ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND, 2010

NERI Technical Report no. 811 2010

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Data sheet

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Abstract: This seventh monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 25-31 August 2010. No ore had been shipped to foreign gold production since the monitoring study in August 2009. Most work has dealt with the excavation of a production chamber and the preparation of the gold separation. Low grade ore stored at the pier was transported back to the mine. Mussels, seaweed and sculpins were collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected both in the area and transplanted to the valley from an uncontaminated area. Samples were analysed for 11 elements with ICP-MS. In lichens, elevated concentrations (2-9 times of background levels) of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) were found at the waste rock stockpile and in the mine area. A non-linear temporal trend with decreasing concentrations of the four elements was found in lichens from the two areas. This trend was explained by limited mining activities. All element concentrations showed a significant decrease with increasing distance to the road. Elevated concentrations were found to distances between 500 and 1000 m from the road. Concentrations of elements in transplanted lichens had decreased to lower levels than those found in 2009 and 2008. No elevated concentrations were found in mussels, sculpins and chars, while seaweed had slightly elevated Co concentrations at one station. In 2010, an impact from the mining activities was primarily seen in the Kirkespir Valley due to dust dispersal. The impact of the mine on the marine environment was negligible.

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

Summary

This seventh monitoring study was carried out in the Nalunaq gold mining area, Nanortalik, South Greenland, on 25-31 August 2010. No ore had been shipped to foreign gold production since the last monitoring study in August 2009. Most work during 2009-2010 has dealt with the excavation of a production chamber inside the mine and the preparation of the gravimetric and chemical gold separation. Parts of the low grade ore have been transported from the pier to the mine.

Blue mussels, brown seaweed and shorthorn sculpin were sampled at 4 marine stations in the Kirkespir Bay. Resident Arctic char were caught in the river and lichens *Cetraria nivalis* were collected at 20 stations in the valley and along the bay. In addition, lichens were transplanted from an uncontaminated area (AMI1) to the mining area (Fig. 1). Collected samples were analysed for 11 elements (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co and Au) and the results were compared both to background levels and to previous monitoring studies.

The impact from the mining activities on the marine environment was found to be very low in 2010. No elevated concentrations were found in mussels and in sculpin livers, while seaweed had slightly elevated concentrations of Co at one sampling station situated near mouth of the Kirkespir River. During the period 2006-2010, only Co was consistently elevated in seaweed and only at the same station.

In resident Arctic char livers, average concentrations were not elevated in 2010 compared to baseline concentrations. During 2004-2010, only minor elevations of Cr, Co and Cd were found in 2004 and 2006.

In lichens, concentrations of Cu, Cr, As and Co were, like in previous years, significantly elevated compared to the background levels in the stockpile and the mine area. In 2010, element elevations in these two areas were 2-3 times for Cu and Cr, 5-8 times for As and 4-9 times for Co. The elevated concentrations are likely to be an effect of dust from the road.

Temporal trends during 2004-2010 of the concentrations of the four elements in the two areas described above showed a non-linear course with a decrease in 2010 for all elements in both areas. Most pronounced was the decrease in the camp and mine area. This trend can be explained by limited mining activities in 2010.

We tested the relationship between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the road. All concentrations of the four elements showed a significantly decrease with increasing distance. Concentrations of Cu, As and Co above the background level could be found to a distance of about 1000 m from the road, while concentrations of Cr met the baseline level about 500 m from the road. In 2010, concentrations of elements in the transplanted lichens had decreased to lower levels than the concentrations in the transplanted lichens in 2009 and 2008.

Sammenfatning

Denne syvende moniteringsundersøgelse blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 25. til 31. august 2010. Der er ikke blevet udskibet malm siden moniteringen i august 2009. I minen har der primært været arbejdet med at bryde en produktionshal inde i minen til guld-udvinding med tyngdeseparering og kemisk udvinding (Carbon-in-Pulp med brug af cyanid). Malm med lav lødighed er blevet transporteret tilbage til minen med minekøretøjer med begrænset hastighed og lasteevne.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4 stationer i Kirkespirbugten, standørreder blev fisket i Kirkespirelven og snekruslav *Cetraria nivalis* blev samlet på 20 stationer i Kirkespirdalen og ved bugten. Lav blev endvidere transplanteret fra et uforurenet område (AMI1) til mineområdet (Fig. 1). Alle prøver blev analyseret for 11 grundstoffer (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co og Au) og resultaterne blev sammenholdt med baggrundsniveauet målt i 1998-2001 og med resultaterne fra de tidligere moniteringsundersøgelser.

Det marine miljø var i 2010 kun ganske svagt påvirket af mineaktiviteterne. Der blev ikke fundet forhøjede koncentrationer i muslinger og i ulkelever, mens tang havde svagt forhøjede koncentrationer af Co på én station nær Kirkespirelvens munding. Co var også forhøjet i tang fra den samme station i perioden 2006-2009.

Der blev ikke fundet forhøjede metal koncentrationer i lever fra standørred. I perioden 2004-2010 var der kun i 2004 og 2006 svagt forhøjede koncentrationer af Cr, Co og Cd.

I laver fra områderne ved depotet for knust gråbjerg og ved minen og lejren var koncentrationerne af Cu, Cr, As og Co som i tidligere år signifikant forhøjede. Forhøjelserne i begge områder i 2010 var 2-3 gange for Cu og Cr, 5-8 gange for As og 4-9 gange for Co. Forhøjelserne formodes især at skyldes vejstøv.

I perioden 2004-2010 udviste koncentrationerne af de fire metaller i de to områder en ikke-lineær udviklingstendens med et fald i 2010 for alle fire metaller i begge områder. Faldet var tydeligst i mineområdet. Denne udviklingstendens var forventet som følge af de begrænsede mineaktiviteter i 2010.

Forholdet mellem koncentrationerne i lav af Cu, Cr, As og Co og den vinkelrette afstand til vejen blev undersøgt for perioden 2005-10. For alle metalkoncentrationer var der et signifikant fald med stigende afstande til vejen. Som i de tidligere år blev der fundet forhøjede koncentrationer af Cu, As og Co i en afstand af op til ca. 1000 m fra vejen, mens Cr, som i 2009, nåede baggrundsniveauet ca. 500 m fra vejen.

Koncentrationerne af metaller i de transplanterede laver var i 2010 faldet yderligere i forhold til 2009 og 2008.

Eqikkaaneq

Kujataani Nalunami, Nanortallip kommuniani arfineq aappassaanik nakkutilliilluni misissuineq 2010-mi ingerlanneqarpoq 25.-31. augustusimut. 2009 nakkutilliilluni misissuinerup kingornagut aatsitassamik umiarsuakkut aallarussisoqarsimanngilaq. Aatsitassarsiorfimmi guultimik piiaanermi oqimaassuseq kemilu atorlugu immikkoortiterivilluni (Carbon-in-Pulp cyanid atorlugu) tunisassiorfissap inissaa salliutillugu suliarineqarsimavoq. Piiagaq guultimik akoqarpianngitsoq aatsitassamik piiaavimmut assartorlugu oqqussorneqarsimavoq aatsitassarsiorfimmi qamutit sukkasoorsuunatillu usitoorsuunngitsut atorlugit.

Uillut, equutit kanajorlu nalinginnaasoq misissugassat Kirkespirbugtenimi assigiinngitsuni sisamani katersorneqarput, eqaluit sisujuitsut Kirkespirelvenimi aalisarneqarlutik tingaasallu Snekruslav *Cetraria nivalis* sumiiffinni assigiinngitsuni 20-ni Kirkespirdalenimi iterlammilu katersorneqarlutik. Tingaasattaaq mingutsinneqanngitsumiit (AMI1) aatsitassarsiorfiup eqqaani ikkussorneqarput (Fig. 1). Misissugassat tamarmik grundstoffinik 11-nik (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co aamma Au) misissuiffigineqarput paasisallu aallaavigalugu tunuliaqutarineqartumut 1998-2001-imi uuttorneqartumut siusinnerusukkullu misissuinerit inernerinut sanilliussuunneqarput.

Immami avatangiisit annikitsuaraannannguamik aatsitassarsiornikkut ingerlatanit 2010-mi sunnerneqarsimapput. Uilluni kanassullu tinguini akuusut annertunerulersimanngillat, kisiannili qeqqussani tigusiffimmi ataatsimi Kirkespirelvenip akuani akuusuni Co annertusiallalaarsimavoq. Co aamma tigusiffimmi tassani 2006-2009-mut annertuseriartarsimavoq.

Eqaluit sisujuitsut tinguini saffiugassat akuusut annertuseriarsimanngillat. 2004-2010-mut taamaallaat 2004-mi 2006-imilu Cr, Co aamma Cd annertuserialaartarsimapput.

Tingaasani sequnnernik katersuiffiup eqqaaniittuni aatsitassarsiorfimmi sulisullu ineqarfianni Cu, Cr, As aamma Co akkuusut ukiuni siusinnerusunitulli malunnartumik annertuseriarsimapput. Taakunani marlunni annertuseriaatit 2010-mi Cu aamma Cr 2-3-riaammik, As 5-8-riaammik aamma Co 4-9-riaammik aannertusisimapput. Annertuseriaatit pingaartumik aqquserngup pujoralaaneersimasorineqarput.

2004-2010-mut taakkunani marlunni saffiugassat sisamat akuusut allanngoriartornerat assigiiginnartuusimanngilaq sumiiffinni taakkunani marlunni saffiugassat taakkua sisamat akuunerat 2010-mi annikilleriarsimalluni. Aatsitassarsiorfiup eqqaani annikilleriarneq malunnarnerpaavoq. Taama allanngoriartornissaa ilimagineqareerpoq 2010-mi aatsitassarsiornikkut ingerlatat annertunngimmata.

2005-2010-mut tingaasani Cu, Cr, As aamma Co akuunerisa annertussusiata aqqusinermiit vinkelrettimik ungasissusianut attuumassutaa misissorneqarsimavoq. Saffiugassanut taakkununnga sisamaasunut tunngatillugu aqqusinermiit ungasilliartortilluni malunnartumik annikilliartorneqartarpoq. Ukiuni siusinnerusunisulli Cu, As aamma Co aqqusinermiit 1000 m missiliorlugu ungasissusilimmut akuunerat paasineqarpoq, Cr-ili akuusoq, 2009-misulli mingutsinneqanngitsumi akooreersutut annertutigiinnalerpoq aqqusinermiit 500 m missiliorlugu ungasissusilimmi.

Tingaasani nuutani 2010-mi saffiugassat akuunerat 2009-mut 2008-mullu sanilliullugu suli annikilleriaqqissimavoq.

Photo 1. Chief geologist Kurt Christensen in the production chamber inside the Nalunaq Gold mine.

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 is situated eight km from the coast in the Kirkespir Valley, which lies 40 km northeast of Nanortalik in South Greenland.

The Nalunaq gold deposit is a high-grade gold-only mineralization (c. 20 g gold/ton ore) associated with quartz-veins. The ore sheet has an average strike angle of 45-50º inside the Nalunaq Mountain being 1,340 meters high. The preferred mining method during 2004-2009 was longhole mining with about 11 m vertical spacing between horizontal drifts. Nalunaq Gold Mine had no processing facilities on site. The ore was 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 consisted of modular single occupancy living units with room for about 100 people and included also other modern facilities. A gravel road connects the mine and camp with the Kirkespir Bay. On the southern coastline of the bay, a pier and a barge enabled the crushed ore to be loaded into bulk carriers that shipped the ore to a foreign gold extraction plant.

During the period 2004-2006, the ore was shipped to Rio Narcea Gold Mines Ltd, Spain for gold extraction. From 7 February 2007 onwards, the ore was shipped to Nugget Pond, Newfoundland, Canada. Close to the pier was a stockpile area with an approximate capacity of 60,000 tonnes (Crewgold 2008). The first shipment of gold ore took place on 7 January 2004. During the mining period 2004-2009 a total of 42 shipments with approximately 700,000 tonnes (wet weight) of ore were transported to Spain and Canada. The last shipment took place on 27 March 2009.

All underground mining activities were completed prior to 28 February 2009 and the mine was placed on care and maintenance (Crewgold 2008, 2009). On 1 July 2009, Crew concluded the sale of NGM to Angus and Ross plc – later Angel Mining Gold A/S. Included in the sale was an environmental bond of 16 million DKK, expected to be sufficient for all anticipated mine closure liabilities (Angel Mining 2009; Crewgold 2009). Most mining work during 2009-2010 has dealt with the excavation of a production chamber inside the mine and the preparation of the gravimetric and chemical gold separation (Carbon-in-Pulp including cyanide use). Low grade ore stored at the pier has been transported back to the mine by underground loaders with limited speed and capacity. Late August 2010 the gravimetric part of the production line had been abandoned and the chemical part was still under construction. During this last period the loader in the pier area and some accommodation containers and tents were shipped away. In 2010 the camp could accommodate about 80 persons.

1.2 Environmental baseline studies

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

1.3 Monitoring programme

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

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

The sampling stations for brown seaweed, blue mussel, shorthorn sculpin and Arctic char must be placed relatively close to, and on each side of the shipping facility. Sampling stations for the lichen *Cetraria nivalis* must be placed both in connection with the above mentioned 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. According to the May 2010 BMP approval of phase 6, §§ 19 & 43, chapter 8, specific conditions regarding environmental monitoring will be given in § 86. Due to production problems, § 86 was not finalised prior to the 2010 monitoring; therefore, the present study was performed according to the 19 March 2004 licence.

Photo 2. Brown seaweed (*Fucus vesiculosus*) and blue mussel (*Mytilus edulis*) samples prepared for freeze drying and analyses.

Monitoring studies 2004 – 2009

Since the official opening of the Nalunaq Gold Mine in August 2004, every year during July or August NERI has performed a monitoring study in the area. The monitoring studies are reported in the Nalunaq monitoring reports (Glahder & Asmund 2005, 2006, 2007; Glahder et al. 2008, 2009, 2010) and they can be found on the NERI web address: http://www.dmu.dk/en/publications/ and Technical Reports.

Monitoring study 2010

The monitoring study was performed in the Nalunaq area during 25-31 August 2010.

- Sampling was carried out in accordance with the monitoring programme described in the exploitation licence with the following divergences:
- As in the previous monitoring studies, blue mussels were sampled at one more station, AMI1, on the north-east side of the Amitsoq Island about 15 km north of the Kirkespir Bay (Fig. 1).
- Brown seaweed was collected at one more station, AMI1, with a total of two more samples.
- Lichens were sampled at two more stations.
- Lichens were collected from the six transplantation stations (M2-*t*, 20-*t*, 5-*t*, 6-*t*, 11-*t* and 12-*t*) established during 2007-2009 in Kirkespir Bay and Valley. New lichens, collected at AMI1, were transplanted to these six stations.

- Fish livers from 21 specimens consisted of 16 shorthorn sculpin livers from four marine stations in the Kirkespir Bay and five resident Arctic char livers from the Kirkespir River near the waterfall.

Analyses were performed according to the programme, however 62 samples were analysed instead of 54 and the following 3 elements were added to the analytical programme: nickel (Ni), selenium (Se) and gold (Au).

1.4 Acknowledgements

We wish to thank Ture Grønlund who sailed us to the different marine sampling stations in the Kirkespir area, for his help with jigging for sculpins and for driving us to and from the harbour. Kurt Christensen is thanked for his help with a smooth planning of the tight monitoring programme and an interesting visit to the production chamber. Abel transported us safe and fast from Nanortalik to the mine and back. All three persons are employed by Angel Mining Gold. Jette Sommer is thanked for her participation in collecting and preparing the samples. Sigga Joensen and Lene Bruun, laboratory technicians at NERI, are thanked for sample preparation, analyses and fast delivery of analytical results.

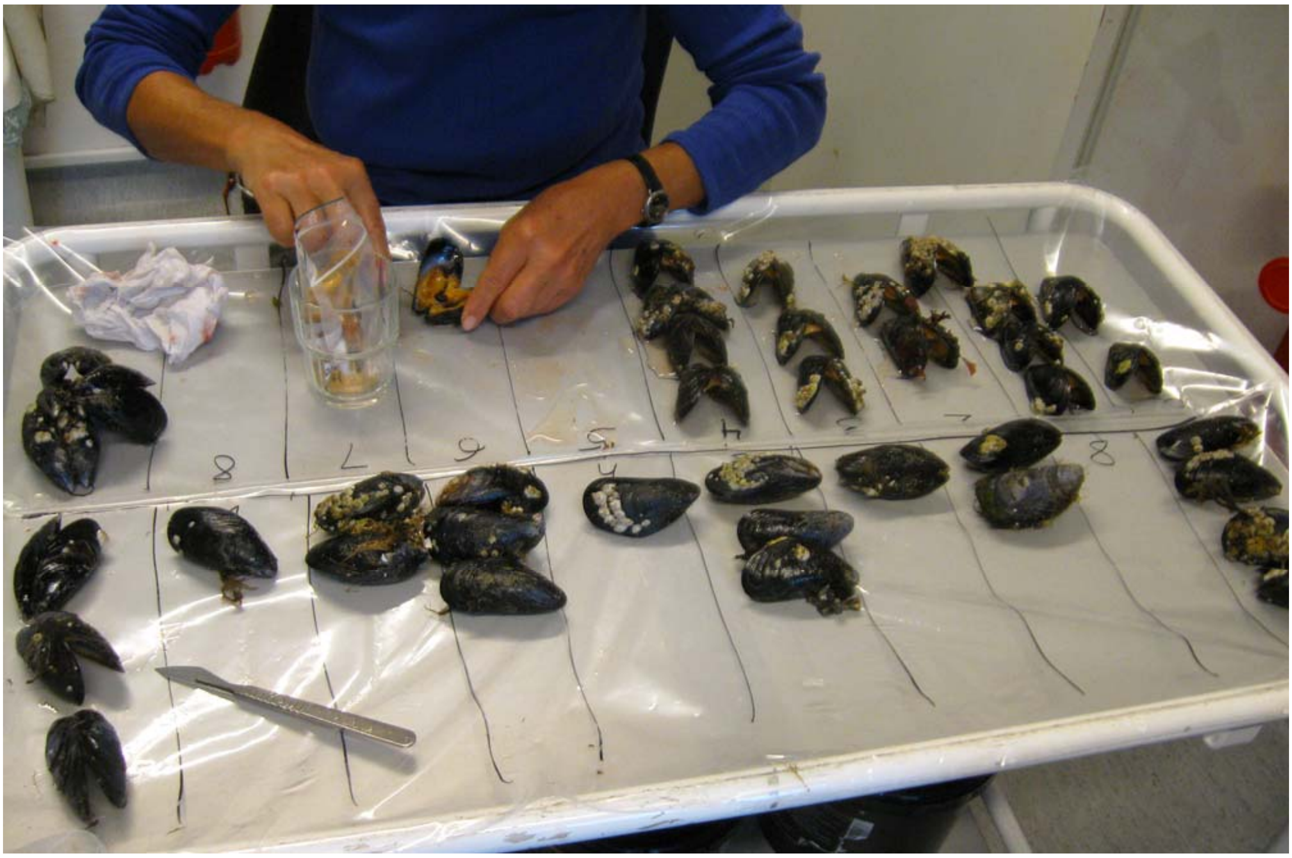


Photo 3. Two size groups of blue mussel (*Mytilus edulis*) from one marine station are sorted in 0.1 cm sizes, opened and the soft parts cut free.

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 0.0-0.2 m (Danish Maritime Safety Administration 2010).

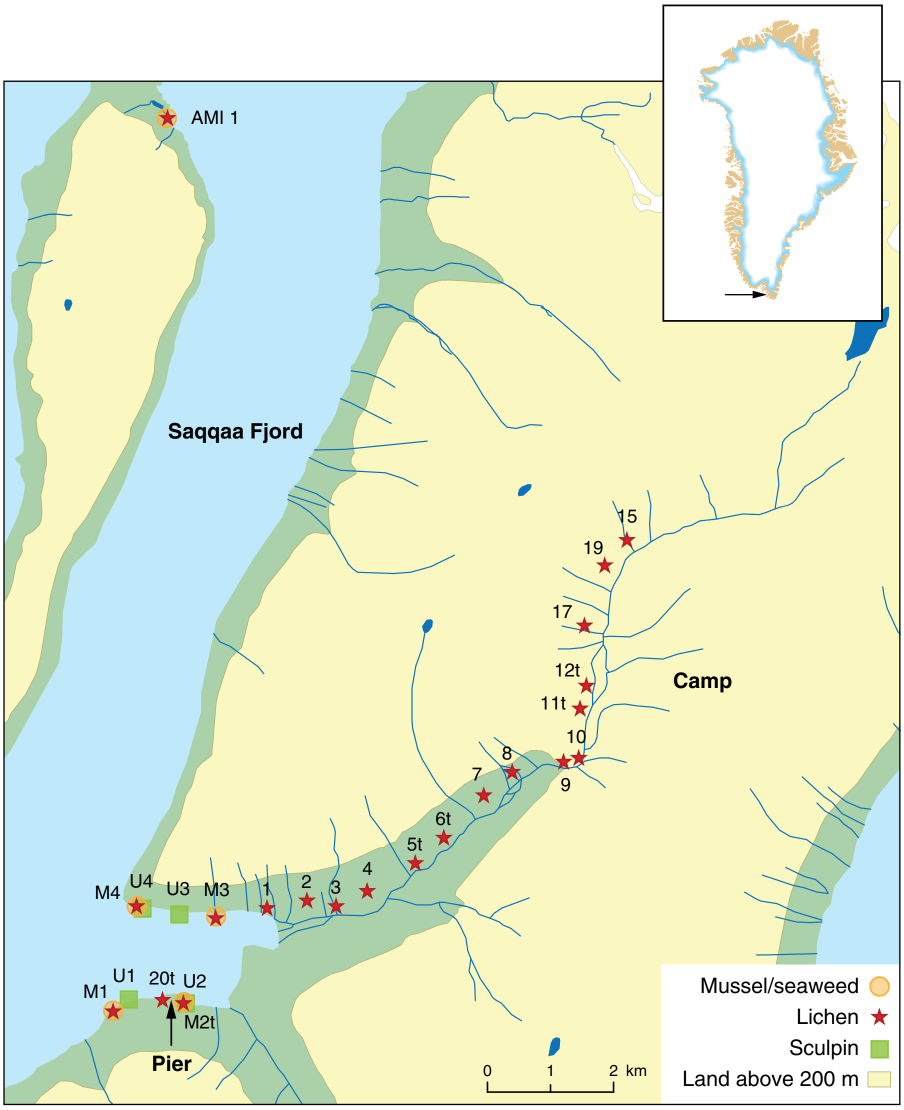


Figure 1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland. M: Marine stations: Blue mussel and brown seaweed, including lichens. U: Shorthorn sculpin stations. Arctic char were caught near the lichen station 9 near the waterfall. Lichens transplanted in 2009 from AMI1 were sampled at stations 20t, M2t, 5t, 6t, 11t and 12t and replaced with new lichens from AMI1. The mine entrance is west of the camp area.

Two size groups of mussels of 4-5, 5-6, 6-7 or 7-8 cm were collected at each of the five stations M1-M4 and AMI1. The shell lengths were measured and the average shell lengths were calculated for each size group at each station (see Appendix 2). One sample consists of 20 individuals. All mussels in a sample were opened and allowed to drain, the soft parts cut free and frozen in plastic bags.

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

Shorthorn sculpins were jigged for from the motor boat at the stations U1, U3, and U4. Sculpins at U2 were caught from the barge at the pier. In total 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 five resident char were caught. All Arctic char were frozen as whole fish. Resident Arctic char stay all their life in the Kirkespir River, whereas the migratory form leaves the river during May and returns around August to spawn and winter. The migratory char spend the summer feeding in the Kirkespir Bay and the Saqqaa Fjord.

Lichens were sampled at 21 stations: Ten from the Kirkespir Valley downstream the camp, two stations in the camp area, three upstream from the camp, five in the Kirkespir Bay area and one in the northeastern part of Amitsoq Island (station AMI1) (Fig. 1). Lichens sampled at AMI1 were transplanted to t-stations 20, M2, 5, 6, 11 and 12 after transplanted lichens from 2009 were sampled and the stations cleaned (Appendix 1).

2.2 Analyses

All samples were transported either frozen or dry directly to NERI on 2 September 2010. The analyses have been reported by Søndergaard & Asmund (2010). A total of 62 samples from blue mussel (10), brown seaweed (10), livers of Shorthorn sculpin (16), livers of Arctic char (5) and the lichen *Cetraria nivalis* (21) were analysed for the following 11 elements: Mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), selenium (Se), cobalt (Co) and gold (Au).

Following freeze drying of blue mussels and brown seaweed at NERI, subsamples of 0.3-1.0 g of biota were digested in half-concentrated Suprapure nitric acid under pressure in Teflon bombs in a microwave oven. The samples where then diluted to c. 25 grams with milliQ water and all elements were analysed by ICP-MS (an accredited method according to DANAK, accreditation No. 411). Hg and Co are not included in this accreditation. All chemical results are listed in Appendix 3. Simultaneously with the Nalunaq samples, blind samples, duplicates and the certified reference materials Dorm-3 and Tort-2 were analysed as part of the laboratory quality control. In Table 1, the analytical results of the certified reference materials are compared to the certificate values. As shown, the analytical results are close to the certificate values.

Table 1. ICP-MS analytical results of certified reference materials (Dorm-3 and Tort-2) compared to the certificate values. The detection limits, quantified as 3 times the standard deviation of the blind values, are also shown. Eleven different elements were analysed. The 2 x SD of the certificate values expresses the 95% confidence interval. Concentrations are in mg/kg dry weight. nd= not determined.

	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Au
Detection limit	***0.007***	***0.01***	***0.033***	***0.35***	***0.14***	***0.10***	***0.50***	***0.10***	***0.08***	***0.01***	***0.008***
Dorm-3	0.32	0.31	0.39	49.1	15.7	1.88	1.22	6.5	3.28	0.26	0.01
Dorm-3	0.29	0.30	0.36	46.3	15.0	2.82	1.51	6.1	3.09	0.26	0.02
Average	0.31	0.31	0.38	47.7	15.3	2.35	1.37	6.3	3.18	0.26	0.01
Certificate value	0.38	0.29	0.40	51.3	15.5	1.89	1.28	6.9	nd	nd	nd
2 x SD	0.06	0.02	0.05	3.1	0.6	0.17	0.24	0.3	nd	nd	nd
Tort-2	0.26	26.90	0.36	173.5	95.2	0.75	2.21	20.0	5.33	0.53	0.02
Tort-2	0.25	25.48	0.38	164.8	94.5	0.95	2.63	19.0	5.07	0.50	0.03
Tort-2	0.31	26.35	0.35	171.3	99.0	0.85	2.18	19.1	5.20	0.52	0.02
Average	0.28	26.24	0.36	169.9	96.2	0.85	2.34	19.4	5.20	0.52	0.03
Certificate value	0.27	26.70	0.35	180.0	106.0	0.77	2.50	21.6	5.63	nd	nd
2 x SD	0.06	0.60	0.13	6.0	10.0	0.15	0.19	1.8	0.67	nd	nd

Statistical analyses

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

We tested separately the following two areas, the stockpile of crushed waste rock and the camp area, for differences in concentrations of Cu, Cr, As and Co in lichens in the years 2004-2010 compared to background concentrations using a one-way ANOVA. Prior to the analyses data were logarithmic (base e) transformed to meet the assumptions of normal distribution and variance homogeneous of the tests. The post hoc Tukey's studentized range test was applied to test differences between years and background. The level of statistical significance used was $p=0.05$.

Also, we applied local polynomial regression fitting (loess) to illustrate temporal trends in element concentrations in the two areas. This graphical analytical method was used because a non-linear temporal trend was expected due to reduced activities in 2009 and 2010.

Finally, we analysed the relationship between concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road in 2010 with linear regression analyses using logarithmic transformed (base e) element concentrations as dependent variable and logarithmic transformed (base e) distance as independent variable.

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 ($p<0.05$) higher than the background concentrations.

3.1 The marine environment

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

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

Brown seaweed at station M3 were significantly elevated in Co with twice as high concentrations compared to background concentrations (t-test, two-sample assuming equal variances, $p=0.03$, $t=-3.31$, $df=4$). No elevated concentrations of other elements analysed were found at any of the other seaweed stations (Appendix 3).

In **sculpin liver**, average concentrations were not elevated compared to the background concentrations. The average Cu concentration at U1 was 2-3 times higher than the background level, but this was not significant (t-test, two-sample assuming unequal variances, $p=0.44$, $t=0.88$, $df=3$). Also, average Cu concentrations at U3 was 2 times higher than the background level, but this was not significant (t-test, two-sample assuming unequal variances, $p=0.18$, $t=1.57$, $df=5$).

Conclusions on the marine environment

As in previous years, the impact from the mining activities on the marine environment in 2010 was found to be very low. During 2006-2010, the only significant element elevation in the marine environment was Co concentrations in seaweed from station M3.

During the last five years, concentrations of elements in the marine environment have been low and in general not different from the background level.

In 2004 and 2005, concentrations of especially Cr, but also concentrations of Cu, Co and Zn were elevated in seaweed. In 2006-2009, Co was also elevated in seaweed from station M3 by a factor 2-3. In 2004, elevations of Cr were found in sculpin livers and of Co in blue mussel.

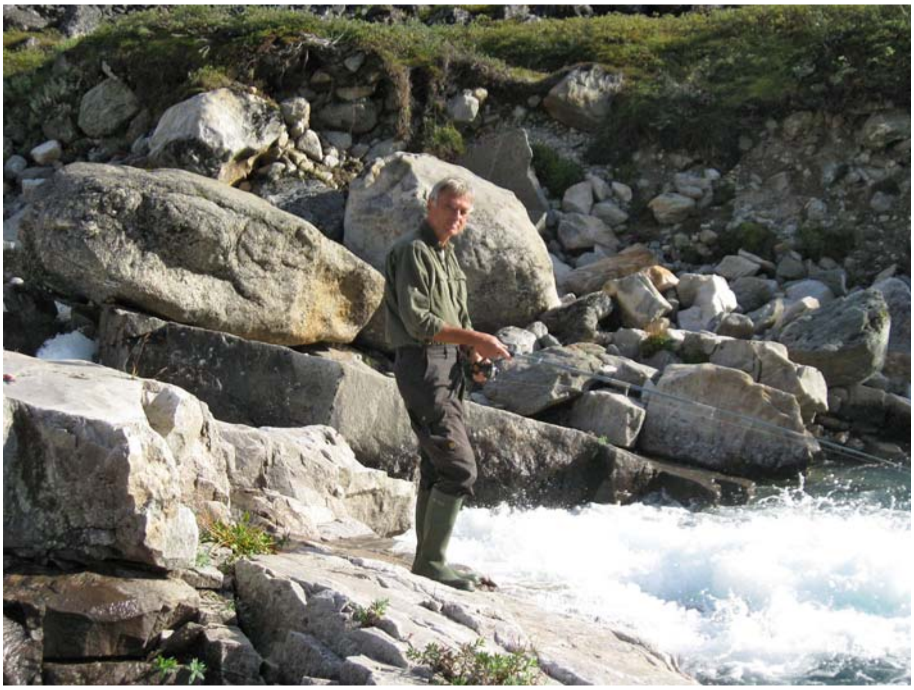
3.2 The freshwater environment

In livers from resident Arctic char the average concentrations were not significantly elevated compared to baseline concentrations. Average concentrations of Cd and Cu were 2-3 times higher than the background level, but they were not significant (Cd: t-test, two-sample assuming unequal variances, $p=0.06$, $t=2.37$, $df=5$; Cu: t-test, two-sample assuming equal variances, $p=0.34$, $t=1.01$, $df=8$).

Conclusions on the freshwater environment

In 2010 no element concentrations were elevated in arctic char. In 2004 and 2006 Cr was elevated 2-3 times, Co 3 times in 2004 and Cd 2 times in 2006; no elevations were found in 2005 and during 2007-2010.

Photo 4. Resident Arctic char (*Salvelinus alpinus*) are caught in the Kirkespir River near the water fall (Photo by J. Sommer).



3.3 The terrestrial environment

We have compared concentrations of four metals (Cu, Cr, As and Co) in lichens (*Cetraria nivalis*) during 2004-2010. Two areas were selected, the stockpile of crushed waste rock (stations 5 and 6) and the camp and mine area (stations 11 and 12). Again in 2009, lichens were transplanted from an uncontaminated area (station AMI1) to these four stations: 5, 6, 11 and 12. In 2010 these transplanted lichens were analysed together with lichens growing naturally in the Kirkespir Valley and Bay.

The idea of transplanting lichens from an uncontaminated area to the mine area was derived from studies performed at the lead-zinc mine at Maarmorilik; these studies showed that metals were excreted from the lichens at a low rate, if at all (Johansen et al. 2008). As a consequence, a reduction in the dust pollution can be difficult to detect within a few years period. In 2007, lichens were therefore transplanted from the uncontaminated Amitsoq Island (station AMI1) to the Nalunaq area in order to determine the annual rate of dust pollution.

We compared average concentrations in each of the two areas with background concentrations and Cu, Cr, As and Co were significantly elevated in the years 2004-2010 (Tukey's post hoc test, $p<0.05$). Elevations in the two areas in 2010 were 2-3 times for Cu and Cr, 5-8 times for As and 4-9 times for Co (Fig. 5a, Appendix 3). Concentrations of these four metals were not significantly different between the years 2004-2010, except for As in area 1 where concentrations in 2007 and 2008 were significantly higher than in 2004 and 2006 (Tukey's post hoc test, $p<0.05$). Concentrations of the four metals at the pier (station 20, M2) were 9-10 times higher than the background concentrations for As and 3 times for Co, while Cu and Cr were not different from the background concentrations (Fig. 5a).

We examined the temporal trends in concentrations of the four metals in the two areas described above. The results of the applied local polynomial regression fitting are shown in Figs. 2 (Area 1) and 3 (Area 2). Concentrations of all four metals in both areas have decreased further in 2010 and most pronounced in the camp and mine area, area 2. Yet, Co concentrations in Area 1 seem only to have stabilized.

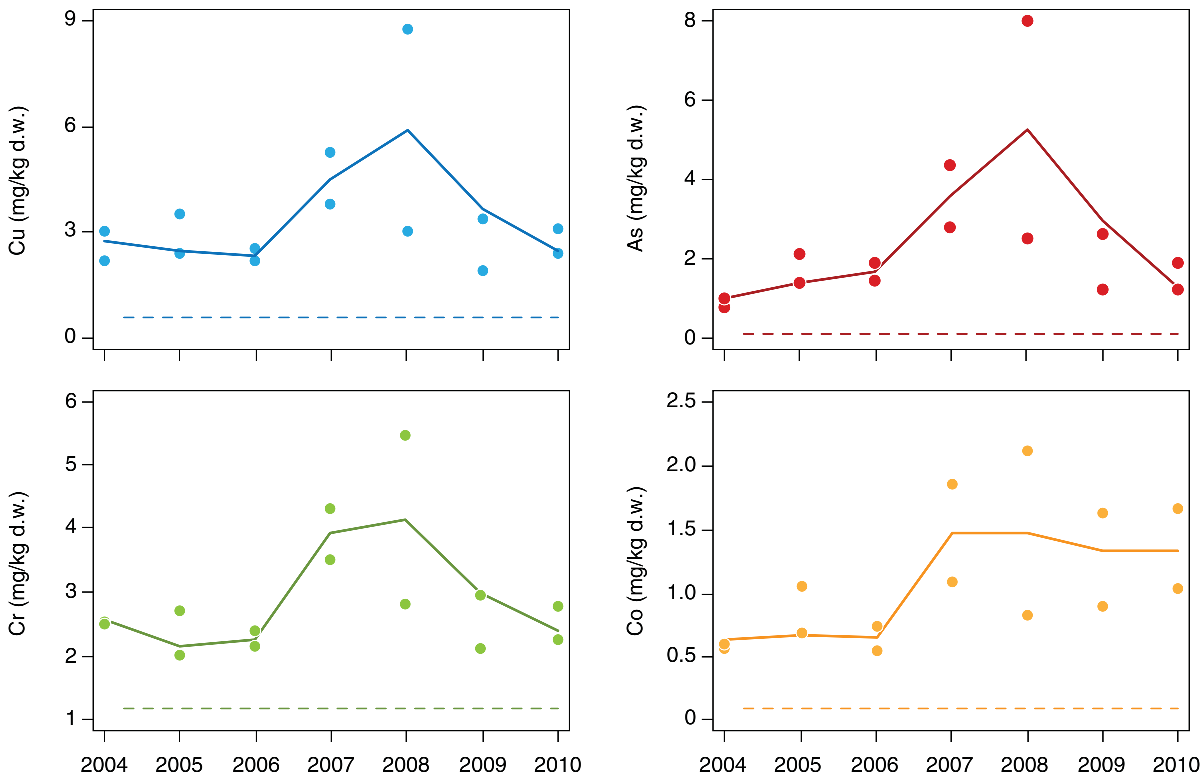


Figure 2. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from area 1 during 2004-2010. Area 1 is the stockpile of crushed waste rock (stations 5 and 6). From 2008 onwards concentrations are from transplanted lichens. Baseline average concentrations from 1998 are shown as dashed lines.

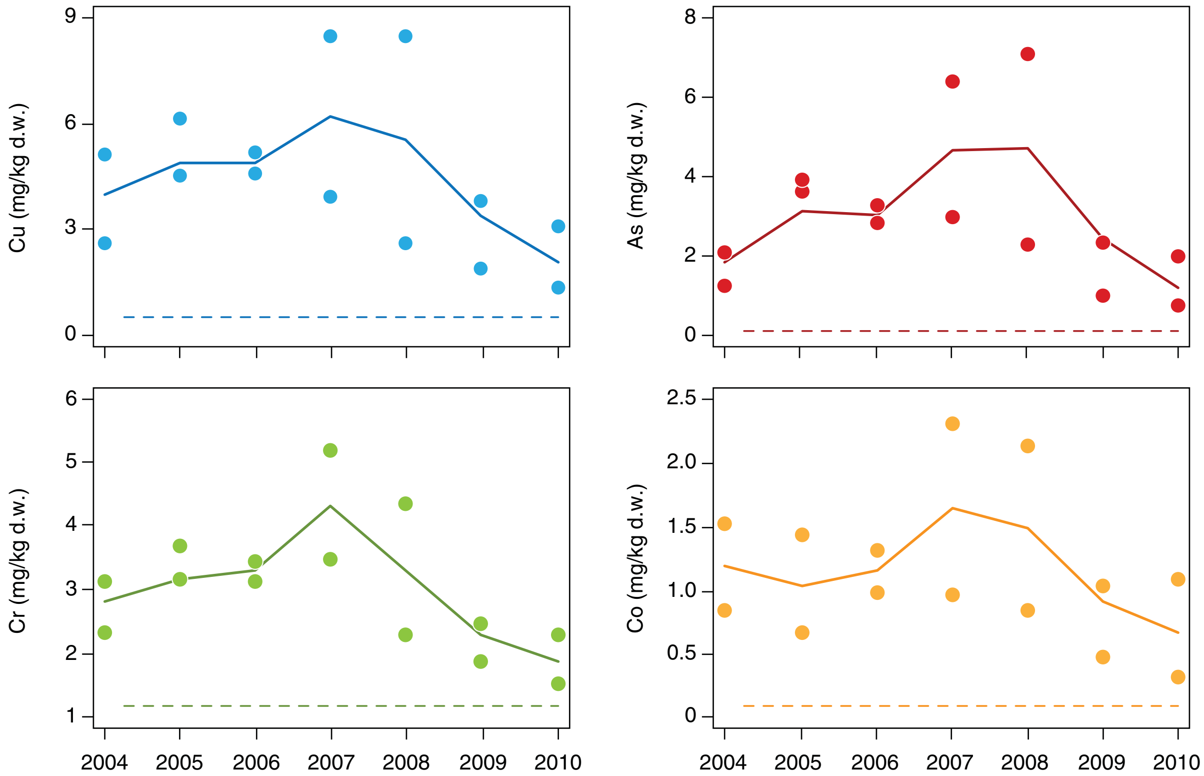


Figure 3. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from area 2 during 2004-2010. Area 2 is the camp and mine area (stations 11 and 12). From 2008 onwards concentrations are from transplanted lichens. Baseline average concentrations from 1998 are shown as dashed lines.

Concentrations of Cu, Cr, As and Co have been analysed in transplanted lichens since 2008 and we have compared these concentrations with those measured in naturally growing lichens from the same stations in 2007. The stations are M2 in the pier area, 5 and 6 in the stockpile area and 11 and 12 in the mine area (Fig. 4).

The transplanted lichens show the yearly uptake of elements, while the naturally grown lichens also are influenced by uptake since 2004. All stations show a decrease in concentrations since 2008, most pronounced at stations M2, 6 and 11. This decrease in the annual rate of dust pollution during that period is in accordance with the reduced mining activities and ore transportation in 2009 and 2010. Interestingly, concentrations have increased from 2007 to 2008 at M2 and 6 and remained unchanged at 11. This means that the transplanted lichens in one year have had an uptake of elements that are higher or equal to the naturally growing lichens. The activities in 2008 therefore seem to have been rather high compared to 2007.

We have tested a possible relationship between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the gravel road; the test included differences in levels among years (refer to Figs. 5a, b & 6 regarding 2010). These four metals were tested because they showed the highest concentrations compared to background levels. All concentrations of the four metals showed a significantly decrease with increasing distance (Linear regression, $p<0.001$).

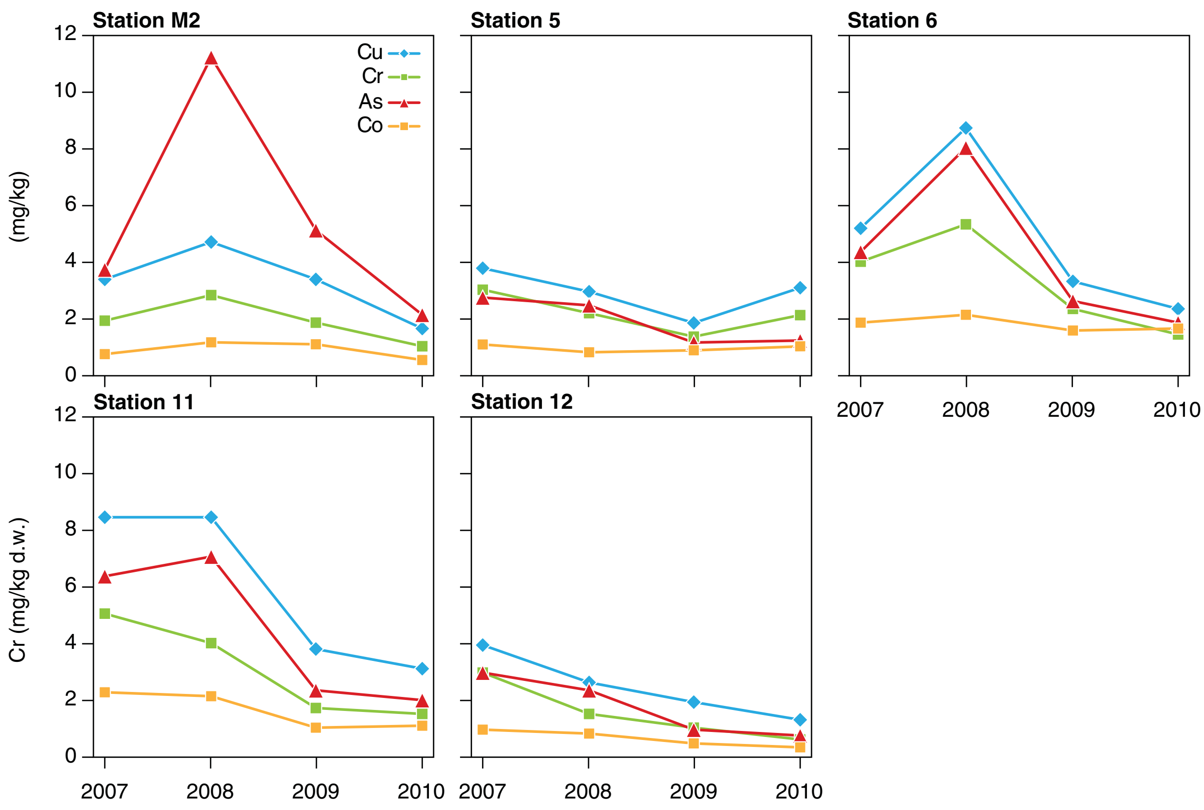


Figure 4. Concentrations of Cu, Cr, As and Co in transplanted lichens from the pier (M2), stockpile (5, 6) and mine (11, 12) areas during 2008-2010 compared with concentrations in naturally growing lichens from 2007.

Figure 5a shows concentrations of the four elements in lichens from Amitsoq Island, the Kirkespir Bay area and the Kirkespir Valley. Two areas have markedly higher concentrations of the four elements, namely the pier area and the inner valley area including the stockpile of waste rock and the camp and mine area. The relatively high concentrations in these areas can be explained as an effect of the nearness to the gravel road illustrated by Figure 5b. Before 2009, the higher concentrations in the camp and mine area were explained as an effect of the mine rather than an effect of the road (Glahder et al. 2010). Especially the pier area has seen a marked decrease in the concentrations of all four metals compared to concentrations found in 2009. This indicates that the effect of the road is now the main source of contamination after the storage in the pier area and the ship-loading activities have ceased.

Figure 6 shows how far from the road elevated concentrations of Cu, Cr, As and Co were found in the Kirkespir Valley in 2010. For Cu, As and Co background concentrations were met about 1000 m from the road, whereas Cr reached background levels at around 500 m. Background concentrations are average values with a standard deviation similar to the average due to the natural variation in concentrations. Therefore single concentrations can be lover than the given background levels (Fig. 5 & 6).

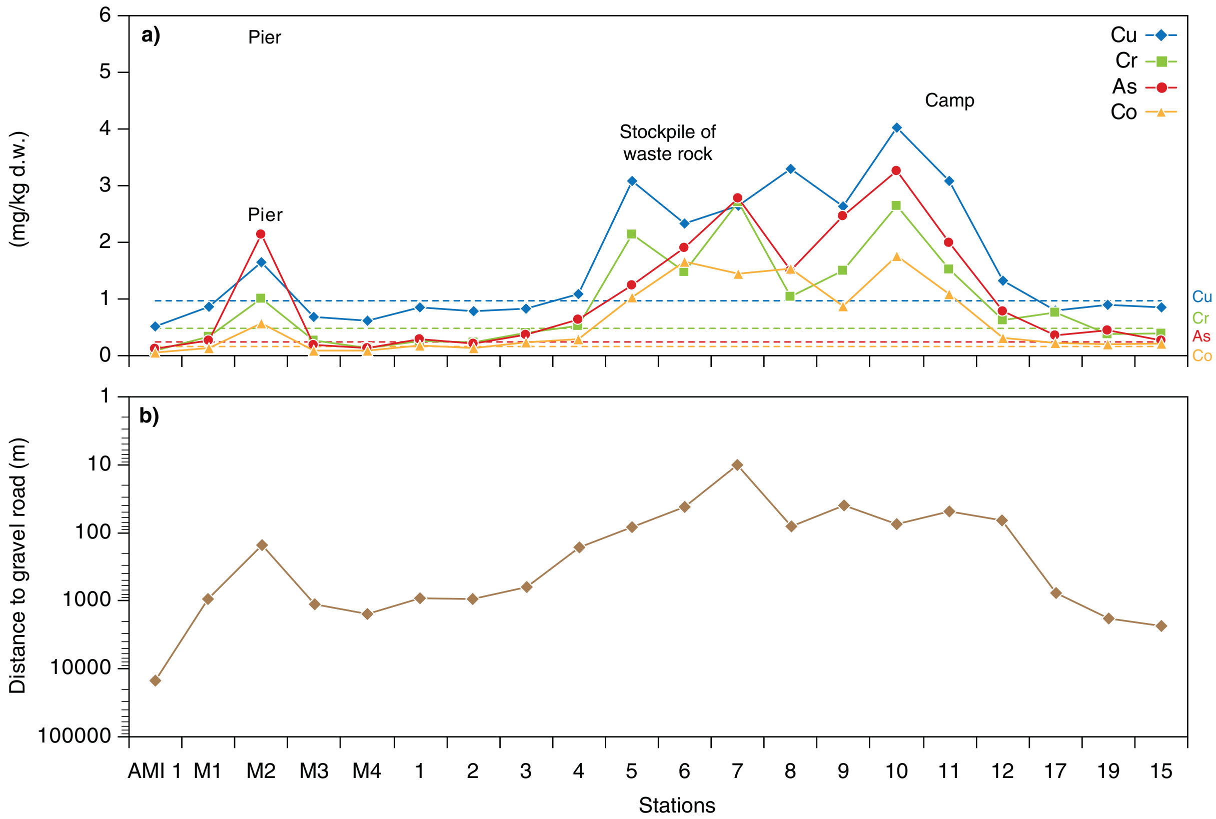


Figure 5. a) Concentrations of Cu, Cr, As and Co in the lichen *Cetraria nivalis* measured at the lichens stations in 2010 and b) distances (in meter on a log scale) from the road to the lichen stations. For localisation of lichen stations see Fig. 1. M1-M4 are stations in the Kirkespir Bay area, stations 1-19 are situated in the Kirkespir Valley from the coast (station 1) to up-stream the camp area (station 15). The dashed horizontal lines in a) indicate average background concentrations of the four metals (see Table 2). d.w. = dry weight.

Photo 5. Lichens (*Cetraria nivalis*) transplanted in mid August 2009 at station 6 in the Kirkespir Valley were sampled late August 2010. Transplanted lichens were covered by a net secured by stones. Lichens sampled at Amitsoq Island in 2010 replaced the sampled lichens.

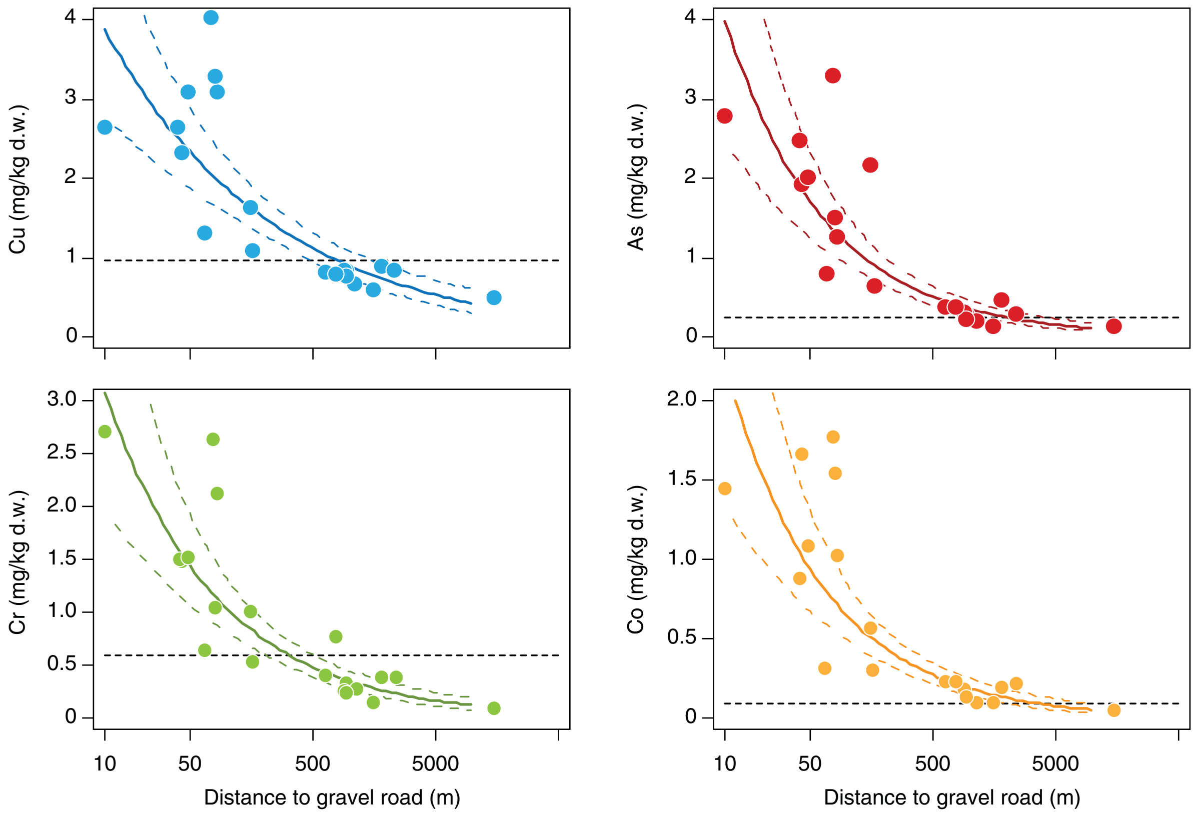


Figure 6. Concentrations of Cu, Cr, As and Co in the lichen *Cetraria nivalis* as a function of the stations' distances to the gravel road (in meters). Dashed curves show 95 % confidence intervals. Background average concentrations are shown with horizontal dashed lines. d.w. = dry weight.

Conclusions on the terrestrial environment

It is concluded that concentrations of Cu, Cr, As and Co in lichens during 2004-2010 were significantly elevated at the waste rock stockpile and in the mine area compared to the background levels. Concentrations of all four metals in both areas have further decreased in 2010, especially in the mine area. The relatively high concentrations in these areas can be explained as an effect of the gravel road. Before 2009, the higher concentrations in the mine area were explained as an effect of the mine rather than an effect of the road. In 2010, a marked decrease in concentrations of all four metals were seen in the pier area, indicating that the road is now the main source of contamination after activities in this area have ceased.

In 2010, metal concentrations in the transplanted lichens had decreased further compared to concentrations in the transplanted lichens in 2009 and 2008. Compared to lichens growing naturally at the same stations in 2007, concentration levels in transplanted lichens in 2010 were 30-50% lower. This indicates a general decrease in the annual dry deposition rate of elements in the Nalunaq Gold Mine area.

All metal concentrations showed significant decreases with increasing distance to the road. Concentrations of Cu, As and Co met the background level c. 1000 m from the road, while this distance was 500 m for Cr.

Photo 6. The growth tips of seaweed (*Fucus vesiculosus*) from this year were cut, washed in freshwater from upstream the camp and frozen in plastic bags.

4 Conclusions

This report describes the results of the seventh year of environmental monitoring in the Nalunaq Gold Mine area. Most mining work since August 2009 has dealt with the excavation of a chamber inside the mine and the building of a production plant. Parts of the low grade ore has been transported from the pier to the mine.

The impact from the mining activities on the marine environment was in 2010 found to be very low. No elevated concentrations were found in blue mussels and sculpin livers, while brown seaweed had slightly elevated Co concentrations. During 2006-2010, Co concentrations in seaweed at station M3 near the Kirkespir River mouth were the only significant element elevation in the marine environment.

In resident Arctic char livers, average concentrations were not elevated in 2010 compared to baseline concentrations. During 2004-2010, only minor elevations of Cr, Co and Cd were found in 2004 and 2006.

In the lichen *Cetraria nivalis* concentrations of Cu, Cr, As and Co in 2010, like in previous years, were significantly elevated compared to the background level at the stockpile of crushed waste rock and in the camp and mine area. In 2010, element elevations in these areas were 2-3 times for Cu and Cr, 5-8 times for As and 4-9 times for Co. The elevated concentrations are likely to be an effect of dust from the road. In the pier area, As was elevated 9-10 times, Co 3 times, while Cr and Cu were not elevated.

Temporal trends during 2004-2010 of the concentrations of the four elements in the two areas described above showed a non-linear course with a decrease in 2010 for all elements in both areas. Most pronounced was the decrease in the camp and mine area. This trend can be explained by limited mining activities in 2010.

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

In 2010, concentrations of metals in the transplanted lichens had decreased to lower levels than the concentrations in the transplanted lichens in 2009 and 2008.

In 2010, the impact from the gold mine on the local environment was primarily observed in the Kirkespir Valley and originated mainly from dust dispersed from the road. Metal concentrations in lichens decreased further in 2010 due to limited mining activities. In the Kirkespir River and Bay, only Co in seaweed was elevated at one station and the impact in the fjord is therefore considered negligible.

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Appendix 1. Samples and stations

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
45452	Lichen	Cetraria nivalis	29.08.2010	1	60	19’34”	44	55’22”
45153	Lichen	Cetraria nivalis	29.08.2010	2	60	19’38”	44	54’40”
45154	Lichen	Cetraria nivalis	29.08.2010	3	60	19’35”	44	54’10”
45155	Lichen	Cetraria nivalis	29.08.2010	4	60	19’43”	44	53’38”
45156	Lichen	Cetraria nivalis	29.08.2010	5-transplanted	60	19’56.9”	44	52’48.1”
45157	Lichen	Cetraria nivalis	29.08.2010	6-transplanted	60	20’09.7”	44	52’18.6”
45158	Lichen	Cetraria nivalis	29.08.2010	7	60	20’32”	44	51’37”
45159	Lichen	Cetraria nivalis	29.08.2010	8	60	20’44”	44	51’07”
45112	Lichen	Cetraria nivalis	27.08.2010	9	60	20’49”	44	50’14”
45111	Lichen	Cetraria nivalis	27.08.2010	10	60	20’51”	44	49’58”
45109	Lichen	Cetraria nivalis	26.08.2010	11-transplanted	60	21’16.4”	44	49’56.6”
45110	Lichen	Cetraria nivalis	26.08.2010	12-transplanted	60	21’28.2”	44	49’50.1”
45105	Lichen	Cetraria nivalis	26.08.2010	15	60	22’43”	44	49’08”
45106	Lichen	Cetraria nivalis	26.08.2010	17	60	21’59”	44	49’52”
45107	Lichen	Cetraria nivalis	26.08.2010	19	60	22’30”	44	49’31”
45115	Lichen	Cetraria nivalis	27.08.2010	20-transplanted	60	18’47.1”	44	57’10.2”
45143	Lichen	Cetraria nivalis	28.08.2010	M 1	60	18’41”	44	58’01”
45116	Lichen	Cetraria nivalis	27.08.2010	M2-transplanted	60	18’45.1”	44	56’48.5”
45113	Lichen	Cetraria nivalis	27.08.2010	M 3	60	19’29”	44	56’15”
45114	Lichen	Cetraria nivalis	27.08.2010	M 4	60	19’35”	44	57’37”
45108	Lichen	Cetraria nivalis	26.08.2010	AMI 1	60	26’20”	44	57’04”
45148	Brown seaweed	Fucus vesiculosus	28.08.2010	M 1	60	18’41”	44	58’01”
45149	Brown seaweed	Fucus vesiculosus	28.08.2010	M 1	60	18’41”	44	58’01”
45151	Brown seaweed	Fucus vesiculosus	28.08.2010	M 2	60	18’46”	44	56’47”
45150	Brown seaweed	Fucus vesiculosus	28.08.2010	M 2	60	18’46”	44	56’47”
45135	Brown seaweed	Fucus vesiculosus	27.08.2010	M 3	60	19’29”	44	56’15”
45136	Brown seaweed	Fucus vesiculosus	27.08.2010	M 3	60	19’29”	44	56’15”
45137	Brown seaweed	Fucus vesiculosus	27.08.2010	M 4	60	19’35”	44	57’37”
45138	Brown seaweed	Fucus vesiculosus	27.08.2010	M 4	60	19’35”	44	57’37”
45101	Brown seaweed	Fucus vesiculosus	26.08.2010	AMI1	60	26’20”	44	57’04”
45102	Brown seaweed	Fucus vesiculosus	26.08.2010	AMI1	60	26’20”	44	57’04”
45117	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 1	60	18’47”	44	57’45”
45118	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 1	60	18’47”	44	57’45”
45119	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 1	60	18’47”	44	57’45”
45120	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 1	60	18’47”	44	57’45”
45123	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 2	60	18’45”	44	56’46”
45124	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 2	60	18’45”	44	56’46”
45125	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 2	60	18’45”	44	56’46”
45126	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 2	60	18’45”	44	56’46”
45127	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 3	60	19’31”	44	56’53”
45128	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 3	60	19’31”	44	56’53”
45130	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 3	60	19’31”	44	56’53”
45129	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 3	60	19’31”	44	56’53”
44131	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 4	60	19’34”	44	57’31”
45132	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 4	60	19’34”	44	57’31”
45133	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 4	60	19’34”	44	57’31”

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
45134	Shorthorn sculpin	Myoxocephalus scorpius	27.08.2010	U 4	60	19'34''	44	57'31''
45144	Blue mussel	Mytilus edulis	28.08.2010	M 1	60	18'41''	44	58'01''
45145	Blue mussel	Mytilus edulis	28.08.2010	M 1	60	18'41''	44	58'01''
45146	Blue mussel	Mytilus edulis	28.08.2010	M 2	60	18'46''	44	56'47''
45147	Blue mussel	Mytilus edulis	28.08.2010	M 2	60	18'46''	44	56'47''
45139	Blue mussel	Mytilus edulis	27.08.2010	M 3	60	19'29''	44	56'15''
45140	Blue mussel	Mytilus edulis	27.08.2010	M 3	60	19'29''	44	56'15''
45141	Blue mussel	Mytilus edulis	27.08.2010	M 4	60	19'35''	44	57'37''
45142	Blue mussel	Mytilus edulis	27.08.2010	M 4	60	19'35''	44	57'37''
45103	Blue mussel	Mytilus edulis	26.08.2010	AMI 1	60	26'20''	44	57'04''
45104	Blue mussel	Mytilus edulis	26.08.2010	AMI 1	60	26'20''	44	57'04''
45160	Arctic char	Salvelinus alpinus	30.08.2010	Near waterfall	60	20'47''	44	50'32''
45161	Arctic char	Salvelinus alpinus	30.08.2010	Near waterfall	60	20'47''	44	50'32''
45162	Arctic char	Salvelinus alpinus	30.08.2010	Near waterfall	60	20'47''	44	50'32''
45163	Arctic char	Salvelinus alpinus	30.08.2010	Near waterfall	60	20'47''	44	50'32''
45166	Arctic char	Salvelinus alpinus	30.08.2010	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 different size groups including standard deviation (*SD*)			
		4-5	5-6	6-7	7-8
M1	Average			6.44	7.41
	SD			*0.30*	*0.26*
M2	Average	4.55	5.45		
	SD	*0.30*	*0.29*		
M3	Average			6.43	7.44
	SD			*0.29*	*0.28*
M4	Average			6.44	7.45
	SD			*0.25*	*0.32*
AMI1	Average			6.53	7.25
	SD			*0.27*	*0.23*

The number of mussels in each size group was 20 except for M2, 4-5 cm, which consisted of 19 specimens.

Appendix 3. Chemical analyses

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

ID no.	Lab no	% d.w.	Species	Shell (cm)	Sta-tion	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Au
Detection limits, Mytilus edulis						0.105	0.014	0.033	0.35	0.14	0.102	0.50	0.10	0.08	0.01	0.008
45144	7879	15.62	Myt. edu.	6-7	M 1	0.137	3.508	0.637	65.90	6.07	0.827	1.04	12.59	3.05	0.37	0.039
45145	7880	15.16	Myt. edu.	7-8	M 1	0.118	3.454	0.742	79.85	6.34	0.761	1.00	13.63	2.78	0.37	0.038
45146	7881	13.95	Myt. edu.	5-6	M 2	0.115	2.293	0.795	73.43	6.66	0.827	1.16	17.54	3.81	0.44	0.034
45147	7882	16.27	Myt. edu.	4-5	M 2	<D.l.	2.401	0.503	60.68	6.68	0.548	1.14	13.41	4.13	0.38	0.026
45139	7875	14.06	Myt. edu.	7-8	M 3	<D.l.	3.856	0.960	79.08	6.70	0.973	0.97	14.17	3.12	0.43	0.033
45140	7876	14.17	Myt. edu.	6-7	M 3	<D.l.	2.593	0.677	81.71	6.50	0.764	0.99	12.50	3.15	0.37	0.029
45141	7877	15.92	Myt. edu.	6-7	M 4	<D.l.	5.617	0.686	81.32	7.11	0.603	0.82	10.89	3.56	0.40	0.022
45142	7878	15.32	Myt. edu.	7-8	M 4	0.332	12.436	0.902	78.33	6.91	0.742	1.00	11.89	3.91	0.42	0.112
45103	7873	17.88	Myt. edu.	6-7	AMI 1	<D.l.	5.923	0.875	73.23	6.10	0.622	0.69	10.03	2.80	0.35	0.023
45104	7874	16.72	Myt. edu.	7-8	AMI 1	<D.l.	7.271	0.931	77.77	6.34	0.720	0.66	10.54	2.96	0.35	0.023
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, Fucus vesiculosus						0.105	0.014	0.033	0.35	0.14	0.102	0.50	0.10	0.08	0.01	0.008
45148	7862	100	Fuc. ves.		M 1	<D.l.	1.544	0.748	5.74	1.05	0.116	0.68	52.72	<D.l.	0.25	0.010
45149	7863	100	Fuc. ves.		M 1	<D.l.	1.556	<D.l.	4.64	1.01	<D.l.	<D.l.	42.66	<D.l.	0.17	0.019
45151	7864	100	Fuc. ves.		M 2	<D.l.	0.994	<D.l.	5.81	1.09	<D.l.	<D.l.	52.83	<D.l.	0.25	0.008
45150	7865	100	Fuc. ves.		M 2	<D.l.	1.107	<D.l.	6.11	1.18	<D.l.	0.51	68.00	<D.l.	0.25	0.010
45135	7858	100	Fuc. ves.		M 3	<D.l.	1.052	<D.l.	5.95	1.65	<D.l.	0.71	45.51	<D.l.	0.39	<D.l.
45136	7859	100	Fuc. ves.		M 3	0.162	1.067	0.063	5.92	1.50	<D.l.	0.74	52.22	<D.l.	0.48	0.025
45137	7860	100	Fuc. ves.		M 4	<D.l.	1.894	0.041	5.19	1.29	<D.l.	1.02	46.23	<D.l.	0.45	0.023
45138	7861	100	Fuc. ves.		M 4	<D.l.	1.881	0.043	6.25	1.29	<D.l.	0.83	48.53	<D.l.	0.29	0.020
45101	7855	100	Fuc. ves.		AMI 1	<D.l.	1.766	0.066	4.13	1.14	0.134	0.73	61.17	<D.l.	0.25	0.010
45101	7856	100	Fuc. ves.		AMI 1	<D.l.	1.735	0.078	3.91	1.04	<D.l.	0.73	59.33	<D.l.	0.25	<D.l.
45102	7857	100	Fuc. ves.		AMI 1	<D.l.	2.188	0.042	4.49	1.02	<D.l.	1.25	61.85	<D.l.	0.49	<D.l.
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*	
Detection limits, Cetraria nivalis						0.105	0.014	0.033	0.35	0.14	0.102	0.50	0.10	0.08	0.01	0.008
45143	7826	100	Cet. niv.		M 1	0.136	0.035	0.341	33.07	0.86	0.334	<D.l.	0.27	<D.l.	0.13	0.010
45116	7824	100	Cet. niv.		M 2-*t*	<D.l.	0.059	1.069	21.70	1.87	1.113	1.04	2.35	0.14	0.63	<D.l.
45116	7825	100	Cet. niv.		M 2-*t*	<D.l.	0.050	0.977	17.76	1.43	0.906	0.75	1.94	0.11	0.51	0.008
45113	7820	100	Cet. niv.		M 3	<D.l.	0.027	0.440	10.05	0.69	0.274	<D.l.	0.19	<D.l.	0.09	<D.l.
45114	7821	100	Cet. niv.		M 4	<D.l.	0.065	0.283	34.32	0.62	0.134	<D.l.	0.13	<D.l.	0.10	<D.l.
45108	7815	100	Cet. niv.		AMI 1	<D.l.	0.031	0.357	18.45	0.52	0.094	<D.l.	0.13	<D.l.	0.05	<D.l.
45452	7827	100	Cet. niv.		1	<D.l.	0.080	0.909	24.96	0.85	0.259	<D.l.	0.30	<D.l.	0.18	<D.l.
45153	7828	100	Cet. niv.		2	<D.l.	0.055	0.488	30.85	0.79	0.237	<D.l.	0.22	<D.l.	0.14	<D.l.
45154	7829	100	Cet. niv.		3	<D.l.	0.104	0.613	14.37	0.83	0.405	<D.l.	0.37	<D.l.	0.23	<D.l.
45155	7866	100	Cet. niv.		4	<D.l.	0.042	0.632	19.43	1.09	0.523	0.64	0.64	<D.l.	0.30	<D.l.
45156	7884	100	Cet. niv.		5-*t*	<D.l.	0.095	1.594	22.22	3.37	2.597	2.09	1.38	<D.l.	1.14	<D.l.
45156	7885	100	Cet. niv.		5-*t*	<D.l.	0.084	1.426	18.88	2.80	1.677	1.59	1.11	<D.l.	0.92	<D.l.
45157	7869	100	Cet. niv.		6-*t*	<D.l.	0.095	0.892	26.48	2.56	1.631	2.47	2.13	0.09	1.83	<D.l.
45157	7870	100	Cet. niv.		6-*t*	<D.l.	0.083	0.691	22.74	2.11	1.333	1.83	1.68	0.08	1.48	<D.l.
45158	7886	100	Cet. niv.		7	<D.l.	0.070	1.356	17.59	2.53	2.634	2.76	2.59	0.10	1.39	0.009
45158	7887	100	Cet. niv.		7	<D.l.	0.061	1.291	15.51	2.76	2.801	2.82	2.98	<D.l.	1.50	<D.l.
45159	7872	100	Cet. niv.		8	<D.l.	0.085	0.956	40.64	3.30	1.045	2.08	1.50	<D.l.	1.54	<D.l.
45112	7819	100	Cet. niv.		9	<D.l.	0.105	1.401	16.17	2.64	1.499	1.58	2.47	0.15	0.88	<D.l.
45111	7818	100	Cet. niv.		10	<D.l.	0.123	2.464	27.64	4.02	2.650	2.94	3.27	<D.l.	1.76	0.059
45109	7816	100	Cet. niv.		11-*t*	<D.l.	0.047	0.844	14.41	3.09	1.524	1.70	1.99	<D.l.	1.08	<D.l.

ID no.	Lab	% d.w.	Species	Shell	Sta-	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Au
45110	7817	100	Cet. niv.		12-*t*	<D.l.	0.043	0.662	15.80	1.33	0.633	<D.l.	0.78	<D.l.	0.32	0.038
45105	7811	100	Cet. niv.		15	<D.l.	0.071	1.399	13.80	0.90	0.678	<D.l.	0.40	<D.l.	0.19	<D.l.
45105	7812	100	Cet. niv.		15	<D.l.	0.072	1.654	9.44	0.80	0.844	<D.l.	0.32	<D.l.	0.23	<D.l.
45106	7813	100	Cet. niv.		17	<D.l.	0.063	0.957	14.18	0.80	0.383	<D.l.	0.45	<D.l.	0.23	<D.l.
45107	7814	100	Cet. niv.		19	<D.l.	0.066	0.588	48.80	0.90	0.391	<D.l.	0.27	<D.l.	0.20	<D.l.
45115	7822	100	Cet. niv.		20-*t*	<D.l.	0.062	0.908	17.28	1.54	0.709	0.80	2.49	0.14	0.48	<D.l.
Background			Cet. niv.	*Average*		*0.033*	*0.081*	*1.076*	*21.61*	*0.97*	*0.48*		*0.24*		*0.157*	
Background			Cet. niv.	*SD*		*0.006*	*0.029*	*0.378*	*7.28*	*0.77*	*0.70*		*0.27*		*0.157*	
Detection limits, Myoxycephalus scorpius						0.032	0.004	0.010	0.11	0.04	0.031	0.15	0.03	0.02	0.00	0.002
45117	7830	26.71	Myo. sco.		U 1	0.067	1.161	<D.l.	34.75	1.72	<D.l.	<D.l.	7.39	0.90	0.02	0.006
45118	7831	25.12	Myo. sco.		U 1	0.044	1.140	<D.l.	37.10	2.04	<D.l.	<D.l.	6.54	1.02	0.02	0.004
45119	7832	29.41	Myo. sco.		U 1	<D.l.	0.162	<D.l.	24.59	0.98	0.031	<D.l.	1.19	0.71	0.01	0.004
45120	7833	-	Myo. sco.		U 1	<D.l.	1.139	<D.l.	41.75	12.67	<D.l.	<D.l.	2.83	0.79	0.06	0.006
45123	7834	21.94	Myo. sco.		U 2	<D.l.	0.337	<D.l.	33.83	1.09	<D.l.	<D.l.	2.54	0.70	0.03	0.002
45124	7835	24.89	Myo. sco.		U 2	0.061	0.961	<D.l.	34.42	1.20	<D.l.	<D.l.	3.26	1.00	0.02	0.003
45125	7836	31.71	Myo. sco.		U 2	0.037	1.168	<D.l.	35.17	1.84	<D.l.	<D.l.	5.24	0.84	0.03	0.003
45126	7837	28.76	Myo. sco.		U 2	<D.l.	0.378	<D.l.	34.17	1.26	<D.l.	<D.l.	3.04	0.75	0.01	<D.l.
45127	7839	16.13	Myo. sco.		U 3	0.045	1.414	<D.l.	38.97	6.03	<D.l.	<D.l.	3.30	0.91	0.07	0.005
45128	7840	-	Myo. sco.		U 3	<D.l.	0.745	<D.l.	34.91	7.68	0.043	<D.l.	3.90	1.26	0.08	0.003
45130	7842	23.91	Myo. sco.		U 3	0.040	0.752	<D.l.	32.90	2.23	<D.l.	<D.l.	6.78	1.07	0.02	<D.l.
45130	7843	23.91	Myo. sco.		U 3	0.039	0.708	<D.l.	31.88	2.19	0.031	<D.l.	5.32	0.95	0.02	<D.l.
45129	7854	29.82	Myo. sco.		U 3	<D.l.	0.311	<D.l.	26.61	1.34	<D.l.	<D.l.	3.15	1.07	0.02	<D.l.
45131	7844	38.32	Myo. sco.		U 4	0.094	0.903	<D.l.	31.67	2.67	<D.l.	<D.l.	2.89	0.76	0.07	0.007
45132	7845	42.72	Myo. sco.		U 4	<D.l.	0.492	0.012	17.11	0.63	<D.l.	<D.l.	2.44	1.06	0.01	0.005
45133	7846	27.47	Myo. sco.		U 4	0.045	0.377	<D.l.	29.22	1.40	<D.l.	<D.l.	5.19	0.69	0.02	0.003
45134	7847	24.77	Myo. sco.		U 4	<D.l.	0.292	<D.l.	24.52	2.05	0.190	<D.l.	2.66	0.51	0.01	0.003
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*	
Detection limits, Salvelinus alpinus						0.032	0.004	0.010	0.11	0.04	0.031	0.15	0.03	0.02	0.00	0.002
45160	7848	19.35	Sal. alp.		Wf	<D.l.	0.090	<D.l.	23.44	1.21	0.043	<D.l.	0.21	0.71	0.03	<D.l.
45161	7849	18.84	Sal. alp.		Wf	0.033	0.243	0.013	38.74	36.81	<D.l.	<D.l.	0.38	1.85	0.08	<D.l.
45162	7850	-	Sal. alp.		Wf	<D.l.	0.163	<D.l.	33.15	9.14	0.044	<D.l.	0.31	1.90	0.07	0.002
45163	7851	-	Sal. alp.		Wf	<D.l.	0.073	<D.l.	26.29	4.62	<D.l.	<D.l.	0.30	2.35	0.08	0.004
45166	7852	21.23	Sal. alp.		Wf	<D.l.	0.170	<D.l.	47.89	59.59	<D.l.	0.16	0.16	1.74	0.09	0.003
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.l. = value below detection limit; -*t* = station with transplanted lichens; Wf=Water fall; Myt. edu. = Blue mussel (*Mytilus edulis*); Fuc. ves. = Brown seaweed (*Fucus vesiculosus*); Cet. niv. = Lichen (*Cetraria nivalis*); Myo. sco. = Shorthorn sculpin (*Myoxycephalus scorpius*); Sal. alp. = Arctic char (*Salvelinus alpinus*).

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ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND, 2010

This seventh monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik, South Greenland during 25-31 August 2010. No ore had been shipped to foreign gold production since the monitoring study in August 2009. Most work has dealt with the excavation of a production chamber and the preparation of the gold separation. Low grade ore stored at the pier was transported back to the mine. Mussels, seaweed and sculpins were collected in the Kirkespir Bay, resident Arctic char were caught in the river and lichens were collected both in the area and transplanted to the valley from an uncontaminated area. Samples were analysed for 11 elements with ICP-MS. In lichens, elevated concentrations (2-9 times of background levels) of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) were found at the waste rock stockpile and in the mine area. A non-linear temporal trend with decreasing concentrations of the four elements was found in lichens from the two areas. This trend was explained by limited mining activities. All element concentrations showed a significant decrease with increasing distance to the road. Elevated concentrations were found to distances between 500 and 1000 m from the road. Concentrations of elements in transplanted lichens had decreased to lower levels than those found in 2009 and 2008. No elevated concentrations were found in mussels, sculpins and chars, while seaweed had slightly elevated Co concentrations at one station. In 2010, an impact from the mining activities was primarily seen in the Kirkespir Valley due to dust dispersal. The impact of the mine on the marine environment was negligible.

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