.4
	Average	7.21	124	35.3	36.5	321	6.0
7	17.03.95	7.68	318	117	140	980	20
	19.04.95	7.18	224	83	195	1300	30
	09.05.95	7.47	277	99	72	750	13.5
	01.06.95	6.98	99	31	12.2	160	0.5
	Average	7.33	230	82.5	104.8	798	16.0
5	17.03.95	7.50	327	115	150	700	18
	19.04.95	7.30	270	89	210	1250	34
	09.05.95	7.48	285	95.5	60	670	13
	01.06.95	7.12	143	49	18	250	1.1
	07.06.95	7.22	122	39	9.6	180	3.8
	02.08.95	7.63	256	93.3	10.6	350	3.8
	21.09.95	7.35	242	79	10.3	390	5.8
	Average	7.37	235	80.0	66.9	541	11.4

(Continued)

Table 7. Chemical analysis of samples taken in the Nikel area 1995. Analysed by INEP. Other parameters have been determined, complete list in Appendix B.
(Continued)

Station no.	Date	pH	Conduc-tivity µS/cm	Sulphate mg/l	Copper µg/l	Nickel µg/l	Cobalt µg/l
6	17.03.95	7.96	710	300	50	350	11
	19.04.95	7.40	519	205	120	840	33
	09.05.95	7.95	700	283	28	320	9
	01.06.95	7.55	672	282	37	280	5.5
	07.06.95	7.88	700	301	17.5	240	11.5
	02.08.95	7.83	755	341	11	420	6.1
	21.09.95	8.47	797	306	16.4	245	5.9
	Average	7.86	693	288.3	40.0	385	11.7
4	17.03.95	7.81	579	242	60	400	11
	19.04.95	7.40	489	192	150	1050	35
	09.05.95	7.72	500	188	36	530	15
	01.06.95	7.20	222	81	11.2	255	3.3
	Average	7.53	448	175.8	64.3	559	16.1
3	17.03.95	7.70	397	143	85	550	15.5
	19.04.95	7.15	305	102	180	1100	31
	09.05.95	7.45	322	102	55	630	13
	01.06.95	7.13	156	53	17	235	3.1
	07.06.95	7.24	168	47	12	185	2.9
	02.08.95	7.70	321	126	12.5	410	4
	21.09.95	7.45	313	114	7.6	470	5.7
	Average	7.40	283	98.1	52.7	511	10.7
2	17.03.95	7.28	80	8.9	1.5	19	< 0.5
	19.04.95	7.36	76	8.8	2.8	23	< 0.5
	09.05.95	7.34	78	8.8	3.6	21	< 0.5
	01.06.95	6.73	39	7.6	3.8	24	< 0.5
	07.06.95	7.10	48	9.5	2.9	38	< 0.5
	02.08.95	7.50	68	13.4	2.7	33	0.7
	21.09.95	7.21	71	13.3	1.9	41	0.9
	Average	7.22	66	10.0	2.7	28	0.8
1	17.03.95	6.95	133	35.7	4.4	63	< 0.5
	19.04.95	7.05	136	37.4	4.9	70	< 0.5
	09.05.95	7.28	147	38.5	5.8	74	< 0.5
	01.06.95	7.15	128	34.4	6.3	88	0.6
	07.06.95	7.23	121	31.6	5.8	85	< 0.5
	02.08.95	7.52	114	31.4	4.8	71	0.7
	21.09.95	7.28	116	31	4.4	68	< 0.5
	Average	7.21	128	34.3	5.2	74	0.7

Data from MUGMS's monitoring programme have also been used in the study. In table 8, annual means for years 1989 to 1995 are presented. For the background station N 16 the data are only from the years 1994 and -95. The variations at this point are, however, small compared to the pollution load from other sources in the catchment area. The data from each sampling by MUGMS are found in table 15 to table 18 in Appendix C.

The study is not supposed to discuss the effects of the heavy metal pollution in the Kolosjoki, Kuetsjarvi and the Pasvik river, and only a few comments are given here.

The copper concentration in the Kolosjoki and in Kuetsjarvi is above the expected background value for the area, even at stations only influenced by airborne deposition. The concentrations are not very high compared to values found in river systems in other mining areas. The highest copper concentrations in the Kolosjoki seem to be associated with particles.

The nickel concentrations are quite high at all stations. The measured values do mainly represent dissolved nickel, but dilution, precipitation and immobilisation through biological processes result in the lowest concentrations in the outlet from Kuetsjarvi to the Pasvik river. The results from the creek from the water source for Nikel (N 10 and N 12) indicate that the deposition from airborne pollution seems to influence the water quality more near the smelter than further away (N16). Prevailing wind conditions or other sources may also be responsible for this impact, so before a conclusion can be drawn, further studies should be performed.

Table 8. Annual means of data from Kolosjoki. Sampled and analysed by MUGMS, Murmansk.
N16 "Background" above Nikel
N3 Below the industrial area in Nikel

Station	Year	Water flow m^3/sec	Copper mg/l	Nickel mg/l	Sulphate mg/l
N16	1994	1.39	0.01	0.02	19.26
N16	1995	0.51	0.01	0.02	14.83
N3	1989	3.18	0.01	0.54	
N3	1990	3.00	0.010	0.480	
N3	1991	2.85	0.010	0.440	
N3	1992	3.13	0.006	0.387	
N3	1994	3.01	0.012	0.383	269
N3	1995	3.53	0.025	0.362	178.5

A direct comparison with statistical methods between the data obtained by MUGMS and INEP is not possible. There are very few samples taken in the same places at the same time. The average for the samples taken in 1995 for station N 16 and N 3 are, however, not more different than might be expected. The data from MUGMS are representing one whole year, while the data from INEP only represents 2 summer months. In this report, we have assumed that the data from the two laboratories are comparable.

5. Transport of pollutants

To calculate transport values for pollutants in river systems, it is necessary to have good estimates of water flow and concentrations of relevant constituents. The calculations made from single values of both concentration and runoff, will be valid for only short periods of time. To give values for annual transport, extensive programmes with measurements over at least one year is necessary. The runoff is usually varying within wider ranges than the concentrations. NIVA therefore recommends that the water flow is measured daily or as we often do in our programmes, continuously.

With the data available in this study, the confidence limits for the estimated transport values will be very wide. The relative values, however, may be quite good. The main objective for this investigation was to identify the different sources and evaluate their individual importance. For this purpose the data will be sufficient.

To determine the relative importance of the individual sources of heavy metal pollution, the chemical data from INEP were used. The runoff was estimated at each station by multiplying the annual mean for 1995 from MUGMS's data from the station downstream Nikel, by the coefficient found in table 4. These transport values are listed in kgs/day table 9. To give a better impression of the location of the different sources, related to the Kolosjoki river, the data are presented graphically in figure 4.

Table 9. Transport values calculated as kgs/day from INEP-data. Samples from the Nikel area 1995. Stations in the main part of Kolosjoki are in bold.

Station	Distance km	Area km^2	Sulphate kgs/day	Copper kgs/day	Nickel kgs/day	Runoff m^3/s
N 16	15	39.94	6377	0.10	0.62	1.02
N 17	11	50.69	8508	0.09	0.80	1.27
N 18		15.56	11513	0.05	1.19	1.94
N 19	7	76.31	25503	0.17	2.87	2.26
N 20	4	89.56	47753	0.50	9.18	
N 12		23.31	6177	0.12	1.27	
N 21		31.6	10184	0.23	2.02	
N 9	3.5	125.87	64735	1.74	22.81	3.18
N5	3	134.06	156361	3.41	40.99	3.39
N 6		5.34	23486	0.09	1.22	
N 3	0.3	140	199887	2.80	40.34	3.53
N 2		385.9	58918	0.42	6.46	
N 1	-4	628.4	327533	1.29	27.44	10.2

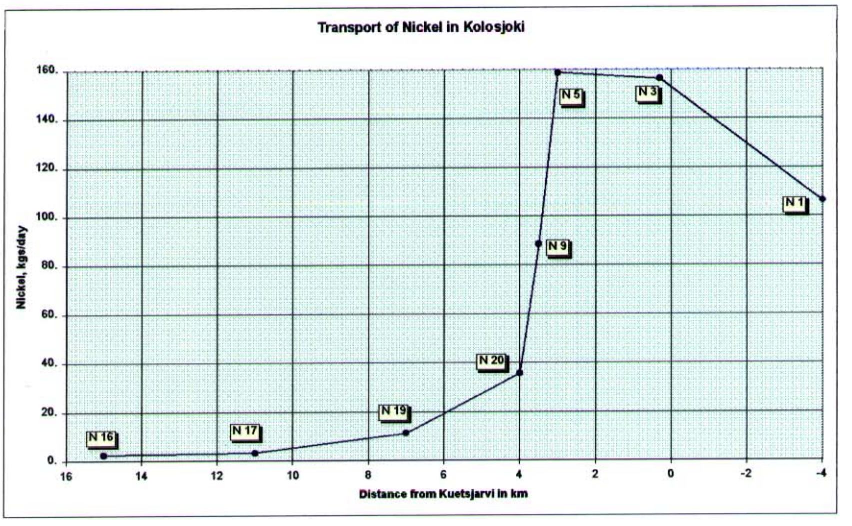

Figure 4. Average transport of nickel at the individual stations during INEP's sampling programme, summer 1995

It is seen from the graph that the most important sources, apart from airborne deposition, are found between the stations N 19 and N 5. Between N 19 and N 20 the drainage from mine sites gives the most important contribution to the heavy metals load on the river. From station N 20 to N 5 it is not possible, with the existing data, to link the pollution load to specific areas or activities. The possibilities are discharge of mine water, process water from ore dressing or smelter and drainage from mine sites and tailing pond. To locate these individual sources of pollution it is necessary to perform a special study within the industrial area in Nikel.

Table 10. Yearly mean transport of pollutants. Above the industrial area, Station N 16 and downstream the industrial area station N 3. Based on data from MUGMS, Murmansk

Above the industrial area			
Year	Copper tons/year	Nickel tons/year	Sulphate tons/year
1994	0.57	0.61	633
1995	0.11	0.28	223
Downstream the industrial area			
Year	Copper tons/year	Nickel tons/year	Sulphate tons/year
1989	1.06	46.85	
1990	1.00	43.76	
1991	0.98	37.32	
1992	0.74	36.16	
1994	1.17	36.40	25592
1995	2.75	40.34	19887

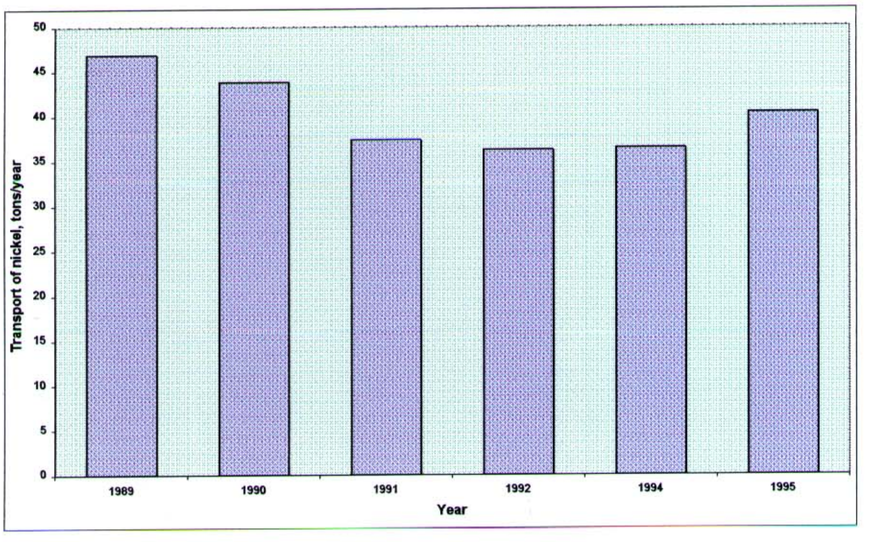

Figure 5. Transport of nickel in the Kolosjoki downstream the industrial area in Nikel.

To get the most reliable value for the annual transport of copper, nickel and sulphate, we have used the data from MUGMS. In table 10 these values are listed in tons/year and shown graphically in figure 5. We have also estimated the annual transport values at the sampling stations. This has been done by distributing the total transport values on each station relative to the pollution loads in kgs/day given in table 9. The results of these calculations are given in table 11.

Table 11. Estimated annual transport values at the sampling stations in the Kolosjoki river system. The coefficients are calculated for each component as the fraction between transport values at each station and at station N 3 in table 9.

Station	Sulphate tons/year	Sulphate Coeff.	Copper tons/year	Copper Coeff.	Nickel tons/year	Nickel Coeff.
N 16	635	0.03	0.10	0.04	0.6	0.02
N 17	846	0.04	0.09	0.03	0.8	0.02
N 18	1146	0.06	0.05	0.02	1.2	0.03
N 19	2537	0.13	0.17	0.06	2.9	0.07
N 20	4751	0.24	0.50	0.18	9.2	0.23
N 12	615	0.03	0.12	0.04	1.3	0.03
N 21	1013	0.05	0.23	0.08	2.0	0.05
N 9	6440	0.32	1.74	0.62	22.8	0.57
N5	15556	0.78	3.41	1.22	41.0	1.02
N 6	2337	0.12	0.09	0.03	1.2	0.03
N 3	19887	1.00	2.80	1.00	40.3	1.00
N 2	5862	0.29	0.42	0.15	6.5	0.16
N 1	32586	1.64	1.29	0.46	27.4	0.68

6. Discussion

In the results of chemical analysis at the different laboratories which have taken part in the project, there are some discrepancies. The differences are not significant for data where we have sufficient data for to make a statistical test, but the variances in the differences are quite large. If the investigations in the area are to be continued, a programme for intercalibration between the laboratories through parallel analyses should be performed.

The problem of chemical analysis have been of little significance for this study, and the results from both INEP and MUGMS have been used throughout the report.

The concentrations of sulphate, nickel and copper at all sampling stations in the river system are higher than an expected background value. There is, however, no information of exactly what this value should be. In the Kolosjoki, the values for these pollutants are very high downstream the industrial area. Shuoenijoki, the tributary to Kuetsjarvi from the south, also have quite high concentrations of the pollutants mentioned above. This is probably due to drainage form the western part of the mining area.

The transport of pollutants have been estimated in two different ways:

1. Calculation of transport values at each station as a mean of the values for each of the samplings during the summer 1995. This will give the best estimate of the relative importance of the different sources in the catchment area. The values are given in kgs/day.

2. The annual means are calculated from the MUGMS data at station N3. To estimate the transport at the other stations, this value is multiplied with a factor, equal to the transport at each station calculated as described above, relative to the transport at N3. These values are given in tons/year.

It seems that the contribution from airborne pollution to Kolosjoki is relatively moderate. If we assume the load to be proportional to the area drained, and the specific load to be the average for the values at N 16, N17 and N12, the values calculated for N3 are shown in table 12.

Table 12. Estimated transport values in Kolosjoki due to deposition from airborne pollution. The methods for calculation are described in the text.

Station	Area km²	Sulphate tons/year	Sulphate %	Copper tons/year	Copper %	Nickel tons/year	Nickel %
N 3	140.3	2758	13.9	0.61	21.8	5.5	13.6

The investiagtion has given a good overview of the main sources of pollution in the watershed of Kolosjoki. It must, however, be emphasised that the data available are insufficient for a detailed discussion. To make plans for practical measures to reduce the pollution load, it will be necessary to repeat the samplings and at some stations increase the programme both in time and number, to give a good description of the pollution sources in the area. This is especially important in the area around the smelter, and it should be considered to make stations for continuous measurement of water flow in some of the tributaries within this area if the work is to carry on.

It will be necessary to cooperative with the "Pechenganickel" company to make such investigation worth while.

7. Conclusions - further work

During the summer 1995 NIVA and INEP performed a cooperative study of water quality and transport of pollutants in the Kolosjoki/Kuetsjarvi/Pasvik river system. MUGMS has been monitoring the river system for many years, and their data have kindly been put at our disposal, and have been incorporated in the study. The results of the project may be summarised in the following conclusions:

The concentration of sulphate, copper and nickel are markedly above the background concentrations to be expected in the area. Due to airborne deposition it is not possible to give any exact values for this.

The transport of pollutants has been determined in the main river and in some of the tributaries. The water quality in the main river has been characterised, and sources of pollution within the catchment area of Kolosjoki have ben located. The industrial area in the town of Nikel seems to give the main contribution to the transport. Possible sources are seepage from the tailings pond, discharges of waste water from ore dressing plant and smelter, discharge of mine water and drainage from area with ore or waste rock dumps. It has, however, not been possible to discuss the individual importance of different sources in this area. There has also been documented that some pollution goes into Kolosjoki and Shuonijoki from mining areas outside the town of Nikel.

The transport in Kolosjoki downstream Nikel is estimated to 40 tons of nickel, 2.8 tons of copper and 19890 tons of sulphate pr. year. The transport from Kuetsjarvi to Pasvik is a little less for heavy metals, 27 tons of nickel and 1.3 tons of copper. The reduction is probably due to precipitation of insoluble compounds, adsorption on particles and immobilisation due to biological processes. The transport of sulphate is higher out of Kuetsjarvi than that into the lake. Sulphate is a much more mobile ion than the heavy metals in nature, and few processes will reduce this transport.

To make cost effective measures against the pollution in the area, it is necessary to have more details about the sources. This calls for a more extensive programme for investigations. The programme should include sampling preferably for one whole year at all stations. Some of the stations used in this study can be left out, but others should be included in the industrial area. Runoff should be measured in more places, preferably continuously. Such programme may be accomplished through a cooperative project between the "Pechenganickel" company, INEP, MUGMS and NIVA.

8. References

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Appendix A.

Table 13. Some sampling stations for water in the Nikel-area used in the study

Sample no.	Locality
N 1	Kuetsjarvi at the outlet to Pasvik river
N 2	Shuonijoki at road bridge
N 3	Kolosjoki downstream Nikel (MUGMS station)
N 4	Kolosjoki at road bridge in Nikel, downstream industrial area
N 5	Kolosjoki main river above bridge at N 4
N 6	Outlet from slag-dam
N 9	Kolosjoki downs. creek from Luchlompolo (Water source)
N 10	Creek from Luchlompolo
N 12	Creek from Luchlompolo upstream N 10
N 15	Near railroad track downstream N 16
N 16	Kolosjoki "background" for MUGMS- monitoring
Cr-1	Creek at road to Nikel
Cr-2	Creek from mines, crossing road
Cr-3	Creek crossing road to Nikel
L 1	Inlet lake seen from road
L2	Outlet lake, watersource for plant

Figure 6. Kolosjoki at sampling station N3, downstream Nikel. (MUGMS station)

Figure 7. Kolosjoki in Nikel, station N 4. Slag deposits between smelter and the river. Sampling point N 5 on the left hand side of the photo.

Figure 8. Sampling point N 16. "Background" station for MUGMS in Kolosjoki.

Figure 9. Mine with waste rock dumps at road between Nikel and Murmansk. Near sampling station station Cr - 2.

Appendix B.

Table 14. Chemical analysis of samples taken by INEP, summer 1995.

Station	Date	pH	Cond	Sulfate	Chloride	Copper				Nickel				Cobalt			
						Total	Dis-solved	Part.	Part.	Total	Dis-solved	Part.	Part	Total	Dis-solved	Part.	Part.
			µS/cm	mg/l	mg/l	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%
16	01.06.95	6.65	37	8.4	2.31	4.8	4.2	0.6	12.5	29	28	1	3.4	< 0.5			
	07.06.95	6.87	35	7.6	2.04	14	8.8	5.2	37.1	31	29	2	6.5	< 0..5			
	02.08.95	7.24	54	12.8	2.36	5.2	3.9	1.3	25.0	24	23	1	4.2	< 0.5			
	21.09.95	6.97	61	14.4	2.3	2.1	1.6	0.5	23.8	23	22	1	4.3	< 0.5			
17	07.06.95	6.88	37	7.9	2.24	7.3	4.9	2.4	32.9	39	31	8	20.5	< 0.5			
	02.08.95	7.33	55	12.1	2.58	4	3.1	0.9	22.5	23	21	2	8.7	< 0.5			
	21.09.95	7.08	62	14.8	2.46	1.9	1.4	0.5	26.3	24	23	1	4.2	< 0.5			
Cr-1	01.06.95	6.79	86	30	2.17	7.7	5.2	2.5	32.5	89	88	1	1.1	1.4	1.2	0.2	
Cr-2	01.06.95	7.32	603	304	3.36	17	2.6	14.4	84.7	1230	1220	10	0.8	17.5	16.9	0.6	
L-1	01.06.95	6.83	390	194	3.08	19	4	15	78.9	760	730	30	3.9	9.2	8.7	0.5	
18	07.06.95	7.16	113	39	2.85	11.5	8.2	3.3	28.7	110	108	2	1.8	0.8			
	02.08.95	7.1	164	62.2	3.16	6.3	4.2	2.1	33.3	170	167	3	1.8	0.8			
	21.09.95	6.92	160	53	3.25	4.6	3.2	1.4	30.4	135	147	8	5.9	0.5			
19	07.06.95	6.9	67	19.8	2.58	9	5.4	3.6	40.0	86	81	5	5.8	0.6			
	02.08.95	7.24	74	17.9	3.24	4	3.5	0.5	12.5	38	36	2	5.3	< 0.5			
	21.09.95	6.92	106	30.6	2.86	5.7	4.3	1.4	24.6	75	69	6	8.0	< 0.5			
Cr-3	01.06.95	7.33	318	116	11.2	7	1.9	5.1	72.9	260	245	15	5.8	2.6	2.3	0.3	
L-2	01.06.95	7.34	111	29	3.58	53	13	40	75.5	300	290	10	3.3	6.6	6.3	0.3	

Continued

Table 14 Chemical analysis of samples taken by INEP, summer 1995 (Continued)

Station	Date	pH	Cond	Sulfate	Chloride	Copper				Nickel				Cobalt			
						Total	Dis-solved	Part.	Part.	Total	Dis-solved	Part.	Part	Total	Dis-solved	Part.	Part.
			µS/cm	mg/l	mg/l	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%
20	07.06.95	7	69	20.5	2.55	29	13.5	15.5	53.4	102	100	2	2.0	1.6	1.1	0.5	
	02.08.95	7.5	119	36.4	3.52	7.9	4.9	3	38.0	173	168	5	2.9	2	1.9	0.1	
	21.09.95	7.21	164	53	3.96	7.2	4.2	3	41.7	270	265	5	1.9	3.3	3.1	0.2	
12	01.06.95	7.22	75	14.6	3.02	10.1	7.7	2.4	23.8	80	78	2	2.5	< 0.5			
	07.06.95	7.44	86	18.8	3.42	30	9.2	21	70.0	105	100	5	4.8	1	0.9	0.1	
	02.08.95	7.74	95	18.3	3.24	10.2	7.6	2.6	25.5	92	89	3	3.3	0.5			
	21.09.95	7.45	103	19.7	3.47	6.3	4.6	1.7	27.0	103	10	2	1.9	0.5			
10	17.03.95	7.48	210	44.5	7.02	55	35	20	36.4	390	330	60	15.4	8.5	5	3.5	
	19.04.95	7.36	117	28.4	4.29	60	32	28	46.7	330	300	30	9.1	7	4.5	2.5	
	09.05.95	7.28	94	21	4	35	20	15	42.9	210	180	30	14.3	2.5	1.6	0.9	
	01.06.95	7.22	76	17	3.14	18	9.5	8.5	47.2	130	125	5	3.8	< 0.5			
21	07.06.95	7.44	92	20.3	3.4	25	11	14	56.0	110	107	3	2.7	3.5	2.7	0.8	
	02.08.95	7.72	99	21.1	3.24	12.9	8.9	4	31.0	103	99	4	3.9	0.6			
	21.09.95	7.38	113	23.8	3.52	18.6	14.5	4.1	22.0	120	117	3	2.5	0.8			
9	17.03.95	7.43	143	36.7	5.45	39	30	9	23.1	330	300	30	9.1	5.6	5	0.6	
	19.04.95	7.13	136	38.7	4.77	130	35	95	73.1	850	770	80	9.4	21	16	5	
	09.05.95	7.27	132	35.4	5.22	37	21	16	43.2	420	390	30	7.1	7.3	3.9	3.4	
	01.06.95	7.03	82	24	2.86	13	8.4	4.6	35.4	130	125	5	3.8	1.1	1	0.1	
	07.06.95	6.63	83	25	2.7	24	7	17	70.8	125	120	5	4.0	1.5	1.3	0.2	
	02.08.95	7.59	124	35.4	3.63	7.1	5.2	1.9	26.8	175	172	3	1.7	1.9	1.7	0.2	
	21.09.95	7.4	167	52	3.7	5.6	4.2	1.4	25.0	220	218	2	0.9	3.4	3.1	0.3	

Continued

Table 14 Chemical analysis of samples taken by INEP, summer 1995 (Continued).

Station	Date	pH	Cond	Sulfate	Chloride	Copper				Nickel				Cobalt			
						Total	Dis-solved	Part.	Part.	Total	Dis-solved	Part.	Part	Total	Dis-solved	Part.	Part.
			µS/cm	mg/l	mg/l	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%
7	17.03.95	7.68	318	117	6.62	140	11.5	130	92.9	980	780	200	20.4	20	10.5	9.5	
	19.04.95	7.18	224	83	6.23	195	17	178	91.3	1300	1250	50	3.8	30	25	5	
	09.05.95	7.47	277	99	7.1	72	13	59	81.9	750	730	20	2.7	13.5	8.5	5	
	01.06.95	6.98	99	31	2.97	12.2	6.7	5.5	45.1	160	155	5	3.1	0.5			
5	17.03.95	7.5	327	115	7.56	150	8.5	142	94.7	700	550	150	21.4	18	9.5	8.5	
	19.04.95	7.3	270	89	8.48	210	21	189	90.0	1250	1210	40	3.2	34	27	7	
	09.05.95	7.48	285	95.5	7.36	60	8.5	51	85.0	670	630	40	6.0	13	10.5	2.5	
	01.06.95	7.12	143	49	3.63	18	5.8	12.2	67.8	250	200	50	20.0	1.1	0.9	0.2	
	07.06.95	7.22	122	39	3.24	9.6	5.2	4.4	45.8	180	170	10	5.6	3.8	2	1.8	
	02.08.95	7.63	256	93.3	5.22	10.6	4.2	6.4	60.4	350	340	10	2.9	3.8	3.6	0.2	
	21.09.95	7.35	242	79	5.6	10.3	3.6	6.7	65.0	390	350	40	10.3	5.8	2.2	3.6	
6	17.03.95	7.96	710	300	18.4	50	2.5	48	96.0	350	300	50	14.3	11	5.5	5.5	
	19.04.95	7.4	519	205	15.9	120	4.5	115	95.8	840	780	60	7.1	33	25	8	
	09.05.95	7.95	700	283	12.6	28	2.5	25	89.3	320	280	40	12.5	9	7.5	1.5	
	01.06.95	7.55	672	282	13.2	37	3	34	91.9	280	210	70	25.0	5.5	3.2	2.3	
	07.06.95	7.88	700	301	13.4	17.5	2.5	15	85.7	240	220	20	8.3	11.5	4.5	7	
	02.08.95	7.83	755	341	14.8	11	3.4	7.6	69.1	420	395	25	6.0	6.1	5.6	0.5	
	21.09.95	8.47	797	306	15.7	16.4	4.4	12	73.2	245	240	5	2.0	5.9	5.2	0.7	
4	17.03.95	7.81	579	242	11.9	60	3.5	57	95.0	400	330	70	17.5	11	6.5	4.5	
	19.04.95	7.4	489	192	10.8	150	3.9	146	97.3	1050	990	60	5.7	35	29	6	
	09.05.95	7.72	500	188	9.76	36	5.5	30	83.3	530	490	40	7.5	15	9.5	5.5	
	01.06.95	7.2	222	81	5.18	11.2	5.5	5.7	50.9	255	215	40	15.7	3.3	2.6	0.7	

Continued

Table 14. Chemical analysis of samples taken by INEP, summer 1995.Chemical analysis of samples taken by INEP, summer 1995 (Continued).

Station	Date	pH	Cond	Sulfate	Chloride	Copper				Nickel				Cobalt			
						Total	Dis-solved	Part.	Part.	Total	Dis-solved	Part.	Part	Total	Dis-solved	Part.	Part.
			µS/cm	mg/l	mg/l	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%	µg/l	µg/l	µg/l	%
3	17.03.95	7.7	397	143	10.1	85	5.5	80	94.1	550	480	70	12.7	15.5	7	8.5	
	19.04.95	7.15	305	102	10.7	180	9.5	170	94.4	1100	1020	80	7.3	31	25	6	
	09.05.95	7.45	322	102	13.2	55	7.5	47	85.5	630	570	60	9.5	13	9.5	3.5	
	01.06.95	7.13	156	53	4.73	17	6.5	11.5	67.6	235	225	10	4.3	3.1	2.7	0.4	
	07.06.95	7.24	168	47	4.18	12	6.5	5.5	45.8	185	180	5	2.7	2.9	2.2	0.7	
	02.08.95	7.7	321	126	6.46	12.5	4.8	8.5	68.0	410	360	50	12.2	4	3.8	0.2	
	21.09.95	7.45	313	114	8.12	7.6	3	4.6	60.5	470	460	10	2.1	5.7	5.1	0.6	
2	17.03.95	7.28	80	8.9	3.29	1.5	1.1	0.4	26.7	19	13	6	31.6	< 0.5			
	19.04.95	7.36	76	8.8	3.4	2.8	2.2	0.6	21.4	23	14	9	39.1	< 0.5			
	09.05.95	7.34	78	8.8	3.48	3.6	2.5	1.1	30.6	21	13	8	38.1	< 0.5			
	01.06.95	6.73	39	7.6	1.92	3.8	3.1	0.7	18.4	24	22	2	8.3	< 0.5			
	07.06.95	7.1	48	9.5	1.98	2.9	2.3	0.6	20.7	38	29	9	23.7	< 0.5			
	02.08.95	7.5	68	13.4	2.56	2.7	2.4	0.3	11.1	33	31	2	6.1	0.7			
	21.09.95	7.21	71	13.3	2.52	1.9	1.7	0.2	10.5	41	36	5	12.2	0.9			
1	17.03.95	6.95	133	35.7	5.51	4.4	3.9	0.5	11.4	63	61	2	3.2	< 0.5			
	19.04.95	7.05	136	37.4	5.3	4.9	4.4	0.5	10.2	70	64	6	8.6	< 0.5			
	09.05.95	7.28	147	38.5	5.35	5.8	4.5	1.3	22.4	74	69	5	6.8	< 0.5			
	01.06.95	7.15	128	34.4	5.1	6.3	4.3	2	31.7	88	82	6	6.8	0.6			
	07.06.95	7.23	121	31.6	4.51	5.8	4.3	1.5	25.9	85	81	4	4.7	< 0.5			
	02.08.95	7.52	114	31.4	4.68	4.8	3.7	1.1	22.9	71	62	9	12.7	0.7			
	21.09.95	7.28	116	31	3.92	4.4	3.8	0.6	13.6	68	63	5	7.4	< 0.5			

Appendix C.

Table 15. Chemical analysis of samples taken upstreams the Nikel-area 1994-95. Background station for MurmanskHydromet. Samples taken and analysed by Hydromet.

Date	Water flow m^3/s	Copper mg/l	Nickel mg/l	Sul-phate mg/l	Date	Water flow m^3/s	Copper mg/l	Nickel mg/l	Sul-phate mg/l
10.01.94	0.075	0.002	0.033	20.8	11.01.95	0.082	0.008	0.005	21.3
24.01.94	0.082	0.005	0.013	-	25.01.95	0.08	0.005	0.025	-
08.02.94	0.082	0.01	0.015	20	15.02.95	0.071	0.001	0.013	20.7
21.02.94	0.084	-	0.043	-	20.02.95	0.073	0.004	0.026	-
15.03.94	0.078	0.003	0.004	26.4	20.03.95	0.075	0.005	0.017	22.8
23.03.94	0.079	0.003	0.038	-	23.03.95	0.08	0.006	0.008	-
12.04.94	0.11	0.001	0.011	17.8	24.04.95	0.117	-	0.015	-
22.04.94	0.009	0.016	-	-	29.05.95	0.93	0.004	0.011	7.8
10.05.94	3.41	0.014	0.002	18.6	01.06.95	-	0.005	0.02	5.6
25.05.94	0.92	0.006	0.026	19.6	13.06.95	1.34	-	0.008	-
08.06.94	5.91	0.014	0.026	14.1	03.07.95	-	-	0.02	-
17.06.94	5.97	0.012	0.007	-	10.07.95	-	0.02	0.016	-
11.07.94	2.42	0.004	0.033	6.7	10.08.95	0.79	0.015	0.019	-
20.07.94	8.06	0.014	-	-	17.08.95	0.7	0.016	0.021	11
17.08.94	0.93	0.002	0.031	(547)	11.09.95	1.18	0.002	0.054	11.7
24.08.94	0.92	-	0.02	-	21.09.95	0.98	0.007	0.013	-
20.09.94	0.55	0.008	0.01	17.8	19.10.95	0.83	-	0.001	19.1
26.09.94	0.56	0.006	0.018	-	24.10.95	0.7	-	0.003	-
17.10.94	0.1	-	0.009	-	13.11.95	0.093	-	0.011	-
18.11.94	0.09	0.006	0.007	-	22.11.95		-	0.013	13.5
20.11.94	0.093	0.001	0.011	30.8					
21.12.94	0.08	0.002	0.006	-					
Average	1.39	0.01	0.02	19.26	Average	0.51	0.01	0.02	14.83

Table 16. Chemical analysis of samples taken from the Kolosjoki river, Nikel
Samples taken downstream the industrial area in Nikel by Murmansk-hydromet 1989-90

Date	Water flow m³/s	Copper mg/l	Nickel mg/l	Date	Water flow m³/s	Copper mg/l	Nickel mg/l
10.01.89	1.72	0.006	0.778	05.01.90	1.86	0.005	0.660
03.02.89	0.85	0.022	0.633	10.01.90	1.86	0.007	0.160
22.02.89	0.79	0.014	0.713	09.02.90	1.56	0.023	0.500
28.02.89	0.79	0.01	0.626	21.02.90	1.56	0.008	0.524
16.03.89	0.85	0.023	0.574	13.03.90	1.56	0.009	0.736
27.03.89	0.85	0.007	0.798	19.03.90	1.28	0.005	0.700
10.04.89	1.25	0.024	0.868	05.04.90	1.36	0.009	0.604
21.04.89	8.86	0.019	0.692	16.04.90	3.6	0.067	0.976
08.05.89	9.72	0.014	0.331	03.05.90	5.56	0.016	0.341
24.05.89	7.99	0.006	0.291	23.05.90	4.7	0.01	0.293
07.06.89	7.7	0.011	0.3	12.06.90	5.36	0.004	0.413
22.06.89	4.13	0.007	0.44	14.06.90	5.36	0.006	0.270
05.07.89	2.98	0.007	0.528	12.07.90	3.61	0.014	0.764
10.07.89	2.15	0.012	0.484	23.07.90	3.29	0.007	0.676
15.08.89	2.29	0.007	0.362	15.08.90	3.45	0.007	0.464
17.08.89	2.42	0.006	0.434	23.08.90	2.55	0.004	0.496
20.09.89	3.66	0.012	0.52	25.09.90	2.55	0.009	0.444
22.09.89	6.64	0.007	0.386	28.09.90	4.73	0.006	0.540
12.10.89	2.42	0.008	0.508	09.10.90	2.98	0.006	0.340
27.10.89	2.15	0.004	0.402	11.10.90	3.45	0.002	0.281
20.11.89	1.25	0.005	0.472	12.11.90	2.69	0.003	0.364
27.11.89	2.15	0.009	0.656	21.11.90	2.69	0.004	0.412
11.12.89	1.56	0.005	0.564	05.12.90	2.28	0.005	0.508
21.12.89	1.25	0.004	0.588	20.12.90	2.01	0.005	0.053
Average	3.18	0.01	0.54	Average	3.00	0.010	0.480

Table 17. Chemical analysis of samples taken from the Kolosjoki river, Nikel Samples taken downstream the industrial area in Nikel by Murmansk-hydromet 1991-92

Date	Water flow m^3/s	Copper mg/l	Nickel mg/l	Date	Water flow m^3/s	Copper mg/l	Nickel mg/l
08.01.91	1.86	0.008	0.502	08.01.92	2.15	0.003	0.418
23.01.91	1.43	0.005	0.532	22.01.92	1.86	0.0001	0.595
06.02.91	1.35	0.005	0.460	11.02.92	1.86	0.001	0.533
25.02.91	1.43	0.006	0.516	24.02.92	2.01	0.001	0.569
14.03.91	1.19	0.012	0.548	10.03.92	1.43	0.002	0.309
26.03.91	1.26	0.002	0.668	24.03.92	1.57	0.006	0.424
09.04.91	3.45	0.047	1.016	20.04.92	1.35	0.004	0.454
24.04.91	2.55	0.017	0.548	24.04.92	1.43	0.011	0.494
06.05.91	3.45	0.008	0.396	12.05.92	-	0.014	0.349
22.05.91	6.88	0.014	0.272	21.05.92	6.68	0.015	0.408
12.06.91	-	0.015	0.320	16.06.92	4.22	0.013	0.263
24.06.91	-	0.009	0.400	25.06.92	5.4	0.011	0.295
11.07.91	3.79	0.005	0.262	02.07.92	6.17	0.012	0.296
23.07.91	2.69	0.009	0.356	10.07.92	6.9	0.012	0.302
12.08.91	-	0.004	0.432	11.08.92	-	0.011	0.296
26.08.91	2.09	0.013	0.464	25.08.92	-	0.013	0.382
16.09.91	5.2	0.01	0.346	15.09.92	3.86	0.004	0.211
23.09.91	4.4	0.009	0.132	25.09.92	3.86	0.008	0.457
15.10.91	3.79	0.007	0.141	19.10.92	2.61	0.003	0.49
22.10.91	4.35	0.007	0.642	22.10.92	2.61	0.002	0.451
18.11.91	2.09	0.012	0.484	17.11.92	2.42	0.002	0.276
25.11.91	2.36	0.007	0.477	25.11.92	2.55	0.002	0.168
20.12.91	2.18	0.002	0.326	15.12.92	2.29	0.002	0.392
26.12.91	2.15	0.003	0.319	21.12.92	2.42	0.001	0.447
Average	2.85	0.010	0.440	Average	3.13	0.006	0.387

Table 18. Chemical analysis of samples taken from the Kolosjoki river, Nikel Samples taken downstream the industrial area in Nikel by Murmansk-hydromet 1994

Date	Water flow m³/s	Copper mg/l	Nickel mg/l	Sulphate mg/l	Date	Water flow m³/s	Copper mg/l	Nickel mg/l	Sulphate mg/l
11.01.94	1.34	0.004	0.378	320	11.01.95	1.72	0.018	0.382	95.6
24.01.94	1.72	0.016	0.411	-	25.01.95	1.56	0.027	0.51	-
08.02.94	1.72	0.008	0.365	288	15.02.95	1.19	-	0.352	320.0
21.02.94	1.86	0.01	0.418	-	20.02.95	1.28	0.029	0.392	-
15.03.94	1.43	0.01	0.352	46.3	20.03.95	1.35	0.004	0.415	278.0
23.03.94	1.58	0.009	0.411	-	23.03.95	1.58	0.058	0.638	-
12.04.94	3.04	0.027	0.517	133	24.04.95	3.5	0.076	0.803	-
22.04.94	2.22	0.023	0.533	-	29.05.95	13.3	0.017	0.188	64.9
10.05.94	9.96	0.017	0.188	169	01.06.95	7.13	0.048	0.181	70.8
25.05.94	4.4	0.018	0.28	500	13.06.95	5.4	0.026	0.211	-
08.06.94	8.04	0.016	0.253	266	03.07.95	3.61	0.01	0.184	-
17.06.94	-	0.016	0.27	-	10.08.95	4.16	-	0.326	-
13.07.94	3.5	0.004	0.461	422.2	17.08.95	3.45	0.007	0.315	114.0
20.07.94	3.35	0.011	0.526	-	21.09.95	2.98	0.011	0.087	-
17.08.94	2.74	0.011	0.398	-	19.10.95	3.68	0.002	0.398	-
24.08.94	3.35	0.011	0.526	-	24.10.95	2.61	-	0.523	-
20.09.94	2.35	0.017	0.316	211	13.11.95	2.42	-	0.295	-
26.09.94	2.35	0.015	0.276	-	22.11.95	2.68	0.013	0.316	306.0
17.10.94	2.09	0.008	0.408	-					
02.11.94	2.42	0.004	0.26	338					
18.11.94	2.42	0.009	0.418	-					
21.12.94	1.39	0.006	0.464	-					
Average	3.01	0.012	0.383	269	Average	3.53	0.025	0.362	178.5

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