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NERI Tehnical Report, No. 567

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Data sheet

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Abstract:

This second monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland during 10 August-5 September 2005. Four shipments of ore have been carried out after the first monitoring study in August 2004. Samples were collected at two to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River, and lichens were collected at 20 stations in the Kirkespir Valley. Samples were analysed for 12 elements with an ICP-MS. Average concentrations of Cu, As and Co were, compared to background levels, elevated 2-5 times in lichens only. Compared to the 2004 monitoring study, there were no elevated average concentrations in the marine environment, only three elements had elevated concentrations compared to five in 2004 and elevations were in general lower in 2005. Elevated concentrations (5-16 times) of Cu, Cr, As and Co in lichens at single stations were an effect of dust from the road and the mine area. Elevated concentrations were found at a distance of c. 1000 m from the road. Dust from road and mine area should be prevented.

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

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Contents

Preface

This is the second monitoring report since the Nalunaq Gold Mine A/S (NGM) officially started mining in August 2004. After the first monitoring study, performed late August 2004 (Glahder & Asmund 2005a), there have been four shipments of ore. The gold ore is processed by Rio Narcea Gold Mines Ltd in Spain. This monitoring study was performed according to the exploitation licence of 19 March 2004, Phase 2, §§ 10-19, chapter 5. The exploitation licence was issued by the Bureau of Minerals and Petroleum (BMP), the Greenland Home Rule.

The monitoring program, as described in the exploration licence, is in short that mussels, seaweed and sculpins are sampled at four marine stations in the Kirkespir Bay, Arctic char is sampled in the Kirkespir River and lichens are collected at 18 stations around the different mining activities. Samples are analysed for eight elements and the results are compared with background concentrations. NERI performed environmental baseline studies in the Nalunaq area during 1998-2001, and Nalunaq I/S financed these studies (Glahder et al. 2005).

The actual monitoring study can diverge slightly from the described program, and the differences are explained in the introduction.

We wish to thank Nalunaq Gold Mine A/S for making the monitoring study feasible and providing us with technical information, and J. B. Andersen, laboratory technician, NGM, for collecting and preparing samples.

Summary

Monitoring period

The monitoring study was carried out in the Nalunaq gold mining area, Nanortalik municipality, South Greenland, from 10 August to 5 September 2005. Four shipments of ore were carried out since the last monitoring study in August 2004.

Sampling program and analyses

Blue mussels, brown seaweed and shorthorn sculpin were sampled at two to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River and lichens *Cetraria nivalis* were collected at 20 stations in the Kirkespir Valley and along the Kirkespir Bay (Fig. 1). Samples were analysed for 12 elements (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo and Au) and the results were compared with background levels. An overview of the contamination of the entire area is presented by average concentrations, while contaminations of specific areas are presented by stations concentrations.

Entire area: Elevated average concentrations of Cu, As and Co

Average concentrations of Cu, As and Co were elevated 2-5 times in lichens only. None of the remainder average concentrations of the analysed elements in any of the organisms were elevated.

Specific areas: Marine environment slightly impacted from mine and pier areas

In the Kirkespir Bay, seaweed had slightly elevated concentrations of Zn and Co at stations near the Kirkespir River and the pier area and elevated concentrations of Cr near the river. This indicates that impacts come from both the mining area (e.g. mine water and crushing of waste rock) and the pier area (e.g. ore stockpiling and loading). Dust from the road can also contribute to elevated concentrations.

Specific areas: Freshwater

Resident Arctic char had no elevated concentrations in their liver.

Specific areas: Terrestrial environment impacted through dust from road and mine area

In the Kirkespir Valley and Bay area, 5-16 times higher concentrations of Cu, Cr, As and Co in lichens were found at stations near the pier, the waterfall and the camp areas. Elevated concentrations of the four elements in lichens were in most of the Kirkespir Valley an effect of dust from the road, partly built of waste rock. Concentrations above the background level could be found to a distance of about 1000 m from the road. An additional contribution came from the camp area, probably from the ore crusher and mine traffic.

Moderate local pollution

As in 2004, the local environment is impacted by the mine. Slightly elevated concentrations are found within c. 5 km of coastline on each side of the river's outfall. Compared to 2004 the impacted marine area is smaller. This could be an effect of stockpiled fine-ground ore removed from the area prior to this monitoring study. The Kirkespir Valley floor is impacted mainly from dust from the road, but also from mine activities. Element concentrations in 2005 were similar to 2004, except for arsenic in the camp area where the level is doubled.

Possible actions

Prevention of dust from the road and the camp area should be discussed with the company. Use of waste rock for road maintenance should be reconsidered and based on chemical analysis. Dust from the road can be reduced by watering the road during dry periods.

Sammenfatning

Moniteringsperiode	Moniteringen blev udført i Nalunaq området, Nanortalik kommune, Sydgrønland, fra 10. august til 5. september 2005. I alt fire malmudskibninger har fundet sted siden den første monitering i august 2004.
Indsamlings- og analyseprogram	Blåmusling, blæretang og alm. ulk blev indsamlet på 2-5 stationer i Kirkespir Bugt, standørred blev fisket i Kirkespir Elv og snekruslav *Cetraria nivalis* blev samlet på 20 stationer i Kirkespir Dal og langs bugten (Fig. 1). Prøverne blev analyseret for 12 grundstoffer (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo og Au) og resultaterne blev sammenholdt med baggrundsniveauet. Et overblik over forureningen af hele området er givet vha. gennemsnitskoncentrationer, mens forureningen i specifikke områder er angivet vha. stationskoncentrationer.
Hele området: Forhøjede gennemsnitskoncentrationer af Cu, As og Co	Kun laver havde højere gennemsnitskoncentrationer af Cu, As og Co (2-5 gange) i forhold til baggrundskoncentrationerne. I ingen af de øvrige organismer var der grundstoffer med forhøjede gennemsnitskoncentrationer.
Specifikt område: Det marine miljø er påvirket af mine- og moleområdet	Tang fra Kirkespir Bugt havde svagt forhøjede koncentrationer af Zn og Co på stationer nær Kirkespir Elvens udløb og nær molen og forhøjede koncentrationer af Cr nær elven. Dette tyder på, at påvirkningerne stammer både fra mineområdet (f.eks. fra minevand og fra knusning af gråbjerg) og fra malmudskibningsområdet. Et bidrag til de forhøjede koncentrationer kan også komme fra vejstøv.
Specifikt område: Ferskvand	Standørreder havde ikke forhøjede koncentrationer i deres lever.
Specifikt område: Det terrestriske miljø er påvirket af støv fra vejen og minen	I Kirkespir Dal og Bugt blev der på stationer fra mole-, mine- og vandfaldsområdet fundet 5-16 gange højere koncentrationer af Cu, Cr, As og Co i laver. De forhøjede koncentrationer i laverne fra størstedelen af Kirkespir Dal skyldtes støv fra grusvejen. Denne er delvist vedligeholdt med knust gråbjerg. De forhøjede koncentrationer kunne findes i en afstand af ca. 1000 meter fra vejen. Et bidrag til de forhøjede koncentrationer kom fra lejrområdet og stammer formodentlig fra knusning af gråbjerg og trafik på minevejene.
Moderat lokal forurening	Som det blev set i forbindelse med moniteringen i 2004 er det lokale miljø påvirket af minen. Mindre forhøjelser findes indenfor en ca. 5 km lang kyststrækning ved Kirkespirelvens munding. I forhold til 2004 er det påvirkede marine område blevet mindre. Dette kan skyldes, at tidligere finknust malm er sejlet ud af området før denne monitering. Kirkespirdalen er især påvirket af støv fra vejen, men også fra mineaktiviteterne i lejrområdet. I forhold til 2004 er det kun As der ligger på et højere koncentrationsniveau i 2005.
Mulig regulering	Forebyggelse af støvspredning fra vejen og mineområdet bør diskuteres med selskabet. Brug af gråbjerg til vejvedligeholdelse bør genovervejes og baseres på kemiske analyser af gråbjerg og tidligere anvendt vejmateriale. Støv kan reduceres ved at vande vejen i tørre perioder.

Eqikkaaneq

Piffissaq nalunaarsuiffik

Nalunaarsuineq Kujataani, Nanortallup kommuniani, Nalunami, 2005-imi 10. augustusimiit 5. septemberimut ingerlanneqarpoq. 2004-mi augustusimi siullermeerluni nalunaarsuinerup kingornagut sisamariarluni aatsitassamik aallarussineqarpoq.

Katersuinissamik misissuinissamillu pilersaarut

Uillut, equutit kanajorlu nalinginnaasoq Napasorsuup Iterlaani -imi assigiinngitsuni 2-5-ini misissugassatut katersorneqarput, eqaluit sisujuitsut Napasorsuup kuuani pisarineqarput orsuaasarlu snekruslav , *Cetraria nivalis* Napasorsuup Qooruani sineriammilu assigiinngitsuni 20-ni katersorneqarluni (Fig. 1). Misissugassat grundstoffinik 12-inik (Hg, Cd, Pb, Zn, Cu, Cr, Ni, As, Se, Co, Mo aamma Au) misissuiffigineqarput misissuinerullu inerneri tunngavigineqartumi pissutsinut naleqqiussuunneqarlutik. Nunap tamatuma tamakkerluni mingutsinneqarnerata annertussusianik takussutissaq pissarsiarineqarpoq agguaqatigiissitsinikkut, misissuiffiulli ilaani aalajangersuni mingutitsineq pissarsiarineqarluni stationimi annertussutsit tunngavigalugit.

Misissuiffik tamakkerlugu: Agguaqatigiissitsinikkut Cu, As aamma Co annertusisimapput

Taamaallaat orsuaasani Cu, As aamma Co agguaqatigiissillugu annertunerulersimapput (marloriaammiit tallimariaammut) tunngavigineqartumi pissutsinut naleqqiullugit. Uumassusilinni allani grundstofit agguaqatigiissitsinikkut annertussutsinit annertunerulersimanngillat.

Misissuiffimmi aalajangersumi: Imaq piiaavimmit nunniukkamillu sunnersimaneqarpoq

Qeqqussat Napasorsuup Iterlaaniittut, Napasorsuup Kuuata qanittuaniittut aammalu nunniukkap qanittuaniittut annikitsumik Zn aamma Co-mik akoqarnerulaalersimapput kuullu qanittuaniittut Cr-imik akoqarnerulersimallutik. Tamatumuuna takuneqarsinnaavoq sunniutit aatsitassarsiorfeqarfimmeersuusut (soorlu imeq aatsitassarsiorfimmeersoq aammalu qaqqap qasertup aserorterneqarneraneersoq) aammalu aatsitassamik usilersuiffeqarfimmeerlutik. Akuusut annertunerulersimanerannut aamma aqqusernup pujoralaa pisooqataasinnaavoq.

Misissuiffimmi aalajangersumi: Imeq

Eqaluit sisujuitsut tinguini akuusut annertunerulersimanngillat.

Misissuiffimmi aalajangersumi: Nunami avatangiisit aqqusernup aatsitassarsiorfiullu pujoralaannit sunnersimaneqarput

Napasorsuup Qooruani Iterlaanilu nunniukkami, aatsitassarsiorfimmi qorlortumi taakkualu eqqaanni qanittuni orsuaasat misissukkat Cu, Cr, As aamma Co-mik 5-16-eriaammik akoqarnerupput. Napasorsuup Qooruata annersaani orsuaasat akoqarnerulersimanerat aqqusernup qallersugaanngitsup pujoralaanik pissuteqarpoq. Tamannalu ilaatigut qaqqap qasertup aserorterneqarneranmit allanngutsaalineqarpoq. Akoqarnerulersimanerit aqqusinermit 1000 meter miss. ungasissusilik tikillugu malugineqarsinnaapput. A-koqarnerulersitsisunut ilaagunarpoq tammaarsimaafeqarfik, tamatumunngalu pissutaagunarluni qaqqap qasertup aserorterneqarneranit aatsitassarsiorfimmullu aqqusinerni angallannermit.

Annertunngitsumik najukkami mingutsitsineq

Soorlu 2004-mi nalunaarsuinermut atatillugu takuneqareersoq najugaq tamanna aatsitassarsiorfimmit sunnersimaneqarpoq. Annikitsumik akoqarnerulersimanerit nassaarineqarsinnaapput Napasorsuup

Kuuata akuani sinerissami 5 km miss. isorartutigisumi. 2004-mut naleqqiullugu imaq sunnersimaneqartoq annikinnerulersimavoq. Tamanna aatsitassap seqummarissup siusinnerusukkut tamaaniissimasup misissuinerup uuma siornagut aallarussorneqarsimaneranik pissuteqarsinnaavoq. Napasorsuup Qoorua pingaartumik aqqusernup pujoralaanit sunnersimaneqarpoq, aammalumi tammaarfimmi aatsitassarsiornermit. 2004-mut naleqqiullu akuusuni taamaattaat As 2005-imi annertuneruvoq.

Malittarisassaliuussisinnaaneq

Aqqusinermiit aatsitassarsiorfimmiillu pujoralaap siaruarternerata pinngitsoorniarnissaa ingerlatsivimmut oqaloqatigiissutigineqartariaqarpoq. Qaqqap qasertup aqqusinermik aserfallatsaaliinermut atorneqarnera isumaliutigeqqinneqartariaqarpoq qaqqaq qasertumillu aammalu siornatigut aqqusinniornermi atorneqarsimasut naasuitsulerinikkut misissuinernik tamanna tunngaveqartinneqartariaqarluni. Pujoralak annikillisinneqarsinnaavoq nunap panernerani aqqusernup masatsertarneratigut.

1 Introduction

Mining activities and monitoring periods

The Nalunaq Gold Mine A/S opened officially on 26 August 2004. Prior to the mine start extensive exploration programs had been carried out since the discovery of gold bearing veins in 1992. The first shipment of gold ore took place late December 2003, and together with the second shipment on 12 August 2004 c. 70,000 tonnes of ore were shipped to Rio Narcea Gold Mines Ltd, Spain, for gold extraction. These two shipments took place prior to the first monitoring study performed during 20 - 26 August 2004. The present second monitoring study was performed from 10 August to 5 September 2005. During the period from the first to the second monitoring study, a total of four shipments of ore had been carried out: On 22 November 2004 of c. 28,000 tonnes, on 6 March 2005 of c. 28,000 tonnes, on 6 June 2005 of c. 21,000 tonnes and on 28 August 2005 of c. 33,000 tonnes; tonnages are in wet weight (CCNMatthews 2005, K. Christensen, NGM, 7.11.2005, *in litt.*).

Monitoring program according to the BMP exploitation licence

Requirements for monitoring of the environment in relation to the mining activity is described in the BMP exploitation licence of 19 March 2004, Phase 2, §§ 10-19, chapter 5:

The objective of monitoring is to document environmental impacts associated with the activities. BMP finds that the environmental monitoring program described in the approval of the shipment of the stockpiled ore from the exploration phase (refer to BMP's approval of 2 May 2003), also should apply for the exploitation plan, Phase 2.

The sampling stations for brown seaweed, blue mussel, shorthorn sculpin and Arctic char must be placed relatively close to, and on each side of the shipping facility (Fig. 1). Sampling stations for the lichen *Cetraria nivalis* must be placed both in connection with the above marine stations and around existing ore stockpiles at the Kirkespir Valley campsite and along the road. The following samples must be collected at the number of stations specified:

- Brown seaweed: 4 stations with 2 samples per station; a total of 8 samples.
- Blue mussel: 4 stations with 2 samples (2 different size groups) per station; a total of 8 samples.
- Liver from shorthorn sculpin and Arctic char: 2-4 stations with a total of 20 specimens.
- Lichens *Cetraria nivalis*: 18 stations; a total of 18 samples.

The samples collected must be analysed for the following elements: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn).

BMP may demand changes to the scope and content of the environmental monitoring if it considers the existing monitoring programme inadequate based on the results obtained and experience from the mining operation.

Samples must be collected on an annual basis during operations and closure and for a period of two years after closure. Samples must be analysed immediately after being collected. The analytical findings must be data processed, and a report prepared. This report must reach BMP no later than four months after the samples have been collected.

The samples must be collected and analysed in accordance with guidelines prepared by NERI.

Monitoring August - September 2005

The monitoring study was performed in the Nalunaq area from 10 August to 5 September 2005.

Sampling was carried out in accordance with the monitoring program described in the exploitation licence with the following divergences:

- Like in 2004, blue mussels were sampled at one more station, AMI1, on the north-east side of the Amitsoq island about 15 km from the Kirkespir Bay. Blue mussels from this presumably uncontaminated area were transplanted to the harbour area to replace the mussels transplanted in 2004 that in 2005 were collected for analyses.
- Lichens were sampled at two more stations.

The 20 fish liver analyses were separated in 16 Shorthorn sculpin livers from two marine stations in the Kirkespir Bay and four Arctic char livers from the Kirkespir River near the waterfall. The chars were of the resident form.

Analyses were done according to the program, however 59 samples were analysed in stead of 54. Moreover, 12 elements including nickel (Ni), selenium (Se), molybdenum (Mo) and gold (Au) were analysed for.

A preliminary report was issued to BMP and NGM on 4 November 2005 (Glahder & Asmund 2005b).

2 Methods

2.1 Collection of samples

Sampling in the Kirkespir Bay and at the north-eastern point of Amitsoq (AMI1) was performed with a motor boat equipped with a small rubber dinghy with an outboard motor for landing. Sampling of blue mussels was facilitated by rather low tide.

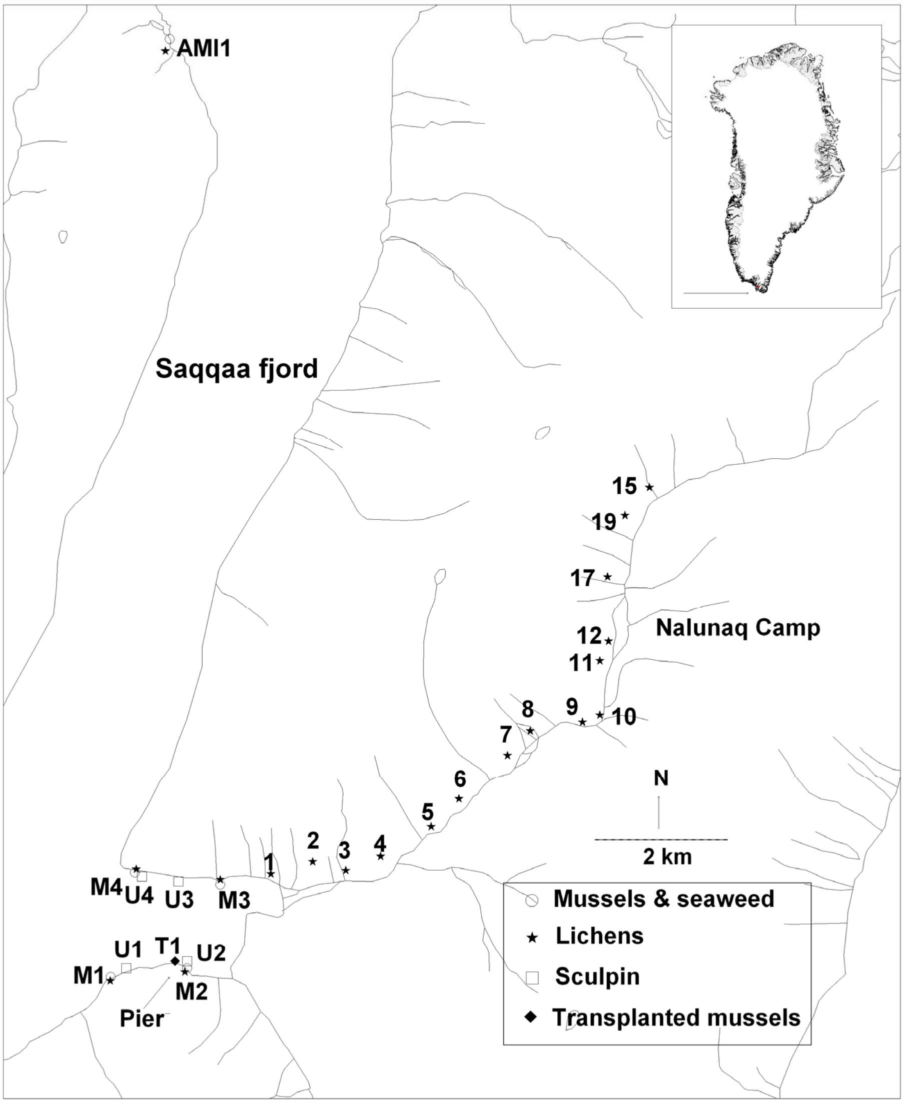

Figure 1. Sampling stations in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland.
M: Marine stations: Blue mussel and brown seaweed, including lichens. U: Shorthorn sculpin stations. Only U2 and U3 were sampled in 2005. T1: Blue mussels transplanted 2004 and 2005 to the pier, were sampled at station AMI1 on NE Amitsoq Island. Arctic char were caught near the lichen station 9 close to the waterfall.

Blue mussel

Two size groups of mussels were collected at each station with the following size groups represented: M1 (3-5 and 6-7 cm); M2 (3-4 and 5-8 cm); M3 (3-5 and 6-8 cm); M4 (3-5 and 5-7 cm). Average shell length was calculated for each size group at each station (see Appendix 2). All mussels in a sample were opened, the soft parts cut free and the resulting sample was frozen. Blue mussels transplanted in 2004 from north-western Amitsoq Island to the barge in the harbour area, T1 (4-6 and 6-7 cm), were collected for analyses. Of these about half were dead. New mussels from Amitsoq Island replaced those retrieved for analyses. Other mussels (5-6 cm) from Amitsoq Island, AMI1, were collected for analyses of the background level. Mussels were primarily transplanted to secure that there were mussels available in the harbour area for monitoring, but they can also give information about the annual accumulation rate of the elements analysed.

Brown seaweed

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

Shorthorn sculpin

Shorthorn sculpins were jigged for at two stations, U2 and U3. Sculpins at U2 were caught from the barge while sculpins at U3 were caught from a motor boat. In total 20 sculpins were caught; eight shorthorn sculpins and four other sculpin species were from station U3, and seven shorthorns and one Arctic staghorn sculpin *Gymnacanthus tricuspis* from U2. All sculpins were frozen as whole fish. Only shorthorn sculpins were analysed except for the one Arctic staghorn sculpin.

Arctic char

A total of 12 Arctic char were fished in the Kirkespir River in the first pool downstream from the waterfall. Both resident (4) and migratory (8) forms of Arctic char were caught, but only the resident form was analysed. All Arctic char were frozen as whole fish. It was recommended by J. B. Andersen (*pers. comm.*) that resident char should be caught in June were the migratory form has left the river.

Lichens, Cetraria nivalis

Lichens were sampled at 20 stations: Ten from the Kirkespir Valley downstream the camp, three stations in the camp area, two upstream of the camp, four in the Kirkespir Bay area and one at Amitsoq.

2.2 Analyses

Species and elements

All samples were delivered frozen or dry to NERI on 8 September 2005 by J. B. Andersen, NGM. The analyses were performed according to the "Prøvningsrapport nr. 77" (Asmund 2005). A total of 59 samples from Blue mussel (11), Brown seaweed (8), livers of Shorthorn sculpin (16), livers of Arctic char (4) and the lichen *Cetraria nivalis* (20) were analysed for the following 12 elements: Mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), selenium (Se), cobalt (Co), molybdenum (Mo) and gold (Au).

Methods

Samples were opened in suprapur nitric acid under pressure in Teflon bombs in a microwave oven. The samples where then diluted to c. 25 grams and all elements were analysed in an ICP-MS (an accredited method according to DANAK, accreditation No. 411). Hg, Co, Mo and Au are not included in the accredited method No. 411. Simultaneously with the Nalunaq samples the reference materials Dorm, Dolt-3 and Tort were analysed. In Table 1 the analytical results are compared to the certificates. In general the ICP-MS analytical results are close to those of the certificates. Two obviously contaminated samples were excluded from the data treatment.

Table 1. ICP-MS analytical results of reference material (Dorm, Dolt-3 and Tort) compared to the certificates. Twelve different elements are analysed. Concentrations are in mg/kg. SD: Standard deviation.

	% dry matter	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limit		0.008	0.007	0.012	1.3	0.14	0.02	0.03	0.10	0.26	0.007	0.053	0.004
Dorm	95.11	3.936	0.037	0.026	23.8	2.03	38.13	18.16	17.83	1.42	0.176	0.15	<0.004
Dorm	95.11	3.777	0.051	0.470*	23.6	2.16	28.58	15.56	15.88	1.44	0.165	0.33	0.002
mean		**3.857**	**0.044**	**0.248**	**23.7**	**2.09**	**33.36**	**16.86**	**16.85**	**1.43**	**0.171**	**0.24**	**<0.004**
SD		0.056	0.005		0.066	0.045	3.376	0.919	0.689	0.008	0.004	0.065	0.002
Certificate		4.64	0.043	0.065	25.6	2.34	34.70	19.40	18.00	1.40	0.182		
*95% confidence***		0.26	0.008	0.007	2.3	0.16	5.5	3.1	1.1	0.09	0.031		
Dolt-3	87.61	3.306	19.076	0.313	99.6	36.15	6.34	3.32	9.96	7.52	0.314	3.48	<0.004
Dolt-3	87.61	3.103	18.605	0.248	91.0	31.94	3.35	2.06	9.60	6.30	0.298	3.52	0.019
Dolt-3	87.61	3.226	18.436	7.370*	94.7	33.10	4.18	2.48	9.26	7.04	0.294	4.08	<0.004
Mean		**3.212**	**18.706**	**2.644**	**95.1**	**33.73**	**4.63**	**2.62**	**9.61**	**6.95**	**0.302**	**3.69**	**0.007**
SD		0.102	0.331	0.046	4.341	2.176	1.547	0.641	0.350	0.613	0.010	0.333	0.010
Certificate		3.370	19.400	0.319	88.6	31.20		2.72	10.20	7.06			
*95% confidence***		0.14	0.6	0.045	2.4	1.0		0.35	0.5	0.48			
Tort	91.02	0.261	27.809	0.316	201.0	118.69	2.28	3.15	23.39	6.48	0.622	0.96	0.062
Tort	91.02	0.255	26.020	0.215	185.3	115.39	0.96	2.49	21.79	5.41	0.537	1.18	0.024
Tort	91.02	0.290	23.919	0.226	169.5	98.09	0.80	2.17	19.79	5.36	0.506	1.13	0.011
mean		**0.268**	**25.916**	**0.252**	**185.2**	**110.72**	**1.35**	**2.61**	**21.66**	**5.75**	**0.555**	**1.09**	**0.032**
SD		0.019	1.947	0.055	15.742	11.066	0.813	0.501	1.802	0.629	0.060	0.113	0.027
Certificate		0.270	26.70	0.35	180.0	106.0	0.77	2.50	21.60	5.63	0.510	0.95	
*95% confidence***		0.06	0.6	0.13	6	10	0.15	0.19	1.8	0.67	0.09		

*Obviously a contaminated sample. This result is not included in the data treatment.
** 95% confidence for the certificate.

Statistics

Concentrations of Zn, Cu, Cr and Co in seaweed collected in 2005 at the four marine stations in Kirkespir Bay were compared to background concentrations from seaweed collected at the same stations during the baseline study performed in 2000 and 2001. Thereby local variations were omitted. At each station data were log transformed to obtain normal distribution and means were tested with a t-test. Data used are shown in Appendix 4.

3 Results and evaluation

3.1 Overview of entire area

Overview of the entire area - average concentrations

The analytical results are given in Appendix 3. To present an overview of the results, average concentrations of the 12 elements in all five sample types are given in Table 2. The average concentrations are compared to background concentrations found in the same area prior to the mine start (Glahder et al. 2005).

Table 2. Average element concentrations in biota from the Nalunaq area
The table includes concentrations from samples collected during the monitoring studies 2005 and 2004 and the background studies. Figures are given in mg/kg dry weight (mussels, seaweed and *Cetraria nivalis*) and mg/kg wet weight (sculpins and chars). Av: Average, SD: Standard deviation.

		Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limit		*0.008*	*0.007*	*0.012*	*1.3*	*0.14*	*0.02*	*0.03*	*0.10*	*0.26*	*0.007*	*0.053*	*0.004*
Blue mussels *Mytilus edulis*													
Monitoring 2005	Av	0.052	2.51	0.460	82.5	7.75	0.83	1.33	12.97	3.63	0.464	0.471	0.018
	SD	0.018	1.287	0.139	17.2	1.25	0.32	0.44	2.54	0.90	0.140	0.121	0.007
Monitoring 2004	Av	0.093	2.63	0.725	84.95	9.58	1.30	1.99	12.60	4.365	**0.562**		
	SD	0.022	1.22	0.263	19.92	1.82	0.41	0.52	2.60	0.679	0.133		
Background	Av	0.131	5.49	1.195	87.82	7.58	0.73		11.80		0.239		
	SD	0.025	1.97	0.365	16.42	1.08	0.28		1.59		0.053		
Brown seaweed *Fucus vesiculosus*													
Monitoring 2005	Av	<0.008	0.824	0.050	13.5	2.02	0.16	1.39	38.88	0.38	0.414	0.053	0.016
	SD	0.004	0.277	0.020	4.6	1.92	0.09	0.28	5.46	0.16	0.200	0.022	0.006
Monitoring 2004	Av	0.009	1.05	0.158	**21.07**	***7.30***	***0.89***	2.06	52.69	0.379	**0.713**		
	SD	0.003	0.23	0.091	6.29	3.29	0.75	0.80	8.85	0.184	0.369		
Background	Av	0.01	1.77	0.105	7.57	1.04	0.11		47.55		0.209		
	SD	0.008	0.51	0.039	2.38	0.24	0.12		8.47		0.045		
Lichen ***Cetraria nivalis***													
Monitoring 2005	Av	0.002	0.055	0.784	15.0	**2.02**	1.12	0.87	**1.34**	<0.26	**0.461**	<0.053	<0.004
	SD	0.009	0.032	0.364	5.8	1.81	1.14	0.79	1.35	0.09	0.461	0.016	0.006
Monitoring 2004	Av	0.028	0.074	1.116	13.42	**2.86**	**1.64**	1.59	**1.01**	0.082	**0.527**		
	SD	0.009	0.026	0.549	5.13	1.56	1.05	1.00	1.32	0.034	0.469		
Background	Av	0.033	0.081	1.076	21.61	0.97	0.68		0.24		0.157		
	SD	0.006	0.029	0.378	7.28	0.77	1.22		0.27		0.157		
Shorthorn sculpin *Myoxocephalus scorpius* **liver**													
Monitoring 2005	Av	0.016	0.496	<0.012	35.8	2.28	<0.02	<0.03	3.45	0.90	0.037	0.058	0.004
	SD	0.009	0.401	0.005	13.6	3.22	0.01	0.01	1.92	0.22	0.033	0.051	0.004
Monitoring 2004	Av	0.018	0.526	0.0050	21.85	2.30	**0.065**	0.053	2.58	0.632	0.038		
	SD	0.010	0.304	0.0030	6.13	2.80	0.026	0.035	1.34	0.129	0.040		
Background	Av	0.028	1.041	0.0045	32.14	1.80	0.016		3.23		0.021		
	SD	0.013	0.404	0.0037	1.64	0.66	0.019		2.07		0.017		
Arctic char *Salvelinus alpinus* **liver**													
Monitoring 2005	Av	0.035	0.259	<0.012	35.5	5.42	<0.02	<0.03	1.34	1.41	0.051	0.094	<0.004
	SD	0.025	0.220	0.006	11.5	7.63	0.01	0.15	0.94	1.05	0.044	0.057	0.001
Monitoring 2004	Av	0.03	0.107	0.0079	21.24	12.32	**0.063**	0.188	0.24	2.780	**0.114**		
	SD	0.01	0.042	0.0051	5.87	9.29	0.013	0.087	0.11	1.497	0.043		
Background	Av	0.025	0.077	0.0057	34.88	8.72	0.025		0.45		0.041		
	SD	0.009	0.026	0.0023	6.13	10.22	0.022		0.13		0.013		

Three categories

We have grouped the average concentrations in three categories:

Not elevated	<2 times background	Normal fond
Slightly elevated	2-5 times background	**Bold fond**
Elevated	>5-10 times background	**Bold *italics* fond**

Significant difference

All average concentrations marked with bold in Table 2 are significantly higher than background concentrations at a 98% confidence level (students t-test), except for Cr in seaweed where the confidence level is 95%. Average concentrations of Cd and As in Arctic char liver from 2005 seem to be about three times above the background concentrations, but these elevations are not significant. It is recommended to double the number of resident Arctic char samples in 2006 to eight specimens to improve the statistical basis.

Comparisons between the 2005 and 2004 monitoring studies

In the present 2005 monitoring study only slightly elevated average concentrations were found in lichens. In lichens, Cu, As and Co was elevated 2-5 times compared to the background concentrations (Table 2). None of the remainder average concentrations of the analysed elements in any of the organisms were elevated.

When the results from this 2005 monitoring study are compared to the monitoring study performed in 2004, only three elements (Cu, As and Co) show elevated average concentrations compared to five (Cu, As, Co, Zn and Cr) in 2004, elevations are in general lower in 2005, and there are no elevated average concentrations in 2005 in the marine environment. In 2004, seaweed had elevated concentrations of Zn, Cu, Cr and Co, sculpin liver had elevated Cr concentrations and mussels had elevated Co concentrations. In the terrestrial and freshwater environments, slightly elevated Cr concentrations were also found in lichens and Arctic char in 2004, but not in 2005.

The 2005 monitoring study compared to baseline studies in 1998-1999

According to the Nalunaq I/S Environmental Baseline Study, 1998-1999, freshwater and sediment samples from the Kirkespir River and drainage from ore and waste rock dumps were analysed for metal concentrations prior to adit (tunnel) driving and mining. Freshwater samples were compared to ”Ontario Provincial Water Quality Objectives” (Ontario PWQO) for surface waters (http://www. testmark. ca/w_obj.htm of 13/12/2005, Glahder & Asmund 2000, Lakefield Research Ltd 1998a,b, 1999a-d). Freshwater samples had slightly elevated natural concentrations of Co and aluminium (Al), and sediments had slightly elevated to elevated natural concentrations of As. Drainage from ore and waste rock had slightly elevated concentrations of As, Cd, Pb and Zn, and elevated concentrations of Al, Co, Cu and Hg.

In the present study, copper, arsenic and cobalt were found slightly elevated in lichens. These elements were also slightly elevated or elevated in drainage from ore and waste rock analysed in the Nalunaq I/S Environmental Baseline Study. Dust from ore and waste rock are therefor also expected to contain elevated concentrations of these elements.

3.2 Concentrations in specific areas

Elevated concentrations in different environments

Following the above general overview a more thorough assessment is presented on element concentrations in the marine environment in the Kirkespir Bay, in the Kirkespir River and in the terrestrial environment of the Kirkespir Valley (Fig. 1). Element concentrations at the different stations will be evaluated. Reference is made to Appendix 3 and 4.

The marine environment

Samples in the Kirkespir Bay were collected at five mussel stations (M1-4 and T1), four seaweed stations (M1-4) and two sculpin stations (U2 and U3) (Fig. 1). In *Blue mussel,* only concentrations of Co were slightly higher at M2 and M3, but not significantly different from the background concentration. At station T1 the mussels transplanted from northern Amitsoq Island (AMI1) in 2004 had low concentrations of all elements, but the level was in general higher than that found in mussels from AMI1. *Brown seaweed* from station M2 had slightly elevated concentrations of Zn (2.5 times, t-test, $p=0.0004$, $t=-11.21$, $df=4$) and Co (2 times, t-test, $p=0.0013$, $t=-7.97$, $df=4$). Seaweed from station M3 had elevated concentrations of Cr (9.5 times, t-test, $p=0.012$, $t=-4.37$, $df=4$) and slightly elevated concentrations of Zn (2.8 times, t-test, $p=0.0002$, $t=-12.39$, $df=4$) and Co (2.5 times, t-test, $p=0.024$, $t=-3.56$, $df=4$). Seaweed sampled at station M4 had slightly elevated concentrations of Zn (2 times, t-test, $p=0.016$, $t=-4.03$, $df=4$). No elevated concentrations were found in *sculpin livers* from the two stations.

Possible sources

Elevated concentrations of Cr and slightly elevated concentrations of Zn and Co were found in brown seaweed from station M3 near the mouth of Kirkespir River and slightly elevated concentrations of Zn and Co were found in brown seaweed from station M2 close to the pier area. This indicates that contamination of the marine environment comes from both the mining area (e.g. mine water and ore crushing) and the pier area (ore stockpiling and loading). Dust from the road, maintained primarily by waste rock material, and from the mining area, can also contribute to elevated concentrations; refer to "The terrestrial environment of the Kirkespir Valley".

Affected coastal area

Of the two stations situated at the mouth of the Kirkespir Bay (M1 and M4), only seaweed from M4 had slightly elevated concentrations of Zn. This gives an indication of the extension of the coastal pollution. The length of coastline with slightly elevated element concentrations can roughly be estimated to about 5 km.

The Kirkespir River environment

Resident Arctic char had no elevated element concentrations in their liver, see Table 2. Resident Arctic char stay all their life in the river, whereas the migratory form summers in the Kirkespir Bay and Saqqaa Fjord.

The terrestrial environment of the Kirkespir Valley

The 19 lichen stations in the Kirkespir Valley and Bay area had on average 2-5 times higher concentrations of Cu (2 times), As (5) and Co (3) compared to background levels (Table 2).

If single lichen stations are considered, there are, like in 2004 (Glahder & Asmund 2005), three areas with up to 5-16 times higher concentrations of Cu (6 times), Cr (5), As (16) and Co (9). These areas are the pier area (station M2), the lower waterfall area (stations 6-8) and the camp area (stations 10-12) (Fig. 2a).

In the monitoring report from 2004 (Glahder & Asmund 2005) the elevated concentrations in the three areas were explained by the dispersal of dust from stockpiles in the pier and camp areas. The high concentrations in the waterfall area were difficult to explain, but they could be an effect of dust carried by the wind from the stockpiles in the camp area. Subsequently, Nalunaq Gold Mine A/S argued that elevations in all three areas probably were an effect of the distance from the lichen stations to the gravel road.

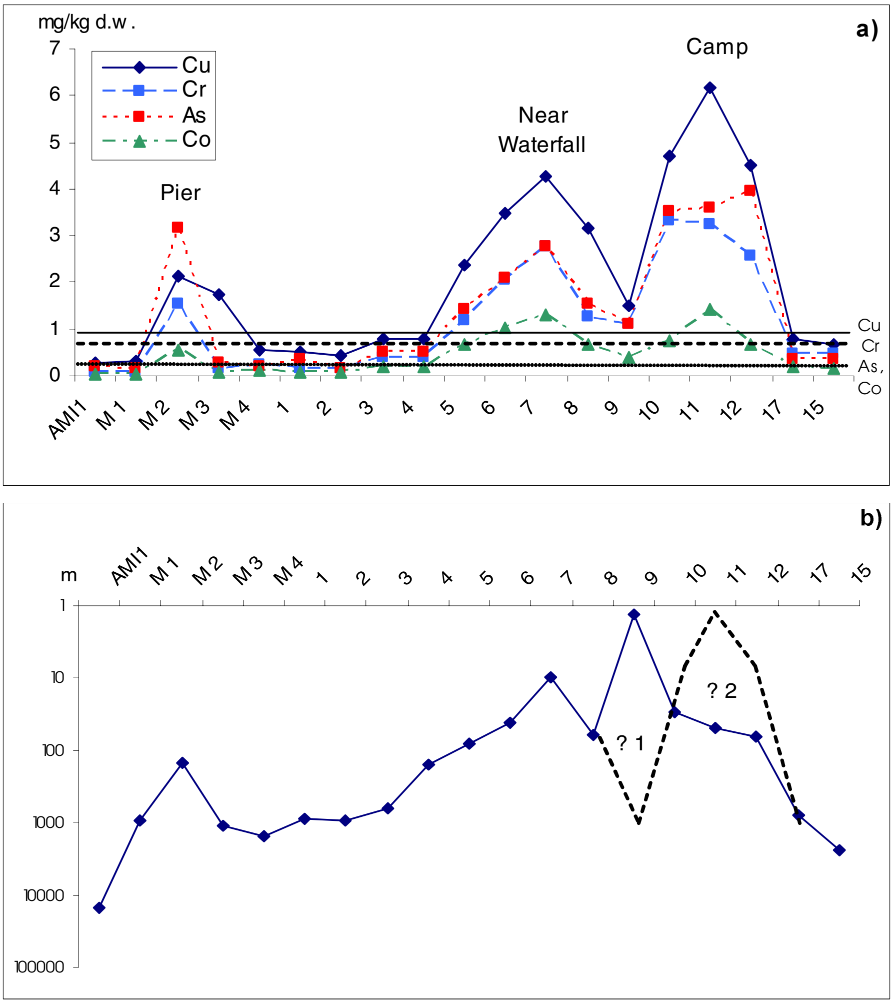

Figure 2. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis*.
For localisation of lichen stations see Fig. 1. M1-M4 are stations in the Kirkespir Bay area, stations 1-17 are situated in the Kirkespir Valley from coast (1) to up-stream camp area (17). Horizontal lines in Fig 2a indicate average background concentrations of the four metals (Refer to Table 2). d.w. = dry weight. Fig. 2 b shows distances (in meter) from road to stations. Broken line indicates distances expected from concentrations in Fig 2a. Expectations are according to the hypothesis : Inverse correlation between distance to road and lichen element concentration. ? 1 and 2: see text.

We have tested that hypothesis for copper, chromium, arsenic and cobalt (Fig. 3). The figures show that concentrations of all four elements are inversely correlated to distances to the road. We have omitted station 9 from the figures (Fig. 3) because concentrations were exceptionally low for lichens sampled only 1 meter from the road ("? 1" in Fig. 2 b). We have no explanation of this apparent mismatch. Stations 10-12 (camp area) have for all elements higher concentrations than expected from hypothesis tested (Fig. 3, "? 2" in Fig 2 b).

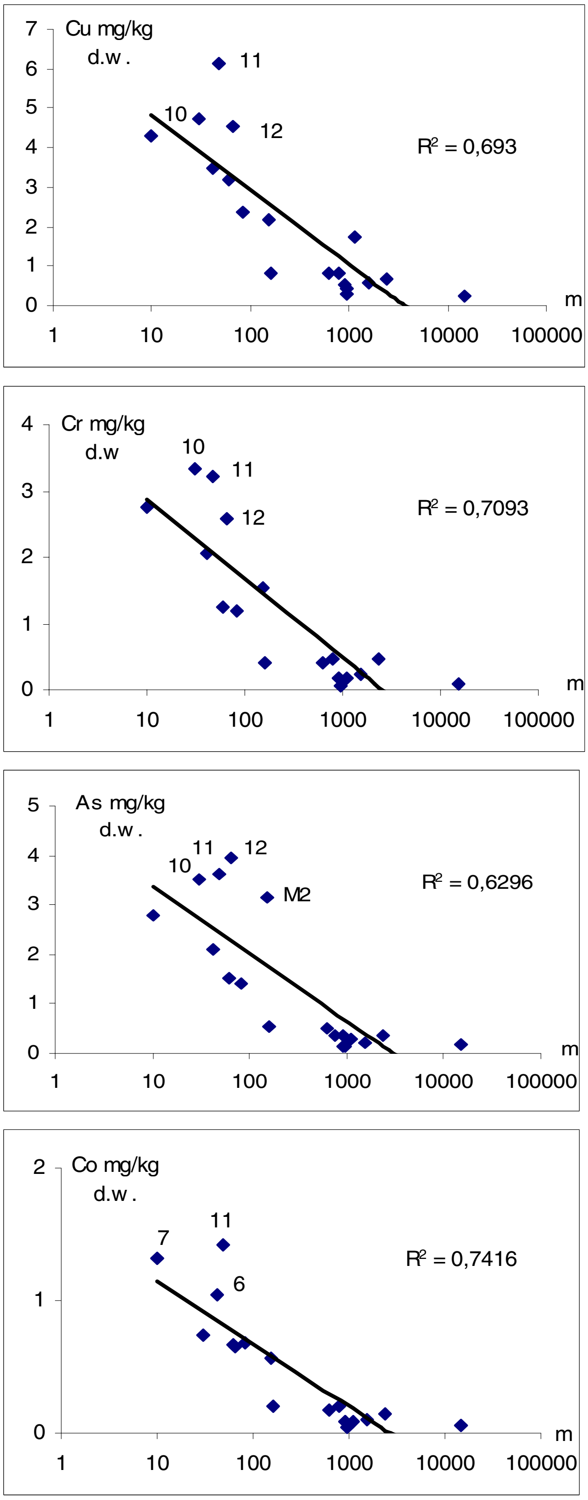

Figure 3. Concentrations of copper (Cu), chromium (Cr), arsenic (As) and cobalt (Co) in the lichen *Cetraria nivalis* as a function of station's distance to the gravel road (in meter). d.w. = dry weight.
Stations with concentrations well above the trend line are shown with their number (Fig. 1). Station 9 is omitted from the figures, see to text for explanation.

It is therefore concluded that the elevated concentrations of copper, chromium, arsenic and cobalt in the lichen *Cetraria nivalis* are an effect of dust from the road, and concentrations above the background level can be found at a distance of about 1000 m from the road. An additional contribution to the concentrations comes from the camp area, probably from the ore crusher and mine traffic.

4 Conclusions

Entire area overview: Less contamination in 2005 compared to 2004

In this 2005 monitoring study slightly elevated (2-5 times) average concentrations of Cu, As and Co were found in lichens only. None of the remainder average concentrations of the analysed elements in any of the organisms were elevated. An overview of the contamination of the entire area is presented by average concentrations, while contaminations of specific areas are presented by concentrations at single stations.

Compared to the monitoring study conducted in 2004, only three elements (Cu, As, Co) showed elevated average concentrations compared to five (Cu, As, Co, Zn and Cr) in 2004. Elevations were in general lower in 2005, and in 2005 there were no elevated average concentrations in the marine environment.

Specific areas: Marine environment slightly impacted from mine and pier areas

Elevated concentrations of Cr (9 times) were found in brown seaweed from station M3 near the mouth of Kirkespir River, and slightly elevated concentrations (2 times) of Zn and Co were found in seaweed from both station M3 and M2 close to the pier. This indicates that impacts come from both the mining area (e.g. mine water and rock crushing) and the pier area (ore stockpiling and loading). Also, slightly elevated concentrations (2 times) of Zn were found in seaweed from station M4. Dust from the road, maintained primarily by waste rock material, and from the mining area can also contribute to elevated concentrations. No elevated concentrations were found in sculpin liver.

Specific areas: Freshwater environment

Resident Arctic char had no elevated element concentrations in their liver.

Specific areas: Terrestrial environment impacted through dust from road and mine area

In the Kirkespir Valley and Bay area, 5-16 times higher concentrations of Cu, Cr, As and Co in lichens were found in the pier, the waterfall and the camp areas. An identical picture was found in 2004 except for As which was elevated 16 times compared to 9 times in 2004 in the camp area. Elevated concentrations of the four elements in lichens were in most of the Kirkespir Valley an effect of dust from the road, and concentrations above the background level could be found at a distance of about 1000 m from the road. An additional contribution to the concentrations came from the camp area, probably from the rock crusher, from stockpiled fine-ground rock and from mine traffic.

Moderate local pollution

As in 2004, there is an impact from the mine on the local environment. Slightly elevated concentrations are found within c. 5 km of coastline near the mouth of the Kirkespir River. Compared to 2004 the impacted marine area is smaller. This could be an effect of stockpiled fine-ground ore that was removed from the area and shipped to Spain late 2003 and mid 2004. The Kirkespir Valley floor is impacted mainly from dust from the road, but also from mine activities. Element concentrations in 2005 were similar to 2004, except for arsenic in the camp area where the level was doubled.

Possible actions

Prevention of dust from road and camp areas should be discussed with Nalunaq Gold Mine. It is recommended that waste rock is used for road maintenance only if element analyses of fine-ground waste rock show no significant differences from fine-ground rock from existing approved quarries. Dust from the road can be reduced by watering the road during dry periods.

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Appendix 1. Samples and stations

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
34035	Lichen	Cetraria nivalis	20050831	1	60	19′34′′	44	55′22′′
34036	Lichen	Cetraria nivalis	20050831	2	60	19′38′′	44	54′40′′
34008	Lichen	Cetraria nivalis	20050816	3	60	19′35′′	44	54′10′′
34007	Lichen	Cetraria nivalis	20050816	4	60	19′43′′	44	53′38′′
34006	Lichen	Cetraria nivalis	20050816	5	60	19′57′′	44	52′48′′
34005	Lichen	Cetraria nivalis	20050816	6	60	20′10′′	44	52′18′′
34003	Lichen	Cetraria nivalis	20050810	7	60	20′32′′	44	51′37′′
34004	Lichen	Cetraria nivalis	20040810	8	60	20′44′′	44	51′07′′
34040	Lichen	Cetraria nivalis	20050901	9	60	20′49′′	44	50′14′′
34041	Lichen	Cetraria cucullata	20050901	10	60	20′51′′	44	49′58′′
34038	Lichen	Cetraria nivalis	20050906	11	60	21′17′′	44	49′57′′
34042	Lichen	Cetraria cucullata	20050830	12	60	21′28′′	44	49′49′′
34002	Lichen	Cetraria nivalis	20050810	15	60	22′43′′	44	49′08′′
34037	Lichen	Cetraria nivalis	20050830	17	60	21′59′′	44	49′52′′
34001	Lichen	Cetraria cucullata	20050810	19	60	22′30′′	44	49′31′′
34031	Lichen	Cetraria nivalis	20050823	M 1	60	18′41′′	44	58′01′′
34032	Lichen	Cetraria nivalis	20050822	M 2	60	18′46′′	44	56′47′′
34033	Lichen	Cetraria nivalis	20050819	M 3	60	19′29′′	44	56′15′′
34034	Lichen	Cetraria nivalis	20050821	M 4	60	19′35′′	44	57′37′′
34039	Lichen	Cetraria nivalis	20050903	AMI 1	60	26′20′′	44	57′04′′
34023	Brown seaweed	Fucus vesiculosus	20050823	M 1	60	18′41′′	44	58′01′′
34024	Brown seaweed	Fucus vesiculosus	20050823	M 1	60	18′41′′	44	58′01′′
34019	Brown seaweed	Fucus vesiculosus	20050822	M 2	60	18′46′′	44	56′47′′
34020	Brown seaweed	Fucus vesiculosus	20050822	M 2	60	18′46′′	44	56′47′′
34009	Brown seaweed	Fucus vesiculosus	20050819	M 3	60	19′29′′	44	56′15′′
34010	Brown seaweed	Fucus vesiculosus	20050819	M 3	60	19′29′′	44	56′15′′
34015	Brown seaweed	Fucus vesiculosus	20050821	M 4	60	19′35′′	44	57′37′′
34016	Brown seaweed	Fucus vesiculosus	20050821	M 4	60	19′35′′	44	57′37′′
33875	Arctic staghorn sculpin	Gymnacanthus tricuspis	20050904	U 2	60	18′45′′	44	56′46′′
33876	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33877	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33878	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33879	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33880	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33881	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33882	Shorthorn sculpin	Myoxocephalus scorpius	20050904	U 2	60	18′45′′	44	56′46′′
33867	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33868	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33869	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33870	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33871	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33872	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33873	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
33874	Shorthorn sculpin	Myoxocephalus scorpius	20050812	U 3	60	19′31′′	44	56′53′′
34021	Blue mussel	Mytilus edulis	20050823	M 1	60	18′41′′	44	58′01′′
34022	Blue mussel	Mytilus edulis	20050823	M 1	60	18′41′′	44	58′01′′
34017	Blue mussel	Mytilus edulis	20050821	M 2	60	18′46′′	44	56′47′′

ID-No	Sample type	Latin name	Collection date	Station	Lat deg *)	Lat min and sec *)	Long deg *)	Long min and sec *)
34018	Blue mussel	Mytilus edulis	20050822	M 2	60	18′46′′	44	56′47′′
34011	Blue mussel	Mytilus edulis	20050819	M 3	60	19′29′′	44	56′15′′
34012	Blue mussel	Mytilus edulis	20050819	M 3	60	19′29′′	44	56′15′′
34013	Blue mussel	Mytilus edulis	20050821	M 4	60	19′35′′	44	57′37′′
34014	Blue mussel	Mytilus edulis	20050821	M 4	60	19′35′′	44	57′37′′
34027	Blue mussel	Mytilus edulis	20050903	AMI 1	60	26′20′′	44	57′04′′
34025	Blue mussel	Mytilus edulis	20050903	T 1	60	18′51′′	44	56′57′′
34026	Blue mussel	Mytilus edulis	20050903	T 1	60	18′51′′	44	56′57′′
33883	Arctic char	Salvelinus alpinus	20050905	Near waterfall	60	20′47′′	44	50′32′′
33884	Arctic char	Salvelinus alpinus	20050905	Near waterfall	60	20′47′′	44	50′32′′
33885	Arctic char	Salvelinus alpinus	20050905	Near waterfall	60	20′47′′	44	50′32′′
33886	Arctic char	Salvelinus alpinus	20050905	Near waterfall	60	20′47′′	44	50′32′′

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

Appendix 2. Blue mussel average shell lengths

Station	Average length (cm, in bold) in different size groups including standard deviation and number							
	3-4	3-5	4-6	5-6	5-7	5-8	6-7	6-8
M1		**3.85** 0.36;30					**6.45** 0.29;20	
M2	**3.55** 0.29;33					**6.09** 0.68;20		
M3		**4.00** 0.45;30						**6.91** 0.56;15
M4		**3.88** 0.51;30			**5.94** 0.41;20			
AMI1				**5.40** 0.31;23				
T1			**5.24** 0.41;14				**6.46** 0.30;16	

Appendix 3. Chemical analyses

Concentrations are given in mg/kg d.w. (mussels, seaweed and *Cetraria nivalis*) and mg/kg w.w. (sculpins and chars).

ID no.	Lab no	% dry matter	Species	Shell (cm)	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limits						*0.008*	*0.007*	*0.012*	*1.25*	*0.14*	*0.018*	*0.030*	*0.10*	*0.26*	*0.007*	*0.05*	*0.004*
34021	2048	17.22	Myt. edu.	3-5	M 1	0.053	1.349	0.344	88.80	7.03	0.491	1.813	13.15	3.58	0.417	0.49	0.011
34022	2049	19.75	Myt. edu.	6-7	M 1	0.039	1.436	0.313	68.86	5.84	0.413	1.041	10.20	2.37	0.297	0.38	0.009
34017	2045	17.29	Myt. edu.	3-4	M 2	0.058	1.616	0.509	95.36	9.16	1.233	1.745	16.04	4.34	0.619	0.53	0.021
34017	2046	17.29	Myt. edu.	3-4	M 2	0.061	1.589	0.501	93.20	8.81	1.241	1.729	15.38	4.41	0.604	0.51	0.018
34018	2047	18.24	Myt. edu.	5-8	M 2	0.054	2.288	0.517	82.24	7.66	0.845	1.327	12.74	3.28	0.445	0.42	0.018
34011	2039	16.37	Myt. edu.	3-5	M 3	0.045	2.013	0.387	84.87	9.40	0.953	1.740	15.57	4.96	0.641	0.45	0.025
34011	2040	16.37	Myt. edu.	3-5	M 3	0.058	2.088	0.395	86.60	9.76	0.992	1.792	15.96	4.90	0.658	0.49	0.021
34012	2041	16.52	Myt. edu.	6-8	M 3	0.086	5.187	0.732	59.24	7.01	1.027	1.346	14.73	3.42	0.518	0.71	0.036
34012	2041	16.52	Myt. edu.	6-8	M 3	0.088	5.272	0.748	60.62	7.05	1.069	1.522	14.96	4.03	0.525	0.74	0.023
34013	2042	20.47	Myt. edu.	3-5	M 4	0.028	2.300	0.371	89.76	8.81	1.130	1.486	12.70	4.39	0.511	0.40	0.017
34014	2043	21.86	Myt. edu.	5-7	M 4	0.023	2.516	0.397	71.46	7.47	0.923	1.096	10.57	3.15	0.407	0.38	0.013
34025	2050	17.86	Myt. edu.	5-6	T 1	0.053	2.358	0.453	126.68	7.77	0.506	0.683	10.86	3.11	0.313	0.38	0.014
34026	2051	21.46	Myt. edu.	6-7	T 1	0.044	3.588	0.482	75.54	6.38	0.426	0.559	8.36	2.23	0.269	0.35	0.012
34027	2052	20.44	Myt. edu.	5-6	AMI 1	0.041	1.571	0.291	72.23	6.32	0.359	0.718	10.35	2.61	0.271	0.37	0.010
34023	2030	100	Fuc. ves.		M 1	-0.009	0.996	0.043	7.16	0.90	0.067	1.033	32.74	0.25	0.220	0.04	0.030
34023	2030	100	Fuc. ves.		M 1	-0.004	0.946	0.045	7.08	0.89	0.091	1.054	32.44	0.16	0.229	0.05	0.019
34024	2032	100	Fuc. ves.		M 1	-0.003	1.060	0.049	8.47	1.01	0.101	1.095	36.70	0.42	0.258	0.05	0.016
34019	2033	100	Fuc. ves.		M 2	-0.009	0.486	0.090	17.58	7.05	0.252	1.484	36.06	0.24	0.468	0.03	0.014
34020	2034	100	Fuc. ves.		M 2	0.003	0.479	0.065	17.35	1.62	0.222	1.434	35.90	0.31	0.448	0.03	0.012
34009	2035	100	Fuc. ves.		M 3	-0.011	0.511	0.060	18.45	1.60	0.196	1.564	40.79	0.36	0.464	0.05	0.015
34010	2036	100	Fuc. ves.		M 3	-0.008	0.709	0.038	15.55	2.01	0.324	1.894	48.42	0.54	0.878	0.05	0.018
34015	2037	100	Fuc. ves.		M 4	-0.003	1.108	0.036	14.70	1.55	0.107	1.437	44.27	0.61	0.391	0.10	0.015
34016	2038	100	Fuc. ves.		M 4	-0.009	1.118	0.021	15.47	1.59	0.099	1.470	42.59	0.55	0.375	0.08	0.010
34031	2070		Cet. niv.		M 1	-0.005	0.056	0.494	9.05	0.31	0.068	0.101	0.16	-0.27	0.049	-0.02	-0.002
34032	2071		Cet. niv.		M 2	0.013	0.061	0.752	16.33	2.15	1.523	1.039	3.15	-0.21	0.566	0.00	0.014
34033	2072		Cet. niv.		M 3	-0.004	0.042	0.579	16.29	1.72	0.161	0.286	0.28	-0.25	0.091	-0.02	-0.003
34034	2073		Cet. niv.		M 4	0.003	0.052	0.610	30.97	0.56	0.224	0.209	0.22	-0.50	0.103	-0.01	-0.005
34039	2076		Cet. niv.		AMI 1	0.005	0.038	0.376	6.63	0.26	0.074	0.099	0.15	-0.22	0.046	-0.01	-0.005
34039	2076		Cet. niv.		AMI 1	0.003	0.036	0.349	13.02	0.27	0.089	0.145	0.22	-0.20	0.056	0.01	-0.004
34035	2053		Cet. niv.		1	0.006	0.058	0.699	14.62	0.51	0.162	0.199	0.35	-0.28	0.091	-0.03	-0.004
34036	2054		Cet. niv.		2	-0.011	0.038	0.308	13.60	0.44	0.176	0.212	0.15	-0.29	0.080	-0.05	-0.007
34008	2055		Cet. niv.		3	0.011	0.053	0.577	21.43	0.80	0.398	0.431	0.51	-0.43	0.181	-0.01	0.004
34007	2056		Cet. niv.		4	0.004	0.035	0.600	18.18	0.80	0.411	0.415	0.53	-0.33	0.202	-0.02	0.001
34006	2057		Cet. niv.		5	-0.013	0.083	1.201	15.49	2.38	1.187	1.173	1.41	-0.32	0.684	-0.02	0.002
34005	2058		Cet. niv.		6	-0.007	0.066	1.070	18.32	3.47	2.053	1.893	2.11	-0.33	1.038	-0.02	0.009
34003	2060		Cet. niv.		7	0.014	0.071	1.337	16.12	4.02	2.658	2.133	2.96	-0.30	1.277	0.00	0.001
34003	2061		Cet. niv.		7	0.007	0.073	1.516	18.30	4.53	2.842	2.329	2.60	-0.10	1.356	-0.01	0.004
34004	2062		Cet. niv.		8	0.015	0.041	0.978	15.77	3.18	1.260	1.336	1.52	-0.28	0.667	-0.02	0.002
34040	2063		Cet. niv.		9	0.018	0.052	1.068	7.48	1.50	1.121	0.742	1.13	-0.27	0.400	-0.02	-0.002
34041	2064		Cet. cuc.		10	-0.005	0.041	0.759	11.61	4.72	3.330	1.436	3.51	-0.09	0.741	0.02	-0.001
34038	2065		Cet. niv.		11	-0.010	0.179	1.499	16.23	6.15	3.227	2.558	3.62	-0.28	1.426	0.00	0.001
34042	2066		Cet. cuc.		12	-0.010	0.038	0.737	8.58	4.52	2.584	1.376	3.94	-0.17	0.655	0.00	0.011
34002	2067		Cet. niv.		15	0.007	0.035	0.716	9.58	0.69	0.467	0.318	0.37	-0.32	0.138	-0.01	-0.003
34037	2068		Cet. niv.		17	0.001	0.052	0.697	24.02	0.80	0.470	0.431	0.37	-0.14	0.209	-0.02	-0.004
34001	2069		Cet. cuc.		19	0.000	0.016	0.315	9.41	0.71	0.229	0.212	0.25	-0.24	0.086	-0.03	-0.004
33875	2009	48.15	Gym. tri.		U 2	0.	0.036	0.012	68.98	1.35	0.001	0.016	2.28	0.76	0.019	0.04	0.004
33876	2010	26.87	Myo. sco.		U 2	0.012	0.299	-0.001	34.70	1.18	0.023	0.016	1.59	0.69	0.040	0.05	0.003
33877	2011	27.85	Myo. sco.		U 2	0.018	0.307	-0.003	38.50	1.46	-0.001	0.010	1.70	1.00	0.087	0.05	0.002
33878	2012	34.55	Myo. sco.		U 2	0.002	0.335	0.001	39.23	1.19	0.010	-0.003	1.93	0.90	0.050	0.07	0.002
33879	2013	39.09	Myo. sco.		U 2	0.010	0.224	-0.002	34.87	1.08	0.006	-0.005	1.45	0.65	0.051	0.05	0.000

ID no.	Lab no	% dry matter	Species	Shell (cm)	Station	Hg	Cd	Pb	Zn	Cu	Cr	Ni	As	Se	Co	Mo	Au
Detection limits						*0.008*	*0.007*	*0.012*	*1.25*	*0.14*	*0.018*	*0.030*	*0.10*	*0.26*	*0.007*	*0.05*	*0.004*
33880	2015	40.34	Myo. sco.		U 2	0.015	0.488	-0.008	29.83	1.19	0.008	0.023	2.22	0.65	0.011	0.00	0.000
33880	2016	40.34	Myo. sco.		U 2	0.013	0.468	-0.007	28.77	1.11	-0.002	0.013	2.12	0.62	0.009	0.01	-0.001
33881	2017	15.28	Myo. sco.		U 2	0.027	0.868	-0.006	30.36	0.78	0.011	0.013	8.32	0.94	0.012	0.03	0.000
33882	2018	34.51	Myo. sco.		U 2	0.017	0.319	-0.006	23.99	0.75	0.003	0.004	5.65	0.65	0.011	0.00	0.000
33867	2000	36.49	Myo. sco.		U 3	0.012	0.245	0.001	18.53	1.31	0.024	-0.003	4.52	0.88	0.006	0.06	0.008
33867	2001	36.49	Myo. sco.		U 3	0.005	0.285	0.002	25.01	1.67	0.010	0.007	6.08	1.40	0.012	0.03	0.013
33868	2002	29.7	Myo. sco.		U 3	0.013	0.552	-0.001	32.84	0.95	0.026	0.018	4.03	1.22	0.028	0.03	0.009
33869	2003	35.2	Myo. sco.		U 3	0.022	0.266	-0.002	23.78	1.02	0.001	0.009	4.92	1.07	0.030	0.02	0.006
33870	2004	24.56	Myo. sco.		U 3	0.031	1.806	-0.008	69.36	14.55	0.008	0.010	4.78	1.15	0.119	0.11	0.007
33871	2005	27.69	Myo. sco.		U 3	0.013	0.445	0.001	41.88	3.88	-0.007	-0.014	3.57	0.95	0.034	0.16	0.005
33872	2006	25.31	Myo. sco.		U 3	0.031	1.025	0.004	37.55	4.50	0.000	-0.004	2.17	0.97	0.096	0.15	0.008
33873	2007	31.43	Myo. sco.		U 3	0.023	0.545	-0.006	33.11	1.35	-0.006	-0.004	2.83	0.84	0.032	0.15	0.009
33874	2008	37.5	Myo. sco.		U 3	0.021	0.422	-0.005	33.01	1.69	0.001	0.001	1.90	0.90	0.019	0.05	0.005
33883	2019	24.49	Sal. alp.			0.034	0.614	-0.004	44.84	2.45	0.002	0.003	2.63	1.05	0.025	0.09	0.002
33884	2020	21.44	Sal. alp.			0.006	0.025	0.008	48.76	1.01	0.000	0.009	1.70	0.48	0.013	0.03	0.001
33884	2021	21.44	Sal. alp.			0.017	0.292	-0.008	32.85	1.11	0.017	0.008	1.51	0.44	0.037	0.05	0.001
33885	2022	27.88	Sal. alp.			0.071	0.178	-0.002	30.63	18.94	0.025	-0.215	0.45	2.59	0.052	0.15	0.001
33886	2023	28.32	Sal. alp.			0.046	0.183	-0.002	20.26	3.59	0.020	-0.301	0.40	2.47	0.126	0.15	0.002

d.w. = Dry weight; w.w = Wet weight; Myt. edu. = Blue mussel; Fuc. ves. = Brown seaweed; Cet. niv. = Lichen, *Cetraria nivalis*; Cet. cuc. = Lichen, *Cetraria cucullata*; Gym. tri. = Arctic staghorn sculpin; Myo. sco. = Shorthorn sculpin; Sal. alp. = Arctic char.

Appendix 4. Element concentrations in seaweed in 2000/01 and 2005

Element concentrations in Brown seaweed *Fucus vesiculosis* collected at four marine stations in the Kirkespir Bay during the present monitoring study (2005) and during the baseline study performed in 2000 and 2001. The data were used to calculate statistical differences at single stations between the two sampling periods (refer to t-tests in chapter 2. Methods).

Concentrations are given in mg/kg d.w.

Station	Collection date	ID no.	Hg	Cd	Pb	Zn	Cu	Cr	As	Co
Detection limits			*0.008*	*0.007*	*0.012*	*1.25*	*0.14*	*0.018*	*0.10*	*0.007*
M 1	20000926	23630	0.017	1.851	0.147	5.05	1.09	0.068	44.52	0.164
M 1	20000926	23631	0.006	1.841	0.098	5.22	0.65	0.057	35.44	0.147
M 1	20010930	30205	0.003	1.619	0.092	6.32	0.70	0.022	39.38	0.205
M 1	20010930	30206	0.004	1.832	0.082	5.07	0.74	0.018	44.91	0.198
M 1	20050823	34023	-0.007	0.971	0.044	7.12	0.90	0.079	32.59	0.225
M 1	20050823	34024	-0.003	1.060	0.049	8.47	1.01	0.101	36.70	0.258
M 2	20000926	23632	0.006	0.929	0.189	7.90	0.94	0.088	41.70	0.214
M 2	20000926	23633	0.005	1.081	0.175	7.18	0.87	0.124	41.46	0.205
M 2	20010930	30207	0.004	0.926	0.090	6.11	0.88	0.038	49.64	0.258
M 2	20010930	30208	0.005	1.020	0.068	6.63	0.86	0.028	36.94	0.250
M 2	20050822	34019	-0.009	0.486	0.090	17.58	7.05	0.252	36.06	0.468
M 2	20050822	34020	0.003	0.479	0.065	17.35	1.62	0.222	35.90	0.448
M 3	20000926	23634	0.006	1.190	0.134	6.70	1.32	0.049	47.72	0.242
M 3	20000926	23635	0.004	0.904	0.155	5.49	1.12	0.024	40.72	0.222
M 3	20010928	24676	0.004	1.289	0.093	6.27	1.26	0.018	66.76	0.351
M 3	20010928	24677	0.004	0.957	0.099	5.87	1.25	0.018	49.56	0.266
M 3	20050819	34009	-0.011	0.511	0.060	18.45	1.60	0.196	40.79	0.464
M 3	20050819	34010	-0.008	0.709	0.038	15.55	2.01	0.324	48.42	0.878
M 4	20000926	23636	0.005	1.802	0.205	6.17	0.89	0.022	40.05	0.197
M 4	20000926	23637	0.005	2.217	0.164	5.82	1.02	0.018	47.30	0.159
M 4	20010928	24678	0.004	2.326	0.121	5.82	1.14	0.018	55.96	0.261
M 4	20010928	24679	0.006	2.379	0.067	10.04	1.13	0.116	55.35	0.256
M 4	20050821	34015	-0.003	1.108	0.036	14.70	1.55	0.107	44.27	0.391
M 4	20050821	34016	-0.009	1.118	0.021	15.47	1.59	0.099	42.59	0.375

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This second monitoring study was performed in the Nalunaq Gold Mine area, Nanortalik municipality, South Greenland during 10 August-5 September 2005. Four shipments of ore have been carried out after the first monitoring study in August 2004. Samples were collected at two to five marine stations in the Kirkespir Bay, resident Arctic char were sampled in the Kirkespir River, and lichens were collected at 20 stations in the Kirkespir Valley. Samples were analysed for 12 elements with an ICP-MS. Average concentrations of Cu, As and Co were, compared to background levels, elevated 2-5 times in lichens only. Compared to the 2004 monitoring study, there were no elevated average concentrations in the marine environment, only three elements had elevated concentrations compared to five in 2004 and elevations were in general lower in 2005. Elevated concentrations (5-16 times) of Cu, Cr, As and Co in lichens at single stations were an effect of dust from the road and the mine area. Elevated concentrations were found at a distance of c. 1000 m from the road. Dust from road and mine area should be prevented.

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