ENVIRONMENTAL MONITORING AT THE SEQI OLIVINE MINE 2010

NERI Technical Report no. 813 2011

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Data sheet

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Abstract: The olivine mine at Seqi in West Greenland operated between 2005 and 2010. Since 2004, environmental monitoring studies have been conducted at Seqi every year in order to assess pre-mining conditions and subsequently the impact from mining during operation. This report contains the results from monitoring studies conducted in 2010. Results from previous years have shown that operation of the mine caused levels of some elements, particularly chromium and nickel, to increase in lichens, blue mussels and seaweed within the surrounding area compared to pre-mining conditions. The main source of contamination is considered the generation and spreading of metal-contaminated dust from the roads and the ore-crushing facility. Results from 2010 show that levels of chromium and nickel in lichens are still elevated but that dust deposition rates have decreased from 2008 to 2010. Similarly, levels of chromium and nickel in seaweed and blue mussels have decreased from 2008/2009 to 2010 at the few previously impacted stations near the mine and were in 2010 no longer significantly above concentrations measured prior to mining. Similar to the previous years, no contamination was measured in fish (shorthorn sculpin) in 2010. Consequently, the environmental impact of the mine at Seqi has decreased and is considered insignificant for the Niaquungunaq fjord system.

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Summary

The Swedish mining company Minelco A/S (formerly named Seqi Olivine A/S) was in 2005 granted permission to exploit the industry-mineral olivine at Seqi in Niaqunngunaq (Fiskefjord) in West Greenland. In late 2005, the first ship was loaded with olivine from the mine at Seqi. In 2009, the mining was stopped due to economy reasons and the mine site is currently (in 2010) closing down.

Prior to mining, baseline studies were performed in 2004 and 2005 to characterize the natural state and variability of the environment at Seqi. These studies included measurements of element concentrations in biota such as lichens, seaweed, blue mussels and fish as well as in sea and lake water. No measureable natural elevation of elements was found in biota or in the water near the mining area. After the mining activity started, environmental studies have been conducted at Seqi every year to monitor the impact from mining during and after the mining operation. In this report, the results from the sampling campaign in 2010, which includes lichens, seaweed, blue mussels and shorthorn sculpins, are presented and discussed.

In lichens, elevated concentrations of some elements, particularly chromium (Cr) and nickel (Ni), were measured in 2010. This also includes lichens transplanted into the Seqi monitoring area from an unpolluted reference site the previous year. Using the method of lichen transplantation, it was possible to determine the dust deposition that had occurred during the past year only. In 2010, elevated concentrations were observed in transplanted lichens in a distance of c. 5 km from the mine site, thus showing that there is still an on-going deposition of contaminated dust in the area that can be related to the past mining operation. However, the results also show that the levels of Cr and Ni in 2010 were generally lower than in 2009, indicating that the spreading of dust has decreased from 2008 to 2010 as a result of the reduced activity.

In blue mussels and seaweed, the concentrations of Cr and Ni near the mine site had decreased from 2008/2009 to 2010 and were no longer significantly above Cr and Ni concentrations measured prior to mining. This indicates a decrease in contamination of the marine environment at Seqi from 2008 to 2010. No contamination was observed in fish caught in the fjord around Seqi (shorthorn sculpin).

Based on the above-mentioned results, it is concluded that spreading of metal-contaminated dust is still occurring at Seqi but has decreased from 2008 to 2010. The impact of the mine on the marine environment has decreased and can be regarded as insignificant for the Niaquungunaq fjord system.

Resume

Det svenske mineselskab Minelco A/S (tidligere Seqi Olivine A/S) blev i 2005 givet en udnyttelsestilladelse til brydning af industrimineralet olivin ved Seqi i Niaqunngunaq (Fiskefjord) i Vestgrønland. Den første ladning olivin blev udskibet fra minen ved Seqi i slutningen af 2005. I slutningen af 2009 blev brydningen af olivin stoppet af økonomiske årsager og minen er pt. (i 2010) i en nedlukningsfase.

Inden minen åbnede, blev der i 2004 og 2005 udført baggrundsundersøgelser med det formål at bestemme den upåvirkede naturs tilstand, bl.a. ved at undersøge grundstofsammensætningen i lav, tang, blåmusling og fisk. Ved disse undersøgelser blev der ikke påvist nogen naturligt forhøjede grundstofkoncentrationer i disse organismer nær minen. Siden minen åbnede i 2005, har der hvert år været gennemført studier af miljøet i området for at følge påvirkningen fra minen under og efter minedriften. Denne rapport indeholder resultater af prøver indsamlet i 2010 og omfatter prøver af lav, tang, blåmuslinger og ulke.

Forhøjede koncentrationer af nogle grundstoffer, især krom (Cr) og nikkel (Ni), blev i 2010 observeret i lavprøver indsamlet i området. Disse lavprøver inkluderer lav transplanteret ind i Seqi området fra et uforurenet referenceområde det foregående år. Ved at anvende transplanteret lav er det muligt at få et mål for støvforureningen i det forgangne år. I 2010 blev der målt forhøjede værdier af Cr og Ni i transplanteret lav indenfor en distance på ca. 5 km fra minen. Dette viser, at der stadig sker en kontaminering med metalholdigt støv i området, som kan relateres til minedriften. Resultaterne for 2010 viser imidlertid også, at niveauerne generelt var lavere i 2010 i forhold til 2009, hvilket indikerer at støvspredningen er aftaget fra 2009 til 2010 som følge af stoppet af produktionen.

Koncentrationerne af Cr og Ni i blåmusling og tang nær minen faldt fra 2008/2009 til 2010 og er ikke længere signifikant forhøjede i forhold til koncentrationerne målt i området før minedriftens begyndelse. Dette indikerer en faldende kontaminering af det marine miljø. Der blev ikke målt nogen forhøjede værdier af grundstoffer i ulke i området.

Baseret på ovennævnte resultater kan det konkluderes, at støvspredning relateret til den tidligere minedrift stadig kan måles i Seqi området, men at deponeringsraten er faldet fra 2008 til 2010. Påvirkningen af det marine miljø er ligeledes aftaget og vurderes som ubetydelig for miljøet i Niaquungunaq fjordsystemet.

Imaqarniliaq

Svenskit aatsitassarsioqatigiiffiat Minelco A/S (siusinnerusukkut Seqi Olivine A/S-iusimasoq) Kalaallit Nunaata Kitaani Niaqunngunami aatsitassamik suliffissuarni atorneqartartumik olivenimik piiaanissaminut 2005-imi akuerineqarpoq. 2005-mi 2006-imilu aallarnisaataasumik misissuinerit sanaartornerillu pereermata olivinemik tunisassiornivik 2007-imi upernaakkut aallartippoq. 2009-imi aningaasaqarniarneq pissutigalugu olivenimik piiaaneq unitsinneqarpoq, massakkullu (2010-imi) aatsitassarsiorfik matujartuaarneqarpoq.

Aatsitassarsiornerup ammarnissaa sioqqullugu 2004-imi 2005-imilu ilaatigut qillinerit (ujaqqat naanii), qeqqussat (equutit), uillut aammalu aalisakkat pinngoqqaatinik akuisa misissuiffiginerisigut pinngortitap sunnerneqanngikkallarnermini pissuserisai misissuiffigineqarput. Misissuinerni taakkunani uumassusilinni pineqartuni pinngoqqaatit qaffasinnerussusiannik malussartoqanngilaq. 2005-imi aatsitassarsiorfik ammarmalli ukioq tamaasa avatangiisit aatsitassarsiorfimmit sunnerneqarsimanersut misissuiffigineqartarput. Nalunaarusiaq manna 2010-imi misissuinermit paasisanik imaqarpoq, misissorneqartullu tassaapput, qillinerit, qeqqussat, uillut aammalu kanassut.

Pinngoqqaatit ilaat, pingaartumik krom (Cr) aammalu nikkel (Ni) tamatuma qillinerini qaffasinnerulersimasut 2010-imi paasineqarpoq. Qillinernik misiligutit taakku ilaat tassaapput qillinerit aatsitasarsiorfiup Seqip avataani mingoqanngitsumeersut siornaammagu nuussat. Qillinerit nuussat atorlugit ukiumi qaangiuttumi pujoralannik mingutsitsinerup annertussusia uuttorneqarsinnaavoq. 2010-imi qillinerit nuussat aatsitassarsiorfimmut 5 kilometerit missaata iluani Cr-imik aammalu Ni-mik akoqarnerulersimanerat uuttorneqarpoq. Tamatumuuna takuneqarsinnaavoq tamaani aatsitassarsiorfimmut attuumatinneqarsinnaasumik suli saffiugassanik akulinnik pujoralammik mingutsitsisoqartoq. 2010-imi paasisat takutippaattaaq 2010-imi qaffasissusii 2009-imut sanilliullugit appasinnerusut, tamatumuunalu erserpoq tunisassiornerup uninneratigut pujoralatserineq 2009-imiit 2010-imut annikilleriarsimasoq.

Cr-ip Ni-ip uilluni qeqqussanilu aatsitassarsiorfiup eqqaani qaffasissusii 2008/2009-imiit 2010-mut appariarsimapput aatsitassarsiorfiullu aallartinnissaa sioqqullugu qaffasissusiinut sanilliullugit qaffasinnerunerat ingasagisassaajunnaarsimalluni. Imaani mingutitsinerup appariartorsimanera tamatumuunakkut takuneqarsinnaavoq. Tamaani kanassut pinngoqqaatinik akui qaffassimanngillat.

Paasisat siuliiniittut tunngavigalugit oqartoqarsinnaavoq aatsitassarsiorfiup Seqip pujoralatsitsinera suli uuttorneqarsinnaasoq, unerarneralli 2008-imiit 2010-mut appariartorsimasoq. Aammattaaq immami avatangiisinut sunniutaa milliartorsimavoq Niaquungunamilu kangerlunnut ajoqutaanani.

1 About the Seqi olivine mine

The olivine mine is located in Seqi in West Greenland at a long and narrow fjord called Niaqunngunaq (in Danish Fiskefjord) (Fig. 1 and 2). The mine is accessible for ships most of the year due to limited sea ice cover. The fjord is characterised by strong tidal currents caused by its shape and topography and is only navigable for larger ships during a short period of time around high tide. The nearest settlement is Atammik at the inlet of the fjord.

Figure 1. Map of Greenland with the location of Seqi and Nuuk.

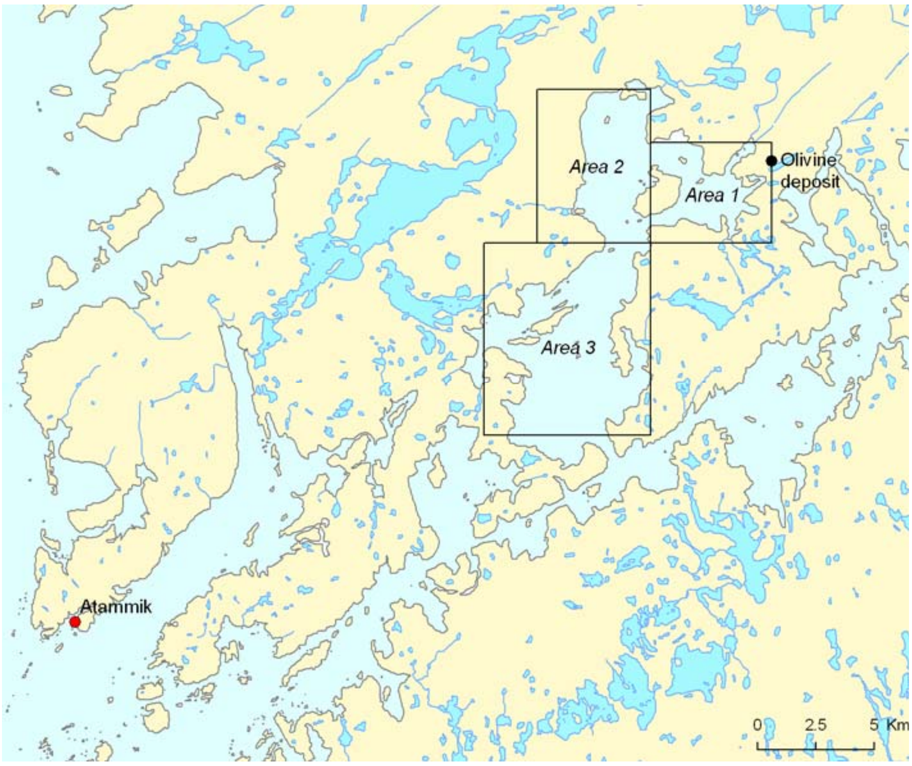


Figure 2. Map of Fiskefjord and the olivine deposit at Seqi. Area 1-3 refers to sampling locations for shorthorn sculpin.

Olivine is a common mineral on earth and is mined in several countries today, among others Norway. It is an industrial mineral with the composition $(Fe,Mg)_2SiO_4$ and is mainly used in the steel industry. Olivine is used for sand blasting, as foundry sand as well as a slag conditioner.

The olivine deposit at Seqi has been known for a long time and has previously been described in detail geologically (Nielsen, 1976). The deposit is expected to contain roughly 150 million tons of olivine (Råstofdirektoratet, 2009). In 2005, the company Seqi Olivine A/S got permission to mine 120,000 tons of olivine. On November 24, 2005, the first ship was loaded with 46,000 tons of olivine. Later, the company was given a permanent license to full scale mining and exportation of olivine for 30 years. In 2006, the company conducted a drilling campaign to estimate the size of the deposit and in the spring of 2007 the construction of mining facilities and associated infrastructure was finished and the full scale production began. In 2007, the mine produced approximately 620,000 tons and in 2008 approximately 450,000 tons of olivine. In October 2009, the production was stopped again due to economy reasons, including high costs of transportation (Råstofdirektoratet, 2009).

The deposit was mined in an open pit and the ore was crushed and stored at the coast before being shipped out in bulk carriers (Photo 1 and 2). These bulk carriers have capacity of up to 50.000 tons. Approximately 30 persons were employed at the mine (Råstofdirektoratet, 2009). An overview of the mining area with roads, buildings, and quay areas is shown in Fig. 3.

In 2007, the mining company changed its name from Seqi Olivine A/S to Minelco A/S. Minelco A/S is a daughter company of Swedish LKAB, which is owned by the Swedish state.

Photo 1. The open pit mine at Seqi. Photo: Sigga Joensen.

Photo 2. The ore crushing facility and storage area at Seqi. Photo: Sigga Joensen.

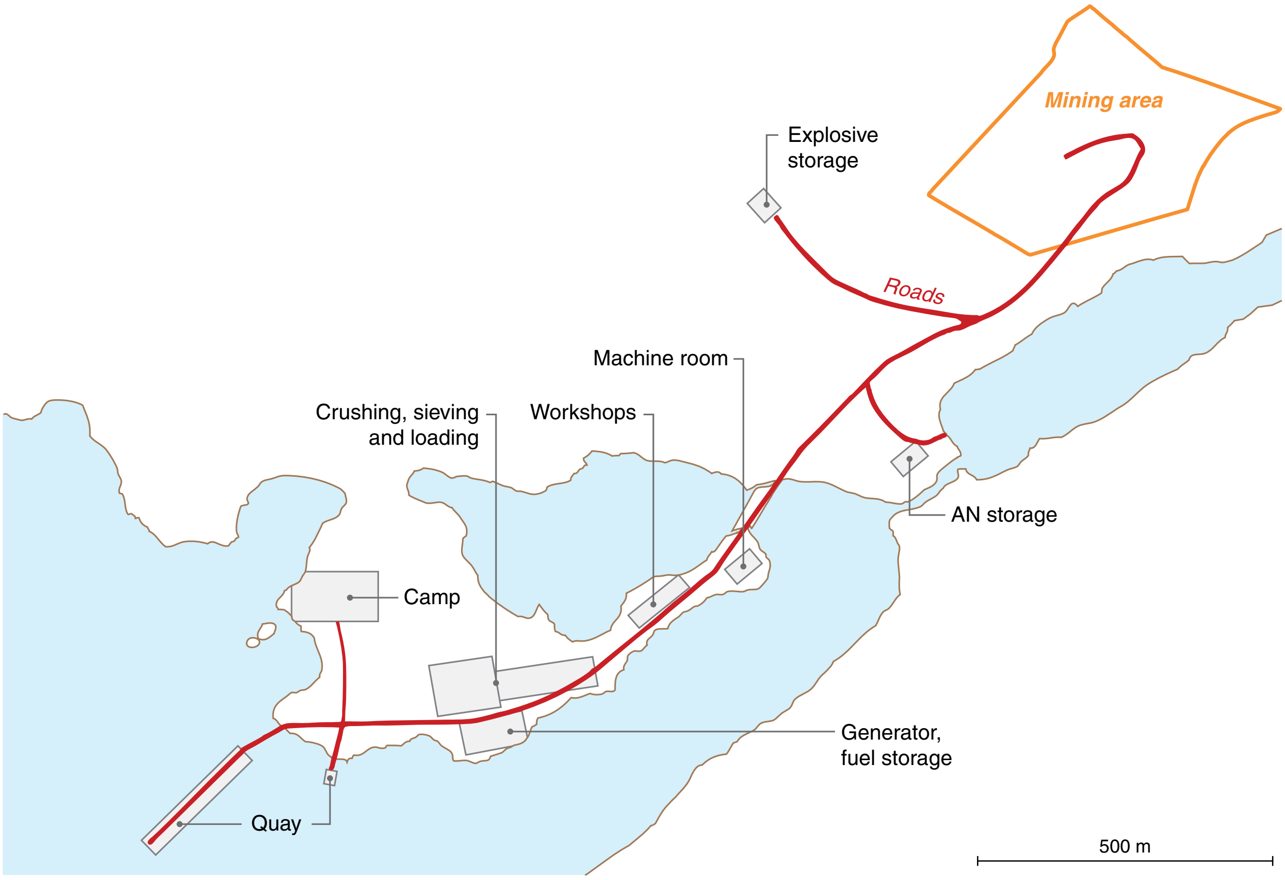


Figure 3. Roads, buildings, quays, and mining area at Seqi.

2 Environmental studies

Prior to mining, in 2004 and 2005, baseline studies were conducted in the Seqi area by NERI. The first background studies were carried out in May 2004 with the research vessel Adolf Jensen. Thereafter, studies were performed with assistance from people from the mining company using a smaller boat.

The baseline studies in 2004 and 2005 included sampling of blue mussels, seaweed, snow crabs, Greenland cod, shorthorn sculpin, lichens and sediments as well as water from the river running out of Long Lake near Seqi. In addition, a general survey of fish and shellfish in the inlet of Tasiussarsuaq was conducted and bird observations were made.

Between 2006 and 2009, samples of biota and water were collected and the environmental effects of the mining activity were evaluated. This was done by comparing the pre-mining concentrations of certain elements in the sampled biota and water to concentrations in samples from 2006 to 2009. The spatial extent of environmental effects was evaluated by analyzing samples collected within the entire Fiskefjord area. A full description of the sampling performed between 2004 and 2009 and the results obtained are given in Asmund et al. (2009) and in Søndergaard et al. (2009).

In 2010, samples of blue mussels, seaweed, shorthorn sculpins and lichens were collected as described in the following. All samples were frozen at the mining company's camp and then sent to NERI. This work was done by Lene Bruun and Sigga Joensen, both from NERI, with assistance of local people working for Minelco A/S at the mine site.

In the monitoring programme at Seqi, focus is on four species of biota: blue mussels (*Mytilus edulis*), brown seaweed (*Fucus vesiculosus*), lichens (*Cetraria nivalis*) and shorthorn sculpin (*Myoxocephalus scorpius*). These species have been selected because they are well suited as indicators of pollution described in more details below. These four species have been widely used in other monitoring programs at mines in Greenland (e.g. Riget et al. 1997a, Riget et al. 1997b, Riget et al. 2000a, Riget et al. 2000b, Johansen et al. 2008, Glahder et al. 2008, Schiedek et al. 2009).

Lichens are known as bioaccumulators of atmospheric contaminants and are abundant in the Arctic environment. The lack of roots, a large surface area and a long life span enable them to effectively bioaccumulate air contaminants. In many studies, it has been shown that lichens are good indicators for various kinds of air contaminants including those caused by mining activities (e.g. Naeth and Wilkinson, 2008).

Blue mussels are well-suited since they are widely distributed and sessile and thus able to concentrate metals. In this respect they reflect contamination in the marine environment. i. e. metals bound to particles, as well as those dissolved in the seawater (Rainbow, 1995).

Brown seaweed (*Fucus vesiculosus*) is also a well-suited indicator and in contrast to blue mussels, the metals accumulated in seaweed are reported to reflect only dissolved metals in seawater and not metals bound to particles (Rainbow, 1995). Since only the growing tips were analyzed each year, the accumulated metals in seaweed are expected to reflect the year to year variations in dissolved metals at each station.

Shorthorn sculpin is known to be a sensitive indicator species for marine pollution in fish, as they live near the bottom and are very stationary (Riget et al., 2000b).

2.1 Sampling in 2010

In the area around Seqi, a total of 26 tidal stations (St. 1-26, Fig. 4) have been established in the past years with highest density closest to the mine site. The stations furthest away from the mine, St. 22 and St. 23 situated outside the inlet of the inner fjord Tasiussarsuaq, are regarded as reference stations not impacted by mining activities. In addition to the tidal stations, 18 lichens stations have been established close to Seqi where only lichens have been sampled (Lav 1-18, Fig. 5).

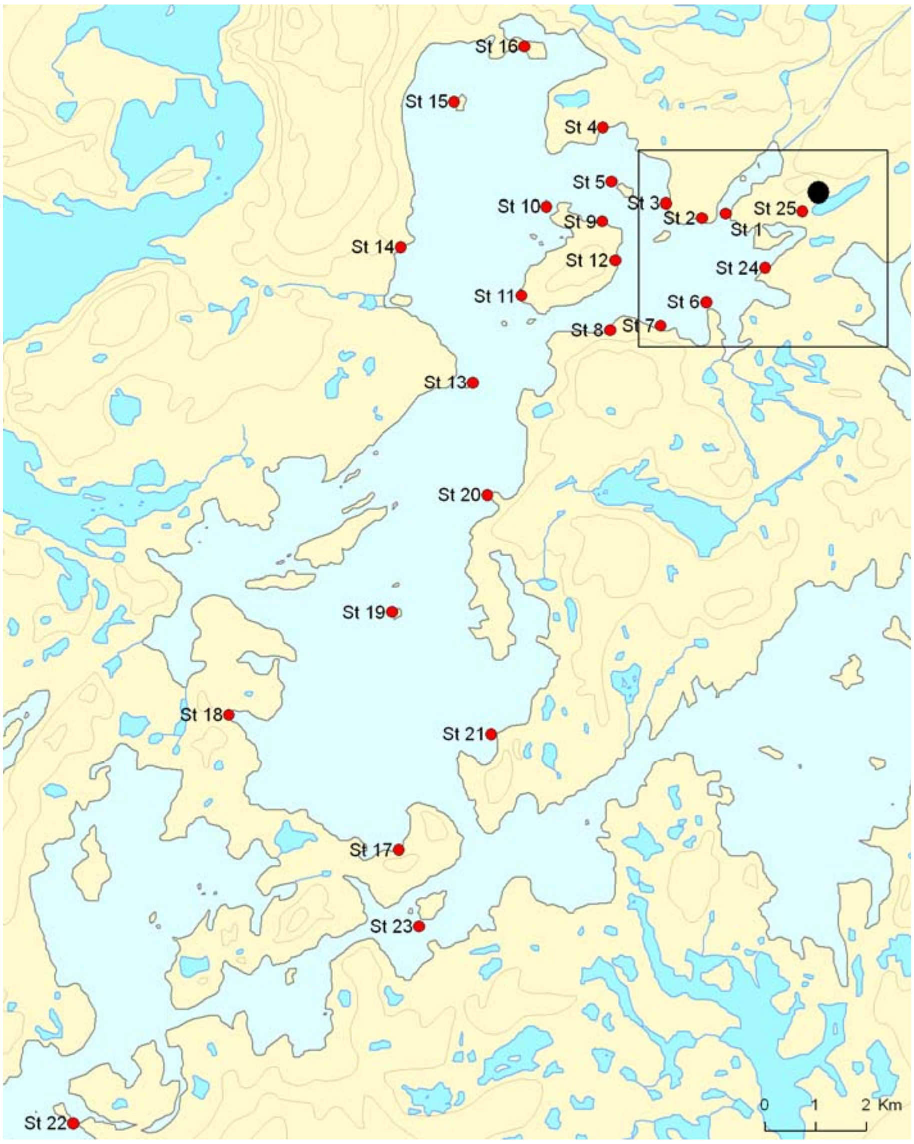
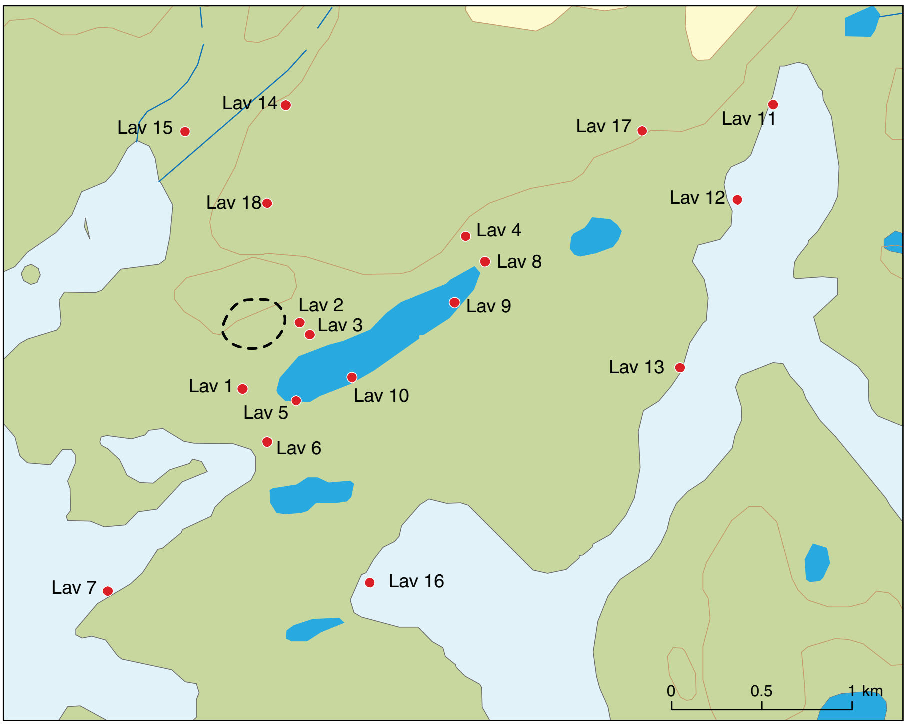


Figure 4. Map showing the area around the mine site (black dot) and the tidal stations (St. 1-26) where blue mussels, seaweed, and lichens are sampled. The box indicates the area where additional lichens stations have been established (see also Fig. 5).

Figure 5. Map showing the lichens stations (Lav 1-18) around the Seqi mine site. The circle indicates the mining area.



The coordinates of all the tidal stations and lichens stations are listed in Table 1.

Table 1. Positions of tidal stations (St. 1-26) and lichen stations (Lav 1-18).

Station	Position		Station	Position	
	64 N + min.	51 W + min.		64 N + min.	51 W + min.
St. 1	59.082	35.489	St. 24	58.354	34.767
St. 2	58.922	35.981	St. 25	58.839	33.617
St. 3	59.342	37.292	St. 26	58.594	34.107
St. 4	59.747	39.142			
St. 5	59.172	38.428	Lichen stations		
St. 6	57.922	35.789	Lav 1	58.932	33.665
St. 7	57.721	37.699	Lav 2	59.125	33.206
St. 8	57.584	38.449	Lav 3	59.096	33.195
St. 9	58.839	38.564	Lav 4	59.392	32.099
St. 10	59.007	39.838	Lav 5	58.898	33.281
St. 11	58.048	40.587	Lav 6	58.774	33.486
St. 12	58.021	38.815	Lav 7	58.326	34.596
St. 13	57.030	42.073	Lav 8	59.317	31.965
St. 14	58.554	43.561	Lav 9	59.196	32.174
St. 15	60.037	42.334	Lav 10	58.972	32.890
St. 16	60.527	40.556	Lav 11	59.794	29.939
St. 17	52.056	43.592	Lav 12	59.509	30.188
St. 18	53.415	47.788	Lav 13	59.006	30.583
St. 19	54.604	43.767	Lav 14	59.781	33.377
St. 20	55.846	41.395	Lav 15	59.699	34.083
St. 21	53.292	41.252	Lav 16	58.359	32.751
St. 22	49.124	51.672	Lav 17	59.712	30.859
St. 23	51.264	43.094	Lav 18	59.486	33.503

2.1.1 Blue mussels

Blue mussels (*Mytilus edulis*) were collected by hand at the tidal stations at low tide (Photo 3). In 2010, blue mussels were sampled at most of the 26 tidal stations (see Appendix 2 for a detailed description). At St. 1, St. 25 and St. 26, blue mussels were collected that had been transplanted from an unpolluted reference area (between St. 17 and St. 18) the previous year in order to monitor the uptake of metals during the past year.

At the mine camp, the mussels were measured and separated into size groups. For each size group, 20 mussels were cut open and left for drainage for a few minutes. Thereafter, the soft parts were scraped out with a scalpel into a polyethylene bag. The pooled samples were then deep-frozen (-20°C) at the mine site before being sent to Denmark.

Photo 3. Lene Bruun from NERI collects blue mussels as part of the environmental monitoring program at Seqi. Photo: Sigga Joensen.

2.1.2 Seaweed

Brown seaweed (*Fucus vesiculosus*) was sampled in 2010 at most of the 26 tidal stations at low tide (see Appendix 3 for a detailed description). At each station, two 10 litres plastic bags were filled with seaweed. These two samples were collected 10 to 20 meters apart, thus constituting two separate samples.

In the mine camp, the year's growth tips were cut of with a pair of stainless steel scissors. The tips were then washed three times with clean fresh water, packed in polyethylene bags and deep-frozen (-20°C) before being sent to Denmark.

2.1.3 Lichens

Samples of lichens (C*etraria nivalis*) were collected at most of the tidal stations in 2010 (for details, see Appendix 4) and at the lichens stations: Lav1, 2, 3, 4, 5, 6, 9 and 10. At the tidal stations, only resident lichens were sampled. At the lichen stations, samples consisted of transplanted lichens i.e. lichens that had been transplanted from an unpolluted reference station (St. 23) the previous year. The latter method was used in order to monitor the recent annual dust contamination.

Only lichens growing on dead organic matter were collected in order to ensure that the lichens would only be able to accumulate metals from the air and not from the underlying rock. The collected lichens were kept in paper bags until they were analyzed.

2.1.4 Shorthorn sculpin

Shorthorn sculpins (*Myoxocephalus scorpius*) were caught by angling in Area 1 and Area 3 in 2010 (Fig. 2). Six and three individuals were caught in Area 1 and Area 3, respectively.

At the mine camp, the fish were measured, weighted and their sex determined. The liver was then cut out using a stainless steel scalpel, packed in polyethylene bags and deep-frozen (-20°C) before being sent to Denmark.

Data of all samples being taken are kept in a database at NERI, containing information about sampling (date, position, time etc.) and biometric measures for blue mussels and fish, such as length and weight.

2.2 Data analysis

Results from analyses of seaweed and lichens can be used for comparison of metal contamination between sites and years without much further data treatment. Blue mussel data, however, needs some treatment to allow for a comparison since it involved transplantation of mussels.

First, the transplantation of mussels has previously been shown to have a negative effect on the condition of the mussels and often results in reduction of the mussel weight (Riget et al., 1997a). To account for that, the measured metal concentration in µg g^{-1} dry wt. mussel was converted into µg metal pr. mussel by multiplying the measured concentration by the average mussel dry wt. Furthermore, as the metal content in mussels depends on its length (Riget et al., 1997a) and since the mean length of the samples varied, all metal contents in mussels were normalized to the content in a 6 cm blue mussel using the following equation based on data on the metal amount/length relationship found in blue mussels in Maarmorilik, West Greenland (Riget et al., 1997a):

$$Metal\_amount_{6cm\_mussel} = Metal\_amout_{L} \bullet \left(\frac{6}{L}\right)^{2.54}$$

where $Metal\_amount_L$ is the metal amount in a blue mussel with a mean shell length of L.

Normalizing all mussel data to the metal content in a 6 cm blue mussel enabled a comparison between sites and years, including both resident and transplanted mussels.

3 Analytical methods

Samples collected in 2010 were analyzed at the Department of Arctic Environment, NERI, in Roskilde, Denmark by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) using an Agilent 7500ce. Samples were analyzed for the elements: Li, Al, V, Cr, Mn, Fe, Ni, Cu, Zn, Co, As, Se, Rb, Y, Ag, Cs, Ba, La, Ce, Nd, Hg, Pb and Th after a pre-treatment as described in the following.

3.1 Mussels

The soft parts of the blue mussels were freeze-dried to constant weight and the weights before and after drying were noted in order to determine the individual mussel weight and the dry matter percentage of the sample. After drying, the sample was homogenized in an agate mortar. A 0.3 g sub-sample was then digested in a mixture of 4 ml concentrated Merck suprapure nitric acid and 4 ml milliQ water in Teflon bombs in an Anton Paar Multiwave 3000 Microwave Oven. After this treatment, the remaining solution was diluted to 25 grams with milliQ water and stored in polyethylene bottles until analyzed by ICP-MS.

3.2 Seaweed

Seaweed was treated in the same way as the blue mussels but the dry matter percentage was not determined.

3.3 Lichens

Lichen samples were rinsed by hand using a pair of stainless steel tweezers and only fresh looking parts of the lichens were used. Remains of other plants, moss, soil, or dead lichens were removed. After rinsing, the lichens were dried at 105° C for 24 hours, then digested and analysed in the same way as blue mussels, seaweed and fish.

3.4 Shorthorn sculpin

For shorthorn sculpins, a subsample of the liver (ca. 1 gram) was cut out with stainless steel blade from the inner part of the liver in order to avoid contamination from the outer exposed part of the liver. The cutting was done on a plastic carving board, while the sample was still partly frozen, using plastic pincers. The sample was then digested, treated, and analyzed in the same way as mussels and seaweed, the only difference being that the elements were determined on a wet weight basis. To determine the dry weight percentage of the sample, 2-3 g of liver was added to a porcelain crucible and dried at 105° C until constant weight.

3.5 Detection limits and quality control

Detection limits for the measured elements using ICP-MS were calculated based on measurements of blank solutions as three times the standard deviation on these. Blank solutions are the digestion solution alone, treated in the Teflon bombs and diluted in the same way as the samples. One blank solution was prepared for every series of microwave-digestions, containing a total of 16 vials.

All relevant concentration values were used to calculate the mean concentrations used in this report, also the concentrations below the detection limit. The concentration values below the detection limit were used as they were computed based on an external calibration line and subtracted the concentration of the blank solutions.

In addition to a blank solution included in every series of microwave-digestions, two replicates of one sample (same sample ID but two difference acid digestions) and one sample of certified reference material were analyzed. The duplicate sample was analyzed to check the repeatability of the measurement and the certified reference materials were measured to check the accuracy. The certified reference materials used were Dorm-3, Dolt-3 and Tort-2.

The laboratory at the Department of Arctic Environment (DAE) at NERI is accredited by the Danish Accreditation and Metrology Fund DANAK to analyses of biota for Cr, Ni, Cu, Zn, As, Se, Cd and Pb.

The quality of the methods is documented by participating in the international QUASIMEME laboratory intercalibration program.

The results of DAE's participation in the QUASIMEME program during the past five years are shown in Fig. 6. In these graphs each point represents one sample. On the x-axis, the assigned concentration values for the different samples are shown and on the y-axis the relative deviation from these assigned concentrations measured by DAE. The lines represent the allowed uncertainty on a 95% confidence level, based on the accredited detection limit and relative accuracy.

These results document that for Cu, Zn, Cd, and As, the uncertainty by DAE-NERI is ~20% for samples with concentrations well above the detection limit. For Cr, Ni, Se, and Pb, the uncertainty by DAE-NERI is ~30%. Close to the detection limit, the uncertainty increases.

The elements that are not part of the accreditation by DANAK have a higher uncertainty as they have not been controlled by independent organisations like DANAK and QUASIMEME. We expect that the uncertainty for concentrations well above the detection limit for these elements is approximately 30% relative on a 95% confidence level.

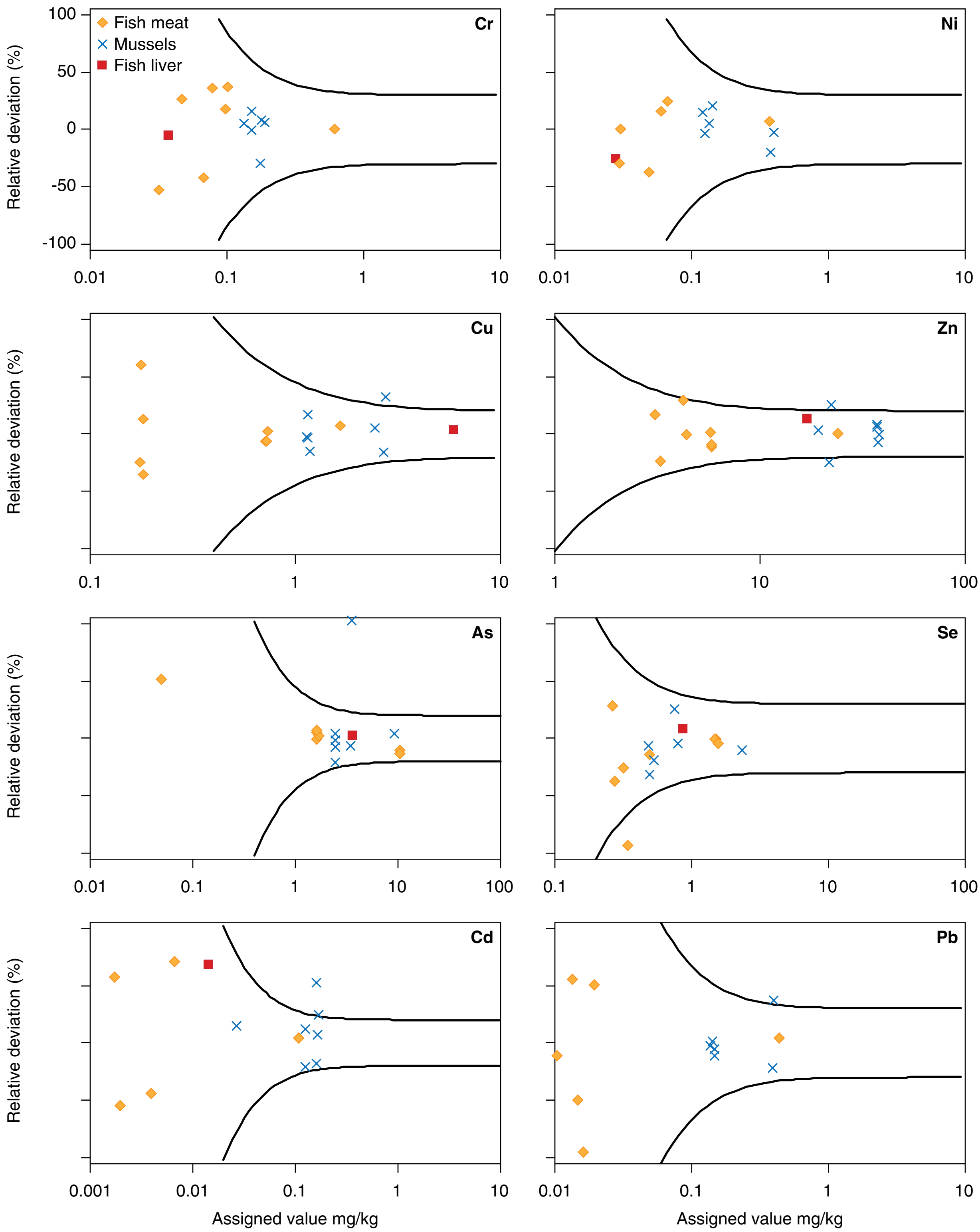


Figure 6. DAE-NERI results in the QUASIMEME laboratory proficiency testing in the period 2005-10 using ICP-MS.

4 Results and discussion

In this chapter, results from 2010 on blue mussels, seaweed, lichens and shorthorn sculpin are described and compared with results from the previous years.

4.1 Blue mussels

Table 2 shows mean concentrations of a range of elements measured in blue mussels at the tidal stations at Seqi in 2010 and in previous years (2004-2009). Separate mean values are presented for St. 25 closest to the mine site and the rest of the stations. In 2008 and 2009, significantly elevated concentrations of Cr and Ni were measured at the stations St. 24, 25 and 26 closest to the mine site compared to pre-mining levels (defined as above the mean concentration + two times the standard deviation of 2004-2005 measurements). Concentrations of these elements were in average 2-3 times higher compared to mean concentrations at the other stations.

Table 2. Mean element concentrations (µg/g dry weight) in blue mussels (4-6 cm's length) in the period 2004-2010. For 2008, 2009 and 2010, separate mean values are calculated for the station closest to the mine site (St. 25) and the rest of the stations (mean all, excl. St. 25). D.l. (2010) = detection limit for 2010 samples.

		2004-2005		2006	2007	2008		2009		2010	
Element	**D.l. (2010)**	**Mean, all**	**std.dev.**	**Mean, all**	**Mean, all**	**Mean, St. 25**	**Mean, all excl. St. 25**	**Mean, St. 25**	**Mean all, excl. St. 25**	**Mean, St. 25***	**Mean all, excl. St. 25**
Li	*0.05*	0.76	0.31	0.53	0.69	0.47	0.60	0.87	0.69	1.43	0.84
Al	*16*	163	225	50	98	520	81	242	114	689	62
V	*0.20*	0.59	0.36	0.42	0.56	0.70	0.45	1.40	0.94	1.95	0.58
Cr	*0.31*	1.39	0.81	1.04	1.66	4.22	2.50	2.99	1.78	4.49	1.21
Mn	*0.31*	6	3	3	5	5	5	7	6	10	5
Fe	*19*	206	173	118	156	277	118	409	190	630	141
Ni	*0.18*	2.72	0.92	1.55	2.31	7.94	2.09	6.96	2.82	6.48	1.92
Cu	*0.19*	5.85	1.38	5.20	6.92	4.69	6.72	8.56	7.92	8.95	7.50
Zn	*0.16*	77	23	61	80	64	84	97	93	117	88
Co	*0.34*	0.47	0.23	0.27	0.40	0.52	0.40	0.68	0.46	0.87	0.42
As	*0.23*	10	3	9	11	14	12	27	15	20	14
Se	*0.56*	3.86	1.00	4.17	3.30	3.76	5.67	4.94	4.97	7.30	7.08
Rb	*0.04*	6.25	2.03	4.24	6.89	3.96	5.88	8.33	7.85	7.74	7.17
Y	*0.04*	0.10	0.04	0.06	0.11	0.08	0.10	0.15	0.11	0.30	0.11
Ag	*0.13*	0.12	0.27	0.06	0.10	0.04	0.05	<D.l.	<D.l.	0.06	0.02
Cs	*0.04*	0.02	0.01	0.01	0.03	<D.l.	0.04	0.05	0.04	0.04	0.01
Ba	*0.09*	2.05	3.18	0.45	1.56	2.00	0.79	2.51	1.47	7.39	1.95
Nd	*0.01*	0.30	0.13	0.21	0.29	0.22	0.22	0.46	0.31	0.71	0.27
Hg	*0.03*	0.20	0.12	0.16	0.12	0.13	0.20	0.12	0.14	0.25	0.15
Pb	*0.13*	0.38	0.13	0.32	0.41	0.47	0.36	0.71	0.38	0.67	0.35

*) Concentrations in mussels transplanted from an unpolluted area into St. 25 the previous year.

In 2010, blue mussels at St. 24 and 26 still contained above average concentrations of Cr and Ni but they were no longer significantly elevated when compared with pre-mining levels. At St. 25, only transplanted blue mussels were sampled in 2010 and the concentrations measured could therefore not be directly compared with the previous years since transplantation often affects the conditions of the mussels (Riget et al., 1997a).

In order to enable a comparison between transplanted and resident mussels, concentration were normalised to the contents of Cr and Ni in a blue mussel with a shell length of 6 cm (see chapter 5.2). Cr and Ni contents in mussels from 2004-2005 as well as prior to and after a one-year transplantation at St. 25 in 2009-2010 are presented in Table 3. As seen, contents of Cr and Ni after one year of transplantation at St. 25 were above average of the 2004-2005 samples and higher when compared to the initial content prior to transplantation. However, the contents of Cr and Ni at St. 25 were not significantly elevated compared to the 2004-2005 samples (less than the mean + two standard deviations). Note that the transplanted mussels at st 25 had quite high concentrations of Cr and Ni but an extremely low dry weight %. The high concentrations are thus mainly a result of a malthriving and emaciation of the transplanted mussels.

Table 3. Concentrations of Cr and Ni in mussels normalised to the content in a 6 cm blue mussel (see text for explanation). Values are shown for 2004-2005 pre-mining samples and for mussels prior to and after transplantation at St. 25 in 2009-2010.

	Shell length interval (cm)	Average shell length (cm)	Number of individuals	Sample wet weight (g)	Dry matter %	Cr (ug/g dry wt.)	Ni (ug/g dry wt.)	ug Cr per mussel	ug Ni per mussel	Cr in a 6 cm mussel	Ni in a 6 cm mussel
All mussels, 2004-2005											
Mean	4-6	5.3	20	83	14	1.32	2.72	0.74	1.54	1.00	2.08
std.dev.	-	0.3	-	24	2	0.64	0.92	0.40	0.66	0.51	0.81
Mussels prior to transplantation, 2009											
	4-5	4.5	20	56	16	1.03	<d.l	0.46	-	0.96	-
	5-6	5.4	17	82	16	1.46	1.90	1.14	1.48	1.47	1.91
Mussels after one year at St. 25, 2010											
	4-6	4.9	20	56	9	4.49	6.48	1.10	1.59	1.81	2.62

4.2 Seaweed

Table 4 shows the mean concentrations of a range of elements measured in seaweed at the tidal stations at Seqi from 2004 to 2010. Separate mean concentrations are given for St. 25, located closest to the ore-crushing facility, and for the rest of the stations in 2008, 2009 and 2010. Note that the analytical detection limits for the elements varies between the years and that only the 2010 values are given. No natural elevated concentrations of elements were measured in seaweed near the mine site prior to mining (Asmund et al., 2009). Elevated concentrations of Cr and Ni were measured in seaweed at St. 25 in 2008 and 2009. The concentrations of these elements were 2-3 times higher compared to mean concentrations found in seaweed prior to mining (2004-05). In 2010, the concentrations of Cr and Ni had decreased by a factor of 2-3 from the 2008-2009 level and were not significantly higher than the pre-mining level (defined as higher than the mean + two standard deviations of the 2004-2005 samples). Thus, the seaweed and the transplanted mussels give the same result that the marine environment at St. 25 now is close to the natural levels.

Table 4. Mean element concentrations in seaweed (µg/g dry weight) in the period 2004-2010. For 2008, 2009 and 2010, separate mean values are calculated for St. 25, closest to the quay area, and for the rest of the stations. D.l. (2010) = detection limit for the 2010 samples.

		2004-2005		2006	2007	2008		2009		2010	
Element	D.l. (2010)	Mean all	Std.dev.	Mean, all	Mean, all	Mean, St. 25	Mean, all excl. St. 25	Mean, St. 25	Mean all, excl. st. 25	Mean, St. 25	Mean all, excl. st. 25
Li	*0.05*	0.454	0.224	0.422	0.578	0.286	0.377	0.400	0.472	0.434	0.490
Al	*16*	32	32	13	21	30	8	74	20	65	<D.l.
V	*0.20*	0.396	0.342	0.237	0.318	0.313	0.206	0.534	0.300	0.385	<D.l.
Cr	*0.31*	0.398	0.390	0.364	0.480	1.027	0.346	0.969	0.185	0.341	<D.l.
Mn	*0.31*	18	10	18	20	61	19	21	14	27	15
Fe	*19*	69	73	29	56	94	21	197	107	130	35
Ni	*0.18*	2.28	1.19	1.24	1.56	4.47	1.07	5.40	1.58	2.76	1.21
Cu	*0.19*	1.9	0.6	2.2	4.9	2.5	2.8	3.3	4.7	3.2	3.3
Zn	*0.16*	12.1	3.5	8.4	13.0	10.3	7.4	16.7	12.4	11.6	8.8
Co	*0.34*	0.588	0.340	0.294	0.452	0.661	0.275	0.665	0.411	0.426	<D.l.
As	*0.23*	42	12	48	58	49	52	61	58	52	55
Se	*0.56*	0.248	0.079	0.450	0.306	<D.l.	0.116	<D.l.	0.058	0.816	0.628
Rb	*0.04*	9	3	10	18	20	14	12	12	15	13
Y	*0.04*	0.063	0.033	0.035	0.066	0.053	0.041	0.136	0.106	0.061	<D.l.
Ag	*0.13*	0.106	0.045	0.053	0.128	<D.l.	0.037	<D.l.	<D.l.	<D.l.	<D.l.
Cs	*0.04*	0.029	0.008	0.034	0.055	0.039	0.039	<D.l.	<D.l.	<D.l.	<D.l.
Ba	*0.09*	10.0	3.3	7.3	11.1	23.2	12.3	29.7	12.5	14.9	8.8
Nd	*0.01*	0.151	0.081	0.078	0.135	0.087	0.053	0.336	0.185	0.155	0.062
Hg	*0.03*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	0.200	<D.l.	<D.l.	<D.l.	<D.l.
Pb	*0.13*	<D.l.	<D.l.	<D.l.	0.066	0.025	<D.l.	0.066	<D.l.	<D.l.	<D.l.

4.3 Lichens

4.3.1 Element levels

Table 5 shows the mean concentrations of a range of elements measured in lichens in the period 2004 to 2010. Mean concentrations are given for lichens sampled in an area close to the mine (Lav 1-10, Fig. 5) and further away (St. 10, 13, 15, 19, Fig. 4). The concentrations measured in 2004-2005 are treated as the pre-mining level. No natural elevated concentrations of elements were measured near the mine site prior to mining (Asmund et al., 2009). In 2009 and 2010, lichens sampled at the stations Lav 1-10 had been transplanted from an unpolluted site (Site 23) the previous year.

The results show that lichens collected close to Seqi in 2010 contain elevated concentrations of some elements, particularly Cr and Ni. Both Cr and Ni were found in concentrations above the mean concentration plus three times the standard deviation of pre-mining measurements (2004-2005), which results in a probability of more than 99% that the result is not a result of the random variations in metal concentrations.

Table 5. Measured element concentrations (µg/g dry weight) in lichens sampled close to the mine (Lav 1-10) versus lichens sampled further away (St. 10, 13, 15 and 19) during the period 2006-10. The 2004-2005 is regarded as the pre-mining level. Lichens from the stations Lav 1-10 in 2009 and 2010 was transplanted to the stations from an unpolluted area the previous year. D.l. (2010) = detection limit for the 2010 samples.

		2004-2005		2006		2007		2008		2009		2010	
Element	**D.l. (2010)**	**Mean, all**	**std. dev.**	**Mean, Lav 1-10**	**Mean, St. 10, 13, 15, 19**	**Mean, Lav 1-10**	**Mean, St. 10, 13, 15, 19**	**Mean, Lav 1-10**	**Mean, St. 10, 13, 15, 19**	**Mean, Lav 1-10**	**Mean, St. 10, 13, 15, 19**	**Mean, Lav 1-10**	**Mean, St. 10, 13, 15, 19**
Li	*0.05*	0.05	0.03	0.07	0.03	0.12	0.04	0.12	0.07	0.07	0.05	0.06	<D.l.
Al	*16*	222	111	223	149	317	223	344	266	240	260	222	231
V	*0.20*	0.26	0.15	0.45	0.18	0.65	0.29	0.37	0.25	0.35	0.40	0.32	0.30
Cr	*0.31*	0.35	0.36	2.72	0.33	9.91	0.57	22.66	1.95	10.41	0.88	5.97	0.81
Mn	*0.31*	71	69	75	24	50	33	113	20	50	22	22	20
Fe	*19*	123	77	251	95	578	94	872	102	414	176	287	133
Ni	*0.18*	1.07	1.66	6.91	0.65	20.83	0.93	55.71	3.10	16.46	1.12	14.32	1.71
Cu	*0.19*	0.93	0.55	0.66	0.62	0.60	0.88	1.25	0.63	0.77	0.66	0.54	0.53
Zn	*0.16*	22	12	20	13	18	12	27	14	14	11	9	12
Co	*0.34*	0.20	0.19	0.33	0.07	1.18	0.11	2.50	0.22	0.79	0.14	0.70	<D.l.
As	*0.23*	0.27	0.28	0.01	0.08	0.07	0.05	0.04	0.10	0.06	0.15	<D.l.	<D.l.
Se	*0.56*	0.06	0.03	0.05	0.08	0.08	0.06	0.10	0.12	0.08	0.07	<D.l.	<D.l.
Rb	*0.04*	2.3	1.2	3.6	1.7	6.6	2.5	6.2	2.1	5.1	3.2	2.1	2.1
Y	*0.04*	0.08	0.04	0.10	0.04	0.22	0.09	0.20	0.06	0.13	0.10	0.10	0.08
Ag	*0.13*	0.02	0.01	0.01	0.01	0.04	0.01	0.05	0.03	0.11	0.05	<D.l.	<D.l.
Cs	*0.04*	0.04	0.02	0.07	0.03	0.11	0.04	0.16	0.05	0.11	0.06	0.05	<D.l.
Ba	*0.09*	12	15	10	4	16	7	14	11	11	7	6	5
Nd	*0.01*	0.24	0.19	0.47	0.13	0.48	0.17	0.50	0.15	0.33	0.22	0.23	0.19
Hg	*0.03*	0.18	0.40	0.03	0.02	0.03	0.02	0.16	0.19	0.02	0.02	0.03	0.04
Pb	*0.13*	0.60	0.22	0.52	0.52	0.68	0.79	0.99	0.52	1.06	0.62	0.51	0.34

4.3.2 Spatial distribution of dust deposition

Fig. 7 and 8 give a spatial overview of Cr and Ni concentrations measured in transplanted lichens in the Seqi area sampled in 2010. The lichens were transplanted from St. 23 in 2009. Lichens at St. 23 had mean Cr and Ni concentrations of 0.38 and 0.42 µg/per g dry weight, respectively.

After one year of transplantation, up to 11 µg Cr /g dry weight and 33 µg Ni/g dry weight were measured close to the mine, corresponding to concentrations 30 to 80 times higher than the initial concentrations. Transplanted lichens at Lav 1, situated close to the mine, contained the most elevated concentrations. Elevated concentrations were measured in all transplanted lichens samples; the station being most distant to the mine site was St. 9 about 5 km from the mine.

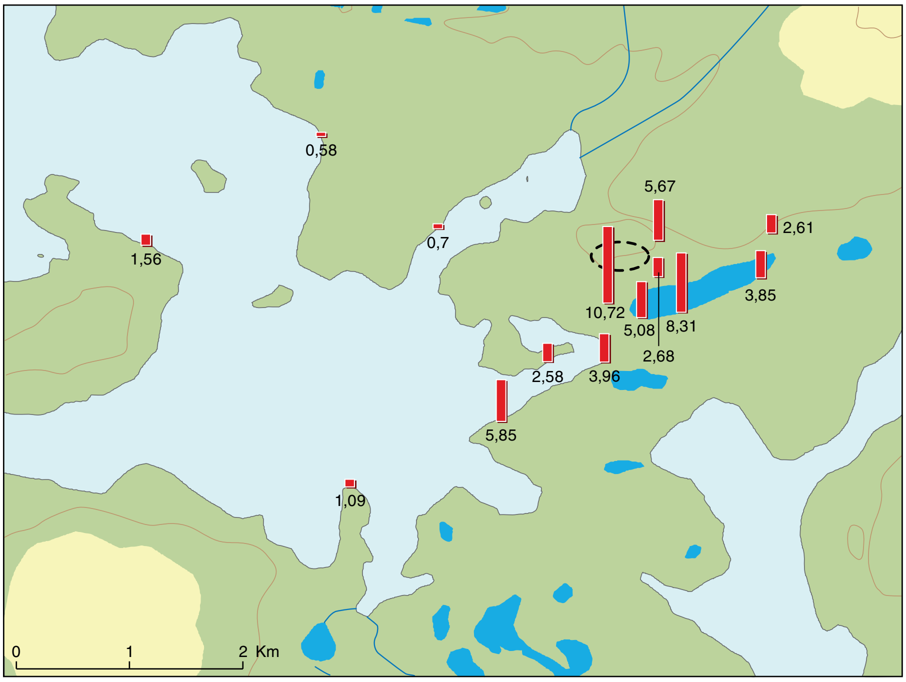


Figure 7. Mean Cr concentrations (µg/g dry weight) in transplanted lichens sampled in 2010 in the area around Seqi. The dotted circle marks the location of the mining area. The lichens were transplanted to the stations from an unpolluted area the previous year (St. 23; Cr: 0.38 µg/g dry weight).

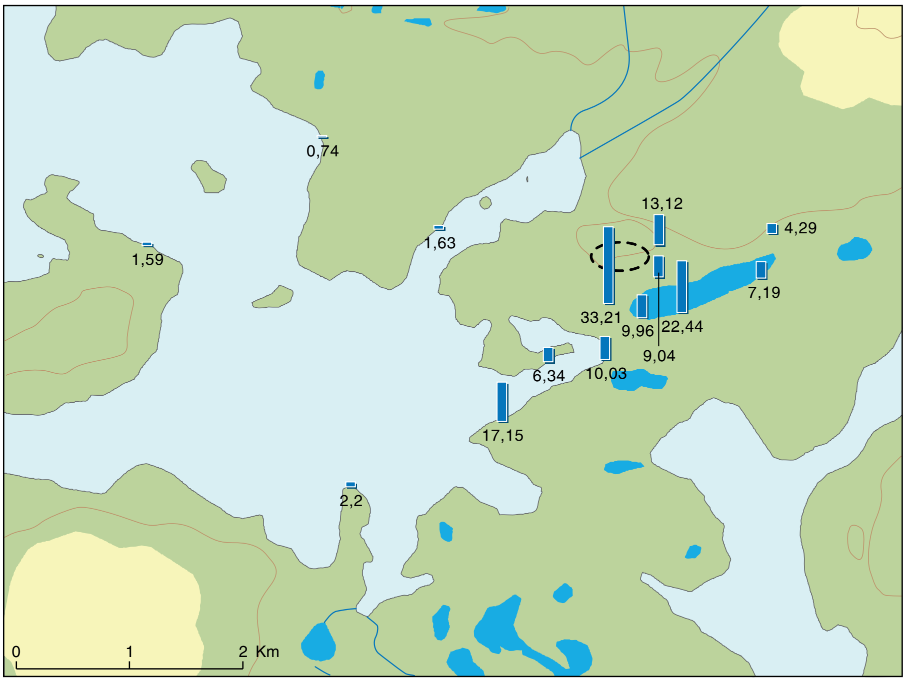


Figure 8. Mean Ni concentrations (µg/g dry weight) in transplanted lichens sampled in 2010 in the area around Seqi. The dotted circle marks the location of the mining area. The lichens were transplanted to the stations from an unpolluted area the previous year (St. 23; Ni: 0.42 µg/g dry weight).

4.3.3 Annual variation of dust deposition

In order to assess the annual variations in dust deposition after mining started, lichens from the same stations have to be compared, as the deposition rate at a specific location varies with distance from the mine and as there are local topographical differences .The mean values listed in Table 5 are therefore not suitable for a comparison between years as the stations included have sometimes varied from year to year. To perform temporal comparisons during the mining period, lichens stations were selected, which are located close to the mine site and for which metal levels have been measured every year since 2005. These stations were

Lav 1, 2, 3, 4, 5 and 6. In addition, the stations St. 1, 3, 6 and 9, located further away but within 5 km from the mine were selected to compare dust deposition rates from 2008 to 2010.

Roughly speaking, there are two ways to estimate the annual accumulation rate in lichens: 1) By measuring the concentrations in natural lichen sampled at the same location in two consecutive years and then calculate the difference in concentration between years; 2) By transplanting lichens from an unpolluted area to the sample station, collecting and analyzing them the year after and subtracting the initial concentration. The last option is generally preferred as natural lichens response to variations in deposition rate is not well defined (e.g. the concentration may not increase linearly as a response to a constant dust deposition and may not decrease if the deposition rate decreases). Furthermore, by using transplanted lichens one is sure to sample from the same lichens before and after the exposure, whereas this is not the case when collecting natural lichens.

Lichens were not transplanted to the area before 2008. Therefore, the annual variation in dust deposition for the period 2005-2008 was estimated based on collection of natural lichens using method 1) and for 2009 and 2010 on transplanted lichens using method 2). The variation in Cr and Ni deposition, based on lichen sampling, can be seen in Fig. 9.

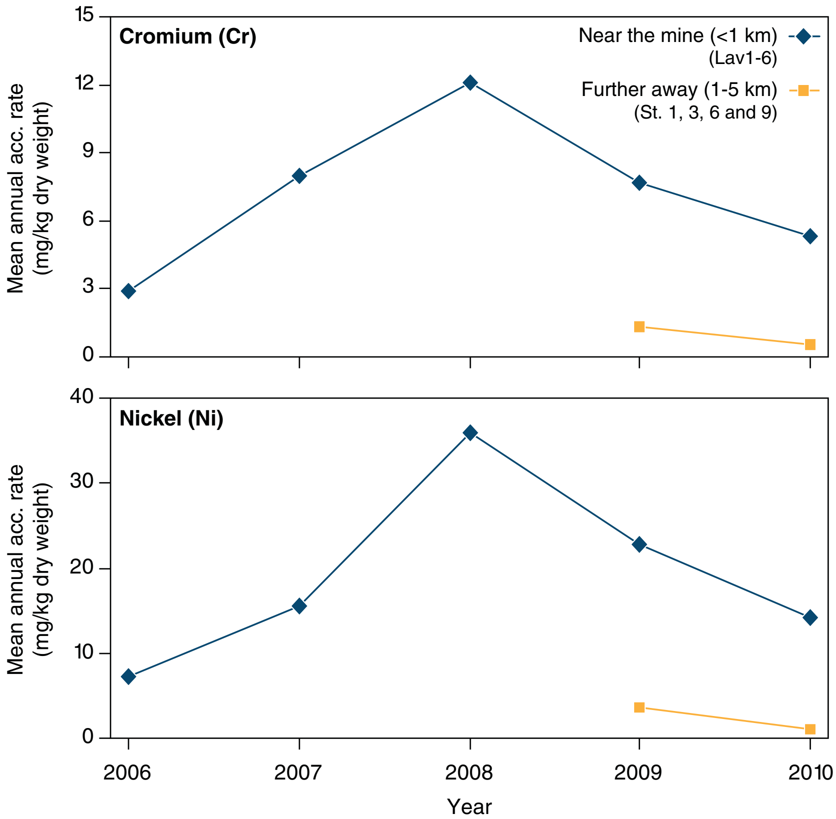


Figure 9. Mean annual accumulation rates of Cr (upper graph) and Ni (lower graph) in lichens located near the mine (<1 km) and further away (1-5 km). The annual accumulation rates in lichens from the stations are estimated either as the difference in concentrations measured in resident lichens during two consecutive years (2005-2008) or as the concentrations measured in lichens transplanted from an unpolluted area the previous year, substracted the initial concentration (2009 and 2010).

As shown in Fig. 9, the annual accumulation of Cr and Ni in lichens less than 1 km from the mine site (Lav1-6) increased from 2005 to 2008 and decreased from 2008 to 2010. The annual accumulation of Cr and Ni in lichens situated within an area 1 to 5 km from the mine (St. 1, 3, 6 and 9) decreased from 2008 to 2010.

4.4 Shorthorn sculpin

Spreading of some elements related to mining at Seqi, Cr and Ni in particular, have been observed in lichens, blue mussels, and seaweed. In order to monitor whether the mine has any effect on the marine fish, shorthorn sculpin (*Myoxocephalus scorpius)* were sampled in Area 1 and 3 (Fig. 2) in 2010.

Table 6 shows the mean concentrations of a range of elements measured in shorthorn sculpin liver in the period 2004 to 2010. For 2008, 2009 and 2010, separate mean concentrations are shown for Area 1 closest to the mine and for Area 2-3 further away. If mining has an impact on these fish, the liver should contain higher Cr and Ni concentrations compared to pre-mining levels (2004-2005) and fish in Area 1 should have higher Cr and Ni concentrations compared to fish from Area 2-3. However, very low (below detection limit) concentrations of Cr and Ni were measured in shorthorn sculpin liver in all areas in the period 2004 to 2010.

Consequently, it is not likely that the mining operation has affected the marine fish near Seqi.

Table 6. Mean element concentrations in shorthorn sculpin liver (µg/g wet weight) in the period 2004-2010. For 2008, 2009 and 2010, separate mean values are calculated for the sampling area closest to the mine site (Area 1) and the sampling areas further away (Area 2-3). D.l. (2010) = detection limit for the 2010 samples.

		2004-2005		2006	2007	2008		2009		2010	
Element	**D.l. (2010)**	**Mean, all**	**std. dev.**	**Mean, all**	**Mean, all**	**Mean, area 1**	**Mean, area 2/3**	**Mean, area 1**	**Mean, area 2/3**	**Mean, area 1**	**Mean, area 2/3**
Li	*0.05*	0.03	0.01	0.02	0.03	0.01	0.01	0.02	0.01	<D.l.	<D.l.
Al	*16*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.
V	*0.20*	0.054	0.069	0.066	0.050	0.033	0.246	0.076	0.150	<D.l.	<D.l.
Cr	*0.31*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.
Mn	*0.31*	0.59	0.16	0.38	0.76	0.78	0.75	0.80	0.81	0.90	1.27
Fe	*19*	188	150	124	115	235	210	244	156	132	126
Ni	*0.18*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.
Cu	*0.19*	3.41	2.66	1.03	2.16	2.16	3.92	3.83	3.43	2.19	3.70
Zn	*0.16*	45	17	27	27	91	78	32	36	33	52
Co	*0.34*	0.07	0.06	0.04	0.10	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.
As	*0.23*	5.85	9.15	3.31	4.17	5.55	14.68	22.01	10.29	6.04	6.97
Se	*0.56*	1.50	0.73	1.20	1.12	1.78	2.64	1.62	1.83	1.19	1.98
Rb	*0.04*	0.52	0.12	0.34	0.98	0.76	0.93	0.78	0.86	1.36	0.81
Y	*0.0363*	<D.l.	<D.l.	<D.l.	<D.l.	0.0008	0.0011	0.0013	<D.l.	<D.l.	<D.l.
Ag	*0.13*	0.27	0.17	0.11	0.12	0.20	0.39	0.38	0.49	<D.l.	0.28
Cs	*0.04*	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.02	<D.l.	<D.l.
Ba	*0.093*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.
Nd	*0.010*	0.00	0.00	<D.l.	<D.l.	0.004	0.003	<D.l.	<D.l.	<D.l.	<D.l.
Hg	*0.03*	0.12	0.07	0.09	0.08	0.14	0.15	0.11	0.04	0.07	0.03
Pb	*0.13*	<D.l.	<D.l.	<D.l.	<D.l.	<D.l.	0.02	<D.l.	<D.l.	<D.l.	<D.l.

Photo 4. A female shorthorn sculpin. Photo: Gert Asmund.

5 Evaluation and recommendations

Baseline studies conducted prior to mining in 2004 and 2005 revealed no natural elevation of elements in biota near the mine at Seqi. After the mining activity started in late 2005, spreading of metal-contaminated dust related to the mining activities could be measured as elevated concentrations of several elements, including Cr and Ni in lichens. In 2010, deposition of metal-contaminated dust during the past year could still be measured within an area of c. 5 km from the mine site, despite very low activity during this period. However, decreases in mean annual dust deposition rates were found in both 2009 and 2010.

Elevated concentrations of Cr and Ni were observed in the marine indicator species, blue mussels and seaweed, in 2008 and 2009, at a few stations located in close vicinity to the mine site. In 2010, however, concentations of Cr and Ni in blue mussels and seaweed were no longer significantly above concentrations measured prior to mining. Similarly, no measureable contamination was observed in shorthorn sculpins caught in the Fiskefjord. Consequently, the effect of the mine on the marine environment has likely decreased from 2008 to 2010 and is assessed as insignificant to the environment at Fiskefjord.

NERI are pleased to see that a decrease in dust contamination has occurred at Seqi during the last two years. However, the significant spreading and deposition of metal-contaminated dust within Seqi area during the past years shows that dust spreading is an important issue at this mine site. Consequently, in the case that the mine is re-opened some time in the future, actions to limit the spreading of dust due to ore-crushing, road traffic etc. has to be taken by the mining company.

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Appendix 1. Biometric data for fish

Description of the fish caught in 2010.

ID no.	Sample type	Collection date	Station	Sex	Length (cm)	Weight (g)
43900	Shorthorn sculpin	20100707	Område 1	female	31	519
43901	Shorthorn sculpin	20100707	Område 1	male	25	258
43902	Shorthorn sculpin	20100707	Område 1	female	29	380
43903	Shorthorn sculpin	20100707	Område 1	female	28	239
43904	Shorthorn sculpin	20100707	Område 1	female	27	221
43905	Shorthorn sculpin	20100707	Område 1	male	22	143
43897	Shorthorn sculpin	20100707	Område 3	female	32	449
43898	Shorthorn sculpin	20100707	Område 3	female	28	227
43899	Shorthorn sculpin	20100707	Område 3	female	25	146

Appendix 2. Analyses of blue mussels

Chemical analyses of blue mussels in µg/g dry weight. D.l.= Detection limit.

ID no.	Station	Length	Year	Dry matter %	Li	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn
D.l.					**0.05**	**16**	**0.20**	**0.31**	**0.31**	**19**	**0.18**	**0.19**	**0.16**	**0.34**
43889	St. 19	4-6 cm	2010	15	0.82	21	0.48	1.07	4.87	112	1.32	0.40	7.46	100.96
43889	St. 19	4-6 cm	2010	15	0.78	19	0.46	0.87	4.58	106	1.72	0.38	7.01	95.87
43890	St. 23	4-6 cm	2010	16	0.68	42	0.46	0.87	6.15	114	1.38	0.35	7.74	89.25
43896	For transpl.	4-6 cm	2010	18	0.60	61	0.49	0.73	5.75	159	1.09	0.33	6.95	81.20
43907	St. 1	4-6 cm	2010	13	0.98	128	0.72	1.67	5.25	208	2.07	0.45	7.83	89.09
43908	St. 1	4-6 cm/Trans 2009	2010	11	1.21	90	0.69	1.26	4.06	174	2.08	0.43	7.82	82.36
43911	St. 24	4-6 cm	2010	13	1.03	103	0.73	1.77	5.37	178	2.76	0.45	7.71	86.89
43912	St. 25	4-6 cm/Trans 2009	2010	9	1.43	689	1.95	4.49	10.45	630	6.48	0.87	8.95	116.78
43917	St. 26	3,6-4,7 cm	2010	14	0.86	84	0.65	1.37	4.78	157	2.84	0.44	7.32	79.47
43918	St. 26	4-6 cm/Trans 2009	2010	12	1.15	75	0.71	1.25	4.59	165	2.55	0.48	7.70	76.74
43919	St. 2	4-6 cm	2010	16	0.70	31	0.49	1.16	4.17	102	1.75	0.40	7.31	96.80
43920	St. 3	4-6 cm	2010	15	0.78	25	0.50	1.28	4.07	108	1.55	0.41	7.16	89.28
43921	St. 6	4-5 cm	2010	15	0.88	85	0.54	1.19	4.88	141	1.80	0.37	7.60	85.14
43922	St. 12	4-6 cm	2010	17	0.75	106	0.64	1.69	5.63	187	1.83	0.43	7.69	88.73
43923	St. 15	4-6 cm	2010	16	0.72	40	0.55	0.93	4.84	111	1.99	0.51	7.70	95.33
43923	St. 15	4-6 cm	2010	16	0.77	35	0.57	0.94	5.20	114	2.12	0.53	7.93	97.87
43932	St. 9	4-6 cm	2010	19	0.79	50	0.52	1.28	4.30	114	1.81	0.40	6.99	77.90

ID no.	Station	Length	Year	As	Se	Rb	Y	Ag	Cs	Ba	La	Ce	Nd	Hg	Pb	Th
D.l.				**0.23**	**0.56**	**0.04**	**0.04**	**0.13**	**0.04**	**0.09**	**0.01**	**0.02**	**0.01**	**0.03**	**0.13**	**0.02**
43889	St. 19	4-6 cm	2010	15.92	6.06	7.54	0.15	<D.l.	<D.l.	1.77	0.42	0.28	0.29	0.17	0.34	<D.l.
43889	St. 19	4-6 cm	2010	14.95	6.42	7.09	0.14	<D.l.	<D.l.	1.55	0.39	0.25	0.25	0.12	0.34	<D.l.
43890	St. 23	4-6 cm	2010	16.70	5.50	7.66	0.07	<D.l.	<D.l.	4.26	0.23	0.19	0.14	0.09	0.37	<D.l.
43896	For transpl.	4-6 cm	2010	13.35	6.40	7.05	0.07	<D.l.	<D.l.	2.53	0.28	0.26	0.18	0.10	0.31	<D.l.
43907	St. 1	4-6 cm	2010	17.91	7.46	7.63	0.14	<D.l.	<D.l.	2.41	0.58	0.44	0.35	0.19	0.45	<D.l.
43908	St. 1	4-6 cm/Trans 2009	2010	17.24	7.06	6.67	0.14	<D.l.	<D.l.	1.72	0.52	0.34	0.31	0.20	0.49	<D.l.
43911	St. 24	4-6 cm	2010	14.10	8.06	7.02	0.16	<D.l.	<D.l.	2.81	0.61	0.50	0.39	0.15	0.36	<D.l.
43912	St. 25	4-6 cm/Trans 2009	2010	19.75	7.30	7.74	0.30	<D.l.	<D.l.	7.39	1.09	1.17	0.71	0.25	0.67	<D.l.
43917	St. 26	3,6-4,7 cm	2010	13.43	7.29	6.55	0.10	<D.l.	<D.l.	1.56	0.40	0.30	0.24	0.15	0.29	<D.l.
43918	St. 26	4-6 cm/Trans 2009	2010	14.80	8.22	6.80	0.14	<D.l.	<D.l.	1.33	0.50	0.34	0.30	0.15	0.37	<D.l.
43919	St. 2	4-6 cm	2010	12.27	7.01	6.78	0.09	<D.l.	<D.l.	1.12	0.42	0.28	0.25	0.15	0.40	<D.l.
43920	St. 3	4-6 cm	2010	11.52	7.25	6.67	0.11	<D.l.	<D.l.	1.02	0.42	0.29	0.28	0.15	0.27	<D.l.
43921	St. 6	4-5 cm	2010	13.20	7.13	7.03	0.09	<D.l.	<D.l.	2.43	0.52	0.46	0.30	0.14	0.31	<D.l.
43922	St. 12	4-6 cm	2010	13.91	6.77	7.95	0.11	<D.l.	<D.l.	2.58	0.66	0.61	0.34	0.11	0.30	<D.l.
43923	St. 15	4-6 cm	2010	13.24	7.58	7.40	0.09	<D.l.	<D.l.	1.32	0.36	0.25	0.21	0.18	0.36	<D.l.
43923	St. 15	4-6 cm	2010	13.73	8.67	7.59	0.10	<D.l.	<D.l.	1.19	0.52	0.55	0.32	0.18	0.36	<D.l.
43932	St. 9	4-6 cm	2010	12.43	6.37	7.25	0.10	<D.l.	<D.l.	1.68	0.42	0.29	0.26	0.14	0.32	<D.l.

Appendix 3. Analyses of seaweed

Chemical analyses of seaweed in µg/g dry weight. D.l.= Detection limit.

ID no.	Station	Year	Li	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn
D.L.			**0.05**	**16**	**0.20**	**0.31**	**0.31**	**19**	**0.18**	**0.19**	**0.16**	**0.34**
43891	St. 19	2010	0.49	<D.l.	0.29	<D.l.	7.39	37	1.16	0.21	1.85	5.66
43892	St. 23	2010	0.47	<D.l.	0.26	<D.l.	7.08	29	1.19	0.23	2.51	6.19
43906	St. 1	2010	0.57	<D.l.	<D.l.	<D.l.	11.07	35	1.31	0.23	3.05	8.93
43909	St. 24	2010	0.56	<D.l.	<D.l.	<D.l.	18.74	35	1.15	0.22	4.20	11.47
43910	St. 24	2010	0.44	<D.l.	<D.l.	<D.l.	13.90	31	1.26	0.20	3.16	10.23
43913	St. 25	2010	0.45	51	0.39	0.32	27.52	142	2.17	0.40	3.10	11.40
43914	St. 25	2010	0.42	80	0.38	0.36	27.09	117	3.35	0.45	3.30	11.83
43914	St. 26	2010	0.57	<D.l.	<D.l.	<D.l.	18.00	35	1.45	0.25	4.84	12.39
43916	St. 26	2010	0.57	<D.l.	<D.l.	<D.l.	19.93	37	1.48	0.25	4.42	13.63
43924	St. 2	2010	0.50	<D.l.	<D.l.	<D.l.	9.88	29	1.14	<D.l.	3.04	7.03
43925	St. 3	2010	0.43	<D.l.	<D.l.	<D.l.	28.72	39	1.49	0.38	3.09	9.11
43926	St. 4	2010	0.46	<D.l.	<D.l.	<D.l.	25.67	35	1.25	0.34	3.68	9.44
43926	St. 4	2010	0.48	<D.l.	<D.l.	<D.l.	23.66	34	1.13	0.33	3.72	9.31
43927	St. 6	2010	0.50	<D.l.	<D.l.	<D.l.	9.44	31	1.03	<D.l.	3.20	8.21
43928	St. 8	2010	0.31	<D.l.	<D.l.	<D.l.	10.16	36	0.90	0.22	3.71	10.16
43929	St. 9	2010	0.47	<D.l.	<D.l.	<D.l.	11.83	30	1.15	0.24	2.18	6.30
43930	St. 12	2010	0.50	16	<D.l.	<D.l.	13.48	60	1.39	0.56	2.98	7.17
43931	St.15	2010	0.55	<D.l.	<D.l.	<D.l.	7.54	26	0.86	<D.l.	2.75	5.76

ID no.	Station	Year	As	Se	Rb	Y	Ag	Cs	Ba	La	Ce	Nd	Hg	Pb	Th
D.L.			**0.23**	**0.56**	**0.04**	**0.04**	**0.13**	**0.04**	**0.09**	**0.01**	**0.02**	**0.01**	**0.03**	**0.13**	**0.02**
43891	St. 19	2010	43.65	0.97	12.28	0.05	<D.l.	<D.l.	7.47	0.06	0.07	0.05	<D.l.	<D.l.	<D.l.
43892	St. 23	2010	42.73	<D.l.	11.41	0.05	<D.l.	<D.l.	6.99	0.05	0.05	0.04	<D.l.	<D.l.	<D.l.
43906	St. 1	2010	51.74	<D.l.	12.63	<D.l.	<D.l.	<D.l.	8.05	0.06	0.06	0.05	<D.l.	<D.l.	<D.l.
43909	St. 24	2010	63.68	0.98	13.47	<D.l.	<D.l.	<D.l.	9.43	0.06	0.06	0.05	<D.l.	<D.l.	<D.l.
43910	St. 24	2010	57.74	<D.l.	10.54	0.05	<D.l.	<D.l.	8.68	0.09	0.09	0.08	<D.l.	<D.l.	<D.l.
43913	St. 25	2010	52.73	0.93	14.75	0.05	<D.l.	<D.l.	14.65	0.18	0.19	0.14	<D.l.	<D.l.	0.02
43914	St. 25	2010	50.34	0.70	14.26	0.07	<D.l.	<D.l.	15.10	0.22	0.26	0.17	<D.l.	<D.l.	0.05
43914	St. 26	2010	53.70	<D.l.	15.33	<D.l.	0.13	<D.l.	9.32	0.06	0.06	0.06	<D.l.	<D.l.	<D.l.
43916	St. 26	2010	54.93	0.98	15.96	0.04	0.27	0.06	9.02	0.07	0.08	0.06	<D.l.	<D.l.	<D.l.
43924	St. 2	2010	46.08	0.64	11.45	<D.l.	<D.l.	<D.l.	7.09	0.06	0.06	0.05	<D.l.	<D.l.	<D.l.
43925	St. 3	2010	59.19	1.19	11.60	0.04	<D.l.	<D.l.	12.10	0.07	0.08	0.07	<D.l.	<D.l.	<D.l.
43926	St. 4	2010	79.84	0.88	12.64	0.05	<D.l.	<D.l.	10.48	0.06	0.07	0.06	<D.l.	<D.l.	<D.l.
43926	St. 4	2010	82.89	0.69	13.13	0.04	<D.l.	0.04	10.29	0.05	0.05	0.05	<D.l.	<D.l.	<D.l.
43927	St. 6	2010	50.22	<D.l.	13.18	0.04	<D.l.	<D.l.	7.82	0.06	0.06	0.05	<D.l.	<D.l.	<D.l.
43928	St. 8	2010	56.98	<D.l.	11.48	<D.l.	<D.l.	<D.l.	9.23	0.15	0.13	0.13	<D.l.	<D.l.	<D.l.
43929	St. 9	2010	40.26	<D.l.	11.29	0.04	<D.l.	<D.l.	7.13	0.07	0.07	0.06	<D.l.	<D.l.	<D.l.
43930	St. 12	2010	49.71	0.72	12.61	<D.l.	0.16	<D.l.	9.27	0.08	0.10	0.07	<D.l.	<D.l.	<D.l.
43931	St.15	2010	50.67	0.91	12.81	0.04	<D.l.	<D.l.	7.99	0.06	0.07	0.05	<D.l.	<D.l.	<D.l.

Appendix 4. Analyses of lichens

Chemical analyses of lichens (*Cetraria nivalis*) in µg/g dry weight. D.l.= Detection limit.

ID no.	Station	Year	Notes	Li	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	As	Se
D.l.				**0.05**	**16**	**0.20**	**0.31**	**0.31**	**19**	**0.18**	**0.19**	**0.16**	**0.34**	**0.23**	**0.56**
43933	St. 3	2010	Trans.	0.11	313	0.45	0.58	51.84	176	0.74	<D.l.	0.48	10.12	<D.l.	<D.l.
43933	St. 3	2010	Trans.	0.10	255	0.49	0.56	18.38	181	0.89	<D.l.	0.56	6.40	<D.l.	<D.l.
43934	St.6	2010	Trans.	0.09	412	0.63	1.09	34.21	252	2.20	0.20	0.58	7.43	<D.l.	<D.l.
43935	St. 9	2010	Trans.	0.10	334	0.46	1.56	44.46	200	1.59	0.21	0.70	12.31	<D.l.	<D.l.
43936	St. 1	2010	Trans.	0.08	181	0.26	0.70	22.01	124	1.63	<D.l.	0.52	9.41	<D.l.	<D.l.
43938	St. 24/Lav 7	2010	Trans.	0.10	508	0.81	3.96	32.88	384	10.03	1.05	0.79	9.82	<D.l.	<D.l.
43939	St. 26	2010	Trans.	0.10	378	0.71	2.58	17.03	299	6.34	0.39	0.52	6.54	<D.l.	<D.l.
43940	St. 2	2010	Nat.	<D.l.	102	<D.l.	0.89	39.88	75	1.76	<D.l.	0.66	20.80	<D.l.	<D.l.
43941	St. 10	2010	Nat.	<D.l.	234	0.37	1.80	30.55	200	5.02	0.47	0.53	12.58	<D.l.	<D.l.
43942	St. 12	2010	Nat.	<D.l.	206	0.29	1.16	156.35	149	2.41	<D.l.	0.55	11.72	<D.l.	<D.l.
43943	St. 15	2010	Nat.	0.06	339	0.43	0.69	21.51	163	0.74	<D.l.	0.68	21.09	<D.l.	<D.l.
43944	St. 25/Lav 1	2010	Trans.	0.12	210	0.50	10.72	34.32	597	33.21	1.55	0.67	10.48	0.35	<D.l.
43945	Lav 2	2010	Trans.	0.06	184	0.28	5.67	25.65	250	13.12	0.70	0.43	10.08	<D.l.	<D.l.
43946	Lav 3	2010	Trans.	0.06	174	0.25	2.68	14.35	226	9.04	0.44	0.52	9.22	<D.l.	<D.l.
43947	Lav 4	2010	Trans.	<D.l.	198	0.21	2.61	25.90	130	4.29	0.31	0.56	10.87	<D.l.	<D.l.
43948	Lav 5	2010	Trans.	0.06	279	0.43	5.08	19.67	253	9.96	0.49	0.55	9.83	<D.l.	<D.l.
43948	Lav 5	2010	Trans.	0.06	322	0.38	9.00	16.80	275	12.48	0.58	0.54	7.80	<D.l.	<D.l.
43949	Lav 6	2010	Trans.	0.07	272	0.47	5.85	24.45	358	17.15	0.82	0.64	9.40	<D.l.	<D.l.
43950	Lav 9	2010	Trans.	<D.l.	192	<D.l.	3.85	11.72	144	7.19	0.37	0.49	9.15	<D.l.	<D.l.
43951	Lav 10	2010	Trans.	<D.l.	164	<D.l.	8.31	25.92	352	22.44	1.04	0.48	8.16	<D.l.	<D.l.
43893	St. 13	2010	Nat.	<D.l.	167	0.22	0.38	21.51	87	0.65	<D.l.	0.45	7.03	<D.l.	<D.l.
43894	St. 19	2010	Nat.	<D.l.	185	<D.l.	0.38	7.13	81	0.43	<D.l.	0.45	8.11	0.28	<D.l.
43895	St. 23	2010	Nat.	<D.l.	133	<D.l.	<D.l.	4.53	60	<D.l.	<D.l.	0.41	5.99	<D.l.	<D.l.

ID no.	Station	Year	Notes	Rb	Y	Ag	Cs	Ba	La	Ce	Nd	Hg	Pb	Th
D.l.				**0.04**	**0.04**	**0.13**	**0.04**	**0.09**	**0.01**	**0.02**	**0.01**	**0.03**	**0.13**	**0.02**
43933	St. 3	2010	Trans.	1.73	0.11	<D.l.	<D.l.	6.51	0.26	0.56	0.23	0.04	0.36	0.06
43933	St. 3	2010	Trans.	0.70	0.09	<D.l.	<D.l.	4.41	0.24	0.47	0.21	0.04	0.38	0.05
43934	St.6	2010	Trans.	1.07	0.12	<D.l.	<D.l.	6.25	0.24	0.50	0.23	0.04	0.48	0.06
43935	St. 9	2010	Trans.	2.54	0.15	<D.l.	<D.l.	10.17	0.37	0.75	0.33	0.05	0.75	0.06
43936	St. 1	2010	Trans.	2.02	0.09	<D.l.	<D.l.	5.42	0.26	0.55	0.24	0.04	0.51	0.05
43938	St. 24/Lav 7	2010	Trans.	2.46	0.22	<D.l.	<D.l.	12.50	0.58	1.12	0.48	0.04	0.81	0.13
43939	St. 26	2010	Trans.	0.84	0.12	<D.l.	<D.l.	4.33	0.31	0.59	0.26	0.03	0.43	0.07
43940	St. 2	2010	Nat.	4.67	0.04	<D.l.	<D.l.	8.60	0.13	0.25	0.10	<D.l.	0.18	0.03
43941	St. 10	2010	Nat.	3.86	0.10	<D.l.	<D.l.	8.18	0.31	0.62	0.25	0.04	0.48	0.07
43942	St. 12	2010	Nat.	2.16	0.08	<D.l.	<D.l.	17.25	0.27	0.50	0.20	0.04	0.31	0.05
43943	St. 15	2010	Nat.	2.47	0.11	<D.l.	<D.l.	6.00	0.33	0.61	0.25	0.04	0.36	0.07
43944	St. 25/Lav 1	2010	Trans.	3.19	0.15	<D.l.	0.10	7.50	0.43	0.84	0.36	<D.l.	0.55	0.10
43945	Lav 2	2010	Trans.	2.19	0.09	<D.l.	0.06	6.54	0.27	0.53	0.24	<D.l.	0.38	0.03
43946	Lav 3	2010	Trans.	1.00	0.05	<D.l.	<D.l.	2.36	0.14	0.27	0.12	0.04	0.30	<D.l.
43947	Lav 4	2010	Trans.	2.44	0.08	<D.l.	<D.l.	8.24	0.22	0.47	0.20	0.04	0.81	0.03
43948	Lav 5	2010	Trans.	2.56	0.13	<D.l.	0.07	6.42	0.33	0.65	0.28	0.04	0.74	0.04
43948	Lav 5	2010	Trans.	2.32	0.11	<D.l.	0.06	5.57	0.27	0.55	0.25	<D.l.	0.63	0.03
43949	Lav 6	2010	Trans.	2.34	0.12	<D.l.	<D.l.	6.92	0.32	0.63	0.29	<D.l.	0.66	0.04
43950	Lav 9	2010	Trans.	1.19	0.06	<D.l.	<D.l.	2.99	0.16	0.33	0.14	<D.l.	0.23	<D.l.
43951	Lav 10	2010	Trans.	1.29	0.07	<D.l.	<D.l.	3.42	0.19	0.37	0.16	<D.l.	0.30	<D.l.
43893	St. 13	2010	Nat.	1.67	0.06	<D.l.	<D.l.	4.33	0.18	0.36	0.16	0.04	0.32	<D.l.
43894	St. 19	2010	Nat.	0.58	0.04	<D.l.	<D.l.	2.04	0.10	0.22	0.09	0.03	0.20	<D.l.
43895	St. 23	2010	Nat.	0.90	0.04	<D.l.	<D.l.	1.67	0.13	0.27	0.12	<D.l.	0.29	<D.l.

Appendix 5. Analyses of sculpin liver

Chemical analyses of *Shorthorn sculpin* liver in µg/g on a wet weight basis. D.l.= Detection limit.

ID no.	Station	Year	Dry matter %	Li	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	As
D.l.				**0.02**	**4.84**	**0.06**	**0.09**	**0.09**	**6**	**0.05**	**0.06**	**0.05**	**0.10**	**0.07**
43902	Område 1	2010	30.94	<D.l.	<D.l.	<D.l.	0.19	0.73	85	0.07	0.06	1.30	24.27	7.18
43903	Område 1	2010	29.69	<D.l.	<D.l.	<D.l.	<D.l.	0.69	101	0.08	<D.l.	1.87	35.02	5.39
43904	Område 1	2010	22.39	<D.l.	<D.l.	<D.l.	<D.l.	1.29	220	0.13	0.26	2.81	42.66	2.89
43905	Område 1	2010	-	0.02	<D.l.	<D.l.	<D.l.	1.10	184	0.14	0.16	5.17	51.44	4.84
43900	Område 1	2010	34.42	<D.l.	<D.l.	<D.l.	<D.l.	0.61	79	<D.l.	0.09	1.01	21.38	8.87
43901	Område 1	2010	28.41	<D.l.	7.73	<D.l.	<D.l.	0.97	120	<D.l.	0.16	0.99	26.02	7.09
43897	Område 3	2010	25.17	0.02	<D.l.	0.11	<D.l.	1.06	87	<D.l.	0.07	2.52	44.23	10.36
43898	Område 3	2010	18.62	0.02	<D.l.	<D.l.	<D.l.	1.36	109	<D.l.	0.07	6.00	58.62	5.18
43899	Område 3	2010	16.46	0.04	<D.l.	<D.l.	<D.l.	1.39	183	<D.l.	0.06	2.59	51.88	5.35

ID. no.	Station	Year	Se	Rb	Y	Ag	Cs	Ba	La	Ce	Nd	Hg	Pb	Th
D.l.			**0.17**	**0.01**	**0.01**	**0.04**	**0.01**	**0.03**	**0.003**	**0.006**	**0.003**	**0.01**	**0.04**	**0.01**
43902	Område 1	2010	1.04	1.86	<D.l.	0.24	0.03	<D.l.	<D.l.	<D.l.	<D.l.	0.07	0.00	<D.l.
43903	Område 1	2010	1.65	1.00	<D.l.	0.08	0.02	<D.l.	0.004	<D.l.	<D.l.	0.03	0.02	<D.l.
43904	Område 1	2010	1.19	0.94	<D.l.	0.09	0.01	<D.l.	0.009	<D.l.	0.004	0.10	0.00	<D.l.
43905	Område 1	2010	1.18	1.20	<D.l.	0.19	0.02	<D.l.	0.006	<D.l.	<D.l.	0.06	0.01	<D.l.
43900	Område 1	2010	0.92	1.76	<D.l.	0.07	0.04	<D.l.	0.004	<D.l.	<D.l.	0.09	0.00	<D.l.
43901	Område 1	2010	1.18	1.39	<D.l.	0.07	0.02	<D.l.	0.004	<D.l.	<D.l.	0.05	0.00	<D.l.
43897	Område 3	2010	2.72	0.66	<D.l.	0.16	0.03	<D.l.	0.004	<D.l.	<D.l.	0.07	0.01	<D.l.
43898	Område 3	2010	1.67	0.94	<D.l.	0.56	0.02	<D.l.	0.006	<D.l.	<D.l.	0.03	0.01	<D.l.
43899	Område 3	2010	1.55	0.83	<D.l.	0.11	0.02	<D.l.	0.005	<D.l.	0.003	<D.l.	0.00	<D.l.

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ENVIRONMENTAL MONITORING AT THE SEQI OLIVINE MINE 2010

The olivine mine at Seqi in West Greenland operated between 2005 and 2010. Since 2004, environmental monitoring studies have been conducted at Seqi every year in order to assess pre-mining conditions and subsequently the impact from mining during operation. This report contains the results from monitoring studies conducted in 2010. Results from previous years have shown that operation of the mine caused levels of some elements, particularly chromium and nickel, to increase in lichens, blue mussels and seaweed within the surrounding area compared to pre-mining conditions. The main source of contamination is considered the generation and spreading of metal-contaminated dust from the roads and the ore-crushing facility. Results from 2010 show that levels of chromium and nickel in lichens are still elevated but that dust deposition rates have decreased from 2008 to 2010. Similarly, levels of chromium and nickel in seaweed and blue mussels have decreased from 2008/2009 to 2010 at the few previously impacted stations near the mine and were in 2010 no longer significantly above concentrations measured prior to mining. Similar to the previous years, no contamination was measured in fish (shorthorn sculpin) in 2010. Consequently, the environmental impact of the mine at Seqi has decreased and is considered insignificant for the Niaquungunaq fjord system.

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