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Recent trends of environmental radioactivity in Greenland and the Faroe Islands

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Abstract. Environmental radioactivity in Greenland and the Faroe Islands was investigated from samples collected in 2004 of seawater, seaweed, marine fish, seal, whale, lake water, freshwater fish and total diet. Anthropogenic radionuclides in Greenland and the Faroe Islands are present due to long-range transport by air and water mainly due to fallout from nuclear weapons testing, from the Chernobyl accident and discharges from European reprocessing facilities, Sellafield in the UK and La Hague in France. Concentrations of anthropogenic radionuclides in environment and food are low, however, and present insignificant health risks to humans. Naturally occurring radionuclides are present in the environment and human food and dominate the radiation dose from ingestion. Even in case of landlocked Arctic char from South Greenland showing elevated concentrations of anthropogenic ^{137}Cs, the radiation doses to man from ingestion derive mainly from the presence of the naturally occurring radionuclide ^{210}Po. Samples of total diet from Uummannaq indicate that annual radiation doses by ingestion could approach 1 mSv from ^{210}Po possibly due to a high proportion of seal flesh and liver in the diet.

1. INTRODUCTION

Radioactivity is a key contaminant group of the Arctic Monitoring and Assessment Programme (http://AMAP.no) and considered to be an environmental pollution issue of first circumpolar priority. Environmental radioactivity in Greenland and the Faroe Islands has been studied since the early 1960's and the data have been included in previous AMAP assessments [1–5]. The present project covers results from sampling in 2004. The sampling programme has focused on providing information on the following issues

- Monitoring of radioactivity in the sea current along the east coast of Greenland transporting pollution from nuclear facilities in Western Europe and Russia,
- Monitoring radioactivity in the sea around the Faroe Islands,
- Investigation of elevated levels of radiocaesium in freshwater fish in South Greenland and the Faroe Islands,
- Monitoring of radiocaesium in reindeer and lamb in South Greenland and lamb in the Faroe Islands, and
- Investigation of radioactivity in traditional Inuit diet and derived radiation doses.

2. MATERIALS AND METHODS

Sampling was carried out during 2004 in collaboration with a number of partners. Samples from Greenland of seawater and whale were provided by Greenland Institute of Natural Resources, samples of seaweed, marine fish, seal, lake water and freshwater fish were provided by the National Environmental Research Institute, Department of Arctic Environment, and samples of diet were provided by University of Aarhus, Institute of Environmental and Occupational Medicine. Sampling of reindeer and lamb in

Greenland was unsuccessful. Seawater samples from the Denmark Strait were provided by the Icelandic Radiation Protection Institute. Samples from the Faroe Islands were provided by the University of Faroe Islands.

The samples were analysed for contents of naturally occurring radionuclides (^{40}K, ^{210}Pb, ^{210}Po) and anthropogenic radionuclides (^{90}Sr, ^{99}Tc, ^{137}Cs, ^{238}Pu, ^{239,241}Pu and ^{241}Am). Prior to radionuclide determination the samples were subject to various pre-treatments and radiochemical procedures. The radionuclides ^{40}K and ^{137}Cs were determined by gamma spectrometry, ^{90}Sr and ^{99}Tc were determined by total beta counting, and ^{210}Pb, ^{210}Po, ^{238}Pu, ^{239,241}Pu and ^{241}Am were determined by alpha spectrometry.

3. RESULTS

3.1 Seawater

Concentrations of anthropogenic radionuclides in seawater were obtained from locations which cover the west coast of Greenland, the Denmark Strait and the Faroe Islands. No samples were collected from the east coast of Greenland. The concentrations of ^{90}Sr and ^{137}Cs show relatively small variation across the region with levels in the range 0.9–1.3 Bq m^{-3} and 2–3 Bq m^{-3}, respectively. Concentrations of ^{90}Sr are found down to 0.2 Bq m^{-3} near Disko due to dilution from melting ice, whereas the lowest concentrations of ^{137}Cs of 1.5–2.0 Bq m^{-3} are found at the Faroe Islands. The highest seawater concentrations of ^{90}Sr and ^{137}Cs are generally found in the Denmark Strait and at the south coast of Greenland.

Concentrations of transuranics in seawater are low and show little variability along the west coast of Greenland. Levels of Pu-isotopes are in the range 2–6 mBq m^{-3} for ^{239,240}Pu, below 0.3 mBq m^{-3} for ^{238}Pu and below 1 mBq m^{-3} for ^{241}Am. Concentrations of ^{99}Tc in seawater, which are due to releases from Sellafield mainly, are somewhat higher, in the range 30–75 mBq m^{-3} with the lowest concentrations at the Faroe Islands. The highest concentrations are also here found in the Denmark Strait and at the south coast of Greenland.

The seawater concentrations of ^{90}Sr and ^{137}Cs in the North Atlantic are shown in Figs. 1 and 2 covering the years 1960–2006. The data illustrate that the seawater concentrations are higher on the east coast of Greenland than on the west coast and that the concentrations are generally lower at the Faroe Islands.

3.2 Seaweed

Concentrations of radionuclides in seaweed were obtained for the naturally occurring radionuclide ^{40}K and the two anthropogenic radionuclides ^{99}Tc and ^{137}Cs. The concentrations of ^{137}Cs in seaweed are found in the range 0.2–2.7 Bq kg^{-1} dw and for ^{99}Tc in the range 4–33 Bq kg^{-1} dw. ^{99}Tc and ^{137}Cs is accumulated in seaweed which shows the highest levels on the east coast of Greenland due to the East Greenland Current that is influenced by Chernobyl fallout and industrial pollution from Europe. The concentration of ^{40}K in Fucus vesiculosus from the Faroe Islands was 1320–1350 Bq kg^{-1} dw.

3.3 Fish

Concentrations of radionuclides were determined in Shorthorn Sculpin from Greenland. The levels of ^{40}K found in the range 70–90 Bq kg^{-1} fw are related directly to the potassium content and show therefore very small variation. The ^{137}Cs concentrations are in the range 0.1–0.3 Bq kg^{-1} fw showing higher concentrations on the east coast of Greenland at Ittoqqortoormiit (Scoresbysund) compared with the west coast at Qaanaaq in agreement with the seawater transport pattern. Concentrations of ^{137}Cs in cod and haddock from the Faroe Islands were found in the range of 0.1–0.2 Bq kg^{-1} fw. Time series of ^{137}Cs in cod and haddock from the Faroes is shown in Fig. 3.

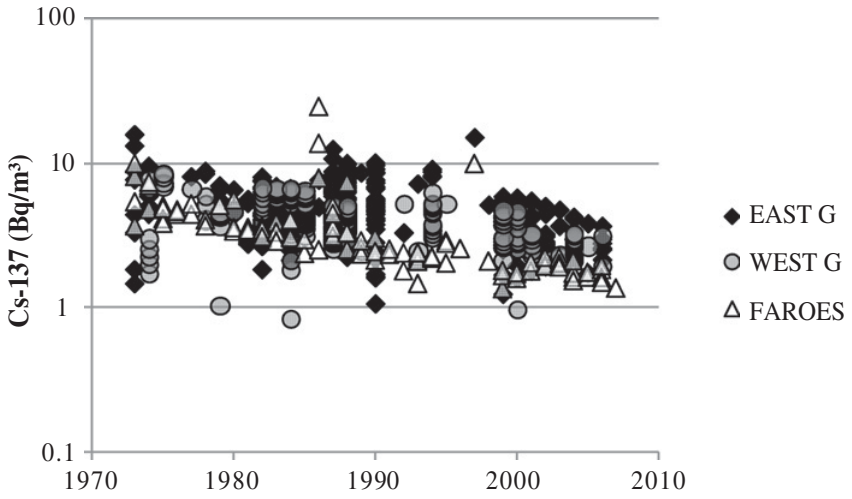

Figure 1. Caesium-137 in seawater (Bq m^{-3}) from East and West Greenland and the Faroe Islands during 1970–2007.

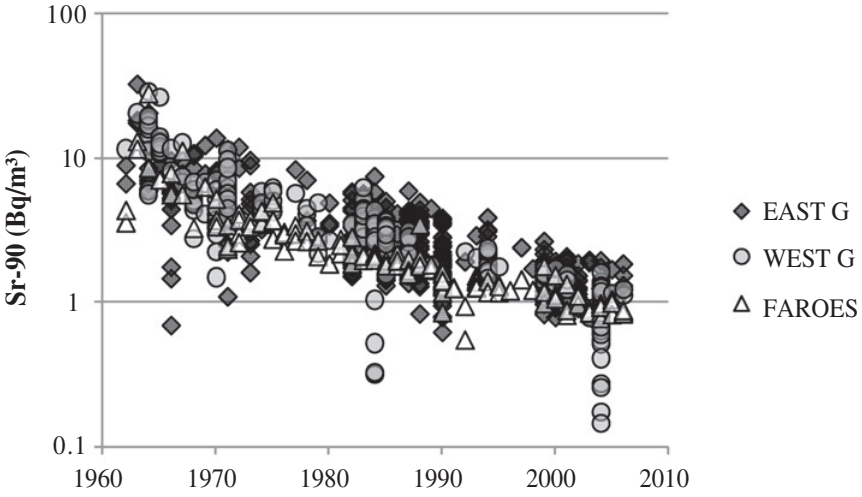

Figure 2. Strontium-90 in seawater (Bq m^{-3}) from East and West Greenland and the Faroe Islands during 1970–2007.

3.4 Seal and whale

Concentrations of naturally occurring and anthropogenic radionuclides were determined in seal flesh and liver and in whale flesh from Greenland. The concentrations of ^{137}Cs in seal from 2004 are found in the range 0.1–0.6 Bq kg^{-1} fw with the highest concentration from the east coast of Greenland. The concentrations of ^{137}Cs in samples of Minke whale were in the range 0.4–0.5 Bq kg^{-1} fw. Concentrations of the naturally occurring radionuclides ^{40}K, ^{210}Po and ^{210}Pb in seal and whale were found in the ranges 33–127 Bq kg^{-1} fw, 11–69 Bq kg^{-1} fw and 0.1–2.8 Bq kg^{-1} fw, respectively. Concentrations of ^{40}K show considerably smaller variation than for ^{210}Po and ^{210}Pb. The concentrations of ^{210}Po in seal flesh are found in the range 10–11 Bq kg^{-1} fw and in seal liver in the range 29–69 Bq kg^{-1} fw.

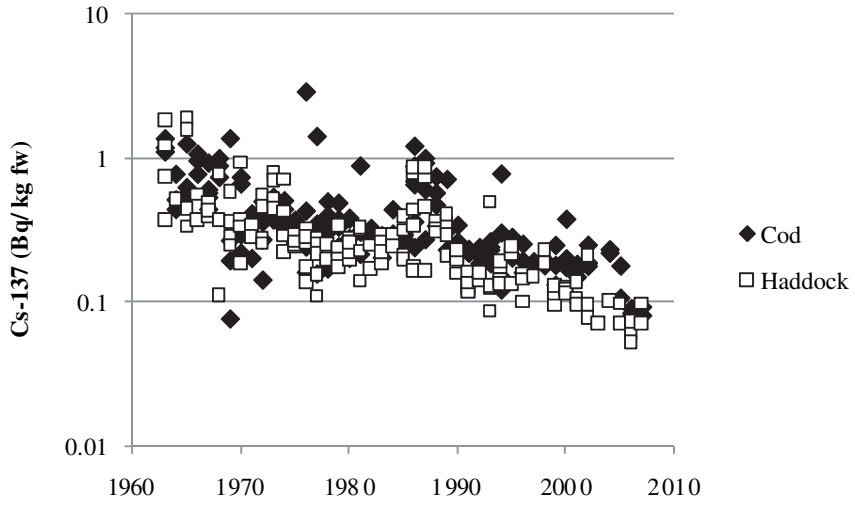

Figure 3. Concentrations of ^{137}Cs in cod and haddock from Faroe Islands during 1960–2006.

The concentrations of ^{210}Pb in seal flesh are found in the range 0.04–0.2 Bq kg^{-1} fw and in seal liver in the range 0.1–2.8 Bq kg^{-1} fw.

Concentrations of 0.2 Bq kg^{-1} fw of ^{137}Cs and 92 Bq kg^{-1} fw of ^{40}K were found in flesh from Pilot Whale caught at the Faroe Islands. Fig. 4 shows concentrations of ^{137}Cs in seal and whale from Greenland and in whale from Faroe Islands during 1960–2006.

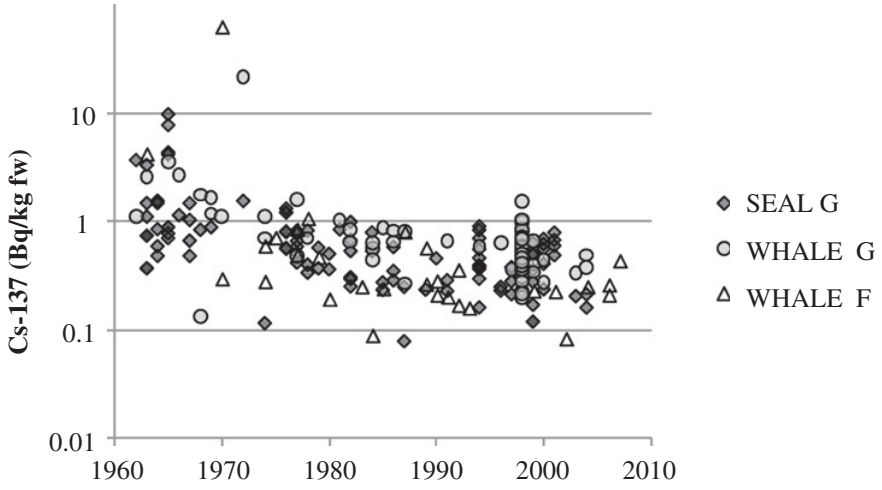

Figure 4. Concentration of ^{137}Cs in seal and whale from Greenland and in whale from Faroe Islands during 1960–2006.

3.5 Lake water and landlocked Arctic char

Samples of lake water were available from Narsaq in South Greenland and from Toftavatn in the Faroe Islands. Concentrations of ^{137}Cs in lake water were higher from Toftavatn (3.6 Bq m^3) than from Narsaq (1.2 Bq m^{-3}), whereas the concentrations of ^{90}Sr were higher from Narsaq (4.0 Bq m^{-3})

than from Toftavatn (2.5 Bq m^{-3}). The concentrations of ^{90}Sr and ^{137}Cs in lake water are due to fallout from atmospheric nuclear weapons testing and the Chernobyl accident. The significantly higher concentrations of ^{90}Sr relative to ^{137}Cs in lake water from Narsaq compared with Toftavatn are probably due to a larger amount of Chernobyl fallout at Toftavatn compared with Narsaq.

The concentration of ^{137}Cs in landlocked Arctic char of 20 Bq kg^{-1} fw from the lake at Narsaq is relatively high compared with the concentration in water. A high uptake of radiocaesium in freshwater fish is characteristic for oligotrophic lakes.

3.6 Lamb

Samples of lamb were collected in the Faroe Islands. The concentrations of ^{137}Cs were in the range 2–27 Bq kg^{-1} fw reflecting geographical variation in the deposition from the Chernobyl accident and fallout from the nuclear weapons testing. The level of ^{90}Sr was 0.01 Bq kg^{-1} fw.

3.7 Total diet

Samples of total diet were collected from Uummannaq in May 2004 and analysed for ^{137}Cs, ^{40}K, ^{210}Po and ^{210}Pb. The concentrations of ^{137}Cs range from below the detection limit of 0.04 Bq kg^{-1} fw to 1.6 Bq kg^{-1} fw with an average concentration of 0.2 Bq kg^{-1} fw. The concentrations of ^{40}K are found in the range of 26–79 Bq kg^{-1} fw with an average concentration of 48 q kg^{-1} fw corresponding to potassium contents in the range of 0.8–2.6 g K kg^{-1} fw and an average value of 1.6 g K kg^{-1} fw. Concentrations of ^{210}Po were found in the range of 0.04–1.6 Bq kg^{-1} fw and for ^{210}Pb in the range of 0.06–0.1 Bq kg^{1} fw. The higher concentrations of ^{210}Po in the diet samples indicate a higher component of seafood (e.g. seal liver and flesh).

If we assume these diet samples to be representative for an annual diet, we may estimate annual radiation doses to humans from ingestion of the radionuclides mentioned. Based on an annual food consumption of 500 kg and recommended dose coefficients, we find an average annual radiation dose of 0.3 mSv from the diet content of ^{137}Cs, ^{210}Po and ^{210} Pb. The corresponding relative dose contributions from these radionuclides are 0.3%, 92% and 8% respectively. The dominating contribution from ^{210} Po is due to the alpha particles emitted by this radionuclide compared with the other radionuclides from which the dose is delivered by beta radiation mainly. The average annual dose of 0.3 mSv is about twice the dose from naturally occurring ^{40}K in potassium that all humans contain, cf. Fig. 5. The diet sample with the highest ^{210}Po concentration corresponds to an annual radiation dose of about 1 mSv of which

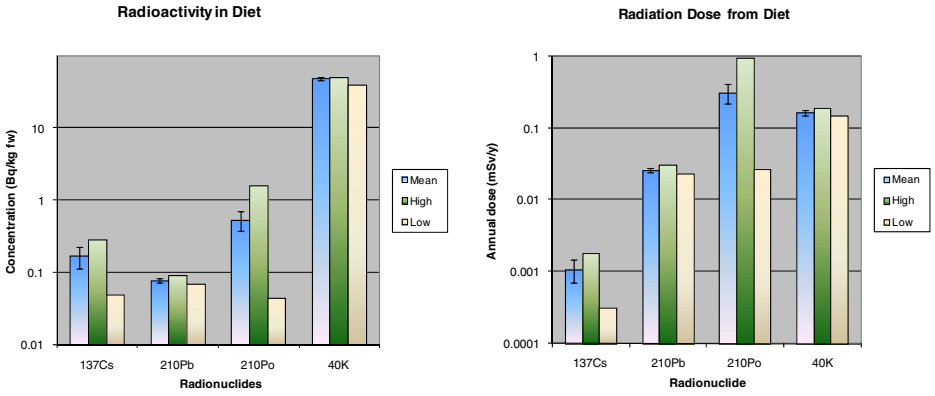

Figure 5. Radioactivity in diet from Uummannaq in 2004 and derived annual radiation doses. Error bars show standard errors of the mean values (1 sem).

97% is received from that radioisotope. The diet sample with a low ^{210}Po concentration corresponds to an annual dose of 0.05 mSv of which 53% is received from ^{210}Po, 47% from ^{210}Pb and 0.6% from ^{137}Cs.

Acknowledgment

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