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Authors: Liliosa Magombedze & Øystein Jæger		Client: Fylkesmannen i Finnmark, NGU	
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		Person responsible: <i>Jamf. Kranner</i>	
Summary: <p>The main activity during 2004 has been the collection and analysis of 30 groundwater and 3 snow samples from the three monitoring stations located at Karpdalen, Svanvik and Skjellbekken. All samples were analysed for cation concentration by inductively coupled plasma-atomic emission spectrometry (ICP-AES: Si, Fe, Ti, Mg, Ca, Na, Ba, Sr, Sc), heavy metals and trace elements by inductively coupled plasma-mass spectrometry (ICP-MS: Y, Nb, Ag, In, Sb, Cs, Nd, Sm, Ho, Yb, Ta, W, Tl, Bi, Th, V, Mn, Cu, Zn, Ga, Ge, Li, Be, B, Rb, Zr, Mo, Cd, La, Ce, Pb, U, Al, Cr, Co, Ni, P, I, K, As, Se), anions by ion chromatography (IC: F, Cl, Br, NO₃, NO₂, PO₄, SO₄), alkalinity, pH, electrical conductivity, colour and turbidity. All elements show slight variations in concentration with time. A comparison of groundwater content of 7 toxic heavy metals with background data from the Nellim station in Finland shows that all elements are below or equal to the background values except for Cu at Svanvik and As at all 3 stations. However all 7 heavy metals concentrations in groundwater are well below the Norwegian drinking water standard values. There are no indications of contamination of groundwater at the three stations so far. However surface media are contaminated, likely by emissions from the Nickel smelters, as shown by higher concentrations of Cd, Cu, Ni, Pb in snow compared with groundwater.</p>			
Keywords: Groundwater		Monitoring	Contamination
Sampling		Chemical analysis	Snow

CONTENTS

1.0	INTRODUCTION.....	5
2.0	SAMPLING.....	5
2.1	<i>Groundwater sampling</i>	5
2.2	<i>Snow sampling</i>	5
3.0	FIELDWORK.....	6
3.1	<i>Nellim station</i>	6
3.2	<i>Similarities in groundwater monitoring in Pasvik and at Nellim station</i>	7
3.3	<i>Differences in groundwater monitoring in Pasvik and at Nellim station</i>	7
4.0	ANALYTICAL RESULTS.....	8
4.1	<i>Comparison of laboratory and field measurements</i>	8
4.2	<i>Analysis of results</i>	11
5.0	FINANCIAL STATUS.....	12
6.0	REFERENCES.....	13

FIGURES

Figure 1	Snow sampling equipment.....	6
Figure 2	Comparison of field and laboratory measurements of EC.....	8
Figure 3	Comparison of field and laboratory measurements of pH.....	11

TABLES

Table 1	Statistical summary of parameter values in groundwater and in snow at Svanvik and Karpdal.....	9
Table 2	Statistical summary of parameter values in groundwater and in snow at Skjellbekken.....	10
Table 3	Comparison of heavy metal concentrations in groundwater with background values.....	12

Table 4	Project expenditure for 2004.....	13
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APPENDICES

Appendix 1	Groundwater sampling protocol.....	14
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Appendix 2	Parameter values in groundwater.....	16
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Appendix 3	Groundwater parameter values – Time series plots.....	19
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1.0 INTRODUCTION

The Pasvik project is a collaborative project between Norway and Finland. NGU carries out monitoring of groundwater quality at three monitoring stations in the Pasvik area with financing from the Fylkesmannen i Finnmark. The collaboration with Lapland Regional Environmental Centre (LREC) involves the use of long term monitoring background data on groundwater quality from the Nellim station and other groundwater monitoring stations in Finland.

The main activities during the year 2004 have been sample collection and analysis, plus a joint field trip with our Finnish counterpart (LREC) to the Nellim groundwater monitoring station in Finland and to the three groundwater monitoring stations in Pasvik. The work is completed according to our activity plan, dated 24 July 2004.

2.0 SAMPLING

2.1 Groundwater Sampling

With the help of a local assistant at Svanhovd Environmental Centre, groundwater samples were collected from Skjellbekken, Svanvik and Karpdalen monitoring wells every 5 weeks throughout the year. Samples were collected during weeks 4, 9, 14, 19, 24, 28, 34, 39, 44 and 49 giving a total of 30 groundwater samples. In addition to sampling, pH, electrical conductivity (EC), groundwater temperature and groundwater level were measured concurrently in the field.

As stated in the Status report of 2003, each well is equipped with a small electric pump and hose, which were left in the wells to minimise contamination during sampling. Contamination must be minimised as much as possible during sampling. There are widely diverging opinions on how best to avoid contamination from field equipment, especially from sampling bottles. Many researchers suggest the use of factory new Teflon bottles, while others prefer that all field equipment should be pre-washed. Teflon bottles are very expensive and we therefore opted for pre-washing and pre-acidification with super-pure HNO₃ of sample bottles for cation analysis samples and use of brand new field equipment like syringes, filters, sample bottles (for anion and physical parameters) and gloves were used. Groundwater samples are collected following a standardised sampling procedure (Appendix 1).

2.2 Snow sampling

Snow generally contains many impurities, which may come from natural sources, locally created contaminants or from long distance sources of pollutants (Soveri, 1985).

Snow samples were collected from sites around each of the monitoring stations towards the end of the winter season, during week 14, giving a total of 3 snow samples. The samples were collected by pushing plexiglass samplers vertically into the snowpack. The snow samples were stored in polyethylene bags (Figure 1) and transported whilst frozen to the laboratory at Svanhovd Environmental centre. In this lab they were then melted at room temperature to liquid water, which was then transferred to sample bottles for analysis at NGU lab. After melting the snow sample is handled in the same way as the groundwater sample.



Figure 1: Snow sampling equipment.

3.0 FIELDWORK

NGU carries out the groundwater quality monitoring part of the project in collaboration with Lapland Regional Environmental Centre (LREC) in Finland. LREC will provide NGU with long term monitoring background data on groundwater quality from their Nellim station for integration with groundwater quality data from the Norwegian side through this cooperation. Following a kick off meeting in March 2004, at Svanhovd Environmental Centre, NGU and their Finnish counterparts decided to exchange information about their monitoring stations. A one-day joint trip to Nellim station was organised on 5 July 2004 followed by another day's visit to the 3 monitoring stations in Pasvik. The main purpose of this visit was to compare and contrast the monitoring stations in terms of hydrogeological setting and groundwater sampling procedure, sampling bottle material and analytical methods.

3.1 Nellim station (Finland)

Nellim station is a very big station in area, with facilities for meteorological, hydrological and hydrogeological measurements. It has been a part of the Finnish National groundwater-monitoring network for the past 35 years. Measured parameters include rainfall, air temperature, wind direction, wind speed, air pressure, humidity, lake level (from lake Enare), snow depth and water quality. A total of 6 water samples per year are collected from a lysimeter for water quality testing. Water samples from the lake are collected every 10m, once every 2 months. At the same station are 3 groundwater-monitoring points: 2 wells and one spring. The wells are less than 5m deep in till deposits and are only used for groundwater level and groundwater temperature measurements. Groundwater samples are collected from a spring, which is at the southeastern shore of Lake Enare. The spring, like the monitoring

stations in Pasvik, is situated in quaternary deposits. Concrete rings of ≈ 1 m in diameter have been installed around the spring making a well for water sample collection. Lake level is lower than the spring, so there has been no chances of contamination from the lake. In fact water flows from the spring into the lake. Water from the spring is used for drinking purposes by the habitants of a cabin nearby.

Lowering a bottle in the well collects water, which is then transferred into plastic sample bottles pre-washed with Degounex. Degounex does not affect pH, hence no contamination of the sample from the bottle. A groundwater sample includes the following subsamples: 1 l water for anions, 2 l bottle prewashed by HCl for heavy metals, 1 l glass bottle for mercury, 100 ml plastic bottle for carbon and 100 ml for alkaline metals. Filtration and acidification of samples is done in the laboratory. The hydrogeological description of the monitoring wells on the Norwegian side and what constitutes a groundwater sample are given in the 2003 Status report.

3.2 Similarities in groundwater monitoring in Pasvik and at Nellim station

- The monitoring stations are located in the same geological environment, i.e. quaternary deposits.
- They are all far from direct human influence. Though there is a cabin close to the spring at Nellim, the dwelling is rarely used eliminating the fear of human contamination though this is not 100% guaranteed.
- Sampling bottles made of the same plastic material are used in both cases.

3.3 Differences in groundwater monitoring in Pasvik and at Nellim station

There seems to be more differences than similarities between the two groundwater monitoring systems.

- The groundwater monitoring point at Nellim is a spring while wells are used on the Norwegian side. However this does not pause a big difference since wells and spring are both sources of groundwater.
- Frequency of sampling: At Nellim, groundwater samples are collected every 2 months. That means 6 samples a year. In Norway samples were collected every 5 weeks giving a total of 10 samples per station in 2004.
- Sampling methods: At Nellim, bailer sampling method is used whereby a sample is collected directly from the well by lowering a bottle (sample collector) and then transferred to the sample bottles. On the Norwegian side, samples are collected through pumping.
- Samples from the Norwegian stations are filtered in the field and collected in bottles pre-acidified with super pure HNO_3 for cation analysis whereas in Finland, filtration and acidification are done in the laboratory. Sample bottles for analysis of heavy metals are pre-washed with HCl.
- Measurement of EC, pH and water level are also done in the field on the Norwegian stations whereas no field measurements are done on the Finnish station.

4.0 ANALYTICAL RESULTS

All samples from the Norwegian stations were sent to NGU laboratory for chemical analysis. Each sample was analysed for 29 elements (cations) by ICP-AES, 41 elements (cations) by ICP-MS, 7 elements (anions) by IC, pH, EC, alkalinity, turbidity and colour. However due to technical problems at the laboratory, ICP-MS analyses could not be done until October 2004. Chemical analysis results are given in Appendix 2, while a statistical summary of parameters determined in groundwater and concentrations of parameters in snow are shown in Tables 1 and 2. The accuracy of chemical analyses can be estimated from charge balance of major ions. Concentrations of major ions were loaded into a geochemical software called Aq.QA. The software calculated the charge balance error of all the analysis to be within acceptable range.

4.1 Comparison of field and laboratory measurements

EC and pH measurements were done both in the field and in the lab. EC measurements are particularly useful as a control on analysis and conservation of samples (Appelo & Postma, 1996). The pH of water represents the interrelated result of a number of chemical equilibria. According to Hem (1970) the equilibria in a groundwater system are altered when water is pumped out to the surface due to degassing. Oxidation reactions may also alter equilibria conditions and as such, pH measured at the moment of sampling may represent the original equilibria conditions better than lab measurements done after some days or weeks. However pH field measurements should be done with reliable equipment and precaution.

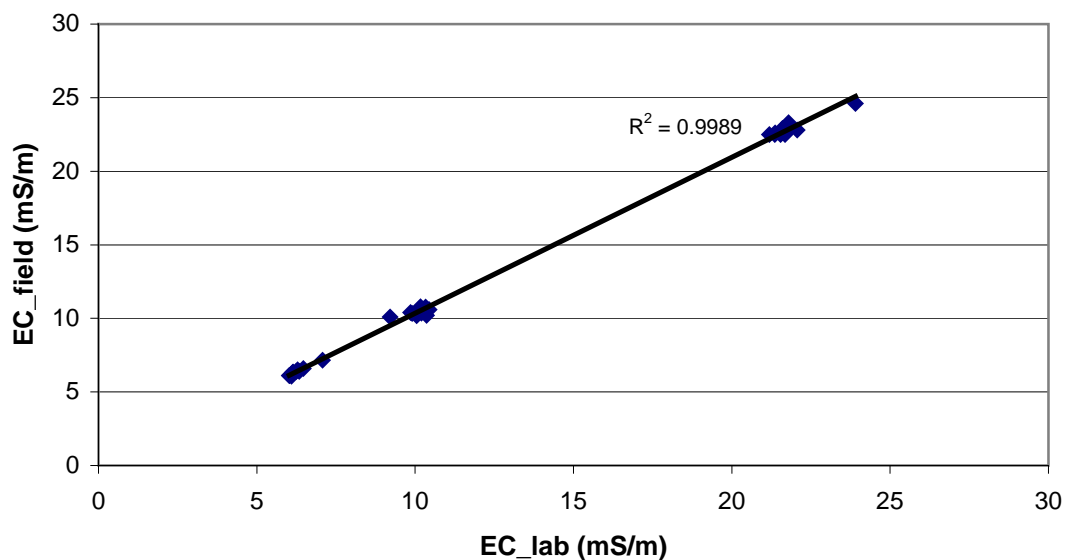


Figure 2: Comparison of field and laboratory measurements of EC.

Table 1: Statistical summary of parameter values in groundwater and in snow at Svanvik and Karpdal.

Svanvik

Element/Parameter	Units	Min	Median	Mean	St. Dev.	Max	Snow
pH_lab		6.870	7.041	7.031	0.0706	7.165	5.20
tAlk_lab	mmol/l	0.290	0.302	0.310	0.0242	0.380	<0.04
EC_lab	mS/m	6.020	6.150	6.478	0.8680	9.210	1.18
Colour		0.700	0.700	1.546	1.6954	6.600	< 1.4
Turbiditet	FTU	0.230	0.360	11.894	41.4963	150.000	0.09
F	mg/l	0.025	0.025	0.035	0.0347	0.150	< 0.05
Cl	mg/l	3.910	4.350	4.420	0.4932	5.400	1.85
NO3	mg/l	0.060	0.320	0.349	0.2014	0.920	0.48
SO4	mg/l	6.050	6.480	7.269	2.5419	15.400	1.15
Si	mg/l	4.580	4.760	4.807	0.1810	5.080	<0.02
Fe	mg/l	0.004	0.005	0.007	0.0069	0.030	<0.01
Mg	mg/l	0.928	1.070	1.115	0.1231	1.360	0.145
Ca	mg/l	5.270	5.840	5.905	0.5007	7.280	0.224
Na	mg/l	3.390	3.840	4.247	1.3036	8.370	1.21
Ba	mg/l	0.020	0.026	0.025	0.0039	0.032	0.0359
Sr	mg/l	0.014	0.016	0.017	0.0022	0.022	0.0019
Y	µg/l	0.084	0.091	0.096	0.0129	0.131	<0.005
Ag	µg/l	0.005	0.158	0.196	0.2122	0.563	<0.01
Sb	µg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cs	µg/l	0.021	0.024	0.025	0.0041	0.037	<0.002
Nd	µg/l	0.217	0.234	0.256	0.0391	0.342	<0.01
Sm	µg/l	0.034	0.040	0.041	0.0065	0.058	<0.002
Ho	µg/l	0.002	0.002	0.002	0.0004	0.003	<0.001
Yb	µg/l	0.004	0.004	0.005	0.0006	0.006	<0.002
W	µg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bi	µg/l	0.005	0.012	0.012	0.0056	0.021	<0.01
V	µg/l	0.321	0.407	0.411	0.0718	0.545	0.325
Mn	µg/l	0.384	1.400	1.530	0.9116	3.440	1.01
Cu	µg/l	3.300	3.790	3.938	0.8889	6.750	19.8
Zn	mg/l	0.319	0.338	0.341	0.0148	0.373	0.344
Ga	µg/l	0.005	0.015	0.017	0.0076	0.034	<0.01
Li	µg/l	0.250	0.550	0.523	0.1499	0.860	<0.5
Be	µg/l	0.005	0.024	0.028	0.0217	0.085	0.029
B	µg/l	2.5	2.5	2.736364	0.78393	5.1	<5
Rb	µg/l	1.930	2.110	2.196	0.3117	3.090	<0.05
Zr	µg/l	0.025	0.050	0.054	0.0361	0.140	<0.05
Mo	µg/l	0.840	0.990	1.047	0.1872	1.600	<0.2
Cd	µg/l	<0.03	<0.03	<0.03	<0.03	<0.03	0.042
La	µg/l	0.183	0.209	0.223	0.0367	0.314	<0.01
Ce	µg/l	0.029	0.054	0.080	0.0963	0.396	<0.01
Pb	µg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.47
U	µg/l	0.065	0.087	0.088	0.0152	0.114	<0.0005
Al	µg/l	15.900	25.900	33.392	20.7468	93.800	15
Cr	µg/l	0.360	0.610	0.626	0.1592	0.930	0.33
Co	µg/l	0.010	0.180	0.163	0.1126	0.380	0.248
Ni	µg/l	1.200	1.600	1.554	0.2727	2.000	11.3
P	µg/l	<5	<5	<5	<5	<5	<5
I	µg/l	<5	<5	<5	<5	<5	<5
K	mg/l	0.588	0.686	0.678	0.0568	0.812	0.06
As	µg/l	0.069	0.118	0.106	0.0223	0.140	0.38

Karpdal

Min	Median	Mean	St. Dev.	Max	Snow
7.20	7.33	7.33	0.097	7.60	5.15
1.54	1.58	1.60	0.086	1.87	<0.04
21.2	21.7	21.8	0.670	23.90	1.73
1.6	2.8	5.1	5.785	23.40	4.0
5.4	8.9	39.2	93.362	345.00	0.12
0.17	0.24	0.23	0.030	0.26	< 0.05
10.10	10.60	10.68	0.481	11.70	3.02
0.025	0.15	0.12	0.084	0.23	0.05
11.40	13.00	13.10	0.803	15.00	1.57
5.45	6.08	6.09	0.345	6.77	<0.02
0.25	1.60	1.43	0.502	2.11	0.019
6.12	6.39	6.50	0.291	7.14	0.224
19.60	21.00	21.06	1.179	24.20	0.333
10.30	11.40	11.42	0.614	12.40	1.94
0.03	0.04	0.04	0.006	0.05	0.0359
0.09	0.10	0.10	0.006	0.11	0.0076
0.0501	0.0778	0.0795	0.0221	0.1280	0.0104
0.0050	0.3260	0.3040	0.2594	0.6560	<0.01
0.02	0.07	0.10	0.105	0.28	<0.01
0.0031	0.0042	0.0062	0.0066	0.0279	<0.002
0.0600	0.0930	0.1122	0.0696	0.3240	0.016
0.0105	0.0161	0.0189	0.0094	0.0468	0.002
0.0014	0.0021	0.0022	0.0008	0.0042	<0.001
0.0035	0.0051	0.0053	0.0013	0.0079	<0.002
0.0250	0.0250	0.0420	0.0195	0.0700	<0.05
0.0050	0.0130	0.0115	0.0057	0.0190	0.011
0.3000	0.6600	0.7434	0.3655	1.7400	0.25
79.70	88.60	88.97	7.205	103.00	1.63
0.0250	0.0700	0.1281	0.1870	0.7210	12.4
0.2990	0.3310	0.3278	0.0181	0.3600	0.341
0.0050	0.0050	0.0201	0.0389	0.1420	<0.01
2.60	2.80	2.88	0.215	3.30	<0.5
0.005	0.033	0.033	0.024	0.105	0.024
2.50	19.00	17.64	4.740	21.00	<5
0.984	1.070	1.196	0.402	2.470	<0.05
0.025	0.110	0.111	0.050	0.240	<0.05
2.89	3.80	3.69	0.398	4.32	<0.2
<0.03	<0.03	<0.03	<0.03	<0.03	0.045
0.051	0.088	0.107	0.075	0.338	0.029
0.113	0.156	0.202	0.163	0.731	0.046
<0.05	<0.05	<0.05	<0.05	<0.05	1.322
3.18	5.61	11.86	14.188	55.40	<0.0005
5.80	13.00	32.42	55.150	210.00	13
0.24	0.71	0.61	0.229	0.98	0.21
0.010	0.293	0.304	0.135	0.534	0.215
0.70	1.10	1.15	0.383	1.90	8.31
2.50	11.50	10.44	4.263	15.00	<5
2.50	6.10	5.60	1.935	8.50	<5
3.31	3.81	3.79	0.329	4.70	0.09
0.481	0.696	0.684	0.114	0.909	0.29

Table 2: Statistical summary of parameter values in groundwater and in snow at Skjellbekken.

Element/Parameter	Units	Min	Median	Mean	St. Dev.	Max	Snow
pH_lab		7.49	7.64	7.637	0.062	7.72	5.03
tAlk_lab	mmol/l	0.63	0.69	0.696	0.032	0.76	<0.04
EC_lab	mS/m	9.33	10.05	10.028	0.303	10.44	0.82
Colour		0.7	1.60	1.892	1.551	6.00	5.6
Turbiditet	FTU	0.07	0.10	0.118	0.064	0.32	0.08
Cl	mg/l	2.44	2.61	2.617	0.080	2.76	0.81
NO3	mg/l	0.025	0.08	0.112	0.119	0.39	0.11
SO4	mg/l	7.95	9.84	9.451	0.886	11.00	0.80
Si	mg/l	3.90	4.11	4.16	0.217	4.62	<0.02
Fe	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mg	mg/l	1.30	1.45	1.44	0.094	1.60	0.057
Ca	mg/l	11.7	13.30	13.254	0.919	14.80	0.076
Na	mg/l	2.19	2.67	2.652	0.265	3.26	0.580
Ba	mg/l	0.0331	0.04	0.040	0.005	0.05	0.0186
Sr	mg/l	0.0263	0.03	0.030	0.002	0.03	<0.001
Y	µg/l	0.0077	0.01	0.011	0.001	0.01	<0.005
Ag	µg/l	0.005	0.205	0.196	0.203	0.536	0.614
Cs	µg/l	0.001	0.001	0.001	0.001	0.003	0.0021
Nd	µg/l	0.005	0.011	0.009	0.003	0.012	<0.01
Sm	µg/l	0.0010	0.0023	0.0048	0.0102	0.0386	<0.002
W	µg/l	0.675	0.91	0.889	0.098	1.02	<0.05
Bi	µg/l	0.005	0.013	0.011	0.006	0.021	0.015
V	µg/l	0.265	0.315	0.332	0.071	0.548	0.154
Mn	µg/l	4.22	8.07	7.962	2.379	11.10	0.514
Cu	µg/l	0.094	0.15	0.156	0.047	0.25	4.19
Zn	mg/l	0.293	0.346	0.342	0.022	0.380	0.305
Ga	µg/l	0.005	0.015	0.015	0.004	0.022	<0.01
Li	µg/l	0.83	0.92	0.944	0.084	1.10	<0.5
Be	µg/l	0.012	0.023	0.027	0.013	0.062	0.037
Rb	µg/l	0.888	0.95	0.948	0.040	1.01	0.059
Mo	µg/l	0.51	0.74	0.825	0.230	1.30	<0.2
Cd	µg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
La	µg/l	0.010	0.016	0.021	0.017	0.075	<0.01
Ce	µg/l	0.004	0.011	0.015	0.018	0.070	<0.01
Pb	µg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.27
U	µg/l	0.107	0.134	0.138	0.019	0.170	<0.0005
Al	µg/l	5.6	9.80	10.222	3.517	18.00	3.9
Cr	µg/l	0.23	0.44	0.445	0.156	0.81	<0.1
Co	µg/l	0.01	0.15	0.152	0.078	0.29	0.035
Ni	µg/l	0.32	0.45	0.466	0.084	0.63	2.37
K	mg/l	2.790	3.050	3.028	0.119	3.150	0.033
As	µg/l	0.138	0.19	0.206	0.077	0.44	0.11

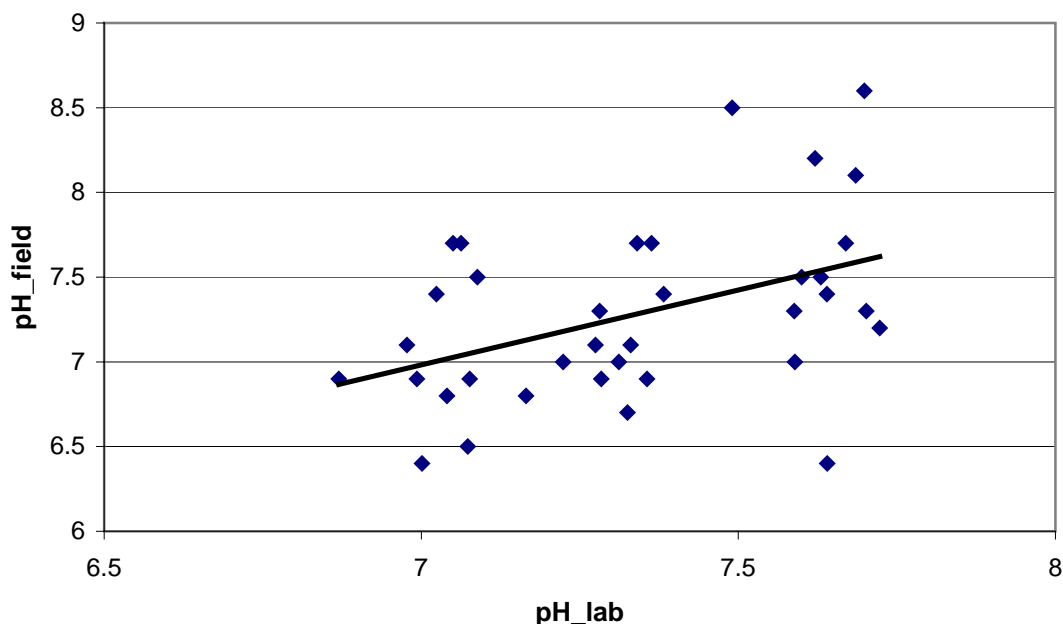


Figure 3: Comparison of field and laboratory measurements of pH.

Figure 2 shows positive correlation for EC between the field measurements and the laboratory measurements. This means that there was no major changes in the dissolved concentrations from the time samples were collected to the time they were analysed. On the other hand Figure 3 shows very poor correlation between pH field measurements and laboratory measurements. The poor correlation could be due to a number of reasons varying from human error, temperature differences in the field and laboratory, sampling procedure to performance of the electrode. Laboratory results for pH are considered more reliable since they are more consistent than field results.

4.2 Analysis of results

Line graphs have been plotted for each element with some concentrations values above detection limit to assess temporal variation. Time series of some toxic elements, pH, EC, alkalinity, are shown in Appendix 3. For interpretation and presentation purposes, half the detection limit value was used where parameter values were below detection limit. NO₂, Br, PO₄, Ti, Sc, Nb, In, Sb, Ta, Tl, Th, Ge, Cd, and Pb have concentrations lower than detection limit for all groundwater samples from all 3 stations. Boron is below detection limit at Skjellbekken and Svanvik stations. Almost all elements do not show any significant variation of concentrations with time. Median background values were estimated from Nellim station data collected between June 1999 and June 2004 which were analysed by ICP-MS. Prior to 1999 several different methods were used for chemical analysis of samples and information regarding detection limits and units used should be sorted out before data can be used. Table 3 shows a comparison of median background values of 7 heavy metals content in groundwater, drinking water standards for Norway and the median content in groundwater at each of the 3 stations in Pasvik.

Table 3: Comparison of 7 heavy metal concentrations in groundwater with background values from Nellim station and Norwegian Drinking water standard values.

Element	Background values, Nellim (ug/l)	Svanvik Median (ug/l)	Karpdal median (ug/l)	Skjellbekken median (ug/l)	Norwegian Drinking water standards (Recommended limits (ug/l))
As	<0.06	0.119	0.697	0.19	10
Cd	<0.03	<0.03	<0.03	<0.03	5
Cr	0.76	0.61	0.65	0.42	50
Cu	0.42	3.81	0.0745	0.15	100
Ni	2.35	1.5	1.15	0.45	20
Pb	0.08	<0.05	<0.05	<0.05	10
Zn	0.5	0.339	0.331	0.346	-

Table 3 shows that only Cu at Svanvik and As at all 3 stations exceed the background values from Nellim station. Cu is higher by a factor of 9, while As is higher by factors of 4, 23 and 6, respectively, at Svanvik, Karpdal and Skjellbekken (half the detection limit was used for As at Nellim). However all elements have concentrations below the recommended limits for drinking water in Norway.

Element concentrations in snow samples are shown in Tables 1 and 2 and are plotted together with groundwater sample concentrations (Appendix 2). For most elements, their concentration in snow is much lower than in groundwater, or below detection limit. However it is interesting to note that concentrations in snow are higher in snow than in groundwater for Cd, Pb, Ni and Cu, at all three stations. This shows that these elements are found in surface media and are of anthropogenic origin in this case. They are bound to the snow during snowfall. There are no indications of contamination of groundwater so far, despite the fact that pollution of air, surface water and vegetation by emissions from the Nickel smelters was detected since the early 90's as documented in NGU report 97.113 and Reiman et.al (1997). The toxic elements from the contaminated media are expected to subsequently leach and contaminate groundwater. However, there seems to be an attenuation of pollutants in the unsaturated zone as water infiltrates to the groundwater zone. It is not well understood how fast chemical elements move in the unsaturated zone or how long it will take them to be released from the soil zone to the groundwater zone, creating the need for long term monitoring. In order to meet this need, NGU will incorporate one of the 3 stations in its National groundwater-monitoring network, LGN at the end of this project.

5.0 FINANCIAL STATUS

The expenses of the project are given in table 4 below.

Table 4: Project expenses for the period 01.01 2004 – 31.03.2005.

	Budget 01.01.-31.12.2004 (NOK)	Expenses 01.01.–31.12.2004 (NOK)	Expenses 01.07.2004–15.03.2005 (Interreg Phase 2) (NOK)
Project personnel	85 200	175 380	123 229
External services	60 000	62 680	49 766
Administration costs	61 800	51 584	52 269
Material costs	3 000	0	0
Investments	0	0	0
Travel costs	30 000	35 315	19 955
Sum	240 000	324 959	245 219
Financing			
Fylkesmannen i Finmark		120 000	
NGU		204 959	

6.0 REFERENCES

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Appendix 1: Groundwater sampling protocol

1. EC meter must be checked/calibrated at the lab. 1 or 2 days before sampling
2. Remember keys to open locks on wells
3. Measure the water level to the top of casing
4. Raise the pump a little from the bottom of the well and connect the electric cable to the battery. **Each well must have its own pump to avoid contamination**
5. Pump out 3 well casing volumes before taking a sample. It has been estimated that 1m is equivalent to 2 litres of water. So for a well with 8m of water, you will need to pump out 48 l of water before sampling.
6. Record the volume pumped out
7. Calibrate pH meter everyday before sampling.
8. Measure and record EC, pH and temperature measured after pumping.

9. Taking a sample

- Label the sample bottles with BH/Sample ID, location, date sampled, filtered (**F**) and/or Filtered and acidified (**FS**)
- Use disposable gloves when taking a sample to avoid contamination.
- Rinse a 500 ml bottle 2 to 3 times with sample water and fill it to the top and close tightly.
- ***Rinse the filtering syringe with deionised water and then rinse it with sample water prior to collection of sample at each new sampling point. Use a new filtering membrane at each sampling point.***
- Filter water through 0,45 µm millipore filtering membrane. Rinse a small non-acidified bottle 100 ml, 2 to 3 times with **filtered** water. Fill it up to the top with filtered water and close it tightly.
- ***Do not rinse*** the small pre-acidified bottle with red dot on the cap. Fill it up to the top with filtered water and close it tightly.
- ***Do not sample from the bucket. Pump water into a 500 ml bottle and sample from there.***
- ***Keep the samples upright in a cool place.***

- ***When it is very cold (below 0 °C), it is difficult to filter in the field. Take an extra 500 ml sample and filter later in the lab. The filtration should be done as soon as possible at least the same day the sample is collected. Remember to rinse the sample bottle 2 to 3 times with filtered water before collecting a sample.***
- 10 Disconnect electric cable from battery. Pump with hose and electric cable to be left in the well until next sampling round.
- 11 ***Samples should be sent NGU laboratory for analysis as soon as possible.***

Appendix 3: Groundwater parameter values-Time series plots

