



ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND 2009

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Data sheet

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Abstract: This sixth monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 15-22 August 2009. Twelve shipments of ore, the last on 27 March 2009, went to Canada for gold extraction since the last monitoring study in August 2008. Angel Mining bought the gold mine on 1 July 2009, but no gold mining was initiated prior to the present monitoring study. Biota was collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected in the area and transplanted to the valley from an uncontaminated area. Samples were analysed for 12 elements with ICP-MS. In lichens, elevated concentrations (2-10 times of background levels) of copper, chromium, arsenic and cobalt were found at the waste rock depot and in the mine area. A non-linear temporal trend with decreasing concentrations in 2009 of the four metals in lichens from the two areas was found. This trend was expected due to reduced activities. All metal concentrations showed a significant decrease with increasing distance to the road. Elevated concentrations of Cu and As could be found to a distance of c. 1000 m from the road, while Cr and Co reached the background levels at about 500 m. Concentrations of metals in transplanted lichens were lower in 2009 than in 2008. No elevated concentrations were found in mussels, sculpins and chars, while seaweed had slightly elevated Co concentrations at one station. In 2009, an impact from the mine was primarily seen in the Kirkespir Valley due to dust dispersal. The impact of the mine in the marine environment was negligible.

Keywords: Monitoring, elements, blue mussel, brown seaweed, shorthorn sculpin, Arctic char, *Cetraria nivalis*, transplantation, Nalunaq Gold Mine, Greenland.

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Summary

This sixth monitoring study was carried out in the Nalunaq gold mining area, Nanortalik, South Greenland, on 15-22 August 2009. Twelve shipments of ore, the last on 27 March 2009, had been transported to Canada for gold extraction since the last monitoring study performed late August 2008. Mining stopped late 2008. Angel Mining (Gold) bought the Nalunaq gold mine on 1 July 2009, but no gold ore was mined prior to the present monitoring study.

Blue mussels, brown seaweed and shorthorn sculpin were sampled at 4 marine stations in the Kirkespir Bay, resident Arctic char were caught in the river and lichens *Cetraria nivalis* were collected at 20 stations in the valley and along the bay. In addition, lichens were transplanted from an uncontaminated area (AMI1) to the mining area (Fig. 1). Collected samples were analysed for 12 elements (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo and Au) and the results were compared both to background levels and to previous monitoring studies.

No elevated concentrations were found in mussels and in sculpin livers, while seaweed had slightly elevated concentrations of Co at one sampling station. The impact from the mining activities on the marine environment was found to be very low in 2009. During 2006-2009, only Co was consistently elevated in seaweed and only at the same station.

In livers from resident Arctic char, average concentrations were not elevated in 2009 compared to baseline concentrations. During 2004-2009, minor elevations of Cr, Co and Cd were found in 2004 and 2006.

In lichens, concentrations of Cu, Cr, As and Co were, like in previous years, significantly elevated compared to the background levels in the depot and the camp and mine area. In 2009, elevations in the two areas were 2-3 times for Cu and Cr, 4-10 times for As and 2-10 times for Co. In 2008 elevations in the two areas were about the double.

Temporal trends in concentrations of Cu, Cr, As and Co in lichens in the two impacted areas showed a non-linear course during 2004-2009 with a decrease in 2009 for all metals. Most pronounced was the decrease in the camp and mine area. This trend was expected due to the reduced mining activities in 2009.

We tested the relationship between the concentrations of Cu, Cr, As and Co in lichens and the distance to the road. All concentrations of the four metals showed a significantly decrease with increasing distance. Cu and As concentrations above the background levels could, as in previous years, be found to a distance of about 1000 m from the road, while Cr and Co reached the background level at about 500 m.

In 2009, concentrations of metals in the transplanted lichens were lower than in the transplanted lichens in 2008. Also, fewer metals showed elevated concentrations in 2009 compared to 2008.

Sammenfatning

Denne sjette monitoringsundersøgelse blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 15. til 22. august 2009. Siden monitoringen i august 2008 er der blevet udskibet tolv malmladninger til Canada, hvor guldet udvindes. Brydningen stoppede i slutningen af 2008, og det sidste malmskib afsejlede d. 27. marts 2009. Angel Mining (Gold) købte minen 1. juli 2009, men der er ikke blevet brudt malm frem til denne miljømonitoring.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4 stationer i Kirkespirbugten, standørreder blev fisket i Kirkespirelven og snekruslav *Cetraria nivalis* blev samlet på 20 stationer i Kirkespirdalen og ved bugten. Lav blev transplanteret fra et uforurenede område (AMI1) til mineområdet (Fig. 1). Alle prøver blev analyseret for 12 grundstoffer (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo og Au) og resultaterne blev sammenholdt med baggrundsniveauet målt i 1998-2001 og med resultaterne fra de tidligere monitoringsundersøgelser.

Der blev ikke fundet forhøjede koncentrationer i muslinger og i ulkelever, mens der i tang var svagt forhøjede koncentrationer af Co på én station. Det marine miljø var således også i 2009 kun ganske svagt påvirket af mineaktiviteterne. Co var også forhøjet i tang fra den samme station i perioden 2006-2008.

I standørred lever blev der ikke fundet forhøjede metal koncentrationer. I perioden 2004-2009 var der kun i 2004 og 2006 svagt forhøjede koncentrationer af Cr, Co og Cd.

I laver fra områderne ved depotet for knust gråbjerg og ved minen og lejren var koncentrationer af Cu, Cr, As og Co som i tidligere år signifikant forhøjede. Forhøjelserne i begge områder i 2009 var 2-3 gange for Cu og Cr, 4-10 gange for As og 2-10 gange for Co. I 2008 var forhøjelserne i de to områder omtrent dobbelt så høje.

I perioden 2004-2009 udviste koncentrationerne af de fire metaller i de to områder en ikke-lineær udviklingstendens med et fald i 2009 for alle fire metaller i begge områder. Faldet var tydeligst i mineområdet. Denne udviklingstendens var forventet som følge af de begrænsede mineaktiviteter i 2009.

Forholdet mellem koncentrationerne i lav af Cu, Cr, As og Co og afstanden til vejen blev undersøgt for perioden 2005-09. For alle metalkoncentrationer var der et signifikant faldt med stigende afstande til vejen. Som i de tidligere år blev der fundet forhøjede koncentrationer af Cu og As i en afstand af op til ca. 1000 m fra vejen, mens Cr og Co var faldet til baggrundsniveauet ca. 500 m fra vejen.

Koncentrationerne af metaller i de transplanterede laver var lavere i 2009 end i 2008. Desuden var der i 2009 færre metaller, der havde forhøjede koncentrationer i de transplanterede laver end i 2008.

Eqikkaaneq

Kujataani Nanortallup kommuniani, Nalunami, misissuilluni nalunaarsuinerit arfinilissaat 2009-mi 15. – 22. augustusimut ingerlanneqarput. 2008-mi augustusimi taamatut misissuinerit kingornagut piiakkanik, Canadami guultitaajagassanik, aqqaneq marloriarluni umiarsuakkut aalalrussisoqarnikuvoq. Piianeq 2008-p naanerani unitsinneqarpoq umiarsuarlu piiakkanik usisoq kingulleq 27-marts 2009 aallarpoq. Angel Mining (Gold)-ip piiaaftik pisiaraa 1. juli 2009, kisiannili avatangiisinik misissuinissap uuma tungaanut suli piianeqaqqilersimangilaq.

Uillut, equutit kanajorlu nalinginnaasoq Kirkespirbugtenimi assigiinngitsuni sisamani katersorneqarput, eqaluit sisujuitsut Kirkespirip kuuani aalisarneqarput tingaasallu snekruslav *Cetraria nivalis* Kirkespirdalenimi iterlammilu sumiiffinni assigiinngitsuni 20-ni katersorneqarlutik. Tingaasat mingutsinneqanngitsumiit (AMI1) piiaaftaqarfirmut (Fig. 1) nuutaapput. Misissuigassat tamarmik grundstofinik 12-inik peqarnersut misissorneqarput (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo og Au) misissukkallu inerneru aallaaviusumik toqqammavagineqartumut 1998-2001-imut uuttortarneqarsimasumut siusinnerusukkullu misissuisarnermi angusanut sanilliussuunneqarput.

Uilluni kanassullu tinguini akuusut annertuseriarsimanerannik malunnartoqanngilaq, qeqqussanili misissugassanik tigusiffimmi ataatsimi Co annertuserialaarsimalluni. Taamaattumik immami avatangiisit 2009-mi annikitsuararsuarmik aatsitassarsiornikkut ingerlatanit sunnerneqarsimapput. Co tassani 2006-2008-mut tigusiffimmi tassani annertuseriartarsimavoq.

Eqaluit sisujuitsut tinguini saffiugassat akuusut annertunerulersimangillat. 2004-2009-mut taamaallaat 2004 aamma 2006 Cr, Co aamma Cd-mik akuusut annikitsumik annertuseriarfiulaarsimapput.

Tingaasani piiakkanik piiaviup eqqaani ineqarfiusullu eqqaani asersortikkanik katersuiffiit eqqaanni akuusut Cu, Cr, As aamma Co ukiuni siusinnerusunisulli malunnartumik annertuseriarsimapput. Taaneqartuni taakkunani marlunni 2009-mi Cu aamma Cr 2-3-riaammik, As 4-10-riaammik Co-lu 2-10-riaammik annertuseriarsimapput. 2008mi taakkunani marlunni annertuseriaatsit marloriaatingajaasimapput.

2004-2009-mut saffiugassanik taakkuninnga sisamanit akuusut sumiiffinni pineqartuni marlunni assigiinngitsumik annertuseriartortut malunnarsimapput 2009-mili saffiugassat sisamat taakkua akuusut najukkani pineqartuni annikillisimallutik. Appariarneq piiaaftiup eqqaani malunnarnerpaavoq. Taama allanngoriarnissaa ilimagineqareersimavoq 2009-mi piiaanikkut ingerlatat annikitsuinnaasimammata.

Tingaasani Cu, Cr, As aamma Co akuusut annertussusiat aqqusinnermut ungasissusiannut sanilliullugu 2005-09-mut misissorneqartarsimavoq.

Saffiugassanut tamanut tunngatillugu aqqusineq ungasillartortillugu akuusut aannikillartortartut erseqqippoq. Ukiuni siuliinisulli aqqusinermit 1000 m ungasissusilik tikillugu Cu aamma As akuusut annertuseriarsimapput, Cr aamma Co aqqusinermit 500 m ungasissusilimmiit sunnersimaneqanngitsumisut annertussueqaannalersimallulni.

Tingaasani nuutani akuusut 2009-mi akuusut 2008-mi akuusunit annikinnerupput. Aammalu 2009-mi saffiugassat tingaasani nuutani akuusut 2008-mit annikinnerupput.

Photo 1. Lichens (*Cetraria nivalis*) sampled at station 9 in the Kirkespir Valley not far from the water fall.



1 Introduction

1.1 Mining activities

The Nalunaq Gold Mine A/S (NGM) opened officially on 26 August 2004. Prior to the mine start extensive exploration programmes had been carried out since the discovery of gold bearing veins in 1992. The gold mine and the camp is situated eight km from the coast in the Kirkespir Valley, which lies 40 km northeast of Nanortalik in South Greenland.

The Nalunaq gold deposit is a high-grade gold-only mineralization (c. 20 g gold/ton ore) associated with quartz-veins. The ore sheet has an average strike angle of 45-50° inside the Nalunaq Mountain being 1,340 meters high. The preferred mining method is longhole mining with about 11 m vertical spacing between horizontal drifts. Nalunaq Gold Mine has no processing facilities on site. The ore is transported by 25-tonne trucks from stockpiles in the camp area to a stockpile area at the port facility about 11 km from the mine site. The camp layout currently consists of modular single occupancy living units together with other modern facilities. The camp currently has accommodation for about 100 people. A gravel road connects the mine and camp with the Kirkespir Bay. On the southern coastline of the bay, a pier and a barge enable the crushed ore to be loaded into bulk carriers that ship the ore to a foreign gold extraction plant.

During the period from 2004 to 2006, the ore was shipped to Rio Narcea Gold Mines Ltd, Spain for gold extraction. From 7 February 2007 onwards, the ore has been shipped to Nugget Pond, Newfoundland, Canada. Close to the pier is a stockpile area with an approximate capacity of 60,000 tonnes (Crewgold 2008). The first shipment of gold ore took place on 7 January 2004. Up until the fifth monitoring study, performed during 20-27 August 2008, a total of 30 shipments with approximately 575,000 tonnes (wet weight) of ore were transported to Spain and Canada. The sixth monitoring study, described in the present report, was performed between 15 and 22 August 2009. During the period from the fifth to the sixth monitoring study, a total of 12 shipments of c. 103,000 tonnes of ore were transported to Canada.

The last shipment took place on 27 March 2009. All underground mining activities were completed prior to 28 February 2009 and the mine was placed on care and maintenance (Crewgold 2008, 2009; Ture Grønlund, NGM, August 2009, *in litt.*). On 1 July 2009, Crew concluded the sale of NGM to Angus and Ross plc – later Angel Mining Gold A/S. Crew based this decision on the uneconomic nature of the resource. Included in the sale was an environmental bond of 16 million DKK, expected to be sufficient for all anticipated mine closure liabilities (Angel Mining 2009; Crewgold 2009).

1.2 Environmental baseline studies

Prior to the mine start a number of environmental baseline studies was performed. The first study was on the Arctic char population in the Kirkespir River in 1988 (Boje 1989). During the exploration phase freshwater samples from the Kirkespir River were analysed for metals and general parameters (Lakefield 1998a, b, 1999a-d). Comprehensive baseline studies performed during 1998-2001 collected fish, mussels, seaweed, snow crab, sea urchin, benthic macrofauna and sediments and analysed these for different metals (Glahder et al. 2005). The above and other studies were included in the Environmental Impact Assessment by SRK Consulting (2002). Based on the above mentioned studies and the mining methods and activities used at present, the monitoring programme presented below was designed.

1.3 Monitoring programme

Requirements for monitoring of the environment in relation to the mining activity have been set by the Bureau of Minerals and Petroleum (BMP) of the Greenland Self-rule Government. These requirements are described in the BMP exploitation licence of 19 March 2004, Phase 2, §§ 10-19, chapter 5:

The objective of monitoring is to document environmental impacts associated with the activities.

The sampling stations for brown seaweed, blue mussel, shorthorn sculpin and Arctic char must be placed relatively close to, and on each side of the shipping facility. Sampling stations for the lichen *Cetraria nivalis* must be placed both in connection with the above marine stations and around existing ore stockpiles at the Kirkespir Valley campsite and along the road. The following samples must be collected at the number of stations specified:

- Brown seaweed: 4 stations with 2 samples per station; a total of 8 samples.
- Blue mussel: 4 stations with 2 samples (2 different size groups) per station; a total of 8 samples.
- Liver from shorthorn sculpin and Arctic char: 2-4 stations with a total of 20 specimens.
- Lichens *Cetraria nivalis*: 18 stations; a total of 18 samples.

The samples collected must be analysed for the following elements: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn).

BMP may demand changes to the scope and content of the environmental monitoring if it considers the existing monitoring programme inadequate based on the results obtained and experience from the mining operation.

Samples must be collected on an annual basis during operations and closure and for a period of two years after closure. Samples must be analysed immediately after being collected. The analytical findings must

be data processed, and a report prepared. This report must reach BMP no later than four months after the samples have been collected.

The samples must be collected and analysed in accordance with guidelines prepared by NERI.

1.3.1 Monitoring studies 2004 – 2008

Since the official opening of the Nalunaq Gold Mine in August 2004, NERI has every year performed a monitoring study in the area during July or August. The monitoring studies are reported in the Nalunaq monitoring reports (Glahder & Asmund 2005, 2006, 2007; Glahder et al. 2008, 2009) and they can be found on the NERI web address: <http://www.dmu.dk/International/Publications/TechnicalReports/>

1.3.2 Monitoring study 2009

The monitoring study was performed in the Nalunaq area during 15-22 August 2009.

Sampling was carried out in accordance with the monitoring programme described in the exploitation licence with the following divergences:

- As in the previous monitoring studies, blue mussels were sampled at one more station, AMI1, on the north-east side of the Amitsoq Island about 15 km north of the Kirkespir Bay (Fig. 1). Blue mussels from this uncontaminated area were not this year transplanted to the harbour area because mussels the last two years were taken by the ice. Luckily, we jigged the net with mussels, but only to find that all were dead.
- Brown seaweed was collected at one more station, AMI1, with a total of two more samples.
- Lichens were sampled at two more stations.
- Lichens were collected from the five transplantation stations (M2-t, 5-t, 6-t, 11-t and 12-t) established in 2007 in Kirkespir Bay and Valley. New lichens, collected at AMI1, were transplanted to these five stations, including a new station 20-t west of the pier. This station will supplement M2-t in the statistical analyses.
- Fish livers from 20 specimens consisted of 16 shorthorn sculpin livers from four marine stations in the Kirkespir Bay and four resident Arctic char livers from the Kirkespir River near the waterfall.

Analyses were performed according to the programme, however 60 samples were analysed instead of 54 and the following 4 elements were added to the analytical programme: nickel (Ni), selenium (Se), molybdenum (Mo) and gold (Au).

1.4 Acknowledgements

We wish to thank Ture Grønlund, Angel Mining Gold, for transporting us by boat to and from Nanortalik and to the different marine sampling stations in the Kirkespir area. He is also thanked for his help with jigging for sculpins, driving us to and from the harbour, accommodation and technical information. Ævar is thanked for driving us to the harbour area. Jette Sommer is thanked for her participation in collecting and preparing the samples.

Photo 2. The Kirkespir cathedral is looming over the Kirkespir Valley where the Nalunaq Gold Mine is situated.



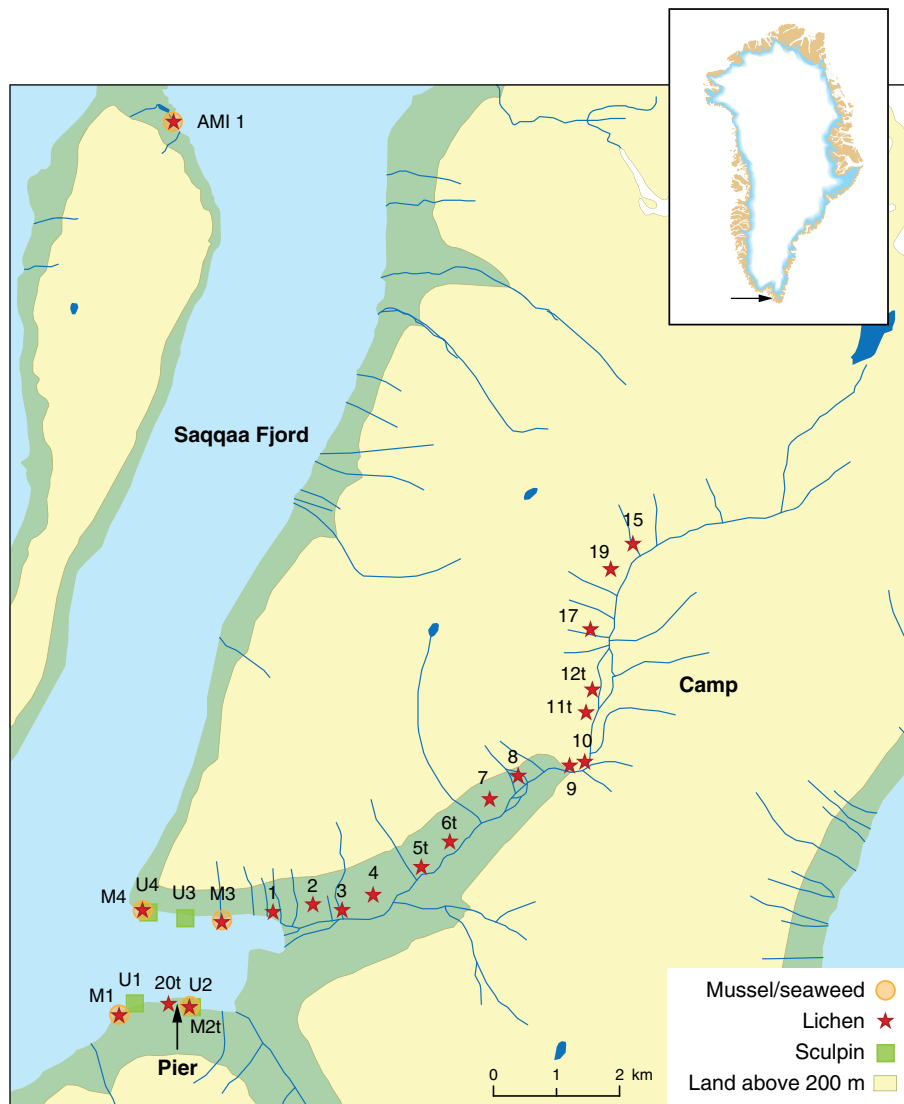
2 Methods

2.1 Collection of samples

Sampling in the Kirkespir Bay and at the north-eastern point of Amitsoq Island (AMI1) was performed with a motor boat equipped with a small rubber dinghy for landing. Sampling of blue mussels was performed at low tides of 0.2-0.7 m (Farvandsvæsnat 2009).

Figure 1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland.

M: Marine stations: Blue mussel and brown seaweed, including lichens. U: Shorthorn sculpin stations. Arctic char were caught near the lichen station 9 near the waterfall. Lichens transplanted in 2008 from AMI1 were sampled at stations M2t, 5t, 6t, 11t and 12t and replaced with new lichens from AMI1. A new transplantation station, 20t, was established a few hundred meters west of M2t. The mine entrance is west of the camp area.



Two size groups of mussels of 5-6, 6-7 or 7-8 cm were collected at each of the five stations M1-M4 and AMI1. The shell lengths were measured and the average shell lengths were calculated for each size group at each station (see Appendix 2). One sample consists of 20 individuals. All mussels in a sample were opened and allowed to drain, the soft parts cut free and frozen in plastic bags.

Blue mussels transplanted in 2008 from north-western Amitsoq Island (AMI1) to the barge in the Pier area (Fig. 1), had also this year disappeared and could therefore not be analysed. Because this was the second year without mussels from this station, it was decided to abandon the station in the future; no mussels were therefore transplanted to the barge. Mussels were primarily transplanted to secure that there were mussels available in the harbour area for monitoring. Because it is now possible to collect enough mussels from M2 the above purpose is no longer important.

The growth tips of seaweed from this year were cut, washed in freshwater from upstream the camp and frozen in plastic bags. Stations were similar to the blue mussel stations M1-M4 and AMI1.

Shorthorn sculpins were jigged for from the motor boat at the stations U1, U3, and U4. Sculpins at U2 were caught from the barge at the pier. In total 21 shorthorn sculpins were caught. All sculpins were frozen as whole fish.

Arctic char were fished in the Kirkespir River downstream from the waterfall and four resident char were caught. All Arctic char were frozen as whole fish.

Lichens were sampled at 20 stations: Ten from the Kirkespir Valley downstream the camp, three stations in the camp area, two upstream from the camp, four in the Kirkespir Bay area and one in the north-eastern part of Amitsoq Island (station AMI1). Lichens sampled at AMI1 replaced the lichens transplanted in 2008 to stations M2, 5, 6, 11 and 12; lichens from 2008 were sampled (Appendix 1). One new station, 20t, with transplanted lichens was established (Fig. 1, Appendix 1).

2.2 Analyses

All samples were transported either frozen or dry directly to NERI on 22 August 2009. The analyses were performed according to the "Test Report no. 339" (Asmund 2009). A total of 57 samples from blue mussel (10), brown seaweed (9), livers of Shorthorn sculpin (14), livers of Arctic char (4) and the lichen *Cetraria nivalis* (20) were analysed for the following 12 elements: Mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), selenium (Se), cobalt (Co), molybdenum (Mo) and gold (Au).

Samples were opened in suprapure nitric acid under pressure in Teflon bombs in a microwave oven. The samples were then diluted to c. 25 grams and all elements were analysed by ICP-MS (an accredited method according to DANAK, accreditation No. 411). Hg, Co and Mo are not included in the accreditation No. 411. All chemical results are listed in Appendix 3. Simultaneously with the Nalunaq samples the reference materials Dorm-3, Dolt-3 and Tort-2 were analysed. In Table 1, the analytical results are compared to the certificate values. In general, the analytical results are close to the certificate values.

Table 1. ICP-MS analytical results of reference material (Dorm-3, Dolt-3 and Tort-2) compared to the certificates. The detection limits, quantified as 3 times the standard deviation of the blind values, are also shown. Twelve different elements were analysed. Concentrations are in mg/kg dry weight. <dI: below the detection limit.

	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limit	0.007	0.009	0.018	0.08	0.01	0.012	0.07	0.05	0.07	0.07	0.007	0.017
Dorm-3	0.462	0.38	0.47	49.1	17.1	2.15	1.41	6.32	4.57	0.1	0.243	0.025
Dorm-3	0.542	0.31	0.51	50.7	16.3	2.05	1.47	6.53	3.36	0.31	0.237	0.073
<i>Average</i>	<i>0.502</i>	<i>0.35</i>	<i>0.49</i>	<i>49.9</i>	<i>16.7</i>	<i>2.10</i>	<i>1.44</i>	<i>6.43</i>	<i>3.965</i>	<i>0.205</i>	<i>0.24</i>	<i>0.049</i>
<i>Certificate</i>	<i>0.382</i>	<i>0.29</i>	<i>0.39</i>	<i>51.3</i>	<i>15.5</i>	<i>1.89</i>	<i>1.28</i>	<i>6.88</i>		<i>0.18</i>		
Dolt-3	4.51	19.6	0.33	88.2	34.5	4.75	3.33	8.61	6	0.27	3.61	<d.I.
Dolt-3	4.18	24.6	0.30	93.7	37.2	5.79	3.91	9.08	7.9	0.13	3.97	<d.I.
<i>Average</i>	<i>4.35</i>	<i>22.1</i>	<i>0.32</i>	<i>91.0</i>	<i>35.8</i>	<i>5.27</i>	<i>3.62</i>	<i>8.85</i>	<i>6.95</i>	<i>0.2</i>	<i>3.79</i>	
<i>Certificate</i>	<i>3.37</i>	<i>19.4</i>	<i>0.32</i>	<i>86.6</i>	<i>31.2</i>		<i>2.72</i>	<i>10.2</i>	<i>7.06</i>			
Tort-2	0.32	35.6	0.45	197	115	0.91	2.66	20.53	6.53	0.38	1.10	<d.I.
<i>Certificate</i>	<i>0.27</i>	<i>26.7</i>	<i>0.35</i>	<i>180</i>	<i>106</i>	<i>0.77</i>	<i>2.5</i>	<i>21.6</i>	<i>5.63</i>	<i>0.51</i>	<i>0.95</i>	

2.2.1 Statistical analyses

Differences in Co concentrations in brown seaweed and Cu concentrations in sculpin livers were tested with a two-sample t-test after data was tested for equal variances with an F-test.

We tested separately the following two areas, the depot of crushed waste rock and the camp area, for differences in concentrations of Cu, Cr, As and Co in lichens in the years 2004-2009 compared to background concentrations using a one-way ANOVA. Prior to the analyses data were logarithmic (base e) transformed to meet the assumptions of normal distribution and variance homogeneous of the tests. The post hoc Tukey's studentized range test was applied to test differences between years and background. The level of statistical significance used was $p=0.05$.

Also, we applied local polynomial regression fitting (loess) to illustrate temporal trends in element concentrations in the two areas. This graphical analytical method was used because a non-linear temporal trend was expected due to reduced activities in 2009.

Finally, we analysed the relationship between concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road in 2009 with linear regression analyses using logarithmic transformed (base e) element concentrations as dependent variable and logarithmic transformed (base e) distance as independent variable.



Photo 3. Brown seaweed (*Fucus vesiculosus*) was collected at low tide on the Amitsoq Island at station AMI1. Inland from this station lichens (*Cetraria nivalis*) were sampled for transplantation in the Kirkespir Valley area approximately 15 km to the south.

3 Results and discussion

Element concentrations are given in biota sampled in the marine environment in the Kirkespir Bay, in the fresh water environment in the Kirkespir River and in the terrestrial environment of the Kirkespir Valley (Fig. 1). The analytical results and detection limits, as well as background concentrations from Glahder et al. (2005) are given in Appendix 3. Element concentrations in the species analysed are considered elevated if they are significantly higher than the background concentrations.

3.1 The marine environment

Samples from the Kirkespir Bay were collected at four mussel and seaweed stations (M1-M4) and four sculpin stations (U1-U4) (Fig. 1).

No elevated concentrations were found in **blue mussel** samples.

Brown seaweed at station M3 had twice as high concentrations of Co compared to background concentrations (t-test, two-sample assuming equal variances, $p=0.005$, $t= -4.71$, $df=5$). No elevated concentrations of the elements that were analysed were found at any of the other seaweed stations (Appendix 3).

In **sculpin liver**, the average concentrations were not elevated compared to the background concentrations. At station U3 average concentrations of Cu was twice as high as background concentrations, but this elevation was not significant (t-test, two-sample assuming equal variances, $p=0.06$, $t= 2.22$, $df=7$).

In 2009, Co was significantly elevated in seaweed from only one of the stations (M3). No elevations of any elements were found in the analysed mussels and sculpins.

In 2004 and 2005, concentrations of especially Cr, but also concentrations of Cu, Co and Zn were elevated in seaweed. In 2006-2008, Co was also elevated in seaweed from station M3 by a factor 2-3. In 2004, elevations of Cr were found in sculpin livers and of Co in blue mussel.

The impact from the mining activities on the marine environment was again found to be very low. During 2006-2009, the only significant element elevation in the marine environment was Co concentrations in seaweed from station M3.

During the last four years concentrations of metals in the marine environment have been low and in general not different from the baseline level.

3.2 The freshwater environment

In livers from resident **Arctic char** the average concentrations were not elevated compared to baseline concentrations. Resident Arctic char stay all their life in the Kirkespir River, whereas the migratory form summers in the Kirkespir Bay and the Saqqaa Fjord. Compared to previous years, Cr was elevated 2-3 times in 2004 and 2006, Co 3 times in 2004 and Cd 2 times in 2006; no elevations have been found in 2005 and during 2007-2009. So, only minor elevations have been seen in two of the six years.

Photo 4. Resident Arctic char (*Salvelinus alpinus*) were caught in the Kirkespir River near the water fall.



3.3 The terrestrial environment

We have compared concentrations of four metals (Cu, Cr, As and Co) in lichens (*Cetraria nivalis*) during 2004-2009. Two areas were selected, the depot of crushed waste rock (stations 5-7) and the camp and mine area (stations 11-12). Again in 2008, lichens were transplanted from an uncontaminated area (station AMI1) to the stations 5, 6, 11 and 12. In 2009 these transplanted lichens were analysed together with lichens growing naturally in the Kirkespir Valley and Bay. With the same level of pollution in 2009 as in previous years it could be expected that element concentrations in lichens from these four stations in 2009 would be lower than in 2004-2007 and at the same level as in 2008 where transplanted lichens were analysed for the first time. Because mining activities, including ore transportation from mine to harbour, were lower in this last monitoring period (2008-2009) we expect concentrations to be lower than in the previous monitoring period (2007-2008).

We compared average concentrations in each of the two areas with background concentrations and Cu, Cr, As and Co were significantly elevated in the years 2004-2009 (Tukey's post hoc test, $p < 0.05$). Elevations in the two areas in 2009 were 2-3 times for Cu and Cr, 4-10 times for As and 2-10 times for Co (Fig. 4a, Appendix 3). Concentrations of these four metals were not significantly different between the years

2004-2009. Concentrations of the four metals at the pier (station M2) appear to be elevated (Cu and Cr 2-3 times, As 20 times and Co 7 times) compared to background concentrations, but because we have only one sample from this area it has not been possible to test if elevations were significant (Fig. 4a).

We examined the temporal trends in concentrations of the four metals in the two areas described above. Due to the reduced mining activities in 2009 we expected a non-linear temporal trend during the period 2004-2009. The results of the applied local polynomial regression fitting are shown in Figs. 2 (Area 1) and 3 (Area 2). Concentrations of all four metals in both areas have decreased in 2009 and most pronounced in the camp and mine area, area 2.

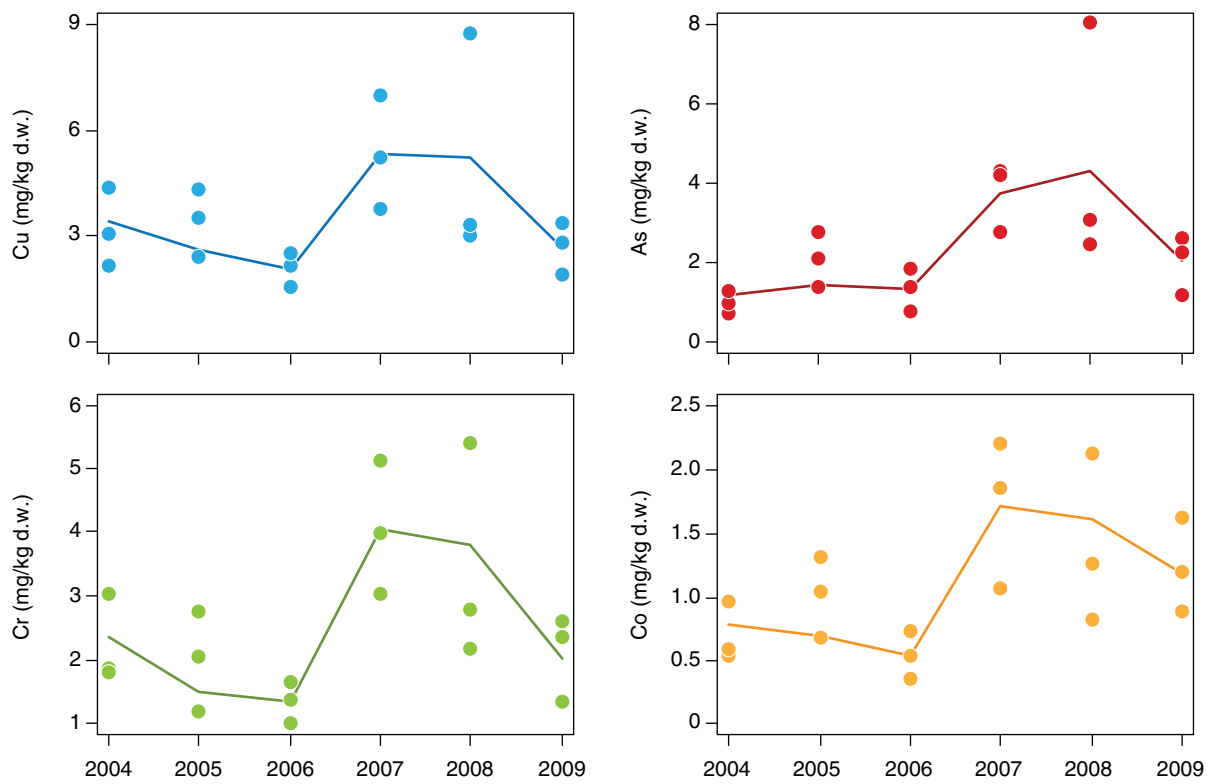


Figure 2. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from area 1 during 2004-2009. Area 1 is the depot of crushed waste rock (stations 5-7).

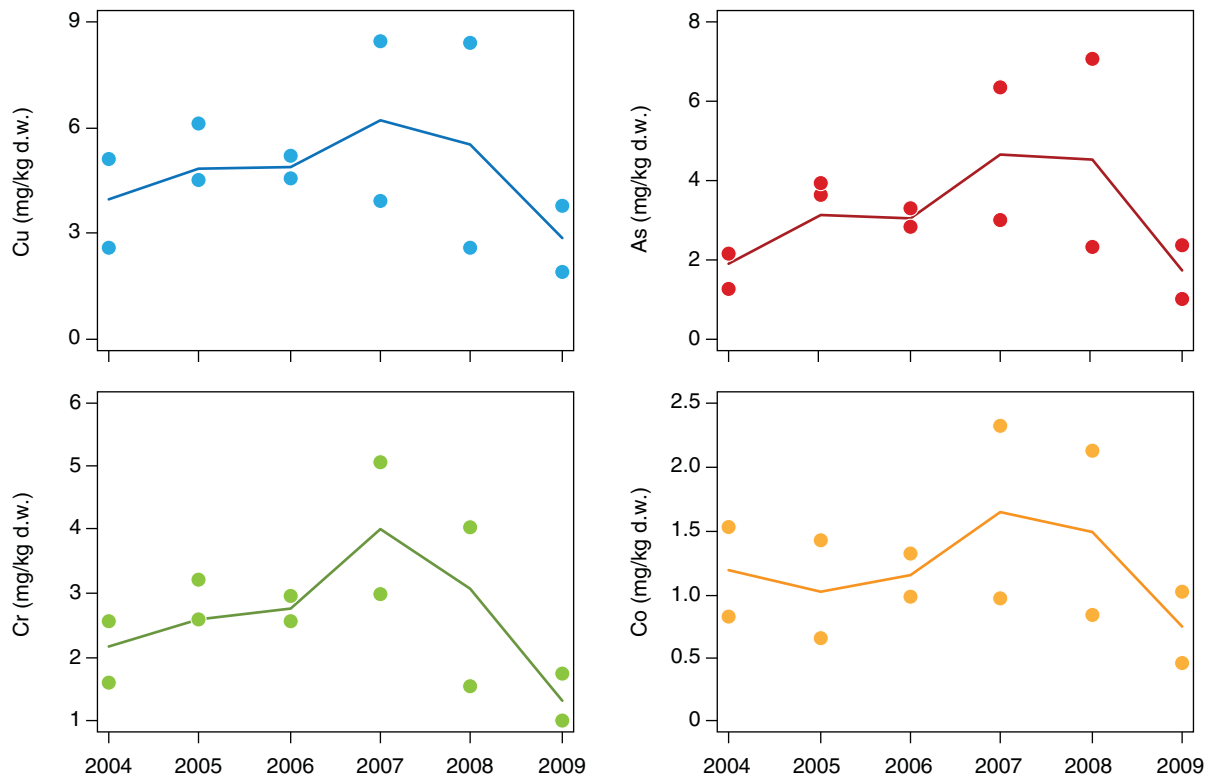


Figure 3. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from area 2 during 2004-2009. Area 2 is the camp and mine area (stations 11-12).

We have tested a possible relationship between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the gravel road; the test included differences in levels among years (refer to Figs. 4a, b & 5 regarding 2009). These four metals were tested because they showed the highest elevations compared to background levels. All concentrations of the four metals showed a significantly decrease with increasing distance (Linear regression, $p < 0.001$).

Figure 4a shows concentrations of the four elements in lichens from Amitsoq Island, the Kirkespir Bay area and the Kirkespir Valley. Two areas have markedly higher concentrations of the four elements, namely the pier area (station M2) and the inner valley area including the depot of waste rock and the camp and mine area (stations 5-12). The relatively high concentrations in these areas can be explained as an effect of the nearness to the gravel road illustrated by Figure 4b. In 2009, concentrations in the camp area were not as high as in earlier years, where concentrations were explained as an effect of the mine rather than an effect of the road. In 2009, an elevated level of especially As and Co was found in the inner valley from station 5 to station 12. We have no information that can explain the new peak found at station 8.

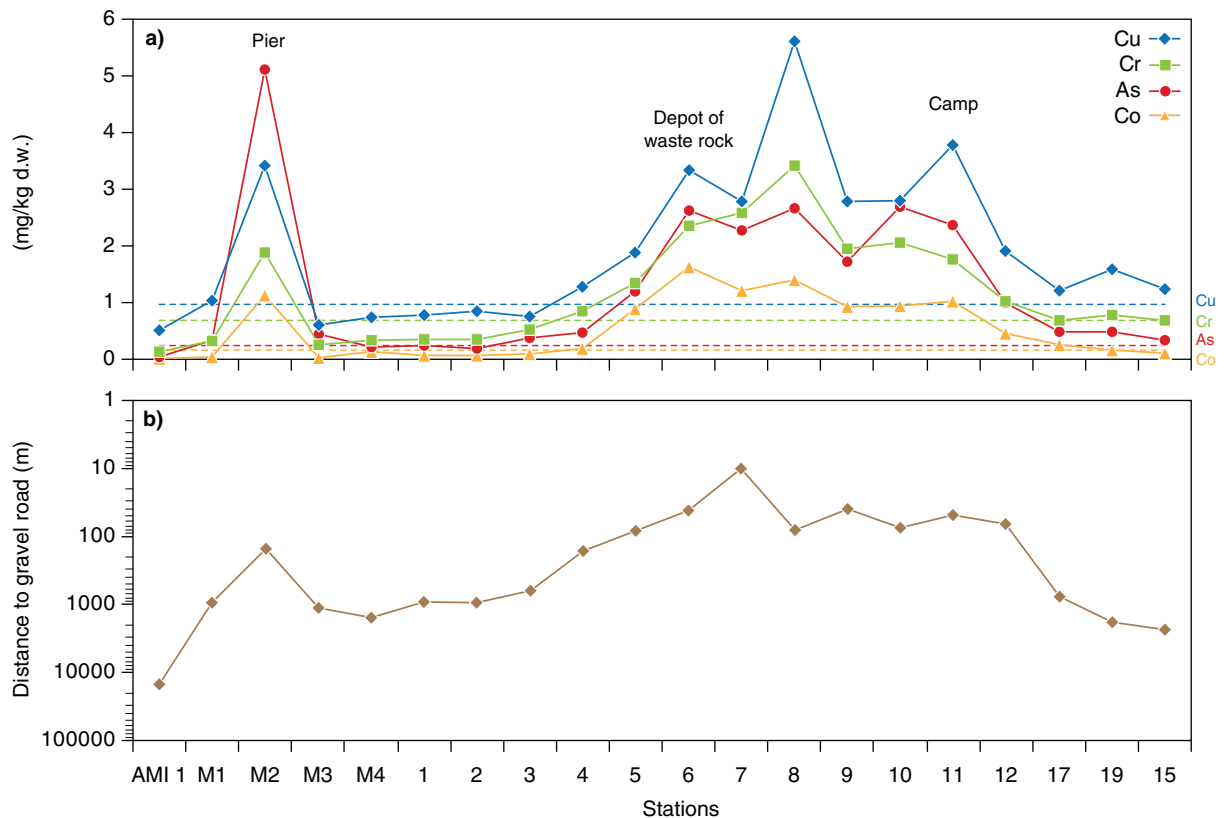


Figure 4. a) Concentrations of Cu, Cr, As and Co in the lichen *Cetraria nivalis* measured at the lichens stations in 2009 and b) distances (in meter on a log scale) from the road to the lichen stations. For localisation of lichen stations see Fig. 1. M1-M4 are stations in the Kirkespir Bay area, stations 1-19 are situated in the Kirkespir Valley from the coast (station 1) to up-stream the camp area (station 15). The dashed horizontal lines in a) indicate average background concentrations of the four metals (see Table 2). d.w. = dry weight.

Figure 5 shows how far elevated concentrations of Cu, Cr, As and Co were found in the Kirkespir Valley in 2009. For Cu and As background concentrations were, as in previous years, found from distances of c. 1000 m from the road, whereas Cr and Co reach the background levels at around 500 m from the road compared to former c. 1000 m.

It is concluded that concentrations of Cu, Cr, As and Co during 2004-2009 were significantly elevated at the depot of crushed waste rock and in the camp and mine area compared to the background levels. Concentrations of all four metals in both areas have decreased in 2009 and most pronounced in the camp and mine area.

All metal concentrations showed a significant decrease with increasing distance to the gravel road. Concentrations of Cu and As above the background level could, as in previous years, be found to a distance of about 1000 m from the road. Concentrations of Cr and Co had on the other hand decreased so that the baseline level was met at about 500 m from the road.

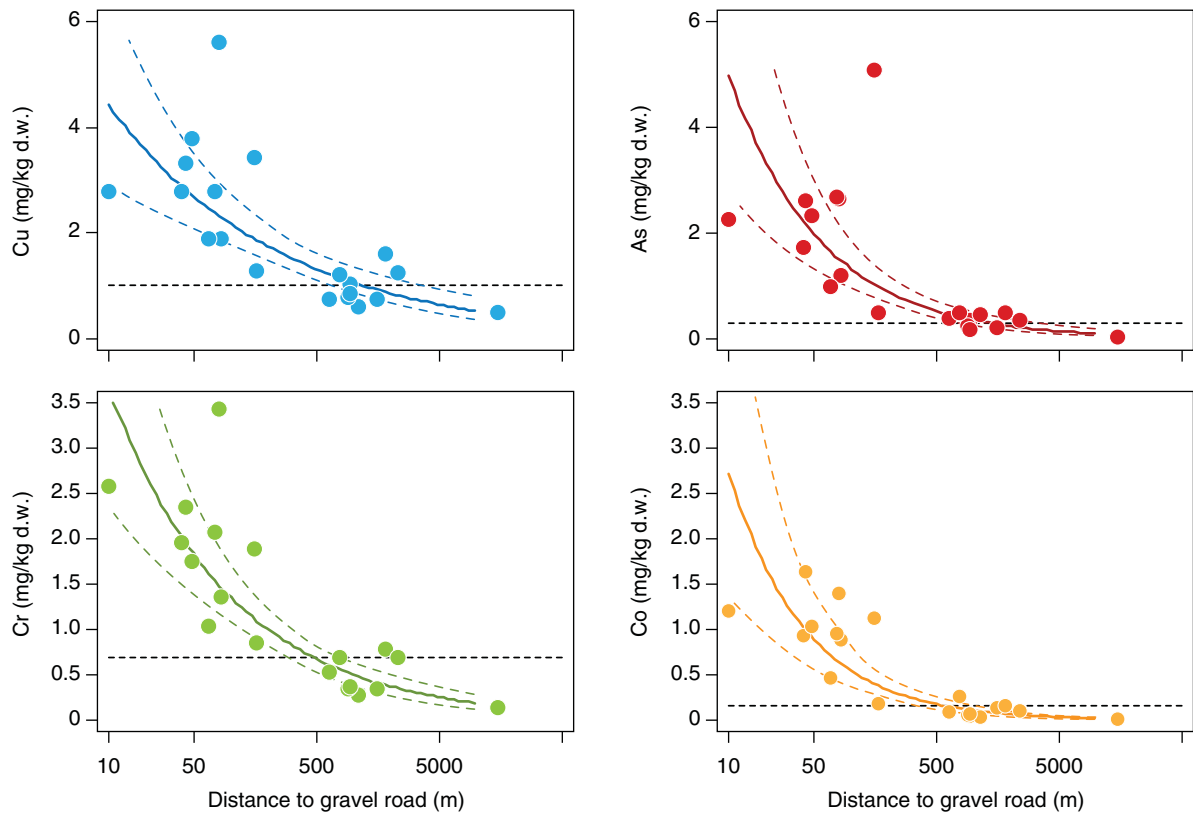


Figure 5. Concentrations of Cu, Cr, As and Co in the lichen *Cetraria nivalis* as a function of the stations' distances to the gravel road (in meter). Dashed curves show 95 % confidence intervals. Background concentrations are shown with horizontal dashed lines. d.w. = dry weight.

Photo 5. Lichens (*Cetraria nivalis*) transplanted in 2008 at station 6 in the Kirkespir Valley were sampled one year later. Transplanted lichens were covered by a net secured by stones. Lichens sampled at Amitsoq 2009 replaced the sampled lichens.





Photo 6. The pier and the stockpile area with a capacity of c. 60,000 tonnes of ore are situated on the southern coastline of the Kirkespir Bay. To the right the Saqqa Fjord is seen.

In 2009, concentrations of metals in the transplanted lichens were lower than in the transplanted lichens in 2008. Also, fewer metals had elevated concentrations in 2009 compared to 2008. This indicates a general decrease in the annual dry deposition rate of metals in the Nalunaq Gold Mine area.

4 Conclusions

This report describes the results of the sixth year of environmental monitoring in the Nalunaq Gold Mine area. Mining and shipping stopped in early 2009 and after this date no gold ore was mined prior to the present monitoring study. Angel Mining Gold A/S bought the mine on 1 July 2009.

No elevated concentrations were found in blue mussels and shorthorn sculpin livers, while brown seaweed had slightly elevated concentrations of Co at one sampling station. The impact from the mining activities on the marine environment was in 2009 found to be very low. During 2006-2009, Co concentrations in seaweed at station M3 was the only significant element elevation in the marine environment.

In livers from resident Arctic char average concentrations were not elevated in 2009 compared to baseline concentrations. During 2004-2009, only minor elevations of Cr, Co and Cd were found in 2004 and 2006.

In the lichen *Cetraria nivalis* concentrations of Cu, Cr, As and Co in 2009, like in previous years, were significantly elevated compared to the background level at the depot of crushed waste rock and in the camp and mine area. Element elevations in these areas in 2009 were 2-3 times for Cu and Cr, 4-10 times for As and 2-10 times for Co. In 2008 elevations in the two areas were about the double.

Temporal trends in concentrations of the four metals in the two areas described above showed during 2004-2009 a non-linear course with a decrease in 2009 for all metals in both areas. Most pronounced was the decrease in the camp and mine area. This trend can be explained by the reduced mining activities in 2009.

We have tested the relationship between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the gravel road. All concentrations of the four metals showed a significantly decrease with increasing distance. Concentrations of Cu and As above the background level could, as in previous years, be found to a distance of about 1000 m from the road, while Cr and Co reached the baseline level at about 500 m.

In 2009, concentrations of metals in the transplanted lichens were lower than in the transplanted lichens in 2008. Also, fewer metals had elevated concentrations in 2009 compared to 2008.

In 2009, the impact from the mining activities on the local environment was primarily observed in the Kirkespir Valley and originated mainly from dust dispersed from the road. Metal concentrations in lichens decreased in 2009 due to reduced mining activities. In the Kirkespir River and in the Kirkespir Bay, element elevations were found only in seaweed from just one station and the impact is therefore considered negligible.

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Appendix 1. Samples and stations

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
41332	Lichen	<i>Cetraria nivalis</i>	18.08.2009	1	60	19'34"	44	55'22"
41333	Lichen	<i>Cetraria nivalis</i>	18.08.2009	2	60	19'38"	44	54'40"
41334	Lichen	<i>Cetraria nivalis</i>	18.08.2009	3	60	19'35"	44	54'10"
41335	Lichen	<i>Cetraria nivalis</i>	18.08.2009	4	60	19'43"	44	53'38"
41336	Lichen	<i>Cetraria nivalis</i>	18.08.2009	5-transplanted	60	19'57.1"	44	52'47.7"
41337	Lichen	<i>Cetraria nivalis</i>	18.08.2009	6-transplanted	60	20'10.1"	44	52'18.2"
41338	Lichen	<i>Cetraria nivalis</i>	18.08.2009	7	60	20'32"	44	51'37"
41339	Lichen	<i>Cetraria nivalis</i>	18.08.2009	8	60	20'44"	44	51'07"
41340	Lichen	<i>Cetraria nivalis</i>	17.08.2009	9	60	20'49"	44	50'14"
41341	Lichen	<i>Cetraria nivalis</i>	17.08.2009	10	60	20'51"	44	49'58"
41342	Lichen	<i>Cetraria nivalis</i>	17.08.2009	11-transplanted	60	21'16.5"	44	49'56.9"
41343	Lichen	<i>Cetraria nivalis</i>	17.08.2009	12-transplanted	60	21'28.1"	44	49'50.3"
41346	Lichen	<i>Cetraria nivalis</i>	16.08.2009	15	60	22'43"	44	49'08"
41344	Lichen	<i>Cetraria nivalis</i>	16.08.2009	17	60	21'59"	44	49'52"
41345	Lichen	<i>Cetraria nivalis</i>	16.08.2009	19	60	22'30"	44	49'31"
-	Lichen	<i>Cetraria nivalis</i>	19.08.2009	20-transplanted	60	18'47.1"	44	57'10.2"
41384	Lichen	<i>Cetraria nivalis</i>	19.08.2009	M 1	60	18'41"	44	58'01"
41385	Lichen	<i>Cetraria nivalis</i>	19.08.2009	M2-transplanted	60	18'45.2"	44	56'48.5"
41370	Lichen	<i>Cetraria nivalis</i>	20.08.2009	M 3	60	19'29"	44	56'15"
41371	Lichen	<i>Cetraria nivalis</i>	20.08.2009	M 4	60	19'35"	44	57'37"
41347	Lichen	<i>Cetraria nivalis</i>	17.08.2009	AMI 1	60	26'20"	44	57'04"
41349	Brown seaweed	<i>Fucus vesiculosus</i>	19.08.2009	M 1	60	18'41"	44	58'01"
41352	Brown seaweed	<i>Fucus vesiculosus</i>	19.08.2009	M 2	60	18'46"	44	56'47"
41353	Brown seaweed	<i>Fucus vesiculosus</i>	19.08.2009	M 2	60	18'46"	44	56'47"
41372	Brown seaweed	<i>Fucus vesiculosus</i>	20.08.2009	M 3	60	19'29"	44	56'15"
41373	Brown seaweed	<i>Fucus vesiculosus</i>	20.08.2009	M 3	60	19'29"	44	56'15"
41329	Brown seaweed	<i>Fucus vesiculosus</i>	20.08.2009	M 4	60	19'35"	44	57'37"
41375	Brown seaweed	<i>Fucus vesiculosus</i>	20.08.2009	M 4	60	19'35"	44	57'37"
41326	Brown seaweed	<i>Fucus vesiculosus</i>	17.08.2009	AMI1	60	26'20"	44	57'04"
41348	Brown seaweed	<i>Fucus vesiculosus</i>	17.08.2009	AMI1	60	26'20"	44	57'04"
41359	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 1	60	18'47"	44	57'45"
41360	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 1	60	18'47"	44	57'45"
41321	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	16.08.2009	U 2	60	18'45"	44	56'46"
41322	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	16.08.2009	U 2	60	18'45"	44	56'46"
41324	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	16.08.2009	U 2	60	18'45"	44	56'46"
41325	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	16.08.2009	U 2	60	18'45"	44	56'46"
41361	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 3	60	19'31"	44	56'53"
41362	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 3	60	19'31"	44	56'53"
41363	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 3	60	19'31"	44	56'53"
41364	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 3	60	19'31"	44	56'53"
41365	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 4	60	19'34"	44	57'31"
41367	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 4	60	19'34"	44	57'31"
41368	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 4	60	19'34"	44	57'31"
41369	Shorthorn sculpin	<i>Myoxocephalus scorpius</i>	20.08.2009	U 4	60	19'34"	44	57'31"

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
41350	Blue mussel	<i>Mytilus edulis</i>	19.08.2009	M 1	60	18'41"	44	58'01"
41351	Blue mussel	<i>Mytilus edulis</i>	19.08.2009	M 1	60	18'41"	44	58'01"
41354	Blue mussel	<i>Mytilus edulis</i>	19.08.2009	M 2	60	18'46"	44	56'47"
41355	Blue mussel	<i>Mytilus edulis</i>	19.08.2009	M 2	60	18'46"	44	56'47"
41376	Blue mussel	<i>Mytilus edulis</i>	20.08.2009	M 3	60	19'29"	44	56'15"
41377	Blue mussel	<i>Mytilus edulis</i>	20.08.2009	M 3	60	19'29"	44	56'15"
41378	Blue mussel	<i>Mytilus edulis</i>	20.08.2009	M 4	60	19'35"	44	57'37"
41379	Blue mussel	<i>Mytilus edulis</i>	20.08.2009	M 4	60	19'35"	44	57'37"
41327	Blue mussel	<i>Mytilus edulis</i>	17.08.2009	AMI 1	60	26'20"	44	57'04"
41328	Blue mussel	<i>Mytilus edulis</i>	17.08.2009	AMI 1	60	26'20"	44	57'04"
41330	Arctic char	<i>Salvelinus alpinus</i>	21.08.2009	Near waterfall	60	20'47"	44	50'32"
41331	Arctic char	<i>Salvelinus alpinus</i>	21.08.2009	Near waterfall	60	20'47"	44	50'32"
41382	Arctic char	<i>Salvelinus alpinus</i>	21.08.2009	Near waterfall	60	20'47"	44	50'32"
41383	Arctic char	<i>Salvelinus alpinus</i>	21.08.2009	Near waterfall	60	20'47"	44	50'32"

*) All co-ordinates are given in WGS 84.

Appendix 2. Blue mussel average shell lengths

Station	Average length (cm, in bold) in different size groups including standard deviation and number of individuals		
	5-6	6-7	7-8
M1		6.47 0.28; 20	7.28 0.27; 13
M2	5.48 0.27; 20	6.41 0.28; 20	
M3	5.45 0.29; 20	6.46 0.30; 20	
M4	5.56 0.21; 20	6.50 0.26; 20	
AMI1		6.45 0.29; 20	7.48 0.28; 20

Appendix 3. Chemical analyses

Concentrations are given in mg/kg d.w. (dry weight) for mussels, seaweed and *Cetraria nivalis* and mg/kg w.w. (wet weight) for livers from sculpins and Arctic chars. Detection limits (d.l.) are given as well as average background concentrations and standard deviations (SD) for each species.

ID no.	Lab no	% d.w.	Species	Shell (cm)	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
<i>Detection limits, wet (mussels and fish)</i>						0.007	0.009	0.018	0.08	0.01	0.012	0.07	0.05	0.07	0.07	0.01	0.017
<i>Detection limits, dry (seaweed and lichens)</i>						0.017	0.029	0.059	0.27	0.02	0.039	0.25	0.18	0.23	0.24	0.02	0.057
41350	7100	16.99	Myt. edu.	6-7	M 1	0.068	6.869	0.770	90.07	6.81	0.610	1.03	12.74	4.49	0.19	0.49	<d.l.
41351	7101	17.25	Myt. edu.	7-8	M 1	0.085	4.440	0.795	75.22	6.39	0.629	0.98	12.34	3.82	0.21	0.54	<d.l.
41354	7102	15.68	Myt. edu.	5-6	M 2	0.104	5.315	1.008	80.92	8.24	0.865	1.42	14.92	4.80	0.36	0.59	0.025
41355	7103	15.52	Myt. edu.	6-7	M 2	0.078	6.612	0.735	87.28	8.27	0.632	1.07	13.83	4.42	0.28	0.55	0.019
41376	7104	13.68	Myt. edu.	5-6	M 3	0.182	3.625	0.999	82.59	8.21	1.158	1.35	15.33	4.51	0.39	0.59	<d.l.
41377	7105	13.22	Myt. edu.	6-7	M 3	0.242	5.914	0.989	67.57	6.98	1.435	1.26	14.48	3.82	0.33	0.55	0.029
41378	7106	16.68	Myt. edu.	5-6	M 4	0.095	8.201	0.823	84.41	8.80	0.800	1.19	12.36	4.91	0.34	0.58	0.024
41379	7107	10.12	Myt. edu.	6-7	M 4	0.086	8.222	0.828	93.14	7.87	0.791	1.21	12.01	4.76	0.32	0.60	<d.l.
41327	7098	16.67	Myt. edu.	6-7	AMI 1	0.088	7.352	1.081	82.84	6.68	0.663	1.05	11.57	3.97	0.26	0.54	0.048
41328	7099	18.01	Myt. edu.	7-8	AMI 1	0.086	9.125	0.914	75.19	6.83	0.591	0.83	9.90	3.08	0.20	0.54	0.027
<i>Background</i>			Myt. edu.	<i>Average</i>		0.131	5.49	1.195	87.82	7.58	0.73		11.80		0.239		
<i>Background</i>			Myt. edu.	<i>SD</i>		0.025	1.97	0.365	16.42	1.08	0.28		1.59		0.053		
41349	7087	100	Fuc. ves.		M 1	0.17	1.596	0.060	3.99	0.99	0.089	0.95	32.32	<d.l.	<d.l.	0.13	<d.l.
41353	7090	100	Fuc. ves.		M 2	<d.l.	1.123	<d.l.	7.70	1.35	0.094	1.04	45.09	<d.l.	0.30	0.11	<d.l.
41352	7092	100	Fuc. ves.		M 2	<d.l.	1.148	<d.l.	7.33	1.42	0.157	1.07	42.95	<d.l.	0.25	0.10	<d.l.
41372	7091	100	Fuc. ves.		M 3	<d.l.	1.095	<d.l.	6.62	2.15	0.099	1.37	29.50	<d.l.	0.41	0.10	<d.l.
41373	7094	100	Fuc. ves.		M 3	0.053	0.932	0.088	6.28	1.45	0.072	1.19	39.65	<d.l.	0.46	0.17	0.066
41373	7095	100	Fuc. ves.		M 3	<d.l.	0.930	0.063	6.33	1.42	0.081	1.24	39.85	<d.l.	0.47	0.16	<d.l.
41329	7096	100	Fuc. ves.		M 4	<d.l.	1.784	<d.l.	3.84	0.99	0.134	1.28	40.85	<d.l.	<d.l.	0.14	<d.l.
41375	7088	100	Fuc. ves.		M 4	<d.l.	1.530	<d.l.	6.02	1.32	0.089	1.12	35.23	<d.l.	<d.l.	0.13	<d.l.
41326	7089	100	Fuc. ves.		AMI 1	<d.l.	2.025	<d.l.	4.41	1.29	0.091	1.23	44.70	<d.l.	<d.l.	0.13	<d.l.
41348	7097	100	Fuc. ves.		AMI 1	<d.l.	1.434	0.069	5.37	1.15	0.062	1.16	32.33	<d.l.	<d.l.	0.14	<d.l.
<i>Background</i>			Fuc. ves.	<i>Average</i>		0.01	1.77	0.105	7.57	1.04	0.11		47.55		0.209		
<i>Background</i>			Fuc. ves.	<i>SD</i>		0.008	0.51	0.039	2.38	0.24	0.12		8.47		0.045		
41384	7085	100	Cet. niv.		M 1	<d.l.	0.042	0.359	23.01	1.04	0.326	0.32	0.34	<d.l.	<d.l.	0.03	<d.l.
41385	7086	100	Cet. niv.		M 2-t	<d.l.	0.089	1.323	17.00	3.42	1.881	2.31	5.11	<d.l.	1.12	0.03	<d.l.
41370	7083	100	Cet. niv.		M 3	0.025	0.060	0.504	14.15	0.61	0.261	<d.l.	0.44	<d.l.	<d.l.	0.04	<d.l.
41371	7084	100	Cet. niv.		M 4	0.039	0.120	0.859	20.97	0.74	0.336	0.31	0.21	<d.l.	<d.l.	0.03	<d.l.
41347	7082	100	Cet. niv.		AMI 1	0.070	0.039	0.570	14.33	0.51	0.138	<d.l.	<d.l.	<d.l.	<d.l.	0.05	<d.l.
41332	7064	100	Cet. niv.		1	0.075	0.051	0.816	23.61	0.62	0.345	0.34	0.25	<d.l.	<d.l.	0.03	<d.l.
41332	7065	100	Cet. niv.		1	0.039	0.061	1.652	24.13	0.93	0.351	0.40	0.24	<d.l.	<d.l.	<d.l.	<d.l.
41333	7066	100	Cet. niv.		2	<d.l.	0.038	0.442	28.46	0.85	0.350	0.38	0.18	<d.l.	<d.l.	<d.l.	<d.l.
41334	7067	100	Cet. niv.		3	0.062	0.063	0.851	9.07	0.75	0.528	0.39	0.38	<d.l.	<d.l.	<d.l.	<d.l.
41335	7068	100	Cet. niv.		4	<d.l.	0.033	1.110	7.93	1.27	0.843	0.80	0.48	<d.l.	<d.l.	<d.l.	<d.l.
41336	7069	100	Cet. niv.		5-t	0.029	0.095	1.235	15.45	1.88	1.348	1.65	1.20	<d.l.	0.89	<d.l.	<d.l.
41337	7070	100	Cet. niv.		6-t	0.038	0.081	0.665	18.00	3.33	2.351	2.77	2.62	<d.l.	1.63	0.03	<d.l.
41338	7071	100	Cet. niv.		7	<d.l.	0.073	1.119	13.43	2.78	2.586	2.67	2.28	<d.l.	1.20	<d.l.	<d.l.
41339	7072	100	Cet. niv.		8	0.029	0.106	1.671	17.34	5.61	3.423	3.03	2.66	<d.l.	1.40	0.03	<d.l.
41340	7073	100	Cet. niv.		9	<d.l.	0.091	1.599	12.78	2.78	1.953	2.05	1.72	<d.l.	0.93	<d.l.	<d.l.
41341	7074	100	Cet. niv.		10	0.032	0.081	1.281	15.52	2.80	2.064	2.23	2.69	0.24	0.95	0.02	<d.l.
41342	7075	100	Cet. niv.		11-t	<d.l.	0.152	1.048	13.41	3.78	1.757	2.12	2.36	<d.l.	1.03	<d.l.	<d.l.
41343	7076	100	Cet. niv.		12-t	<d.l.	0.059	0.969	9.39	1.91	1.022	1.03	1.00	<d.l.	0.46	<d.l.	<d.l.
41346	7081	100	Cet. niv.		15	0.041	0.101	1.636	16.74	1.24	0.680	0.46	0.34	<d.l.	<d.l.	0.03	<d.l.
41344	7077	100	Cet. niv.		17	<d.l.	0.060	1.302	23.73	1.21	0.692	0.69	0.49	<d.l.	0.26	<d.l.	<d.l.
41345	7079	100	Cet. niv.		19	0.090	0.208	0.669	25.54	1.43	0.685	0.58	0.49	<d.l.	0.15	0.10	<d.l.
41345	7080	100	Cet. niv.		19	0.065	0.359	0.336	35.37	1.75	0.865	0.70	0.48	<d.l.	0.16	0.06	0.059
<i>Background</i>			Cet. niv.	<i>Average</i>		0.033	0.081	1.076	21.61	0.97	0.68		0.24		0.157		

ID no.	Lab no	% d.w.	Species	Shell	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
<i>Background</i>			Cet. niv.		<i>SD</i>	0.006	0.029	0.378	7.28	0.77	1.22		0.27		0.157		
41359	7111	24.22	Myo. sco.		U 1	0.055	1.237	<d.l.	32.42	1.64	<d.l.	<d.l.	1.54	0.81	<dl	0.07	0.019
41359	7112	24.22	Myo. sco.		U 1	0.036	1.320	<d.l.	34.06	1.80	0.012	<d.l.	1.74	0.81	<dl	0.07	<d.l.
41360	7113	33.33	Myo. sco.		U 1	0.035	0.399	<d.l.	26.00	1.26	0.015	<d.l.	3.72	1.51	<dl	0.06	<d.l.
41321	7114	23.36	Myo. sco.		U 2	0.012	0.289	<d.l.	35.50	1.51	<d.l.	<d.l.	1.34	1.01	<dl	0.11	<d.l.
41322	7115	22.14	Myo. sco.		U 2	0.019	0.618	<d.l.	26.00	1.01	<d.l.	<d.l.	3.87	1.05	<dl	0.07	<d.l.
41324	7116	34.91	Myo. sco.		U 2	0.010	0.205	<d.l.	45.39	2.37	<d.l.	<d.l.	5.39	0.83	<dl	0.06	<d.l.
41325	7117	25.42	Myo. sco.		U 2	0.018	0.393	<d.l.	28.78	0.87	0.016	<d.l.	1.99	0.86	<dl	0.05	<d.l.
41361	7118	25.19	Myo. sco.		U 3	0.029	0.690	<d.l.	36.27	6.01	0.016	<d.l.	2.30	0.95	<dl	0.10	<d.l.
41362	7119	0.00	Myo. sco.		U 3	0.022	0.643	<d.l.	31.30	1.92	0.014	<d.l.	1.75	0.73	<dl	0.09	<d.l.
41363	7120	27.78	Myo. sco.		U 3	0.010	0.519	<d.l.	31.50	4.35	<d.l.	<d.l.	2.40	1.58	<dl	0.07	<d.l.
41364	7121	27.94	Myo. sco.		U 3	0.067	0.637	0.018	34.41	2.88	<d.l.	<d.l.	1.92	0.57	0.08	0.09	0.038
41365	7122	22.22	Myo. sco.		U 4	0.032	1.387	<d.l.	36.17	2.65	<d.l.	0.28	2.12	0.97	<dl	0.11	0.022
41367	7124	21.15	Myo. sco.		U 4	0.038	1.146	<d.l.	33.27	5.34	<d.l.	<d.l.	1.73	0.61	<dl	0.10	<d.l.
41368	7125	18.52	Myo. sco.		U 4	0.034	0.912	0.021	30.87	2.58	<d.l.	<d.l.	2.34	0.76	<dl	0.09	<d.l.
41369	7126	27.74	Myo. sco.		U 4	0.033	0.648	<d.l.	27.54	2.37	<d.l.	<d.l.	1.60	0.48	<dl	0.04	<d.l.
41369	7127	27.74	Myo. sco.		U 4	0.030	0.666	<d.l.	27.12	2.51	<d.l.	<d.l.	1.64	0.47	<dl	0.04	<d.l.
<i>Background</i>			Myo. sco.		<i>Average</i>	0.028	1.041	0.004	32.14	1.80	0.016		3.23		0.021		
<i>Background</i>			Myo. sco.		<i>SD</i>	0.013	0.404	0.003	1.64	0.66	0.019		2.07		0.017		
41330	7128	34.09	Sal. alp.			0.025	0.107	<d.l.	23.46	4.45	<d.l.	<d.l.	0.34	0.68	0.10	0.13	<d.l.
41331	7129	19.61	Sal. alp.			0.070	0.139	<d.l.	26.11	17.22	0.026	<d.l.	0.08	1.70	0.07	0.20	<d.l.
41382	7130	25.38	Sal. alp.			0.011	0.137	<d.l.	21.20	5.47	<d.l.	<d.l.	0.18	0.47	<d.l.	0.06	<d.l.
41383	7131	21.28	Sal. alp.			0.018	0.056	<d.l.	21.12	7.00	0.031	<d.l.	0.24	0.63	<d.l.	0.11	<d.l.
<i>Background</i>			Sal. alp.		<i>Average</i>	0.025	0.077	0.005	34.88	8.72	0.025		0.45		0.041		
<i>Background</i>			Sal. alp.		<i>SD</i>	0.009	0.026	0.002	6.13	10.22	0.022		0.13		0.013		

<d.l. = value below detection limit; -t = station with transplanted lichens; Myt. edu. = Blue mussel (*Mytilus edulis*); Fuc. ves. = Brown seaweed (*Fucus vesiculosus*); Cet. niv. = Lichen (*Cetraria nivalis*); Myo. sco. = Shorthorn sculpin (*Myoxocephalus scorpius*); Sal. alp. = Arctic char (*Salvelinus alpinus*).

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ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND 2009

This sixth monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 15-22 August 2009. Twelve shipments of ore, the last on 27 March 2009, went to Canada for gold extraction since the last monitoring study in August 2008. Angel Mining bought the gold mine on 1 July 2009, but no gold mining was initiated prior to the present monitoring study. Biota was collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected in the area and transplanted to the valley from an uncontaminated area. Samples were analysed for 12 elements with ICP-MS. In lichens, elevated concentrations (2-10 times of background levels) of copper, chromium, arsenic and cobalt were found at the waste rock depot and in the mine area. A non-linear temporal trend with decreasing concentrations in 2009 of the four metals in lichens from the two areas was found. This trend was expected due to reduced activities. All metal concentrations showed a significant decrease with increasing distance to the road. Elevated concentrations of Cu and As could be found to a distance of c. 1000 m from the road, while Cr and Co reached the background levels at about 500 m. Concentrations of metals in transplanted lichens were lower in 2009 than in 2008. No elevated concentrations were found in mussels, sculpins and chars, while seaweed had slightly elevated Co concentrations at one station. In 2009, an impact from the mine was primarily seen in the Kirkespir Valley due to dust dispersal. The impact of the mine in the marine environment was negligible.