NORWEGIAN ENVIRONMENT AGENCY

REPORT

M-322 | 2015

Russian-Norwegian ambient air monitoring in the border areas

COLOPHON

Executive institution

Murmansk Regional Administration for hydrometeorology and environmental monitoring (Murmansk UGMS), Norwegian Institute for Air Research (NILU), Norwegian Environment Agency

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M-no	Year	Pages	Contract number
M-322	2015	22	[Contract number]

Publisher

[Publisher]

The project is funded by

[The project is funded by]

Author(s)

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Title – Norwegian and English

Russian-Norwegian ambient air monitoring in the border areas

Summary - sammendrag

The report presents the levels of sulphur dioxide (SO2) and heavy metals (nickel and copper) in ambient air at the Russian monitoring stations in Nikel and Zapoljarny and the Norwegian stations in Karpdalen and Svanvik. MUGMS and NILU use internationally well recognized the state-of-the-art methods for analyzing both SO2 and heavy metals. SO2 emissions and ambient air levels have decreased over the last two decades, but elevated levels of SO2 were observed in Nikel and Zapoljarny in the period 2009-2012, exceeding the Russian norms. The border areas in Norway experienced levels of SO2 exceeding the Norwegian air quality standards over the years 2011-2012. The levels of heavy metals did not exceed neither the Russian norms for heavy metals, nor the Norwegian annual mean target values for heavy metal. The levels of both SO2 and heavy metals were higher at the Russian stations than the Norwegian stations. The Russian monitoring stations are located closer to the emission sources in Nikel and Zapoljarny.

4 emneord

Bilateralt samarbeid, overvåking, luftkvalitet, svoveldioksid, tungmetaller.

4 subject words

Bilateral cooperation, monitoring, ambient air quality, sulphur dioxide, heavy metals.

Front page photo

The border between Norway and Russia. Photo: Tor Johannessen, Norwegian Environment Agency

Russian-Norwegian ambient air monitoring in the border areas

Preamble

In May, 2013 at the meeting in Sollia (Storskog, Norway) the Russian-Norwegian expert group under the Project DGS-2 of the Working Program for Russian-Norwegian cooperation in environment protection for 2013-2015, approved at the 17th Session of Joint Russian-Norwegian commission on Environmental Cooperation (Svanhovd, 2012), made a decision to prepare a joint report on ambient air pollution in the border area between Russia and Norway.

The present report is mainly focused on ambient air pollution of sulphur dioxide (SO_2) and heavy metals – nickel (Ni) and copper (Cu) in the border area between Russia and Norway.

The joint report has been prepared by O.I. Mokrotovarova, T.D. Korotkova, T.V. Pavlova (all Murmansk Regional Administration for hydrometeorology and environmental monitoring (Murmansk UGMS), and T.F. Berglen (Norwegian Institute for Air Research – NILU), A. Berteig and T. Johannessen (Norwegian Environment Agency).

Oslo and Murmansk, 21 March 2014

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1 Introduction

Murmansk Region has a large concentration of mining and metal processing companies. The Pechenganickel plant is situated in the northwestern part of the Kola Peninsula near the Norwegian border and is operating at two sites - in Zapoliarny and Nikel.

As the results of the ambient air pollution monitoring show, emissions from the Pechenganikel plant have an impact on the ambient air in the border area. Compounds of sulphur and heavy metals generated in the industrial process are emitted into the ambient air and are further transferred by the air masses.

In spite of the significant reduction of SO_2 emissions from the plants in Nikel and Zapoliarny achieved in the period since 1970's until now (ca. from 400,000 tons per year down to 100,000 tons per year), the emissions are still approximately 5 times more than the total Norwegian SO_2 emissions. Exact emission figures of sulphuric compounds and heavy metals are not publicly available.

The Russian and Norwegian ambient air monitoring started in the 1970s, and a bilateral expert group on air existed also in the years 1988 – 1994. The present expert group was established in 2009 and is currently a part of the cooperation in the framework of the Joint Russian-Norwegian commission on Environmental cooperation (DGS-2 project). This report provides the results for the period 2009 to 2012.

The cooperation on air pollution monitoring in the border region is implemented through regular meetings of authorities and experts in order to achieve mutual understanding of the situation regarding air pollution in the border areas, including cooperation in intercalibration of monitoring methods and interpretation of their results.

The Norwegian-Russian expert group on air quality cooperation includes representatives of the Norwegian Environment Agency, Finnmark County Administration, the Norwegian Institute for Air Research (NILU), Ministry of Natural resources and environment of Murmansk Region, Murmansk Regional Administration for hydrometeorology and environmental monitoring (Murmansk UGMS).

2 Monitoring systems

In the territory of Murmansk Region the Federal State Institution Murmansk Administration for Hydrometeorology and Environmental Monitoring – MUGMS of the Federal Department of Hydrometeorology and Environmental Monitoring (Rosgidromet) – is a competent authority authorized by the government to conduct, among other things, environmental pollution monitoring and provide the authorities, industries and the public with information on the actual and forecast condition of the environment and environmental pollution.

The program of the Russian governmental monitoring includes discrete air sampling at monitoring stations 3-4 times a day. The concentrations of pollutants from industrial and automobile emissions in the ambient air are determined.

In Norway, the responsible state authority for environmental monitoring is the Norwegian Environment Agency. The monitoring programme for air quality in the border area is funded by the Norwegian Ministry of Climate and Environment and by the Norwegian Environment Agency. The main goal of the monitoring is to quantify the levels of air pollutants (SO_2 and heavy metals) in the Norwegian part of the border areas of Russia and Norway, and to provide information on the air pollution situation to the authorities and the public. The monitoring of air pollution is performed by the Norwegian Institute for Air Research (NILU).

Ambient air monitoring stations in the border areas are located in Svanvik and Karpdalen (Norway) and Zapoliarny and Nikel (Russia) (fig. 2.1).

Fig.2.1. Norwegian and Russian ambient air monitoring stations in the border areas

2.1 Russian SO2 monitoring, limit values

Murmansk UGMS has been monitoring ambient air in the Pechenga region since the 1970's at 2 permanent stations in Nikel and 1 in Zapoliarny under the governmental monitoring program. The air is monitored for the following substance: nitrogen oxide, sulphur dioxide, carbon oxide, particulate matter, formaldehyde, benzo(a)pyren, and heavy metals (iron, copper, nickel, manganese, and lead).

In 2009, continuous sulphur dioxide monitoring data measurement systems were installed in Nickel and Zapoliarny under a regional target program. The system is based on Russian C-105 gas analyzers (fabricated by St.Petersburg-based ZAO OPTEK) for continuous detection of SO_2 mass concentration in the ambient air. The classical method of fluorescent spectroscopy is used in the gas analyzers.

In continuous monitoring of sulphur dioxide the average measurements for 20 minutes are taken. In discrete sampling at the monitoring station the air is pumped to the absorption tube for 20 minutes, one sample is analyzed for sulphur dioxide.

In addition, chemical composition of atmospheric precipitations is monitored at the station in Nikel, along with continuous meteorological observations.

The results of the ambient air monitoring are included in the 'Annual Report on Pollution in the Towns of Russia' (http://www.meteorf.ru/product/infomaterials/ezhegodniki) published by A.I. Voeykov's Main Geophysical Observatory (FGBU MGO) of Rosgidromet, and are also provided to the Murmansk Region Ministry of Natural Resources and Environment.

In Russia, air quality evaluation is performed in accordance with the approved sanitary standards – GN 2.1.6.1338-03 "Maximum Allowable Concentrations (MAC) of pollutants in the ambient air in populated areas". Table 2.1 shows the values of maximum one-time and daily mean concentrations set for sulphur dioxide.

Table 2.1. Maximum Allowable Concentrations (MAC) for pollutants in populated areas ambient air

Substance	MAC (μg /m^3)		Limiting harm index	Hazard class
	One-time maximum	Daily mean		
Sulphur dioxide	500	50	Reflectory-resorptive effect	3

The maximum allowable concentration (MAC) of a pollutant in the ambient air of populated areas is a concentration that does not have a negative impact, direct or indirect, on the present or future generations, on the people's working efficiency, on their well-being, and sanitary living conditions during the whole life.

The standards are stipulated by way of maximum one-time and daily mean MAC's specifying the hazard class and limiting harm index as a basis for setting up a standard for a specific substance.

The limiting (defining) harm index describes the specific character of the substance's biological effect: *reflectory* and *resorptive*.

Reflectory effect means a reaction by the upper respiratory passages' receptors: smelling an odor, mucous membrane irritation, respiratory distress etc. Such effects are observed during short-term impacts by substances, that is why reflectory effect is taken as the basis for the maximum one-time MAC's (20-30 min).

Resorptive effect means a possibility of general toxic, mutagenic, carcinogenic and other effects depending on the duration of inhalation. To prevent resorptive effects, the daily mean MAC's (as a 24-hour maximum and/or average during a lengthy period – a year or more) are established.

The hazard class of substances for which both one-time and daily mean MAC's have been established, is determined considering the possibility degree of the effects which development under the influence of the specific substance is the most dangerous.

In describing air pollution in towns, the average concentrations are compared to the daily mean MAC's; the 20-minut concentrations are compared to one-time MAC's.

2.2 Norwegian SO2 monitoring, limit values

NILU – the Norwegian institute for air research has been monitoring air and precipitation quality in the border areas since 1974. In 1988 – 1991 there was a common base line monitoring program conducted at both sides of the border. Since then the number of stations has been reduced. Today there are two well-equipped stations at Svanvik and in Karpdalen. Svanvik is located 8 km west of Nikel and Karpdalen is located 30 km north of Nikel (fig.2.1). Both stations have monitoring of SO_2 in air (continuously), heavy metals in air and precipitation (weekly samples) and meteorology (continuously). In addition there are passive SO_2 samplers at Viksjøfjell (2 weeks sampling).

The results are published in annual reports (Berglen et al., 2013, in Norwegian, with a summary translated into Russian).

Norwegian air quality criteria are based on the EU Air Quality Directive (2004/50/EC) and implemented in Norwegian law, "FOR 2004-06-01 nr 931: Forskrift om begrensning av forurensning (forurensningsforskriften)" (in Norwegian only). The threshold values applied are listed in "Part 3 Local air pollution".

Table 2.2: Norwegian air quality criteria for sulphur dioxide (SO_2).

	Limit value [1]	Upper assessment threshold [2]	Lower assessement threshold [3]
SO_2 mean over 10 minutes, WHO, EU alert threshold [4]	500 µg/m^3		
SO_2 hourly mean value for protection of human health	350 µg/m^3		
Number of allowed exceedances per year	24		
SO_2 daily mean value for protection of human health	125 µg/m^3	75 µg/m^3	50 µg/m^3
Number of allowed exceedances per year	3		
SO_2 winter season mean value for protection of vegetation	20 µg/m^3	12 µg/m^3	8 µg/m^3
SO_2 annual mean value for protection of vegetation	20 µg/m^3	12 µg/m^3	8 µg/m^3

[1] 'Limit value' means a level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained.
[2] 'upper assessment threshold' means a level below which a combination of fixed measurements and modeling techniques and/or indicative measurements may be used to assess ambient air quality.
[3] 'lower assessment threshold' means a level below which modeling or objective-estimation techniques alone may be used to assess ambient air quality.
[4] 500 µg/m^3 over 10 minutes corresponds approximately to 350 µg/m^3 over 1 hour.

2.3 Russian heavy metals in air monitoring, limit values

The permanent stations in Nikel and Zapoliarny are used for systematic monitoring of metals concentrations (iron, manganese, copper, nickel, lead) in the ambient air. The analyzed air is pumped through the same filter at a rate of 0.1 m^3/min for 20-30 minutes 6 times a day. The volume of the pumped air at the filter with a weekly exposure is at least 100m^3.

The laboratory measurement method is based on the measurement of selective absorption of the external radiation of the atomic resonance lines of the determined metals by the atoms of metals in the flame (atomic absorption spectrometry method).

In respect of metals content the air quality evaluation is performed in accordance with the approved sanitary standards – GN 2.1.6.1338-03 "Maximum Allowable Concentrations (MAC) of pollutants in the ambient air in populated areas".

Table 2.3 shows the values of maximum allowable daily mean concentrations for copper and nickel. Weekly concentrations of metals are used for calculations of monthly mean and annual mean concentrations, which are compared to the maximum allowable daily mean concentration. The daily mean MAC is approved as the sanitary and hygiene standard of a long-term (annual) mean concentration.

Table 2.3. Maximum Allowable Concentrations (MAC) for metals in populated areas ambient air.

Substance	MAC		Limiting harm index	Hazard class
	One-time maximum	Daily mean		
Copper	-	2000 ng/m^3	Resorptive	2
Nickel	-	1000 ng/m^3	Resorptive	2
Cadmium	-	300 ng/m^3	Resorptive	1
Arsenic	-	300 ng/m^3	Resorptive	2
Lead	1,0 $\mu g/m^3$	0,3 $\mu g/m^3$	Resorptive	1

The Hazard Class of substances which impact is limited by resorptive effect is defined according to the risk of such effects development.

2.4 Norwegian heavy metals in air monitoring, limit values

There were many stations sampling heavy metals during the base line program in the years 1988-1991. In the following years the program was reduced, and the only station left was sampling and analysis of heavy metals in rain at Svanvik. An increase in heavy metal deposition was observed in Norway around 2004-2005. The deposition of heavy metals is still at a higher level than before 2004 in the Norwegian areas, and there are no signs of a decreasing trend.

Monitoring of heavy metals in air is a two-step process. First there is sampling at the stations. For air this means collection of dust at filters. At Svanvik and in Karpdalen NILU has a Kleinfiltergerät with a PM_{10} impactor plate so that only particles smaller than 10 µm are collected at filters. Step 2 is to send the samples to NILU for analysis in the laboratory and hence determine the concentration.

Sampling and analysis of heavy metals in air/dust at Svanvik was started again in 2008 (only maximum daily values until 2011). In Karpdalen sampling of heavy metals in air started in autumn 2011, at the same time the sampling frequency at Svanvik changed into weekly sampling where 52 weekly filters constitute an annual mean. The monitoring program also comprises sampling and analysis of heavy metals in precipitation at Svanvik and Karpdalen.

The air quality criteria for heavy metals are listed as ‘target values’. These mean a level fixed with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained where possible over a given period.

Table 2.4: EU and Norwegian target values for heavy metals in air.

	Target value [1]	Upper assessment threshold	Lower assessement threshold
Nickel Ni annual mean	20 ng/m^3	14 ng/m^3	10 ng/m^3
Arsenic As annual mean	6 ng/m^3	3,6 ng/m^3	2,4 ng/m^3
Cadmium Cd annual mean	5 ng/m^3	3 ng/m^3	2 ng/m^3
Lead Pb annual mean	0,5 $\mu g/m^3$	0,35 $\mu g/m^3$	0,25 $\mu g/m^3$

[1] ‘target value’ shall mean a level fixed with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained where possible over a given period.

For copper Cu there is no target value as Cu is considered much less toxic than the other metals emitted from smelter activity.

2.5 Intercalibration

Both FBGU Murmansk UGMS laboratory and NILU have been participating in the international intercalibration of chemical analysis methods of metals and major ions in precipitation samples under the Joint European Monitoring and Evaluation Program (EMEP) since 2009. The samples are delivered from the Norwegian Institute for Air Research (NILU).

Table 2.5 a and b shows the results of laboratory tests made in 2012.

Table 2.5.a: Results from the 2012 EMEP – Analytical intercomparison for heavy metals, for Murmansk UGMS laboratory.

NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research

EMEP – Analytical intercomparison of heavy metals in precipitation 2012

Laboratory 179, Murmansk Environmental Monitoring Center, Murmansk (Russian Federation)

Heavy metals in precipitation (H-samples)

Sample name	Determinand	Reported value	Expected value	Mean value	Standard deviation	Z score	EMEP quality norm ¤
H1	As	0.64	0.7	0.661	0.127	-0.114	S
H2	As	0.53	0.55	0.529	0.113	0.143	S
H3	As	6.49	6	6.054	0.526	0.829	S
H4	As	5.05	4.5	4.569	0.37	1.299	S
H1	Cd	0.071	0.07	0.067	0.01	0.232	S
H2	Cd	0.052	0.05	0.047	0.008	0.609	S
H3	Cd	0.375	0.55	0.547	0.032	-5.397	U
H4	Cd	0.846	0.8	0.796	0.061	0.825	S
H1	Cr	0.7	0.55	0.553	0.06	2.132	Q
H2	Cr	0.53	0.6	0.581	0.047	-0.457	S
H3	Cr	9.61	8.4	8.261	0.583	2.315	S
H4	Cr	8.37	7	6.829	0.485	3.179	Q
H1	Cu	0.81	1.2	1.206	0.204	-1.942	Q
H2	Cu	1.21	1.2	1.327	0.668	-0.11	S
H3	Cu	5.48	7	6.847	0.502	-2.722	Q
H4	Cu	4.33	5.5	5.466	0.497	-2.288	Q
H1	Ni	0.67	0.6	0.594	0.202	0.429	S
H2	Ni	0.9	0.8	0.752	0.097	1.02	S
H3	Ni	10.8	10.3	10.366	0.637	0.682	S
H4	Ni	9.63	9	9.034	0.781	0.764	S
H1	Pb	1.48	1.2	1.233	0.178	1.091	S
H2	Pb	1.17	0.9	0.922	0.313	0.795	Q
H3	Pb	22.9	23.5	22.629	2.584	0.105	S
H4	Pb	24.5	20	19.642	1.651	2.943	Q
H1	Zn	6.68	6	6.32	1.027	0.351	S
H2	Zn	7.7	7.5	7.779	1.193	-0.066	S
H3	Zn	114.3	115	117.817	7.238	-0.486	S
H4	Zn	96.5	97	99.615	5.978	-0.521	S

If your laboratory reported values as less than the detection limit, and your detection limit equal or is lower than the expected value, ½ DL is taken as the reported value in further calculations.

¤ EMEP quality norm; the letters in the column indicates:

- S – Satisfactory: Your result deviates less than ±25% of the expected value for samples H1 and H2, and less than ±15% for samples H3 and H4
- Q – Questionable: Your result deviates between ±25-50% of the expected value for samples H1 and H2, and between ±15-30% for samples H3 and H4
- U – Unsatisfactory: Your result deviates more than ±50% of the expected value for samples H1 and H2, and more than ±30% for samples H3 and H4
- B – Blank: You reported either no value or the detection limit

Please check the EMEP intercalibration website for Youden plots, updated expected values ect:
http://www.nilu.no/projects/ccc/intercomparison.html

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Table 2.5.b: Results from the 2012 EMEP – Analytical intercomparison for heavy metals, for NILU.

Norsk institutt for luftforskning
Norwegian Institute for Air Research

EMEP – Analytical intercomparison of heavy metals in precipitation 2012

Laboratory 15, Norwegian Institute for Air Research NILU (Norway)

Heavy metals in precipitation (H-samples)

Sample name	Determinand	Reported value	Expected value	Mean value	Standard deviation	Z score	EMEP quality norm ¤
H1	As	0.71	0.7	0.661	0.127	0.264	S
H2	As	0.55	0.55	0.529	0.113	0.274	S
H3	As	5.93	6	6.054	0.526	-0.236	S
H4	As	4.39	4.5	4.569	0.37	-0.485	S
H1	Cd	0.07	0.07	0.067	0.01	0.143	S
H2	Cd	0.05	0.05	0.047	0.008	0.348	S
H3	Cd	0.53	0.55	0.547	0.032	-0.534	S
H4	Cd	0.78	0.8	0.796	0.061	-0.255	S
H1	Cr	0.55	0.55	0.553	0.06	0.07	S
H2	Cr	0.6	0.6	0.581	0.047	0.462	S
H3	Cr	8.2	8.4	8.261	0.583	-0.104	S
H4	Cr	6.82	7	6.829	0.485	-0.018	S
H1	Cu	1.21	1.2	1.206	0.204	0.019	S
H2	Cu	1.2	1.2	1.327	0.668	-0.124	S
H3	Cu	6.57	7	6.847	0.502	-0.552	S
H4	Cu	5.45	5.5	5.466	0.497	-0.033	S
H1	Ni	0.6	0.6	0.594	0.202	0.121	S
H2	Ni	0.79	0.8	0.752	0.097	0.377	S
H3	Ni	10.3	10.3	10.366	0.637	-0.103	S
H4	Ni	8.94	9	9.034	0.781	-0.12	S
H1	Pb	1.13	1.2	1.233	0.178	-0.348	S
H2	Pb	0.89	0.9	0.922	0.313	-0.014	S
H3	Pb	22.9	23.5	22.629	2.584	0.105	S
H4	Pb	19.4	20	19.642	1.651	-0.147	S
H1	Zn	6.35	6	6.32	1.027	0.029	S
H2	Zn	8	7.5	7.779	1.193	0.185	S
H3	Zn	113	115	117.817	7.238	-0.666	S
H4	Zn	95	97	99.615	5.978	-0.772	S

If your laboratory reported values as less than the detection limit, and your detection limit equal or is lower than the expected value, ½ DL is taken as the reported value in further calculations.

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- U – Unsatisfactory: Your result deviates more than ±50% of the expected value for samples H1 and H2, and more than ±30% for samples H3 and H4
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2.6 Discussion and conclusion on comparability of the monitoring systems

At present both FBGU Murmansk UGMS and NILU use monitors to quantify concentrations of SO_2. Although the monitors are different (API 100E in Norway, OPTEC-105C in Russia) they both give results with high temporal resolution (seconds). The results are comparable and of similar high scientific standard. The concentrations from the monitors are calculated and reported as average over 10-minutes (Norway, NILU) and 20 minutes respectively (Russia, Murmansk UGMS).

In order to compare the levels of SO_2 in air at the Russian and the Norwegian stations we have also listed the seasonal (summer, winter) mean values, see tables 3.2 (Russia) and 3.5 (Norway).

The sampling methods for heavy metals concentrations are different. In Russia air is sampled with filters for further analysis of metals as part of particulate matter without size differentiation (gross dust). In Norway heavy metals concentration analysis is performed in the composition of particulate fraction PM10.

The methods for analyzing heavy metals are comparable. Results from both monitoring programs are trustworthy and scientifically sound, but the differences in the size fraction that is sampled and analyzed makes it difficult to compare the levels of heavy metals in air from the Russian and Norwegian areas.

Furthermore, the air quality criteria given for heavy metals in the Norwegian and Russian legislation are very much different both concerning limit values and concerning time resolution.

In Norway annual mean target values are given for metals concentrations in a particulate fraction PM10. This is also the case with EU regulations.

In Russia daily mean MAC's are given for metals concentrations in particulate matter (non-differentiated by the dust composition) without division into fractions.

The differences in sampling methods and the approved criteria of air pollution make the work more complicated because the concentrations in the border area are differently interpreted by the two sides. E.g. values that are considered acceptable when calculated on a yearly basis by the Russian side may be considered unacceptable on a yearly basis by the Norwegian side.

3 Monitoring results

3.1 Russian annual and monthly mean values of SO2 2009-2012/2013

In the assessment of air pollution the average concentrations are compared to the mean daily MAC's, and the 20-minute concentrations are compared to the maximum one-time MAC's, according to the Russian sanitary standards.

According to Rosgidromet assessment criteria, if the pollutant's concentration exceeds MAC 10 times or more, the ambient air pollution is considered high.

Information on high ambient air pollution levels is delivered to Rosprirodnadzor Directorate for Murmansk Region, Murmansk Interregional Environmental Prosecutor's Office, Murmansk Region Ministry for Natural Resources and Environment, and to municipalities' administrations for administrative decision making.

In 2009-2012 the concentrations of sulphur dioxide in the ambient air of Zapoliarny and Nikel was elevated. The annual mean concentrations of sulphur dioxide in Nikel ranged 1.4 to 2.2 MAC's; in Zapoliarny - 1.7 to 1.8 MAC's (fig.3.1).

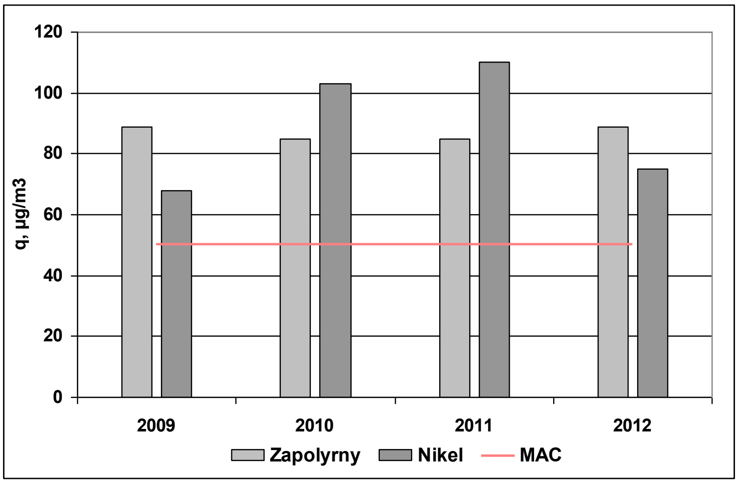

Fig.3.1. Annual mean concentrations of sulphur dioxide in the ambient air of Nikel and Zapoliarny (µg/m³) in the period 2009-2012.

The maximum one-time concentration of sulphur dioxide in the ambient air in Zapoliarny reached 8 MAC's, and in Nikel – up to 14 MAC's (high pollution level). The largest number of ambient air high pollution episodes in Nikel was observed in 2009: 14 episodes of concentrations exceeding 10 MAC's (Table 3.1).

Table 3.1. Sulphur dioxide air pollution in Zapoliarny and Nikel in 2009 -2012

PARAMETER	Nikel				Zapoliarny			
	2009	2010	2011	2012	2009	2010	2011	2012
Highest 20-minute (one-time) concentration, µg/m³ (MAC mnr = 500 µg/m³)	7063	5150	6410	4000	3538	3270	3400	3900
In MAC's	14	10	13	8	7	7	7	8
Number of 20-minute concentrations ≥ 500 µg/m³ (≥ 1 MAC)	864	1069	1183	759	1172	854	720	977
Mean annual concentration, µg/m³ (MAC ma = 50 µg/m³)	68	103	110	75	89	85	85	89
In MAC's	1.4	2.1	2.2	1.5	1.8	1.7	1.7	1.8

Elevated levels of ambient air pollution of sulphur dioxide are observed in periods of adverse weather conditions (still air, air blanketing, ground inversion, low air temperature) facilitating accumulation of pollutants in the ground layer of the atmosphere. The observations data show that sulphur dioxide concentration in Nikel increases in periods of northern winds, and in Zapoliarny – in periods of southern winds.

According to climatic data, southern winds are most frequent in winter, and northern winds – in summer.

In the period 2009-2012, monthly mean concentrations of sulphur dioxide exceeding the norm were observed in Zapoliarny in winter (the highest monthly mean concentration – 4 MAC's – was registered in February 2012) (fig. 3.2).

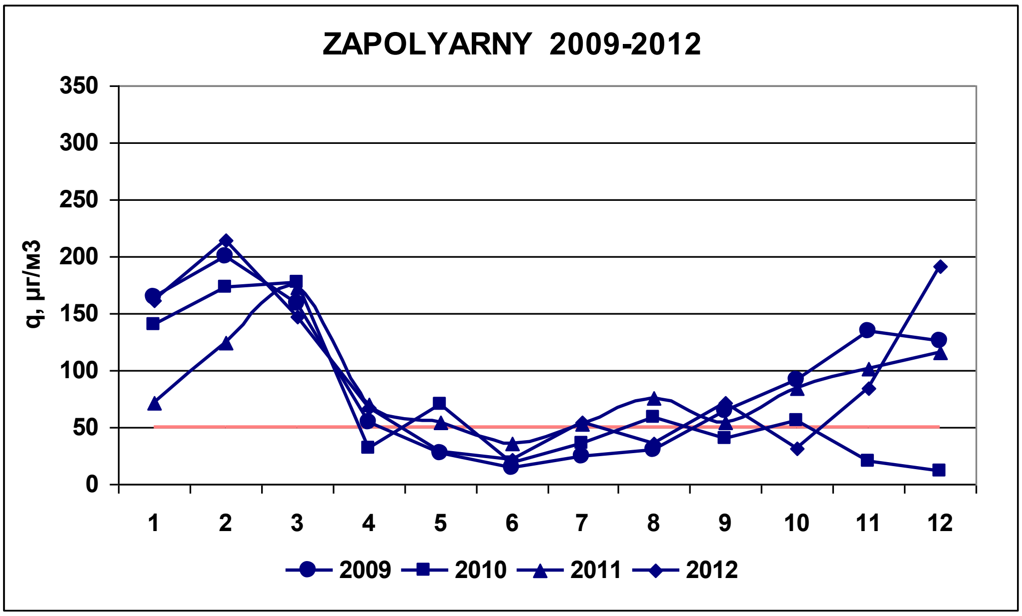

Fig.3.2. Monthly mean concentrations of sulphur dioxide in Zapoliarny in 2009-2012

Monthly mean concentrations of sulphur dioxide exceeding the sanitary norm in Nikel are observed in summer (the highest concentration – 5 MAC's in June 2012) and in winter during adverse weather conditions (the highest concentration – 6 MAC's in February 2011) (Fig. 3.3).

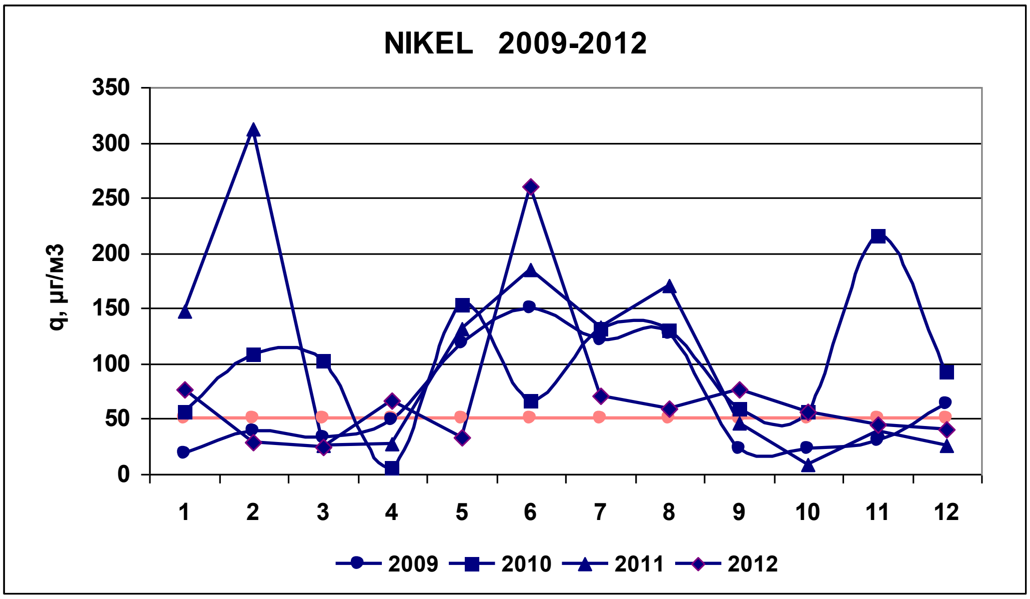

Fig.3.3. Monthly mean concentrations of sulphur dioxide in Nikel in 2009-2012

Seasonal analysis of the monthly mean concentrations of sulphur dioxide show that the concentrations in the ambient air of Nikel are higher in summer, and in Zapoliarny – in winter (Table 3.2). The highest monthly mean concentration of sulphur dioxide in the ambient air of Zapoliarny in winter equals to 2.8 MAC's, in Nikel – 1.3 MAC's, in summer in Zapoliarny– 1.2 MAC's, in Nikel – 2.3 MAC's.

Table 3.2: Seasonal mean concentrations of sulphur dioxide in the ambient air, Nikel and Zapoliarny, 2011-2013

Station	Period	SO_2, µg/m³
Nikel	April - September 2011	116
	October 2011- March 2012	34
	April - September 2012	95
	October 2012- March 2013	67
Zapoliarny	April - September 2011	61
	October 2011- March 2012	138
	April - September 2012	47
	October 2012- March 2013	128

3.2 Norwegian annual and monthly mean values of SO2, 2008-2012/2013

The results from the Norwegian monitoring program are presented in annual reports. These reports show results for monitoring period April through March the following year. A summary of the 10-minutes values are given in Table 3.3, sorted by calendar year.

Due to the prevailing wind direction from south to north during wintertime Karpdalen experiences the highest values and most frequent episodes in the winter season. Karpdalen also receives pollution from both Nikel (to the south) and from Zapoliarny (to the south-east). The winter 2010/2011 was special in the sense that there were extraordinarily many episodes with high concentration (179 and 156 10-minute values above 500 µg/m^3 in 2010 and 2011 respectively). Among these, 84 values occurred on 19 December 2010 and 71 on 13 February 2011.

Table 3.3: Sulphur dioxide air pollution at Svanvik and in Karpdalen, 10-minutes values over 500 µg/m^3, 2008 - March 2013.

PARAMETER	Svanvik					
	2008 (April-Dec)	2009	2010	2011	2012	2013 (Jan-Mar)
Highest 10-minute concentration, µg/m^3	1195	1216	620	1099	1026	-
Number of 10-minute concentrations ≥ 500 µg/m^3	15	14	13	25	14	0
	Karpdalen					
	2008	2009 (April-Dec)	2010	2011	2012	2013 (Jan-Mar)
Highest 10-minute concentration, µg/m^3	-	695	917	1732	848	836
Number of 10-minute concentrations ≥ 500 µg/m^3	-	7	179	156	33	10

Annual mean values of SO2 are given in table 3.4, figure 3.4, and seasonal mean values are given in table 3.5. These results show that annual mean concentrations at Svanvik typically are a factor 10 lower than Nikel. Karpdalen has higher annual average than Svanvik, and one year the average exceeded the Norwegian threshold value for annual mean (20 µg/m^3), notably 2010.

Table 3.4: Annual mean values of SO_2, number of days and number of hours above some values relevant for Norwegian air quality criteria.

Station	Year	Annual mean value (µg/m3)	No. days >125 µg/m3	No. days >50 µg/m3	No. hours >350 µg/m3
Svanvik	2008	8,0	1	12	10
	2009	6,8	0	17	3
	2010	8,0	1	15	6
	2011	7,3	0	14	6
	2012	7,1	1	14	7
Karpdalen	2009	13,8	3	22	12
	2010	20,4	13	39	73
	2011	19,8	7	30	51
	2012	16,6	6	35	15

Norwegian legislation has been violated for the three last years in Karpdalen (more than three days with daily mean over 125 µg/m^3, and more than 24 hourly means above 350 µg/m^3 in 2010 and 2011).

Table 3.5: Seasonal mean concentrations of sulphur dioxide in the ambient air, Svanvik and Karpdalen, 2010-2013

Station	Period	SO_2, µg/m^3
Svanvik	April - September 2010	7,4
	October 2010- March 2011	8,5
	April - September 2011	7,2
	October 2011- March 2012	6,1
	April - September 2012	5,7
	October 2012- March 2013	7,9
Karpdalen	April - September 2010	9,4
	October 2010- March 2011	39,1
	April - September 2011	12,0
	October 2011- March 2012	18,3
	April - September 2012	8,1
	October 2012- March 2013	26,2

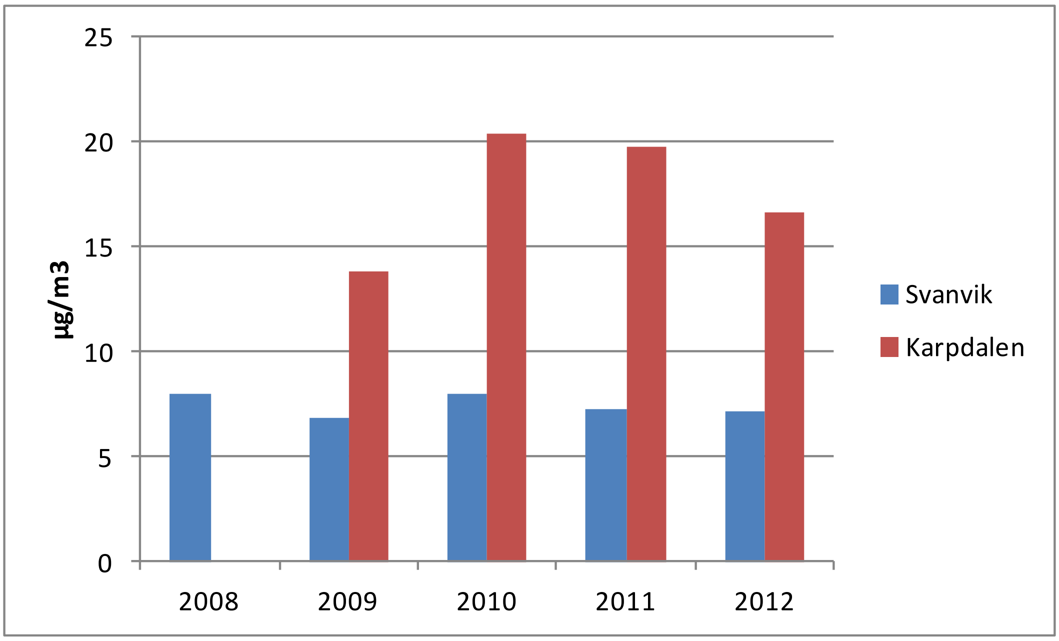

Figure 3.4: Mean annual concentrations of sulphur dioxide in ambient air at Svanvik and in Karpdalen (µg/m^3) 2008-2012 (the threshold value for annual mean value is 20 µg/m^3).

Annual and monthly values are given in Table 3.6. At Svanvik monthly mean values vary between 0.2 µg/m^3 (September 2009, close to background concentrations) and 25.5 µg/m^3 (March 2008). In Karpdalen monthly mean values vary between 4.4 µg/m^3 (July 2009) and 62.3 µg/m^3 (December 2010). The values in Karpdalen are higher than Svanvik in most of the months reported. At Svanvik high values may occur at all seasons. In Karpdalen the highest values occur during winter.

Table 3.6: Annual and monthly mean values of SO_2 for Svanvik and Karpdalen from 2008 - 2012.

Station	Year	Annual Mean (µg/m^3)	Monthly Means											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Svanvik	2008	8,0	3,4	13	25,5	11,6	3,9	6,8	5,7	3,3	4,9	3,5	11,8	2,8
	2009	6,8	6	6,8	7,4	3,1	9,7	6,3	12,8	12	0,2	1,5	4,8	10,6
	2010	8,0	13,8	11,6	9,8	5,2	14,7	9,3	5,8	3,5	5,7	1,1	5	11
	2011	7,3	15	18,5	0,4	1,7	6	9,4	6,4	12,7	6,9	1,9	3,6	5,3
	2012	7,1	15,7	3,7	6,5	6,5	6,2	7,4	2,8	7,8	3,2	3,5	6,8	14,9
Karpdalen	2008											10	18,7	10,9
	2009	13,8	27,1	37,1	19,2	5,6	6,1	5,6	4,4	12	10,1	5,8	15,3	18,4
	2010	20,4	22,8	36,6	17,3	13,9	10,8	6,3	9,2	8,3	7,7	10,1	39,5	62,3
	2011	19,8	54,8	56,6	11,5	15,7	11,4	7	7,2	12	18,9	11,6	11,4	19,6
	2012	16,6	31,2	17,6	18,5	14,6	3,6	2,9	3,7	10,4	13,9	5,7	23,9	52,2

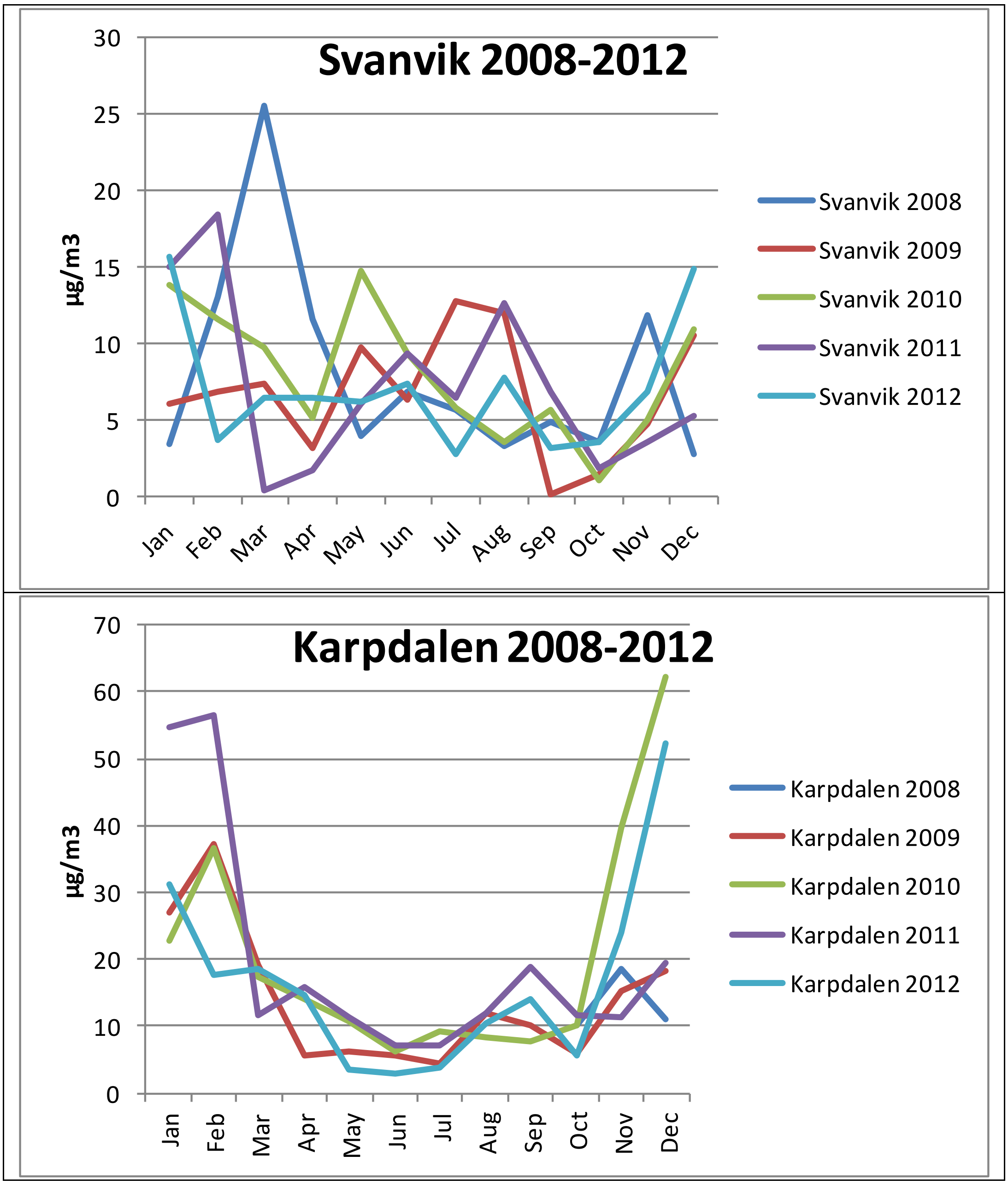

Figure 3.5: Monthly mean values of SO_2 ($\mu g/m^3$) at Svanvik and in Karpdalen 2008-2012.

3.3 Russian annual mean values of heavy metals for the years 2008 -2012

According to monitoring data in the period 2008-2012 the annual mean concentrations of copper and nickel in the ambient air of Nikel and Zapoliarny did not exceed the sanitary norms (for copper MAC = 2000 ng/m^3; for nickel MAC = 1000 ng/m^3) (fig.3.6)

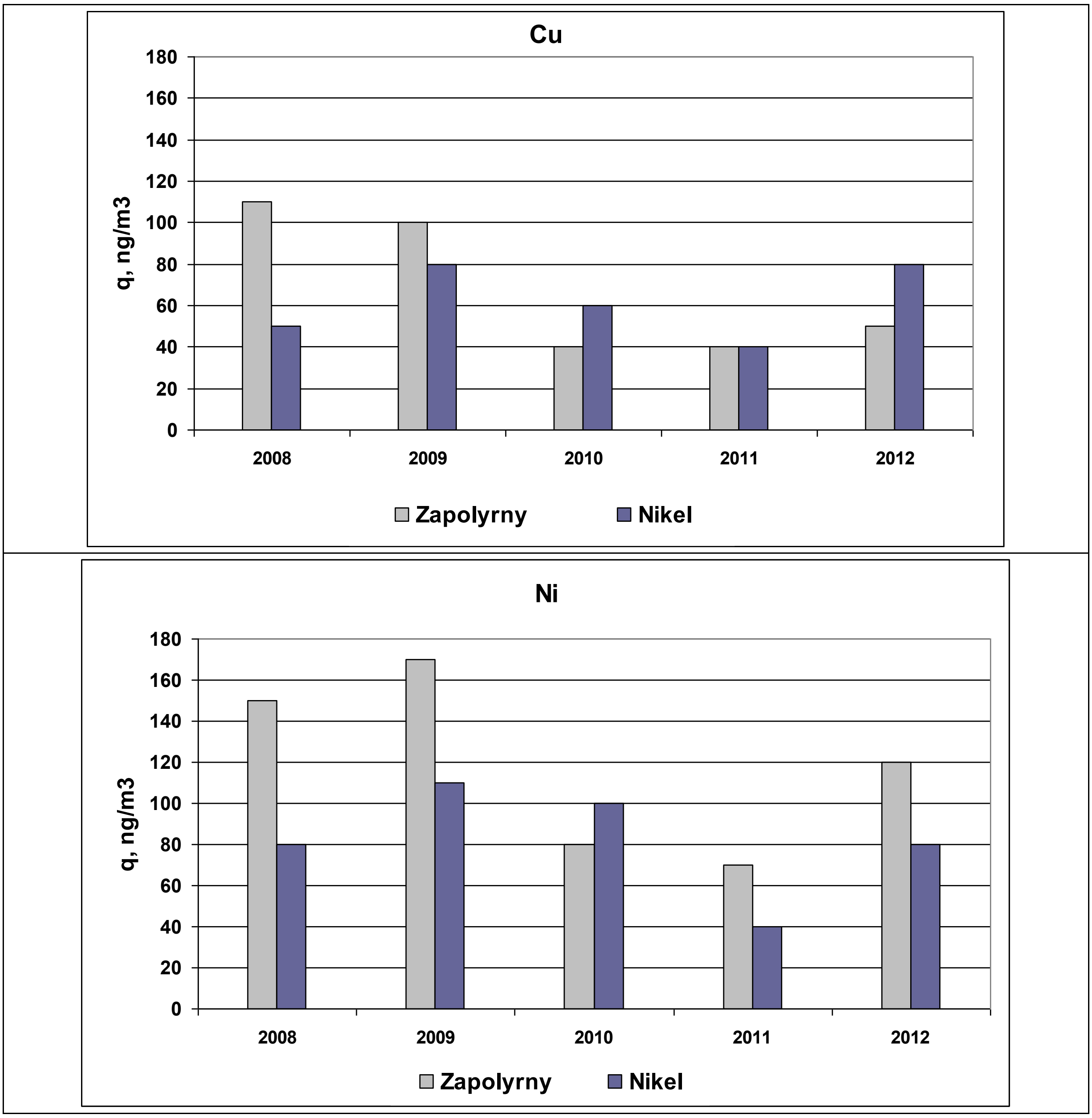

Figure 3.6: Annual mean concentrations of copper and nickel, ng/m^3 in the ambient air of Nikel and Zapoliarny in 2008-2012.

In seasonal distribution, in 2011-2013 the nickel and copper concentrations were observed to increase in the ambient air of Nikel in winter.

The nickel concentration increased from 87 ng/m^3 to 130 ng/m^3 and copper concentration - from 63 ng/m^3 to 110 ng/m^3 in the winter of 2013 as compared to the same period in 2012 (October - March) (Table 3.7). The sulphur dioxide concentration in the same period doubled – from 34 µg/m^3 to 67 µg/m^3.

The seasonal concentrations of copper and nickel in the ambient air of Zapoliarny virtually did not change in 2011-2013.

Table 3.7: Seasonal mean concentrations of metals in the ambient air of Nikel and Zapoliarny in 2011-2013

Station	Period	Copper, ng/m^3	Nickel, ng/m^3
Zapoliarny	April - September 2011	50	93
	October 2011- March 2012	35	83
	April - September 2012	63	95
	October 2012 - March 2013	38	72
Nikel	April - September 2011	65	82
	October 2011 - March 2012	63	87
	April - September 2012	63	95
	October 2012 - March 2013	110	130

3.4 Norwegian annual mean values heavy metals for the years 2011-2013

Primarily, nickel (Ni) and copper (Cu), but also arsenic (As) and cobalt (Co) are considered trace metals from smelter activity. These four elements plus lead (Pb), cadmium (Cd), zink (Zn), chromium (Cr), vanadium (V) and aluminium (Al) are sampled and analyzed in air/dust at Svanvik and in Karpdalen in the Norwegian monitoring program. Sampling of elements in air began at Svanvik in autumn 2008 and in Karpdalen in 2011. At Svanvik there was daily sampling until 2011 and only the filters exposed during easterly wind were analyzed. This gave maximum daily concentrations, but not the mean value. From 2011 and onwards the filters from Svanvik and Karpdalen are exposed one week and all filters are analyzed. This gives in total long term mean values (seasonal mean and annual mean). The results from Svanvik and Karpdalen are given in table 3.8. The daily maximum values during autumn 2008 through autumn 2011 at Svanvik are in the same range as during the base line study 1988-1991.

The seasonal mean values in Karpdalen show higher concentrations than at Svanvik (this is also the case with SO_2). Also note that the values for winter season 2012/13 at Svanvik and in Karpdalen are higher than the winter before.

Table 3.8: Seasonal mean values of elements in air at Svanvik and in Karpdalen autumn 2011 – spring 2013

Station	Period	Ni ng/m^3		Cu ng/m^3	
Svanvik	October 2011 – March 2012	4,51		5,03	
	April – September 2012	7,87		8,03	
	October 2012 – March 2013	10,22		10,34	
Karpdalen	November 2011 – March 2012	7,20		7,55	
	April – September 2012	9,69		9,73	
	October 2012 – March 2013	27,49		27,62	

4 Discussion

The monitoring results for SO_2 from the Russian and the Norwegian monitoring stations are consistent and comparable. The SO_2 levels at the Russian stations are much higher than the levels observed at the Norwegian stations, as they are located closer to the emission sources in Nikel and Zapoliarny.

In Svanvik the wind direction is variable in summer, but winds from north-east can be considered the most dominant. In winter, the most frequent wind direction is from the south and south-west.

In Nikel in summer northern (19%) and north-eastern winds (15%) are predominant.

In Karpdalen the most dominant wind direction is from the south and south-east most of the year.

In winter, in Nikel and Zapoliarny the most dominant wind direction is from the south (38%) and south-west (21%).

As can be seen from the figures 3.2 (Zapoliarny) and 3.5 (Karpdalen) there is a clear seasonal variation in the levels of SO_2. This is because the monitoring stations are located north of the emission source (Zapoliarny, and for Karpdalen Nikel is also an important source), which is in the prevailing wind direction. Nikel and Svanvik show no such seasonal pattern, as these stations are located respectively south and west of the smelter in Nikel.

A comparison of the seasonal means for SO_2 shows that the levels in Nikel (located south of the smelter) are around 16 times higher than the levels in Svanvik (located west of the smelter) during summer and around 5 to 9 times higher in winter. When comparing the levels in Zapoliarny and Karpdalen (both stations are located north of the emission sources), the SO_2 levels in Zapoliarny are around 5 to 8 times higher, with no marked seasonal variation in the ratios. We also see that the annual SO_2 means in Zapoliarny are between 0.75 and 1.3 times higher than the levels in Nikel. Similarly the SO_2 levels in Karpdalen are betweeen 2 to 3 times higher than the levels in Svanvik.

The Russian legislation with respect to SO_2 is violated at both Russian monitoring stations. Also the Norwegian legislation is violated in Karpdalen where the daily mean values of 125 µg/m^3 have been exceeded more than three days per year for the years 2010-2012.

Comparing the levels of nickel in air shows that the levels in Zapoliarny are approximately 3 to 12 times higher than in Karpdalen, and 7 to 18 times higher in Nikel than in Svanvik. Looking at the levels of cupper in Nikel and Svanvik shows that the seasonal means are 8 to 13 times higher in Nikel, and it looks like the differences are slightly higher in winter than summer. Comparing the levels in Zapoliarny with Karpdalen shows that the differences are less, around 1.5 to 6.5. For heavy metals, the seasonal mean levels in Nikel and Zapoliarny are, at large, almost the same, while Karpdalen levels are around 1.2 to 2.7 times higher than Svanvik.

Neither the Russian nor the Norwegian legislation is violated with respect to heavy metals, but the seasonal mean in Karpdalen exceeds the target values for nickel.

The differences in sampling methods and approved criteria of air pollution make the work more complicated.

The differences in methods of sampling of particles for heavy metal analyzes (total vs. smaller than 10 µm) may partly explain the differences in the observed levels. Since the Russian stations are located closer to the emission sources, the samples may consist of a larger share of coarse particles. Also the close vicinity to the smelters contributes to explain the higher levels observed at the Russian stations.

The heavy metals concentrations in the border area are also interpreted differently by the two sides. Values that are considered acceptable when calculated on a yearly basis by the Russian side may be considered unacceptable on a yearly basis by the Norwegian side.

5 Conclusions

1. In the territory of Murmansk Region the Federal State Institution Murmansk Administration for Hydrometeorology and Environmental Monitoring - MUGMS of Rosgidromet – is a competent authority authorized by the government to conduct, environmental pollution monitoring and provide the state government authorities, industries and the public with information on the actual and forecast condition of the environment and environmental pollution.

2. In Norway, the monitoring of air pollution is performed by the Norwegian Institute for Air Research (NILU). The monitoring activities are funded by the Norwegian Ministry of Climate and Environment and by the Norwegian Environment Agency. The main goal of the monitoring is to quantify the levels of air pollutants (SO_2 and heavy metals) in the Norwegian part of the border areas of Russia and Norway, and to provide information on the air pollution situation to the authorities and the public.

3. Both Murmansk UGMS and NILU use state-of-the-art methods for both SO_2 and heavy metals monitoring. These methods are internationally well recognized. Both participating institutes performed with satisfactory results for most analyses of heavy metals in the 2012 EMEP intercomparison exercise. Both institutes have highly qualified personnel.

4. The monitoring results on SO_2 in the air from the monitoring stations in the border areas are consistent and comparable. The results from the Russian and Norwegian monitoring programs give a good description of the state of air pollution in this region.

5. According to the Russian border area monitoring data, in the period 2009-2012 elevated levels of sulphur dioxide pollution were observed in Nikel and Zapoliarny. The Russian norms are exceeded each year, according to the Russian monitoring stations data. The concentrations of the monitored metals including copper and nickel do not exceed the Russian sanitary norms.

6. The border areas in Norway experience elevated levels of SO_2 when the wind comes from the industrial plants in Nikel and Zapoliarny. Norwegian legislation for SO_2 has been violated several times over the years 2011-2012 in Karpdalen. Measured levels of heavy metals in air did not exceed Norwegian target values.

7. Despite SO_2 emissions and levels of SO_2 in ambient air have decreased over the last two decades, high levels of SO_2 in ambient air can still be observed, more often at the Russian monitoring stations. Generally, levels are much higher at the Russian monitoring stations, due to the fact that they are located closer to the emission sources. Seasonal means for the last three years for SO_2 have been between 16 and 5 times higher at the Russian stations than at the Norwegian stations.

8. The sampling methods, regulations and limit values for metals are different in the two countries. In Norway annual mean target values are given for metals concentrations in a particulate fraction PM_{10}. In Russia daily mean MAC's are given for metals concentrations in particulate matter (non-differentiated by the dust composition) without division into fractions.

9. The measured seasonal levels for heavy metals have been between 3 and 18 times higher on the Russian side for nickel and between 1.5 and 13 times for cupper. Two reasons that can explain this are that the Russian stations are located closer to the emissions sources, and that the Russians samples are analyzed for total particulate matter.

10. The cooperation in the expert group is perceived as meaningful and of great professional value to both parties. Future work should be aiming at further harmonization of monitoring methods and the reporting and presentation of the monitoring results. Modeling the dispersion and distribution of the pollutants in the region could also be a topic for a future common project.

References and further reading

Further references and reading can be found in the reports listed below.

1. Report of the current status and protection of the environment in Murmansk Region. Committee for Industrial Development, Environment and Natural Resources of Murmansk Region (2009-2012).

2. Review of the environment status and pollution in the Russian Federation. Ministry of Natural Resources and the Environment of the Russian Federation. Rosgidromet. (2009-2012)

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5. EU Air Quality Directive:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF [URL 30-09-2013]

6. WHO Air Quality Guidelines: http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulphur-dioxide

7. Norwegian legislation:
http://www.lovdata.no/for/sf/md/xd-20040601-0931.html[URL30-09-2013]
http://www.handboka.no/Sak/Forskrifter/Foru/Fore/fu20g.htm [URL 30-09-2013]

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We are under the Ministry of Climate and Environment and have over 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.