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Gert Asmund

# Data sheet


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Abstract: This third monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland during 2-9 August 2006. Three shipments of ore had been transported to Spain for gold extraction since the last monitoring study performed in August-September 2005. Samples were collected at four to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River, and lichens were collected at 20 stations in the Kirkespir Valley. Samples were analysed for 12 elements with an ICP-MS. Elevated concentrations (2-15 times) of Cu, Cr, As and Co in lichens were found at the waste rock depot and in the camp area. Elevations in these two areas were not different from those found in 2005. The contamination of Cu, Cr and Co from the road was smaller in 2006 than in 2005, but elevated concentrations can, as in 2005, be found to a distance of about 1000 m from the road. Co was slightly elevated in seaweed from only one marine station in the Kirkespir Bay. Compared to the two former years the marine environment has gradually become less polluted. Cd was elevated twice in resident Arctic chars. No elevations were seen in 2005, whereas Cr and Co were slightly elevated in 2004. In 2006 the main impact from mining activities was observed in lichens. The rate of dust pollution should be evaluated by transplanting lichens from uncontaminated areas to the Nalunaq area.



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

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# Summary

This third monitoring study was carried out in the Nalunaq gold mining area, Nanortalik municipality, South Greenland, between 2 and 9 August 2006. Three shipments of ore had been transported to Spain for gold extraction since the last monitoring study performed in August-September 2005.

Blue mussels, brown seaweed and shorthorn sculpin were sampled at four to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River and lichens *Cetraria nivalis* were collected at 20 stations in the Kirkespir Valley and along the Kirkespir Bay (Fig. 1). 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 with background levels from 1998-2001 and the results from the two former monitoring studies in 2004 and 2005.

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. Thus, element elevations were very few in the Kirkespir Bay indicating a very low impact on the marine environment in 2006. Compared to higher concentrations in mainly seaweed in 2004 and 2005 the concentrations of metals appear gradually to have become less from 2004 to 2006.

In resident Arctic char livers, average Cd concentrations were elevated twice. Cr and Co were slightly elevated in 2004, while no elevations were found in 2005. Thus, during the three years period only minor elevations of Cr, Cd and Co have been seen.

In lichens, elevated concentrations of Cu, Cr, As and Co between 2 and 15 times above the background concentrations were found at the waste rock depot and in the camp area. Elevated concentrations in the two areas in 2006 were not significantly different from those found in 2005. Concentrations of the four metals in lichens from the waste rock depot were in 2006 significantly lower than concentrations in lichens from the camp area; in 2005 a significant difference was seen only in arsenic. The contamination of Cu, Cr and Co from the road was significantly smaller in 2006 than in 2005, but concentrations above the background level can, as in 2005, be found to a distance of about 1000 m from the road.

As in the two previous years, an impact from the mining activities on the local environment could be seen in 2006, primarily in the Kirkespir Valley from dust dispersal. The impact from the road was in 2006 lower than in 2005. In the river and in the bay element elevations were very few and the impacted area was smaller than previous years.

To evaluate the rate of dust pollution from the different sources, it is recommended that the year to year variation in lichen contamination is measured by transplanting lichens from an uncontaminated area to 5-10 stations in the Nalunaq area.

# Sammenfatning


Denne tredje moniteringsundersøgelse blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 2. til 9. august 2006. Siden moniteringen i august-september 2005 er der frem til denne monitering blevet udskibet tre malmladninger til Spanien, hvor guldet udvindes.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4-5 stationer i Kirkespirbugten, standørred blev fisket i Kirkespirelven og snekruslav *Cetraria nivalis* blev samlet på 20 stationer i Kirkespirdalen og langs bugten (Fig. 1). Prøverne 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 to tidligere moniteringsundersøgelser i 2004 og 2005.

Der blev ikke fundet forhøjede koncentrationer i blåmuslinger og i lever fra almindelig ulk, mens der i blæretang blev fundet svagt forhøjede koncentrationer af Co på en station. De fundne forhøjelser var således ganske få i Kirkespirbugten, hvilket tyder på at det marine miljø i 2006 kun var svagt påvirket. Sammenholdt med de relativt store forhøjelser i især tang i 2004 og 2005 er påvirkningen af bugten gradvist blevet mindre fra 2004 til 2006.

I standørreder var Cd koncentrationen i leveren to gange over baggrundsniveauet. I 2004 var Cr og Co forhøjet med en faktor to, mens der ikke fandtes forhøjelser i 2005. I den undersøgte tre års periode er der således kun fundet mindre forhøjelser af Cr, Cd og Co.

Områderne ved depotet for knust gråbjerg langs vejen og ved lejren og minen havde 2-15 gange højere koncentrationer af Cu, Cr, As og Co i laver i forhold til baggrundsniveauet. De forhøjede koncentrationer i de to områder i 2006 var ikke signifikant forskellige fra koncentrationerne i 2005. Koncentrationerne af de fire metaller i laverne fra gråbjergsdepotet var signifikant lavere end koncentrationerne fundet i lejr området. I 2005 var det kun arsen der var signifikant lavere ved gråbjergsdepotet. Påvirkningen af Cu, Cr og Co fra vejen var i 2006 signifikant lavere end i 2005, men ligesom i 2005 kunne der findes koncentrationer over baggrundsniveauet i en afstand af ca. 1000 m fra vejen.

Ligesom de to foregående år blev det lokale miljø i 2006 påvirket af mineaktiviteterne. En påvirkning som følge af støvspredning kunne især spores i Kirkespirdalen. Påvirkningen fra vejen var lavere i 2006 end i 2005. I Kirkespirelven og bugten var forhøjelserne ganske få og det påvirkede område var i 2006 mindre end i de to foregående år.

Det anbefales, at den årlige støvbelastning fra de forskellige kilder vurderes ved at undersøge år til år variation i metalkoncentrationerne i laverne. Dette kan gøres ved hvert år at transplantere laver fra upåvirkede områder til 5-10 indsamlingsstationer i Nalunaq området.

# Eqikkaaneq

Pingajussaanik nakkutilliilluni misissuineq una Kalaallit Nunaata kujataani, Nanortallip kommuniani Nalunap eqqaani ingerlanneqarpoq 2006-imi augustusip aappaaniit qulingiluaanut. 2005-imimili august-septemberimi nakkutilliilluni misissuisoqarmat nakuutilliilluni misissuinerup uuma tungaanut pingasoriarluni aatsitassamik Spaniamut nassiussisoqarpoq, tasamani kuulti immikkoortinneqassammat.

Uillut, equutit kanajorlu nalinginnaasoq Napasorsuup iterlaani misissuiffinni assigiinngitsuni sisamat-tallimani katersorneqarput, eqaluit sisujuitsut Napasorsuup kuuani aalisarneqarput aammalu orsuaasat snekruslav *Cetraria nivalis* Napasorsuup qooruani iterlaallu sineriaani misissuiffinni assigiinngitsuni 20-ni katersorneqarlutik (Ass. 1). Misissugassatut katersukkat pinngoqqaatinik aqqaneq marlunnik (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo aamma Au) akoqarnersut misissoqqissaarneqarput inernerilu aallaavigisatut tunuliaqutarineqartunut nalunaarsuillunilu siusinnersukkut marloriarluni 1998-2001-imut aammalu 2004-mi 2005-imilu misissuisimanerni paasisanut sanilliussuunneqarlutik.

Uilluni kanasswullu tinguini akuusut annertunerulersimanngitsut paasineqarpoq, equutinili Co katersuiffinni marlunni annertusiallalaarsimasoq paasineqarluni. Taamaattumik qaffariaatit nassaarineqartut Napasorsuup iterlaani annikitsuinnaallutik, tamannalu immami avatangiisit 2006-imi annikitsuinnarmik sunnerneqarsimanerannut takussutissaavoq. 2004-mi 2005-imilu pingaartumik equutit annertujaarsuarmik akoqarnerulersimaneranut sanilliukkaanni sunnerneqarsimaneq 2004-miit 2006-imut annikilliartuaarsimavoq.

Eqaluit sisujuitsut tinguini akuusoq avatangiisini aallaavigalugu tunuliaqutarineqartumut naleqqiullugu Cd marloriaammik qaffariarsimavoq. 2004-mi Cr aamma Co aallaavigalugu tunuliaqutarineqartumit marloriaataasimavoq kisiannili 2005-imi annertuseriarnermik malussartoqanngilaq. Taamaalilluni ukiuni pingasuni misissuiffiusuni Cr, Cd aamma Co annikitsuinnarmik qaffariarsimasut paasineqarpoq.

Ujaqqanik sequtsigaasiviup eqqaani, aqqusernup sinaani sulisullu ineqarfiata aatsitassarsiorfiullu eqqaanni Cu, Cr, As aamma Co orsuaasani akuusut, aallaavigalugu tunuliaqutarineqartumut sanilliullugu marloriaatip 15-eriaatillu akornanni qaffasinneruvoq. Taakkunani marlunni 2006-imi akuusut 2005-imit allaarujussuanngillat. Saffiugassat sisamat taakkua orsuaasani ujaqqanik aserortigaasivimmeersuni malunnartumik tammaarsimaffiup eqqaaneersunit annikinnerupput. 2005-imi arsen kisimi malunnartumik ujaqqanik aserortigaasivimmi annikinnerusimagaluarpoq. Cu, Cr aamma Co-mik aqqusinermiit sunnersimaneqarneq 2006-imi malunnartumik 2005-imiit annikinneruvoq, kisiannili 2005-imisulli aqqusinermiit 1000 m ungasitsigisoq tikkillugu aallaavigalugu tunuliaqutarineqartumut sanilliullugu qaffasinnerusoq nassarineqarsinnaalluni.

Ukiuni marlunni siuliinisulli 2006-imi avatangiisit tamaaniittut aatsitassarsiornermit sunnersimaneqarput. Sunnersimaneqarneq, pingaartumik pujoralammit siaruarterneqartumit pisoq, pingaartumik Napasorsuup qooruani malunnarpoq. Aqqusinermiit sunnersimaneqarneq 2006-imi 2005-imiit annikinneruvoq. Napasorsuup kuuani iterlammilu annertuseriarnerit ikitsuinnaapput aammalu sumiiffik sunnersimaneqartoq 2006-imi ukiunut siuliinut marlunnut sanilliullugu minnerulluni.

Inassutigineqassaaq ukiup ingerlanerani assigiinngitsuniit pujoralatitsineq ukiumiit ukiumut saffiugassat orsuaasani akuussut annertussusiisa misissorneqartarneratigut nalilersorneqartassasoq. Tamanna pisinnaavoq orsuaasanik nunamit sunnerneqarsimanngitsuneersunik Nalunap eqqaanut sumiiffinnut assigiinngitsunut tallimaniit qulinut amerlassusilinnut ukiut tamaasa nuutsisarnikkut.

# 1 Introduction

### Mining activities

The Nalunaq Gold Mine A/S 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 (ca. 20 g gold/ton ore), gold-only mineralization associated with quartz-veins. The ore sheet has an average strike angle of 45-50$^{o}$ 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 so therefore the ore is trucked 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 sail the ore to Rio Narcea Gold Mines Ltd, Spain, for gold extraction. Close to the pier is a stockpile area with an approximate capacity of 60,000 tonnes (Crewgold 2006). The first shipment of gold ore took place late December 2003. Up until the second monitoring study, performed during 10 August – 5 September 2005, a total of six shipments with approximately 180,000 tonnes of ore were transported to Spain. The third monitoring study, described in the present report, was performed between 2 and 9 August 2006. During the period from the second to the third monitoring study, a total of three shipments of ore had been carried out: On 12 November 2005 of c. 33,500 tonnes, on 16 February 2006 of c. 34,000 tonnes and on 28 June 2006 of c. 41,000 tonnes; tonnages are in wet weight (CCNMatthews 2005; E. Andersen, NGM, 8 August 2006, *in litt.*).

### Environmental baseline studies

Prior to the mine start different environmental baseline studies have been 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 studies and the mining methods and activities used at present, the monitoring programme presented below was designed.

### 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 Homerule administration. 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. BMP finds that the environmental monitoring programme described in the approval of the shipment of the stockpiled ore from the exploration phase (refer to BMP's approval of 2 May 2003), also should apply for the exploitation plan, Phase 2.

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.

### Monitoring study 2006

The monitoring study was performed in the Nalunaq area during 2 -9 August 2006.

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 from the Kirkespir Bay (Fig. 1). Blue mussels from this uncontaminated area were transplanted to the harbour area to replace the mussels transplanted in 2005 and collected for analyses in 2006.
- Brown seaweed was collected at one more station, AMI1, with a total of two more samples.
- Lichens were sampled at two more stations.
- The 20 fish liver analyses were separated in 16 shorthorn sculpin livers from four marine stations in the Kirkespir Bay and four Arctic char livers from the Kirkespir River near the waterfall. The chars were of the resident form.

Analyses were done according to the programme, however 62 samples were analysed in stead of 54 and the following 4 elements were added to the analytical programme: nickel (Ni), selenium (Se), molybdenum (Mo) and gold (Au).

**Acknowledgements**

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# 2 Methods

### Collection of samples

Sampling in the Kirkespir Bay and at the north-eastern point of Amitsoq (AMI1) was performed with a motor boat equipped with a small rubber dinghy with an outboard motor for landing. Sampling of blue mussels was performed at low tides of 0.5-0.7 m (Farvandsvæsnet 2005).

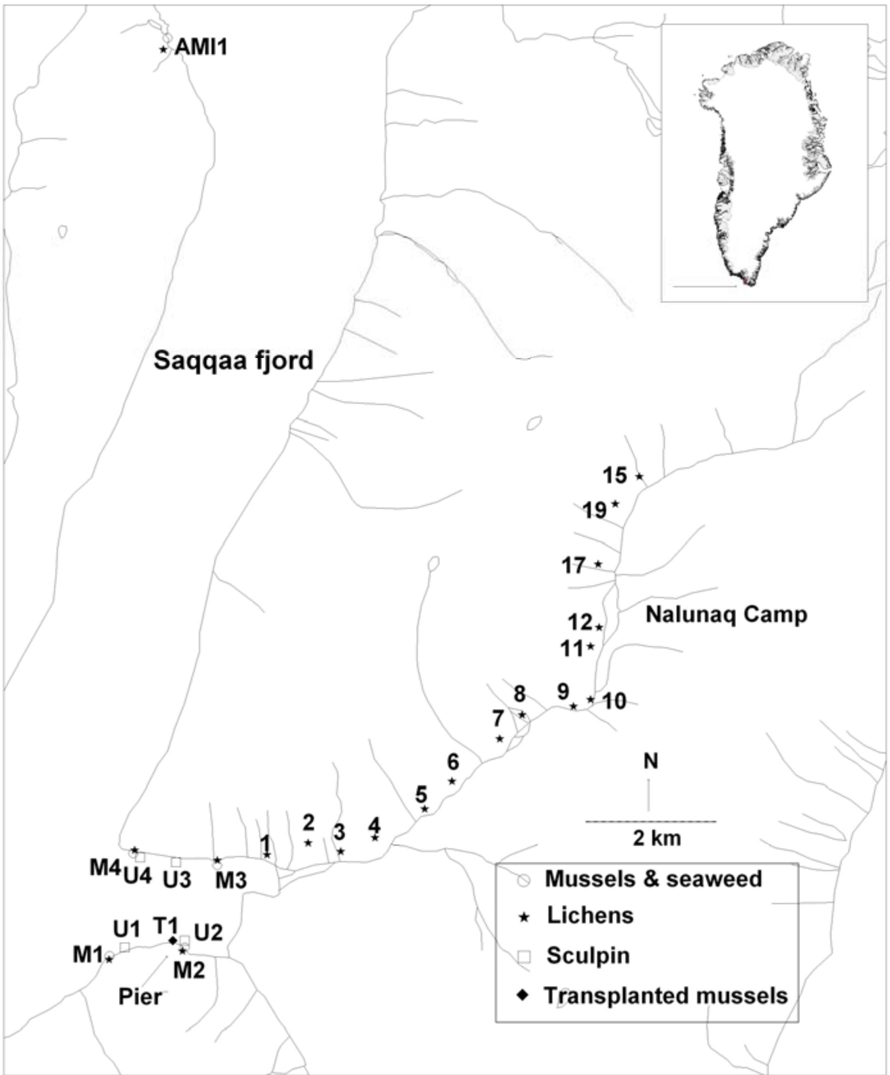



**Figure 1.** Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland.

M: Marine stations: Blue mussel and brown seaweed, including lichens. U: Shorthorn sculpin stations. T1: Blue mussels transplanted 2005 to the pier, were sampled at station AMI1 on NE Amitsoq Island. Arctic char were caught near the lichen station 9 close to the waterfall.

Two size groups of mussels were collected at each station with the following size groups represented: M1 (4-5 and 5-6 cm); M2 (4-5 and 5-6 cm); M3 (4-5 and 5-6 cm); M4 (4-5 and 6-8 cm). Average shell length was calculated for each size group at each station (see Appendix 2). All mussels in a sample were opened and allowed to drain, the soft parts cut free and frozen. Blue mussels transplanted in 2005 from north-western Amitsoq Island to the barge in the harbour area, T1 (5-6 and 6-7 cm), were collected for analyses. Only few of the transplanted mussels had died. New mussels from Amitsoq Island replaced those retrieved for analyses.

Other mussels (5-6 cm and 6-7 cm) from Amitsoq Island, AMI1, were collected for analyses of the background level in this area. Mussels were primarily transplanted to secure that there were mussels available in the harbour area for monitoring. However, the transplanted mussels can also be used to assess if the annual accumulation rate of the elements analysed has increased.

Brown seaweed was collected with two samples at each of the five marine stations. Samples were 50-100 m apart. The growth tips from this year were cut, washed in freshwater from upstream the camp and frozen.

Shorthorn sculpins were jigged for from a motor boat at the stations U1, U3 and U4. Sculpins at U2 were mainly caught from the barge at the pier. In total 20 shorthorn sculpins were caught. All sculpins were frozen as whole fish.

Arctic char were fished in the Kirkespir River downstream from the waterfall. Both resident and migratory forms of Arctic char were caught, but only four resident fish was analysed. 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 of the camp, four in the Kirkespir Bay area and one in the north-eastern part of Amitsoq Island.

### Analyses

All samples were transported either frozen or dry directly to NERI on 9 August 2006. The analyses were performed according to the "Prøvningsrapport nr. 156 & nr. 163" (Asmund 2006, 2007). A total of 62 samples from blue mussel (12), brown seaweed (10), livers of Shorthorn sculpin (16), 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 suprapur nitric acid under pressure in Teflon bombs in a microwave oven. The samples where then diluted to c. 25 grams and all elements were analysed in an ICP-MS (an accredited method according to DANAK, accreditation No. 411). Hg, Co, Mo and Au are not included in the accredited method No. 411. Simultaneously with the Nalunaq samples the reference materials Dorm-2, Dolt-3 and Tort were analysed. In Table 1 the analytical results are compared to the certificates. In general the ICP-MS analytical results are close to those of the certificates.

**Table 1.** ICP-MS analytical results of reference material (Dorm-2, Dolt-3 and Tort) compared to the certificates. The detection limits, quantified as 3 times the standard deviation of the blind values, are also shown.
Twelve different elements are analysed. Concentrations are in mg/kg. % d.m. = Percent dry matter.

| | **% d.m.** | **Hg** | **Cd** | **Pb** | **Zn** | **Cu** | **Cr** | **Ni** | **As** | **Se** | **Co** | **Mo** | **Au** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Detection limit* | | *0.0385* | *0.0123* | *0.0235* | *0.11* | *0.03* | *0.08* | *0.03* | *0.04* | *0.27* | *0.003* | *0.014* | *0.0103* |
| Dorm-2 | 95.11 | 5.0583 | 0.0748 | 0.0602 | 21.99 | 2.26 | 31.21 | 15.75 | 14.80 | 0.76 | 0.128 | 0.2484 | 0.0256 |
| Dorm-2 | 95.11 | 4.8464 | 0.0521 | 0.0623 | 25.75 | 2.33 | 30.24 | 15.20 | 15.53 | 1.66 | 0.137 | 0.2596 | 0.0586 |
| Dorm-2 | 95.11 | 4.6883 | 0.0194 | 0.0558 | 20.52 | 2.02 | 30.58 | 15.83 | 15.77 | 1.36 | 0.130 | 0.2579 | 0.1712 |
| Dorm-2 | 95.11 | 4.1972 | 0.0251 | 0.0522 | 21.57 | 1.99 | 30.52 | 16.59 | 17.18 | 1.27 | 0.142 | 0.2628 | 0.0172 |
| **mean** | | **4.70** | **0.043** | **0.058** | **22.46** | **2.15** | **30.64** | **15.84** | **15.8** | **1.26** | **0.13** | **0.26** | **0.07** |
| *certificate* | | *4.413* | *0.041* | *0.062* | *24.348* | *2.226* | *33.003* | *18.45* | *17.1* | *1.33* | *0.173* | | |
| Dolt-3 | 87.61 | 3.44 | 17.12 | 0.276 | 79.37 | 27.95 | 3.48 | 2.52 | 8.27 | 6.37 | 0.216 | 3.12 | 0.090 |
| Dolt-3 | 87.61 | 3.34 | 15.67 | 0.317 | 67.90 | 27.56 | 4.97 | 3.17 | 7.16 | 4.48 | 0.214 | 3.04 | 0.346 |
| **mean** | | **3.39** | **16.40** | **0.30** | **73.64** | **27.76** | **4.23** | **2.84** | **7.71** | **5.42** | **0.21** | **3.08** | **0.22** |
| *certificate* | | *2.95* | *17.00* | *0.28* | *75.87* | *27.33* | | *2.38* | *8.94* | *6.19* | | | |
| **Tort** | **91** | **0.41** | **26.28** | **0.27** | **167.19** | **118.6** | **1.30** | **2.26** | **19.25** | **6.12** | **0.41** | **0.97** | **0.02** |
| *certificate* | | *0.25* | *24.30* | *0.32* | *163.84* | *96.48* | *0.70* | *2.28* | *19.66* | *5.12* | *0.46* | *0.86* | |

# 3 Results and evaluation

Element concentrations are given in organisms from the marine environment in the Kirkespir Bay, from the fresh water environment in the Kirkespir River and from 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. In some species the background concentration of an element is lower than the detection limit of that element; in those cases the detection limit is used as "background concentration".

In the two previous Nalunaq monitoring reports (Glahder & Asmund 2005, 2006) mean element concentrations in the five different sample types were presented. Mean concentrations are not presented in the present report.

### The marine environment

Samples from the Kirkespir Bay were collected at five mussel stations (M1-4 and T1), five seaweed stations (M1-4 and AMI1) and four sculpin stations (U1-U4) (Fig. 1).

No elevated concentrations were found in *blue mussel* samples. The mussels transplanted in 2005 from the northern Amitsoq Island (AMI1) to station T1 at the pier had low concentrations of all elements compared to the background concentrations. The concentrations were comparable to the mussels analysed from AMI1 (Appendix 3).

*Brown seaweed* at station M3 had about 3 times higher concentrations of Co than background concentrations (t-test, $p=0.003$, $t=6.56$, $df=4$). None of the other seaweed stations had elevated concentrations of the elements that were analysed (Appendix 3).

The Cr concentration in one *sculpin liver* from station U1 was 0.573 mg/kg w.w. (wet weight) or about 35 times above the background concentration. Despite this high concentration the average Cr concentration at the station was not significantly different from the background concentration (t-test, $p=0.382$, $t=1.16$, $df=7$).

In 2006, only Co was significantly elevated in only one of the seaweed stations (M3). No elevations of any elements were found in the analysed mussels and sculpins. So, in 2006 the impact from the mining activities on the marine environment was very low.

In 2004, concentrations of Cr, Cu and Co were elevated in seaweed (14, 10 and 6 times, respectively), Cr was elevated in sculpin livers from one station (5 times) and Co was elevated in blue mussel from one station (3 times). The source seemed mainly to be the mining area via the Kirkespir River. In 2005, Cr was elevated up to 10 times in seaweed, whereas Co and Zn were slightly elevated in seaweed. The sources seemed both to be the mining and the pier areas.

The concentrations of metals in the marine environment appear gradually to have become less from 2004 to 2006.

### The freshwater environment

In resident Arctic char liver average Cd concentrations were elevated twice (t-test, $p=0.014$, $df=7$). Resident Arctic char stay all their life in the river, whereas the migratory form summers in the Kirkespir Bay and Saqqaa Fjord. Compared to the two previous years where monitoring was performed, Cr and Co were elevated about 3 times in 2004 while no elevations were found in 2005. So, in conclusion only minor elevations of Cr, Cd and Co have been seen over the three years.

### The terrestrial environment

In two areas, the depot of crushed waste rock (stations 5-7) and the camp area (stations 11-12), average concentrations in lichens of Cu, Cr, As and Co were significantly higher than background concentrations (t-test, $p<0.002$, $df=5$ (camp area) and 6 (depot)). Concentrations of the four metals at the pier (station M2) seem elevated, but because we have only one sample from this area it has not been possible to test if the elevation was significant (Fig. 2a). Elevations in the areas were 2-5 times in Cu, 2-4 times in Cr, 6-15 times in As and 4-7 times in Co. Significantly elevated concentrations of the four metals in the two areas were also found in 2005 (t-test, $p<0.006$, $df=5$ (camp area) and 6 (depot)). Concentrations of the four metals in the two areas in 2006 were not significantly different from those found in 2005 (t-test, $p>0.1$, $df=2$ (camp area) and 4 (depot)). In 2006 the metal concentrations in lichens from the waste depot were significantly lower than concentrations at the camp area (t-test, $p(Cu)=0.007$, $p(Cr)=0.015$, $p(As)=0.031$, $p(Co)=0.046$, $df=3$). In 2005, a significantly lower concentration in lichens from the waste depot compared to the camp area was found only in As (t-test, $p=0.049$, $df=3$).

In the monitoring report from 2005 (Glahder & Asmund 2006) we concluded that dust from the gravel road between the mine and the pier was a source of heavy metals being dispersed to the vegetation along the road. Based on the 2006 data we have tested the influence of contaminated road dust on concentrations in lichens. This was done for the four elements that showed highest elevations compared to background concentrations: copper, chromium, arsenic and cobalt (Fig. 2a, b & 3). The perpendicular distances from the lichen stations 8, 9 and 10 to the road have been revised according to paced distances performed during the present monitoring study in August 2006. Figure 3 shows that concentrations of all four elements are correlated to low distances to the road. We have tested if these correlations in 2006 were different from those from 2005, and found no significant differences for any of the four metals ($p>0.05$, analysis of covariance, both slope of regression lines and intercept were tested). As it is obvious from figure 2 and 3 that the concentrations at station 11 and 12 (camp and mining area) are mainly a result of the mining activities, we have omitted these two stations and run the same test as above. We now find that the contamination of Cu, Cr and Co from the road is significantly smaller in 2006 than in 2005 ($p<0.02$, analysis of covariance); the slope of the regression lines are in 2006 about 2 times slighter than in 2005. Arsenic showed no significant difference between the two years (p=0.17, analysis of covariance).

It is concluded that concentrations of Cu, Cr, As and Co in 2006 were significantly elevated compared to the background level at the depot of crushed waste rock and at the camp and mine area. These elevated concentrations were not significantly different from those found in 2005. Concentrations of the four metals in lichens from the waste rock depot were in 2006 significantly lower than concentrations in lichens from the camp area; in 2005 a significant difference was seen only in arsenic. The contamination of Cu, Cr and Co from the road was significantly smaller in 2006 than in 2005, but concentrations above the background level can, as in 2005, be found to a distance of about 1000 m from the road.

Because metals are excreted from the lichens at a low rate - if at all - a reduction in the dust pollution will be difficult to detect within a few years period. We can solve this problem by transplanting lichens from an uncontaminated area, e.g. northern Amitsoq, to the Nalunaq area (e.g. the stations along the road), leaving them there for one year and then analyzing them for metals. In this way we will be able to measure the year to year variation in the lichen contamination and thereby the rate of dust pollution.

**Figure 2.** Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis.*

For localisation of lichen stations refer to Fig. 1. AMI1 is the station on Amitsoq island 15 km from the Kirkespir Bay, M1-M4 are stations in the Kirkespir Bay area, stations 1-17 are situated in the Kirkespir Valley from coast (1) to upstream camp area (15). Horizontal lines in a) indicate average background concentrations of the four metals (Refer to Table 2). d.w. = dry weight. Fig. 2 b shows distances (in meter) from road to stations.

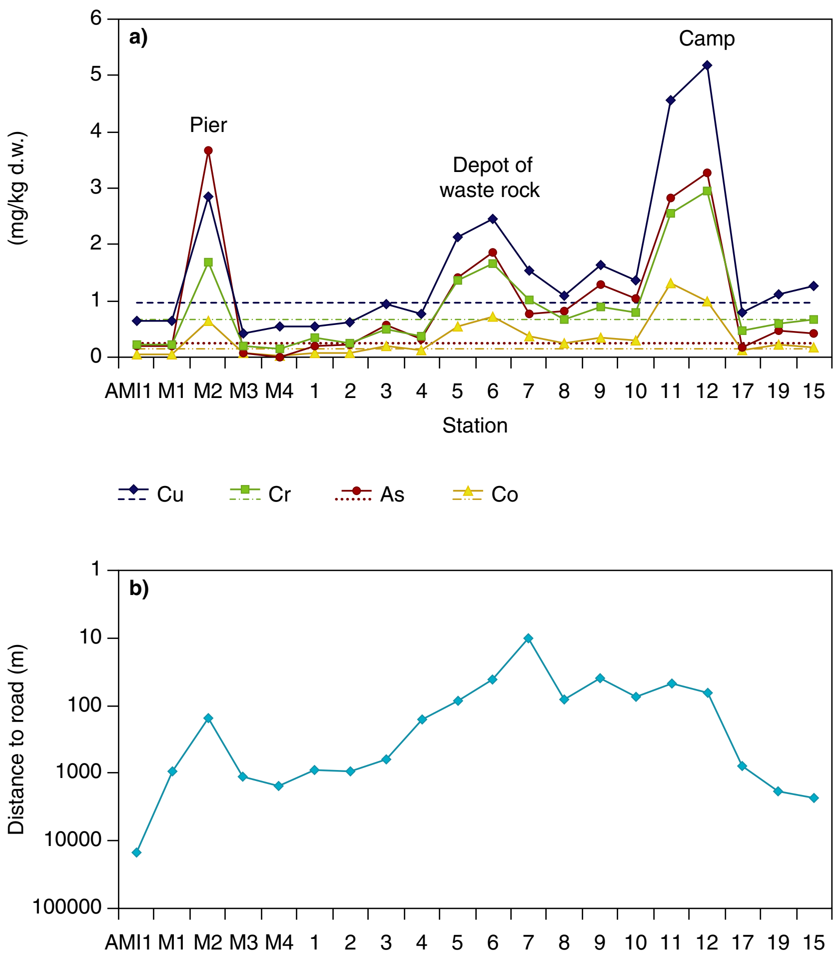
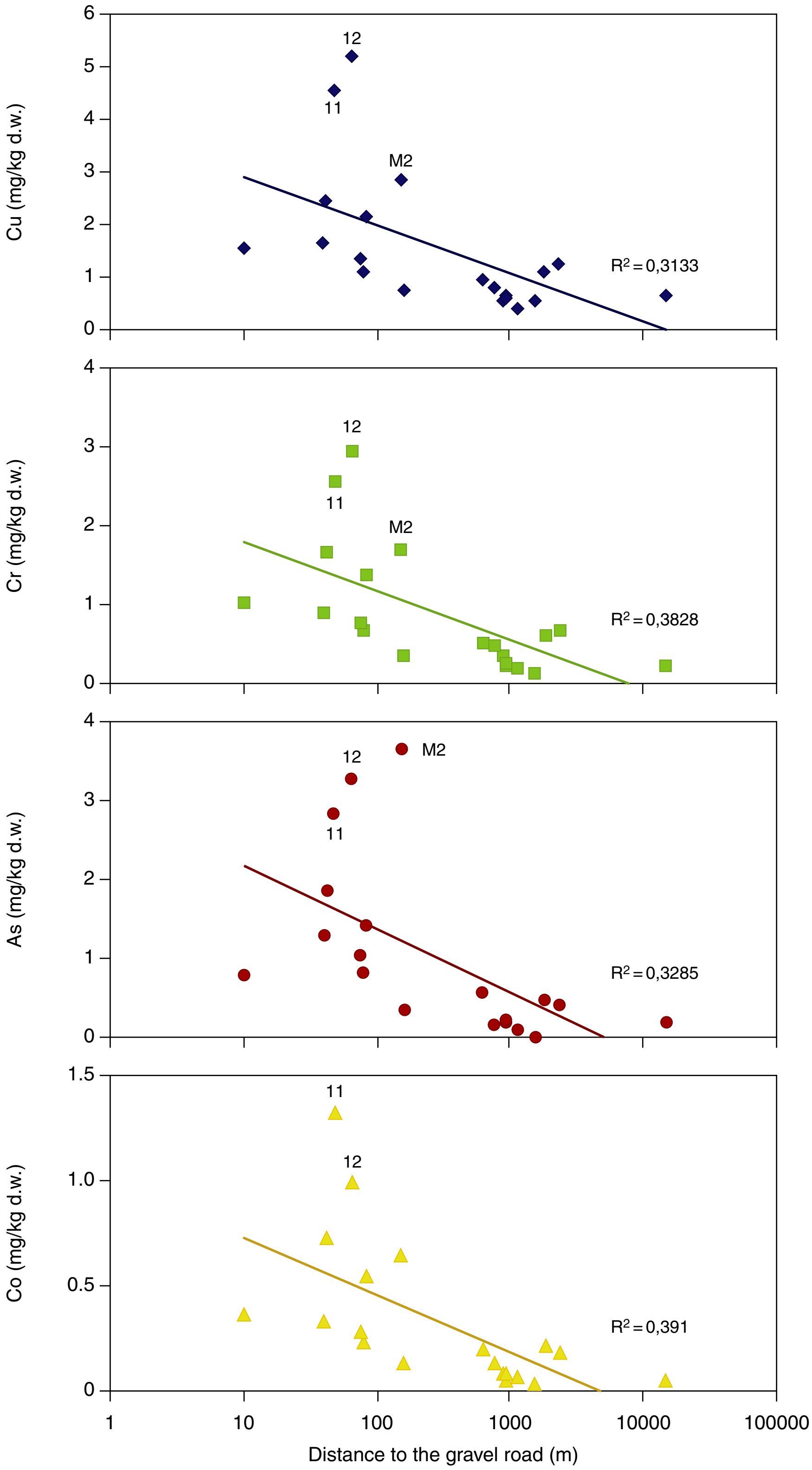


**Figure 3.** Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis* as a function of stations distance to the gravel road (in meter).

Stations with concentrations well above the trend line are shown with their number (Fig. 1). d.w. = dry weight.



# 4 Conclusions

The report describes the third year of environmental monitoring in the Nalunaq Gold Mine area. Sampling procedures in 2006 were unchanged so results are comparable to those from the two former years.

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. Thus, element elevations were very few in the Kirkespir Bay indicating a very low impact on the marine environment in 2006. Compared to higher concentrations in mainly seaweed, but also in blue mussel and sculpin, in 2004 and 2005 the concentrations of metals in the marine environment appear gradually to have become less from 2004 to 2006.

In resident Arctic char liver average Cd concentrations were elevated twice. Cr and Co were slightly elevated in 2004 while no elevations were found in 2005. Thus, during the three years period only minor elevations of Cr, Cd and Co have been seen.

In the lichen *Cetraria nivalis* elevated concentrations of Cu, Cr, As and Co between 2 and 15 times above the background concentrations were found at the waste rock depot and in the mine and the camp area. Elevations were caused by dust dispersal from the camp area, from waste rock crushing and from driving on the roads. Elevated concentrations in the two areas were not significantly different from those found in 2005. Concentrations of the four metals in lichens from the waste rock depot were in 2006 significantly lower than concentrations in lichens from the camp area; in 2005 a significant difference was seen only in arsenic. The contamination of copper, chromium and cobalt from the road was significantly smaller in 2006 than in 2005, but concentrations above the background level can, as in 2005, be found to a distance of about 1000 m from the road.

As in the two previous years, an impact from the mining activities on the local environment could be seen in 2006, primarily in the Kirkespir Valley from dust dispersal. The impact from the road was in 2006 lower than in 2005. In the river and in the bay, element elevations were very few and the impacted area was smaller than previous years.

To evaluate the rate of dust pollution from the different sources, it is recommended that the year to year variation in lichen contamination is measured by transplanting lichens from an uncontaminated area to 5-10 stations in the Nalunaq area.

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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 *) |
|---|---|---|---|---|---|---|---|---|
| 36027 | Lichen | Cetraria nivalis | 20060805 | 1 | 60 | 19’34” | 44 | 55’22” |
| 36028 | Lichen | Cetraria nivalis | 20060805 | 2 | 60 | 19’38” | 44 | 54’40” |
| 36029 | Lichen | Cetraria nivalis | 20060805 | 3 | 60 | 19’35” | 44 | 54’10” |
| 36030 | Lichen | Cetraria nivalis | 20060805 | 4 | 60 | 19’43” | 44 | 53’38” |
| 36031 | Lichen | Cetraria nivalis | 20060805 | 5 | 60 | 19’57” | 44 | 52’48” |
| 36032 | Lichen | Cetraria nivalis | 20060805 | 6 | 60 | 20’10” | 44 | 52’18” |
| 36033 | Lichen | Cetraria nivalis | 20060805 | 7 | 60 | 20’32” | 44 | 51’37” |
| 36034 | Lichen | Cetraria nivalis | 20060805 | 8 | 60 | 20’44” | 44 | 51’07” |
| 36035 | Lichen | Cetraria nivalis | 20060805 | 9 | 60 | 20’49” | 44 | 50’14” |
| 36036 | Lichen | Cetraria nivalis | 20060805 | 10 | 60 | 20’51” | 44 | 49’58” |
| 36037 | Lichen | Cetraria nivalis | 20060808 | 11 | 60 | 21’17” | 44 | 49’57” |
| 36038 | Lichen | Cetraria nivalis | 20060808 | 12 | 60 | 21’28” | 44 | 49’49” |
| 36039 | Lichen | Cetraria nivalis | 20060807 | 15 | 60 | 22’43” | 44 | 49’08” |
| 36040 | Lichen | Cetraria nivalis | 20060807 | 17 | 60 | 21’59” | 44 | 49’52” |
| 36041 | Lichen | Cetraria nivalis | 20060807 | 19 | 60 | 22’30” | 44 | 49’31” |
| 36023 | Lichen | Cetraria nivalis | 20060806 | M 1 | 60 | 18’41” | 44 | 58’01” |
| 36024 | Lichen | Cetraria nivalis | 20060806 | M 2 | 60 | 18’46” | 44 | 56’47” |
| 36025 | Lichen | Cetraria nivalis | 20060805 | M 3 | 60 | 19’29” | 44 | 56’15” |
| 36026 | Lichen | Cetraria nivalis | 20060805 | M 4 | 60 | 19’35” | 44 | 57’37” |
| 36042 | Lichen | Cetraria nivalis | 20060808 | AMI 1 | 60 | 26’20” | 44 | 57’04” |
| 36005 | Brown seaweed | Fucus vesiculosus | 20060806 | M 1 | 60 | 18’41” | 44 | 58’01” |
| 36006 | Brown seaweed | Fucus vesiculosus | 20060806 | M 1 | 60 | 18’41” | 44 | 58’01” |
| 36009 | Brown seaweed | Fucus vesiculosus | 20060806 | M 2 | 60 | 18’46” | 44 | 56’47” |
| 36010 | Brown seaweed | Fucus vesiculosus | 20060806 | M 2 | 60 | 18’46” | 44 | 56’47” |
| 36001 | Brown seaweed | Fucus vesiculosus | 20060805 | M 3 | 60 | 19’29” | 44 | 56’15” |
| 36002 | Brown seaweed | Fucus vesiculosus | 20060805 | M 3 | 60 | 19’29” | 44 | 56’15” |
| 36003 | Brown seaweed | Fucus vesiculosus | 20060805 | M 4 | 60 | 19’35” | 44 | 57’37” |
| 36004 | Brown seaweed | Fucus vesiculosus | 20060805 | M 4 | 60 | 19’35” | 44 | 57’37” |
| 36021 | Brown seaweed | Fucus vesiculosus | 20060808 | AMI1 | 60 | 26’20” | 44 | 57’04” |
| 36022 | Brown seaweed | Fucus vesiculosus | 20060808 | AMI1 | 60 | 26’20” | 44 | 57’04” |
| 35830 | Shorthorn sculpin | Myoxocephalus scorpius | 20060806 | U 1 | 60 | 18’47” | 44 | 57’45” |
| 35831 | Shorthorn sculpin | Myoxocephalus scorpius | 20060806 | U 1 | 60 | 18’47” | 44 | 57’45” |
| 35832 | Shorthorn sculpin | Myoxocephalus scorpius | 20060806 | U 1 | 60 | 18’47” | 44 | 57’45” |
| 35833 | Shorthorn sculpin | Myoxocephalus scorpius | 20060806 | U 1 | 60 | 18’47” | 44 | 57’45” |
| 35834 | Shorthorn sculpin | Myoxocephalus scorpius | 20060805 | U 2 | 60 | 18’45” | 44 | 56’46” |
| 35835 | Shorthorn sculpin | Myoxocephalus scorpius | 20060805 | U 2 | 60 | 18’45” | 44 | 56’46” |
| 35836 | Shorthorn sculpin | Myoxocephalus scorpius | 20060805 | U 2 | 60 | 18’45” | 44 | 56’46” |
| 35837 | Shorthorn sculpin | Myoxocephalus scorpius | 20060805 | U 2 | 60 | 18’45” | 44 | 56’46” |
| 35838 | Shorthorn sculpin | Myoxocephalus scorpius | 20060804 | U 3 | 60 | 19’31” | 44 | 56’53” |
| 35839 | Shorthorn sculpin | Myoxocephalus scorpius | 20060804 | U 3 | 60 | 19’31” | 44 | 56’53” |
| 35840 | Shorthorn sculpin | Myoxocephalus scorpius | 20060804 | U 3 | 60 | 19’31” | 44 | 56’53” |
| 35841 | Shorthorn sculpin | Myoxocephalus scorpius | 20060804 | U 3 | 60 | 19’31” | 44 | 56’53” |
| 35871 | Shorthorn sculpin | Myoxocephalus scorpius | 20060808 | U 4 | 60 | 19’34” | 44 | 57’31” |
| 35872 | Shorthorn sculpin | Myoxocephalus scorpius | 20060808 | U 4 | 60 | 19’34” | 44 | 57’31” |
| 35873 | Shorthorn sculpin | Myoxocephalus scorpius | 20060808 | U 4 | 60 | 19’34” | 44 | 57’31” |
| 35874 | Shorthorn sculpin | Myoxocephalus scorpius | 20060808 | U 4 | 60 | 19’34” | 44 | 57’31” |
| 36015 | Blue mussel | Mytilus edulis | 20060807 | M 1 | 60 | 18’41” | 44 | 58’01” |

| ID-No | Sample type | Latin name | Collection date | Station | Lat deg *) | Lat min and sec *) | Long deg *) | Long min and sec *) |
|---|---|---|---|---|---|---|---|---|
| 36016 | Blue mussel | Mytilus edulis | 20060807 | M 1 | 60 | 18’41” | 44 | 58’01” |
| 36013 | Blue mussel | Mytilus edulis | 20060807 | M 2 | 60 | 18’46” | 44 | 56’47” |
| 36014 | Blue mussel | Mytilus edulis | 20060807 | M 2 | 60 | 18’46” | 44 | 56’47” |
| 36011 | Blue mussel | Mytilus edulis | 20060805 | M 3 | 60 | 19’29” | 44 | 56’15” |
| 36012 | Blue mussel | Mytilus edulis | 20060805 | M 3 | 60 | 19’29” | 44 | 56’15” |
| 36007 | Blue mussel | Mytilus edulis | 20060805 | M 4 | 60 | 19’35” | 44 | 57’37” |
| 36008 | Blue mussel | Mytilus edulis | 20060805 | M 4 | 60 | 19’35” | 44 | 57’37” |
| 36019 | Blue mussel | Mytilus edulis | 20060808 | AMI 1 | 60 | 26’20” | 44 | 57’04” |
| 36020 | Blue mussel | Mytilus edulis | 20060808 | AMI 1 | 60 | 26’20” | 44 | 57’04” |
| 36017 | Blue mussel | Mytilus edulis | 20060808 | T 1 | 60 | 18’51” | 44 | 56’57” |
| 36018 | Blue mussel | Mytilus edulis | 20060808 | T 1 | 60 | 18’51” | 44 | 56’57” |
| 35826 | Arctic char | Salvelinus alpinus | 20060807 | Near waterfall | 60 | 20’47” | 44 | 50’32” |
| 35827 | Arctic char | Salvelinus alpinus | 20060807 | Near waterfall | 60 | 20’47” | 44 | 50’32” |
| 35828 | Arctic char | Salvelinus alpinus | 20060807 | Near waterfall | 60 | 20’47” | 44 | 50’32” |
| 35829 | Arctic char | Salvelinus alpinus | 20060807 | 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 | | | |
|---|---|---|---|---|
| | 4-5 | 5-6 | 6-7 | 6-8 |
| M1 | **4.55**<br>0.25; 20 | **5.45**<br>0.29; 20 | | |
| M2 | **4.51**<br>0.27; 20 | **5.46**<br>0.28; 20 | | |
| M3 | **4.49**<br>0.23; 20 | **5.41**<br>0.28; 20 | | |
| M4 | **4.41**<br>0.28; 20 | | | **6.62**<br>0.60; 19 |
| AMI1 | | **5.39**<br>0.23; 20 | **6.39**<br>0.28; 14 | |
| T1 | | **5.47**<br>0.28; 20 | **6.45**<br>0.28; 13 | |

# 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 sculpins and Arctic chars. Detection limits are given as well as average background concentrations and standard deviations (*SD*) for each species.

| ID no. | Lab no | % dry matter | Species | Shell (cm) | Station | Hg | Cd | Pb | Zn | Cu | Cr | Ni | As | Se | Co | Mo | Au |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Detection limits* | | | | | | *0.039* | *0.012* | *0.023* | *0.11* | *0.03* | *0.079* | *0.031* | *0.04* | *0.27* | *0.003* | *0.01* | *0.010* |
| 36015 | 4300 | 17.33 | Myt. edu. | 4-5 | M 1 | 0.077 | 1.454 | 0.409 | 87.57 | 6.85 | 0.793 | 1.173 | 11.91 | 2.55 | 0.245 | 0.44 | 0.030 |
| 36016 | 4301 | 17.91 | Myt. edu. | 5-6 | M 1 | 0.058 | 1.310 | 0.388 | 68.82 | 5.36 | 0.962 | 1.407 | 10.48 | 2.46 | 0.229 | 0.40 | 0.020 |
| 36013 | 4298 | 18.94 | Myt. edu. | 4-5 | M 2 | 0.094 | 1.205 | 0.360 | 68.09 | 5.76 | 0.574 | 0.874 | 11.57 | 3.05 | 0.204 | 0.38 | 0.029 |
| 36014 | 4299 | 17.58 | Myt. edu. | 5-6 | M 2 | 0.079 | 1.601 | 0.626 | 68.20 | 5.75 | 0.707 | 0.949 | 11.64 | 2.65 | 0.219 | 0.40 | 0.029 |
| 36011 | 4296 | 15.53 | Myt. edu. | 4-5 | M 3 | 0.116 | 2.095 | 0.406 | 86.77 | 7.58 | 0.893 | 1.296 | 13.72 | 4.15 | 0.319 | 0.48 | 0.038 |
| 36012 | 4297 | 15.13 | Myt. edu. | 5-6 | M 3 | 0.135 | 2.083 | 0.503 | 66.94 | 6.74 | 0.923 | 1.170 | 13.13 | 2.92 | 0.306 | 0.47 | 0.040 |
| 36007 | 4293 | 17.56 | Myt. edu. | 4-5 | M 4 | 0.106 | 2.195 | 0.491 | 75.12 | 6.59 | 0.759 | 0.935 | 11.15 | 2.88 | 0.226 | 0.40 | 0.061 |
| 36007 | 4294 | 17.56 | Myt. edu. | 4-5 | M 4 | 0.127 | 2.021 | 0.441 | 69.08 | 6.65 | 0.704 | 0.913 | 11.20 | 3.34 | 0.223 | 0.42 | 0.056 |
| 36008 | 4295 | 16.86 | Myt. edu. | 6-8 | M 4 | 0.253 | 2.915 | 0.619 | 70.45 | 5.49 | 0.772 | 0.907 | 10.30 | 2.89 | 0.236 | 0.44 | 0.031 |
| 36017 | 4302 | 20.03 | Myt. edu. | 5-6 | T 1 | 0.056 | 2.596 | 0.512 | 79.21 | 5.82 | 0.642 | 0.785 | 9.54 | 2.48 | 0.253 | 0.43 | 0.045 |
| 36018 | 4303 | 18.76 | Myt. edu. | 6-7 | T 1 | 0.087 | 5.231 | 0.638 | 82.29 | 5.07 | 0.876 | 0.857 | 10.45 | 3.00 | 0.278 | 0.48 | 0.114 |
| 36019 | 4304 | 18.57 | Myt. edu. | 5-6 | AMI 1 | 0.051 | 2.061 | 0.422 | 68.99 | 5.46 | 0.645 | 1.266 | 9.70 | 2.85 | 0.213 | 0.39 | 0.017 |
| 36020 | 4305 | 17.36 | Myt. edu. | 6-7 | AMI 1 | 0.075 | 2.440 | 0.733 | 65.89 | 5.57 | 0.843 | 0.903 | 10.87 | 2.59 | 0.243 | 0.47 | 0.019 |
| *Background* | | | Myt. edu. | *Average* | | *0.131* | *5.49* | *1.195* | *87.82* | *7.58* | *0.73* | | *11.80* | | *0.239* | | |
| *Background* | | | Myt. edu. | *SD* | | *0.025* | *1.97* | *0.365* | *16.42* | *1.08* | *0.28* | | *1.59* | | *0.053* | | |
| *Detection limits* | | | | | | *0.013* | *0.014* | *0.004* | *0.21* | *0.02* | *0.025* | *0.014* | *0.02* | *0.37* | *0.001* | *0.01* | *0.031* |
| 36005 | 4126 | 100 | Fuc. ves. | | M 1 | 0.000 | 1.205 | 0.048 | 7.72 | 0.97 | 0.138 | 1.111 | 39.14 | 0.25 | 0.229 | 0.10 | 0.047 |
| 36006 | 4127 | 100 | Fuc. ves. | | M 1 | 0.066 | 1.111 | 0.055 | 7.32 | 0.95 | 0.170 | 1.316 | 32.22 | 0.18 | 0.247 | 0.11 | 0.016 |
| 36009 | 4128 | 100 | Fuc. ves. | | M 2 | -0.011 | 0.650 | 0.074 | 14.19 | 1.50 | 0.460 | 1.881 | 31.73 | 0.09 | 0.385 | 0.10 | 0.156 |
| 36010 | 4129 | 100 | Fuc. ves. | | M 2 | -0.005 | 0.186 | 0.016 | 3.25 | 0.41 | 0.074 | 0.424 | 11.83 | -0.08 | 0.101 | 0.03 | 0.022 |
| 36001 | 4121 | 100 | Fuc. ves. | | M 3 | 0.012 | 1.009 | 0.042 | 9.47 | 1.66 | 0.149 | 1.323 | 51.19 | -0.07 | 0.608 | 0.09 | 2.070 |
| 36001 | 4122 | 100 | Fuc. ves. | | M 3 | -0.015 | 0.972 | 0.048 | 9.01 | 1.65 | 0.201 | 1.381 | 49.35 | -0.27 | 0.611 | 0.09 | 0.647 |
| 36002 | 4123 | 100 | Fuc. ves. | | M 3 | -0.004 | 0.868 | 0.030 | 9.34 | 1.64 | 0.279 | 1.305 | 48.09 | 0.14 | 0.535 | 0.09 | 0.145 |
| 36003 | 4124 | 100 | Fuc. ves. | | M 4 | 0.006 | 1.202 | 0.035 | 8.46 | 1.45 | 0.216 | 1.294 | 41.23 | 0.11 | 0.276 | 0.15 | 0.080 |
| 36004 | 4125 | 100 | Fuc. ves. | | M 4 | -0.010 | 1.282 | 0.037 | 7.99 | 1.50 | 0.188 | 1.196 | 41.23 | 0.12 | 0.261 | 0.11 | 0.447 |
| 36021 | 4130 | 100 | Fuc. ves. | | AMI 1 | -0.016 | 1.522 | 0.048 | 4.28 | 1.23 | 0.176 | 1.378 | 48.05 | -0.22 | 0.235 | 0.13 | 0.057 |
| 30622 | 4131 | 100 | Fuc. ves. | | AMI 1 | -0.012 | 1.737 | 0.053 | 4.37 | 1.09 | 0.261 | 1.625 | 47.39 | 0.19 | 0.227 | 0.14 | 0.034 |
| *Background* | | | Fuc. ves. | *Average* | | *0.01* | *1.77* | *0.105* | *7.57* | *1.04* | *0.11* | | *47.55* | | *0.209* | | |
| *Background* | | | Fuc. ves. | *SD* | | *0.008* | *0.51* | *0.039* | *2.38* | *0.24* | *0.12* | | *8.47* | | *0.045* | | |
| 36023 | 4073 | | Cet. niv. | | M 1 | 0.129 | 0.022 | 0.199 | 3.97 | 0.20 | 0.084 | 0.079 | 0.05 | 0.11 | 0.021 | 0.01 | 0.036 |
| 36023 | 4074 | | Cet. niv. | | M 1 | 0.020 | 0.071 | 0.460 | 15.22 | 0.54 | 0.260 | 0.234 | 0.26 | 0.40 | 0.069 | 0.03 | 0.050 |
| 36024 | 4075 | | Cet. niv. | | M 2 | 0.025 | 0.073 | 1.171 | 24.67 | 2.86 | 1.697 | 1.669 | 3.66 | 0.83 | 0.637 | 0.05 | 0.249 |
| 36025 | 4076 | | Cet. niv. | | M 3 | 0.010 | 0.045 | 0.455 | 13.78 | 0.41 | 0.197 | 0.210 | 0.08 | 0.09 | 0.069 | 0.02 | 0.174 |
| 36026 | 4077 | | Cet. niv. | | M 4 | 0.016 | 0.070 | 0.351 | 9.50 | 0.54 | 0.143 | 0.118 | 0.01 | 0.30 | 0.025 | 0.02 | 0.026 |
| 36042 | 4095 | | Cet. niv. | | AMI 1 | 0.016 | 0.117 | 0.580 | 12.69 | 0.64 | 0.213 | 0.268 | 0.20 | 0.26 | 0.044 | 0.02 | 0.043 |
| 36027 | 4078 | | Cet. niv. | | 1 | 0.014 | 0.073 | 0.835 | 15.54 | 0.55 | 0.352 | 0.222 | 0.19 | 0.12 | 0.075 | 0.05 | 0.058 |
| 36028 | 4079 | | Cet. niv. | | 2 | 0.011 | 0.073 | 0.572 | 16.47 | 0.62 | 0.258 | 0.305 | 0.22 | 0.66 | 0.076 | 0.02 | 0.050 |
| 36029 | 4080 | | Cet. niv. | | 3 | 0.026 | 0.067 | 0.655 | 27.39 | 0.94 | 0.502 | 0.540 | 0.58 | 0.42 | 0.197 | 0.03 | 0.066 |
| 36030 | 4081 | | Cet. niv. | | 4 | 0.009 | 0.052 | 0.642 | 15.90 | 0.77 | 0.364 | 0.372 | 0.33 | 0.33 | 0.129 | 0.03 | 0.071 |
| 36031 | 4082 | | Cet. niv. | | 5 | 0.017 | 0.077 | 1.107 | 12.71 | 2.14 | 1.366 | 1.307 | 1.42 | 0.47 | 0.543 | 0.03 | 0.105 |
| 36032 | 4083 | | Cet. niv. | | 6 | 0.001 | 0.098 | 1.341 | 17.49 | 2.47 | 1.663 | 1.607 | 1.87 | 0.21 | 0.731 | 0.03 | 0.071 |
| 36033 | 4084 | | Cet. niv. | | 7 | 0.007 | 0.027 | 0.542 | 4.92 | 1.54 | 1.018 | 0.884 | 0.78 | 0.09 | 0.369 | 0.01 | 0.028 |
| 36034 | 4085 | | Cet. niv. | | 8 | 0.004 | 0.023 | 0.426 | 4.10 | 1.08 | 0.668 | 0.601 | 0.81 | 0.07 | 0.236 | 0.01 | 0.026 |
| 36035 | 4086 | | Cet. niv. | | 9 | 0.024 | 0.103 | 1.321 | 15.88 | 1.64 | 0.897 | 0.798 | 1.28 | 0.46 | 0.335 | 0.03 | 0.082 |
| 36036 | 4088 | | Cet. niv. | | 10 | 0.022 | 0.072 | 1.062 | 11.53 | 1.96 | 1.431 | 1.169 | 1.58 | 0.40 | 0.418 | 0.03 | 0.058 |

| ID no. | Lab no | % d.w. | Species | Shell (cm) | Station | Hg | Cd | Pb | Zn | Cu | Cr | Ni | As | Se | Co | Mo | Au |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36036 | 4089 | | Cet. niv. | | 10 | 0.033 | 0.063 | 1.022 | 10.79 | 1.71 | 1.271 | 0.945 | 1.47 | 0.00 | 0.366 | 0.03 | 0.706 |
| 36037 | 4090 | | Cet. niv. | | 11 | 0.034 | 0.110 | 2.428 | 12.95 | 4.56 | 2.561 | 3.064 | 2.83 | 0.19 | 1.316 | 0.04 | 0.075 |
| 36038 | 4091 | | Cet. niv. | | 12 | 0.008 | 0.121 | 1.371 | 24.19 | 5.19 | 2.955 | 2.631 | 3.28 | 0.20 | 0.984 | 0.03 | 0.076 |
| 36039 | 4092 | | Cet. niv. | | 15 | 0.007 | 0.053 | 0.693 | 26.27 | 0.81 | 0.474 | 0.433 | 0.16 | 0.05 | 0.131 | 0.02 | 0.043 |
| 36040 | 4093 | | Cet. niv. | | 17 | 0.027 | 0.053 | 0.995 | 21.21 | 1.12 | 0.602 | 0.652 | 0.47 | 0.30 | 0.211 | 0.02 | 1.300 |
| 36041 | 4094 | | Cet. niv. | | 19 | 0.072 | 0.059 | 0.949 | 18.87 | 1.26 | 0.662 | 0.538 | 0.42 | 0.24 | 0.179 | 0.02 | 5.370 |
| *Background* | | | Cet. niv. | *Average* | | *0.033* | *0.081* | *1.076* | *21.61* | *0.97* | *0.68* | | *0.24* | | *0.157* | | |
| *Background* | | | Cet. niv. | *SD* | | *0.006* | *0.029* | *0.378* | *7.28* | *0.77* | *1.22* | | *0.27* | | *0.157* | | |
| 35830 | 4133 | 39.23 | Myo. sco. | | U 1 | 0.022 | 0.975 | 0.002 | 31.33 | 1.72 | 0.009 | 0.025 | 1.79 | 0.47 | 0.020 | 0.05 | 0.012 |
| 35831 | 4134 | 25.48 | Myo. sco. | | U 1 | 0.032 | 1.442 | 0.002 | 37.02 | 2.15 | 0.050 | 0.016 | 2.18 | 0.45 | 0.023 | 0.07 | 0.412 |
| 35832 | 4135 | 32.35 | Myo. sco. | | U 1 | 0.015 | 0.341 | 0.000 | 26.35 | 0.97 | 0.573 | 0.039 | 2.28 | 0.69 | 0.008 | 0.18 | 0.019 |
| 35833 | 4136 | 32.59 | Myo. sco. | | U 1 | 0.034 | 0.816 | 0.004 | 32.39 | 1.30 | 0.001 | 0.041 | 1.56 | 0.73 | 0.014 | 0.05 | 0.037 |
| 35834 | 4137 | 41.48 | Myo. sco. | | U 2 | 0.011 | 0.117 | 0.002 | 22.90 | 0.78 | 0.007 | 0.013 | 2.02 | 0.74 | 0.006 | 0.04 | 0.011 |
| 35835 | 4138 | 41.61 | Myo. sco. | | U 2 | 0.016 | 0.058 | 0.019 | 54.92 | 3.07 | -0.002 | 0.015 | 3.19 | 0.44 | 0.024 | 0.06 | 0.027 |
| 35835 | 4139 | 41.61 | Myo. sco. | | U 2 | 0.014 | 0.056 | 0.014 | 51.35 | 2.96 | 0.012 | 0.027 | 2.90 | 0.34 | 0.022 | 0.05 | 0.835 |
| 35836 | 4140 | 36.43 | Myo. sco. | | U 2 | 0.003 | 0.136 | 0.013 | 43.55 | 3.10 | 0.005 | 0.015 | 3.74 | 0.45 | 0.022 | 0.06 | 0.029 |
| 35837 | 4141 | 35.04 | Myo. sco. | | U 2 | 0.029 | 0.284 | 0.003 | 20.51 | 0.92 | 0.007 | 0.018 | 3.34 | 0.84 | 0.026 | 0.05 | 0.016 |
| 35838 | 4142 | 35.00 | Myo. sco. | | U 3 | 0.052 | 0.511 | 0.001 | 31.94 | 1.90 | 0.010 | 0.020 | 2.35 | 0.61 | 0.036 | 0.05 | 0.033 |
| 35839 | 4143 | 38.46 | Myo. sco. | | U 3 | 0.019 | 0.567 | 0.003 | 28.50 | 1.59 | 0.014 | 0.036 | 3.23 | 0.96 | 0.030 | 0.07 | 0.049 |
| 35840 | 4144 | 24.08 | Myo. sco. | | U 3 | 0.026 | 0.296 | 0.006 | 38.62 | 5.25 | 0.005 | 0.048 | 3.72 | 0.94 | 0.032 | 0.11 | 0.083 |
| 35841 | 4145 | 26.53 | Myo. sco. | | U 3 | 0.042 | 0.414 | 0.004 | 27.74 | 2.32 | -0.002 | 0.028 | 3.75 | 1.77 | 0.038 | 0.09 | 0.041 |
| 35842 | 4146 | 25.20 | Myo. sco. | | U 4 | 0.057 | 0.408 | 0.000 | 32.65 | 3.02 | 0.000 | 0.017 | 4.25 | 0.70 | 0.031 | 0.06 | 0.034 |
| 35843 | 4148 | 35.09 | Myo. sco. | | U 4 | 0.051 | 0.408 | 0.001 | 23.50 | 0.66 | 0.004 | 0.011 | 4.14 | 0.60 | 0.012 | 0.03 | 0.035 |
| 35844 | 4149 | 35.71 | Myo. sco. | | U 4 | 0.090 | 0.313 | 0.000 | 18.69 | 0.90 | 0.000 | 0.006 | 2.22 | 0.41 | 0.008 | 0.03 | 0.032 |
| 35845 | 4150 | 26.85 | Myo. sco. | | U 4 | 0.041 | 0.414 | 0.001 | 23.21 | 3.95 | 0.001 | 0.036 | 1.80 | 0.54 | 0.014 | 0.06 | 0.026 |
| *Background* | | | Myo. sco. | *Average* | | *0.028* | *1.041* | *0.004* | *32.14* | *1.80* | *0.016* | | *3.23* | | *0.021* | | |
| *Background* | | | Myo. sco. | *SD* | | *0.013* | *0.404* | *0.003* | *1.64* | *0.66* | *0.019* | | *2.07* | | *0.017* | | |
| 35826 | 4151 | 25.47 | Sal. alp. | | | 0.058 | 0.133 | 0.011 | 27.21 | 14.07 | 0.121 | -0.021 | 0.24 | 2.06 | 0.043 | 0.27 | 0.042 |
| 35827 | 4152 | 24.93 | Sal. alp. | | | 0.047 | 0.173 | 0.007 | 25.18 | 9.29 | 0.084 | -0.016 | 0.20 | 2.23 | 0.123 | 0.18 | 0.038 |
| 35828 | 4153 | 22.66 | Sal. alp. | | | 0.056 | 0.197 | 0.005 | 20.28 | 4.64 | 0.103 | -0.018 | 0.12 | 0.87 | 0.023 | 0.15 | 0.024 |
| 35828 | 4154 | 22.66 | Sal. alp. | | | 0.057 | 0.233 | 0.011 | 23.41 | 5.93 | 0.093 | -0.004 | 0.16 | 1.04 | 0.024 | 0.15 | 0.086 |
| 35829 | 4155 | | Sal. alp. | | | 0.050 | 0.097 | 0.004 | 23.34 | 5.16 | 0.103 | -0.039 | 0.24 | 2.23 | 0.095 | 0.20 | 0.047 |
| *Background* | | | Sal. alp. | *Average* | | *0.025* | *0.077* | *0.005* | *34.88* | *8.72* | *0.025* | | *0.45* | | *0.041* | | |
| *Background* | | | Sal. alp. | *SD* | | *0.009* | *0.026* | *0.002* | *6.13* | *10.22* | *0.022* | | *0.13* | | *0.013* | | |

d.w. = Dry weight; w.w = Wet weight; Myt. edu. = Blue mussel; Fuc. ves. = Brown seaweed; Cet. niv. = Lichen, *Cetraria nivalis*; Myo. sco. = Shorthorn sculpin; Sal. alp. = Arctic char.

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This third monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland during 2-9 August 2006. Three shipments of ore had been transported to Spain for gold extraction since the last monitoring study performed in August-September 2005. Samples were collected at four to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River, and lichens were collected at 20 stations in the Kirkespir Valley. Samples were analysed for 12 elements with an ICP-MS. Elevated concentrations (2-15 times) of Cu, Cr, As and Co in lichens were found at the waste rock depot and in the camp area. Elevations in these two areas were not different from those found in 2005. The contamination of Cu, Cr and Co from the road was smaller in 2006 than in 2005, but elevated concentrations can, as in 2005, be found to a distance of about 1000 m from the road. Co was slightly elevated in seaweed from only one marine station in the Kirkespir Bay. Compared to the two former years the marine environment has gradually become less polluted. Cd was elevated twice in resident Arctic chars. No elevations were seen in 2005, whereas Cr and Co were slightly elevated in 2004. In 2006 the main impact from mining activities was observed in lichens. The rate of dust pollution should be evaluated by transplanting lichens from uncontaminated areas to the Nalunaq area.

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