ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND, 2011

Scientific Report from DCE – Danish Centre for Environment and Energy No. 20 2012

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Data sheet

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Abstract: This eighth environmental monitoring programme was conducted in the Nalunaq area, about 40 km from Nanortalik, South Greenland, from 29 August to 12 September 2011. The environmental monitoring program is conducted to trace and avoid unwanted impacts of the mining industry to the environment. Since the monitoring in 2010, the mining company Gold Angel Mining A/S is breaking new ore, but is also carrying previously broken ore with low grade back to the mine with vehicles with limited speed and load capacity. The gold is recovered by the use of chemical extraction (carbon-in-pulp) using cyanide. Due to the use of cyanide to extract gold from the ore, strict control with the outflow of cyanide from the mine to the Kirkespir Valley is performed.
The described impact on the environment of the Kirkespir Valley, both terrestrial, freshwater and marine, is considered to be minor, and is generally lower than during the operation in 2004-2009.

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Contents

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Summary

This eighth environmental monitoring programme was conducted in the Nalunaq area, about 40 km from Nanortalik, South Greenland, from 2 to 12 September 2011. The environmental monitoring is conducted to trace and avoid unwanted impacts of the mining industry on the environment. Since the monitoring in 2010, the mining company Gold Angel Mining A/S is breaking new ore, but is also carrying previously broken ore with low grade back to the mine with vehicles with limited speed and load capacity. The gold is recovered by the use of chemical extraction (carbon-in-pulp) using cyanide. Due to the use of cyanide to extract gold from the ore, strict control with the outflow of cyanide from the mine to the Kirkespir Valley is performed.

Blue mussels, seaweed and sculpins were collected at 4-5 stations in Kirkespir Bay, Arctic chars were caught in Kirkespir River and lichens, *Flavocetraria nivalis*, were collected at 20 stations in Kirkespir Valley and around the bay area. Lichens were also transplanted from an unpolluted area (AMIT) to the Kirkespir area. All samples were analysed for 12 elements: arsenic (As), gold (Au), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn). The results were compared with background levels measured in 1998-2001 and with the results of previous monitoring studies.

The marine environment in 2011 was only slightly affected by mining activities. No significantly elevated element concentrations were found in mussels and in sculpin livers while seaweed had slightly elevated concentrations of Cu at all the marine stations, including the reference station. Furthermore, slightly elevated values of Au and Co were found in seaweed.

In the fresh water environment indications of minor elevations of the metals Cd and Pb in livers of Arctic chars were found.

In the terrestrial environment, lichens from the fields at the pier, the depot of crushed waste rock and mine and the camp showed significantly elevated concentrations of Cu, Cr, As and Co compared to background levels as in previous years. The concentrations of metals in the transplanted lichens were however lower in 2011 than in 2007 and 2008 but higher compared to 2010. The increase in 2011 is mainly supposed to be due to mining activities related to outdoor crushing at the 300 m portal, transport of high-grade ore from the depot above the pier back to the mine for mining purposes, and from road dust.

The relations between the concentrations of Cu, Cr, As, and Co in the lichens and the perpendicular distance to the road were examined for the period from 2005-11. For all metal concentrations, there was a significant decrease with increasing distance to the road with the exception of the two most exposed stations, 11-t and 20-t. Elevated levels of As and Co were found at a distance of up to approx. 2000 m from the road, while the Cr concentration reached the background level approx. 1000 m from the road and Cu approx. 500 m from the road.

The described impacts on the environment of the Kirkespir Valley, both terrestrial, freshwater and marine, are considered to be minor, and are generally lower than during the operation in 2004-2009.

Sammenfatning

Denne ottende miljømoniteringsundersøgelse blev udført i Nalunaq området, ca. 40 km fra Nanortalik, Sydgrønland, fra 2. til 12. september 2011. Moniteringsundersøgelserne foretages for at spore og undgå uønskede virkninger af mineindustrien på miljøet. Siden moniteringen i 2010 er mineselskabet Angel Mining Gold A/S begyndt at bryde ny malm, men transporterer også tidligere brudt malm med lav lødighed tilbage til minen med minekøretøjer med begrænset hastighed og lasteevne. Guldet udvindes ved brug af kemisk udvinding (Carbon-in-Pulp) med brug af cyanid. Grundet cyanid anvendelsen til udtrækning af guld fra malmen, føres der streng kontrol med, at udsivninger af cyanid fra minen ud i dalen holder sig under de fastsatte grænseværdier.

Blåmusling, blæretang og alm. ulk blev indsamlet på 4-5 stationer i Kirkespirbugten, ørreder blev fisket i Kirkespirelven og snekruslav *Flavocetraria nivalis* blev samlet på 20 stationer i Kirkespirdalen og ved bugten. Lav blev endvidere transplanteret fra et uforurenet område (AMIT) til mineområdet. Alle prøver blev analyseret for 12 grundstoffer: arsen (As), guld (Au), cadmium (Cd), kobalt (Co), krom (Cr), kobber (Cu), jern (Fe), kviksølv (Hg), nikkel (Ni), bly (Pb), selen (Se) og zink (Zn). Resultaterne blev sammenholdt med baggrundsniveauet målt i 1998-2001 og med resultaterne fra de tidligere moniteringsundersøgelser.

Det marine miljø var i 2011 kun ganske svagt påvirket af mineaktiviteterne. Der blev ikke fundet forhøjede grundstofkoncentrationer i muslinger og i ulkelever, mens tang havde svagt forhøjede koncentrationer af Cu på alle marine stationer inklusiv referencestationen. Desuden blev der fundet lettere forhøjede værdier af Au samt Co i tang ved enkelte stationer.

I det ferske vandmiljø blev der i 2011 fundet indikationer på let forhøjede koncentrationer af metallerne Cd og Pb i lever fra ørred.

I det terrestriske miljø var der i laver fra områderne ved pieren, depotet for knust gråbjerg og ved minen og lejren signifikant forhøjede koncentrationer af Cu, Cr, As og Co sammenlignet med baggrundsniveauer ligesom i de tidligere år. Koncentrationerne af metaller i de transplanterede laver var i 2011 lavere i forhold til 2007 og 2008, men højere end i 2010. Forhøjelserne formodes især at skyldes mineaktiviteter i forbindelse med udendørs knusning ved 300 m portalen, transport af højlødig malm fra depotet ovenfor kajen tilbage til minen i udvindingsøjemed samt vejstøv.

Forholdet mellem koncentrationerne af Cu, Cr, As og Co i lav og den vinkelrette afstand til vejen blev undersøgt for perioden 2005-11. For alle metalkoncentrationer var der et signifikant fald med stigende afstande til vejen med undtagelse af de to mest belastede stationer 11-t samt 20-t. Der blev fundet forhøjede koncentrationer af As og Co i en afstand af op til ca. 2000 m fra vejen, mens Cr koncentrationen nåede baggrundsniveauet ca. 1000 m fra vejen og Cu koncentrationen i ca. 500 m fra vejen. Den beskrevne påvirkning på miljøet i Kirkespirdalen, både terrestrisk, ferskvands, og marint, anses for at være begrænset og påvirkningen er generelt mindre end under minedriften i 2004-2009.

Eqikkaaneq

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2011-imi imaani avatangiisit aatsitassarsiornermiit annikitsuinnarmik sunnerneqarsimapput. Uillut kanassullu tingui pinngoqqaatinik qaffasinnerusunik nassaarfigineqanngillat, qeqqussalli uuttortaavinni tamani kiisalu sanilliussiviusumi Cu-mik akoqarnerulaalersimallutik. Kiisalu uuttortaavinni ataasiakkaani qeqqussat Au-mik kiisalu Co-mik akoqarnerulaalersimapput.

Eqallut kuunniittut tingui 2011-imi saffiugassanik Cd-mik kiisalu Pb-mik akoqarnerat malunnarpoq.

Talittarfiup, ujaqqanik aserortikkanik ilioqqaaviup kiisalu aatsitassarsiorfiup tammaarsimaffiullu eqqaanni Cu, Cr, As aammalu CO ukiuni siuliini sanilliussivinnut sanilliullugit annertungaatsiaqaat. Qillinerit nuussat saffiugassanik akui 2011-imi uuttukkat 2007-imut aammalu 2008-imut sanilliullugit appasinnerupput, 2010-imulli sanilliullugit qaffasinnerullutik. Qaffasinnerunerat pissuteqarsorineqarpoq sullup 300 meterinik qaffasissusillup paavani silami ujaqqanik aserorterinermik, akuiagassap akoqarluartup talittarfiup eqqaanut assartorneqarneranik kiisalu aqquserngup pujoralatsitsineranik.

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Napasorsuup Qooruani avatangiisit sunnigaanerat, nunami imermi, imaanilu, oqaluttuarineqartoq killilittut isigineqarpoq kiisalu sunnigaanerat 2004-2009-imi kuultisiornermit annikinnerusutut isigineqarluni.

1 Introduction

1.1 Mining activities

'Nalunaq' is the Greenlandic name of Greenland's first gold mine and means 'the place that is hard to find'.

The Nalunaq Gold Mine (NGM) is located in Kirkespir Valley 40 km north-east of Nanortalik in the southernmost tip of Greenland and is a Proterozoic narrow-vein, high-grade gold deposit.

Nalunaq Mountain, which hosts the gold deposit, is located in a wide glacial valley reaching into the Saqqaa Fjord about 9 km from the mine site. The terrain is a glacial valley with mountain peaks reaching 1,200-1,600 m above sea level. A river runs through the valley, fed by mountain streams of melting snow, and runs to the fjord.

The first opening of NGM in 2004 was a milestone for Greenland, being the first gold mine and the first new mine to be developed in the country for over 30 years. In 2004 the mining company Crew Gold Corporation was granted a license to exploit the gold deposit at Nalunaq. The license covered an area of 16 km² around the mine site. Before commencing mining operations, Crew completed over 30,000 meters of diamond drilling and established that the gold is in a quartz intrusion in a granite like host rock. The structure is quite uniform with the quartz varying in thickness from 0.75 meter to 1.5 meters but the gold distribution is not evenly dispersed. The Nalunaq gold deposit is a high-grade gold-only mineralization (ca. 10-20 g gold/ton ore) associated with quartz-veins. The ore sheet has an average strike angle of 35° inside the Nalunaq Mountain being 1,340 meters high. Production commenced in mid-2004 and continued until the end of 2008. Over the period, Crew completed more than 19,000 meters of tunneling and produced 8,000 kg of gold. The mined ore was shipped first to Spain and later to Canada for processing. Rising oil prices and shipping costs however made the economics progressively more difficult and the mine closed with the last shipment of ore in March 2009.

In July 2009, Crew concluded the sale of Nalunaq Gold Mine to Angus and Ross plc – now 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). The target annual production rate is approximately 680 kg of gold per year and since the first pure of gold in May 2011, the Nalunaq Mine has until the end of 2011 produced more than 103.4 kg of doré extracted from ore exploited from new drilling and from ore stored at the pier by the former mining company that has now been transported back to the mine (Angel Mining 2012). Most of the mining work from 2009 and until the actual production has dealt with the excavation of a production chamber inside the mine and the preparation of a chemical gold separation (Carbon-In-Pulp, CIP) including cyanide use and optimization of the processes.

The processing plant is believed to be the world's first underground cyanide leaching plant and the on-site plant enables the company to eliminate the costs of shipping and external processing of ore material, which proved to be a costly burden for the previous operation.

The CIP method employs massive tanks aligned whereby gold is dissolved into slurry (pulp) through a chemical process incorporating agitation, oxygen and cyanide. Once dissolved, the gold in aqueous solution requires separation. At this stage, activated carbon pellets are introduced to the circuit and adsorbs the aqueous gold. The gold loaded coarse grained carbon can then be screened from the water and the fine grained ore. The loaded carbon is then introduced to a cyanide solution under heat and pressure with the purpose of stripping the gold from the carbon. Hereafter the gold is electroplated onto stainless steel cathodes and melted into dore bars. Metallurgists strive for the best recovery with the least loss of gold from the circuitry through tailings, and the CIP process leads to an app. 90% recovery of gold from the ore.

As described above the gold extraction involves addition of cyanide, which is a compound that exerts high acute toxic effects even in low concentrations. Cyanide is however easily degraded under light and/or oxygen to nontoxic levels. In the mining process cyanide is added in the first extraction tank as sodium cyanide. After its use the cyanide is treated by sodium meta bisulphite and air in order to decompose the cyanide into cyanate. The cyanide is, however, not decomposed completely, and the rest of the cyanide will follow the tailings into the under-ground tailings chamber and a small amount will be discharged by wastewater from the process. The tailings chambers are outmined areas in the mine.

There are in particular two main environmental risks associated to the mining process:

- The risk of spreading of released elements (metals) due to the crushing effects of the body rock. The environmental risk is associated with discharge of wastewater from the process and to spreading of elements as dust particles.
- The risk of discharging of cyanide in toxic concentrations to the environment. The risk is associated with discharge of mining process waste water or accidental spill of cyanide e.g. from traffic accidents or incorrect pumping of cyanide solutions

As a result of those risks an environmental monitoring programme has been developed to trace and avoid unwanted impacts to the environment.

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 defined by the Bureau of Minerals and Petroleum (BMP)

of the Greenland Self-Government. These requirements are described in the BMP exploitation license of 19 March 2010.

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

1.3.1 Cyanide monitoring programme

Due to the mining activities and the use of the CIP method involving cyanide, an intensive monitoring programme for detection of cyanide in the environment is being conducted. The mining company is responsible for conducting the sampling and sample analyses and must forward the data on a regular basis to BMP.

One process water sample is taken inside the mining area and 5 environmental samples are taken outside in the environment to ensure that cyanide concentrations in the environment does not exceed the limits set by BMP (identical to the Ontario Province Quality Objectives). The environment must be monitored continuously for cyanide as described in the EIA report. To protect organisms and in particular the resident Arctic char from toxic effects, the cyanide concentration in the Kirkespir River must not exceed 0.005 ppm (mg/l, measured as WAD cyanide).

1.3.2 Element monitoring programme

The element monitoring programme is divided into three compartments: the marine, the freshwater and the terrestrial environment. For the marine environment brown seaweed, blue mussel and shorthorn sculpin are sampled at stations that are placed relatively close to, and on each side of the shipping facility. For the freshwater environment, the sampling station is located at the first site downstream the mining area, where Arctic chars are occurring. Sampling stations for the terrestrial environment are 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 have to be collected at the number of stations specified:

Marine environment:
- Brown seaweed at 4 stations with 2 samples per station; a total of 8 samples.
- Blue mussel at 4 stations with 2 samples (2 different size groups) per station; a total of 8 samples.
- Liver from 5 shorthorn sculpin at 4 stations with a total of 20 specimens.

Freshwater environment:
- Liver from Arctic char at 1 station of 4 specimens.

Terrestrial environment:
- Lichens, *Flavocetraria nivalis,* at 18 stations; a total of 18 samples.

The samples collected are 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 the existing monitoring programme is considered 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 shortly after being collected. The analytical data must be processed, and a report prepared. This report must reach BMP no later than four months after the samples have been collected unless otherwise agreed. The samples must be collected and analysed in accordance with guidelines prepared by DCE-AU.

Photo 1.1. Mussels and seaweed are collected at low tide at the marine stations (photo by L Bach).

1.3.3 Monitoring studies 2004 – 2010

Since the official opening of the Nalunaq Gold Mine in August 2004, every year during July or August the National Environmental Research Institute (NERI) 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 DCE-AU web address:
http://www.dmu.dk/en/publications/ and Technical Reports. Danmarks Miljøundersøgelser, DMU or National Environmental Research Institute, NERI was from 2011 replaced by DCE - Danish Centre for Environment and Energy, Aarhus University.

1.3.4 Monitoring studies 2011

As 2011 is the first year with production in the area using cyanide, the present report also describes the cyanide monitoring.

Cyanide monitoring programme

The cyanide monitoring programme is conducted by the mining company with a frequency of reporting to BMP two times a week. In May 2011, the programme and analytical part was inspected by DCE-AU.

Element monitoring programme

The monitoring study was performed in the Nalunaq area during 2-12 September 2011.

Sampling was carried out in accordance with the monitoring programme described in the exploitation license (and in chapter 1.3.2) with the following deviations:

In this year's monitoring studies, both blue mussels and brown seaweed were sampled at two more stations; one new marine station close to the river discharge to the bay M5 and at AMIT, a reference site on the north-east side of the Amitsoq Island about 15 km north of the Kirkespir Bay (figure 2.2).

Further, livers of shorthorn sculpin were sampled at four marine stations (U1-U4) in the Kirkespir Bay and at the reference station AMIT. Four specimens a site were collected, with a total of 20 livers.

At the freshwater environment 6 Arctic char livers were sampled from the Kirkespir River near the waterfall.

Lichens were collected from the six transplantation stations (M2-t, 5-t, 6-t, 11-t, 12-t and 20-t,) established during 2007-2010 in Kirkespir Bay and Valley. New lichens, collected at AMIT, were transplanted to these six stations.

Lichens were not collected at station 1 due to logistic problems.

Besides the monitoring programme, a few more aspects were included to investigate to what extent the marine sediment system is affected by the mining activity. Sediment samples were collected at marine stations M2, M4 and M5 and amphipods, *Orchomenella pinguis*, were sampled at station M2, M3, M4 and M5. This amphipod is a small (~5-10 mm length) sediment living organism that has been shown to be almost ubiquitous in the Arctic. It can be found in high densities and is well known by fishermen for stripping bait and catches. This amphipod occurs also in shallow waters likely to be among the first organisms to be affected by contaminants originating from land, both via food, water but also via contaminants bound to sediment particles (Bach et al. 2009).

Analyses were performed according to the programme, however 77 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 the people at Nalunaq, Angel Mining Gold, for their help and assistance during the tight monitoring programme. Sigga Joensen laboratory technician at DCE-AU is thanked for sample preparation, analyses and delivery of analytical results.

2 Methods

2.1 Cyanide monitoring programme

2.1.1 Collection of samples

Water samples were collected at 6 different sampling stations at different times. Sampling from Marts till late July was conducted with a sampling frequency of daily at station 1 and 2, weekly at station 3 and monthly at station 4, 5 and 6. From late July sampling was conducted more frequent with sampling at station 3 daily, and 4, 5 and 6 weekly (figure 2.1 and table 2.1).

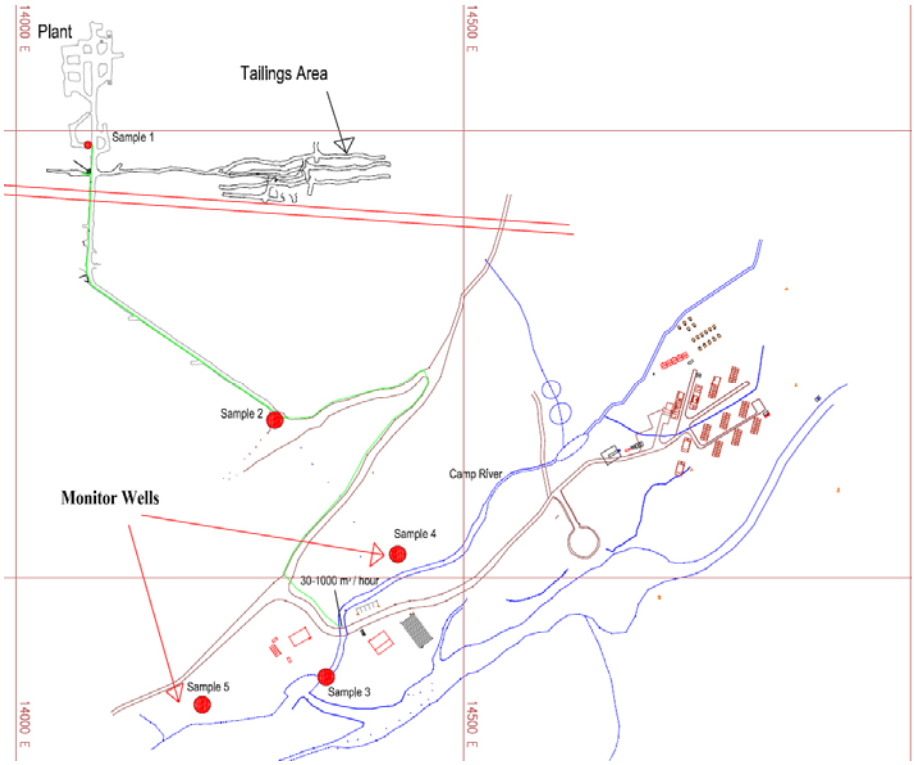

Figure 2.1. Sampling stations for cyanide monitoring. Sample 1 is taken from the tailings water, sample 2 is taken at the 300 m mine entrance, where wastewater is discharged. Sample 3 is taken at the sediment basin and sample 4 and 5 from monitoring wells. Sample 6 is further down the Kirkespir River and is not shown in the map.

Table 2.1. Cyanide sampling programme and maximum limit values in ppm (parts per million or mg/l).* Monthly averages with maximum allowed value of 10.0 ppm.

Sampling Station	Location	Monitoring frequency	Maximum cyanide concentration
1	Process water/ tailingswater	Daily	4.0 ppm in winter* / 2.0 ppm in summer*
2	Wastewater discharge from mine process area/ditch	Daily	0.20 ppm
3	Sedimentation basin	Daily	0.20 ppm
4	Monitoring well a	Weekly	0.005 ppm
5	Monitoring well b	Weekly	0.005 ppm
6	Kirkespir River - waterfall	Weekly	0.005 ppm

2.1.2 Analyses

Water samples were processed shortly after the sampling at the laboratory facilities in the camp. After filtration the samples were analysed for cyanide using the Hach Lange LCK315 method and a Hach-Lange DR2800 instrument. This method is fast and easy and has a measuring range of 0.01 mg/l – 0.60 mg/l within which precise results are obtained, and the detection limit is probably down to 0.002 mg/l.

Photo 2.1. Water sampling at ditch, where the mine processing wastewater is entering the environment (photo by G Asmund).

2.2 Element monitoring programme

2.2.1 Collection of samples

Sampling in the Kirkespir Bay and at the north-eastern point of Amitsoq Island (AMIT) was performed with a boat. Sampling of blue mussels and seaweed was performed at low tides (Danish Maritime Safety Administration 2011).

Mussels were collected at each of the five stations M1-M5 and AMIT in two size groups for each station (see Appendix 3). Each sample consisted of approximately 20 individuals. The mussels were opened and allowed to drain, the soft parts cut free and frozen in plastic bags for later analysis.

Seaweed was collected at two spots within an area of approximately 20 m at each station resulting in two samples per station. The growth tips of seaweed from this year were cut, washed in freshwater and frozen in plastic bags. Stations were identical to the blue mussel stations M1-M5 and AMIT.

Shorthorn sculpins were jigged for from the motor boat at the stations U1, U3, U4 and AMIT. 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.

Amphipods were caught be leaving a baited trap on the seafloor overnight. The amphipods were dried at room temperature and placed in plastic bags.

Sediment samples (upper 2 cm) were sampled, sieved to 1 mm and frozen in plastic bags.

Resident Arctic chars were fished in the Kirkespir River downstream from the waterfall and 6 resident char were caught. In the laboratory each fish was measured, weighed and the liver was dissected out. Resident Arctic chars 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 chars spend the summer feeding in the Kirkespir Bay and the Saqqaa Fjord.

Lichens were sampled at 20 stations: Nine 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 north-eastern part of Amitsoq Island (station AMIT) (figure 2.2). Lichens at station 1 were not sampled due to logistic problems. Lichens sampled at AMIT were transplanted to t-stations M2-t, 5-t, 6-t, 11-t, 12-t and 20-t, after transplanted lichens from 2010 were sampled and the stations cleaned (Appendix 2).

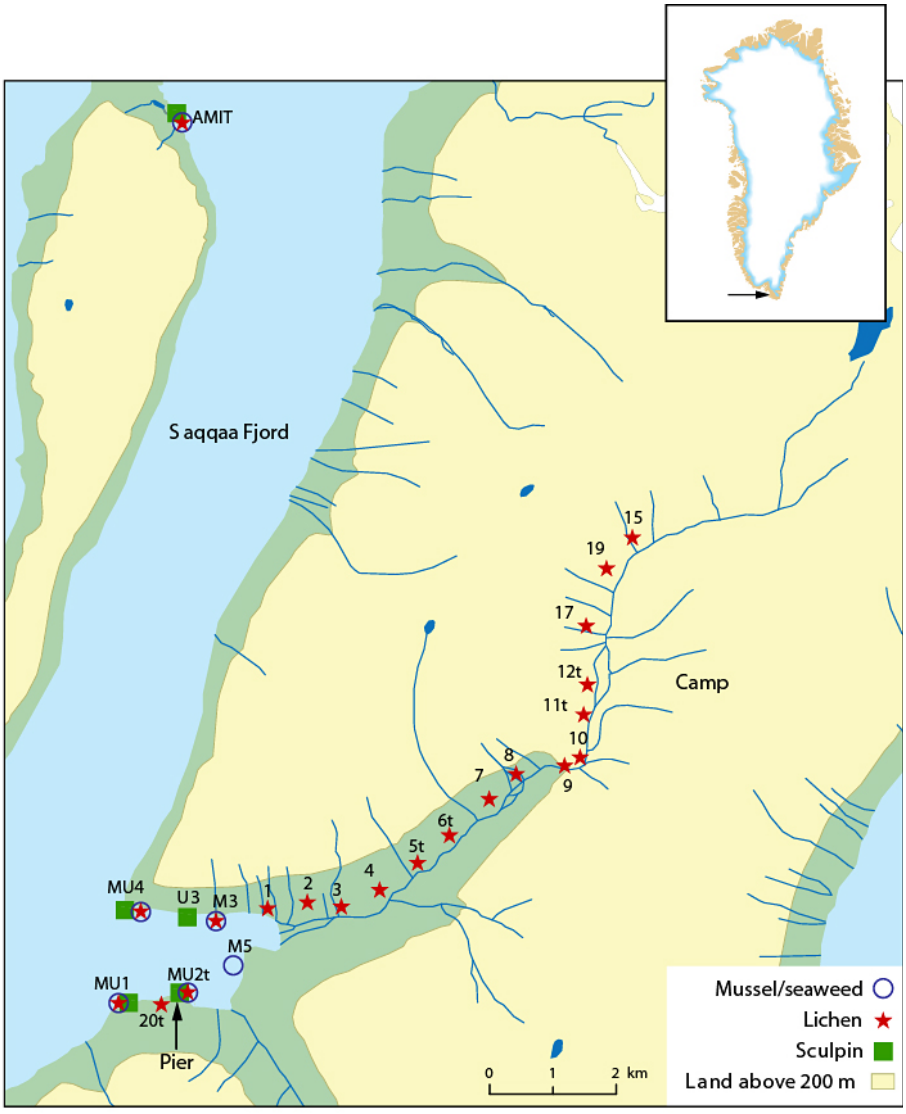

Figure 2.2. Sampling stations in the Nalunaq Gold Mine area, Nanortalik, South Greenland. M: Marine stations: Blue mussel and brown seaweed. U: Shorthorn sculpin stations. Arctic chars were caught near the lichen station 9 at the waterfall station. Sediment samples were collected at marine stations M2, M4 and M5, while amphipods were samples at M2, M3, M4 and M5. Lichens were sampled at 21 stations (station 1 was left out due to logistic problems). Lichens transplanted (t) in 2010 from AMIT were sampled at stations M2-t, 5-t, 6-t, 11-t, 12-t and 20-t and replaced with new lichens from AMIT. The mine entrance is west of the camp area.

2.2.2 Analyses

All samples were transported either frozen or dry directly to DCE-AU on 12 September 2011. A total of 77 samples of blue mussel (12), brown seaweed (12), livers of Shorthorn sculpin (20), amphipods (4), sediment (3), livers of Arctic char (6) and lichens (20) were analysed for the following 12 elements: arsenic (As), gold (Au), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), Mercury (Hg),nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn).

Chemical analyses

Following freeze drying of blue mussels and brown seaweed at DCE-AU, 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 4. Simultaneously with the Nalunaq samples, blind samples, duplicates and the certified reference materials Dorm-3, Dolt-4 and Tort-2 were analysed as part of the laboratory quality control. In table 2.2, 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.

2.2.3 Statistical data analyses

Data obtained in this monitoring programme (2011) was compared with data obtained in the baseline studies (data from 2000-2002) that was conducted before the gold mining started in the area. Further, the monitoring stations were compared to the reference station, AMIT, which is situated 15 km away from the mining area and should not be affected by mining activities.

Differences in element concentrations in brown seaweed, mussels, shorthorn sculpin and Arctic char were tested using a one-way analysis of variance (ANOVA) after logarithmic (base e) transformation of all data to meet the assumption of normal distribution and variance homogeneity. The post hoc Tukey's studentized range test was applied to test of differences between sites and background. The level of statistical significance used was $p < 0.05$.

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 2004-2011 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 $p < 0.05$.

Finally, the relations between concentrations of Cu, Cr, As and Co in lichens were analysed and the distance to the gravel road in 2011 with linear regression analyses using logarithmic transformed element concentrations as dependent variable and logarithmic transformed distance as independent variable.

3 Results and discussion

3.1 Cyanide monitoring programme

Cyanide concentrations are measured in water samples collected in the freshwater system around the mine area and in the Kirkespir River. Water sample data has been forwarded BMP 1-2 times a week and evaluated. Cyanide concentrations in the samples are considered elevated if the values exceed the maximum concentration limit in Table 3.1 except for station 1, where it is the monthly average values that must not exceed the maximum concentrations.

Table 3.1. Cyanide monitoring programme. Monthly average values of cyanide in ppm (mg/l) ± std dev. At station 1 the maximum concentration is 2.0 ppm in the summer time and 4.0 ppm in the winter time. nm indicates that the sample has not been measured due to inaccessibility caused by deep snow in the field. -*: missing std dev due to only one measurement. **: high measured concentration was due to analytical difficulties, that then was corrected. ***: the high concentrations measured in July were due to an operating error that was responded to and corrected promptly..

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
max ppm		**2.0/4.0**	**0.20**	**0.20**	**0.005**	**0.005**	**0.005**
Marts	average	1.703	0.178	0.098	0.001	0.004	nm
	std dev	3.262	0.207	0.078	-*	-*	
April	average	0.308	0.142	0.011	nm	nm	nm
	std dev	0.347	0.211	-*			
May	average	0.192	0.115	0.010	0.002	0.037	nm
	std dev	0.093	0.191	0.006	-*	-*	
June	average	0.323	0.070	0.012	0.002	0.001	0.000
	std dev	0.293	0.050	0.004	-*	-*	-*
July***	average	4.944	1.111	0.093	0.004	0.007	0.009
	std dev	3.014	1.461	0.041	0.003	0.004	0.002
August	average	1.622	0.126	0.036**	0.000	0.001	0.001
	std dev	2.088	0.100	0.043	0.000	0.002	0.002
September	average	0.474	0.155	0.017	0.011	0.016	0.008
	std dev	0.175	0.089	0.012	0.011	0.019	0.003
October	average	0.393	0.087	0.043	0.010	0.007	0.007
	std dev	0.097	0.056	0.043	0.016	0.011	0.007
November	average	0.370	0.119	0.019	0.000	0.001	0.005
	std dev	0.310	0.059	0.015	0.001	0.001	0.006
December	average	1.650	0.117	0.026	nm	nm	0.000
	std dev	1.626	0.064	-*			-*

Strict control on cyanide concentrations in process water, wastewater and in recipients is exercised to avoid risk of adverse effects on the environment. The cyanide concentrations appeared rather stable most of 2011 and the monthly average values were mostly below the maximum limit concentrations set by the BMP. However, in a period in July the measured concentrations of cyanide at station 1 and 2 were higher than the allowed concentrations. This was assigned to an operating error in the carbon in pulp process. The mining company responded by closing down the process shortly. They found the error, cleaned up and started the production again. Hereafter the cyanide concentrations were maintained below the maximum limit. Actions were taken in order to prevent the error from occurring again. This occasion

resulted in adjustments of the monitoring programme with more frequent water sampling. Further, monthly average cyanide measurements were also found to exceed maximum concentrations at station 4, 5 and 6. These exceedances have been explained by NGM as temporary failures in the plant and to analytical uncertainties and a small sample contamination in the test laboratory. In May and in August DCE-AU inspected the cyanide analytical programme. The instrument is by the manufacturer guarantied an operating range from 0.01 to 0.6 ppm, but it has a reading down to 0.002 ppm. A significant exceedance of the maximum value of 0.005 ppm cyanide will be demonstrated with the apparatus.

During winter time the company is experiencing difficulties in taking the station samples 4, 5 and 6 in a safe and secure way due to high snow levels.

Conclusions on the cyanide monitoring programme

In general, the measured cyanide concentrations have not been kept at a stable and low level as expected. However, NGM has performed substantial improvements on technical regulatory units and since January 2012, NGM has been giving permission using a higher cyanide concentration in the process water (sample 1) at 2 ppm during summer time and 4 ppm in winter. In 2011 there was strict control on the use of cyanide and the outlet to the marine environment. The water stream where sample 1 is taken is an internal flow of recirculated process water. It is not directly released into the environment unless an operating error occurs or the mountain unexpectedly should become permeable for seepage.

Photo 3.1. Monitoring well, station 5, in the cyanide monitoring program (photo by L Bach).

3.2 Element monitoring programme

Element concentrations are obtained from biota sampled in the marine environment in the Kirkespir Bay, in the freshwater environment in the Kirkespir River and in the terrestrial environment of the Kirkespir Valley (figure 2.2). The analytical results and detection limits, as well as background concentrations from Glahder et al. (2005) are given in Appendix 4. Element concentra-

tions in the species analysed are considered elevated if they are significantly ($p< 0.05$) higher than the background concentrations.

3.2.1 The marine environment

Samples from the Kirkespir Bay were collected at five mussel and seaweed stations (M1-M5), at four sculpin stations (U1-U4) and at the reference station (AMIT) (figure 2.2).

No elevated element concentrations were found in blue mussel samples. In brown seaweed, significant elevated average concentrations of Cu were found at all the stations (including AMIT) compared to background concentrations. Since also the reference station was higher than the background concentrations the Cu elevations can't be attributed to the mining. Further, significantly elevated concentrations were found for Au at station M3 and Co at station M4 and M5 (one-way ANOVA). No elevated concentrations of other elements analysed were however found at any of the other seaweed stations (Appendix 4).

In sculpin liver, average element concentrations were not significantly elevated compared to the background concentrations (data from 2000). With respect to the sediment dwelling amphipod, even though only few samples, there is a tendency for the amphipod to contain a higher concentration of metals than measured in the sculpin livers. This might be a reflection of the metal concentrations that is found in the sediment samples, as the amphipods are assumed to take up and accumulate the metals from sediment and in particular from pore water. Based on these results and to get more information on the contamination level in the sediment systems in Kirkespir Bay, it is suggested to conduct more detailed sampling of sediment samples and the sediment living amphipods at the environmental monitoring studies in 2012.

Conclusions on the marine environment

As in previous years, the impact from the mining activities on the marine environment in 2011 in terms of elevated metal concentrations was found to be very low.

In general, during the last six years (2006-2011), the concentrations of metals in the marine environment have been low and not remarkably different from the background levels.

Earlier in the mining history elevated concentrations of Cr were found in sculpin livers and of Co in blue mussel in the bay in 2004. Also, in seaweed elevated concentrations were found of especially Cr, and elevated concentrations of Cu, Co and Zn were found in both 2004 and 2005. Later in 2006-2009, only Co was found to be elevated (by a factor 2-3) in seaweed at station M3 in the marine environment.

3.2.2 The freshwater environment

In livers from resident Arctic char caught in Kirkespir River the average concentrations of Cd and Pb (0.173 µg/g and 0.027 µg/g, respectively) were significantly elevated compared to baseline concentrations (2-3 times) (one way-ANOVA). No elevated concentrations of other elements analysed were found (Appendix 4).

Conclusions on the freshwater environment

Elevated element concentrations were in 2011 found for Cd and Pb in Arctic char in the Kirkespir River. Increased concentrations have been observed before, where Cr was found elevated 2-3 times in 2004 and 2006, Co was found elevated 3 times in 2004 and Cd 2 times in 2006; no elevations were however found in 2005 and during 2007-2010. The elevations of Pb and Cd are interpreted as natural variations until the results can be verified by new independent measurements e.g. at the environmental monitoring programme in 2012. The higher concentrations found in 2011 for Pb are still below maximum levels for food consumption (0.2-0.4 µg/g fish for Pb), while for Cd the maximum limit for consumption is 0.05-0.1 µg/g fish (Fødevaredirektoratet 2003), which is a bit below what was found for the liver of Arctic char caught in Kirkespir River.

Photo 3.2. Resident Arctic chars (*Salvelinus alpinus*) are caught in the Kirkespir River at the water fall station (photo M Buckland).

3.2.3 The terrestrial environment

Concentrations of four metals (Cu, Cr, As and Co) were compared in lichens (*Flavocetraria nivalis*) during 2004-2011. Two areas were selected, the stockpile of crushed waste rock (stations 5 and 6) and the camp and mine area (stations 11 and 12). In 2010 as in previous years, lichens were transplanted from an uncontaminated area (station AMIT) to these four stations: M2-t, 5-t, 6-t, 11-t and 12-t. In 2011 these transplanted lichens were analysed together with lichens growing naturally in the Kirkespir Valley.

The method 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 AMIT) to the Nalunaq area in order to determine the annual amount of dust pollution.

Average concentrations in each of the two areas were compared with background concentrations and Cu, Cr, As and Co were significantly elevated in the years 2004-2011 (Tukey's post hoc test). Elevations in the two areas in 2011 were 3-5 times for Cu and Cr, up to 22 times for As and 10 times for Co (figure 3.1a, Appendix 4). Concentrations of these four metals were not significantly different between the years 2004-2011, except for As in area 1 where concentrations in 2008 were significantly higher than in 2004 (Tukey's post hoc test).

The temporal trends in concentrations of the four metals were compared in the two areas described above. The results are shown in figure 3.1 (Area 1) and figure 3.2 (Area 2). Concentrations of all four metals in Area 1, which are station 5 and 6, seem to have stabilized since 2009. This area was previously used for a stockpile of waste rock. Area 2, which is the area around the camp and downhill the mine (station 11-t and 12-t), seemed to stabilize for the four metal concentrations towards 2010 but have since then increased slightly due to the restart of the mining activities.

A third particular area of interest is the area around the pier, the stockpile area. During the last mining period, a large stockpile of low graded ore was placed in the field above the pier, intended for shipping off. As the Crew mine closed, the stockpile was left and the ore has in 2011 been transported back to the mining area for processing. The stations M2-t and 20-t represent lichens in this area. Concentrations of the four metals at the pier (station 20-t and M2-t) were found to be 2-29 times higher than the background concentrations (figure 3.4a).

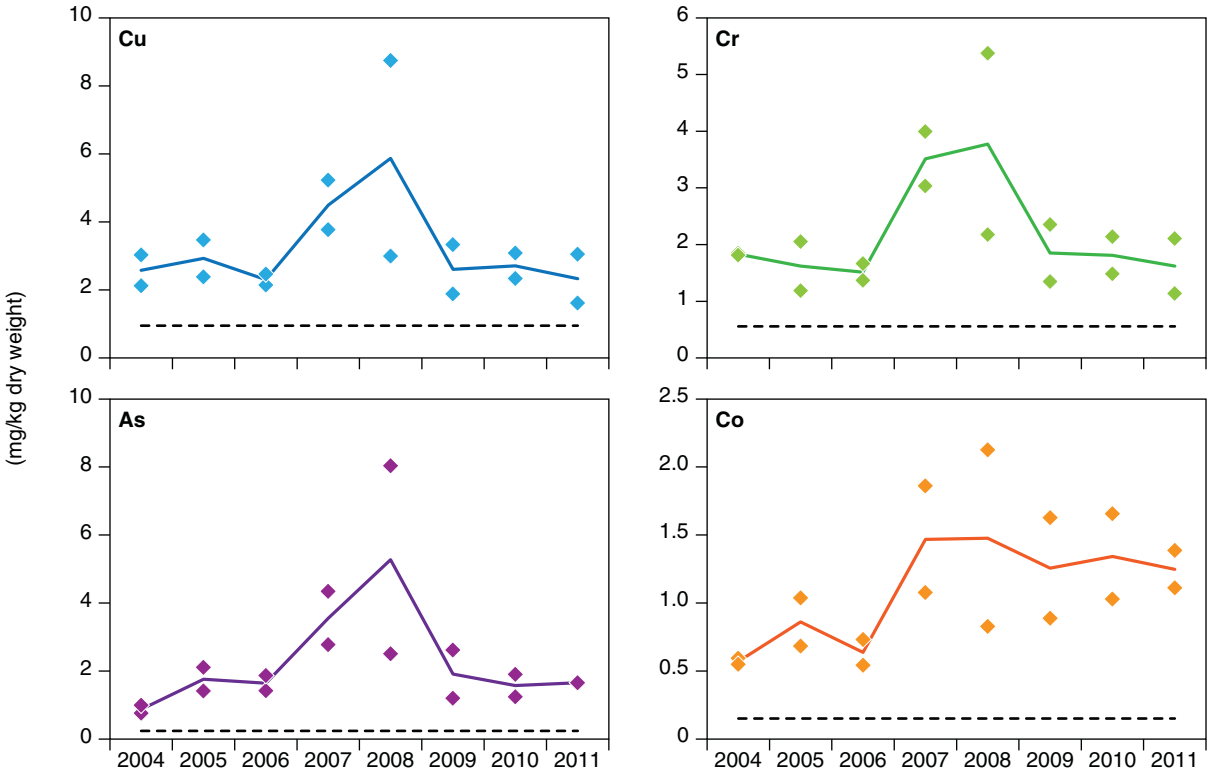

Figure 3.1. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from Area 1 during 2004-2011. Area 1 is the stockpile of crushed waste rock (stations 5-t and 6-t). From 2008 onwards concentrations are from transplanted lichens. Baseline average concentrations from 1998 are shown as dashed lines.

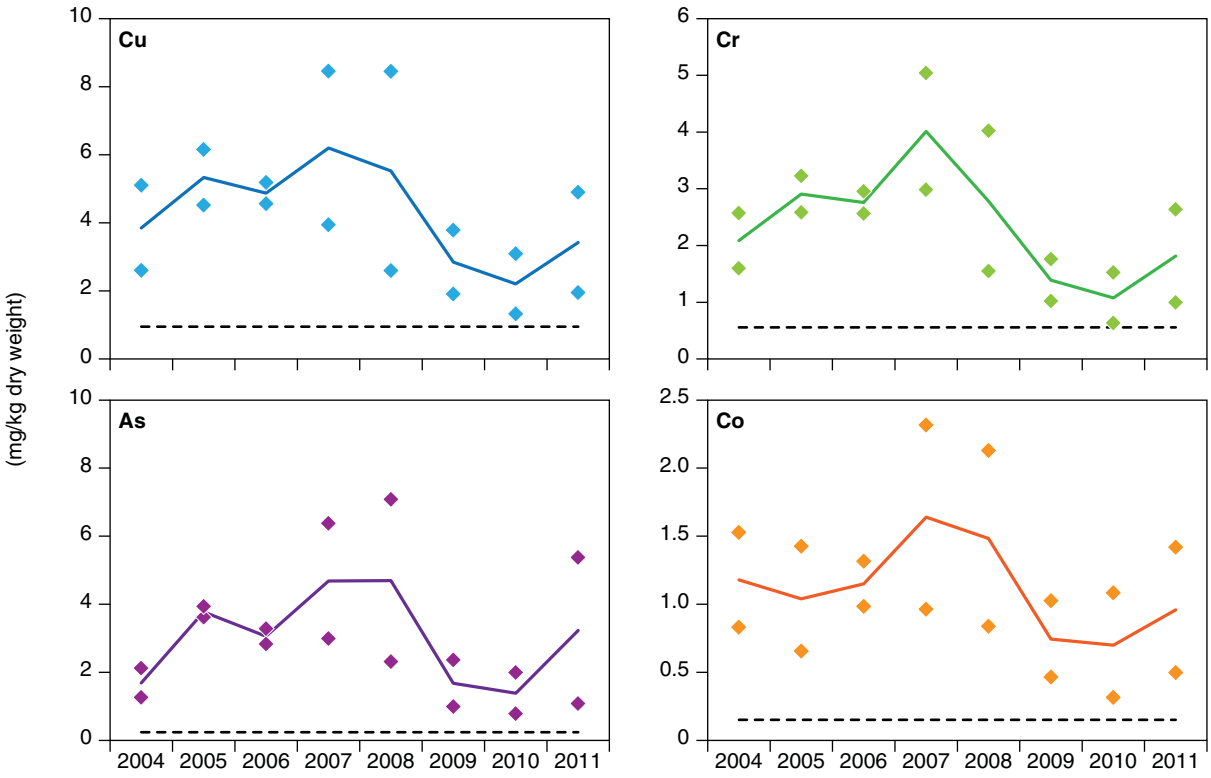

Figure 3.2. Temporal trends in concentrations of Cu, Cr, As and Co in lichens from Area 2 during 2004-2011. Area 2 is the camp and mine area (stations 11-t and 12-t). From 2008 onwards concentrations are from transplanted lichens. Baseline average concentrations from 1998 are shown as dashed lines.

Concentrations of Cu, Cr, As and Co have been analysed in transplanted lichens since 2008 and these concentrations were compared with those measured in naturally growing lichens from the same stations in 2007. The stations are M2-t in the pier area, 5-t and 6-t in the stockpile area and 11-t and 12-t in the mine area (figure 3.3).

The transplanted lichens show the yearly uptake of elements, while the naturally grown lichens also are influenced by uptake since 2004. All stations showed a decrease in concentrations from 2008 till 2010, most pronounced at stations M2-t, 6-t and 11-t. 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. Since 2010 where the production started up again there seems to be an increase in the dust pollution of all the four metals at M2-t, 12-t and in particular at 11-t for Cu and As. This is in accordance with the activity, outdoor crushing at level 300 m and vehicle traffic in the area. The dust pollution from the stockpiles of waste rock at station 5-t and 6-t seems to have stabilized.

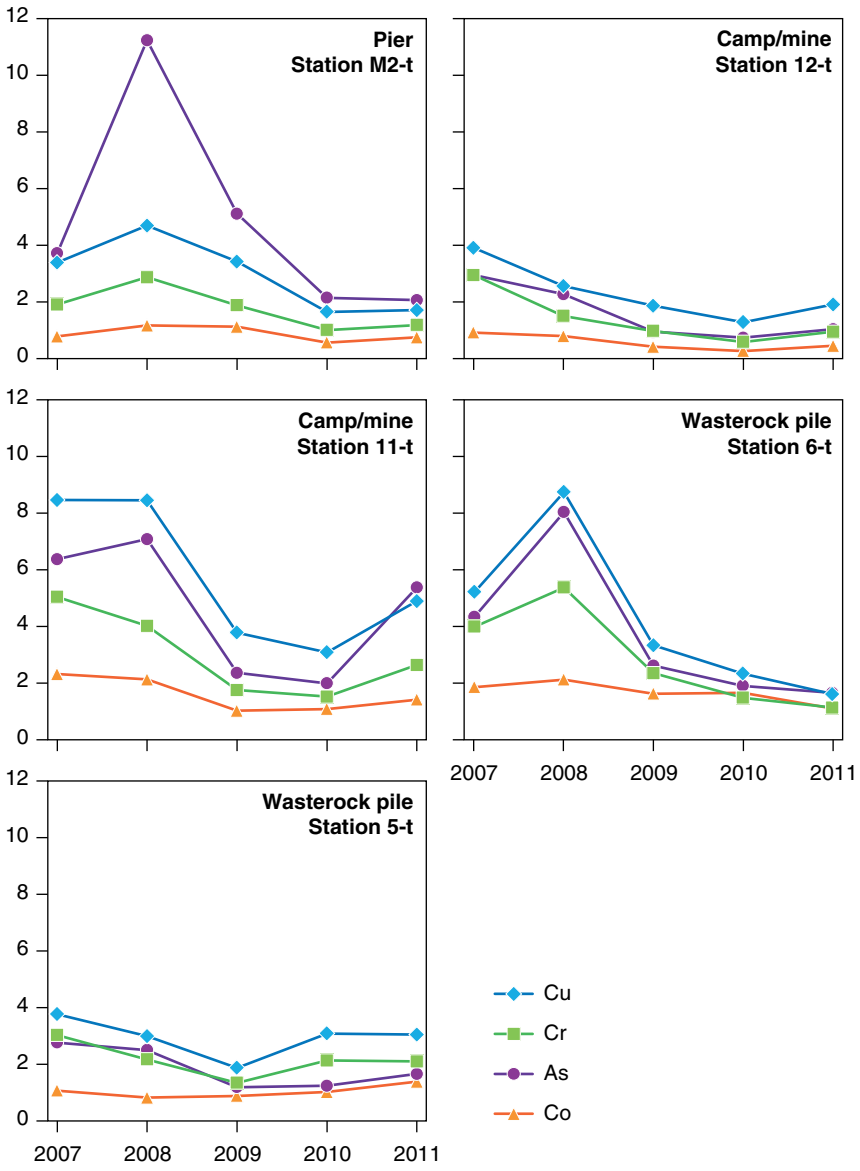

Figure 3.3. Concentrations of Cu, Cr, As and Co in transplanted lichens from the pier (M2-t), stockpile (5-t, 6-t) and mine (11-t, 12-t) areas during 2008-2011 compared with concentrations in naturally growing lichens from 2007.

Possible relations between the concentrations of Cu, Cr, As and Co in lichens and the perpendicular distance to the gravel road were tested. The tests included differences in levels among years (refer to figure 3.4a, b & figure 3.5 regarding 2011). These four metals were tested because they showed the highest concentrations compared to background levels. All concentrations of the four metals showed a significant increase with decreasing distance to the gravel road (log linear regression).

Figure 3.4a shows concentrations of the four elements in lichens from Amitsoq Island, the Kirkespir Bay area and the Kirkespir Valley. Two areas have markedly higher concentrations of the four elements, namely the pier area and the inner valley area counting the stockpile of waste rock and the mining/camp area. The relatively high concentrations in these areas can be explained as an effect of the distance to the gravel road illustrated by figure 3.4b. Before 2009, the higher concentrations in the mining/camp area were explained as an effect of the mine rather than an effect of the road (Glahder et al. 2010). In 2010, a marked decrease was seen at the pier area in the concentrations of all four metals compared to concentrations found in 2009. This indicated that the effect of the road was the main source of contamination af-

ter the storage in the pier area and the ship-loading activities have ceased. In 2011, a 2-3 fold increase was observed for all four metals at the pier area, station M2-t, compared to data from 2010, which reflects the activity of loading and transporting ore back to the mine area for processing. At station 11-t, there was a slight increase in all four metals, most pronounced for As and Cu, compared to the metal concentrations in 2010. This indicates that besides the effect of the gravel road, there is also an effect of the mining in the area, which might be a result of the outdoor crushing.

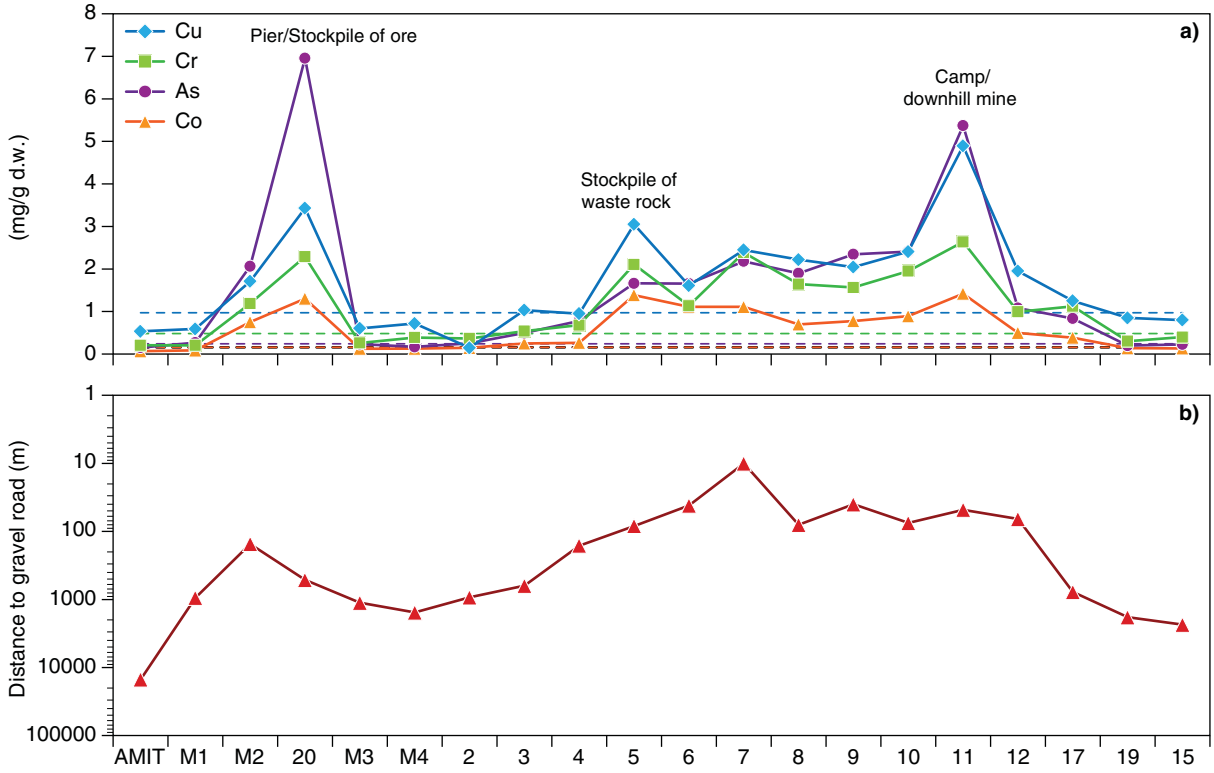

Figure 3.4. a) Concentrations of Cu, Cr, As and Co in the lichen *Flavocetraria nivalis* measured at the lichens stations in 2011 and b) distances (in meter on a log scale) from the road to the lichen stations. For localization of lichen stations see figure 2.1. M1-M4 are stations in the Kirkespir Bay area, stations 2-19 are situated in the Kirkespir Valley from the coast (station 1) to upstream the camp area. The dashed horizontal lines in a) indicate average background concentrations of the four metals (see Appendix 4). d.w. = dry weight.

Figure 3.5 shows how far from the road elevated concentrations of Cu, Cr, As and Co were found in the Kirkespir Valley in 2011. For Co and As background concentrations were met about 2000 m from the road, whereas Cr and Cu reached background levels at around 1000 and 500 m, respectively.

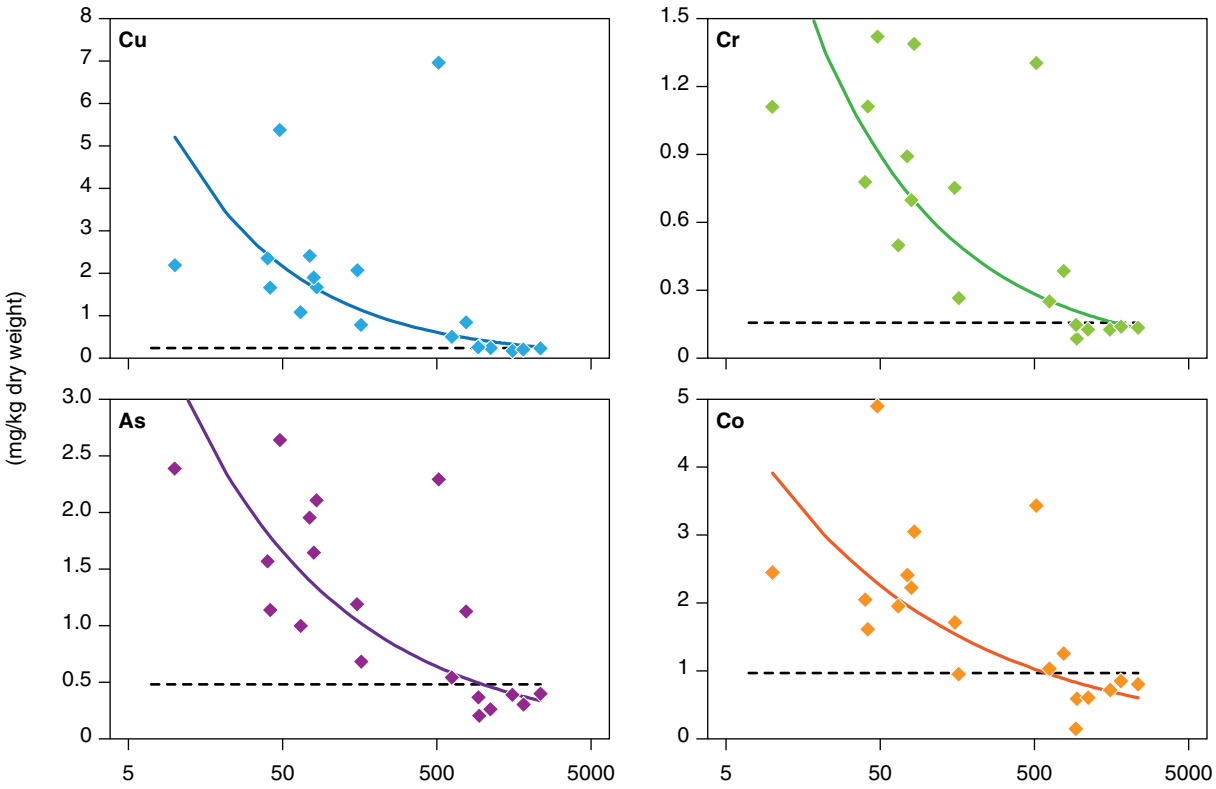

Figure 3.5. Concentrations of A) Cu, B) Cr, C) As and D) Co in the lichens *Flavocetraria nivalis* as a function of the stations' distances to the gravel road (in meters - on a log scale). Background average concentrations are shown with horizontal dashed lines. d.w. = dry weight.

Photo 3.3. Lichens (*Flavocetraria nivalis*) transplanted in mid-August 2010 in the Kirkespir Valley were sampled early September 2011. Transplanted lichens were covered by a net secured by stones. Lichens sampled at Amitsoq Island (reference site) in 2011 replaced the sampled lichens.

Conclusions on the terrestrial environment

It is concluded that concentrations of Cu, Cr, As and Co in lichens during 2004-2011 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 decreased toward 2010, especially in the mine area, but due to new activities the dust pollution increased again in 2011 compared to 2010. The relatively high concentrations in these areas can be explained as an effect of the gravel road with an exception of the most impacted stations (11-t and 20-t), where mining activities may be the reason. Before 2009, the higher concentrations in the mine area were explained as an effect of the mine. In 2010, a marked decrease in concentrations of all four metals was seen in the pier area, indicating that the road at that time was the main source of contamination. However, in 2011 after activities in this area were initiated the concentrations increased again in the Kirkespir Valley, and particular at the pier and mining/camp area where activities related to loading of trucks and outdoor crushing at the 300 m portal led to increased levels.

In 2011, metal concentrations in the transplanted lichens had decreased compared to the transplanted lichens in 2008 and 2009 but were generally at the same level as in 2010. As and Cu were exceptions as they showed marked increases in concentrations in 2011 at station 11-t compared to 2010.

All metal concentrations showed significant decreases with increasing distance to the road except for the most impacted stations (11-t and 20-t). Concentrations of As and Co met the background level concentrations at 2000 m from the road, while this distance was 100 m for Cr and 500 m for Cu.

4 Conclusions

This report describes the results of the eighth year of element environmental monitoring in the Nalunaq Gold Mine area and describes the first year of the cyanide monitoring programme. Most mining work from August 2009 until spring 2011 has dealt with the excavation of a chamber inside the mine and the building of a production plant. In spring 2011 the mining and processing of ore was initiated and parts of the low grade ore has been transported from the pier back to the mine for processing.

With respect to the cyanide monitoring programme, water samples have in 2011 been taken frequently and only low concentrations close to the detection limit have been measured in the rivers (station 6). However, in the production chamber high concentrations of cyanide is being used for the extraction of gold and in July elevated concentrations were measured at sampling station 1 and 2. The elevated concentrations were assigned to technical issues that were corrected promptly. Only slightly elevated concentrations could be measured in the environment in relation to that occasion (data are not shown). The occasion led to a rise of the standards for the monitoring programme with more frequent sampling.

The impact from the mining activities on the marine environment was in 2011 found to be low. No elevated element concentrations were found in blue mussels and sculpin livers, while brown seaweed had significantly elevated Cu concentrations at all marine stations compared to background concentrations. This was however also found at the reference station AMIT, which questions whether the elevated Cu concentrations were caused by mining activities. Next years monitoring programme will reveal that. Significantly elevated concentrations of Au and Co in seaweed were found at some of the marine stations.

In Arctic char livers average concentrations of Cd and Pb were found elevated 2-3 times in 2011 compared to baseline concentrations. The elevations of Pb and Cd are interpreted as natural variations until the results can be verified by new independent measurements e.g. at the environmental monitoring programme in 2012.

In the lichen concentrations of Cu, Cr, As and Co in 2011, like in previous years, were significantly elevated compared to the background level at the pier area, the stockpile of crushed waste rock and in the mining/camp area. In 2011, element elevations in these areas were 2-5 times for Cu and Cr, 7-27 times for As and 4-9 times for Co.

Temporal trends during 2004-2010 of the concentrations of the four elements in the three areas described above showed a non-linear course with a decrease in 2010 for all elements in all three areas. However, compared to 2010 increased concentrations of the four elements, Cu, Cr, As and Co were found in 2011 for the pier area and the mining/camp area, while no increase was observed at the waste rock area. This trend can be explained by the increased mining activity around the mine area, the activity by loading and transporting of the pile of ore from the pier area back to the mine and by an effect of dust from the road.

Photo 4.1. Kirkespir Valley, with the Kirkespir Mountain in the background (photo: L Bach).

The concentrations of Cu, Cr, As and Co in lichens showed a significant decrease with increasing distance to the gravel road, with exception of two of the most impacted stations (11-t and 20-t). Concentrations of As and Co above the background level could be found to a distance of about 2000 m from the road, while concentrations of Cr met the baseline level about 1000 m and of Cu at about 500 m from the road.

In 2011, concentrations of metals in the transplanted lichens in the pier area and in the mining/camp area had increased to higher levels than in 2010. However, the concentrations measured in 2011 were lower than those measured in 2007 and 2008.

In 2011, 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, from the crushing area at the 300 m portal of the mine and from the loading of ore at the area above the pier. Metal concentrations in lichens increased a little in 2011 compared to 2010 due to the mining activities. In the Kirkespir River and Bay, only few elevated concentrations of Cu and Co were found in seaweed and Pb and Cd in Arctic char. Compared to the mining operation period in 2004-2009 the environmental impact of elements in 2011 were generally lower, which probably is a result of the underground crushing and processing as well as less transport of crushed

ore from the mining area to the harbour. The impact from spreading of elements on the Kirkespir Valley, both terrestrial and marine, is therefore considered to be minor.

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Appendix 1. ICP-MS analytical results of certified reference materials

ICP-MS analytical results of certified reference materials (Dorm-3, Dolt-4 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. ± 2 x std dev of the certificate values expresses the 95% confidence interval. Concentrations are in mg/kg dry weight. nd = not determined.

	As	**Au**	**Cd**	**Co**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Se**	**Zn**
Detection limit	*0.05*	*0.001*	*0.005*	*0.002*	*0.006*	*0.01*	*0.011*	*0.04*	*0.016*	*0.06*	*0.54*
Dorm-3	6.24	0.09	0.27	0.24	1.94	14.1	0.43	1.29	0.46	3.13	45.8
Dorm-3	6.85	0.03	0.27	0.25	1.86	15.7	0.43	1.36	0.44	2.81	48.9
Average	6.55	0.06	0.27	0.25	1.90	14.9	0.43	1.33	0.45	2.97	47.4
Certificate value	6.88	nd	0.29	nd	1.89	15.5	0.38	1.28	0.40	nd	51.3
2 x std dev	0.3	nd	0.02	nd	0.17	0.6	0.06	0.24	0.05	nd	3.1
Dolt-4	7.85	0.03	20.2	0.20	1.24	27.9	2.82	1.34	0.14	7.43	99.7
Dolt-4	9.54	0.07	23.4	0.24	1.28	31.6	3.33	1.22	0.16	8.10	116.8
Average	8.70	0.05	21.8	0.22	1.26	29.7	3.07	1.28	0.15	7.77	108.3
Certificate value	9.66	nd	24.3	nd	nd	31.2	2.58	0.97	0.16	8.3	116
2 x std dev	0.62	nd	0.8	nd	nd	1.1	0.22	0.11	0.04	1.3	6
Tort-2	20.18	0.06	25.4	0.49	0.75	94.1	0.31	2.86	0.50	5.62	169.1
Tort-2	19.04	0.04	24.3	0.49	0.79	93.0	0.31	2.55	0.34	4.97	159.1
Average	19.61	0.05	24.9	0.49	0.77	93.6	0.31	2.71	0.42	5.29	164.1
Certificate value	21.6	nd	26.7	0.51	0.77	106	0.27	2.50	0.35	5.63	180
2 x std dev	1.8	nd	0.60	0.09	0.15	10.0	0.06	0.19	0.13	0.67	6.0

Appendix 2. Samples and stations

ID-No	Sample type	Latin name	Station	Latdeg	Lat min'sec	Long deg	Long min'sec
46686	Lichen	*Flavocetraria nivalis*	2	60	19'38''	44	54'40''
46647	Lichen	*Flavocetraria nivalis*	3	60	19'35''	44	54'10''
46688	Lichen	*Flavocetraria nivalis*	4	60	19'43''	44	53'38''
46682	Lichen	*Flavocetraria nivalis*	5-transplanted	60	19'56.9''	44	52'48.1''
46668	Lichen	*Flavocetraria nivalis*	6-transplanted	60	20'09.7''	44	52'18.6''
46684	Lichen	*Flavocetraria nivalis*	7	60	20'32''	44	51'37''
46683	Lichen	*Flavocetraria nivalis*	8	60	20'44''	44	51'07''
46669	Lichen	*Flavocetraria nivalis*	9	60	20'49''	44	50'14''
46649	Lichen	*Flavocetraria nivalis*	10	60	20'51''	44	49'58''
46681	Lichen	*Flavocetraria nivalis*	11-transplanted	60	21'16.4''	44	49'56.6''
46670	Lichen	*Flavocetraria nivalis*	12-transplanted	60	21'28.2''	44	49'50.1''
46694	Lichen	*Flavocetraria nivalis*	15	60	22'43''	44	49'08''
46696	Lichen	*Flavocetraria nivalis*	17	60	21'59''	44	49'52''
46695	Lichen	*Flavocetraria nivalis*	19	60	22'30''	44	49'31''
46648	Lichen	*Flavocetraria nivalis*	20-transplanted	60	18'47.1''	44	57'10.2''
46650	Lichen	*Flavocetraria nivalis*	M 1	60	18'41''	44	58'01''
46687	Lichen	*Flavocetraria nivalis*	M 2-transplanted	60	18'45.1''	44	56'48.5''
46685	Lichen	*Flavocetraria nivalis*	M 3	60	19'29''	44	56'15''
46631	Lichen	*Flavocetraria nivalis*	M 4	60	19'35''	44	57'37''
46689	Lichen	*Flavocetraria nivalis*	AMIT	60	26'20''	44	57'04''
46653	Brown seaweed	*Fucus vesiculosus*	M 1	60	18'41''	44	58'01''
46654	Brown seaweed	*Fucus vesiculosus*	M 1	60	18'41''	44	58'01''
46640	Brown seaweed	*Fucus vesiculosus*	M 2	60	18'46''	44	56'47''
46641	Brown seaweed	*Fucus vesiculosus*	M 2	60	18'46''	44	56'47''
46538	Brown seaweed	*Fucus vesiculosus*	M 3	60	19'29''	44	56'15''
46539	Brown seaweed	*Fucus vesiculosus*	M 3	60	19'29''	44	56'15''
46632	Brown seaweed	*Fucus vesiculosus*	M 4	60	19'35''	44	57'37''
46633	Brown seaweed	*Fucus vesiculosus*	M 4	60	19'35''	44	57'37''
46699	Brown seaweed	*Fucus vesiculosus*	M 5	60	18'56''	44	56'04''
46700	Brown seaweed	*Fucus vesiculosus*	M 5	60	18'56''	44	56'04''
46620	Brown seaweed	*Fucus vesiculosus*	AMIT	60	26'20''	44	57'04''
46621	Brown seaweed	*Fucus vesiculosus*	AMIT	60	26'20''	44	57'04''
46675	Shorthorn sculpin	*Myoxocephalus scorpius*	U 1	60	18'47''	44	57'45''
46676	Shorthorn sculpin	*Myoxocephalus scorpius*	U 1	60	18'47''	44	57'45''
46677	Shorthorn sculpin	*Myoxocephalus scorpius*	U 1	60	18'47''	44	57'45''
46678	Shorthorn sculpin	*Myoxocephalus scorpius*	U 1	60	18'47''	44	57'45''
46636	Shorthorn sculpin	*Myoxocephalus scorpius*	U 2	60	18'45''	44	56'46''
46637	Shorthorn sculpin	*Myoxocephalus scorpius*	U 2	60	18'45''	44	56'46''
46638	Shorthorn sculpin	*Myoxocephalus scorpius*	U 2	60	18'45''	44	56'46''
46639	Shorthorn sculpin	*Myoxocephalus scorpius*	U 2	60	18'45''	44	56'46''
46690	Shorthorn sculpin	*Myoxocephalus scorpius*	U 3	60	19'31''	44	56'53''
46691	Shorthorn sculpin	*Myoxocephalus scorpius*	U 3	60	19'31''	44	56'53''
46692	Shorthorn sculpin	*Myoxocephalus scorpius*	U 3	60	19'31''	44	56'53''
46693	Shorthorn sculpin	*Myoxocephalus scorpius*	U 3	60	19'31''	44	56'53''
46627	Shorthorn sculpin	*Myoxocephalus scorpius*	U 4	60	19'34''	44	57'31''
46628	Shorthorn sculpin	*Myoxocephalus scorpius*	U 4	60	19'34''	44	57'31''
46629	Shorthorn sculpin	*Myoxocephalus scorpius*	U 4	60	19'34''	44	57'31''
46630	Shorthorn sculpin	*Myoxocephalus scorpius*	U 4	60	19'34''	44	57'31''

46623	Shorthorn sculpin	*Myoxocephalus scorpius*	AMIT	60	26’20’’	44	57’04’’
46624	Shorthorn sculpin	*Myoxocephalus scorpius*	AMIT	60	26’20’’	44	57’04’’
46625	Shorthorn sculpin	*Myoxocephalus scorpius*	AMIT	60	26’20’’	44	57’04’’
46626	Shorthorn sculpin	*Myoxocephalus scorpius*	AMIT	60	26’20’’	44	57’04’’
46651	Blue mussel	*Mytilus edulis*	M 1	60	18’41’’	44	58’01’’
46652	Blue mussel	*Mytilus edulis*	M 1	60	18’41’’	44	58’01’’
46642	Blue mussel	*Mytilus edulis*	M 2	60	18’46’’	44	56’47’’
46645	Blue mussel	*Mytilus edulis*	M 2	60	18’46’’	44	56’47’’
46679	Blue mussel	*Mytilus edulis*	M 3	60	19’29’’	44	56’15’’
46680	Blue mussel	*Mytilus edulis*	M 3	60	19’29’’	44	56’15’’
46634	Blue mussel	*Mytilus edulis*	M 4	60	19’35’’	44	57’37’’
46635	Blue mussel	*Mytilus edulis*	M 4	60	19’35’’	44	57’37’’
46697	Blue mussel	*Mytilus edulis*	M 5	60	18’56’’	44	56’04’’
46698	Blue mussel	*Mytilus edulis*	M 5	60	18’56’’	44	56’04’’
46618	Blue mussel	*Mytilus edulis*	AMIT	60	26’20’’	44	57’04’’
46619	Blue mussel	*Mytilus edulis*	AMIT	60	26’20’’	44	57’04’’
46658	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
46661	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
46663	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
46664	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
46665	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
46666	Arcticchar	*Salvelinus alpinus*	Waterfall	60	20’47’’	44	50’32’’
47097	Amphipod	*Orchomenella pinguis*	M 2	60	18’46’’	44	56’47’’
47098	Amphipod	*Orchomenella pinguis*	M 3	60	19’29’’	44	56’15’’
47099	Amphipod	*Orchomenella pinguis*	M 4	60	19’35’’	44	57’37’’
47100	Amphipod	*Orchomenella pinguis*	M 5	60	18’56’’	44	56’04’’
46643	Sediment		M 2	60	18’46’’	44	56’47’’
46644	Sediment		M 4	60	19’35’’	44	57’37’’
46646	Sediment		M 5	60	18’56’’	44	56’04’’

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

Appendix 3. Blue mussel samples

Station	ID NO	No of mussels	Min length (mm)	Max length (mm)
M1	46651	13	60	80
M1	46652	23	50	61
M2	46642	20	50	60
M2	46645	13	60	86
M3	46679	10	70	80
M3	46680	19	50	60
M4	46634	11	50	72
M4	46635	20	40	50
M5	46697	20	40	50
M5	46698	12	60	80
AMIT	46618	14	70	80
AMIT	46619	23	40	50

Appendix 4. Chemical analyses

Concentrations are given in mg/kg dw (dry weight) for mussels, seaweed, amphipods, sediment and lichen and mg/kg ww (wet weight) for livers from sculpins and Arctic chars. Detection limits (DL) are given as well as average background concentrations and standard deviations (*SD*) for each species.

Blue Mussel – *Mytilus edulis*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.14*	*0.004*	*0.02*	*0.007*	*0.018*	*0.03*	*8.0*	*0.033*	*0.122*	*0.049*	*0.167*	*1.62*
46651	8813	17.83	M1	11.48	0.086	3.12	0.324	1.389	5.19	120.9	0.106	1.540	0.655	2.749	57.58
46652	8814	15.83	M1	13.58	0.068	3.21	0.397	0.719	6.48	148.4	0.125	1.304	0.679	3.643	63.77
46642	8809	20.25	M2	11.18	0.102	3.28	0.370	0.474	7.17	199.9	0.052	1.098	0.345	3.431	65.75
46645	8810	17.76	M2	12.19	0.098	4.03	0.393	0.565	7.05	172.6	0.065	1.029	0.726	3.117	60.89
46679	8815	13.48	M3	12.69	0.249	5.56	0.566	1.068	6.98	131.4	0.148	1.341	0.998	4.353	99.16
46680	8816	14.47	M3	11.39	0.289	2.19	0.411	0.738	7.46	122.3	0.102	1.150	0.504	4.494	77.41
46634	8807	15.99	M4	12.50	0.222	3.96	0.448	0.894	8.64	171.1	0.094	1.115	0.841	4.773	60.81
46635	8808	16.78	M4	11.46	0.247	3.57	0.413	0.696	8.21	147.3	0.067	1.113	0.507	4.923	64.69
46697	8817	17.83	M5	12.15	0.179	2.32	0.311	0.483	6.89	185.8	0.067	0.958	0.369	4.398	65.17
46698	8818	16.69	M5	11.13	0.159	2.97	0.315	0.662	5.98	178.7	0.086	0.871	0.643	3.422	60.54
46618	8805	15.42	AMIT	14.66	0.135	5.01	0.466	0.939	7.21	157.8	0.109	1.097	0.987	3.396	72.31
46619	8806	17.58	AMIT	12.76	0.046	3.47	0.543	0.651	7.16	173.2	0.059	1.120	0.448	4.182	80.42
Background		*Average*		*11.73*		*5.47*	*0.240*	*0.736*	*7.60*		*0.132*		*1.215*		*88.95*
		SD		*1.85*		*2.01*	*0.040*	*0.356*	*0.83*		*0.029*		*0.424*		*12.95*

Brown Algae – *Fucus vesiculosus*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.14*	*0.004*	*0.02*	*0.007*	*0.018*	*0.03*	*8.0*	*0.033*	*0.122*	*0.049*	*0.167*	*1.62*
46653	8801	25.12	M1	63.29	0.073	1.86	0.231	0.084	8.35	21.5	< DL	0.896	0.071	< DL	11.69
46654	8802	25.15	M1	61.98	0.054	1.98	0.247	0.066	8.30	16.7	< DL	0.839	0.034	< DL	7.65
46640	8799	25.03	M2	65.81	0.143	1.29	0.368	0.159	17.14	39.7	< DL	0.908	0.077	< DL	11.23
46641	8800	25.06	M2	72.55	0.133	1.04	0.395	0.147	7.62	45.4	< DL	0.767	< DL	< DL	9.90
46538	8795	25.01	M3	56.83	2.047	1.35	0.353	0.131	11.04	28.9	< DL	1.035	0.075	< DL	12.38
46539	8797/98	25.10	M3	67.22	0.307	1.55	0.399	0.094	19.22	28.2	< DL	1.047	0.055	< DL	13.33
46632	8793	25.06	M4	48.95	0.245	1.75	0.281	0.102	4.32	27.8	< DI	1.176	0.071	< DI	8.75
46633	8794	25.18	M4	45.26	0.200	1.63	0.269	0.086	5.48	26.6	< DL	1.151	0.123	< DL	8.97
46699	8803	25.45	M5	47.91	0.237	0.94	0.380	0.096	11.27	40.3	< DL	1.047	2.973	< DL	11.67
46700	8804	25.02	M5	52.66	0.333	0.85	0.448	0.197	8.24	94.1	< DL	1.121	0.055	< DL	9.30
46620	8790/91	25.25	AMIT	60.75	0.043	1.79	0.284	0.215	6.20	49.4	< DL	1.075	1.168	< DL	5.56
46621	9791	25.00	AMIT	60.68	0.094	2.04	0.241	0.141	5.34	26.4	0.045	0.869	0.116	< DL	6.58
Background		*Average*		*46.25*		*1.76*	*0.211*	*0.069*	*1.00*		*0.009*		*0.107*		*7.00*
		SD		*8.43*		*0.58*	*0.046*	*0.076*	*0.24*		*0.006*		*0.043*		*2.09*

Sculpin – *Myoxycephalus scorpius*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.05*	*0.001*	*0.005*	*0.002*	*0.006*	*0.01*	*2.7*	*0.011*	*0.041*	*0.016*	*0.056*	*0.54*
46675	8754	26.62	M1	4.49	0.019	0.295	0.012	0.027	1.11	37.9	0.036	< DL	< DL	0.962	23.42
46676	8755	29.91	M1	1.48	0.010	0.858	0.016	0.026	1.47	61.8	0.025	0.661	< DL	0.778	25.16
46677	8756	40.95	M1	2.72	0.008	0.203	0.014	0.022	0.96	26.1	0.011	< DL	< DL	0.898	22.51
46678	8757	39.77	M1	1.06	0.007	0.276	0.014	0.028	0.85	72.8	< DL	< DL	< DL	1.060	24.21
46636	8749	28.90	M2	3.48	0.008	0.175	0.008	0.021	1.63	23.4	0.035	< DL	< DL	0.907	31.31
46637	8750	28.07	M2	2.31	0.008	0.177	0.015	0.038	1.28	67.0	0.021	0.042	< DL	0.844	27.90
46638	8751	39.71	M2	1.17	0.005	0.110	0.014	0.015	0.99	34.6	< DL	< DL	< DL	0.948	20.18
46639	8752	30.00	M2	2.66	0.004	0.107	0.008	0.010	0.87	46.2	0.009	< DL	< DL	0.653	19.36
46690	8758	31.75	M3	1.77	0.010	0.386	0.030	0.037	1.84	53.4	0.015	< DL	0.376	1.074	28.93
46691	8759	33.04	M3	1.98	0.007	0.320	0.023	0.017	1.78	58.5	0.016	< DL	< DL	1.097	28.65
46692	8760	25.45	M3	4.55	0.013	0.404	0.023	0.043	3.18	114.5	0.016	< DL	0.031	0.977	24.81
46693	8783	24.56	M3	3.86	0.013	0.296	0.079	0.039	6.28	138.0	0.027	< DL	-	0.772	36.23
46627	8744	38.73	M4	0.88	0.011	0.211	0.008	0.032	1.17	34.3	0.024	< DL	< DL	0.806	24.21
46628	8745	37.01	M4	2.05	0.022	0.232	0.014	0.024	1.47	42.7	0.029	0.072	< DL	0.783	24.64
46629	8747	36.15	M4	1.06	0.007	0.156	0.010	0.006	0.94	22.6	< DL	< DL	< DL	0.709	21.98
46630	8748	38.96	M4	2.04	0.004	0.063	0.006	0.007	1.17	5.5	< DL	0.048	1.563	0.661	19.54
46623	8740	36.91	AMIT	1.65	0.018	0.574	0.014	0.021	1.48	14.1	0.015	< DL	< DL	0.451	21.43
46624	8741	29.51	AMIT	2.62	0.014	0.633	0.029	0.049	1.30	68.6	0.049	0.064	0.434	0.858	26.25
46625	8742	27.35	AMIT	4.82	0.013	0.880	0.019	0.053	1.46	41.1	0.039	0.066	0.340	0.884	32.24
46626	8743	32.67	AMIT	15.52	0.012	1.836	0.013	0.034	4.84	10.5	0.031	0.098	0.023	0.801	-
Background		*Average*		*2.75*		*1.094*	*0.017*	*0.017*	*1.88*		*0.026*		*0.004*		*31.81*
		SD		*1.90*		*0.427*	*0.014*	*0.020*	*0.70*		*0.013*		*0.003*		*1.58*

Amphipod – *Orchomenella pinguis*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.06*	*0.01*	*0.00*	-	*0.086*	*0.5*	*2.4*	*0.04*	*2.23*	*0.07*	*0.07*	*0.2*
47097	8943/44	100	M2	7.27	0.018	0.852	-	0.501	79.50	272.3	0.060	0.869	0.145	1.31	134.2
47098	8962/63	100	M3	7.34	0.036	0.685	-	0.622	81.10	310.1	0.060	0.855	0.519	1.17	132.2
47099	8964	100	M4	7.26	0.013	0.688	-	0.555	72.70	265.2	0.086	0.987	0.362	1.05	106.3
47100	8965	100	M5	6.91	0.025	0.710	-	0.470	82.11	296.1	0.035	0.784	0.940	1.32	134.0

Sediment

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.06*	*0.01*	*0.00*	-	*0.086*	*0.5*	*2.4*	*0.04*	*2.23*	*0.07*	*0.07*	*0.2*
46643	8979	100	M2	78.35	5.466	0.225	-	33.0	7.18	20338	0.094	8.27	13.98	< DL	33.3
46644	8980	100	M4	3.53	0.538	0.103	-	35.3	4.88	20611	< DL	7.86	10.70	< DL	42.5
46646	8981	100	M5	7.18	0.140	0.145	-	27.5	12.22	18048	< DL	6.43	14.55	< DL	45.7

Arctic char – *Salvelinus alpinus*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.05*	*0.001*	*0.005*	*0.002*	*0.006*	*0.01*	*2.7*	*0.011*	*0.041*	*0.016*	*0.056*	*0.54*
46658	8784	-	Waterf.	0.08	0.236	0.120	0.063	0.063	50.87	487	0.046	< DL	0.022	2.257	42.04
46661	8785	30.68	Waterf.	0.58	0.007	0.103	0.080	0.056	16.13	56	0.027	< DL	0.048	1.185	33.04
46663	8786	25.45	Waterf.	0.19	0.005	0.082	0.021	0.031	4.73	42	0.021	< DL	< DL	0.621	27.69
46664	8787	33.66	Waterf.	0.48	0.005	0.361	0.102	0.023	6.50	159	0.025	< DL	< DL	1.233	30.23
46665	8788	23.08	Waterf.	0.32	0.035	0.176	0.102	0.025	26.78	360	0.030	< DL	0.022	0.926	43.78
46666	8789	-	Waterf.	0.08	0.094	0.195	0.042	0.090	12.85	568	0.086	< DL	0.057	1.531	33.91
Background		*Average*		*0.45*		*0.071*	*0.042*	*0.026*	*9.88*		*0.025*		*0.006*		*34.81*
		SD		*0.15*		*0.024*	*0.014*	*0.025*	*10.98*		*0.010*		*0.003*		*4.44*

Lichen - *Flavocetraria nivalis*

ID No	Lab. No	% dw	Station	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limits				*0.14*	*0.004*	*0.015*	*0.007*	*0.018*	*0.03*	*8.0*	*0.033*	*0.122*	*0.049*	*0.167*	*1.62*
46650	8722	100	M1	0.27	0.011	0.060	0.085	0.203	0.59	77.2	< DL	0.217	0.387	< DL	15.64
46687	8734	100	M2-t	2.07	0.018	0.067	0.752	1.188	1.71	722.0	0.061	1.251	1.002	< DL	17.95
46685	8730	100	M3	0.23	0.007	0.026	0.126	0.261	0.60	140.6	< DL	0.227	0.855	< DL	10.57
46631	8717/18	100	M4	0.23	0.016	0.038	0.116	0.355	0.73	179.9	0.042	0.253	0.819	< DL	11.91
46686	8733	100	2	0.25	0.013	0.070	0.145	0.366	0.95	179.9	< DL	0.514	0.410	< DL	35.98
46647	8719	100	3	0.50	0.014	0.051	0.249	0.539	1.03	213.5	< DL	0.564	1.355	< DL	12.15
46688	8735	100	4	0.78	0.015	0.038	0.264	0.681	0.95	306.6	0.044	0.703	0.525	< DL	11.98
46682	8727	100	5–t	1.66	0.013	0.094	1.386	2.106	3.05	971.3	0.036	2.459	1.837	< DL	26.42
46668	8723	100	6–t	1.66	0.019	0.101	1.111	1.135	1.61	412.9	0.033	1.633	-	< DL	22.32
46684	8729	100	7	2.18	0.015	0.050	1.109	2.387	2.45	863.6	0.036	2.339	0.775	< DL	14.82
46683	8728	100	8	1.90	0.010	0.050	0.697	1.643	2.22	561.3	0.035	1.461	1.132	< DL	17.70
46669	8724	100	9	2.35	0.019	0.053	0.776	1.565	2.04	553.8	< DL	1.538	1.240	< DL	13.61
46649	8721	100	10	2.41	0.048	0.052	0.890	1.951	2.41	671.5	0.050	1.846	1.130	< DL	23.99
46681	8726	100	11–t	5.37	0.021	0.057	1.419	2.637	4.89	952.3	< DL	3.017	1.104	< DL	18.43
46670	8725	100	12–t	1.08	0.017	0.073	0.498	0.995	1.95	392.5	< DL	1.020	0.950	< DL	17.35
46694	8737	100	15	0.23	0.008	0.016	0.133	0.398	0.80	154.9	< DL	0.432	0.240	< DL	18.54
46696	8739	100	17	0.84	0.011	0.034	0.384	1.122	1.25	453.7	< DL	0.943	1.119	< DL	8.70
46695	8738	100	19	0.20	0.012	0.024	0.138	0.301	0.85	112.8	< DL	0.309	0.248	< DL	29.75
46648	8720	100	20–t	6.96	0.044	0.052	1.302	2.289	3.43	826.5	< DL	2.780	0.953	< DL	13.44
46689	8736	100	AMIT	0.15	0.011	0.034	0.066	0.207	0.53	129.9	0.036	0.132	0.385	< DL	12.99
Background		*Average*		*0.24*		*0.082*	*0.151*	*0.557*	*0.95*		*0.034*		*1.068*		*21.56*
		SD		*0.26*		*0.030*	*0.146*	*0.992*	*0.757*		*0.006*		*0.338*		*7.237*

<D.l. = value below detection limit; -t = station with transplanted lichens; Waterf=Water fall.

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ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE, SOUTH GREENLAND, 2011

This eighth environmental monitoring programme was conducted in the Nalunaq area, about 40 km from Nanortalik, South Greenland, from 29 August to 12 September 2011. The environmental monitoring program is conducted to trace and avoid unwanted impacts of the mining industry to the environment. Since the monitoring in 2010, the mining company Gold Angel Mining A/S is breaking new ore, but is also carrying previously broken ore with low grade back to the mine with vehicles with limited speed and load capacity. The gold is recovered by the use of chemical extraction (carbon-in-pulp) using cyanide. Due to the use of cyanide to extract gold from the ore, strict control with the outflow of cyanide from the mine to the Kirkespir Valley is performed.
The described impact on the environment of the Kirkespir Valley, both terrestrial, freshwater and marine, is considered to be minor, and is generally lower than during the operation in 2004-2009.

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