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INVESTIGATION INTO TERRESTRIAL RADIOACTIVE CONTAMINATION AT THULE AND ASSESSMENT OF RADIATION DOSES

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Background

In January 1968, an American B-52 bomber crashed into the sea ice in the vicinity of Thule Air Base in Greenland. As a result of the accident, radioactive material from the damaged nuclear weapons was dispersed in smoke from the burning engine fuel. The majority of the radioactive material landed on the ice surrounding the crash site and was subsequently cleaned up by the USA. Smaller amounts of the radioactive material were carried by the wind southward over the land. In the years following the accident, Risø DTU has undertaken multiple studies of the marine environment and has recorded significant contamination on the seafloor beneath the crash site, with low levels of transfer to animals and marine plants.

In 2003, terrestrial contamination was recorded at the Narsaarsuk hunting station, which is located on the coast, 8 km south of the crash site. It was decided to undertake studies of terrestrial contamination in order to assess the risk for any humans who might be present in the studied areas and who might inhale radioactive particles, which can be stirred up out of the soil by wind and by dust-producing activities.

The results of the studies are assembled in a report by the Radiation Research Division at Risø DTU, and associated assessments of radiation doses are provided in a report by the National Institute of Radiation Protection within the National Board of Health. A combined summary of the two reports is offered below, accompanied by conclusions and recommendations.

Studies

The studies involved sampling of soil and making measurements in the Thule area in the summers of 2007 and 2008. Besides Narsaarsuk, the studies covered Thule Air Base, Saunders Island,

Wolstenholme Island, Kap Atholl (on the coast, 15 km south of Narsaarsuk, occasionally used for recreational activities), Grønnedal (coastal hunting area 20 km south of Narsaarsuk), and Moriusaq (40 km northwest of Thule Air Base).

Overview map of the Thule area

Overview map of the Thule area, showing the crash site (star) and the hunting area around Kap Atholl, Grønnedal, Narsaarsuk, Saunders Island, Wolstenholme Island, the Thule Air Base, and the Moriusaq settlement.

The Thule area is characterised by uneven terrain and changeable weather conditions. Project participants utilised motorboats and all-terrain vehicles as means of transport from Thule Air Base to the study sites, for instance to transport equipment to Narsaarsuk. While at the sites, research was done primarily on foot.

A large number of soil samples as well as samples of air, rain, and airborne and soil particles were taken near Narsaarsuk, where contamination had previously been recorded. Collection of air, rain, and particle samples took place over periods of two to eight weeks in 2007 and 2008. Portable equipment was used to make supplemental measurements of soil contamination in places with raised contamination levels.

The collected samples were transported to Risø DTU and analysed in the laboratory in order to determine the presence of radioactive material. The analyses included plutonium isotopes as well as americium. Americium occurs as an impurity in plutonium.

Results from the Radioactivity Measurements

Analyses of soil samples show great variation in radioactive contamination near Narsaarsuk. The results vary from the background level for pluto-

nium at 20–40 Bq m^{-2} to more than 1 MBq m^{-2}. Raised contamination levels occur sporadically in places that face north and are damp in the summer, presumably due to the deposition and subsequent melting of snow that was contaminated following the accident. Contamination occurs primarily in the uppermost soil layer, at 0–2 cm.

The total amount of plutonium in the soil near Narsaarsuk is estimated to be 0.1 kg, compared with the estimated 1 kg on the seabed. This is in relation to the total 7–8 kg of plutonium that the B-52 plane is estimated to have carried.

The area around the Narsaarsuk hunting station was systematically surveyed for radioactive contamination, but it was not possible to undertake a systematic search for raised radiation levels throughout the region as a whole. It is thus impossible to rule out the existence of other sites, besides those that have already been identified, with raised contamination levels.

Analyses of soil samples from Kap Atholl and Grønnedal show contamination levels that are lower than near Narsaarsuk but still significantly above the background level. Analyses of soil samples from Thule Air Base, Moriusaq, Saunders Island, and Wolstenholme Island show radioactive contents at the background level: In other words, there are no signs of contamination from the 1968 plane crash.

Near Narsaarsuk, extremely small quantities of plutonium were found in airborne particulates collected with air filters and sticky foils. Both test types resulted in air concentrations at the same low levels as are found in Europe. Rain samples collected near Narsaarsuk also contained small quantities of plutonium, also amounting to very low airborne concentrations. No samples of air or rain from Narsaarsuk showed signs of particles with raised plutonium content.

Reports on Terrestrial Contamination in Thule

Thule-2007 – Investigation of radioactive pollution on land, Risø DTU 2011, Risø-R-1781(EN), http://www.risoedtu.dk/Knowledge_base/publications/Reports/ris-r-1781.aspx

The Thule Accident: Assesement of Radiation Doses from Terrestrial Radioactive Contamination, National Institute of Radiation Protection 2011, www.sst.dk/publ2011/SIS/Thule/SIS_Thule_rapport_2011_EN.pdf

Assessment of Radiation Doses

The potential risk for humans present in the studied areas has been assessed in such a way as to consider all of the ways in which people could be exposed to radiation from the radioactive material that was dispersed following the Thule accident. For every exposure pathway, radiation doses have been calculated on the basis of the measured contamination levels as well as a number of variables concerning time spent in the area, *etc.*

The contaminating radioactive material at Thule does not emit significant amounts of penetrating radiation. Stays in the area thus do not result in external irradiation, for instance of the sort resulting from an x-ray examination. Irradiation can therefore only occur if the radioactive material enters a person's body so that radiation exposure occurs internally. This can happen if the radioactive material occurs in a form in which it may enter a person's body through inhalation, the consumption of contaminated foodstuffs, or through wounds and cuts in the skin.

Based on international recommendations a radiation dose of 1 mSv/year has been selected as a reference for comparison against the calculations. This Thule reference level forms the basis for assessing whether special control or protection measures are necessary as a result of terrestrial contamination in the Thule area. As a comparison with the Thule reference level, we can note that Greenlanders and Danes receive approximately 1 mSv/year as a result of naturally occurring radiation sources such as cosmic rays from space and naturally occurring radioactive materials in soil, construction material, and foodstuffs (natural background radiation). Furthermore, the Danish dose limit for members of the public as a result of planned exposure from all sources of radiation is also 1 mSv/year. A dose of 1 mSv/year has no significance to health.

Radiation Dose from Inhalation

The dose from inhalation of radioactive material due to stays in the area is calculated on the basis of the measured concentrations of plutonium in the air for one person, who is assumed to spend 14 days/year in the area. The result is an dose of 0.000,000,1 mSv/year. This is an extremely small dose.

Radiation Dose from Ingesting Musk Ox Meat

Meat from musk oxen is the most significant source of terrestrial mammal meat from the Thule area in the diets of the local population. No measurements of plutonium and americium in musk ox meat have been undertaken in the Thule area or elsewhere in Greenland. Generally speaking, however, plutonium is transferred very poorly by the digestive systems of both humans and animals, including ruminants such as musk oxen. The possibility of contamination of musk ox meat is therefore assessed on the basis of general considerations and knowledge of meat contamination from other ruminants present in areas contaminated by plutonium elsewhere in the world, though grazing conditions may have differed elsewhere. If such a provisional assessment is based on cattle in the USA and sheep in the United Kingdom, and if it is assumed that an individual consumes 15 kg of musk ox meat/year, the resultant dose from meat ingestion is 0.000,1 mSv annually. Although this dose is greater than the inhalation dose, it must still be regarded as being extremely small.

Glossary

Plutonium and Americium:
The radioactive materials plutonium-239 and americium-241.

Bq (becquerel):
Unit of activity, i.e. the quantity of a given radioactive material.
1 MBq (megabecquerel) = 1,000,000 Bq.
Bq m^{-2} (becquerel per square meter).

mSv (millisievert):
Unit of radiation dose.

Order of Magnitude Estimate:
Radiation doses are given in factors of 10, for instance 1, – 0.1, – 0.01, and – 0.001.

A superior assessment of dose from meat ingestion could be obtained by collecting and measuring samples of musk ox meat taken in the Thule area. The National Institute of Radiation Protection does not anticipate that such measurements would show plutonium concentrations in the meat that deviate significantly (for instance, by a factor of 100–1000) from the plutonium content in the meat estimated for the provisional dose calculation. The dose assessment for meat ingestion can therefore be regarded as broadly robust when considered in light of the reference level of 1 mSv/year.

Radiation Dose from Wound Contamination

Wounds and cuts on individuals present in contaminated areas can be contaminated by dust, soil, or particles. Soil and other foreign materials will normally be thoroughly washed and cleaned from wounds and cuts. If soil or particles remain in the skin after cleaning, these can be absorbed by the body. If the soil or a particle is contaminated by radioactive material, this could result in internal irradiation of the body. The probability of a wound contaminant containing radioactive material from the Thule accident is very small, and the probability of a person being exposed to such wound contamination more than once in his or her life is therefore exceptionally small.

If a wound should, however improbably, nevertheless be contaminated by radioactive material, a dose is calculated on the basis of the measured plutonium concentrations in the soil and particles. The calculation assumes that 0.1 g of soil or a particle of the most-radiating size enters a wound. The result in this case is a dose of 0.001 mSv/year for soil in the wound or 0.1 mSv/year for a particle in the wound. These doses are very small.

Total Dose

The calculations and dose assessments have been undertaken on the basis of very conservative assumptions, which likely overestimate actual doses. Calculations and assessments are, however, subject to uncertainty and qualifications. By the same token, the results are presented as order of magnitude estimates of dose, and the results are valid for all individuals (from "tourists" to Greenlandic trappers) and for all ages (from children to adults) who might stay in the studied areas.

If the results of the three means of radiation exposure (ingestion, inhalation, and wound

contamination) are combined, it is assessed that, even under extreme conditions and assumptions, the total dose for individuals in the Thule area resulting from the 1968 Thule accident is smaller than the applied reference level of 1 mSv/year and therefore has no significance to health.

Recommendations

On the basis of the research conducted, Risø DTU can, from a radioecological perspective, make the following recommendations concerning further planning and measurements:

- A number of small areas were found near Narsaarsuk with raised plutonium levels on the ground surface. It is necessary to ascertain whether there are other sites in the region featuring significantly raised levels of radioactivity as a result of the accident.

- The occurrence of multiple sites near Narsaarsuk with raised radioactivity levels suggests that significant contaminant dispersal from the 1968 accident has taken place. It is likely that radioactive particles were carried by meltwater and precipitation to the local stream, by which they were transported and deposited in the sediments near Narsaarsuk, where the stream runs out into the sea. These sediments should be analysed for potential radioactive contents as a result of the accident. Information on radioactivity levels in the sediments is relevant for estimating the total inventory of plutonium that was dispersed by the 1968 accident.

- Wild animals in the area may be contaminated by radioactivity, especially at sites near Narsaarsuk with raised levels. A screening program should be carried out, testing for the presence of radioactive material in game animals from the area. Relevant game may include musk oxen, arctic hare, and birds.

On the basis of Risø DTU's research as well as the calculations and dose assessments undertaken, the National Institute of Radiation Protection can, from the perspective of radiation protection and public health, make the following recommendations regarding the need for follow up on the measurements and assessments, including assessments on the need for future measurements:

- From a radiation protection assessment perspective, based on the current use of the

contaminated area in Thule, there is no need for restrictions to stays, etc. or for decontamination measures in the area.

- As noted in the assessment of the radiation dose resulting from ingestion of foodstuffs, no direct measurements of plutonium in musk oxen from the Thule area or other parts of Greenland are currently available. As a result, the assessment has relied on models based on experiences from contaminated locations elsewhere in the world, which differ from the conditions in the Thule area in terms of climate, *etc.* The dose calculations from meat ingestion could thus be better qualified via a small survey program that samples musk oxen and other terrestrial mammals from the Thule area. The collected samples should then also be measured for the presence of the naturally occurring radioactive material polonium-210, which is estimated to cause significantly higher doses than the plutonium contamination does.

- The assessment of radiation doses resulting from plutonium contamination for people in the Thule area is based on Risø DTU's research up to and including 2008, applied to the current use of the area. To ensure that the assumptions for this assessment remain valid, a small, tailored survey should be carried out every 5 to 10 years.

- The assessed radiation doses for people in the Thule area are significantly lower than the recommended Thule reference level. There is thus no need, from a dose monitoring perspective, to analyse for the presence of plutonium in individuals living in the area in survey programs such as the search for plutonium in the urine of previous Narsaarsuk residents carried out in 1989.

- If plans arise for changed use of the area, for instance involving the construction of buildings or other installations, including long-term stays or residence in the area, the need for restrictions concerning stays, *etc.* in the area or for decontamination measures should be reconsidered in detail prior to the plan's commencement.

- Protection measures such as signposting or fencing off selected areas for reasons not related to radiation protection would not influence the National Institute of Radiation Protection's assessment of the total radiation dose for people in the Thule area, including

radiation dose assessments for people tasked with placing or maintaining signs or fencing.

- Decontamination measures could cause the disturbance and stirring up of plutonium during decontamination, potentially raising the radiation exposure of not only the people undertaking the operations but also of the local population. Decontamination operations should thus not be decided upon or commenced prior to the completion of a comprehensive radiation protection safety assessment for such a project.

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