ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE SOUTH GREENLAND, 2017

Scientific Report from DCE – Danish Centre for Environment and Energy No. 278 2018

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Data sheet

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Abstract: The mining company Angel Mining Gold A/S closed its gold production in Nalunaq in November 2013 after which the Nalunaq area was affected by decommissioning and restoration until August 2014. This thirteenth environmental monitoring was conducted in the Nalunaq area to detect any undesired environmental impacts of the former mining industry. Since the monitoring in 2015, the area has been visited by an exploration group for field campaigns a few months every summer. Due to the use of cyanide, cyanide outflow from the mine to the Kirkespir Valley was monitored during the production period, and the monitoring will be carried on for a minimum of five years after the closure. In 2017, no signs of cyanide could be detected in any of the samples from the freshwater environment. Also, extensive monitoring has been conducted to reveal release of metals into the Kirkespir Valley and the Kirkespir Bay environment. The content of metals in the terrestrial, freshwater and marine environment in the Kirkespir Valley and Bay is decreasing and considered minor. DCE and GINR assess that no further actions are needed to be taken to reduce environmental impact. The monitoring will expectedly to be completed with environmental studies in 2019.

Keywords: Environment, monitoring, metals, blue mussel, brown seaweed, Arctic char, lichen, Nalunaq Gold Mine, Greenland

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Contents

Summary

The mining company Angel Mining Gold A/S closed its gold production in the Nalunaq area in November 2013 after which the area was decommissioned and restored until August 2014. This thirteenth environmental monitoring was conducted to detect any undesired environmental impacts of the former mining industry. The content of 12 metals was determined in the marine, the freshwater and the terrestrial environment to reveal potential spreading of metals into the Kirkespir Valley and the Kirkespir Bay environment. The content of metals in the terrestrial, freshwater, and marine environment in the Kirkespir Valley and Bay is decreasing and is considered minor. DCE and GINR assess that no further actions are needed to be taken to reduce the environmental impact. Due to the use of cyanide, cyanide outflow from the mine to the Kirkespir Valley was monitored during the production period. In 2017, no signs of cyanide could be detected in any of the samples from the freshwater environment.

Environmental monitoring will continue for minimum five years after the closure and will expectedly be completed with environmental studies in 2019.

Sammenfatning

Denne trettende miljøovervågning blev gennemført i Nalunaq-området for at spore uønskede miljøpåvirkninger i den tidligere mineindustri. Siden overvågningen i 2015 har området været besøgt af et efterforskningsteam gennem sommerperioderne. Mineselskabet Angel Mining Gold A/S lukkede i november 2013 for minedriften, og en lokal entreprenør overtog oprydning og naturgenopretning af området. Oprydning og genopretning blev afsluttet sommeren 2014. Under minedriften blev guldet ekstraheret ved kemisk ekstraktion med cyanid (carbon-i-pulp). På grund af anvendelsen af cyanid blev det udledte spildevand fra minen til Kirkespirdalen overvåget løbende i produktionsperioden, og overvågningen vil fortsætte i fem år frem efter lukning af minen. I 2017 kunne der ikke spores cyanid i nogle af de indsamlede prøver fra ferskvandsmiljøet. Desuden er en omfattende overvågning blevet gennemført for at spore en eventuel spredning af metaller i Kirkespirdalen og Kirkespirbugten. Indholdet af metaller i det terrestriske miljø og ferskvands- og havmiljøet i Kirkespirdalen og bugten er faldende og anses for at være ubetydelig.

DCE og GN vurderer, at der ikke er grundlag for implementering af yderligere tiltag for at reducere miljøbelastningen. Miljøovervågningen forventes at blive afsluttet med en monitering i 2019.

Photo: Lis Bach

Eqikkaaneq

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1 Introduction

The thirteenth environmental monitoring programme was conducted in the Nalunaq area, about 40 km from Nanortalik, South Greenland, from 22-29 August 2017. The purpose of the environmental monitoring is to detect and prevent any undesired environmental impacts from the former goldmine. Since the last monitoring in 2015, the area has been visited by an exploration team during the summer periods. The mining company Angel Mining Gold A/S decommissioned the mine in November 2013 and remediation and restoration processes continued until August 2014 where the license area was abandoned.

With the closure of the mine in November 2013, it was expected that the element concentrations in the environment would decrease even further. A small increase in dust dispersal during remediation and restoration of the landscape in 2013/2014 was foreseen and correspondingly observed in the 2014 monitoring (Bach et al. 2015; Bach and Larsen, 2016). When the area was abandoned in 2014 after restoration work following the mining activities, the level of dust dispersal was observed to decrease in 2015.

In the field seasons 2015, 2016 and 2017 there were exploration activities in the area. The activities included drilling, driving, establishment of working tents and re-establishment of roads among other things, but no significant environmental effects were expected hereof.

Environmental monitoring was planned to continue for at least five years after the closure, involving sampling in 2014, 2015, 2016 and 2019. The monitoring in 2014 and 2015 was successful, but in 2016 the samples were lost during transportation to the laboratory facilities in Denmark and was thus replaced by new samplings in 2017. The last monitoring is expected to take place in 2019.

Requirements for monitoring of the environment in relation to the mining activity have been set by the Mineral Resources Authority (MRA) of the Greenland Government. These requirements are described in the MRA exploitation license of 19 March 2010, Phase 6, §§19/43, Chapter 8.

Prior to the start-up of mining, 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). In comprehensive baseline studies performed during 1998-2001, fish, mussels, seaweed, snow crab, sea urchin, benthic macro fauna and sediments were collected and analysed for different metals (Glahder et al. 2005). The above and other studies were included in the Environmental Impact Assessment prepared by SRK Consulting (2002). Based on the above-mentioned studies and the mining methods and prevailing procedures, the monitoring programme presented below was designed.

2 Monitoring programme

2.1 Element monitoring programme

The monitoring of metals includes three focus areas: the marine, the freshwater and the terrestrial environment. In the marine environment, brown seaweed (*Fucus vesiculosus*) and blue mussel (*Mytilus edulis*) are sampled at stations placed relatively close to and on each side of the Kirkespir River outlet.

In the freshwater environment, the sampling station is placed at the first site downstream the mining area where resident Arctic char (*Salvelinus alpinus*) occur. In the terrestrial environment, the lichen (*Flavocetraria nivalis*) stations are placed around existing and former ore stockpiles, along the road and in the area around the 300 m portal where waste rock was deposited and outdoor crushing took place.

All samples collected at the stations are specified in Appendix 1.

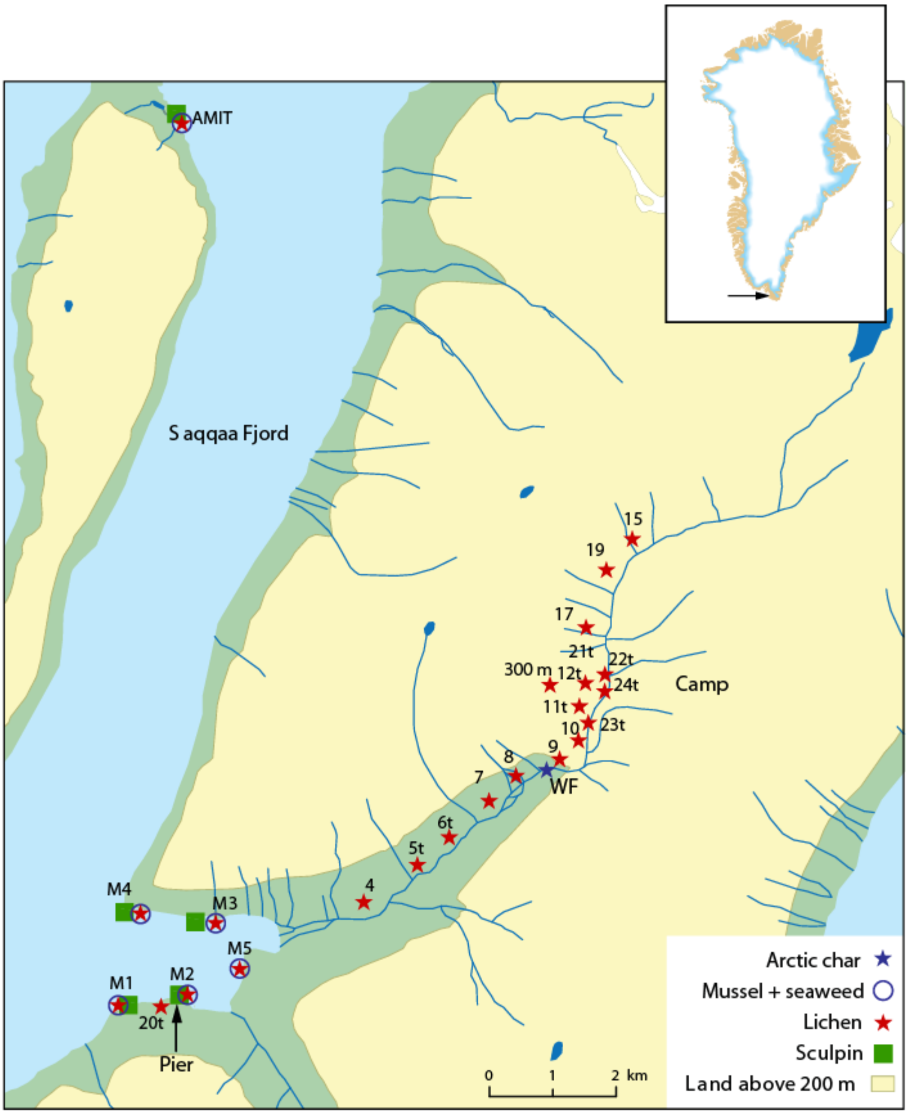

Figure 2.1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik, South Greenland. M: Marine stations: Blue mussel, snails and brown seaweed. Sculpins were sampled at M1, M2, M3, M4 and AMIT as the reference station. Arctic char were caught at the waterfall station. Lichens transplanted in 2016 from the reference station (AMIT) were sampled at stations 5t, 6t, 11t, 12t, 20t, 21t, 22t, 23t and 24t and replaced with new lichens from the reference station. Freshwater samples were collected at the waterfall (WF), at st 22, 23 and at the mine entrance at the position marked by '300 m'.

2.1.1 Collection and analyses of samples

Terrestrial environment

In 2017, lichens were sampled in the Kirkespir Valley south-west of the camp, in the camp area itself and in the pier area (figure 2.1) at AMIT M1, M2, M3, M4, M5, 4, 5t, 6t, 7, 8, 9, 10, 11t, 12t, 15, 17, 19, 20t, 21t, 22t, 23t and 24t. The t-stations held lichens transplanted to the sites in 2016. After sampling, new lichens collected at the reference site were placed for collection in 2019. The transplantation of lichens from an unpolluted area into a monitoring area for the purpose of later collection allows assessment of the relative spatial and temporal variations in dust deposition of metals. The application of transplanted lichens, as opposed to resident lichens, has the advantage that the exposure time of the lichens is known, and any change in the lichen metal composition relative to the original composition can be related to site and period (Søndergaard et al. 2013). In previous years, station M2t was also included in the sampling, but in 2017 the lichens transplanted in 2016 could not be located at the station.

Freshwater environment

Water samples were collected at four sites in the area: at the outlet from the mine at the 300 m portal, upstream the mine water entry to the small river and downstream the small river. Also, a sample was collected in the larger Kirkespir River (see figure 3.1). The water samples were filtered in a 0.45 µm membrane filter at the site immediately after sampling.

Resident Arctic char were caught in the Kirkespir River in the waterfall pond. This population consists of both non-migrating and migrating char and, if possible, non-migrating char are selected. Resident Arctic char stay all their life in the Kirkespir River, whereas the migratory char leave the river during May and return around August to spawn and winter. This year, five char were caught. In the camp, each fish was measured and weighed and the liver was dissected.

Marine environment

Sampling of blue mussels and seaweed was performed in the Kirkespir Bay from a motor boat at low tide (DMI 2017).

Mussels of two-three different size groups were collected at six stations: AMIT and M1-M5. Each sample consisted of approximately 20 individuals. The mussels were opened with a scalpel and allowed to drain after which the soft parts were cut free and frozen in plastic bags for later elemental analysis.

Snails were collected at six stations: AMIT and M1-M5. Each sample included approximately 10 individuals. The soft parts were cut free and frozen in plastic bags for later elemental analysis.

Seaweed was collected at two spots within an area of approximately 20 m at each station. The current year's growth tips were cut, washed in freshwater and frozen in plastic bags. The sampling stations were identical with those sampled for blue mussels and snails: AMIT and M1-M5.

Photo 2.1. Transplanted lichens are collected for chemical analyses of elements (photo L. Bach).

Analyses

All the frozen samples were transported directly to Aarhus University, DCE. A total of 102 samples were collected, including blue mussel (17), brown seaweed (12), snails (12), freshwater (4), livers of Arctic char (4) and lichens (23). All samples were analysed for the following 11 metals: 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). Au is not a part of the obligatory monitoring programme but was included this year.

Following freeze drying at DCE, subsamples of 0.3-1.0 g were digested in half-concentrated Suprapure nitric acid under pressure in Teflon bombs in a microwave oven. The samples were then diluted to approx. 25 g with milli-Q water, and all metals were analysed by ICP-MS (accredited analysis method according to DANAK, accreditation no. 411). All the analysed metals, except Hg and Co, are included in this accreditation. All chemical results are listed in Appendix 1. Simultaneously with the Nalunaq samples, blind samples, duplicates and certified reference material (Dorm-3, Dolt-4 and Tort-2) were analysed as part of the laboratory quality control. The filtered water samples were stabilised with 2 g/l nitric acid and then analysed by ICP-MS.

2.1.2 Analyses

The data obtained in the current monitoring programme (2017) were compared with data obtained in the baseline studies (Boje 1989; Lakefield 1998a, b; Lakefield 1999a-d; Glahder et al. 2005) conducted before gold mining was initiated in the area. Results from the previous monitoring programmes (Glahder & Asmund 2005, 2006, 2007; Glahder et al. 2008, 2009, 2010, 2011; Bach et al. 2012, 2014; 2015; Bach & Asmund 2013) were also included in the analyses for evaluation of the results.

We compared separately the stockpile of crushed waste rock and the camp area to detect possible differences in the concentrations of Cu, Cr, As and Co in lichens in the years 2004-2017 relative to background concentrations. Finally, the relations between the concentrations of Cu, Cr, As and Co in lichens and the distance to the gravel road and the crusher were analysed.

2.2 Cyanide monitoring programme

Due to the mining activities and the gold extraction method using cyanide, an intensive monitoring programme for detection of cyanide in the environment was undertaken when the mine was in production. The mining company was responsible for conducting the daily monitoring (i.e. sampling and sample analyses) and forwarding the data on a regular basis to EAMRA, while DCE undertook a yearly monitoring.

The cyanide monitoring programme consisted of frequent collection of water samples for analysis for free cyanide to ensure that cyanide concentrations in the environment did not exceed the limits set by EAMRA (identical with the Ontario Province Quality Objectives). To protect organisms, in particular the resident Arctic char, from toxic effects, the cyanide concentration in the Kirkespir River should not exceed 0.005 mg/l (measured as WAD CN, Weak Acid Dissociable cyanide). Due to dilution in Kirkespir River and the retention time facilitating natural degradation and evaporation in the settlement pond, the company was allowed to discharge water from the mine with a cyanide concentration of 0.20 mg/l. For further description of water management, see the company's EIA and the previous years' monitoring reports and notes.

At the closure of the mine, DCE recommended prevention of flow out of water containing WAD cyanide concentrations higher than 0.20 mg/l from the mine.

Photo 2.2. Water samples were collecetd for analyses of cyanide and elements (photo L. Bach).

2.2.1 Collection and analyses of samples

Water samples were collected at four sites in the area: at the outlet from the mine at the 300 m portal (1), upstream the mine water entry to the small river (2) and downstream the small river (3). Also, a sample was collected in the larger Kirkespir River (4) (see figure 2.3). The water samples were filtered in a 0.45 µm membrane filter on site immediately after sampling.

Analyses

Water samples for WAD cyanide determination were processed on site shortly after the sampling. After filtration, the samples were analysed for free cyanide using the Hach-Lange LCK315 method and a Hach-Lange DR2800 spectrophotometer. This method is quick and effective and has a factory-guaranteed measuring range of 0.01-0.60 mg/l, within which precise results can be obtained. The practical detection limit is judged to be about 0.002 mg/l.

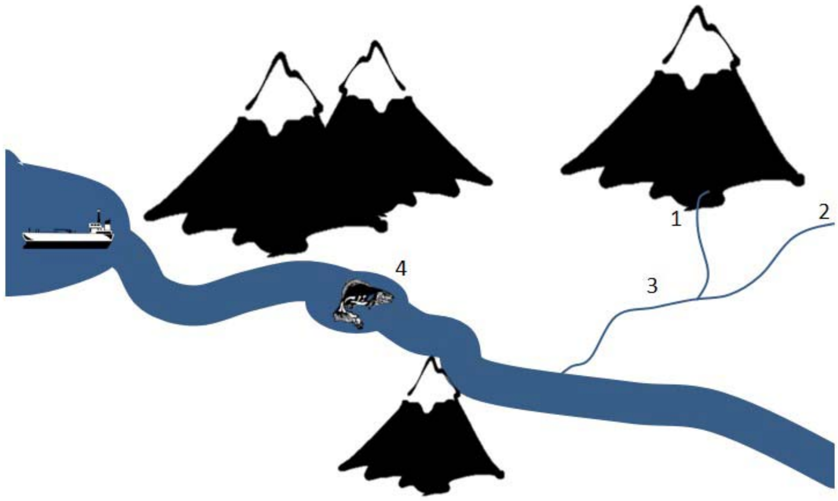

Figure 2.3. Illustration of sampling sites for cyanide and element monitoring in the environment.

3 Results and discussion

3.1 Element monitoring programme

3.1.1 Terrestrial environment

Eleven elements are analysed in the lichens collected in the terrestrial environment. Prior to 2017, elevated concentrations were found of As, Co, Cr and Cu and slightly elevated concentrations of Cd. In 2017, elevated concentrations were found of As, Co and Cu, as well as Cd (table 3.1).

The lichen concentrations of As, Co, Cr and Cu were compared between years for the period 2004 to 2017. Three areas (see figure 2.1 for station numbers) were selected: 1) the stockpile of waste rock (stations 5t and 6t), 2) the camp and mine area (stations 11t, 12t, 21t, 22t, 23t and 24t) and 3) the area around the pier, which was previously used as an ore stock pile area (stations M2t and 20t). The measured concentrations of all elements are listed in table 3.1, indicating elevated concentrations. In 2016, lichens were transplanted from an uncontaminated area (station AMIT) to the monitoring stations, and in 2017 these were collected for elemental analyses. The results are shown in figure 3.2 (Area 1), figure 3.3 (Area 2) and figure 3.4 (Area 3).

Table 3.1. Metal concentrations in the lichen *Flavocetraria nivalis* in mg/kg dry weight. Background concentrations are from baseline studies. * indicates slightly elevated concentrations (2-5 x background concentration), ** elevated (5-10 x background concentration) and ***highly elevated (> 10 x background concentration). The AMIT/Ref concentrations are used to confirm low element concentrations before transplantation. DL: Detection limit.

	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Background conc.	*0.238*		*0.082*	*0.151*	*0.557*	*0.953*		*0.034*		*1.068*		*21.56*
Detection limit	0.019	0.012	0.046	0.007	0.031	0.081	0.861	0.005	0.110	0.027	0.006	0.260
AMIT/Ref	0.337	<DL	*0.152	0.167	0.167	0.660	119.8	0.039	0.171	0.455	0.098	0.455
4	0.293	<DL	0.055	0.178	0.304	0.759	141.9	0.030	0.363	0.691	0.088	0.691
7	**1.263	<DL	0.050	*0.503	1.071	1.254	399.4	0.029	0.886	0.453	0.078	0.453
8	*0.934	<DL	0.055	*0.713	0.724	1.404	287.9	0.028	0.987	0.663	0.101	0.663
9	**1.644	<DL	0.054	*0.278	0.591	0.832	197.9	0.033	0.453	0.585	0.122	0.585
10	*1.159	<DL	<DL	*0.737	0.745	0.995	262.0	0.031	1.033	0.633	0.103	0.633
15	0.140	<DL	<DL	0.097	0.199	0.559	97.9	0.027	0.256	0.199	0.056	0.199
17	0.261	<DL	<DL	0.167	0.238	0.665	112.0	0.029	0.370	0.516	0.085	0.516
19	0.171	<DL	<DL	0.090	0.202	0.807	88.8	0.028	0.218	0.265	0.060	0.265
11t	**1.471	<DL	0.052	*0.414	0.634	*2.683	264.0	0.033	0.773	0.478	0.100	0.478
12t	0.337	<DL	0.106	*0.347	0.272	0.853	131.7	0.031	0.515	0.458	0.083	0.458
20t	0.297	<DL	<DL	0.145	0.236	0.654	144.4	0.042	0.196	0.421	0.121	0.421
21t	*0.458	<DL	<DL	*0.320	0.392	1.515	159.5	0.034	0.735	0.484	0.087	0.484
22t	*0.781	<DL	0.103	**0.807	0.310	*2.700	129.3	0.036	2.756	0.344	0.109	0.344
23t	0.409	<DL	0.075	*0.429	0.372	1.289	135.4	0.036	1.062	0.399	0.103	0.399
24t	0.304	<DL	0.070	0.183	0.312	0.912	106.8	0.031	0.461	0.383	0.098	0.383
5t	*0.565	<DL	0.061	*0.397	0.723	1.482	376.1	0.034	0.657	0.701	0.094	0.701
6t	*0.458	<DL	0.072	*0.622	0.279	1.011	115.7	0.033	0.799	0.335	0.111	0.335
M1	0.113	<DL	0.067	0.093	0.165	0.445	87.5	0.037	0.190	0.374	0.094	0.374
M2	0.165	<DL	<DL	0.051	0.118	0.670	74.0	0.034	0.089	0.173	0.083	0.173
M3	**2.228	<DL	<DL	*0.441	0.769	1.180	334.6	0.033	0.752	0.666	0.071	0.666
M4	0.149	<DL	0.071	0.076	0.200	0.777	99.6	0.028	0.127	0.142	0.050	0.142
M5	0.191	<DL	*0.144	0.086	0.311	0.909	83.4	0.041	0.160	0.839	0.079	0.839

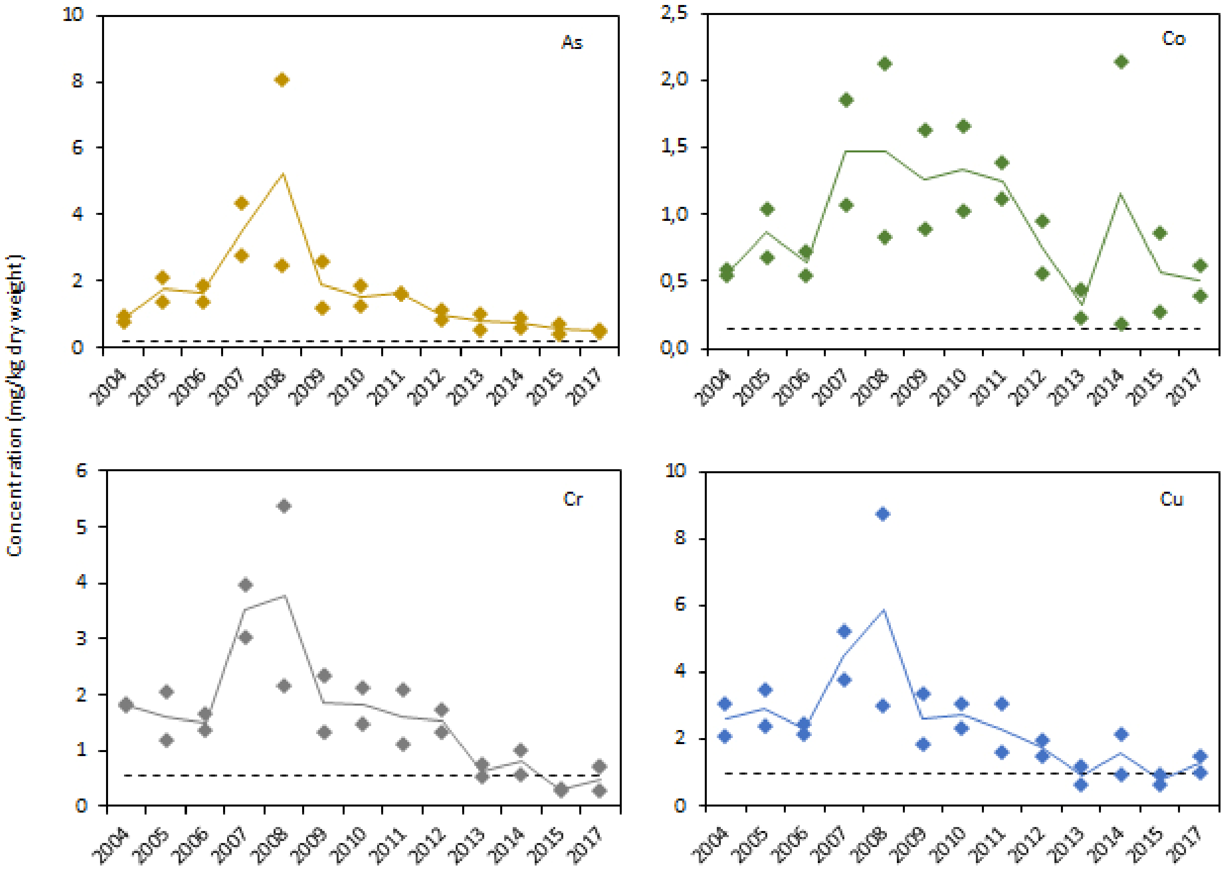

Figure 3.1. Temporal trends in concentrations of As, Co, Cr and Cu in lichens in Area 1 during 2004-2017. Area 1 is the stockpile of crushed waste rock (stations 5t and 6t). From 2008 onwards, metal concentrations are derived from transplanted lichens. Solid lines show average values. Baseline average concentrations from 1998 are indicated as dashed lines.

The lichens collected in Area 2, the area around the camp and downhill the mine (stations 11t, 12t, 21t, 22t, 23t and 24t), showed decreasing concentrations of the four metals towards 2010; the levels fluctuated, however, with peak concentrations in 2011. This is probably due to the restart of the mining activities, and minor peaks of Cu and Co occurred in 2013, followed by a decrease in 2014. In 2015, Co and Cu concentrations increased, while Cr and As concentrations have been stable or decreasing since 2012. The reason for the enhanced lichen concentrations of Co and in particular Cu in 2015 is unknown, but changes in wind speed and/or direction or other variations may be the cause. In 2017, all four metals exhibited decreasing concentrations, average concentrations being the lowest measured since initiation of the monitoring.

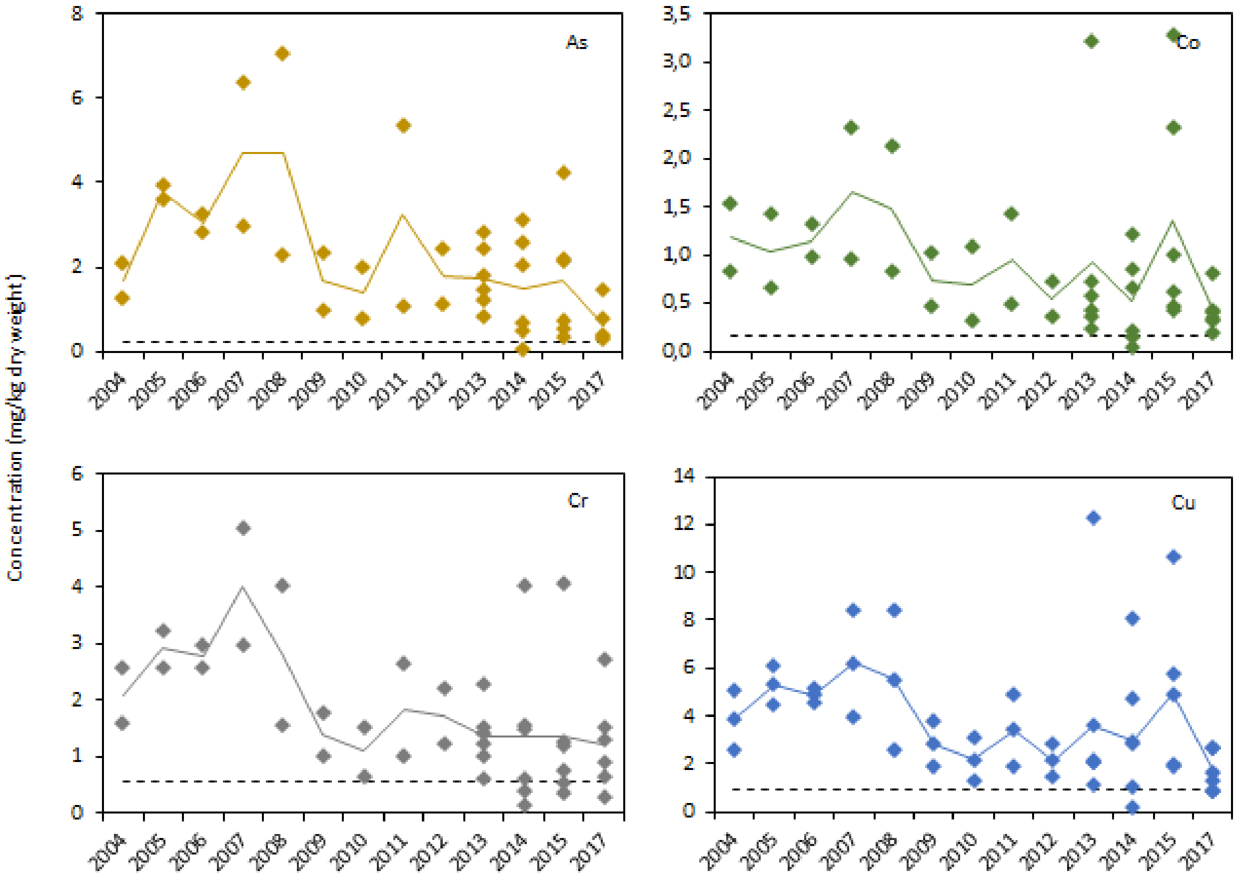

Figure 3.2. Temporal trends in concentrations of Cu, Cr, As and Co in lichens in Area 2 during 2004-2017. Area 2 is the camp and mine area (stations 11t, 12t, 21t, 22t, 23t and 24t). From 2008 onwards, concentrations are derived from transplanted lichens. Solid lines show average values. Baseline average concentrations from 1998 are indicated as dashed lines.

The third area in the monitoring is the former stockpile of ore around the pier (Area 3), including stations 20t and M2t; in 2017, however, M2t could not be located, possibly due to an observed erosion. The results shown are thus based on 20t only. During the last mining period, large stockpiles of ore to be shipped off were deposited in the field above the pier. When the Crew Mine closed in 2009, a stockpile was left and the ore was transported back to the mining area for processing between 2011 and 2012. In 2011, the concentrations of the four metals in the pier area were 2-29 times higher than the background concentrations. However, towards 2014, only As was found in slightly higher concentrations than baseline concentrations (data from 1998). In 2015, Co was found at an increasing concentration, but in 2017 the concentration similar to the concentrations in 2013 and 2014. In 2017, As, Co, Cr and Cu were found in concentrations lower or very similar to the baseline sample concentrations.

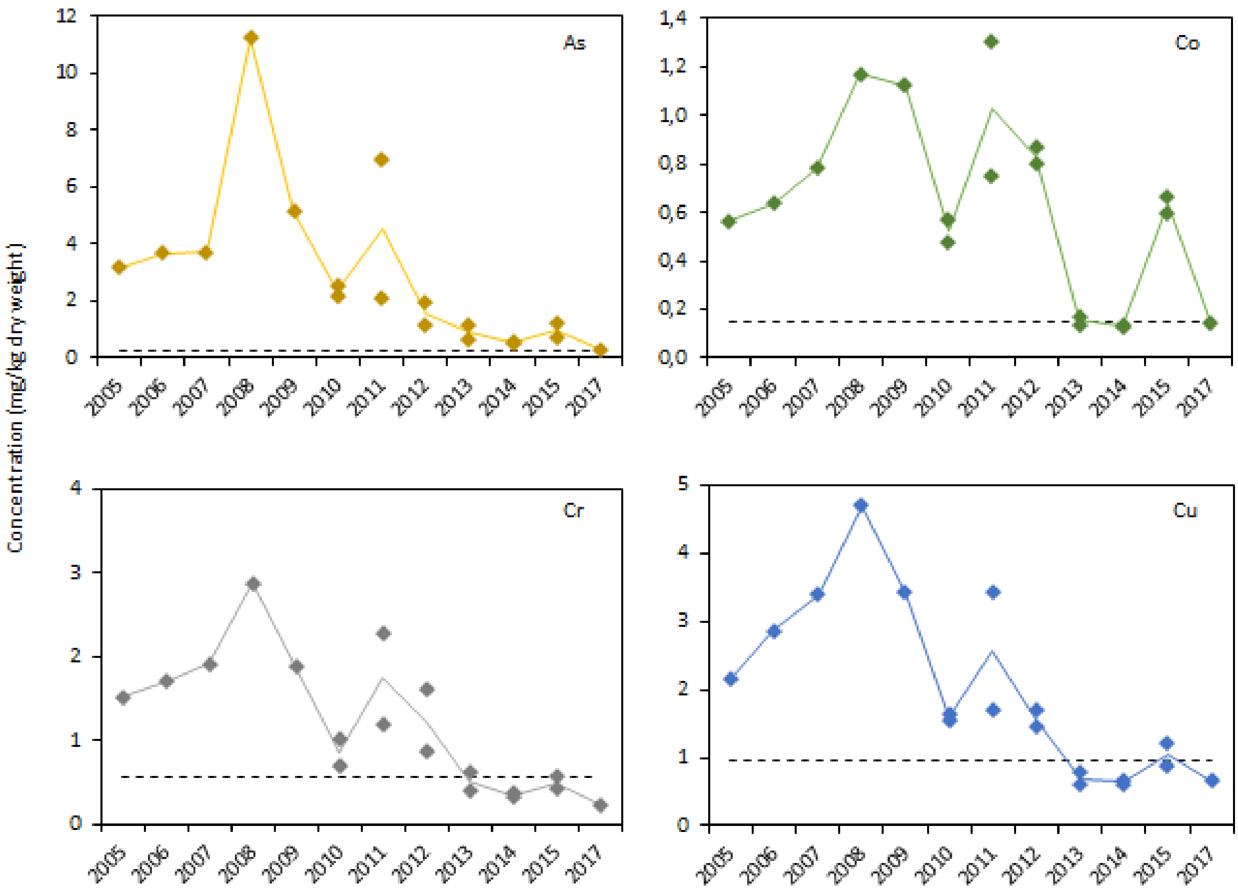

Figure 3.3. Temporal trends in concentrations of Cu, Cr, As and Co in lichens in Area 3 during 2004-2017. Area 3 is the area around the pier (stations M2 and 20t). From 2008 onwards, concentrations are derived from transplanted lichens. Solid lines show average values. Baseline average concentrations from 1998 are indicated as dashed lines.

3.1.2 Freshwater environment

Elevated metal concentrations were not found in livers (n=4) from non-migrating Arctic char in Kirkespir River (table 3.2) compared with the background data (from 2000). In general, all metal concentrations were lower in 2017 compared with 2015.

Table 3.2. Average metal concentrations in livers of Arctic char (mg/kg wet weight) in 2017 and 2011-2015. Background concentrations are those from baseline studies. * indicates slightly elevated concentrations (2 x background concentration). dl: detection limit.

		As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Background conc.		*0.448*		*0.071*	*0.042*	*0.026*	*9.882*		*0.025*		*0.006*		*34.8*
Detection limit 2017		*0.010*	*0.004*	*0.033*	*0.005*	*0.002*	*0.023*	*0.213*	*0.002*	*0.060*	*0.010*	*0.003*	*0.071*
2017	average	0.279	0.006	0.090	0.041	0.014	7.26	64.8	0.019	0.019	0.010	0.805	26.5
	+/- std	0.137	0.002	0.010	0.026	0.009	7.09	30.4	0.002	-	-	0.220	2.38
2015	average	0.535		0.117	0.047	< dl	4.62	119	0.018	< dl	< dl	0.887	28.1
	+/- std	0.138		0.047	0.013	-	2.73	103	0.004	-	-	0.260	2.96
2014	average	0.203	0.529	0.079	*0.097	0.036	18.5	282	0.014	< dl	< dl	1.53	28.6
	+/- std	0.038	0.208	0.028	0.004	0.010	6.03	157	0.006	-	-	0.268	2.11
2013	average	0.249	0.055	*0.159	< dl	< dl	9.37	68.4	0.020	< dl	< dl	0.942	29.6
	+/- std	0.123	0.071	0.110	-	-	5.97	31.1	0.012	-	-	0.275	2.27
2012	average	0.322	0.035	0.142	< dl	0.032	8.60	228	*0.061	< dl	< dl	0.909	32.5
	+/- std	0.175	0.036	0.047	-	0.021	6.02	105	0.041	-	-	0.216	5.60
2011	average	0.289	0.064	*0.173	0.068	0.048	19.6	279	0.039	< dl	0.027	1.29	35.1
	+/- std	0.210	0.091	0.102	< dl	0.027	17.2	225	0.025	-	0.021	0.563	6.45

Water samples were taken in the Kirkespir River upstream the mine, at the outflow of the mine water, downstream the mine and at the waterfall (table 3.3). The data show that the water leaving the mine contained higher levels of As, Fe, Pb and Zn compared with upstream waters. Concentrations above EAMRA guidelines were only detected for As in mine water from the 300 m portal. The increased metal concentrations in the water from the mine did not affect the concentrations downstream in the Kirkespir River. The measurements at the waterfall station in the Kirkespir River showed concentrations below the Greenland Water Quality Guidelines (MRA Guidelines 2011).

Photo 3.1. Arctic char are collected for analyses of liver accumulation of metal element (photo L. Bach).

Table 3.3. Metal concentrations in samples of outflow water from the mine and river water (µg/l) in 2017.
* indicates when the EAMRA guideline values are exceeded. dl: detection limit.

	As	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
EAMRA Guidelines	*4*	*0.100*		*3*	*2*	*300*	*0.050*	*5.00*	*1*		*10*
Detection limit 2017	*0.039*	*0.003*	*0.003*	*0.009*	*0.014*	*0.705*	*0.006*	*0.010*	*0.006*	*0.006*	*1.01*
River upstream	1.69	0.003	0.044	0.211	0.104	16.0	< dl	0.097	0.035	0.056	< dl
Outflow 300 m mine portal 1	*26.8	0.009	0.059	0.347	0.762	3.65	< dl	0.749	0.011	0.148	1.77
River downstream	1.60	< dl	0.052	0.188	0.091	4.97	< dl	0.073	< dl	0.048	< dl
Kirkespir River	1.74	0.005	0.050	0.235	0.349	16.2	< dl	0.116	0.062	0.064	< dl

3.1.3 Marine environment

Mussels and seaweed were collected at five stations (M1-M5) (figure 2.1) in 2017. Data were compared with the background data from 2000 (table 3.5 and table 3.6). Concentrations were considered slightly elevated when the mean of the measured concentrations exceeded the background levels by a factor 2, elevated when concentrations were between 2-5 times the background concentrations and highly elevated when they were above 10 times background concentrations.

In brown seaweed (*Fucus vesiculosus*) elevated concentrations were found at some stations compared with background values (table 3.4). Cr, Co and particularly Cu were found in concentrations slightly higher than the background concentrations. The Cu concentrations were elevated at station M5, the station closest to the outlet of Kirkespir River, but as the concentrations were also elevated at AMIT / ref and M1 , the increased concentrations are not considered to be related to the mine.

Table 3.4. Metal concentrations in the seaweed *Fucus vesiculosus* in mg/kg dry weight (n=2). Background concentrations are derived from baseline studies, when available, or based on 2013 data on seaweed from the reference site. * indicates slightly elevated concentrations (2-5 x background concentration) and ** elevated concentrations (5-10 x background concentration). dl: detection limit.

	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Background conc.	*46.2*	*0.047*	*1.76*	*0.211*	*0.069*	*1.00*	*32.7*	*0.009*	*0.869*	*0.107*	*0.056*	*7.00*
Detection limit 2017	*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
AMIT/ref	69.2	< dl	2.07	0.160	0.098	*2.17	22.7	0.005	0.541	0.062	0.030	6.96
M1	74.6	< dl	2.02	0.181	0.067	*4.31	12.5	< dl	0.498	0.059	0.025	7.85
M2	75.8	< dl	1.56	0.183	0.091	1.82	14.3	< dl	0.440	0.032	0.027	6.26
M3	87.7	0.03	1.22	0.402	*0.262	*3.10	23.8	< dl	0.618	0.045	0.035	8.18
M4	61.2	< dl	2.62	*0.447	0.100	2.07	19.1	< dl	1.254	0.043	0.029	6.67
M5	53.2	0.02	1.11	0.248	0.121	**6.56	39.6	< dl	0.633	0.140	0.027	10.1

In mussels (*Mytilus edulis*) (table 3.5), elevated concentrations were mainly found for Au and Co. One sample with elevated concentrations of Ni and one of Cd appeared. For Au, the mussels at the stations closest to the Kirkespir River outlet had the highest metal concentrations. As to Co, the enhanced concentrations did not appear to be related to the mine as the AMIT station, the reference site, also exhibited increased concentrations. Most of the 2017 metal concentrations were, however, higher than the levels in 2014 but lower or equal to those in 2013. See appendix 1 for detailed information on sample sizes and mussel lengths.

Table 3.5. Metal concentrations in the mussel *Mytilus edulis* in mg/kg dry weight. Background concentrations are derived from baseline studies, when available, or based on the data from 2013 on mussels from the reference site. * indicates slightly elevated concentrations (2-5 x background concentration).

		As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Background conc.		*11.7*	*0.085*	*5.47*	*0.240*	*0.736*	*7.60*	*122*	*0.132*	*0.770*	*1.22*	*3.38*	*89.0*
Detection limit 2017		*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
AMIT/ref	3.0-4.9 cm	11.9	0.015	4.85	*0.503	0.633	8.14	163.7	0.069	1.115	0.382	5.29	79.7
	5.0-6.9 cm	12.0	0.030	5.51	*0.489	0.629	7.62	173.3	0.079	1.007	0.618	4.37	88.6
	7.0 - cm	13.8	0.041	6.31	*0.513	0.886	7.44	209.9	0.120	1.317	2.223	4.12	48.3
M1	3.0-4.9 cm	13.1	0.023	3.21	0.472	0.482	7.45	101.7	0.061	1.405	0.328	4.77	83.9
	5.0-6.9 cm	13.6	0.048	4.26	0.472	0.592	8.09	98.7	0.078	1.448	0.505	4.66	99.7
	7.0 - cm	12.3	0.089	4.16	0.337	0.789	5.69	114.4	0.099	0.871	0.806	3.01	68.0
M2	3.0-4.9 cm	14.1	0.033	2.70	*0.535	0.723	7.83	105.2	0.061	*1.819	0.303	5.38	91.8
	5.0-6.9 cm	14.5	0.052	2.82	0.458	0.421	7.45	92.8	0.065	1.503	0.403	5.24	96.7
	7.0 - cm	11.3	0.083	4.10	0.303	0.454	6.23	90.1	0.079	0.991	0.579	2.87	64.6
M3	3.0-4.9 cm	11.1	0.058	3.92	0.462	0.497	7.39	168.3	0.044	1.037	0.378	4.80	69.0
	5.0-6.9 cm	10.8	0.087	5.14	0.405	0.465	7.89	119.8	0.046	0.872	0.378	4.16	67.9
	7.0 - cm	13.6	*0.292	5.63	*0.481	0.738	6.84	154.7	0.082	1.095	0.968	3.42	83.8
M4	3.0-4.9 cm	11.8	0.060	3.25	*0.538	0.458	7.19	103.1	0.051	1.327	0.278	5.31	78.2
	5.0-6.9 cm	11.5	0.160	5.43	*0.504	0.578	7.42	114.9	0.069	1.243	0.455	4.83	72.7
	7.0 - cm	13.3	*0.376	*14.94	*0.536	0.854	7.60	148.2	0.103	1.247	0.792	4.41	74.9
M5	3.0-4.9 cm	18.0	*0.215	4.41	*0.668	0.655	8.80	164.7	0.067	1.536	0.413	5.80	76.3
	5.0-6.9 cm	19.5	*0.404	5.44	*0.688	0.676	9.20	191.4	0.082	1.540	0.490	6.15	67.4

For the first time, rough periwinkle (*Littorina saxatilis*) was included in the monitoring (table 3.6). As there are no background data on this particular sea snail, data from sites M1-M5 were compared with data from the reference site (the AMIT station). Slightly elevated concentrations of Cd, Cr, Fe, Pb, and particularly of Co and Cu, were found. The station closest to the outlet of Kirkespir River, M5, had the highest concentrations.

Table 3.6. Metal average concentrations in rough periwinkle, *Littorina saxatilis*, in mg/kg dry weight (n =10). Background concentrations are not available and * indicates slightly elevated concentrations (2-5 x AMIT/ref concentration). dl: detection limit.

	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Detection limit 2017	*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
AMIT/ref	18.3	< dl	6.53	0.20	0.17	16.4	121	0.035	1.58	0.115	0.980	47.4
M1	19.8	0.01	11.6	0.29	0.10	20.6	92.9	0.035	1.75	0.110	0.972	47.9
M2	25.1	0.02	*15.9	*0.42	0.22	26.7	129	0.036	2.59	0.127	1.07	52.7
M3	23.2	0.07	9.67	*0.43	0.29	*84.5	214	0.037	1.97	0.159	1.19	51.0
M4	17.9	0.03	10.5	0.20	0.10	*45.8	112	0.033	1.36	0.102	0.919	46.5
M5	17.4	0.03	3.43	*0.48	*0.55	*53.9	*419	0.057	2.40	*0.246	1.07	50.0

In sculpin (*Myoxosephalus scorpius*) livers, elevated metal concentrations were found at some stations relative to background or AMIT (ref) values (table 3.7). As was slightly elevated in the sculpins sampled at M2, and Fe levels were slightly higher in sculpins at M3. Cu was slightly elevated at M2, M3 and M5.

Table 3.7. Average metal concentrations in sculpin (*Myoxosephalus scorpius*) livers in mg/kg dry weight (n=4). Background concentrations are derived from baseline studies, when available, or based on 2013 data on sculpins from the reference site. * indicates slightly elevated concentrations (2-5 x background concentration) and ** elevated (5-10 x background concentration). dl: detection limit.

	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Background conc.	*2.75*		*1.094*	*0.017*	*0.017*	*1.882*		*0.026*		*0.004*		*31.811*
Detection limit 2017	*0.010*	*0.004*	*0.033*	*0.005*	*0.002*	*0.023*	*0.213*	*0.002*	*0.060*	*0.010*	*0.003*	*0.071*
AMIT/ref	2.06	< dl	0.608	0.025	0.005	4.19	36.8	0.016	< dl	< dl	0.878	29.87
M1	3.59	< dl	0.675	0.025	0.015	1.92	67.0	0.023	0.06	< dl	0.966	27.98
M2	*5.60	< dl	0.543	0.031	0.009	*4.06	62.4	0.024	0.08	< dl	0.948	30.77
M3	4.90	< dl	0.476	0.033	0.005	*5.13	*88.6	0.024	< dl	< dl	0.877	29.50
M4	5.48	< dl	0.299	0.013	0.002	1.65	48.0	0.029	< dl	< dl	1.071	31.52
M5	2.06	< dl	0.608	0.025	0.005	*4.19	36.8	0.016	< dl	< dl	0.878	29.87

3.2 Cyanide monitoring programme

3.2.1 Environment

In both 2016 and 2017, cyanide (free cyanide) was not detected in any of the water samples in the environment.

Photo: Lis Bach.

4 Discussion

This report describes the results of the thirteenth environmental monitoring in the area surrounding the Nalunaq Gold Mine operated by Angel Mining during the period 2009-2013. The monitoring was conducted in August 2017. Most mining work from August 2009 until spring 2011 was directed at the excavation of a chamber inside the mine and the construction of a processing plant. In spring 2011, mining and processing of ore were initiated, and parts of the low grade ore were transported from the pier and back to the mine for processing. The mining and processing of ore took place inside the process hall in the mountain and outdoor crushing took place at the 300 m portal. In November 2013, the mine was closed and clean-up and restoration of the area were initiated. Decommissioning and restoration of the landscape were completed in August 2014. In summer 2015, 2016 and 2017, an exploration team visited the license area, which involved the conduct of activities like driving, drilling and camping.

As in previous years, the impact from the mining activities on the marine environment was confined to the area close to the outlet of the Kirkespir River. Small elevations in metal concentrations compared with background levels were, however, found in snails, blue mussels and brown seaweed, mostly at the sampling stations close to the Kirkespir River outlet, but in some cases also regardless of / outside the sampling station. In general, during 2006-2017, the concentrations of metals in the marine environment were low and did not differ remarkably from the background levels. When comparing the sensitivity of the species used in the marine monitoring programme, it appears that snails and mussels accumulate the highest concentrations of metals , of which some demonstrate large differences. For example, the concentrations of copper (Cu) were almost 10 times higher in snails than in mussels, while the concentrations of zinc (Zn) were 1.3 times higher in mussels than in snails. The uptake appears to be highly dependent of the metal, and the highest accumulations of arsenic (As) were found in seaweed.

In the freshwater / river system, an elevated concentration (above EAMRA Guideline value) of arsenic (As) was measured on one occasion in the water leaving the mine. When it enters the small river, the water is diluted, and it becomes even more diluted when the small river enters the Kirkespir River; thus, the concentrations of As were not elevated in the Kirkespir River. Accordingly, there were no signs of metal accumulation in Arctic char livers at the waterfall station in the Kirkespir River, and the metal concentrations recorded here in 2017 were lower than in 2015.

Concerning cyanide, no free cyanide was detected in the water leaching out of the mine, in the small river or in the Kirkespir River that received the water from the mine.

As in previous years, the terrestrial environment was slightly affected by dust spreading in 2017. The concentrations of Cu, As, Cd and Co in lichens were elevated to a different degree depending on station and element species relative to the background level recorded at the stockpile of crushed waste rock and in the mining / camp area. The mining / camp area is the most affected by dust spreading. Dust-containing metals will expectedly be dispersed from the mountain slope where the waste rock was deposited depending on wind speed and direction.

Photo 4.1. The former camp area. The vegetation is still, as expected, very sporadic (photo L. Bach).

5 Concluding remarks

In 2017, impact from the gold mine on the local environment was primarily observed in the Kirkespir Valley, mainly in the form of dust dispersed from the road and from the former crushing area at the 300 m portal, as well as from the mountain slope where waste rock was deposited. Most metals were found in lower concentrations in 2017 than in 2015. For a few metals, around area 2 – the former stockpile of crushed waste rock - there was a small peak in concentrations, indicating increased dispersal compared with 2015, likely due to either yearly variations or exploration activities including driving on the gravel road in the area.

In the Kirkespir River and Kirkespir Bay, no elevated concentrations of concern were found in Arctic char and only few instances of elevated metal concentrations were found in seaweed and blue mussels.

The environmental impact from the spreading of metals due to the decommissioning and restoration of the Nalunaq area are considered to be minor, and overall the effect of the former mining is decreasing. Also, the exploration activities seem to have left no significant trace.

No traces of free cyanide could be detected in the environment.

Based on the present results and those obtained four years after the closure of the mine in November 2013, it is expected that the element concentrations in the environment will decrease even further, though some dispersal of dust from the waste rock is likely to continue years ahead. It is assessed that no further actions are needed to reduce the environmental impact. Environmental monitoring will continue in 2019.

6 Reference list

Bach, L., Asmund, G. & Søndergaard, J. 2012. Environmental Monitoring at the Nalunaq Gold Mine, South Greenland, 2011. Aarhus University, DCE – Danish Centre for Environment and Energy, 42 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 20. http://www.dmu.dk/Pub/SR20.pdf

Bach, L. & Asmund, G. 2013. Environmental Monitoring at the Nalunaq Gold Mine, South Greenland, 2012. Aarhus University, DCE – Danish Centre for Environment and Energy, 42 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 55. http://www.dmu.dk/Pub/SR55.pdf

Bach, L., Olsen, M. & Asmund, G. 2014. Environmental Monitoring at the Nalunaq Gold Mine, South Greenland, 2013. Aarhus University, DCE – Danish Centre for Environment and Energy, 44 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 97. http://dce2.au.dk/pub/SR97.pdf

Bach, L., Asmund, G. & Jia, Y. 2015. Nalunaq Environmental Monitoring 2014. Monitoring note from DCE – Danish Centre for Environment and Energy.

Bach, L & Larsen, M. B. 2016. Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2015. Aarhus University, DCE – Danish Centre for Environment and Energy, 30 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 181. http://dce2.au.dk/pub/SR181.pdf

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

DMI 2017. Tidevandstabeller for grønlandske farvande/Tide tables for Greenlandic waters 2017. http://www.dmi.dk/fileadmin/user_upload/vandstand_txt_pdf/2017/GL/Nanortalik2017.pdf

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

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

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

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

Glahder, C. M., Asmund, G. & Riget, F. 2008. Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2007. - National Environmental Research Institute, Denmark, Technical Report No. 662, 32 pp.

Glahder, C. M., Asmund, G. & Riget, F. 2009. Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2008. - National Environmental Research Institute, Denmark, Technical Report No. 698, 30 pp.

Glahder, C. M., Asmund, G. & Riget, F. 2010. Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2009. - National Environmental Research Institute, Denmark, Technical Report No. 772, 32 pp.

Glahder, C. M., Søndergaard, J., Asmund, G. & Riget, F. 2011. Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2010. - National Environmental Research Institute, Denmark, Technical Report No. 811, 32 pp.

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

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

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

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

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

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

MRA Guidelines for preparing an Environmental Impact Assessment (EIA) Report for Mineral Exploitation in Greenland. 2011. Johansen, P., Glahder, C. & Asmund, G. National Environmental Research Institute, Aarhus University.

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

Søndergaard, J., Bach, L. & Asmund, G. 2013. Modelling atmospheric bulk deposition of Pb, Zn and Cd near a former Pb-Zn mine in West Greenland using transplanted *Flavocetraria nivalis* lichens. Chemosphere 90: 2549-2556.

Photo: Lis Bach.

Appendix 1 – List of samples and element concentrations

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Lichen samples (mg/kg dry weight)														
Detection limit			*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
Flavocetraria nivalis	4	59201	0.293	<dl	0.055	0.178	0.304	0.759	142	0.030	0.363	0.691	0.088	0.691
Flavocetraria nivalis	7	59202	1.26	<dl	0.050	0.503	1.07	1.25	399	0.029	0.886	0.453	0.078	0.453
Flavocetraria nivalis	8	59203	0.934	<dl	0.055	0.713	0.724	1.40	288	0.028	0.987	0.663	0.101	0.663
Flavocetraria nivalis	9	59208	1.64	<dl	0.054	0.278	0.591	0.832	198	0.033	0.453	0.585	0.122	0.585
Flavocetraria nivalis	10	59204	1.16	<dl	<dl	0.737	0.745	0.995	262	0.031	1.03	0.633	0.103	0.633
Flavocetraria nivalis	15	59205	0.140	<dl	<dl	0.097	0.199	0.559	97.9	0.027	0.256	0.199	0.056	0.199
Flavocetraria nivalis	17	59206	0.261	<dl	<dl	0.167	0.238	0.665	112	0.029	0.370	0.516	0.085	0.516
Flavocetraria nivalis	19	59207	0.171	<dl	<dl	0.090	0.202	0.807	88.8	0.028	0.218	0.265	0.060	0.265
Flavocetraria nivalis	11t	59274	1.47	<dl	0.052	0.414	0.634	2.68	264	0.033	0.773	0.478	0.100	0.478
Flavocetraria nivalis	12t	59275	0.337	<dl	0.106	0.347	0.272	0.853	132	0.031	0.515	0.458	0.083	0.458
Flavocetraria nivalis	20t	59286	0.297	<dl	<dl	0.145	0.236	0.654	144	0.042	0.196	0.421	0.121	0.421
Flavocetraria nivalis	21t	59278	0.458	<dl	<dl	0.320	0.392	1.51	159	0.034	0.735	0.484	0.087	0.484
Flavocetraria nivalis	22t	59279	0.781	<dl	0.103	0.807	0.310	2.70	129	0.036	2.76	0.344	0.109	0.344
Flavocetraria nivalis	23t	59280	0.409	<dl	0.075	0.429	0.372	1.29	135	0.036	1.06	0.399	0.103	0.399
Flavocetraria nivalis	24t	59281	0.304	<dl	0.070	0.183	0.312	0.912	107	0.031	0.461	0.383	0.098	0.383
Flavocetraria nivalis	5t	59276	0.565	<dl	0.061	0.397	0.723	1.48	376	0.034	0.657	0.701	0.094	0.701
Flavocetraria nivalis	6t	59277	0.458	<dl	0.072	0.622	0.279	1.01	116	0.033	0.799	0.335	0.111	0.335
Flavocetraria nivalis	AMIT	59248	0.113	<dl	0.067	0.093	0.165	0.445	87.5	0.037	0.190	0.374	0.094	0.374
Flavocetraria nivalis	M1	59231	0.165	<dl	<dl	0.051	0.118	0.670	74.0	0.034	0.089	0.173	0.083	0.173
Flavocetraria nivalis	M2	59232	2.23	<dl	<dl	0.441	0.769	1.18	335	0.033	0.752	0.666	0.071	0.666
Flavocetraria nivalis	M3	59233	0.149	<dl	0.071	0.076	0.200	0.777	99.6	0.028	0.127	0.142	0.050	0.142
Flavocetraria nivalis	M4	59234	0.191	<dl	0.144	0.086	0.311	0.909	183	0.041	0.160	0.839	0.079	0.839
Flavocetraria nivalis	M5	59235	0.337	<dl	0.152	0.167	0.167	0.660	120	0.039	0.171	0.455	0.098	0.455

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Arctic char samples (mg/kg wet weight)														
Detection limit			*0.010*	*0.004*	*0.033*	*0.005*	*0.002*	*0.023*	*0.213*	*0.002*	*0.060*	*0.010*	*0.003*	*0.071*
Salvelinus alpinus	WF	59282	0.273	0.005	0.096	0.022	0.028	1.14	107	0.019	<dl	<dl	0.611	24.7
Salvelinus alpinus	WF	59283	0.470	0.009	0.090	0.035	0.010	15.4	67.6	0.022	<dl	<dl	1.09	29.7
Salvelinus alpinus	WF	59284	0.150	0.004	0.098	0.027	0.010	1.48	43.2	0.019	<dl	<dl	0.658	27.0
Salvelinus alpinus	WF	59285	0.224	0.006	0.077	0.080	0.009	11.1	41.7	0.018	<dl	<dl	0.860	24.7

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Mussel samples (mg/kg dry weight)														
Detection limit			*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
Mytilus edulis	AMIT	59236	11.9	0.015	4.85	0.503	0.633	8.14	163.7	0.069	1.11	0.382	5.29	79.7
Mytilus edulis	AMIT	59237	12.0	0.030	5.51	0.489	0.629	7.62	173.3	0.079	1.01	0.618	4.37	88.6
Mytilus edulis	M1	59238	13.1	0.023	3.21	0.472	0.482	7.45	102	0.061	1.40	0.328	4.77	83.9
Mytilus edulis	M1	59239	13.6	0.048	4.26	0.472	0.592	8.09	98.7	0.078	1.45	0.505	4.66	99.7
Mytilus edulis	M2	59240	14.1	0.033	2.70	0.535	0.723	7.83	105	0.061	1.82	0.303	5.38	91.8
Mytilus edulis	M2	59241	14.5	0.052	2.82	0.458	0.421	7.45	92.8	0.065	1.50	0.403	5.24	96.7
Mytilus edulis	M3	59242	11.1	0.058	3.92	0.462	0.497	7.39	168	0.044	1.04	0.378	4.80	69.0
Mytilus edulis	M3	59243	10.8	0.087	5.14	0.405	0.465	7.89	120	0.046	0.872	0.378	4.16	67.9
Mytilus edulis	M4	59244	11.8	0.060	3.25	0.538	0.458	7.19	103	0.051	1.33	0.278	5.31	78.2
Mytilus edulis	M4	59245	11.5	0.160	5.43	0.504	0.578	7.42	115	0.069	1.24	0.455	4.83	72.7
Mytilus edulis	M5	59246	18.0	0.215	4.41	0.668	0.655	8.80	165	0.067	1.54	0.413	5.80	76.3
Mytilus edulis	M5	59247	19.5	0.404	5.44	0.688	0.676	9.20	191	0.082	1.54	0.490	6.15	67.4
Mytilus edulis	AMIT	59269	13.8	0.041	6.31	0.513	0.886	7.44	210	0.120	1.32	2.22	4.12	48.3
Mytilus edulis	M1	59270	12.3	0.089	4.16	0.337	0.789	5.69	114	0.099	0.871	0.806	3.01	68.0
Mytilus edulis	M2	59271	11.3	0.083	4.10	0.303	0.454	6.23	90.1	0.079	0.991	0.579	2.87	64.6
Mytilus edulis	M3	59272	13.6	0.292	5.63	0.481	0.738	6.84	155	0.082	1.09	0.968	3.42	83.8
Mytilus edulis	M4	59273	13.3	0.376	14.94	0.536	0.854	7.60	148	0.103	1.25	0.792	4.41	74.9

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Seaweed samples (mg/kg dry weight)														
Detection limit			*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
Fucus vesiculosus	AMIT	59209	63.9	<dl	2.05	0.149	0.102	2.46	16.8	0.005	0.517	0.042	0.034	6.83
Fucus vesiculosus	AMIT	59210	74.5	<dl	2.09	0.170	0.094	1.87	28.5	<dl	0.565	0.082	0.027	7.10
Fucus vesiculosus	M1	59211	72.1	<dl	1.87	0.177	0.058	2.36	10.6	<dl	0.439	0.045	0.025	6.93
Fucus vesiculosus	M1	59212	77.0	<dl	2.17	0.184	0.076	6.27	14.3	<dl	0.556	0.072	0.025	8.77
Fucus vesiculosus	M2	59213	86.7	<dl	1.80	0.185	0.097	1.59	15.3	<dl	0.473	0.034	0.030	6.49
Fucus vesiculosus	M2	59214	64.9	<dl	1.32	0.180	0.085	2.05	13.2	<dl	0.408	0.030	0.023	6.04
Fucus vesiculosus	M3	59215	86.9	0.024	1.31	0.397	0.108	3.39	21.7	<dl	0.589	0.054	0.033	9.07
Fucus vesiculosus	M3	59216	88.5	0.031	1.13	0.406	0.415	2.81	25.9	<dl	0.647	0.036	0.036	7.30
Fucus vesiculosus	M4	59217	58.6	<dl	2.68	0.504	0.072	2.33	16.3	<dl	1.376	0.039	0.028	6.71
Fucus vesiculosus	M4	59218	63.9	<dl	2.56	0.390	0.129	1.81	21.9	<dl	1.132	0.046	0.031	6.63
Fucus vesiculosus	M5	59219	58.5	0.019	1.16	0.248	0.127	4.17	31.0	<dl	0.637	0.140	0.029	8.87
Fucus vesiculosus	M5	59220	48.0	0.014	1.06	0.247	0.116	8.94	48.2	<dl	0.629	0.139	0.024	11.32

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Snail samples (mg/kg dry weight)														
Detection limit			*0.019*	*0.012*	*0.046*	*0.007*	*0.031*	*0.081*	*0.861*	*0.005*	*0.110*	*0.027*	*0.006*	*0.260*
Littorina saxatilis	AMIT	Amit	18.3	<dl	6.53	0.199	0.169	16.4	121	0.035	1.58	0.115	0.980	47.4
Littorina saxatilis	M1	59221	19.7	0.012	10.5	0.270	0.120	24.1	93	0.041	1.64	0.106	1.02	47.7
Littorina saxatilis	M1	59222	20.0	<dl	12.8	0.317	0.089	17.1	92	0.030	1.86	0.115	0.929	48.1
Littorina saxatilis	M2	59223	27.0	0.015	18.4	0.459	0.228	24.4	130	0.034	2.79	0.127	1.06	54.4
Littorina saxatilis	M2	59224	23.2	0.016	13.5	0.385	0.207	29.0	129	0.039	2.39	0.126	1.09	51.0
Littorina saxatilis	M3	59225	22.5	0.071	9.54	0.419	0.273	82.4	196	0.036	1.90	0.153	1.13	48.9
Littorina saxatilis	M3	59226	23.9	0.067	9.79	0.446	0.316	86.7	232	0.039	2.04	0.165	1.26	53.1
Littorina saxatilis	M4	59227	18.6	0.022	10.7	0.237	0.102	40.8	115	0.042	1.55	0.128	0.913	45.9
Littorina saxatilis	M4	59228	17.3	0.034	10.2	0.169	0.097	50.8	110	0.024	1.18	0.076	0.926	47.1
Littorina saxatilis	M5	59229	17.5	0.032	2.16	0.452	0.454	66.7	421	0.062	2.47	0.264	1.20	51.9
Littorina saxatilis	M5	59230	17.2	0.026	4.71	0.502	0.651	41.1	418	0.052	2.32	0.227	0.942	48.1

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Sculpin samples (mg/kg dry weight)														
Detection limit			*0.010*	*0.004*	*0.033*	*0.005*	*0.002*	*0.023*	*0.213*	*0.002*	*0.060*	*0.010*	*0.003*	*0.071*
M. scorpius	AMIT	59249	2.04	<dl	0.660	0.020	0.004	3.15	29.6	0.019	<dl	<dl	1.02	34.2
M. scorpius	AMIT	59250	1.10	<dl	0.502	0.016	0.002	3.66	20.6	0.010	<dl	<dl	0.722	26.3
M. scorpius	AMIT	59251	3.52	<dl	0.406	0.018	0.005	2.20	53.0	0.022	<dl	<dl	1.08	29.3
M. scorpius	AMIT	59252	1.56	<dl	0.862	0.046	0.010	7.74	44.1	0.013	<dl	<dl	0.693	29.6
M. scorpius	M1	59253	6.00	<dl	0.240	0.006	<dl	1.01	20.8	0.020	<dl	<dl	1.16	22.3
M. scorpius	M1	59254	3.96	<dl	0.675	0.053	0.015	2.65	74.0	0.029	<dl	<dl	0.909	32.5
M. scorpius	M1	59255	1.48	<dl	1.051	0.023	0.026	1.61	43.9	0.018	<dl	<dl	0.713	26.0
M. scorpius	M1	59256	2.91	<dl	0.737	0.019	0.004	2.43	129.2	0.024	0.060	<dl	1.09	31.1
M. scorpius	M2	59257	6.45	<dl	1.141	0.093	0.019	13.2	154.1	0.025	0.077	<dl	1.56	47.5
M. scorpius	M2	59258	5.33	<dl	0.521	0.006	<dl	0.875	15.7	0.028	<dl	<dl	0.609	31.3
M. scorpius	M2	59259	1.41	<dl	0.171	0.012	0.003	1.19	40.3	0.011	<dl	<dl	0.725	22.2
M. scorpius	M2	59260	9.19	<dl	0.341	0.012	0.006	1.01	39.3	0.031	<dl	<dl	0.896	22.0
M. scorpius	M3	59261	7.00	<dl	0.200	0.014	0.002	0.739	49.9	0.020	<dl	<dl	0.612	22.4
M. scorpius	M3	59262	5.80	<dl	0.585	0.029	0.008	1.91	130.8	0.039	<dl	0.011	1.20	34.9
M. scorpius	M3	59263	2.56	0.005	0.713	0.068	0.006	9.16	140.8	0.025	<dl	<dl	1.00	41.1
M. scorpius	M3	59264	4.24	<dl	0.404	0.022	<dl	8.70	32.9	0.012	<dl	<dl	0.696	19.6
M. scorpius	M4	59265	2.90	<dl	0.149	0.010	<dl	1.59	17.9	0.017	<dl	<dl	0.940	28.2
M. scorpius	M4	59266	11.5	<dl	0.445	0.014	<dl	1.50	52.1	0.039	<dl	<dl	0.739	35.1
M. scorpius	M4	59267	4.80	<dl	0.225	0.010	<dl	1.15	37.6	0.028	<dl	<dl	1.31	29.9
M. scorpius	M4	59268	2.75	<dl	0.376	0.018	0.002	2.36	84.4	0.033	<dl	<dl	1.30	32.8

Sample	Station	ID #	As	Au	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Se	Zn
Freshwater µg/l														
Detection limit			0.039	-	0.003	0.003	0.009	0.014	0.705	0.006	0.010	0.006	0.006	1.005
Upstream st 22		59289	1.69	-	0.003	0.044	0.211	0.104	16.0	< dl	0.097	0.035	0.056	< dl
300 m portal		59288	26.8	-	0.009	0.059	0.347	0.762	3.65	< dl	0.749	0.011	0.148	1.77
Downstream st 23		59290	1.60	-	< dl	0.052	0.188	0.091	4.97	< dl	0.073	< dl	0.048	< dl
Waterfall		59291	1.74	-	0.005	0.050	0.235	0.349	16.2	< dl	0.116	0.062	0.064	< dl

***Mytilus edulis* individual size**

	Amit 59236	Amit 59237	Amit 59269	M1 59238	M1 59239	M1 59270	M2 59240	M2 59241	M2 59271	M3 59242	M3 59243	M3 59272	M4 59244	M4 59245	M4 59273	M 5 59246	M5 59247
1	4.4	7	9	4.3	5.5	8.2	4.3	6	9.5	4.5	7	9.2	4.1	6.1	7.2	2.9	3.9
2	3.7	6.8		4.7	5.3	7.8	4.4	5.8	8.8	4.1	6.2	10.4	4.1	6.1	7.7	3.1	4
3	3.7	6.1		4.8	5.5	7.8	4.8	6.8		4.7	5.7	9.2	4.1	5.7	8	2.9	3.6
4	4.2	6.4		4.1	5.1	7.6	4.7	6.6		4.5	6.2	8.8	4.1	6.1	7.8	2.8	3.6
5	4.1	6.2		5	6.2	8.1	4.4	6.1		4.7	6.1	8.4	4.1	6.3		3	3.9
6	4	6.1		5	5.4	8.4	4.7	5.6		4.6	5.8		4.2	5.7		2.8	3.7
7	4.1	5.8		4.7	6		4.8	5.5		4.1	6.8		4.2	5.8		2.8	3.6
8	4.2	6.5		5	5.7		4.7	5.6		4.2	5.7		4	5.6		2.8	3.7
9	4	6.7		4.2	6.1		4.9			4.1	5.8		4.3	7		3.1	3.8
10	4.2	6.7		4.8	6.7		4.1			4.2	6.8		4.4	6.3		3	4
11	4.2	6.7		4.9	6.3		4.8			4.1	5.8		4.1	6		2.8	3.7
12	4			4.5	6.3		5			4.2	5.5		4.5	5.5		3	4
13	4.1			3.9	5.5		4.5			4.5	6.4		4.3	5.5		3	4
14	3.8			4.6	5.3		4			4.7	5.8		4.8	5.7		2.8	3.7
15	3.9			4.4	5.7		4.8			4.5			4.4	5.5		3	4
16	4			4.6	5.4		4			4.6			4.7			2.7	3.6
17	3.7			3.9	5.6		5			4.4			4.5			2.7	3.6
18	4			4.8			4.5			4			4.9			2.6	3.5
19	4.1			4.6			4.9			4.4			4.3			2.9	3.9
20	4.5			4.6			4.7			4.4			4.9			2.7	
min	3.7	5.8	9	3.9	5.1	7.6	4	5.5	8.8	4	5.5	8.4	4	5.5	7.2	2.6	3.5
max	4.5	7	9	5	6.7	8.4	5	6.8	9.5	4.7	7	10.4	4.9	7	8	3.1	4
average	4.0	6.5	9.0	4.6	5.7	8.0	4.6	6.0	9.2	4.4	6.1	9.2	4.4	5.9	7.7	2.9	3.8
Size group	3.0-5.0	5.0-7.0	7.0-11.0	3.0-5.0	5.0-7.0	7.0-11.0	3.0-5.0	5.0-7.0	7.0-11.0	3.0-5.0	5.0-7.0	7.0-11.0	3.0-5.0	5.0-7.0	7.0-11.0	2.5-3.5	3.5-4.5

Appendix 2 – GPS positions of sampling sites

Sample type	Latin name	Station	Lat deg	Long deg
Lichen	*Flavocetraria nivalis*	4	60.32861	-44.89389
Lichen	*Flavocetraria nivalis*	5-t	60.33247	-44.88003
Lichen	*Flavocetraria nivalis*	6-t	60.33603	-44.87183
Lichen	*Flavocetraria nivalis*	7	60.34222	-44.86028
Lichen	*Flavocetraria nivalis*	8	60.34556	-44.85194
Lichen	*Flavocetraria nivalis*	9	60.34694	-44.83722
Lichen	*Flavocetraria nivalis*	10	60.34750	-44.83278
Lichen	*Flavocetraria nivalis*	11-t	60.35456	-44.83239
Lichen	*Flavocetraria nivalis*	12-t	60.35783	-44.83058
Lichen	*Flavocetraria nivalis*	15	60.37861	-44.81889
Lichen	*Flavocetraria nivalis*	17	60.36639	-44.83111
Lichen	*Flavocetraria nivalis*	19	60.37500	-44.82528
Lichen	*Flavocetraria nivalis*	20-t	60.31308	-44.95283
Lichen	*Flavocetraria nivalis*	22-t	60.35545	-44.83050
Lichen	*Flavocetraria nivalis*	23-t	60.35303	-44.83108
Lichen	*Flavocetraria nivalis*	24-t	60.35626	-44.82755
Lichen	*Flavocetraria nivalis*	M 1	60.31139	-44.96694
Lichen	*Flavocetraria nivalis*	M 2-t	60.31253	-44.94639
Lichen	*Flavocetraria nivalis*	M 3	60.32472	-44.94681
Lichen	*Flavocetraria nivalis*	M 4	60.32639	-44.93750
Lichen	*Flavocetraria nivalis*	M 5	60.31567	-44.96028
Lichen	*Flavocetraria nivalis*	AMIT	60.43889	-44.95111
Brown seaweed	*Fucus vesiculosus*	M 1	60.31139	-44.96694
Brown seaweed	*Fucus vesiculosus*	M 2	60.31278	-44.94639
Brown seaweed	*Fucus vesiculosus*	M 3	60.32472	-44.93750
Brown seaweed	*Fucus vesiculosus*	M 4	60.32639	-44.96028
Brown seaweed	*Fucus vesiculosus*	M 5	60.31567	-44.93463
Brown seaweed	*Fucus vesiculosus*	AMIT	60.43889	-44.95111
Shorthorn sculpin	*Myoxocephalus scorpius*	U 1	60.31306	-44.96250
Shorthorn sculpin	*Myoxocephalus scorpius*	U 2	60.31250	-44.94611
Shorthorn sculpin	*Myoxocephalus scorpius*	U 3	60.32528	-44.94806
Shorthorn sculpin	*Myoxocephalus scorpius*	U 4	60.32611	-44.95861
Shorthorn sculpin	*Myoxocephalus scorpius*	AMIT	60.43889	-44.95111
Blue mussel	*Mytilus edulis*	M 1	60.31139	-44.96694
Blue mussel	*Mytilus edulis*	M 2	60.31278	-44.94639
Blue mussel	*Mytilus edulis*	M 3	60.32472	-44.93750
Blue mussel	*Mytilus edulis*	M 4	60.32639	-44.96028
Blue mussel	*Mytilus edulis*	M 5	60.31567	-44.93463
Blue mussel	*Mytilus edulis*	AMIT	60.43889	-44.95111
Snails	*Littorina saxatilis*	M 1	60.31139	-44.96694
Snails	*Littorina saxatilis*	M 2	60.31278	-44.94639
Snails	*Littorina saxatilis*	M 3	60.32472	-44.93750
Snails	*Littorina saxatilis*	M 4	60.32639	-44.96028
Snails	*Littorina saxatilis*	M 5	60.31567	-44.93463
Snails	*Littorina saxatilis*	AMIT	60.43889	-44.95111
Arctic char	*Salvelinus alpinus*	Waterfall	60.34642	-44.84225
Water		Upstream st 22	60.35545	-44.83050
Water		300 m portal	60.35573	-44.83399
Water		Downstream st 23	60.35303	-44.83108
Water		Waterfall	60.34642	-44.84225

ENVIRONMENTAL MONITORING AT THE NALUNAQ GOLD MINE SOUTH GREENLAND, 2017

The mining company Angel Mining Gold A/S closed its gold production in Nalunaq in November 2013 after which the Nalunaq area was affected by decommissioning and restoration until August 2014. This thirteenth environmental monitoring was conducted in the Nalunaq area to detect any undesired environmental impacts of the former mining industry. Since the monitoring in 2015, the area has been visited by an exploration group for field campaigns a few months every summer. Due to the use of cyanide, cyanide outflow from the mine to the Kirkespir Valley was monitored during the production period, and the monitoring will be carried on for a minimum of five years after the closure. In 2017, no signs of cyanide could be detected in any of the samples from the freshwater environment. Also, extensive monitoring has been conducted to reveal release of metals into the Kirkespir Valley and the Kirkespir Bay environment. The content of metals in the terrestrial, freshwater and marine environment in the Kirkespir Valley and Bay is decreasing and considered minor. DCE and GINR assess that no further actions are needed to be taken to reduce environmental impact. The monitoring will expectedly to be completed with environmental studies in 2019.

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