National Environmental Research Institute
University of Aarhus · Denmark

NERI Technical Report No. 662, 2008

Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2007

[Blank page]

National Environmental Research Institute
University of Aarhus · Denmark

NERI Technical Report No. 662, 2008

Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2007

Christian M. Glahder
Gert Asmund
Frank Riget

Data sheet

Series title and no.: NERI Technical Report No. 662

Title: Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2007

Authors: Christian M. Glahder, Gert Asmund & Frank Riget
Department: Department of Arctic Environment

Publisher: National Environmental Research Institute ©
University of Aarhus - Denmark
URL: http://www.neri.dk

Year of publication: March 2008
Editing completed: February 2008
Referee: Poul Johansen

Financial support: Nalunaq Gold Mine A/S

Please cite as: Glahder, C.M., Asmund, G. & Riget, F. 2008: Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2007. National Environmental Research Institute, University of Aarhus, Denmark. 32 pp. – NERI Technical Report No. 662. http://www.dmu.dk/Pub/FR662.pdf

Abstract: This fourth monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 18-25 July 2007. Seven shipments of ore had been transported to Spain and Canada for gold extraction since the last monitoring study performed in August 2006. Biota was collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected in and transplanted to the valley from an uncontaminated area. Samples were analysed for 12 elements with an ICP-MS. In lichens, elevated concentrations (5-20 times) of Cu, Cr, As and Co were found at the waste rock depot and in the camp area. These metals were also in 2007 significantly elevated compared to the background level. The level was significantly higher in 2007 than in 2006, but no trend during 2004-07 is indicated. All metal concentrations in 2005-07 showed a significant decrease with increasing distance to the road. Elevated concentrations of metals could again this year be found to a distance of c. 1000 m from the road. Co was slightly elevated in seaweed from only one marine station. Compared to higher metal concentrations in mainly seaweed in 2004 and 2005 the levels in the marine environment appear in 2006 and 07 to have stabilised around the baseline level. In resident Arctic char livers no metal concentrations were elevated. The rate of dust pollution can in 2008 be evaluated from lichens transplanted to five Nalunaq areas in 2007.

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

Layout: NERI Graphics Group, Silkeborg

Photos incl. front cover: Christian M. Glahder/J. Sommer collects lichens in the black fly season.

ISBN: 978-87-7073-036-5
ISSN (electronic): 1600-0048

Number of pages: 32

Internet version: The report is available in electronic format (pdf) at NERI's website
http://www.dmu.dk/Pub/FR662.pdf

Contents

Summary

This forth monitoring study was carried out in the Nalunaq gold mining area, Nanortalik, South Greenland, on 18-25 July 2007. Seven shipments of ore had been transported to Spain and Canada for gold extraction since the last monitoring study performed August 2006.

Blue mussels, brown seaweed and shorthorn sculpin were sampled at 4-5 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 former monitoring studies.

No elevated concentrations were found in mussels and sculpin livers, while seaweed had slightly elevated Co concentrations at one sampling station. Thus, metal elevations were very few in the bay indicating a very low impact on the marine environment in 2007. Compared to higher concentrations in mainly seaweed in 2004 and 2005 the concentrations of metals in the marine environment appear in the last two years to have stabilised around the baseline level.

In resident Arctic char livers no concentrations were elevated. Compared to the three previous years, Cr, Co and Cd were slightly elevated in 2004 and 2006, while no elevations were found in 2005.

In lichens, concentrations of Cu, Cr, As and Co were, like in the previous years, significantly elevated compared to the background level in the depot and the camp area. Elevations in the two areas in 2007 were 5 times for Cu and Cr, 15-20 times for As and 10 times for Co. Concentrations of the four metals in the two areas were significantly higher in 2007 than in 2006, but no trend during 2004-07 is indicated. During 2004-2007, concentrations in lichens of Cu and As were significantly higher in the camp than in the depot area. The relationship between metal concentrations in lichens and the distance to the gravel road did not differ significantly between the years 2005-2007 for any of the metals. All metal concentrations showed a significant decrease with increasing distance (Fig. 3). Concentrations of Cu, Cr, As and Co above the background level could, as in previous years, be found to a distance of about 1000 m from the road.

Because metals are excreted from lichens at a low rate it can be difficult to detect a reduction in dust pollution. In 2007 we therefore transplanted lichens from an unpolluted area to the Nalunaq area. By analyzing them in 2008 the rate of dust pollution can be determined.

As in previous years, an impact from the mining activities on the local environment could be seen in 2007, primarily in the Kirkespir Valley from dust dispersal. In the river and in the bay, element elevations were very few and the impacted area was as small as in 2006.

Sammenfatning

Denne fjerde moniteringsundersøgelse blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 18. til 25. juli 2007. Siden moniteringen i august 2006 er der blevet udskibet syv malmladninger til henholdsvis Spanien (1) og Canada (6), hvor guldet udvindes.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4-5 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 uforurenet 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 moniteringsundersøgelser.

Der blev ikke fundet forhøjede koncentrationer i muslinger og i ulkelever, mens der i tang var svagt forhøjede koncentrationer af Co på én station. Forhøjelserne var således ganske få i bugten, hvilket tyder på, at det marine miljø i 2007 kun var svagt påvirket. I forhold til de relativt høje niveauer i især tang i 2004 og 2005 har metalkoncentrationerne i bugten de to sidste år været omkring baggrundsniveauet.

I standørred lever blev der ikke fundet forhøjede metal koncentrationer i 2007. I 2004 og 2006 var Cr, Co og Cd lettere forhøjede i forhold til baggrundsniveauet, mens der ikke fandtes forhøjelser i 2005.

I laver fra områderne ved depotet for knust gråbjerg og ved lejren var koncentrationer af Cu, Cr, As og Co som i tidligere år signifikant forhøjede i forhold til baggrundsniveauet. Forhøjelserne i begge områder i 2007 var 5 gange for Cu og Cr, 15-20 gange for As og 10 gange for Co. Disse forhøjelser var for alle fire metaller signifikant højere i 2007 i forhold til 2006, men i forhold til alle årene er der ikke noget der tyder på en generel trend. I perioden 2004-07 var koncentrationerne af Cu og As signifikant højere i laverne fra lejrområdet end fra depotområdet. I perioden 2005-07 blev der ikke for nogen af metallerne fundet signifikante forskelle mellem årene i relationen mellem koncentrationen i lav og afstanden til vejen. For alle metal koncentrationer var der et signifikant faldt med stigende afstande til vejen (Fig. 3). Som i de tidligere år blev der også i 2007 fundet forhøjede koncentrationer af Cu, Cr, As og Co i en afstand af optil ca. 1000 m fra vejen.

Fordi metaller udskilles relativt langsomt fra laver, kan det være vanskeligt at opdage en reduktion af støvspredningen. For at forbedre undersøgelsen transplanterede vi derfor i 2007 laver fra et uforurenet område til mineområdet. Ved at analysere laverne i 2008 kan vi bestemme den årlige støvpåvirkning.

Også i 2007 kunne der spores en påvirkning af mineaktiviteterne i miljøet og igen var det især Kirkespirdalen der var påvirket af støvspredning. I Kirkespirelven og bugten var forhøjelserne ganske lave og det påvirkede område var af samme størrelsesorden som i 2006.

Eqikkaaneq

Taamatut sisamassaanik nalunaarsuilluni misissuineq Kujataani Nanortallup eqqaani, Nalunami eqqaanilu ingerlanneqarpoq 18. julimiit 25- julimut 2007-imi. 2006-imi augustusimi misissuinerup kingornagut aatsitassamik arfineq marloriarluni umiarsuakkut aallarussisoqarnikuuvoq Spaniamut (ataasiarluni) Canadamullu (arfinileriarluni) guulti nunani taakkunani salinneqartussaammat.

Uillut, equutit kanajorlu nalinginnaasoq Iterlassuarmi (Kirkespirbugt) assigiinngitsuni 4-5-ini misissugassanik tigusiffigineqarput, eqaluit sisujuitsut Iterlassuup kuuani kisarineqarlutik tingaasallu *Cetraria nivalis* Iterlassuarmi iterlaanilu katersuiffinni assiginngitsuni 20-ni katersorneqarlutik. Orsuaasat mingutsinneqanngitsumiitt ujaqqanik piiaaviup eqqaanut (AMI1) nuunneqarput (Titartagaq 1). Misissugassat tamarmik pinngoqqaatinik 12-inik (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo aamma Au) akoqarnersut misissorneqarput inernerilu 1998-2001-imi naleqqiussuussivimmeersunut, siusinnerusukkullu misissuinermi pissarsiaasarsimasunut naleqqiussuunneqarlutik uuttortarneqarlutik.

Uillut kanassullu tinguini akoqarnerulersimanermik nassaatoqaangilaq, qeqqussanili misissuiffimmi ataatsimi Co akuusoq annikitsumik annertuseriarsimavoq. Taamaalilluni iterlammi annertuseriarnerit ikittuinnaapput, tamannalu paasisariaqarunarluni imaq 2007-imi annikitsuinnarmik sunnerneqarsimasoq. 2004-mi 2005-imilu pingaartumik qeqqussani akuusut, annertujaarsimammata saffiugassat iterlammi akuusut ukiuni kingullerni marlunni naleqqiussuussivimmiittutut iinnangajassumapput.

Eqalunni sisujuitsuni saffiugassanik akoqarnerulersimanermik 2007-imi malugisaqartoqanngilaq. 2004-mi 2006-imilu Cr, Co aamma Cd sanilliussuussivimmut naleqqiullugit annikitsumik annertusilaarsimapput, 2005-imili annertuseriarneqarsimanngilaq.

Orsuaasani gråbjergimut aserortikkamut katersuiffiup eqqaanniittuni aammalu najugaqarfimmiittuni Cu, Cr, As aamma Co-p akuunera siornatigutut sanilliussuussivimmut naleqqiullugu malunnartumik annertuseriarsimapput. Taakkunani marlunni 2007-imi Cu aamma CR tallimariaammik, As 15-20-eriaammik aammalu Co quleriaammik annertuseriarsimallutik. Saffiugassanut sisamanut taakkununnga tunngatillugu annertuseriarneq 2006-imut naleqqiullugu 2007-imi malunnarluarpoq, kisiannili ukiunut tamanut sanilliullugu nalinginnaasumik taamaaliartulersoqarneranik malunnartoqanngilaq. 2004-07-imut Cu aamma As-ip akuuneri malunnartumik najugaqarfiup eqqaaniittuni tingaasani malunnarnerusimavoq ujaqqanik katersuiffimmut naleqqiullugu. 2005-07-imut saffiugassat arlaannaalluunnit ukiut ingerlaneranni orsuaasani aqqusernullu ungasissusianut naleqqiullugu pisumut naleqqiullugu malunnaatilimmik allannguuteqarsimanera malugineqanngilaq. Saffiugassat tamarmik akuunerat eqqarsaatigalugu aqqusineq ungasilliartortillugu akkusut annikilliartornerat malunnarluarpoq (titartagaq 3). Ukiuni siuliinisulli 2007-imi malugineqarput Cu, Cr, As aamma Co aqqusinermiit 1000 m miss. ungasissusilik tikillugu annertuseriarsimapput.

Saffiugassat orsuaasaniit arriitsuinnarmik akuujunnaariartortarmata pujoralatserinerup siaruariartorneratigut annikillleriarnermik malugisaqarnissaq ajornakusoorsinnaasarpoq. Misissuineq pitsaanerulersinniarlugu 2007-imi orsuaasat mingutsinneqanngitsut piiaaviup eqqaanut nuussimavagut. Orsuaasat 2008-mi misissornerisigut ukiumut pujoralammit sunnersimaneqarnerup annertussusia aalajangersinnaassavarput.

2007-imissaaq malugineqarsinnaavoq aatsitassarsiornerup avatangiisinik sunniisimanera taamatulliaasiit pingaartumik Iterlassuarmi pujoralatitsinikkut malunnartoq. Iterlassuup Kuuani iterlaanilu annertuseriarnerit annikitsuarannguupput nunalu sunnerneqarsimasoq 2006-imisut annertussuseqaannarluni.

Photo 1. Blue mussel and brown seaweed are collected at station AMI1 on Amitsoq Island by Jette Sommer and Jørgen Andersen.

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 (c. 20 g gold/ton ore), gold-only mineralization associated with quartz-veins. The ore sheet has an average strike angle of 45-50º 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 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 sail the ore to a foreign gold extraction plant. During the period 2004 to 2006 the ore was shipped to Rio Narcea Gold Mines Ltd, Spain. From 7 February 2007 onwards the ore has been sailed to Nugget Pond, Newfoundland, Canada. Close to the pier is a stockpile area with an approximate capacity of 60,000 tonnes (Crewgold 2007). The first shipment of gold ore took place on 7 January 2004. Up until the third monitoring study, performed during 2-9 August 2006, a total of nine shipments with approximately 300,000 tonnes (wet weight) of ore were transported to Spain. The fourth monitoring study, described in the present report, was performed between 18 and 25 July 2007. During the period from the third to the fourth monitoring study, a total of seven shipments of c. 120,000 tonnes of ore were sailed away for extraction; one shipment went to Spain, while the remainder six went to Canada. The bulk carriers that transport the ore to Canada have a capacity of 20-30,000 tonnes (Crewgold 2007, K. Christensen, NGM, July 2007, *in litt.*).

1.2 Environmental baseline studies

Prior to the mine start a number of 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.

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 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.

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.

1.4 Monitoring studies 2004 – 2006

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 mo-

nitoring reports (Glahder & Asmund 2005, 2006, 2007) and they can be found on the NERI web address:
http://www.dmu.dk/International/Publications/NERI+Technical+Reports/.

1.5 Monitoring study 2007

The monitoring study was performed in the Nalunaq area during 18 -25 July 2007.

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 2006 and collected for analyses in 2007.
- 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 transplanted from AMI1 to five stations (M2, 5, 6, 11 and 12) in Kirkespir Bay and Valley. Samples will be analysed late 2008.
- Fish livers from 24 specimens consisted of 20 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 66 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).

1.6 Acknowledgements

We wish to thank G. Bagnell and K. Christensen, NGM, for transportation to and from Narsarsuaq and around in the Kirkespir area, accommodation and for providing us with technical information. J. Andersen, laboratory technician, NGM, is thanked for his participation in collecting the samples, Apollus Gyllich, NGM, for sailing the boat during sampling and Jette Sommer for her participation in collecting and preparing the samples.

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 0.3-0.6 m (Farvandsvæsnet 2006).

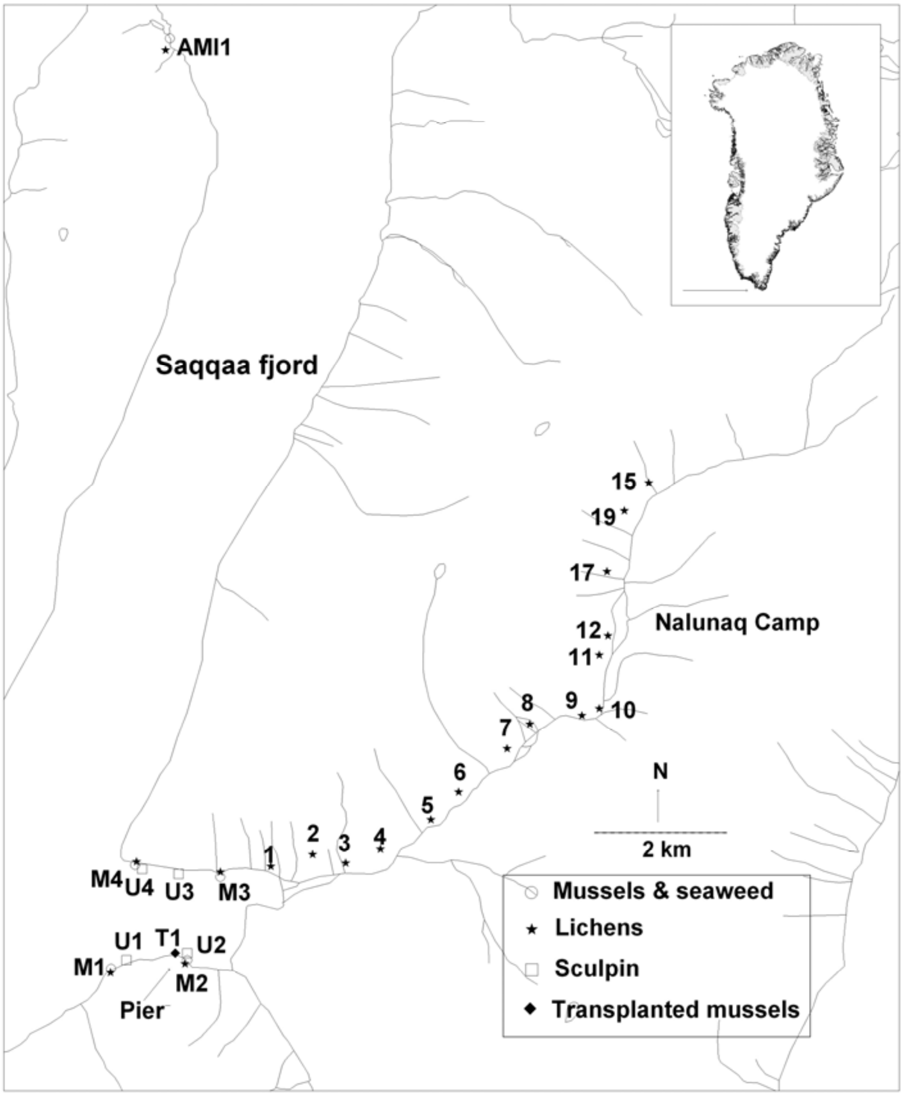

Figure 1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland.

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. Lichens were transplanted from AMI1 to stations M2, 5, 6, 11 and 12.

Two size groups (4-5 and 5-6 cm) of mussels were collected at each of the four stations M1-M4. 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 2006 from north-eastern 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 (size groups 4-5 cm and 5-6 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 changed.

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

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 20 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. Lichens were sampled at the station AMI1 on Amitsoq Island and transplanted to stations M2, 5, 6, 11 and 12 (Appendix 1 and 4). It is the intention to sample and analyse the lichens during the monitoring study in 2008.

2.2 Analyses

All samples were transported either frozen or dry directly to NERI on 25 July 2007. The analyses were performed according to the "Test Report no. 222" (Asmund 2007). A total of 66 samples from blue mussel (12), brown seaweed (10), livers of Shorthorn sculpin (20), 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 accreditation No. 411. Simultaneously with the Nalunaq samples the reference materials Dorm-2, Dolt-3 and Tort-2 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, except for lead in the material Dorm-2, where 2 out of 3 analyses gave clearly too low results. However the two other reference materials with higher lead concentrations gave satisfying results for lead. Therefore, analytical results for lead below 0.1 mg/kg should not be over-interpreted.

Table 1. ICP-MS analytical results of reference material (Dorm-2, 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 are analysed. Concentrations are in mg/kg.

	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limit	*0.004*	*0.001*	*0.030*	*1.25*	*0.123*	*0.027*	*0.128*	*0.023*	*0.032*	*0.016*	*0.002*	*0.0003*
Dorm-2	3.33	0.058	0.011	23.5	1.91	30.17	17.574	19.50	1.64	0.162	0.320	0.0008
Dorm-2	3.25	0.049	0.060	29.5	1.99	35.06	19.686	17.43	1.69	0.181	0.580	0.0028
Dorm-2	3.29	0.058	0.017	26.9	2.31	33.58	19.487	19.76	1.84	0.178	0.300	0.0013
Certificate	*4.64*	*0.043*	*0.065*	*25.6*	*2.34*	*34.70*	*19.40*	*18.00*	*1.40*	*0.182*		
Dolt-3	2.67	20.7	0.269	88.4	30.6	3.36	3.092	9.37	7.68	0.253	3.40	0.0013
Certificate	*3.37*	*19.4*	*0.319*	*86.6*	*31.2*		*2.720*	*10.20*	*7.06*			
Tort-2	0.23	34.7	0.328	223.6	115.5	1.02	3.538	28.70	6.66	0.583	1.40	0.0011
Tort-2	0.21	28.7	0.441	194.2	107.6	1.27	2.583	22.26	6.24	0.467	1.18	0.0037
Tort-2	0.20	28.3	0.334	193.1	108.1	0.70	2.897	22.07	6.12	0.473	1.07	0.0025
Certificate	*0.27*	*26.7*	*0.350*	*180.0*	*106.0*	*0.77*	*2.500*	*21.60*	*5.63*	*0.510*	*0.95*	

2.3 Statistical analyses

Differences in Co concentrations in brown seaweed were tested with an F-test to test for equal variances followed by a two-sample t-test assuming equal variances.

Prior to analyses of variance and covariance, data were logarithmic (base e) transformed to meet the assumptions of normal distribution and variance homogeneous of parametric tests. The level of statistical significance used was $p=0.05$.

We tested 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 2004-2007 compared to background concentrations using a one-way analysis of variance (ANOVA). Tukey's studentized range test was applied as a posterior test.

Also, we tested if there were any differences between areas and years using a two-way ANOVA, including the interaction between the two factors; the test was reduced if the interaction was not significant and the two-way ANOVA was repeated and followed by Tukey's studentized range test.

Finally, we tested the correlation between concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road with an analysis of covariance (ANCOVA), including the interaction between the covariate distance and the factor year; the test was reduced if the interaction term was not significant and the ANCOVA was repeated.

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 five mussel stations (M1-4 and T1), four seaweed stations (M1-4) and four sculpin stations (U1-U4) (Fig. 1).

No elevated concentrations were found in *blue mussel* samples. The mussels transplanted in 2006 from the northern Amitsoq Island (AMI1) to station T1 at the pier had low concentrations of the four elements (Cu, Cr, As and Co) compared to the background concentrations. These average concentrations were slightly lower than those analysed in mussels from AMI1 (Appendix 3).

Brown seaweed at station M3 had about twice as high concentrations of Co compared to background concentrations (t-test, two-sample assuming equal variances, $p=0.00002$, $t=-12.4$, $df=6$). None of the other seaweed stations had elevated concentrations of the elements that were analysed (Appendix 3).

In *sculpin liver* average concentrations were not elevated compared to the background concentrations.

In 2007, 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.

In 2004 and 2005, concentrations of especially Cr, but also concentrations of Cu, Co and Zn were elevated in seaweed. 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 found to be very low. This was found also in 2006 where the only significant elevation in the marine environment was found in seaweed from station M3 and again Co was the only element that was elevated.

The concentrations of metals in the marine environment appear in the last two years to have stabilised around the baseline level.

3.2 The freshwater environment

In resident *Arctic char* livers no average concentrations were elevated compared to baseline concentrations. Resident Arctic char stay all their life in the river, whereas the migratory form summers in the Kirkespir Bay and the Saqqaa Fjord. Compared to the three previous years, Cr was elevated 2-3 times in 2004 and 2006, Co 3 times in 2004 and Cd 2 times in 2006, while no elevations were found in 2005. In conclusion, only minor elevations of Cr, Co and Cd have been seen in two of the four years.

3.3 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* (Cetraria nivalis) of Cu, Cr, As and Co were significantly higher than background concentrations in the years 2004-2007 (ANOVA, $p<0.001$; Tukey's test, $p<0.05$). Elevations in the two areas in 2007 were 5 times for Cu and Cr, 15-20 times for As and 10 times for Co (Fig. 2a, Appendix 3). Concentrations of the four metals at the pier (station M2) appear to be elevated (Cu, Cr and Co 2-4 times, As 15 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. 2a).

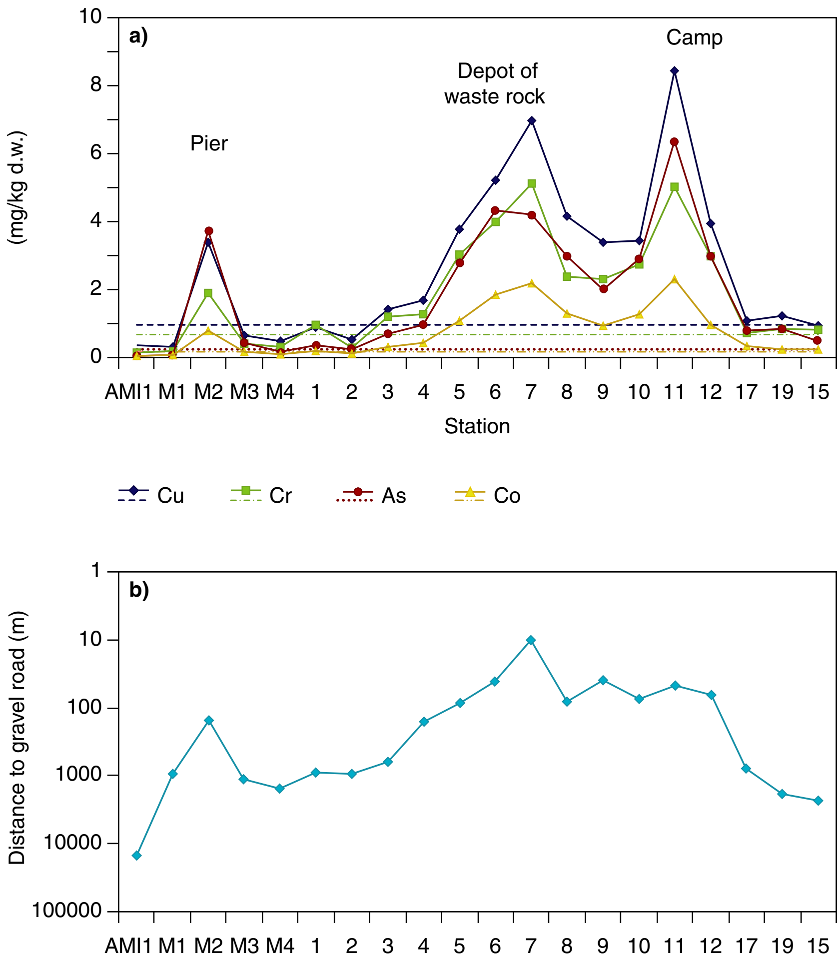

Figure 2. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis.*

For localisation of lichen stations refer to Fig. 1. M1-M4 are stations in the Kirkespir Bay area, stations 1-17 are situated in the Kirkespir Valley from coast (1) to up-stream 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 lichen stations.

Concentrations of the four metals in the two areas were in general significantly higher in 2007 than in 2006 (Tukey's test, $p<0.05$). There seems to be no trend in concentrations over the four years where the ranking from highest to lowest concentrations for all metals is 2007, 2005, 2004 and 2006. In all of the years 2004-2007, concentrations in lichens of Cu and As were significantly higher (Tukey's test, $p<0.05$) in the camp area than in the depot area.

As in 2006 (Glahder & Asmund 2007), we have tested the concentrations of Cu, Cr, As and Co in lichens for a possible correlation to the perpendicular distance to the gravel road (Fig. 2a, b & 3). These four metals tested showed the highest elevations compared to background levels. The relationship between concentrations and distance did not differ significantly between the years 2005-2007 for any of the metals (ANCOVA, $p>0.45$). Furthermore, all metal concentrations showed a significantly decrease with increasing distance (ANCOVA, $p<0.001$).

Figure 2a shows concentrations of the four elements in lichens from Amitsoq Island, the Kirkespir Bay area and the Kirkespir Valley. Three areas have markedly higher concentrations of the four elements namely the pier area, the depot of waste rock and the camp and mine area. The relatively high concentrations in these areas can mostly be explained as an effect of the nearness to the gravel road illustrated by Figure 2b. Figure 2 also shows that the high concentrations in the camp area are higher than explained by the distance to the road and this finding is confirmed by Figure 3, where element concentrations in lichens from station 11 (situated in the camp area) also are well above the regression lines.

Photo 2. Lichens are sampled at station M1 just south of the Kirkespir Bay.

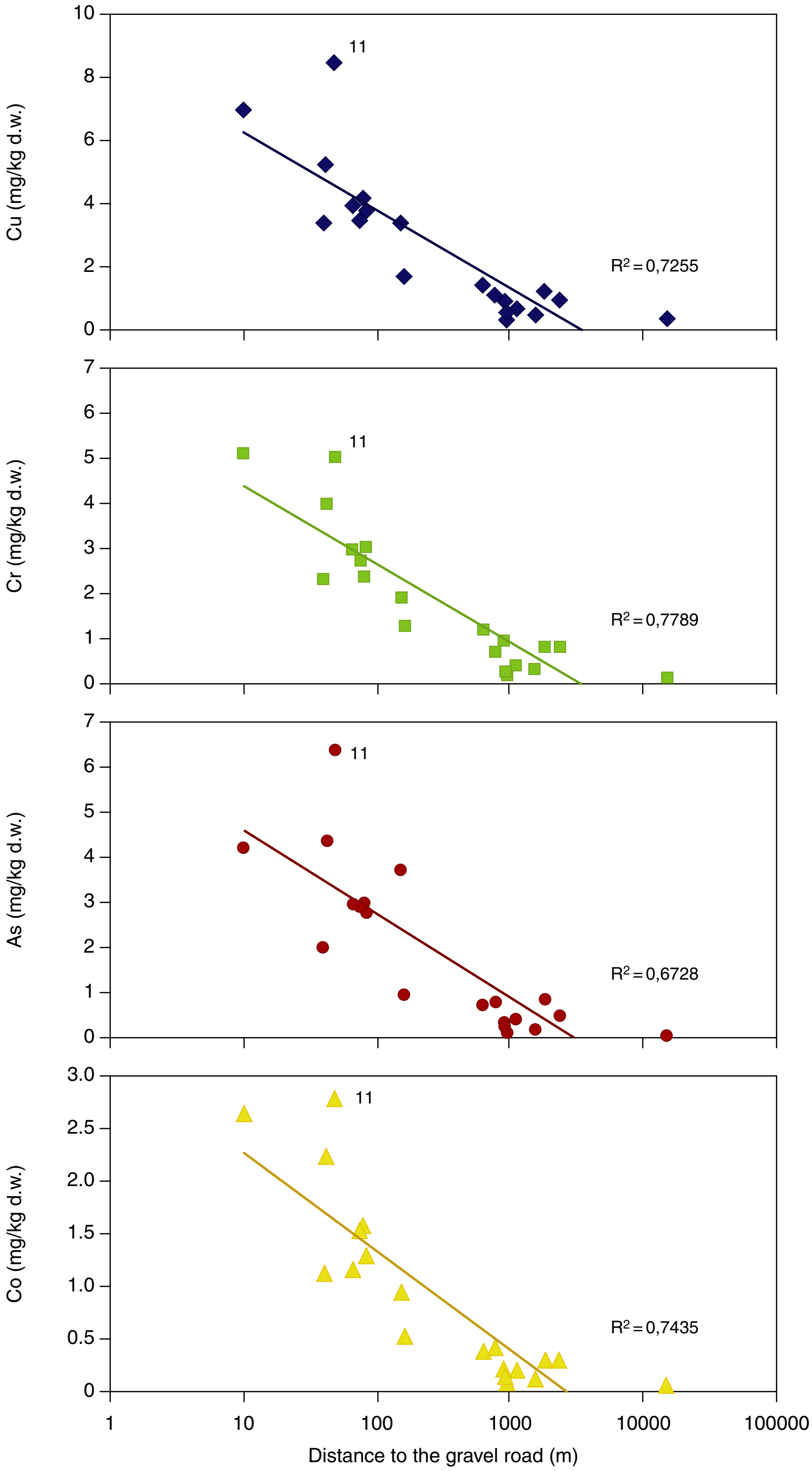

Figure 3. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis* as a function of stations distance to the gravel road (in meter). Station no. 11 from the camp area had metal concentrations well above the trend line. d.w. = dry weight.

It is concluded that concentrations of Cu, Cr, As and Co in 2007, like in the previous three years, were significantly elevated compared to the background level at the depot of crushed waste rock and at the camp and mine area. Concentrations of the four metals in the two areas were in general significantly higher in 2007 than in 2006, but this seems not to indicate a trend from 2004 where monitoring began. In all of the years 2004-2007, concentrations in lichens of Cu and As were significantly higher in the camp area than in the depot area. The relationship between metal concentrations in lichens and the distance to the gravel road did not differ significantly between the years 2005-2007 for any of the metals. All metal concentrations showed a significant decrease with increasing distance. Concentrations of Cu, Cr, As and Co above the background level can, as in previous years, 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. In 2007, we have tried to solve this problem by transplanting lichens from an uncontaminated area on the northern part of Amitsoq Island to the Nalunaq area. Lichens were transplanted to the three most contaminated areas at the pier, near the depot of crushed waste rock and in the camp and mine area (Appendix 4). We plan to leave the lichens for one year, collect them in July or August 2008 and analyze them for metal concentrations. By repeating this procedure every year, we will be able to measure the year to year variation in the lichen contamination and thereby determine the rate of dust pollution in these specific areas.

4 Conclusions

The report describes the results of the fourth year of environmental monitoring in the Nalunaq Gold Mine area.

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 2007. In 2004 and 2005, concentrations of especially Cr, but also concentrations of Cu, Co and Zn were elevated in seaweed. In 2004, elevations of Cr were found in sculpin livers and of Co in blue mussel. The concentrations of metals in the marine environment appear in the last two years to have stabilised around the baseline level.

In resident Arctic char livers no average concentrations were elevated in 2007 compared to baseline concentrations. Compared to the three previous years, Cr, Co and Cd were slightly elevated in 2004 and 2006, while no elevations were found in 2005. Thus, only minor elevations of Cr, Co and Cd have been seen in two of the four years.

In the lichen *Cetraria nivalis* concentrations of Cu, Cr, As and Co in 2007, like in the previous years, were significantly elevated compared to the background level at the depot of crushed waste rock and at the camp and mine area. Elevations in the two areas in 2007 were 5 times for Cu and Cr, 15-20 times for As and 10 times for Co. Concentrations of the four metals in the two areas were in general significantly higher in 2007 than in 2006, but this seems not to indicate a trend from 2004 where monitoring began. In all of the years 2004-2007, concentrations in lichens of Cu and As were significantly higher in the camp area than in the depot area. The relationship between metal concentrations in lichens and the distance to the gravel road did not differ significantly between the years 2005-2007 for any of the metals. All metal concentrations showed a significant decrease with increasing distance. Concentrations of Cu, Cr, As and Co above the background level could, as in previous years, be found to a distance of about 1000 m from the road.

Because metals are excreted from the lichens at a low rate, a reduction in dust pollution will be difficult to detect within a few years period. To solve this problem, lichens were in 2007 transplanted from an uncontaminated area to the Nalunaq area. By leaving the lichens for one year and then analyze them for metal concentrations, we will be able to measure the year to year variation in the lichen contamination and thereby determine the rate of dust pollution in different areas.

As in the three previous years, an impact from the mining activities on the local environment could be seen in 2007, primarily in the Kirkespir Valley from dust dispersal. The impact from the road was in 2007 higher than in 2006. In the river and in the bay, element elevations were very few and the impacted area was as small as in 2006.

5 References

Asmund, G. 2007: Test report no. 222. Analyses of biota samples from Nalunaq 2007. – National Environmental Research Institute, University of Aarhus, 5 pp.

Boje, J. 1989: Fjeldørredundersøgelser ved Itillersuaq, Nanortalik 1988 (In Danish with English summary: Arctic char study at Itillersuaq, Nanortalik 1988). – Greenland Environmental Research Institute, Denmark, 36 pp.

Crewgold 2007:
http://www.crewgold.com/om_nalunaq_gold_mine.php

Farvandsvæsnet 2006: Tidevandstabeller 2007 for grønlandske farvande. – Farvandsvæsnet, Danmark, 117 pp;
http://www.fomfrv.dk/data_produkter/datafiler/TT2007/Tide07_Gr.pdf
(11 February 2008).

Glahder, C. M. & Asmund, G. 2005: Environmental monitoring at the Nalunaq Gold Mine, South Greenland 2004. - National Environmental Research Institute, Technical Report No. 546, 34 pp.

Glahder, C. M. & Asmund, G. 2006: Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2005. - National Environmental Research Institute, Denmark, Technical Report No. 567, 37 pp.

Glahder, C. M. & Asmund, G. 2007: Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2006. - National Environmental Research Institute, Denmark, Technical Report No. 614, 26 pp.

Glahder, C. M., Asmund, G., Josefsen, A., Burmeister, A. D. & Jespersen, M. 2005: Nalunaq environmental baseline study 1998-2001. - National Environmental Research Institute, Technical Report No. 562, 90 pp.

Lakefield 1998a: Progress Report No. 1, July 1998. Nalunaq Project, Environmental baseline, solids and liquids characterisation testing. Project No. L.R. 7777-452. Prepared for: Nunaoil A/S, Greenland. – Lakefield Research Limited, Canada, 60 pp.

Lakefield 1998b: Progress Report No. 2 (*draft*), June 1998. Nalunaq Project, Environmental baseline, solids and liquids characterisation testing. Report Prepared for: Nunaoil A/S, Pilestraede 52, DK-1112 Copenhagen K, Denmark. – Lakefield Research Limited, Canada, 7 pp.

Lakefield 1999a: Progress Report No. 3, February 1999. Nalunaq I/S, Environmental baseline study. Results of the phase 3 sampling program. Project No. L.R. 7777-452. Report Prepared for: Nunaoil A/S, Pilestraede 52, DK-1112 Copenhagen K, Denmark. – Lakefield Research Limited, Canada, 7 pp.

Lakefield 1999b: Progress Report No. 4, May 1999. Nalunaq I/S, Environmental baseline study. Results of the phase IV sampling program. Project No. L. R. 7777-565. Report Prepared for: Nalunaq I/S, O. H. Bangsvei 54-58, N-1363, Hovik, Norway. – Lakefield Research Limited, Canada, 3 pp.

Lakefield 1999c: Progress Report No. 5, August 1999. Nalunaq I/S, Environmental baseline study. Results of the phase V sampling program. Project No. L.R. 7777-565. Report Prepared for: Nalunaq I/S, O. H. Bangsvei 54-58, N-1363, Hovik, Norway. – Lakefield Research Limited, Canada, 4 pp.

Lakefield 1999d: Progress Report No. 6, November 1999. Nalunaq I/S, Environmental baseline study. Results of the phase VI sampling program. Project No. L.R. 7777-565. Report Prepared for: Nalunaq I/S, O.H. Bangsvei 54-58, N-1363, Hovik, Norway. – Lakefield Research Limited, Canada, 16 pp.

SRK Consulting 2002: Nalunaq Gold Project. Environmental Impact Assessment. Report prepared for Nalunaq I/S. - Steffen, Robertson & Kirsten (UK) Ltd., Windsor Court, 1-3 Windsor Place, CF103BX, United Kingdom.

Photo 3. The camp and mine seen from the archaeological summer dwellings towards southwest on July 2007.

Appendix 1. Samples and stations

ID-No	Sample type	Latin name	Collec-tion date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
33973	Lichen	Cetraria nivalis	20070722	1	60	19'34''	44	55'22''
33974	Lichen	Cetraria nivalis	20070722	2	60	19'38''	44	54'40''
33975	Lichen	Cetraria nivalis	20070722	3	60	19'35''	44	54'10''
33976	Lichen	Cetraria nivalis	20070722	4	60	19'43''	44	53'38''
33977	Lichen	Cetraria nivalis	20070722	5	60	19'57''	44	52'48''
	Lichen	Cetraria nivalis	20070722	5-transplanted	60	19'57.1''	44	52'47.7''
33978	Lichen	Cetraria nivalis	20070722	6	60	20'10''	44	52'18''
	Lichen	Cetraria nivalis	20070722	6-transplanted	60	20'10.1''	44	52'18.2''
33979	Lichen	Cetraria nivalis	20070720	7	60	20'32''	44	51'37''
33980	Lichen	Cetraria nivalis	20070720	8	60	20'44''	44	51'07''
33981	Lichen	Cetraria nivalis	20070720	9	60	20'49''	44	50'14''
33982	Lichen	Cetraria nivalis	20070720	10	60	20'51''	44	49'58''
33983	Lichen	Cetraria nivalis	20070720	11	60	21'17''	44	49'57''
	Lichen	Cetraria nivalis	20070720	11-transplanted	60	21'16.5''	44	49'56.9''
33984	Lichen	Cetraria nivalis	20070720	12	60	21'28''	44	49'49''
	Lichen	Cetraria nivalis	20070720	12-transplanted	60	21'28.1''	44	49'50.3''
33985	Lichen	Cetraria nivalis	20070718	15	60	22'43''	44	49'08''
33986	Lichen	Cetraria nivalis	20070718	17	60	21'59''	44	49'52''
33987	Lichen	Cetraria nivalis	20070718	19	60	22'30''	44	49'31''
33988	Lichen	Cetraria nivalis	20070721	M 1	60	18'41''	44	58'01''
33989	Lichen	Cetraria nivalis	20070721	M 2	60	18'46''	44	56'47''
	Lichen	Cetraria nivalis	20070721	M2-transplanted	60	18'45.2''	44	56'48.5''
33990	Lichen	Cetraria nivalis	20070720	M 3	60	19'29''	44	56'15''
33991	Lichen	Cetraria nivalis	20070720	M 4	60	19'35''	44	57'37''
33992	Lichen	Cetraria nivalis	20070719	AMI 1	60	26'20''	44	57'04''
34085	Brown seaweed	Fucus vesiculosus	20070721	M 1	60	18'41''	44	58'01''
34086	Brown seaweed	Fucus vesiculosus	20070721	M 1	60	18'41''	44	58'01''
34087	Brown seaweed	Fucus vesiculosus	20070721	M 2	60	18'46''	44	56'47''
34088	Brown seaweed	Fucus vesiculosus	20070721	M 2	60	18'46''	44	56'47''
34089	Brown seaweed	Fucus vesiculosus	20070720	M 3	60	19'29''	44	56'15''
34090	Brown seaweed	Fucus vesiculosus	20070720	M 3	60	19'29''	44	56'15''
34091	Brown seaweed	Fucus vesiculosus	20070720	M 4	60	19'35''	44	57'37''
34092	Brown seaweed	Fucus vesiculosus	20070720	M 4	60	19'35''	44	57'37''
34093	Brown seaweed	Fucus vesiculosus	20070719	AMI1	60	26'20''	44	57'04''
34094	Brown seaweed	Fucus vesiculosus	20070719	AMI1	60	26'20''	44	57'04''
34065	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34066	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34067	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34068	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34069	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34070	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 1	60	18'47''	44	57'45''
34071	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 2	60	18'45''	44	56'46''
34072	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 2	60	18'45''	44	56'46''
34073	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 2	60	18'45''	44	56'46''
34074	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 2	60	18'45''	44	56'46''

ID-No	Sample type	Latin name	Colletion date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
34075	Shorthorn sculpin	Myoxocephalus scorpius	20070721	U 2	60	18'45"	44	56'46"
34076	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 3	60	19'31"	44	56'53"
34077	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 3	60	19'31"	44	56'53"
34078	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 3	60	19'31"	44	56'53"
34079	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 3	60	19'31"	44	56'53"
34080	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 3	60	19'31"	44	56'53"
34081	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 4	60	19'34"	44	57'31"
34082	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 4	60	19'34"	44	57'31"
34083	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 4	60	19'34"	44	57'31"
34084	Shorthorn sculpin	Myoxocephalus scorpius	20070720	U 4	60	19'34"	44	57'31"
33961	Blue mussel	Mytilus edulis	20070721	M 1	60	18'41"	44	58'01"
33962	Blue mussel	Mytilus edulis	20070721	M 1	60	18'41"	44	58'01"
33963	Blue mussel	Mytilus edulis	20070721	M 2	60	18'46"	44	56'47"
33964	Blue mussel	Mytilus edulis	20070721	M 2	60	18'46"	44	56'47"
33965	Blue mussel	Mytilus edulis	20070720	M 3	60	19'29"	44	56'15"
33966	Blue mussel	Mytilus edulis	20070720	M 3	60	19'29"	44	56'15"
33967	Blue mussel	Mytilus edulis	20070720	M 4	60	19'35"	44	57'37"
33968	Blue mussel	Mytilus edulis	20070720	M 4	60	19'35"	44	57'37"
33969	Blue mussel	Mytilus edulis	20070719	AMI 1	60	26'20"	44	57'04"
33970	Blue mussel	Mytilus edulis	20070719	AMI 1	60	26'20"	44	57'04"
33971	Blue mussel	Mytilus edulis	20070719	T 1	60	18'51"	44	56'57"
33972	Blue mussel	Mytilus edulis	20070719	T 1	60	18'51"	44	56'57"
33993	Arctic char	Salvelinus alpinus	20070719	Near waterfall	60	20'47"	44	50'32"
33994	Arctic char	Salvelinus alpinus	20070719	Near waterfall	60	20'47"	44	50'32"
33995	Arctic char	Salvelinus alpinus	20070719	Near waterfall	60	20'47"	44	50'32"
33996	Arctic char	Salvelinus alpinus	20070719	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
M1	**4.51** 0.29; 20	**5.45** 0.29; 20	
M2	**4.46** 0.28; 20	**5.48** 0.28; 20	
M3	**4.49** 0.30; 20	**5.45** 0.29; 20	
M4	**4.50** 0.30; 20	**5.49** 0.31; 20	
AMI1	**4.73** 0.14; 18	**5.46** 0.32; 20	
T1		**5.75** 0.17; 14	**6.45** 0.31; 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 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)	Sta-tion	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limits						*0.004*	*0.001*	*0.030*	*1.25*	*0.12*	*0.027*	*0.128*	*0.02*	*0.03*	*0.002*	*0.02*	*0.000*
33961	4751	16.66	Myt. edu.	4-5	M 1	0.089	4.373	0.501	70.85	7.76	0.480	1.004	12.48	3.48	0.402	0.46	0.093
33962	4752	17.29	Myt. edu.	5-6	M 1	0.112	4.487	0.477	72.79	8.57	0.495	1.177	14.53	3.93	0.417	0.56	0.066
33963	4754	15.96	Myt. edu.	4-5	M 2	0.051	5.008	0.380	76.37	6.73	0.375	1.544	14.76	4.77	0.295	0.48	0.003
33964	4755	15.41	Myt. edu.	5-6	M 2	0.050	4.168	0.450	81.59	6.57	0.389	1.663	13.53	3.67	0.280	0.46	0.002
33965	4756	15.39	Myt. edu.	4-5	M 3	0.070	2.253	0.451	75.54	7.04	0.822	2.611	15.23	4.39	0.405	0.52	0.004
33966	4757	14.37	Myt. edu.	5-6	M 3	0.074	3.032	0.476	86.16	7.11	0.940	2.139	17.02	4.62	0.458	0.56	0.003
33968	4753	18.90	Myt. edu.	5-6	M 4	0.068	3.861	0.362	60.69	6.12	0.372	0.950	10.94	2.76	0.314	0.40	0.038
33967	4758	18.63	Myt. edu.	4-5	M 4	0.045	4.120	0.357	85.27	6.50	0.515	1.777	12.69	4.24	0.308	0.45	0.002
33971	4761	16.64	Myt. edu.	5-6	T 1	0.056	6.021	0.506	78.73	6.80	0.653	1.707	14.79	3.95	0.315	0.62	0.001
33972	4762	17.94	Myt. edu.	6-7	T 1	0.060	9.616	0.773	104.6	7.50	0.552	1.841	14.56	4.25	0.386	0.68	0.002
33969	4759	17.84	Myt. edu.	4-5	AMI 1	0.082	4.019	0.573	123.4	9.01	0.907	2.574	20.84	5.34	0.386	0.71	0.002
33970	4760	16.65	Myt. edu.	5-6	AMI 1	0.060	7.515	0.664	101.3	7.74	0.575	1.716	13.82	4.36	0.401	0.59	0.002
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*		
34085	4768	100	Fuc. ves.		M 1	0.029	1.912	0.029	6.26	1.16	0.046	0.834	58.26	0.05	0.199	0.17	0.005
34086	4769	100	Fuc. ves.		M 1	0.013	1.929	0.033	6.63	1.16	0.046	0.895	63.34	0.01	0.206	0.16	0.003
34087	4770	100	Fuc. ves.		M 2	0.009	0.919	0.025	7.85	1.10	0.198	1.348	52.00	0.03	0.355	0.12	0.003
34088	4771	100	Fuc. ves.		M 2	0.009	1.006	0.012	7.38	1.10	0.151	1.344	49.62	0.03	0.333	0.11	0.002
34089	4772	100	Fuc. ves.		M 3	0.009	1.016	0.027	9.50	1.36	0.077	1.477	44.78	0.02	0.467	0.11	0.002
34090	4774	100	Fuc. ves.		M 3	0.002	0.892	0.007	6.28	1.30	0.052	1.366	44.86	0.05	0.417	0.09	0.002
34091	4775	100	Fuc. ves.		M 4	0.003	1.509	0.004	7.85	1.45	0.050	1.290	50.90	0.04	0.280	0.13	0.002
34092	4776	100	Fuc. ves.		M 4	0.003	1.597	0.022	7.81	1.46	0.050	1.477	55.91	0.01	0.292	0.14	0.002
34093	4777	100	Fuc. ves.		AMI 1	0.003	1.885	0.042	6.09	1.33	0.204	1.446	74.18	0.03	0.199	0.13	0.001
34094	4749	100	Fuc. ves.		AMI 1	0.036	1.659	0.039	5.06	1.52	0.121	0.702	67.35	0.02	0.274	0.12	0.058
34094	4750		Fuc. ves.		AMI 1	0.018	1.494	0.040	4.84	1.43	0.166	0.677	63.91	0.00	0.278	0.14	0.053
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*		
33988	4600		Cet. niv.		M 1	0.009	0.061	0.575	6.28	0.32	0.182	0.082	0.07	0.09	0.071	0.00	0.000
33989	4601		Cet. niv.		M 2	0.046	0.055	1.049	21.94	3.39	1.908	2.204	3.72	0.17	0.784	0.03	0.004
33990	4602		Cet. niv.		M 3	0.010	0.024	0.319	38.16	0.66	0.408	0.376	0.42	0.01	0.170	-0.01	0.000
33991	4603		Cet. niv.		M 4	0.016	0.067	0.715	6.23	0.49	0.316	0.071	0.16	0.22	0.096	0.03	0.001
33992	4604		Cet. niv.		AMI 1	0.022	0.048	0.645	12.50	0.37	0.134	-0.021	0.05	0.15	0.053	0.04	0.001
33973	4582		Cet. niv.		1	0.030	0.110	0.812	20.65	0.90	0.955	0.511	0.35	0.14	0.183	0.11	0.001
33974	4583		Cet. niv.		2	0.021	0.058	0.387	16.70	0.54	0.280	0.237	0.24	0.07	0.118	0.03	0.001
33975	4584		Cet. niv.		3	0.027	0.074	0.861	25.04	1.41	1.209	1.268	0.70	0.10	0.317	0.04	0.001
33976	4585		Cet. niv.		4	0.021	0.047	1.030	17.69	1.70	1.285	1.241	0.96	0.11	0.435	0.02	0.001
33977	4586		Cet. niv.		5	0.034	0.064	1.030	31.06	3.77	3.034	2.737	2.77	0.15	1.077	0.04	0.001
33978	4587		Cet. niv.		6	0.031	0.079	1.411	39.80	5.22	3.991	4.601	4.34	0.13	1.860	0.05	0.002
33979	4588		Cet. niv.		7	0.031	0.166	1.620	22.69	6.97	5.118	5.351	4.21	0.12	2.200	0.04	0.002
33980	4589		Cet. niv.		8	0.019	0.084	1.025	14.67	4.17	2.384	2.766	2.99	0.09	1.311	0.03	0.002
33981	4590		Cet. niv.		9	0.026	0.075	1.009	29.65	3.39	2.321	2.384	2.00	0.08	0.935	0.02	0.002
33982	4591		Cet. niv.		10	0.037	0.205	2.517	38.69	3.45	2.743	3.107	2.92	0.18	1.279	0.05	0.002
33983	4592		Cet. niv.		11	0.047	0.098	2.113	21.60	8.46	5.041	5.519	6.37	0.15	2.316	0.07	0.003
33984	4593		Cet. niv.		12	0.034	0.079	1.011	14.70	3.94	2.983	2.882	2.99	0.17	0.964	0.03	0.001

ID no.	Lab no	% d.w.	Species	Shell	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
33985	4594		Cet. niv.		15	0.027	0.092	1.683	10.13	0.77	0.547	0.447	0.46	0.19	0.194	0.01	0.001
33985	4595		Cet. niv.		15	0.022	0.120	2.788	12.21	1.09	1.091	0.909	0.51	0.14	0.302	0.02	0.001
33986	4597		Cet. niv.		17	0.010	0.083	0.862	34.25	1.12	0.695	0.708	0.77	0.13	0.352	0.01	0.000
33986	4598		Cet. niv.		17	0.016	0.080	0.803	24.71	1.06	0.737	0.725	0.82	0.09	0.342	0.01	0.000
33987	4599		Cet. niv.		19	0.026	0.061	1.083	29.47	1.22	0.834	0.694	0.84	0.06	0.249	0.01	0.000
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*		
34065	4643	25.98	Myo. sco.		U 1	0.017	1.202	-0.003	31.93	2.39	0.021	-0.009	2.59	0.93	0.022	0.05	0.001
34065	4644	25.98	Myo. sco.		U 1	0.017	1.302	-0.002	31.50	2.43	-0.002	-0.013	2.62	1.10	0.020	0.05	0.001
34066	4645	29.09	Myo. sco.		U 1	0.011	0.686	-0.002	24.87	1.02	0.014	0.033	2.64	1.08	0.010	0.07	0.001
34067	4646	32.67	Myo. sco.		U 1	0.007	0.260	0.003	26.11	2.76	0.009	0.024	2.27	0.75	0.012	0.05	0.001
34068	4647	29.30	Myo. sco.		U 1	0.010	1.158	-0.001	31.10	5.33	0.014	0.054	2.01	0.94	0.039	0.07	0.001
34069	4648	32.97	Myo. sco.		U 1	0.007	0.172	-0.006	18.03	0.63	0.053	0.047	2.66	0.81	0.008	0.03	0.000
34070	4649	30.00	Myo. sco.		U 1	0.007	0.518	-0.006	21.38	1.95	0.055	0.043	2.25	0.72	0.013	0.04	0.000
34071	4650	22.73	Myo. sco.		U 2	0.012	0.375	-0.004	36.49	2.00	0.005	0.090	2.31	1.19	0.029	0.10	0.001
34072	4651	16.88	Myo. sco.		U 2	0.006	0.201	0.004	42.82	2.91	0.005	0.068	3.75	0.63	0.035	0.07	0.000
34073	4654	21.53	Myo. sco.		U 2	0.034	1.595	0.011	58.58	2.28	0.004	0.109	5.84	0.81	0.028	0.06	0.001
34074	4655	34.42	Myo. sco.		U 2	0.004	0.093	0.011	52.69	2.95	-0.004	0.072	5.48	0.60	0.021	0.07	0.001
34075	4656	36.59	Myo. sco.		U 2	0.005	0.461	-0.004	19.94	1.94	0.008	0.085	1.55	0.74	0.024	0.04	0.000
34076	4657	0.00	Myo. sco.		U 3	0.022	0.136	0.001	34.24	1.22	0.012	0.177	2.23	1.02	0.039	0.07	0.000
34077	4658	35.29	Myo. sco.		U 3	0.013	0.218	-0.004	29.66	2.09	0.008	0.103	1.37	0.42	0.030	0.05	0.000
34078	4659	28.75	Myo. sco.		U 3	0.031	0.228	-0.001	36.16	1.10	0.003	0.113	3.60	0.80	0.078	0.05	0.000
34079	4660	32.80	Myo. sco.		U 3	0.011	1.225	-0.007	25.68	1.15	0.002	0.075	3.28	0.91	0.021	0.03	0.001
34080	4661	27.91	Myo. sco.		U 3	0.029	0.439	-0.002	33.84	1.78	0.017	0.088	2.76	0.88	0.035	0.05	0.000
34081	4662	21.43	Myo. sco.		U 4	0.020	0.483	0.001	31.62	1.82	0.002	0.130	3.04	0.74	0.013	0.07	0.000
34082	4663	27.82	Myo. sco.		U 4	0.029	1.269	0.004	34.98	7.72	0.051	0.050	3.76	0.89	0.076	0.08	0.001
34083	4664	28.77	Myo. sco.		U 4	0.015	0.278	-0.002	29.94	1.87	-0.003	0.042	2.54	0.64	0.017	0.06	0.001
34084	4665	28.84	Myo. sco.		U 4	0.014	0.444	0.003	29.64	1.45	0.041	0.080	1.98	0.47	0.035	0.05	0.001
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*		
33993	4668	0.00	Sal. alp.			0.040	0.179	0.010	36.68	11.05	0.028	0.075	0.32	2.74	0.059	0.27	0.001
33994	4669	0.00	Sal. alp.			0.034	0.074	-0.006	32.36	7.31	-0.002	0.114	0.29	2.87	0.057	0.36	0.000
33995	4670	0.00	Sal. alp.			0.042	0.107	0.000	36.10	8.94	0.010	0.123	0.30	2.86	0.060	0.27	0.001
33996	4671	0.00	Sal. alp.			0.039	0.096	-0.002	28.03	3.63	0.013	0.132	0.27	2.78	0.072	0.29	0.000
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.

Appendix 4. Photos of lichens transplanted to the Kirkespir Bay and Valley

Photo 4. Lichens from Amitsoq Island transplanted on 21 July 2007 to station M2 just north of the pier.

Photo 5. Lichens from Amitsoq Island transplanted on 22 July 2007 to station 5 just north of the gravel road.

Photo 6. Lichens from Amitsoq Island transplanted on 22 July 2007 to station 6 just east of the gravel road that can be seen on top of the picture.

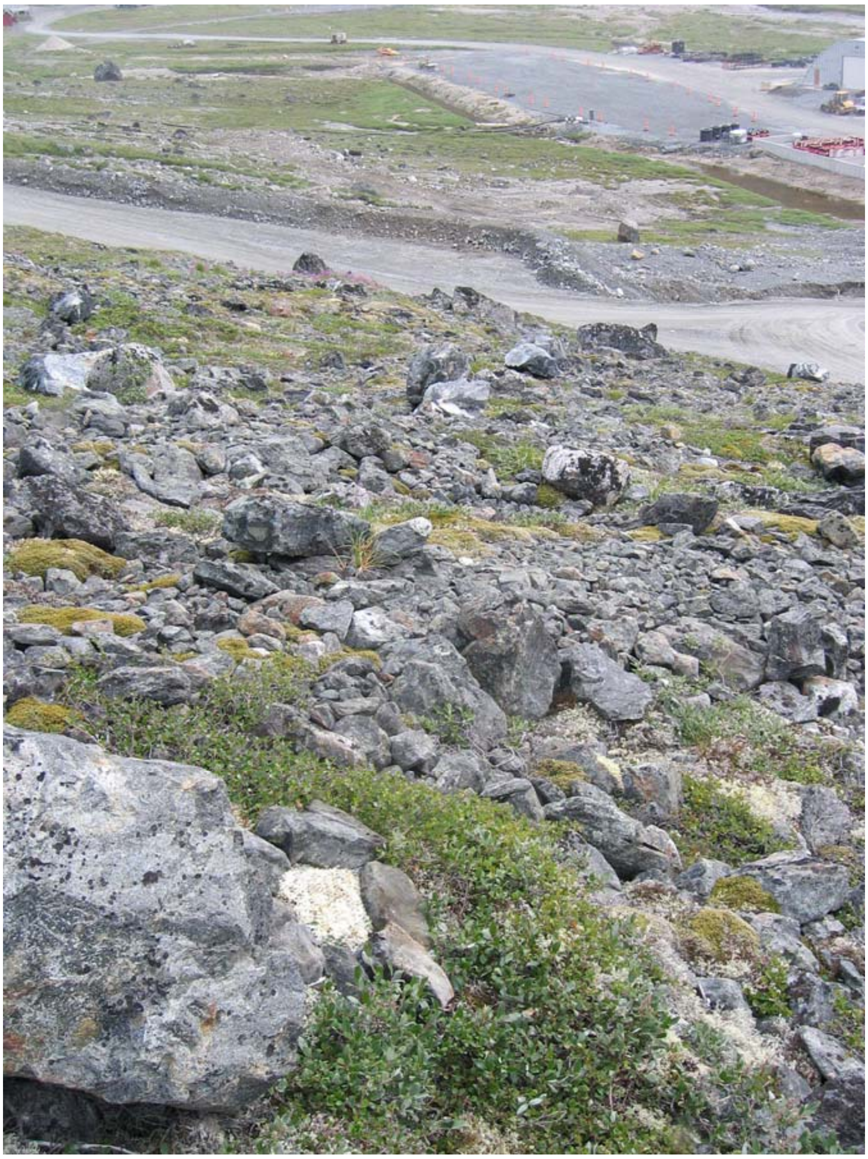

Photo 7. Lichens from Amitsoq Island transplanted on 20 July 2007 to station 11 in the camp area.

Photo 8. Lichens from Amitsoq Island transplanted on 20 July 2007 to station 12 in the camp area.

NERI **National Environmental Research Institute**
DMU Danmarks Miljøundersøgelser

National Environmental Research Institute, NERI, is a part of University of Aarhus.

At NERI's website www.neri.dk you'll find information regarding ongoing research and development projects.

NERI's tasks are primarily to conduct research, collect data, and give advice on problems related to the environment and nature.

Furthermore the website contains a database of publications including scientific articles, reports, conference contributions etc. produced by NERI staff members.

Further information: www.neri.dk

National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

Management
Personnel and Economy Secretariat
Monitoring, Advice and Research Secretariat
Department of Policy Analysis
Department of Atmospheric Environment
Department of Marine Ecology
Department of Environmental Chemistry and Microbiology
Department of Arctic Environment

National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

Monitoring, Advice and Research Secretariat
Department of Marine Ecology
Department of Terrestrial Ecology
Department of Freshwater Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
Fax: +45 8920 1514

Department of Wildlife Ecology and Biodiversity

NERI Technical Reports

NERI's website www.neri.dk contains a list of all published technical reports along with other NERI publications. All recent reports can be downloaded in electronic format (pdf) without charge. Some of the Danish reports include an English summary.

Nr./No. 2008

653 Control of Pesticides 2006. Chemical Substances and Chemical Preparations.
By Krongaard, T., Petersen, K.K. & Christoffersen, C. 25 pp.

652 A preliminary strategic environmental impact assessment of mineral and hydrocarbon activities on the Nuussuaq peninsula, West Greenland.
By Boertmann, D. et al. 66 pp.

651 Undersøgelser af jordhandler i forbindelse med naturgenopretning.
Af Jensen, P.L., Schou, J.S. & Ørby, P.V. 44 s.

650 Fuel consumption and emissions from navigation in Denmark from 1990-2005 – and projections from 2006-2030. By Winther, M. 108 pp.

2007

649 Annual Danish Emission Inventory Report to UNECE. Inventories from the base year of the protocols to year 2005. By Illerup, J.B. et al. 182 pp.

648 Optælling af agerhøns på Kalø Gods 2004-2007 – metodeafprøvning og bestandsudvikling.
Af Odderskær, P. & Berthelsen, J.P. 38 s.

647 Criteria for favourable conservation status in Denmark. Natural habitat types and species covered by the EEC Habitats Directive and birds covered by the EEC Birds Directive.
By Søgaard, b. et al. 92 pp.

646 Vandmiljø og Natur 2006. NOVANA. Tilstand og udvikling – faglig sammenfatning.
Af Boutrup, S. et al. 125 s.

645 Atmosfærisk deposition 2006. NOVANA. Af Ellermann, T. et al. 62 s.

644 Arter 2006. NOVANA. Af Søgaard, B., Pihl, S. & Wind, P. 88 s.

643 Terrestriske Naturtyper 2006. NOVANA. Af Bruus, M. et al. 70 s.

642 Vandløb 2006. NOVANA. Af Bøgestrand, J. (red.). 93 s.

641 Søer 2006. NOVANA. Af Jørgensen, T.B. et al. 63 s.

640 Landovevågningsoplande 2006. NOVANA. Af Grant, R. et al. 121 s.

639 Marine områder 2005-2006. Tilstand og udvikling i miljø- og naturkvaliteten. NOVANA.
Af Ærtebjerg, G. (red.). 95 s.

637 Forvaltningsmetoder i N-belastede habitatnaturtyper. Af Damgaard, C. et al. 46 s.

636 Sørestaurering i Danmark. Del 1: Tværgående analyser, Del 2: Eksempelsamling.
Af Liboriussen, L., Søndergaard, M. & Jeppesen, E. (red.). 86 s. + 312 s.

635 Håndbog om dyrearter på habitatdirektivets bilag IV – til brug i administration og planlægning.
Af Søgaard, B. et al. 226 s.

634 Skovenes naturtilstand. Beregningsmetoder for Habitatdirektivets skovtyper.
Af Fredshavn, J.R. et al. 52 s.

633 OML Highway. Phase 1: Specifications for a Danish Highway Air Pollution Model.
By Berkowicz, R. et al. 58 pp.

632 Denmark's National Inventory Report 2007. Emission Inventories – Submitted under the United Nations Framework Convention on Climate Change, 1990-2005. By Illerup, J.B. et al. 638 pp.

631 Biologisk vurdering og effektundersøgelser af faunapassager langs motorvejsstrækninger i Vendsyssel. Af Christensen, E. et al. 169 s.

630 Control of Pesticides 2005. Chemical Substances and Chemical Preparations.
By Krongaard, T., Petersen, K.K. & Christoffersen, C. 24 pp.

629 A chemical and biological study of the impact of a suspected oil seep at the coast of Marraat, Nuussuaq, Greenland. With a summary of other environmental studies of hydrocarbons in Greenland. By Mosbech, A. et al. 55 pp.

628 Danish Emission Inventories for Stationary Combustion Plants. Inventories until year 2004.
By Nielsen, O.-K., Nielsen, M. & Illerup, J.B. 176 pp.

627 Verification of the Danish emission inventory data by national and international data comparisons. By Fauser, P. et al. 51 pp.

This fourth monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 18-25 July 2007. Seven shipments of ore had been transported to Spain and Canada for gold extraction since the last monitoring study performed in August 2006. Biota was collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected in and transplanted to the valley from an uncontaminated area. Samples were analysed for 12 elements with an ICP-MS. In lichens, elevated concentrations (5-20 times) of Cu, Cr, As and Co were found at the waste rock depot and in the camp area. These metals were also in 2007 significantly elevated compared to the background level. The level was significantly higher in 2007 than in 2006, but no trend during 2004-07 is indicated. All metal concentrations in 2005-07 showed a significant decrease with increasing distance to the road. Elevated concentrations of metals could again this year be found to a distance of c. 1000 m from the road. Co was slightly elevated in seaweed from only one marine station. Compared to higher metal concentrations in mainly seaweed in 2004 and 2005 the levels in the marine environment appear in 2006 and 07 to have stabilised around the baseline level. In resident Arctic char livers no metal concentrations were elevated. The rate of dust pollution can in 2008 be evaluated from lichens transplanted to five Nalunaq areas in 2007.

National Environmental Research Institute
University of Aarhus · Denmark

ISBN 978-87-7073-036-5
ISSN 1600-0048