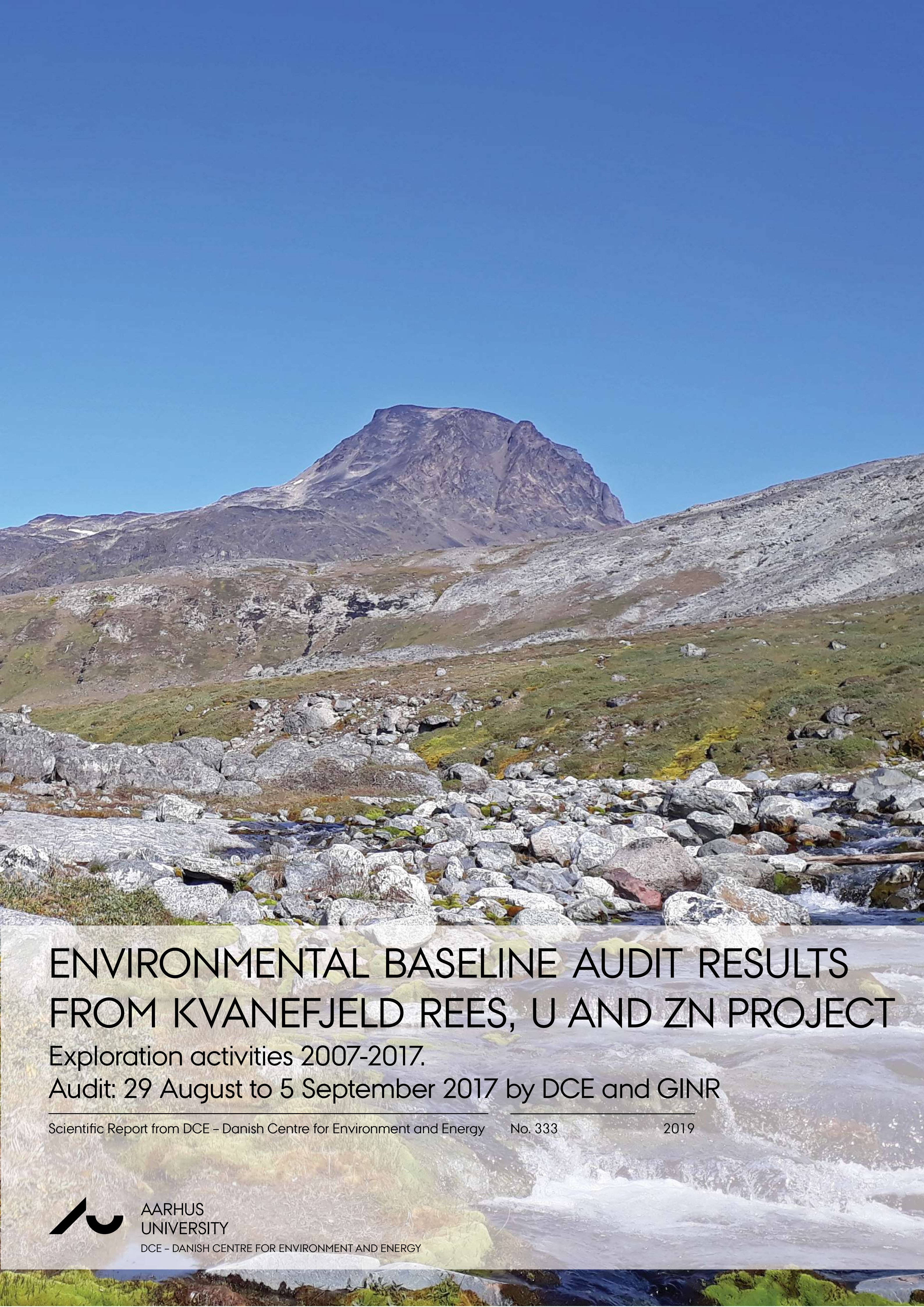

ENVIRONMENTAL BASELINE AUDIT RESULTS FROM KVANEFJELD REES, U AND ZN PROJECT

Exploration activities 2007-2017.
Audit: 29 August to 5 September 2017 by DCE and GINR

Scientific Report from DCE – Danish Centre for Environment and Energy No. 333 2019

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Abstract: Violeta Hansen from DCE - Danish Center for Environment and Energy, Gert Asmund from (DCE) and Morten Birch Larsen from Greenland Institute of Natural Resources (GINR) did an environmental audit at the Kvanefjeld from 29 August to 5 September 2017. Since 2007, Greenland Minerals and Energy Limited (GMEL) have conducted exploration activities at the Kvanefjeld - a Rare Earth Elements (REEs), uranium (U) and zinc (Zn) project in Southern Greenland. GMEL have conducted baseline environmental monitoring at the Kvanefjeld. Baseline monitoring activities included external dose-rate monitoring, passive radon monitoring, dust monitoring and analysis of some selected non-radioactive and radioactive elements in dust and environmental samples. Polonium-210 has been analysed in a number of biological samples and radium-226, radium-228 and lead-210 have been analyzed in a small number of water samples. The extent of monitoring varied from year to year since 2007 to present. In order to verify some of GMEL's environmental baseline studies, a number of environmental samples from Narsaq were collected and analyzed by DCE and GINR. In general, DCE's results of analysed baseline samples from Narsaq/Kvanefjeld are comparable with GMEL reported results in previous years for similar samples. This report include for the first time results of uranium (U), thorium (Th) and polonium-210 (Po-210) levels in drinking water from Narsaq. Background gamma dose rate in Narsaq town and radioactive elements in the analyzed herein samples (except lichens) are not elevated and are comparable with baseline values elsewhere. Levels of Po-210 (680 Bq/Kg d.w.) in lichens collected from Narsaq are higher when compared with levels of Po-210 in lichens collected from Denmark and Sweden (200 Bq/Kg d.w.). High levels of F and non-radioactive elements including also REE are reported in water and biological samples collected from Narsaq.

Keywords: audit, radioecology, ICP-MS, alpha spectrometry, naturally occurring radionuclides, ^{210}Po, drinking water, freshwater, fjord water, lichens, blue mussels, seaweed, arctic char, gamma dose rate, Kvanefjeld, Narsaq, Greenland

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Supplementary notes: This report by DCE and GINR have been submitted to EAMRA on 29 September 2017. This report have been revised by DCE and GINR in August 2019 as follows:
- a summary in Danish and Greenland was added
- the report have been edited
- a front and a back cover has been added
- an audit follow-up status of each recommendation we made in 2017 have been added

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1. Summary

Violeta Hansen from DCE - Danish Center for Environment and Energy, Gert Asmund from (DCE) and Morten Birch Larsen from Greenland Institute of Natural Resources (GINR) did an environmental audit at the Kvanefjeld from 29 August to 5 September 2017.

Since 2007, Greenland Minerals and Energy Limited (GMEL) have conducted exploration activities at the Kvanefjeld - a Rare Earth Elements (REEs), uranium (U) and zinc (Zn) project in Southern Greenland. GMEL have conducted baseline environmental monitoring at the Kvanefjeld. Baseline monitoring activities included external dose-rate monitoring, passive radon monitoring, dust monitoring and analysis of some selected non-radioactive and radioactive elements in dust and environmental samples. Polonium-210 has been analysed in a number of biological samples and radium-226, radium-228 and lead-210 have been analyzed in a small number of water samples. The extent of monitoring varied from year to year since 2007 to present. GMEL sampling locations included the Kvanefjeld plateau, Narsaq town, the farm situated roughly halfway between Narsaq and the Kvanefjeld and the area between Narsaq and the Kvanefjeld. The monitoring was conducted during the summer and winter months and monitoring reports was submitted to EAMRA (Breheny 2012a, 2012b, 2014).

During the audit, DCE measured the gamma dose rate in Narsaq town, between Narsaq and Kvanefjeld and at Kvanefjeld. In order to verify GMEL's environmental baseline studies, the following environmental samples were collected by DCE and GINR as part of the audit:

- Freshwater from Narsaq River, Taseq River, Kvane River, Lake without name and its outlet and old Risø mine outlet.
- Drinking water from Kukasuk, Napassup Kuva and Landnamselven.
- Fjord water at 0 m (surface water) and at the depth of 30 m from the GMEL proposed discharge point of liquid effluents.
- Biota samples such as lichens, blue mussels, seaweed, arctic char (trout).

The collected environmental samples were transported to DCE laboratory in Roskilde and analysed for non-radioactive contaminants by using an ICP-MS and radioactive contaminants by alpha spectrometry. The results are included in this report. This is the second audit report for the Kvanefjeld project by DCE and GINR.

In general, DCE's results of analysed baseline samples from Narsaq/Kvanefjeld are comparable with GMEL reported results in previous years for similar samples. This report include for the first time results of uranium (U), thorium (Th) and polonium-210 (Po-210) levels in drinking water from Narsaq. Background gamma dose rate in Narsaq town and radioactive elements in the analyzed herein samples (except lichens) are *not elevated* and are comparable with baseline values elsewhere (Vesterbacka P. 2005, 2007). Levels of Po-210 (680 Bq/Kg d.w.) in lichens collected from Narsaq are higher when compared with levels of Po-210 in lichens collected from Denmark and Sweden (200 Bq/Kg d.w.) (Persson and Holm 2011). High levels of F and non-radioactive elements including also REE are reported in water and biological samples collected from Narsaq.

2. Sammenfatning

Violeta Hansen fra Nationalt Center for Miljø og Energi (DCE), Gert Asmund fra DCE og Morten Birch Larsen fra Grønlands Naturinstitut (GN) har gennemført miljøtilsyn på Kvanefjeld fra 29. august til 5. september 2017.

Siden 2007 har Greenland Minerals and Energy Limited (GMEL) gennemført efterforskningsaktiviteter ved Kvanefjeld – et projekt om udvinding af sjældne jordarter, uran (U) og zink (Zn) i Sydgrønland. GMEL har gennemført baseline-miljømoniteringen ved Kvanefjeld. Baseline-moniteringsaktiviteter inkluderer ekstern dosismonitering, passiv radon, støvmonitering og analyse af udvalgte ikke-radioaktive og radioaktive stoffer i støv og miljøprøver. Polonium-210 er analyseret i en række biologiske prø-ver, og radium-226, radium-228 og bly-210 er analyseret i et mindre antal af vandprøverne. Omfanget af moniteringen varierer fra år til år i perioden fra 2007 indtil nu. GMEL's prøvesteder inkluderer Kvanefjeld- plateauet, Narsaq by, gården som ligger omtrent halvvejs mellem Narsaq og Kvanefjeldet, og området mellem Narsaq og Kvanefjeldet. Monitering blev gennemført hen over sommer- og vintermånederne og moniteringsrapporter blev sendt til EAMRA (Breheny 2012a, 2012b, 2014).

Under tilsynet målte DCE gammadosis i Narsaq by, mellem Narsaq og Kvanefjeld samt ved Kvanefjeld. For at kunne verificere GMEL's miljømæssige baseline-studier blev følgende miljøprøver indsamlet af DCE og GN som en del af tilsynet:

- Ferskvand fra Narsaq Elv, Taseq Elv, Kvane Elv, Søen uden navn og dens udløb samt det gamle Risø-mineudløb.
- Drikkevand fra Kukasuk, Napassup Kuva og Landnamselven.
- Fjordvand ved 0 m (overfladevand) og ved dybden 30 m ved GMEL's foreslåede udledningspunkt for spildevand.
- Biota-prøver som lav, blåmuslinger, tang, fjeldørred (ørred).

De indsamlede miljøprøver blev transporteret til DCE's laboratorie i Roskilde og analyseret for ikke-radioaktive stoffer ved brug af ICP-MS og radioaktive stoffer ved alfa spektrometri. Resultaterne er inkluderet i denne rapport. Det er nummer to tilsynsrapport for Kvanefjeld-projektet af DCE og GN.

Generelt er DCE's resultater af analyserede baseline-prøver fra Narsaq/Kvanefjeld nogenlunde sammenlignelige med GMEL's tidligere rapporterede resultater for tilsvarende prøver. Denne rapport inkluderer for første gang resultater af uran (U), thorium (Th) og polonium-210 (Po-210) niveauer i drikkevand fra Narsaq. Baggrundsgammadosis i Narsaq by og radioaktive stoffer i analyserede prøver (undtagen lav) er *ikke forhøjede* og er sammenlignelige med baseline-værdier andre steder (Vesterbacka P. 2005, 2007). Niveauer af Po-210 (680 Bq/Kg d.w.) i lav indsamlet fra Narsaq er højere ved sammenligning med niveauer af Po-210 i lav indsamlet i Danmark og Sverige (200 Bq/Kg d.w.) (Persson and Holm 2011). Høje niveauer af F og ikke-radioaktive stoffer, som også inkluderer REE, er rapporteret i vand og biologiske prøver indsamlet fra Narsaq.

3. Eqikkaaneq

Violeta Hansen Danmarkimi Nationalt Center for Miljø og Energi-miit (DCE), Gert Asmund aamma DCE-mit kiisalu og Morten Birch Larsen Pinngortitaleriffimmeersoq Kuannersuarni 29. augustimiit 5. september 2017 ilanngullugu avatangiisinik nakkutilliinermik suliaqarput.

Aatsitassarsiorfik Greenland Minerals and Energy Limited (GMEL) aatsitassarsiorniarluni misissuinernik 2007-imiilli ingerlataqarpoq – suliniut Kalaallit Nunaata kujataani aatsitassanik qaqutigoortunik, uran-italinnik (U) aammalu zink-imik piiaanissanik siunertaqarpoq. GMEL-ip Kuannersuarni nunap aatsitassarsiorfiginiakkamik pissusissamisut isikkoqarallarnerani tamatumalu avatangiisai pillugit nalunaarusiartik naammassereernikuuaa. Nalunaarusiami ilanngunneqarsimapput aatsitassarsiortoqalissagaluarpat aatsitassarsiorfimminngaanneersuniinngitsoq avataaneersuniilli aatsitassarfiorfiup avatangiisaatalu qinngornernik ulorianartoqarsinnaanerannik nakkutilliisarnissani periusissaat, aammalu silaannaap radon-eqassusianik thoriummeqassusianillu alaatsinaattarnissani periusissat, radon, aatsitassarsiorfimmit pujoralatsitsinerup malinnaavigineqarnissaa kiisalu pujoralammik avatangiisiniillu misissugas-sani radiup qinngornerinik akoqanngitsunik aammalu akulinnik misis-sueqqissaarisarnissat ilanngullugit allaaserineqarsimapput. Uumassusilinnit misissugassanit katersat ilaanni arlalippaalunni polonium-210 akuusoq naammattuugassaasarpoq, taakkunanngalu akuttunerusumik misissugassani imermeersuni naammattoorneqartarlutik radium-226-mik, radium-228-mik aammalu suli qaqutigoornerusumik aqerloq-210-mik imeq akoqartoq. Misissuisarnerit annertussusiat ukiumiit ukiumut, tassa 2007-imiit maannamut, nikerarsimavoq. GMEL-ikkut namminneerlutik misissuisarneranni Kuannersuit qaavanni maninnersamiit Narsap illoqarfia, nuna Narsap Kuannersuillu akornanniittup qeqqata missaaniit sinneraniillu misissuisarsimapput. Misissuisarnerminnit aasaaneraniit ukiuunera ilanngullugu pisartunit nalunaarusiarisartakkaminnik EAMRA-mut nassiussisarsimapput (Breheny 2012a, 2012b, 2014).

DCE-meersut nakkutilliinermik ilaanni radiup qinngornerinik gammaqassuseq Narsap illoqarfiani, Kuannersuarnit aammalu tamatuma eqqaanit uuttortaapput. Nakkutilliinermut ilanngullugu DCE-meersut Pinngortitaleriffimmeersullu GMEL-imeersut aatsitassarsiorfiginiakkamik pissusissamisoorallarnerani avatangiisaatalu nalunaarusiarineqarneranni uuttortarsimasaat uppernarsiniarlugit avatangiisinit misissugassanik makkuninnga katersi-simapput:

Imermit Narsap kuuaneersumik, Tatsip kuuaneersumik, tatsimit ateqanngitsumit taassumalu anillagiaaneersumik kiisalu Risørmiut aatsitassarsorfigisimasaasa anillagiaaniit misissugassat.

Imeq imerneqartartoq Kuukasimmeersoq, Napasup kuuaneersoq aammalu kuummiit imeqarfimmiit kuuttumiit taaneqartartumit Nunasiortuunerup nalaaneersumit.

Uumassusilinnit sumiiffimmit aaliangersimasumit misissugassat makku: orsuaasat, uillunit, qeqqussanit aammalu eqalunnit.

Avatangiisit qanoq issusiannik paasisaqarniarluni misissugassat katersorneqartut DCE-p misissuisarfianut Roskildemiittumut nassiunneqarput. Misissugassat radiup qinngornertaqanngitsut ICP-MS-imik atortoqarluni suliarineqarput, misissugassalli radiup qinngorneranik akullit alfa spektrometri atorlugu suliarineqarlutik. Misissuinernit taakkunannga inernerusut nalunaarusiami uani atuarneqarsinnaapput. Nalunaarusiaq una DCE-meersut Pinngortitaleriffimmeersullu Kuannersuarni nakuutilliisarnerminnit nalunaarusiaasa aapparaat.

Ataatsimut isiginnilluni oqartoqarsinnaavoq Narsami / Kuannersuarnilu aatsitassarsiortoqalissagaluarpat, tamanna sioqqullugu, nuna sumiiffiup aatsitassarsiorfiginiakkap eqqaatalu pissusissamisoortumik avatangiiserisaannik nalunaarusiornermut atatillugu DCE-meersut misissuisarnerinit inernerit aatsitassarsiorfiutileqatigiiffiup GMEL-ip misissukkaminnit inernerusutut nalunaarutigisartagaannut sanilliunneqapajaarsinnaammata. Uani nalunaarusiami Narsami ermup imerneqartartup uran-imik (U), thorium-imik polonium 210-millu (Po-250) akoqassusiannit misissuisimanernit inernerusut siullerpaamik saqqummiunneqarput. Narsami avatangiisit qanoq issusiannik paasisaqarniarluni misissuinernit inernerit takutippaat ermup, nunap, silaannaallu pissusissamisoortumik radiup qinngorneranit gammamik akoqassusiat killissarititaasumiit qaffasinnerunngitsut aammalu allani tamani taama ittunik misissuisarsimanernit inernerusunut allanut sanilliunneqarsinnaasut (Vesterbacka P. 2005, 2007). Narsamili orsuaasat katersorneqarsimasut misissuiffigineqarmata paasineqarpoq Po-210-mik (680 Bq / Kg d.w.) akoqarnerat allani soorlu Danmarkimi Sverigemilu (200 Bq / Kg d.w.) (Persson and Holm 2011) kisitsisaatigineqartunit qaffasinnerusut. Narsami imermit aammalu uumassusilinnit allanit misissukkanit inernerit takutippaat F-eqassusiat aammalu aatsitassat qaqugutigoortoqassusiat qaffasissoq.

4. Kvanefjeld environmental audit - Sampling and analysis

4.1 Sampling

Five liters of drinking, river and lake water were collected into polyethylene plastic bottles. Sampling stations included Kukasuk, Napassap Kuva and Landnamselven, Taseq River, Narsaq River, Kvane River, Lake without name and its outlet.

Ten liters of Bredefjord water were collected from the proposed (by GMEL) outlet for liquid discharges from Kvanefjeld. The Fjord water were collected from surface (0 m) and from 30 m.

Seaweed and blue mussels were collected from Narsap Ilua bay, near the outlet of Narsaq River. Lichens were collected from Narsaq town, between Narsaq town and Kvanefjeld and at Kvanefjeld. Arctic trout were collected from Narsaq River just after the Kvane River outlet.

4.2 Analytical methods

4.2.1 Drinking water, fresh water and fjord water

Physical-chemical parameters of all collected water samples was measured by using an In Situ SmarTroll multimeter. Results of physical – chemical parameters of the analysed drinking and freshwater samples are shown in Table 5.2.1.

Ten milliliters of the collected drinking and fresh water samples was filtered (0.45 µm). The samples were acidified with 1 mL/L Merck Suprapure HNO3, left for a minimum of 24 h and analyzed by ICP-MS (Agilent 7900) for non-radioactive elements.

Seawater samples were acidified with 2 mL/L Merck Suprapure HNO_3 and analyzed for non-radioactive elements by using ICP-MS after online pre-concentration of the metals on a Chelex-100-filled micro-column following by elution with 5% Merck Suprapure HNO3. Results for the analysed samples are shown in Table 5.2.2. and Table 5.2.3 (fjord water).

An YSI Multilab equipped with an ion selective fluoride electrode was used to measure fluor (F) concentration in collected water samples except in the fjord water. Results of F for the analysed samples are shown in Table 5.2.2.

For the analysis of the natural radionuclide Po-210, approximately five liters of drinking and fresh water sample were acidified with 1mL/L Merck Suprapure HCl. A known amount of Po-209 tracer was added and the sample was gentle evaporated at 80 0C to a volume of 200 mL. Polonium in the 200 mL sample was spontaneous deposited on a silver disc at around 80 0C for 3.5 hours. The activity concentration of Po-210 was determined by alpha spectrometry (ORTEC). The minimum detectable activity (MDA) was 0.00007 Bq/L for a 5-liter water sample and a 168 hour counting time. The recovery of Po-209 in the water samples was typically 21 – 63%. Po-210 results for the analysed samples are shown in Table 5.2.4. All Po-210 results refer to the sampling date but due to Pb-210 not being analysed the actual levels of Po-210 in these samples may be lower or higher depending on the Po-210 / Pb-210 ratio at the time of sampling and the delay between sampling and analysis. Typical delay between sampling and analysis was between 1-2 months, sometimes even longer. However, uncertainty due to delay between sampling and analysis and lack of information on Pb-210 is believed to be minor.

4.2.2 Biota, trout, blue mussels, seaweed and lichens

Lichens, seaweed and mussels were freeze-dried. The dried samples were homogenized in an agate mortar. For lichens, mussels and seaweed, 0.3 g dry weight subsamples were used. A subsample of trout muscle was cut from the sample without freeze-drying. For trout muscle, 1 g wet weight subsamples were used.

For ICP-MS measurements, biota samples were digested in Teflon bombs using concentrated Suprapure nitric acid in a microwave oven.

For ICP-MS quality control the following samples:

- A freshwater reference material (SLRS-6),
- Two seawater reference materials (CASS-5 and SLEW-3) and three former QUASIMEME seawater samples (QTM247, 248 and 249),
- Three biota reference materials (Dorm-4, Dolt-5 and Tort-3) were analyzed along with the drinking water, freshwater, seawater and biota samples with satisfactory results (Table 5.3.9).

The activity concentration of Po-210 was measured by alpha spectrometry (ORTEC). 10 g of fresh biota sample was mixed with Po-209 tracer, 25 mL of 65% HNO_3, 5 mL of 37% HCl and 0.3 g of NaCl and refluxed on a plate at 150 °C for 5 hours. The digested sample was evaporated to dryness on a hotplate at 120–150 °C. 10 ml of 30% H_2O_2 and 1 ml of 37% HCl was added and the solution was evaporated to dryness at 130 °C. After then, 10 ml of 37% HCl was added and evaporated to dryness at 120–150 °C. To the dried sample, 5 mL of 30% H_2O_2, 0.8 mL of 37% HCl, 15 mL distilled water and 1.0 g of NH_2OH HCl are sequentially added and heated at 200 °C for 10 minutes, respectively. After 15 minute cooling, the sample is filtered through a Munktell Analytical filter paper (OOK, Ø 12.5 cm). The residue and beaker was washed 3 times with 3 mL of 0.3 M HCl containing 1 mg / mL NaCl. The acidity of the filtrate was adjusted to 0.3–0.5 M HCl. Polonium was spontaneous deposited on a clean silver disk under stirring at 80 °C for 3-4 hours.

The activity concentration of Po-210 in biota, MDA and recovery of Po-209 in the analyzed samples are shown in Tables 5.3.2 (trout muscle), 5.3.4 (blue mussel), 5.3.6 (seaweed) and 5.3.8 (lichens). All Po-210 results refer to the sampling date but due to Pb-210 not being analysed the actual levels of Po-210 in these samples may be lower or higher depending on the Po-210 / Pb-210 ratio at the time of sampling and the delay between sampling and analysis. Typical delay between sampling and analysis was between 1-2 months, sometimes even longer. However, uncertainty due to delay between sampling and analysis and lack of information on Pb-210 is believed to be minor.

4.2.3 Gamma dose rate

During the audit, in august 2017, basline gamma dose rate (µSv / h) in Narsaq town (29 locations), between Narsaq and Kvanefjeld (16 locations) and Kvanefjeld plateau (5 locations) was measured (5 minutes counting at each location) by using a Survey Meter Colibri VLD (Very Low Dose). The results are presented in subchapter 5.1.

5. Results

5.1 Gamma dose rate

DCE mean background gamma results in Narsaq town (29 locations measured in August 2017) was 0.14 ± 0.05 µSv/h with a range from 0.04 to 0.2 µSv/h. This equates to an annual background dose of 1.2 mSv/year. DCE mean background gamma between Narsaq and Kvanefjeld was 0.6 ± 0.04 µSv/h with a range from 0.04 to 0.2 µSv/h. This equates to an annual background dose of 5.6 mSv/year. At the farm in Narsaq a value of 0.2 µSv/h was measured. This equates to an annual background dose of 1.7 mSv/year. DCE mean background gamma results at Kvanefjeld plateau was 1.1 ± 0.04 µSv/h (close to GMEL camp work). This equates to an annual background dose of 13 mSv/year.

Background gamma survey was conducted by GMEL between 2008 and 2014. The gamma survey where in Narsaq town, between Narsaq and Kvanefjeld, Critical group (farm in Narsaq), Kvanefjeld plateau, Port, the proposed Accommodation site, Proposed Production Plant site, Tailings site, along the pipe to the tailings site and Effluent line (Breheny, 2012 a and b, 2013, 2014, ARCADIS 2014).

In 2008, GMEL monitored the background gamma dose rate by using a thermoluminescent dosimeter (TLD) which were exposed during summer (117 days) and winter (275 days) months. No traveling blank TLD's were employed to correct for exposure during transit between laboratory and measurement location. The mean gamma background result at Kvanefjeld plateau in 2008 was 1.3 ± 0.7 µSv/h with a range from 0.2 to 2.4 µSv/h for the summer field season (117 days). The mean gamma background in 2008 over Narsaq town was 0.2 ± 0.04 µSv/h with a range from 0.1 to 0.2 µSv/h for the summer field season and 0.1 µSv/h for the winter season. Gamma result at Critical group was 0.3 µSv/h (summer 2008) and 0.2 µSv/h (winter 2008).

GMEL mean gamma background results by TLD measurements where 1.5 ± 1.3 µSv/h (with a range of 0.03 to 6.7 µSv/h for 2009 at Kvanefjeld plateau), 0.6 ± 0.1 µSv/h (for 2010 at Kvanefjeld work camp) and 0.4 ± 0.2 µSv/h (for 2011 – at Kvanefjeld work camp).

In 2009, 2010, 2011, 2013 and 2014 GMEL measured the gamma background in Narsaq town at one meter above the ground and 5 minutes counting time by using a scintillation detector and a Ludlum 44-10 sodium iodide (NaI) probe (for 2014 measurements by ARCADIS). GMEL reported the following background gamma for Narsaq town: 0.2 ± 0.6 µSv/h (2009), 0.2 ± 0.05 µSv/h (2010), 0.5 ± 0.1 µSv/h (2011), 0.4 ± 0.1 µSv/h (2013) and 0.1 (2014 –this measurement was performed by ARCADIS in September–October 2014) (ARCADIS 2014). GMEL background gamma dose rates at Critical group (farm in Narsaq) where 0.2 - 0.3 µSv/h (measured by TLD in 2009), 0.5 (measured by TLD in 2010), 0.3 µSv/h (measured by TLD in 2011) and 0.6 ± 0.1 µSv/h (2013 measured using a scintillation detector).

DCE background gamma dose-rate results obtained in Narsaq town using the Survey Meter Colibri VLD are comparable to results obtained by GMEL during 2008, 2009 and 2014. High results were reported by GMEL for background gamma in 2010, 2011 and 2013 (comparing with GMEL previous year's results and DCE results). The background gamma at Kvanefjeld by DCE (2017) is comparable with background gamma reported by GMEL in 2008 and 2009. Results of background gamma at the critical group (farm in Narsaq) reported by GMEL in 2009 and 2011 are comparable with DCE results from 2017. For some reasons GMEL reported approximatively 2-3 times higher values of background gamma at the critical group in 2010 and 2013 than DCE reported values. The high reported background gamma values for 2010 and 2013 by GMEL can be explained by the fact that GMEL used a scintillation-based instrument for the survey. Stager (2014) and Nielsen (2017) pointed out also that the dose rates derived from measurements by using a scintillation-based instrument are 3-4 times higher than corresponding TLD doses in Narsaq.

5.2 Water samples

The drinking water in Narsaq had a pH of around 7.2 with total dissolved solids of 0.03 g/L (Table 5.2.1.). The pH of analyzed river and lake water vary from 7 to 8.3. The pH of the outlet water from old Risø mine was around 11 with total dissolved solids of 0.2 g/L. This result reflect the Kvanefjeld Ilímaussaq Complex, which is alkaline to peralkaline layered intrusion.

Uranium (U) in the analyzed water samples vary 0.01-0.3 ug/L (drinking water), Kvane River (0.2 ug/L), Taseq River (0.3 ug/L), 1.0 -1.3 ug/L (Narsaq River), 0.03-ug/L (Lake without name and its outlet) and 6.2 ug/L (Old Risø mine outlet) (Table 5.2.2). Uranium in all analyzed water samples are below the recommended water quality criteria for drinking water (30 ug/L, WHO 2011). GMEL reported a U concentration in water samples collected in August – September 2013 from Kvane River (8.2 ug/L), Narsaq River (0.8 - 1.4 ug/L), Narsaq River close to Ilua Fjord (1.1 ug/L) and River from glacier (3.2 ug/L). The DCE reported herein U concentration in the water collected from Narsaq River (1.3 ug/L) is in agreement with the GMEL reported value of U for water collected from a similar location. GMEL reported value for U in Kvane River around 48 times higher than DCE value.

U level in the Bredefjord is around 2.8 ug/L (Table 5.2.3). Up to date GMEL have not analysed nor reported the level of U in the water collected from Bredefjord.

In the analyzed water samples flour (F) concentration is 2.5 times (Kvane River and downstream Narsaq River) and 17 (Old Risø mine outlet) times higher than the recommended drinking water quality criteria. Recommended water quality criteria for F is 1500 µg/L. Flour concentration in the drinking water collected from three sampling locations in Narsaq vary from 180 to 707 ug/L (Table 5.2.2).

Polonium-210 is below the recommended quality water criteria of 0.1 Bq/L in all analysed fresh and drinking water excepting the water from old Risø mine outlet in which the polonium-210 is around 0.9 Bq/L (9 times higher than the recommended water quality criteria) (Table 5.2.4). So far, GMEL have not reported the activity concentration of Po-210 in drinking water and fresh water. Hence, the results included herein for activity concentration of Po-210 in fresh and drinking water are the only existing (available) results so far.

The DCE freshwater database contains full scan ICP-MS analyses of 238 unpolluted freshwater and drinking water samples from different locations in Greenland where baseline sampling for future mining has been performed.

Table 5.2.5, shows the ratio concentrations of elements in Narsaq River and Narsaq drinking water / median concentration of elements in freshwater and drinking water samples from the DCE database (238 samples results). The elements lithium (Li), beryllium (Be), gallium (Ga), arsenic (As), molybdenum (Mo), antimony (Sb), wolfram (W), uranium (U) are ten times higher in the water samples from Narsaq when comparing with median values for similar samples from different locations across Greenland. Particularly low concentrations of iron (Fe), copper (Cu), barium (Ba), europium (Eu), titanium (Ti), cerium (Ce), thorium (Th) was determined in the Narsaq River.

In drinking water from Narsaq only the concentration of Be and Mo are more than 10 times higher than the median of all other analyses from other locations in Greenland, and Ti, Ba, Ce, and thallium (Tl) have very low concentrations. It is interesting that the rare earth elements are not high in Narsaq River, but higher in drinking water compared to the samples collected from other locations in Greenland. In this comparison, data from the following projects in Greenland are used: Isua iron ore project, Fiskenæsset ruby project, White Mountain anorthosite, Nalunaq gold, Pittufik titanium, Hudson resources Sarfartoq project.

Table 5.2.1. Physical-chemical parameters of freshwater and drinking water collected from Narsaq.

	Coordinates	Coordinates	Sample location	Sample type	pH	Temperature (°C)	Conductivity (µS/cm)	ORP (mV)	Total Dissolved Solids (g/L)
Samples	60.913404	46.039161	Kukasuk	Drinking water	7	9	35	46	0.03
	60.928105	46.034894	Napassup Kuva		7	8	26	40	0.03
	60.907065	46.031015	Landnamselven		7	13	35	34	0.03
	60.948393	46.016623	Taseq River	River water	7	10	35	39	0.03
	60.953395	46.014511	Kvane River		7	9	43	35	0.04
	60.952976	46.,014962	Narsaq River		8	8	41	43	0.04
	60.973249	45.975674	Narsaq River Raw Water Dam		8	8	41	43	0.04
	60.98535	46.03745	No name lake outlet	Lake water	8	12	20	39	0.02
	60.971923	46.04082	Lake with no name		8	12	20	39	0.02
	60.96988	45.99278	Old Risø mine outlet	Mine water	11	3	153	22	0.2

Table 5.2.2. Element concentrations in freshwater and drinking water. Results are in µg/L. Detection limits are calculated as three standard deviations on blank values measured during the analyses. Non-accredited elements are marked with a* in the table.

µg/L				**Li**	**Be**	**Na**	**Mg**	**Al**	**P**	**K**	**Ca***	**Sc***	**Ti***	**V**	**Cr**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Ga***	**As**	**Se**	**Rb***
Detection Limit (3 SD Blank)				0.06	0.001	7	0.1	2	17	4	2	0.002	0.02	0.02	0.05	0.3	0.001	0.2	0.09	0.1	0.002	0.03	0.02	0.002
Average of the relative standard deviations in %				2	5	1	1	5	<DL	4	1	15	25	6	<DL	20	12	<DL	28	21	10	9	9	2
	Coordi-nates	**Coordi-nates**	**Sample location**																					
Sample	60.913404	46.039161	Kukasuk	0.2	0.08	5171	706	34	<DL	367	3767	0.02	0.06	0.06	<DL	3	0.01	<DL	0.4	1.4	0.03	0.04	0.04	0.6
Sample	60.928105	46.034894	Napassup Kuva	0.2	0.08	4202	534	14	<DL	331	2599	0.01	0.04	0.07	<DL	1.6	0.007	<DL	0.4	1.1	0.03	0.07	0.03	0.7
Sample	60.907065	46.031015	Landnamselven	0.1	0.005	5240	642	7.5	<DL	518	2204	0.002	0.05	0.02	<DL	40.0	0.008	<DL	0.5	0.8	0.007	0.1	0.02	1.4
Sample	60.948393	46.016623	Taseq River	3	0.1	6596	419	13	<DL	415	2783	0	<DL	0	<DL	1	0	<DL	0	2	0	0	0	2
Sample	60.953395	46.014511	Kvane River	2.6	0.2	10380	321	70.3	<DL	840	1466	0.01	0.03	0.09	<DL	0.8	0.005	<DL	0.3	7	0.1	1.4	0.06	3.3
Sample	60.952976	46.014962	Narsaq River	3.1	0.1	10596	262	49.6	<DL	435	2377	0.01	0.04	0.05	<DL	2.2	0.002	<DL	0.2	2.4	0.5	0.6	0.09	3.2
Sample	60.973249	45.975674	Narsaq River Raw Water Dam	0.8	0.05	4776	258	22.6	<DL	372	2690	0.007	0.06	0.04	<DL	4.3	0.002	<DL	0.2	2	0.3	0.3	0.06	2
Sample	60.98535	46.03745	No name lake outlet	0.2	0.02	2568	374	20.3	<DL	276	1648	0.004	0.04	0.03	<DL	6.0	0.008	<DL	0.4	1.5	0.008	<DL	0.02	0.7
Sample	60.96988	45.99278	Old Risø mine outlet	67	0.2	61323	56	86	2036	645	458	0.06	1.5	0.	0.05	18.3	0.02	<DL	0.3	3	1.2	2	0.4	27.3
Sample	60.971923	46.04082	Lake with no name	0.2	0.01	2262	342	25	<DL	243	1585	0.003	0.07	0.02	<DL	16.3	0.008	<DL	0.2	0.3	0.004	<DL	<DL	0.6
Sample			Tap water																					
Freshwater and drinking water (WHO) quality criteria					12			100							3	300		5	2	10		4	40	
Quality Control /Certified reference material																								
SLRS-6				0.5	0.01	2690	2026	33.7	ND	651	8227	0.02	0.50	0.4	0.2	85.5	0.05	0.5	24.1	1.7	0.02	0.5	0.08	1.3
SLRS-6 (certificate value)				ND	(0.0066)	2760	2133	33.8	ND	651	8760	ND	ND	0.3	0.3	84.3	(0.053)	0.6	24	1.8	ND	0.6	ND	ND
SLRS-6 (certificate uncertainty) (2SD)				ND	(0.0022)	220	58	2.2	ND	54	200	ND	ND	0.006	0.01	3.6	(0.012)	0.02	1.8	0.1	ND	0.08	ND	ND
SLRS-6 (upper DCE acceptance limit)				ND	ND	3117	2354	44.6	ND	739	ND	ND	ND	0.5	0.45	95.7	0.25	1.1	27	11.	ND	1.6	ND	ND
SLRS-6 (lower DCE acceptance limit)				ND	ND	2403	1912	23.0	ND	563	ND	ND	ND	0.2	0.05	73	-0.15	0.1	20.8	-8.2	ND	-0.4	ND	ND

EIA, 2015

WHO, 2011

Table 5.2.2. Continued.

µg/L				Sr	Y*	Zr*	Nb*	Mo	Ru*	Pd*	Ag*	Cd	Sb	Te*	Cs	Ba	La*	Ce*	Pr*	Nd*	Sm*	Eu*
Detection Limit (3 SD Blank)				0.03	0.0003	0.1	0.002	0.005	0.0008	0.0003	0.0005	0.002	0.004	0.007	0.001	0.03	0.0001	0.0005	0.0001	0.0005	0.0002	0.0001
Average of the relative standard deviations in %				1	12	10	15	2	<DL	23	<DL	11	18	<DL	7	3	15	16	15	15	15	17
	Coordi-nates	**Coordi-nates**	**Sample location**																			
Sample	60.913404	46.039161	Kukasuk	21	0.4	0.3	0.005	4	<DL	0.001	<DL	0.005	0.02	<DL	0.004	2	0.6	0.03	0.2	0.6	0.1	0.01
Sample	60.928105	46.034894	Napassup Kuva	14	0.2	0.2	0.003	2	<DL	0.001	<DL	0.003	0.02	<DL	0.003	0.003	0.003	0.05	0.1	0.4	0.1	0.005
Sample	60.907065	46.031015	Landnamselven	18	0.03	<DL	0.002	0.2	<DL	0.001	<DL	<DL	0.02	<DL	0.01	3	0.05	0.06	0.01	0.04	0.01	0.001
Sample	60.948393	46.016623	Taseq River	20	0	<DL	<DL	3	<DL	0	<DL	0	0	<DL	0	1	0	0	0	0	0	0
Sample	60.953395	46.014511	Kvane River	14	0.3	0.2	0.004	5	<DL	0.001	<DL	0.004	0.5	<DL	0.02	5	0.3	0.02	0.1	0.3	0.04	0.004
Sample	60.952976	46.014962	Narsaq River	8	0.1	<DL	0.02	6	<DL	0.0005	<DL	0.004	0.3	<DL	0.02	1	0.1	0.07	0.02	0.1	0.01	0.001
Sample	60.973249	45.975674	Narsaq River Raw Water Dam	9	0.1	<DL	0.03	3	<DL	0.0005	<DL	0.003	0.2	<DL	0.01	1	0.1	0.1	0.02	0.1	0.01	0.001
Sample	60.98535	46.03745	No name lake outlet	10	0.1	<DL	0.004	1.2	<DL	0.0007	<DL	0.004	0.01	<DL	0.003	2	0.1	0.1	0.04	0.1	0.02	0.002
Sample	60.96988	45.99278	Old Risø mine outlet	1	0.4	0.6	0.6	30	<DL	0.0008	0.004	0.008	10	<DL	0.03	0.2	0.1	0.4	0.04	0.1	0.04	0.005
Sample	60.971923	46.04082	Lake with no name	9	0.1	<DL	<DL	1	<DL	0.0006	<0.000	0.002	<0.000	<DL	0.002	1	0.1	0.1	0.02	0.1	0.02	0.002
Sample			Tap water																			
Freshwater and drinking water (WHO) quality criteria												3	20			700						
Quality Control / Certified reference material																						
SLRS-6				38	0.1	ND	0.002	0.2	ND	0.002	ND	0.01	0.3	ND	0.004	13	0.2	0.3	0.05	0.2	0.03	0.01
SLRS-6 (certificate value)				41	ND	ND	ND	0.2	ND	ND	ND	0.006	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (certificate uncertainty) (2SD)				0.3	ND	ND	ND	0.02	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (upper DCE acceptance limit)				45	ND	ND	ND	2	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (lower DCE acceptance limit)				37	ND	ND	ND	-2	ND	ND	ND	-0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

WHO, 2011

Table 5.2.2. Continued.

µg/L				Gd*	Tb*	Dy*	Ho*	Er*	Tm*	Yb*	Lu*	Hf*	Ta*
Detection Limit (3 SD Blank)				0.0002	0.00002	0.0001	0.00003	0.0001	0.00003	0.0001	0.00004	0.0034	0.0001
Average of the relative standard deviations in %				15	19	18	15	16	11	10	9	1	16
Sample	**Coordinates**	**Coordinates**	**Sample location**										
	60.913404	46.039161	Kukasuk	0.07	0.01	0.05	0.01	0.03	0.004	0.03	0.004	0.007	00001
	60.928105	46.034894	Napassup Kuva	0.05	0.006	0.03	0.006	0.02	0.002	0.01	0.002	0.004	0.0002
	60.907065	46.031015	Landnamselven	0.01	0.001	0.004	0.0009	0.003	0.0003	0.002	0.0003	<DL	<DL
	60.948393	46.016623	Taseq River	0	0	0	0	0	0	0	0	<DL	0
	60.953395	46.014511	Kvane River	0.03	0.005	0.03	0.006	0.02	0.003	0.02	0.003	0.004	0.0005
	60.952976	46.014962	Narsaq River	0.01	0.002	0.01	0.002	0.006	0.0007	0.004	0.0006	0.003	0.0008
	60.973249	45.975674	Narsaq River Raw Water Dam	0.01	0.002	0.008	0.002	0.005	0.0006	0.004	0.0006	<DL	0.0003
	60.98535	46.03745	No name lake outlet	0.02	0.003	0.01	0.003	0.007	0.001	0.005	0.0008	<DL	<DL
	60.96988	45.99278	Old Risø mine outlet	0.04	0.007	0.04	0.01	0.02	0.003	0.02	0.002	0.03	0.03
	60.971923	46.04082	Lake with no name	0.01	0.002	0.01	0.002	0.005	0.0008	0.005	0.0005	<DL	<DL
			Tap water										
Quality Control / Certified reference material													
SLRS-6				0.03	0.004	0.02	0.004	0.01	0.002	0.01	0.002	ND	ND
SLRS-6 (certificate value)				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (certificate uncertainty) (2SD)				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (upper DCE acceptance limit)				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SLRS-6 (lower DCE acceptance limit)				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 5.2.2. Continued.

µg/L				W*	Re*	Pt*	Au*	Hg*	Tl*	Pb	Bi*	Th*	U*	F
Detection Limit (3 SD Blank)				0.004	0.0001	0.003	0.004	0.007	0.0003	0.04	0.0002	0.0005	0.0003	
Average of the relative standard deviations in %					31							39	15	3
	Coordinates	**Coordinates**	**Sample location**											
Sample	60.913404	46.039161	Kukasuk	0.01	0.0001	<DL	<DL	<DL	<DL	<DL	<DL	0.007	0.3	688
	60.928105	46.034894	Napassup Kuva	0.03	0.0001	<DL	<DL	<DL	<DL	<DL	0.0006	0.004	0.1	707
	60.907065	46.031015	Landnamselven	<DL	0.0001	<DL	<DL	<DL	<DL	<DL	<DL	0.003	0.01	180
	60.948393	46.016623	Taseq River	0	0	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.3	1453
	60.953395	46.014511	Kvane River	0.09	0.0001	<DL	<DL	<DL	<DL	<DL	<DL	0.003	0.2	3475
	60.952976	46.014962	Narsaq River	0.1	0.0002	<DL	<DL	<DL	<DL	0.09	<DL	0.004	1	3793
	60.973249	45.975674	Narsaq River Raw Water Dam	0.02	0.0002	<DL	<DL	<DL	<DL	0.05	<DL	0.005	1.3	1160
	60.98535	46.03745	No name lake outlet	<DL	0.0001	<DL	<DL	<DL	<DL	<DL	<DL	0.003	0.06	238
	60.96988	45.99278	Old Risø mine outlet	1.2	0.0002	<DL	<DL	0.01		0.5	0.001	0.03	6.2	24900
	60.971923	46.04082	Lake with no name	<DL	<DL	<DL	<DL	<DL		<DL	<DL	0.003	0.03	250
			Tap water											660
Freshwater and drinking water (WHO) quality criteria								0.05		1			30	1500
Quality Control/ Certified reference material														
SLRS-6				0.01	0.01	ND	ND	0.1	0.01	0.1	0.001	0.01	0.07	
SLRS-6 (certificate value)				ND	ND	ND	ND	ND	ND	0.2	ND	ND	0.07	
SLRS-6 (certificate uncertainty) (2SD)				ND	ND	ND	ND	ND	ND	0.03	ND	ND	0.00	
SLRS-6 (upper DCE acceptance limit)				ND	ND	ND	ND	ND	ND	0.5	ND	ND	0.08	
SLRS-6 (lower DCE acceptance limit)				ND	ND	ND	ND	ND	ND	-0.1	ND	ND	0.06	

EIA, 2015

WHO, 2011

Table 5.2.3. Element concentrations in Bredefjord water. Results are in µg/L. Duplicate analyses were made for all three sam-

	V	Mn	Co	Cu	Zn	Cd	Pb	U*
				µg/L				
Detection limit (3 SD Blank)	0.05	0.02	0.006	0.05	0.2	0.03	0.1	0.05
Surface fjord water (0 m)	0.9	3	<DL	0.2	<DL	<DL	<DL	2.0
Fjord water (30 m)	1.5	1.3	<DL	0.4	0.7	0.04	<DL	2.8
Greenland seawater quality criteria				2	10	0.2	2	30
Control samples analyzed along with the samples								
Cass-5	1.5	2.7	0.09	0.5	2.1	<DL	<DL	3.1
Certificate value	1.3	2.6	(0.095)	0.4	0.7	0.02	0.01	(3)
Certificate uncertainty (2 SD)	0.1	0.2	-	0.03	0.07	0.00	0.00	-
Slew-3	1.7	1.7	<DL	1.5	<DL	0.04	<DL	1.7
Certificate value	2.6	1.6	0.04	1.5	0.20	0.05	0.009	(1.8)
Certificate uncertainty (2 SD)	0.3	0.2	0.01	0.1	0.04	0.004	0.001	-
QTM 247	1.4	0.5	<DL	7.8	20.5	<DL	0.3	3.7
Assigned Value	1.4	0.5	ND	6.7	18.7	0.02	0.	-
QTM 248	3.4	1.9	0.2	8.7	23.7	0.2	2.2	3.6
Assigned Value	3.3	1.8	0.2	7.7	21.6	0.2	1.9	-
QTM 249	3.5	1.6	2.2	5.5	16.5	0.6	2.4	1.6
Assigned Value	3.3	1.5	2.0	4.6	13.5	0.6	2.1	-
	V	**Mn**	**Co**	**Cu**	**Zn**	**Cd**	**Pb**	**U**
Detection limit (3 SD Blank)	0.05	0.02	0.006	0.05	0.2	0.0	0.1	0.05
Blank	0.1	-0.03	-0.09	-0.1	0.03	-0.01	-0.2	0.2

Table 5.2.4. Activity concentration of Po-210 in analyzed water samples.

Coordinates	Coordinates	Sample Location	Sample type	pH	Temperature (°C)	Conductivity (µS/cm)	ORP (mV)	Total Dissolved Solids (g/L)	Activity concentration Po-210 (Bq/L)
60.913404	46.039161	Kukasuk	Drinking water	7.1	8.5	34.5	46	0.03	0.001
60.928105	46.034894	Napassup Kuva		7.3	8	26.1	40.4	0.03	0.0003
60.907065	46.031015	Landnamselven		7.2	13	34.5	34	0.03	0.002
60.948493	46.016623	Taseq River	River	7	10	35	39	0.03	0.003
60.952976	46.014962	Narsaq River		8	8	41.2	43.4	0.04	0.001
60.953395	46.014511	Kvane River		7.5	9	43	35.2	0.04	0.001
60.973249	45.975674	Raw Water Dam		8	8	41.2	43.4	0.04	0.005
60.98535	46.03745	No name Lake outlet	Lake	8.3	12	20.3	39	0.02	0.002
60.96988	45.99278	Lake with no name		8.3	12	20.3	39	0.02	0.002
60.971923	46.04082	Old Risø mine outlet	Mine outlet	8.3	12	20.3	39	0.2	0.9
		STDEV							0.0006
		Quality level (WHO)							0.1

Table 5.2.5. Ratio of average element concentration from Narsaq and median of data from the DCE database for Greenland.

	Narsaq River/freshwater from other locations in Greenland	Drinking water/drinking water from other locations in Green-
Li	12	1
Be	25	13
Na	7	3
Mg	0.5	1
Al	2	1
K	0.5	1
Ca	1	1
Sc	0.3	0.3
Ti	0.2	0.2
V	0.3	0.3
Fe	0.1	1
Cu	0.1	0.3
Zn	2.1	1
Ga	24	1
As	18	2
Se	2	1
Rb	2	1
Sr	1	2
Y	1	3
Nb	4	1
Mo	46	14
Cd	1	
Sb	65	4
Cs	2	1
Ba	0.1	0.2
La	0.3	1
Ce	0.2	0.2
Pr	0.3	1
Nd	0.3	1
Sm	0.3	2
Eu	0.1	1
Gd	0.4	2
Dy	0.7	2
Ho	1	3
Er	1	3
Tm	1	2
Yb	1	3
Lu	1	3
Hf	1	
Ta	1	
W	10	
Re	1	0.4
Tl	1	0.1
Pb	2	
Th	0.2	0.3
U	18	3

5.3 Trout, blue mussels, seaweed and lichens

Activity concentration of Po-210 in analysed trout sample collected from Narsaq River was 0.3 Bq/Kg (w.w) (Table 5.3.2). GMEL reported values of1.2 Bq/Kg (w.w) and (Nielsen 2015) and < 10 Bq/Kg (w.w.) (ARCADIS, 2018) for Po-210 in freshwater fish.

Activity concentration of Po-210 in analysed blue mussels collected from Ilua Fjord (outlet of Narsaq River) was 54 Bq/Kg (w.w) (Table 5.3.4). GMEL reported values of 79 Bq/Kg (w.w) (Nielsen 2015) and 20 Bq/Kg (w.w.) (ARCADIS, 2018) for Po-210 in blue mussels.

Activity concentration of Po-210 in analysed seaweed collected from Ilua Fjord (outlet of Narsaq River) was around 1.3 Bq/Kg (w.w) (Table 5.3.6). GMEL have reported a level of Po-210 in seaweed samples from Narsaq of < 10 Bq/Kg (w.w.) (ARCADIS, 2018).

Activity concentration of Po-210 in analysed lichens samples collected from Narsaq, between Narsaq and Kvanefjeld and at the Kvanefjeld varies between 110 - 680 Bq/Kg (d.w) (Table 5.3.8). GMEL reported valuesof 740 Bq/Kg (d.w) (Nielsen 2015) and 330 Bq/Kg (w.w) (ARCADIS, 2018) for Po-210 in lichens collected at the project site.

The results from analysis of trout, blue mussels, seaweed and lichens and ICP-MS quality control are presented in Table: 5.3.1, 5.3.3, 5.3.5, 5.3.7 and 5.3.9.

The lichens DCE database contains ICP-MS full scan analyses of 711 unpolluted lichen samples collected from different locations across Greenland. Table 5.3.10 include the ratio between median results of lichens from Narsaqand the median of 711 samples from the DCE database. Concentration of yttrium (Y), zirconium (Zr), niobium (Nb), and tantalum (Ta) in lichens from Narsaq/Kvanefjeld are more than 5 times higher than the median in lichens collected from different locations across Greenland. Calcium (Ca) and nickel (Ni) levels in lichens from Narsaq are 5 times lower when comparing with those collected across Greenland.

REE levels in lichens samples from Narsaq are 2 to 4 times higher when compared with those collected across Greenland.

In this comparison, the data results from the following projects are used:

- the Ruby project at Fiskenæsset,
- the Malmbjerget project in East Greenland,
- Mestersvig,
- Maarmorilik,
- Nalunaq and
- the Seqi Olivin project.

Table 5.3.10. Element concentrations in lichen. Median values from Narsaq and from other places in Greenland (mg/Kg) and the ratio of those.

	Narsaq	Different locations in Greenland	Narsaq/Different locations in Greenland
Li	0.1	0.07	1.8
Be	0.04	0.02	2.4
Na	486	457	1.1
Mg	644	993	0.6
Al	322	305	1.1
P	538	604	0.9
K	1399	2003	0.7
Ca	1087	4895	0.2
Sc	0.089	0.3	0.3
Ti	37.0	27.0	1.4
V	0.4	0.5	0.9
Cr	0.2	0.8	0.3
Mn	35.8	36.2	1.0
Fe	275	255	1.1
Ni	0.1	0.8	0.2
Cu	0.5	0.8	0.6
Zn	20	15	1.4
Ga	0.2	0.1	1.8
As	0.06	0.1	0.5
Se	0.06	0.09	0.7
Rb	4	2.6	1.5
Sr	12.4	18.6	0.7
Y	0.7	0.1	6.5
Zr	1.1	0.2	5.0
Nb	0.7	0.03	24.6
Mo	0.04	0.02	1.6
Pd	0.002	0.007	0.3
Ag	0.005	0.02	0.3
Cd	0.05	0.08	0.6
Sb	0.008	0.005	1.7
Cs	0.1	0.06	1.8
Ba	8.1	11.1	0.7
La	2.1	0.5	4.0
Ce	3.8	1.0	3.7
Pr	0.4	0.1	4.4
Nd	1.5	0.4	3.,9
Sm	0.2	0.07	3.4
Eu	0.04	0.02	2.5
Gd	0.2	0.08	2.3
Dy	0.1	0.05	2.2
Ho	0.022	0.01	2.1
Er	0.061	0.03	2.3
Tm	0.008	0.004	2.0
Yb	0.045	0.02	2.1
Lu	0.006	0.004	1.7
Hf	0.025	0.005	4.7
Ta	0.016	0.002	10.5
W	0.017	0.006	3.1
Hg	0.034	0.03	1.2
Tl	0.004	0.006	0.7
Pb	0.995	0.8	1.2

Bi	0.003	0.004	0.6
Th	0.136	0.06	2.4
U	0.068	0.04	1.6

Table 5.3.1. Element concentrations in trout muscle. Results are in mg/Kg wet weight (w.w.). Detection limits are calculated as three standard deviations on blank values measured during the analyses. Non-accredited elements are marked with a* in the table.

mg/kg (w.w.)	Li*	Be*	Na*	Mg*	Al*	P*	K*	Ca*	Ti*	Mn*	Fe*	Co*	Ni	Cu	Zn	Ga*	As	Se	Rb*	Sr*	Y*	Zr*	Nb*	Mo*	Ru*
Detection limit (3 SD Blank)	0.03	0.0002	3	0	0.1	2	1	2	0.04	0.001	0.2	0.0001	0.02	0.002	0.3	0.0001	0.002	0.002	0.0005	0.06	0.0001	0.004	0.002	0.007	0.0001
Trout muscle (Average)	<DL	0.0002	572	294	0.6	2793	4206	122	0.1	0.06	3.5	0.001	0.02	0.5	5.6	0.0005	0.6	0.3	1.2	0.2	0.0004	0.02	0.01		
STDEV (n=11)			85	21	0.5	238	290	25	0.02	0.01	0.9	0.0003		0.1	1.4	0.0005	0.2	0.02	0.2	0.1					

Table 5.3.1. Continued.

mg/kg (w.w.)	Pd*	Cd	Sb*	Te*	Cs*	Ba*	La*	Ce*	Pr*	Nd*	Sm*	Eu*	Gd*	Tb*	Dy*	Ho*	Er*	Tm*	Yb*
Detection limit (3 SD Blank)	0.0001	0.0002	0.0003	0.0002	0.0001	0.001	0.0001	0.0002	0.00002	0.0001	0.00003	0.00001	0.00004	0.000004	0.00002	0.000004	0.00002	0.000002	0.00001
Trout muscle (Average)	0.0002	0.001	0.001	0.0003	0.03	0.004	0.001	0.001	0.0001	0.0004	0.0001	0.00002	0.0001	0.00002	0.00008	0.00003	0.00007	0.000007	0.00005
STDEV (n=11)		0.0003		0.0001	0.003	0.002	0.0005	0.0007	0.0001	0.0004	0.00006	0.00001	0.00006	0.00002	0.00009	0.00002	0.00007	0.000007	0.00007

Table 5.3.1. Continued.

mg/kg (w.w.)	Lu*	Hf*	Re*	Hg*	Tl*	Pb	Bi*	U*
Detection limit (3 SD Blank)	0.000002	0.0003	0.00001	0.002	0.001	0.005	0.00005	0.0003
Trout muscle (Average)	0.000005	0.0005	0.00003	0.04	0.001	0.007	0.0001	0.001
STDEV (n=11)	0.000003		0.00002	0.01	0.0002		0.00001	0.0002

Table 5.3.2. Activity concentration of Po-210 in trout muscle.

Coordinates	Coordinates	Sample Location	Activity concentration Po-210 (Bq/kg) (w.w)
60.952992	46.014466	Narsaq River	0.4
			0.1
			0.3
			0.2
			0.3
			0.3
		Average	0.3
		STDV (n=6)	0.1

Minimum detectable activity (MDA) were 0.023 Bq/Kg. Po-209 recovery were typically 43-74%.

Table 5.3.3. Element concentrations in blue mussel. Results are in mg/Kg dry weight (d.w.). Detection limits are calculated as three standard deviations on blank values measured during the analyses. Non-accredited elements are marked with a* in the table.

mg/kg (d.w.)	Li*	Be*	Na*	Mg*	Al*	P*	K*	Ca*	Sc*	Ti*	V*	Cr	Mn*	Fe*	Co*	Ni	Cu	Zn	Ga*	As	Se	Rb*	Sr*	Y*	Zr*	Nb*
Detection limit (3 SD Blank)	0.1	0.0007	9	2	0.5	7	5	6	0.001	0.1	0.005	0.08	0.005	0.7	0.0003	0.05	0.006	0.9	0.0004	0.006	0.005	0.002	0.2	0.0003	0.01	0.006
Blue mussel (Average)	1.0	4.5	20576	2680	2320	11490	10611	4840	0.1	16.5	0.9	1.5	15.8	346	0.6	1.1	6.8	120	2.1	12.4	5.2	5.4	38.3	11.4	4.1	2.0
STDV (n=6)	0.2	10	3013	241	4526	782	322	1564	0.01	6.1	0.2	1.5	5.7	115	0.04	0.1	0.5	62.2	2.5	1.0	0.8	1.0	10.9	2.5	1.2	0.9

Table 5.3.3. Continued.

mg/kg (d.w.)	Mo*	Ru*	Pd*	Ag*	Cd	Sb*	Te*	Cs*	Ba*	La*	Ce*	Pr*	Nd*	Sm*	Eu*	Gd*	Tb*	Dy*	Ho*	Er*
Detection Limit (3 SD Blank)	0.03	0.0004	0.0005	0.0003	0.001	0.001	0.001	0.0003	0.005	0.0004	0.0005	0.0001	0.0002	0.0001	0.00004	0.0001	0.00001	0.0001	0.00001	0.0001
Blue mussel (Average)	0.7	<DL	0.01	0.07	2.1	0.02	0.005	0.6	2.4	39.3	37.1	5.8	19.6	2.5	0.2	2.1	0.3	1.4	0.3	0.7
STDV (n=6)	0.5	<DL	0.003	0.005	0.4	0.01	0.002	1.3	0.7	7.2	5.9	0.7	2.4	0.3	0.02	0.3	0.03	0.2	0.04	0.1

Table 5.3.3. Continued.

mg/kg (d.w.)	Tm*	Yb*	Lu*	Hf*	Ta*	W*	Re*	Pt*	Au*	Hg*	Tl*	Pb	Bi*	Th*	U*
Detection limit (3 SD Blank)	0.00001	0.00003	0.00001	0.001	0.006	0.005	0.00003	0.001	0.01	0.005	0.003	0.02	0.0001	0.003	0.001
Blue mussel (Average)	0.1	0.5	0.07	0.06	0.04	0.04	0.0003	<DL	<DL	0.1	0.03	8.9	0.005	0.8	0.6
STDV (n=6)	0.01	0.1	0.01	0.02	0.01	0.01	0.0001	<DL	<DL	0.01	0.05	1.5	0.001	0.5	0.2

Table 5.3.4. Activity concentration of polonium - 210 in blue mussels.

Coordinates	Coordinates	Sample Location	Activity concentration Po-210 (Bq/kg) (ww)
60.935354	46.04546	Ilua	52
			55
		Average	54
		STDV (n=2)	2.3

Minimum detectable activity (MDA) were 0.0045 Bq/Kg. Po-209 recovery in the blue mussels were typically 68-72%.

Table 5.3.5. Element concentrations in seaweed. Results are in mg/Kg dry weight (d.w.). Detection limits are calculated as three standard deviations on blank values measured during the analyses. Non- accredited elements are marked with a* in the table.

mg/kg (dw)	Li*	Be*	Na*	Mg*	Al*	P*	K*	Ca*	Sc*	Ti*	V*	Cr	Mn*	Fe*	Co*	Ni	Cu	Zn	Ga*	As	Se	Rb*	Sr*
Detection Limit (3 SD Blank)	0.1	0.0007	9	2	0.5	7	5	6	0.001	0.1	0.005	0.08	0.005	0.7	0.0003	0.05	0.006	0.9	0.0004	0.006	0.005	0.002	0.2
Seaweed (Average)	0.2	0.1	10531	8613	55	902	20096	11845	0.02	2	0.1	0.08	44.0	36.4	0.7	1.3	2.1	85.7	0.1	36.7	0.03	10.2	744
STDEV (n=3)	0.03	0.1	2134	312	21	151	3560	870	0.002	0.2	0.02		8.6	9.4	0.3	0.9	0.2	41.6	0.04	3.4	0.001	2.5	71

Table 5.3.5. Continued.

mg/kg (dw)	Y*	Zr*	Nb*	Mo*	Pd*	Ag*	Cd	Sb*	Te*	Cs*	Ba*	La*	Ce*	Pr*	Nd*	Sm*	Eu*	Gd*	Tb*	Dy*	Ho*
Detection Limit (3 SD Blank)	0.0003	0.01	0.006	0.02	0.0005	0.0003	0.001	0.001	0.001	0.0003	0.005	0.0004	0.0005	0.0001	0.0002	0.0001	0.00004	0.0001	0.00001	0.00001	0.00001
Seaweed (Average)	1.1	0.9	0.2	0.09	0.02	0.1	0.5	0.02	0.001	0.04	24.5	1.6	1.3	0.3	1.3	0.2	0.02	0.2	0.03	0.1	0.03
STDEV (n=3)	0.6	0.1	0.1	0.01	0.002	0.01	0.2	0.004	0.0002	0.02	2.8	0.9	0.5	0.2	0.7	0.1	0.01	0.1	0.01	0.06	0.01

Table 5.3.5. Continued.

mg/kg (dw)	Er*	Tm*	Yb*	Lu*	Hf*	Ta*	W*	Re*	Tl*	Pb	Bi*	Th*	U*
Detection Limit (3 SD Blank)	0.00001	0.00001	0.00003	0.00001	0.001	0.006	0.005	0.00003	0.003	0.02	0.0001	0.003	0.001
Seaweed (Average)	0.1	0.01	0.1	0.01	0.01	0.01	0.01	0.01	0.01	0.4	0.001	0.1	0.7
STDEV (n=3)	0.03	0.004	0.02	0.003	0.002	0.001		0.01	0.003	0.2	0.0001	0.02	0.2

Table 5.3.6. Activity concentration of Po-210 in seaweed: Fucus Vesiculosus.

Coordinates	Coordinates	Sample Location	Activity concentration Po-210 (Bq/kg) (ww)
60.935354	46.04546	Ilua	1.4
			1.2
		Average	1.3
		STDV (n=3)	0.2

Minimum detectable activity (MDA) were 0.004 Bq/Kg. Po-209 recovery were typically 65-75%.

Table 5.3.7. Element concentrations in lichens. Results are in mg/kg dry weight. Detection limits are calculated as three standard deviations on blank values measured during the analyses. Non-accredited elements are marked with a* in the table.

Coordi-nates	Coordi-nates	Sample type	Li*	Be*	Na*	Mg*	Al*	P*	K*	Ca*	Sc*	Ti*	V*	Cr	Mn*	Fe*	Co*	Ni	Cu	Zn	Ga*	As	Se	Rb*	Sr*	Y*	Zr*	Nb*	Mo*	Ru*	Pd*	Ag*	Cd	Sb*	Te*
60.9884	45.99982	Flavocetraria N	0.5	1.1	624	686	440	607	1285	2595	0.1	65	0.6	0.2	80.4	398	0.1	0.1	0.5	50.8	2.1	0.1	0.1	10.1	26.0	18.9	3.3	5.0	0.04	<DL	0.03	0.01	0.1	0.1	0.001
60.97135	45.99649	Flavocetraria N	0.2	1.0	441	810	281	384	1347	998	0.1	22.5	0.3	0.1	52.2	187	0.1	0.1	0.4	80.7	0.8	0.1	0.1	3.6	12.4	6.4	2.7	1.6	0.03	<DL	0.01	0.02	0.1	0.01	<DL
60.97369	46.00049	Flavocetraria N	<DL	0.04	487	668	163	524	1614	621	0.0	15.0	0.2	0.1	17.5	122	0.1	0.1	0.4	11.8	0.1	0.03	0.05	2.6	8.1	0.7	0.5	0.4	<DL	<DL	0.001	0.01	0.04	0.004	<DL
60.97024	46.00118	Flavocetraria N	0.1	0.2	553	662	270	267	925	622	0.0	17.0	0.2	<DL	49.2	147	0.1	0.1	0.3	23.6	0.4	0.05	0.1	2.0	9.1	6.5	0.8	0.5	<DL	<DL	0.01	0.01	0.02	0.02	<DL
60.96654	46.0039	Flavocetraria N	0.2	0.2	380	649	244	348	1238	913	0.1	30.5	0.3	0.2	47.6	184	0.1	0.1	0.3	21.2	0.6	0.1	0.1	4.0	11.8	3.6	0.8	0.8	<DL	<DL	0.01	0.01	0.04	0.01	0.001
60.96534	45.98884	Flavocetraria N	0.2	0.1	381	865	232	419	1444	3113	0.1	22.9	0.3	0.1	49.7	156	0.1	<DL	0.4	43.6	0.9	0.1	0.1	6.7	29.6	10.0	3.1	1.3	<DL	<DL	0.02	0.03	0.1	0.01	<DL
60.93583	46.04488	Flavocetraria N	0.3	0.1	656	480	320	779	1641	1326	0.1	37.0	0.3	0.1	39.8	243	0.1	0.1	0.6	17.4	0.5	0.1	0.1	4.5	11.5	2.3	3.1	1.4	<DL	<DL	0.004	0.02	0.03	0.005	<DL
60.94839	46.01662	Flavocetraria N	1.0	0.6	690	566	651	673	1578	952	0.2	64.6	0.6	0.2	51.7	538	0.2	0.2	0.8	24.3	2.1	0.2	0.1	4.6	12.6	8.4	10.3	3.5	0.05	<DL	0.01	0.05	0.05	0.01	0.001
60.90765	46.03238	Flavocetraria N	0.1	0.1	704	593	322	475	1421	760	0.1	37.1	0.5	0.3	16.8	283	0.1	0.1	0.7	16.4	0.2	0.1	0.1	1.9	9.2	0.6	1.0	0.7	<DL	<DL	0.001	0.002	0.03	0.005	0.001
60.9095	46.02342	Flavocetraria N	<DL	0.01	354	456	80	394	1265	2878	0.0	11.4	0.1	<0.000	34.1	55	0.1	<DL	0.5	8.4	0.1	0.05	0.1	2.0	17.2	0.5	0.2	0.1	<DL	<DL	0.001	0.001	0.1	0.003	<DL
60.9090	46.03623	Flavocetraria N	0.1	0.03	1242	533	410	839	1841	1399	0.1	53.9	0.7	0.2	23.5	432	0.3	0.2	1.9	22.9	0.2	0.04	0.1	3.9	9.9	0.8	1.3	0.7	0.10	<DL	0.002	0.003	0.04	0.01	<DL
60.97192	46.04082	Flavocetraria N	<DL	0.02	163	418	199	452	976	584	0.0	15.4	0.3	0.1	21.7	155	0.1	0.1	0.6	9.1	0.1	0.02	0.04	3.9	5.4	0.3	0.3	0.3	<DL	<DL	0.001	0.001	0.03	0.003	<DL
60.91015	46.03547	Flavocetraria N	0.5	0.04	1032	539	550	616	1882	1047	0.1	92.5	1.0	0.7	27.2	581	0.2	0.4	1.4	19.2	0.3	0.1	0.04	8.9	8.9	0.5	1.7	1.3	0.04	<DL	0.001	0.003	0.04	0.01	0.001
60.91162	46.03852	Flavocetraria N	0.2	0.03	691	855	578	1064	2087	2578	0.1	65.0	1.0	0.5	73.6	600	0.3	0.9	1.8	28.1	0.3	0.1	0.04	8.4	9.4	0.6	1.6	0.8	0.04	<DL	0.001	0.002	0.1	0.02	<DL
60.91032	46.0348	Flavocetraria N	0.1	0.03	575	414	397	533	1270	580	0.1	48.0	0.7	0.4	25.3	422	0.2	0.4	1.1	13.2	0.2	0.1	0.1	3.8	6.1	0.5	1.1	0.7	0.04	<DL	0.001	0.001	0.03	0.01	<DL
60.9102	46.03518	Flavocetraria N	0.2	0.04	140	645	411	539	1218	732	0.1	69.9	1.0	1.0	49.1	478	0.3	1.0	0.9	14.3	0.2	0.1	0.1	3.7	8.1	0.4	1.8	0.7	0.03	<DL	0.001	0.001	0.04	0.01	0.001
60.91217	46.03857	Flavocetraria N	0.1	0.03	624	835	342	546	1399	1031	0.1	47.6	0.6	0.6	19.8	349	0.3	0.7	0.9	14.6	0.2	0.05	0.1	2.8	13.0	0.5	0.8	0.6	0.04	<DL	0.001	0.001	0.05	0.01	<DL
60.91255	46.0371	Flavocetraria N	<DL	0.02	428	730	194	915	1180	2312	0.1	24.2	0.3	0.2	18.2	162	0.1	0.1	0.5	17.8	0.1	0.1	0.1	4.3	18.3	0.3	0.4	0.3	0.04	<DL	0.001	0.003	0.1	0.004	0.001
60.91138	46.03528	Flavocetraria N	<DL	0.02	353	711	178	606	1701	3166	0.1	36.3	0.4	0.7	32.4	217	0.3	1.2	0.6	10.7	0.1	0.05	0.1	2.0	23.5	0.5	0.4	0.4	0.04	<DL	0.002	0.002	0.1	0.005	0.001
60.9106	46.0340	Flavocetraria N	0.1	0.02	942	644	399	1162	1742	842	0.1	42.7	0.6	0.5	18.8	348	0.1	0.6	1.2	28.3	0.2	0.05	0.05	4.6	9.9	0.3	1.1	0.6	0.04	<DL	0.001	0.001	0.02	0.01	0.001
60.91087	46.0460	Flavocetraria N	0.1	0.03	423	700	440	564	1673	1035	0.1	55.6	0.7	0.4	18.3	348	0.3	0.3	0.8	16.7	0.2	0.1	0.04	2.1	12.3	0.8	0.9	0.5	0.05	<DL	0.002	0.01	0.03	0.02	0.001
60.9482	46.0155	Flavocetraria N	<DL	0.04	421	736	194	445	1587	760	0.1	23.3	0.3	0.1	23.0	158	0.1	0.1	0.4	12.4	0.2	0.03	0.1	5.1	10.3	0.7	1.0	0.5	0.03	<DL	0.001	0.01	0.03	0.003	0.001
60.9474	46.0267	Flavocetraria N	0.2	0.1	592	517	298	487	1344	1116	0.1	31.4	0.3	0.3	32.2	232	0.1	0.2	0.5	14.8	0.5	0.1	0.1	2.7	23.5	2.8	3.2	1.3	0.1	<DL	0.005	0.005	0.1	0.005	<DL
60.9616	45.9935	Flavocetraria N	0.1	0.1	412	619	155	552	1295	5753	0.0	14.8	0.2	0.1	98.3	98	0.0	0.1	0.3	30.9	0.6	0.1	0.1	6.3	46.3	6.4	2.0	0.9	0.05	<DL	0.01	0.01	0.2	0.01	0.001
60.9576	46.0008	Flavocetraria N	0.5	0.4	600	353	437	613	1272	3358	0.2	41.1	0.4	0.2	51.9	276	0.1	0.1	0.4	21.7	3.2	0.2	0.1	6.0	28.5	47.3	12.6	3.8	0.1	<DL	0.06	0.06	0.2	0.01	<DL
60.9485	46.0203	Flavocetraria N	0.4	0.2	898	597	377	427	1988	1087	0.1	41.0	0.4	0.2	57.1	281	0.1	0.1	0.4	42.6	0.5	0.1	0.1	2.8	17.7	1.9	2.7	1.5	0.05	<DL	0.004	0.02	0.05	0.005	0.002
60.9635	45.9885	Flavocetraria N	0.6	0.5	279	575	532	540	1359	2587	0.1	49.4	0.6	0.3	74.8	415	0.1	0.2	0.5	28.5	1.8	0.1	0.1	4.8	24.1	16.4	12.1	3.8	0.1	<DL	0.02	0.03	0.1	0.01	0.001
61.1660	45.4058	Flavocetraria N	0.1	0.03	366	568	385	870	2276	3673	0.1	54.3	0.9	0.4	35.8	418	0.2	0.3	0.7	20.6	0.2	0.1	0.04	3.3	24.0	0.6	0.7	0.5	0.1	<DL	0.002	0.004	0.1	0.01	<DL

Table 5.3.7. Continued.

Coordinates	Coordinates	Sample type	Cs*	Ba*	La*	Ce*	Pr*	Nd*	Sm*	Eu*	Gd*	Tb*	Dy*	Ho*	Er*	Tm*	Yb*	Lu*	Hf*	Ta*	W*	Re*	Pt*	Au*	Hg*	Hg*	Tl*	Pb	Bi*	Th*	U*
60.9884	45.99982	Flavocetraria N	0.6	22.1	38.0	68.5	7.5	25.3	4.0	0.4	3.5	0.5	2.3	0.4	1.0	0.1	0.6	0.1	0.1	0.03	0.02	0.0003	0.001	<DL	0.04	38.4	0.05	4.8	0.005	2.5	1.2
60.97135	45.99649	Flavocetraria N	1.8	7.3	15.1	22.5	2.4	7.3	1.1	0.1	1.0	0.1	0.7	0.1	0.3	0.04	0.2	0.03	0.04	0.04	0.01	0.0001	<DL	<DL	0.03	32.1	0.01	4.0	0.004	1.9	0.7
60.97369	46.00049	Flavocetraria N	0.1	5.5	1.2	2.4	0.3	1.0	0.2	0.02	0.1	0.02	0.1	0.0	0.1	0.01	0.04	0.004	0.01	0.01	<DL	<DL	<DL	<DL	0.03	28.9	<DL	0.7	0.002	0.1	0.1
60.97024	46.00118	Flavocetraria N	0.1	5.0	5.5	9.9	1.1	4.1	0.8	0.1	0.8	0.1	0.7	0.1	0.3	0.04	0.2	0.03	0.02	0.02	0.01	0.0001	<DL	<DL	0.03	28.5	0.01	2.7	0.002	1.6	1.1
60.96654	46.0039	Flavocetraria N	0.1	11.4	8.7	16.1	1.6	5.4	0.8	0.1	0.7	0.1	0.5	0.1	0.2	0.02	0.1	0.01	0.02	0.03	0.01	0.0001	<DL	<DL	0.03	31.3	0.01	1.7	0.002	0.5	0.2
60.96534	45.98884	Flavocetraria N	0.2	8.0	18.1	24.4	3.2	10.5	1.7	0.2	1.4	0.2	1.1	0.2	0.6	0.1	0.4	0.1	0.1	0.1	0.01	0.0002	<DL	<DL	0.03	34.0	0.01	3.0	0.003	0.7	0.3
60.93583	46.04488	Flavocetraria N	0.2	7.4	7.1	13.7	1.4	4.9	0.8	0.1	0.6	0.1	0.4	0.1	0.2	0.02	0.1	0.02	0.1	0.04	0.03	0.0001	<DL	<DL	0.03	33.9	0.004	1.0	0.002	0.3	0.1
60.94839	46.01662	Flavocetraria N	0.4	18.2	25.3	50.6	5.8	20.2	3.5	0.3	2.6	0.3	1.7	0.3	0.8	0.1	0.5	0.1	0.2	0.03	0.04	0.0002	<DL	<DL	0.04	40.1	0.02	6.4	0.004	1.8	0.7
60.90765	46.03238	Flavocetraria N	0.05	5.2	1.7	3.2	0.4	1.3	0.2	0.03	0.2	0.02	0.1	0.02	0.1	0.01	0.04	0.005	0.02	0.02	0.04	<DL	<DL	<DL	0.03	33.2	<DL	0.9	0.004	0.1	0.05
60.9095	46.02342	Flavocetraria N	0.03	8.5	1.1	2.2	0.2	0.9	0.2	0.02	0.1	0.02	0.1	0.01	0.04	0.005	0.03	0.003	0.005	0.01	0.01	<DL	<DL	<DL	0.03	30.6	<DL	0.4	0.002	0.0	0.01
60.9090	46.03623	Flavocetraria N	0.1	7.6	1.9	3.7	0.4	1.5	0.2	0.04	0.2	0.03	0.1	0.03	0.1	0.01	0.05	0.01	0.03	0.01	0.02	<DL	<DL	<DL	0.04	38.7	<DL	0.7	0.005	0.1	0.1
60.97192	46.04082	Flavocetraria N	0.1	5.0	0.6	1.1	0.1	0.5	0.1	0.01	0.1	0.01	0.04	0.01	0.02	0.00	0.01	0.002	0.01	0.01	<DL	<DL	<DL	<DL	0.03	33.7	<DL	0.2	0.001	0.1	0.02
60.91015	46.03547	Flavocetraria N	0.1	8.1	1.4	2.7	0.3	1.0	0.2	0.03	0.1	0.02	0.1	0.02	0.05	0.01	0.04	0.005	0.04	0.01	0.02	<DL	<DL	<DL	0.03	26.0	0.02	1.0	0.003	0.1	0.1
60.91162	46.03852	Flavocetraria N	0.1	10	1.4	2.8	0.3	1.1	0.2	0.03	0.1	0.02	0.1	0.02	0.1	0.01	0.04	0.005	0.04	0.01	0.02	<DL	<DL	<DL	0.04	40.9	<DL	0.4	0.005	0.2	0.1
60.91032	46.0348	Flavocetraria N	0.04	6.8	1.4	2.6	0.3	1.1	0.2	0.03	0.1	0.02	0.1	0.02	0.04	0.01	0.04	0.005	0.03	0.01	0.02	<DL	<DL	<DL	0.03	33.5	0.004	0.5	0.003	0.1	0.1
60.9102	46.03518	Flavocetraria N	0.05	7.8	1.0	1.9	0.2	0.7	0.1	0.02	0.1	0.01	0.1	0.01	0.04	0.005	0.03	0.004	0.04	0.01	0.02	<DL	<DL	<DL	0.04	44.6	0.01	0.7	0.002	0.1	0.05
60.91217	46.03857	Flavocetraria N	0.1	9.0	1.3	2.5	0.3	1.0	0.2	0.03	0.1	0.02	0.1	0.02	0.04	0.01	0.03	0.004	0.02	0.02	0.02	<DL	<DL	<DL	0.04	39.3	<DL	1.4	0.004	0.1	0.04
60.91255	46.0371	Flavocetraria N	0.04	6.6	1.0	2.0	0.2	0.8	0.1	0.02	0.1	0.01	0.1	0.01	0.03	0.004	0.02	0.003	0.01	0.01	0.02	<DL	<DL	<DL	0.03	28.0	<DL	0.8	0.003	0.1	0.03
60.91138	46.03528	Flavocetraria N	0.02	13.0	1.3	2.5	0.3	1.0	0.2	0.03	0.1	0.02	0.1	0.02	0.04	0.01	0.03	0.004	0.01	0.01	0.01	<DL	<DL	<DL	0.03	29.1	<DL	0.7	0.003	0.04	0.03
60.9106	46.0340	Flavocetraria N	0.1	10.4	0.7	1.4	0.2	0.6	0.1	0.02	0.1	0.01	0.1	0.01	0.03	0.004	0.02	0.003	0.02	0.01	0.1	<DL	<DL	<DL	0.03	33.0	<DL	0.3	0.002	0.1	0.05
60.91087	46.0460	Flavocetraria N	0.1	9.8	2.1	4.1	0.5	1.7	0.3	0.04	0.2	0.03	0.1	0.02	0.1	0.01	0.05	0.01	0.02	0.01	0.1	<DL	<DL	<DL	0.02	23.9	<DL	1.0	0.011	0.1	0.1
60.9482	46.0155	Flavocetraria N	0.3	4.1	2.2	3.9	0.4	1.5	0.2	0.03	0.2	0.02	0.1	0.02	0.1	0.01	0.04	0.005	0.02	0.02	0.01	<DL	<DL	<DL	0.03	33.8	<DL	0.7	0.002	0.1	0.1
60.9474	46.0267	Flavocetraria N	0.1	7.6	8.3	13.4	1.4	4.8	0.8	0.1	0.6	0.1	0.4	0.1	0.2	0.02	0.1	0.02	0.1	0.03	0.02	0.0001	<DL	<DL	0.03	31.0	0.005	2.0	0.003	0.4	0.2
60.9616	45.9935	Flavocetraria N	0.1	8.8	12.4	17.9	2.3	7.7	1.2	0.1	1.0	0.1	0.8	0.1	0.4	0.1	0.3	0.04	0.03	0.04	0.01	0.0003	<DL	<DL	0.03	30.5	0.01	1.8	0.002	0.4	0.2
60.9576	46.0008	Flavocetraria N	0.6	11.6	119.5	115.5	18.6	60.6	8.7	0.8	7.6	1.0	5.0	1.0	2.5	0.3	1.5	0.2	0.2	0.1	0.1	0.001	<DL	<DL	0.04	42.7	0.03	11.4	0.004	2.1	0.6
60.9485	46.0203	Flavocetraria N	0.1	10.2	8.2	13.4	1.5	5.1	0.8	0.1	0.6	0.1	0.3	0.1	0.1	0.02	0.1	0.01	0.1	0.05	0.02	0.0001	0.002	<DL	0.04	38.8	0.01	1.2	0.002	0.4	0.1
60.9635	45.9885	Flavocetraria N	0.4	12.5	43.1	61.6	8.7	30	4.7	0.4	3.6	0.5	2.6	0.5	1.3	0.2	1.0	0.1	0.2	0.03	0.05	0.0002	0.001	<DL	0.03	34.1	0.02	6.9	0.003	2.8	1.0
61.1660	45.4058	Flavocetraria N	0.05	19.1	1.8	3.6	0.4	1.5	0.2	0.04	0.2	0.02	0.1	0.02	0.1	0.01	0.05	0.01	0.02	0.01	0.01	<DL	0.001	<DL	0.02	22.2	0.005	1.5	0.003	0.1	0.1

Table 5.3.8. Activity concentration of Po-210 in lichens: Flavocetraria N

Coordinates	Coordinates	Activity concentration Po-210 (Bq/kg) (dw)
60.9884	45.999816	5.5E+02
60.971352	45.99649	4.8E+02
60.973687	46.000494	3.5E+02
60.970242	46.001175	6.8E+02
60.966541	46.003904	3.1E+02
60.965342	45.98884	4.8E+02
60.935833	46.044877	2.3E+02
Risø ore dump		2.8E+02
60.948393	46.016623	3.0E+02
60.54459	46.01943	3.0E+02
60.5457	46.0205	2.6E+02
60.54542	46.09174	2.4E+02
60.971923	46.04082	1.6E+02
60.948173	46.015525	2.6E+02
60.947407	46.02668	1.1E+02
60.961575	45.99348	4.6E+02
60.957611	46.000843	6.7E+02
60.94852	46.020336	2.2E+02
60.963537	45.98852	4.2E+02

Minimum detectable activity (MDA) were 0.02 Bq/Kg. Po-209 recovery were typically 50-99%.

Table. 5.3.9. ICP-MS Quality Control for biota samples. Certified Reference Materials analyzed along with the biota samples. Concentrations in mg/Kg dry weight (d.w.).

mg/Kg (d.w.)	Li*	Be*	Na*	Mg*	Al*	P*	K*	Ca*	Sc*	Ti*	V*	Cr	Mn*	Fe*	Co*	Ni	Cu	Zn	Ga*	As	Se	Rb*	Sr*	Y*	Zr*
Detection limit (DL) (3 SD Blank)	0.1	0.001	9	2	0.4	7	5	6	0.001	0.1	0.005	0.08	0.005	0.6	0.0003	0.05	0.01	0.9	0.0004	0.006	0.005	0.002	0.206	0.0003	0.01
Dorm-4 Average	1.1	0.02	15648	915	1649	9636	14270	2454	0.1	20.1	1.7	2.0	3.1	356	0.3	1.5	15.9	52.9	0.4	7.1	3.8	5.9	9.8	0.2	0.3
Certificate value	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9	ND	341	ND	1.4	15.9	52.2	ND	6.8	3.6	ND	ND	ND	ND
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	27.0	ND	0.2	0.9	3.2	ND	0.6	0.3	ND	ND	ND	ND
Dolt-5 Average	<DL	0.001	11398	975	21.9	14447	16310	642	0.004	1.6	0.5	2.5	9.2	1165	0.3	1.8	36.7	115	0.01	36.3	8.4	5.2	4.2	0.03	0.1
Certificate value	ND	ND	9900.0	940	(31.7)	(11500)	14400	550	ND	ND	0.5	(2.35)	(8.91)	1070	0.3	(1.71)	35.0	105	ND	34.6	8.3	ND	3.7	ND	ND
Certificate uncertainty (2 SD)	ND	ND	1600.0	100	(4.2)	ND	3000	80	ND	ND	0.1	(0.58)	(0.70)	80	0.0	(0.56)	2.4	5	ND	2.4	1.8	ND	0.3	ND	ND
Tort-3 Average	0.2	0.01	20666	1161	15.1	13817	14797	2573	0.01	1.2	9.3	1.9	14.5	179	1.1	5.2	466	138	0.1	68	11.6	4.8	35.1	1.0	0.1
Certificate value	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.1	2.0	15.6	179	(1.06)	5.3	497	136	ND	59.5	10.9	ND	36.5	ND	ND
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	0.2	1.0	8	ND	0.2	22	6	ND	3.8	1.0	ND	1.6	ND	ND

Table. 5.3.9. Continued.

mg/Kg (d.w.)	Nb*	Mo*	Ru*	Pd*	Ag*	Cd	Sb*	Te*	Cs*	Ba*	La*	Ce*	Pr*	Nd*	Sm*	Eu*	Gd*	Tb*	Dy*
Detection limit (DL) (3 SD Blank)	0.006	0.02	0.0004	0.0005	0.0003	0.001	0.001	0.001	0.0003	0.005	0.0004	0.0005	0.0001	0.0002	0.0001	0.00004	0.0001	0.00001	0.00007
Dorm-4	0.1	0.3	ND	0.001	0.008	0.3	0.009	0.003	0.1	5.8	0.7	1.6	0.2	0.7	0.1	0.03	0.1	0.02	0.1
Certificate value	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	0.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dolt-5	0.02	1.6	ND	ND	2.0	15.3	0.01	0.004	0.1	0.2	0.03	0.05	0.01	0.03	0.005	0.001	0.004	0.001	0.004
Certificate value	ND	1.4	ND	ND	2.1	14.5	(0.013)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Certificate uncertainty (2 SD)	ND	0.2	ND	ND	0.1	0.6	0.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tort-3	0.01	3.7	ND	0.003	9.3	43	0.1	0.01	0.02	0.4	2.7	2.4	0.4	1.4	0.2	0.04	0.2	0.02	0.1
Certificate value	ND	3.4	ND	ND	ND	42.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Certificate uncertainty (2 SD)	ND	0.1	ND	ND	ND	1.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 5.3.9. Continued.

mg/kg (d.w.)	Ho*	Er*	Tm*	Yb*	Lu*	Hf*	Ta*	W*	Re*	Pt*	Au*	Hg*	Tl*	Pb	Bi*	Th*	U*
Detection limit (DL) (3 SD Blank)	0.00001	0.00008	0.000007	0.00003	0.000006	0.0009	0.006	0.005	0.00003	0.0007	0.007	0.005	0.003	0.02	0.0001	0.003	0.001
Dorm-4	0.01	0.02	0.003	0.01	0.002	0.01	ND	0.1	0.001	ND	ND	0.4	0.01	0.4	0.02	0.2	0.1
Certificate value	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	0.4	ND	ND	ND
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	0.1	ND	ND	ND
Dolt-5	0.001	0.002	0.0002	0.002	0.0002	0.002	0.03	2.0	0.01			0.4	0.01	0.2	0.02	0.01	0.1
Certificate value	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	(0.082)	0.2	ND	ND	(0.013)
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	0.0	ND	ND	ND
Tort-3	0.03	0.1	0.01	0.03	0.004	0.001		0.1	0.1	0.001		0.3	0.01	0.2	0.02	0.005	0.1
Certificate value	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	0.2	ND	ND	ND
Certificate uncertainty (2 SD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02	ND	0.02	ND	ND	ND

6. Conclusion

DCE background gamma dose-rate results for Narsaq town and Kvanefjeld plateau using the Survey Meter Colibri VLD are comparable to results obtained by GMEL during 2008, 2009 and 2014. Results of background gamma at the critical group (farm in Narsaq) reported by GMEL in 2009 and 20011 are comparable with DCE results from 2017.

High results were reported by GMEL for background gamma in Narsaq in 2010, 2011 and 2013 (comparing with GMEL previous year's results and DCE results). For some reasons GMEL reported approximatively 2-3 times higher values of background gamma at the critical group in 2010 and 20013 than DCE reported values.

Uranium in the analyzed water samples from Narsaq does not exceed the recommended water quality criteria of 30 µg/L. The GMEL reported value of U in the Kvane River is 48 times higher than the DCEreported value. F levels in the analyzed water samples collected from Narsaq River and Kvane River exceed the water quality criteria of 1500 µg/L by a factor of two. Excepting the water outlet of the old Risø mine (0.8 Bq/L) the Po-210 activity concentration in analyzed water samples is very low and does not exceed the recommended water quality criteria of 0.1 Bq/L. This is the first report so far in which the U, Th and Po results for drinking water from Narsaq are reported.

Following elements Li, Be, Ga, As, Mo, Sb, W, U are ten times higher in the water samples from Narsaq when comparing with median values for similar samples from different locations across Greenland. Particularly low concentrations of Fe, Cu, Ba, Eu,Ti, Ce and Th were noted in the Narsaq River.

In drinking water from Narsaq only the concentration of Be, and Mo are more than 10 times higher than the median of all other analyses from other locations in Greenland, and Ti, Ba, Ce, and Tl have very low concentrations. It is interesting that the rare earth elements are not high in Narsaq River, but higher in drinking water compared to the samples collected from other locations in Greenland. In this comparison, data from the following projects in Greenland are used: Isua iron ore project, Fiskenæsset ruby project, White Mountain anorthosite, Nalunaq gold, Pittufik titanium and Hudson resources Sarfartoq project.

DCE reported activity concentration of Po-210 in trout is six time lower than GMEL reported value. DCE Po-210 results for blue mussels and lichens are comparable with GMEL results.

Concentration of Y, Zr, Nb, and Ta in lichens from Narsaq/Kvanefjeld are more than 5 times higher than the median in lichens collected from different locations across Greenland. Ca and Ni levels in lichens from Narsaq are 5 times lower when comparing with those collected across Greenland.

RRE levels in lichens samples from Narsaq are 2 to 4 times higher when comparing with those collected across Greenland.

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ENVIRONMENTAL BASELINE AUDIT RESULTS FROM KVANEFJELD REES, U AND ZN PROJECT

Exploration activities 2007-2017.
Audit: 29 August to 5 September 2017 by DCE and GINR

Violeta Hansen from DCE - Danish Center for Environment and Energy, Gert Asmund from (DCE) and Morten Birch Larsen from Greenland Institute of Natural Resources (GINR) did an environmental audit at the Kvanefjeld from 29 August to 5 September 2017. Since 2007, Greenland Minerals and Energy Limited (GMEL) have conducted exploration activities at the Kvanefjeld - a Rare Earth Elements (REEs), uranium (U) and zinc (Zn) project in Southern Greenland. GMEL have conducted baseline environmental monitoring at the Kvanefjeld. Baseline monitoring activities included external dose-rate monitoring, passive radon monitoring, dust monitoring and analysis of some selected non-radioactive and radioactive elements in dust and environmental samples. Polonium-210 has been analysed in a number of biological samples and radium-226, radium-228 and lead-210 have been analyzed in a small number of water samples. The extent of monitoring varied from year to year since 2007 to present. In order to verify some of GMEL's environmental baseline studies, a number of environmental samples from Narsaq were collected and analyzed by DCE and GINR. In general, DCE's results of analysed baseline samples from Narsaq/Kvanefjeld are comparable with GMEL reported results in previous years for similar samples. This report include for the first time results of uranium (U), thorium (Th) and polonium-210 (Po-210) levels in drinking water from Narsaq. Background gamma dose rate in Narsaq town and radioactive elements in the analyzed herein samples (except lichens) are ***not elevated*** and are comparable with baseline values elsewhere. Levels of Po-210 (680 Bq/Kg d.w.) in lichens collected from Narsaq are higher when compared with levels of Po-210 in lichens collected from Denmark and Sweden (200 Bq/Kg d.w.). High levels of F and non-radioactive elements including also REE are reported in water and biological samples collected from Narsaq.

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