Radioactive contamination of a peripheral glacier in Southeast Greenland

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Glaciers host complex and dynamic microbial ecosystems that are influenced by anthropogenic contaminants and can be regarded, not only as a considerable pollutant repositories, but also as secondary sources of pollutants. Contaminants such as heavy metals and fallout radionuclides are being brought to glaciers by long-range atmospheric transport and then deposited with wet and dry precipitation. Special attention has been given to cryoconite, debris found on glacier surfaces forming granule-shaped aggregates of minerals and organic matter. Cryoconite is known for its potential for exceptionally high accumulation of radioactive isotopes. Accumulated anthropogenic radionuclides, originating from atmospheric nuclear weapon tests and incidents, can be released back into the environment with sediment and meltwater fluxes and as a melt-out during glacier recession, posing a risk to downstream and proglacial ecosystem health. Many factors contribute to the secondary pollutant release, with climate change and glacier recession playing an increasingly important role in recent decades. Mittivakkat Gletsjer, a peripheral glacier located on Ammassalik Island in Southeast Greenland, shows significant volume and area losses, and although being one of Greenland’s most extensively explored glaciers, little is known about the radioactive pollution presence and its possible sources. This is true not only for Mittivakkat Gletsjer but for glaciers in Greenland in general. Cryoconite samples were collected from the glacier surface of Mittivakkat Gletsjer in August 2022 and activity concentrations of $^{238}$Pu, $^{239+240}$Pu, $^{241}$Am, $^{137}$Cs and $^{210}$Pb were measured (up to 1.44Bq/kg, 28.5Bq/kg, 14.4Bq/kg, 1100Bq/kg, 2900Bq/kg, respectively). Obtained values are higher than other environmental matrices (soils, mosses, lichens) indicating high radionuclide accumulation in cryoconite. Radioactive contamination sources were identified by determining the isotope ratios $^{238}$Pu/$^{239+240}$Pu, $^{239+240}$Pu/$^{137}$Cs and $^{241}$Am/$^{239+240}$Pu (0.0514±0.0071, 0.0251±0.0044, 0.54±0.12). The results suggest that global fallout, an aftermath of atmospheric nuclear weapon tests, is likely the main source of radioactive pollution at Mittivakkat Gletsjer. A two-sources model (global fallout and Chernobyl incident) shows that global fallout is responsible for 92% of plutonium and 62% of cesium in the measured samples. High correlations ($r^2>0.75$) between sample altitude and $^{238}$Pu, $^{239+240}$Pu, $^{241}$Am,
$^{137}$Cs activity concentrations have been found. Samples collected from higher elevation accumulated more radionuclides, a relationship also observed at other glaciers. The same is not true for $^{210}$Pb for which a very weak correlation ($r^2 < 0.3$) might be explained by constant influx of the nuclide from the atmosphere as it varies depending on rainfall and geographical location.

Relationship between organic matter content and radioisotope activity concentrations has been examined, showing stronger correlations for plutonium isotopes ($r^2 > 0.7$) and weaker for $^{137}$Cs and $^{210}$Pb ($r^2 < 0.65$). Higher concentrations in samples with more organic content indicate cryoconite's capability of binding radionuclides in extracellular polymeric substances. Our study documents radioactive pollution in Southeast Greenland and shows that further research regarding possible risks of environmental contamination through glacier recession and climate change is necessary.

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