

## Technical Project Description

English

### ***Why is mercury rising in some northern lakes and not others?***

Activity lead/Primary Investigator: Jennifer Galloway, Geological Survey of Canada

#### Objectives:

The Arctic is warming much faster than the rest of the planet. As a result of warming, cryosphere collapse poses environmental risk through release of trace elements that have been sequestered in permafrost for tens to hundreds to thousands of years. Other consequences of warming, such as longer ice-free/open-water season, increases in primary productivity, and hydrological changes, affect contaminant mobility and fate. For Inuit who rely on the land for sustenance and cultural heritage, climate change challenges human rights, livelihoods, and community well-being and health. Little is known about terrestrial contaminant reservoirs and the climate-related factors that control pathways of contaminant release into the Arctic hydrosphere and biosphere.

Mercury (Hg) is a bioavailable and toxic element with concentrations that are persistently high or rising in some Arctic and subarctic lakes. This is due to rising Hg emissions to the atmosphere outside of North America, enhanced sequestration of Hg to sediments by climate-mediated increases in primary production, and ongoing release of Hg from terrestrial reservoirs, including permafrost thaw.

This project will generate new knowledge of how climate change affects contaminant mobility to and from peatlands and lake sediments that can be released into Arctic surface waters. Specifically, *we will reconstruct past climate–hydrology–contaminant linkages using paleoecological and paleolimnological records from peatlands and lake sediments to determine the processes controlling mercury (Hg) accumulation in sediment of lakes of concern in Nunavut.* Ultimately, improved knowledge on the factors affecting the biogeochemistry of Hg in high northern latitudes will improve land use decision making and management.

#### Background and Rationale:

The Canadian Arctic hosts unique Earth-system processes shaped by permafrost, carbon storage, and biogeochemical cycling that provide critical ecosystem services sustaining northern community health and well-being. These processes are increasingly threatened by rapid climate change. Permafrost thaw, driven by a 2–3 °C increase over the past half-century, has already altered hydrological connectivity, streamflow, and ecosystem functioning, with further amplification expected this century. Climate projections indicate continued warming alongside greater precipitation, directly thawing permafrost, triggering thermokarst, and mobilizing previously frozen solutes. This will shift runoff regimes from snowmelt- to rainfall-dominated systems, lengthen thaw seasons, and deepen active layers, releasing toxic pollutants once locked in ice- and solute-rich permafrost.

Peatlands and lake sediments, which store contaminants such as Hg, lead (Pb), and cadmium (Cd), act as both long-term sinks and potential sources. Cold, anaerobic conditions have allowed deep peat to accumulate over millennia, preserving a record of climate and contaminant history. However,

thaw threatens to remobilize these contaminant reservoirs into Arctic surface waters, with serious risks for Inuit health via drinking water, fish, and country foods. The Arctic also receives pollutants transported atmospherically from lower latitudes, compounding the impacts of local permafrost thaw and bedrock weathering. Understanding how climate change alters contaminant mobility in peatlands and lakes is therefore critical for predicting ecosystem and human health impacts.

This proposed research focuses on the Rankin Inlet region of Nunavut, underlain by mineralized greenstone with naturally high toxic element concentrations. Using paleoecology and paleolimnology, the project will reconstruct climate change over centuries to millennia while analyzing peatland and sediment archives to establish contaminant levels. This will clarify how past and future warming influences contaminant transport and fate across terrestrial and freshwater systems. The goal is to provide knowledge essential for assessing emerging risks, informing mitigation, and supporting Inuit health and well-being, with a focus on Hg that has been identified as an element of particular concern for the region.

Elevated Hg concentrations have been widely reported in northern lake sediments, peat, surface waters, and fish, including in the Deh Cho (Northwest Territories) and the Kivalliq (Nunavut). While anthropogenic Hg emissions in North America have declined, continued emissions from lower latitudes, on-going release of Hg stored in soils and wetlands, and climate-driven processes such as permafrost thaw, increased productivity, and changing fire regimes, are increasing Hg fluxes to aquatic systems.

To better understand the processes and pathways affecting Hg mobility and fate, we have analyzed Hg in northern lake sediments using one of the most spatially extensive datasets available: 60 lakes across a boreal-tundra gradient in the central Northwest Territories. Sequential pyrolysis and petrology were used to distinguish terrestrial, algal, and inert organic matter, and revealed that Hg accumulation in lake sediment of this region depend more on organic matter type and geogenic co-predictors (the concentration of silver, calcium, phosphorus, sulphur, uranium, titanium, cadmium, and zinc) than on latitude or treeline position. The meta-analysis also showed that larger catchments act as sinks for both atmospheric and geogenic Hg. Building on these insights, we propose to conduct targeted studies in lakes of concern in the Kivalliq region, where greenstone bedrock and rising Hg in fish in the region highlight the potential for environmental risk.

## Progress to Date:

Two peat monoliths were collected from near Meliadine Lake by Agnico Eagle Mines. The monoliths were shipped to the University of Alberta where they were sub-sampled. They are currently being analyzed for the concentration of Hg and other elements at the University of Alberta SWAMP laboratory. Sub-samples will also be sent to various laboratories for other analyses (as outlined below). The community of Rankin Inlet via the Kangiqliniq Hunters and Trappers Organization and the Kivalliq Inuit Association (KIA) have identified several lakes of concern to target for sampling and study.

## Recruitment:

We plan to employ one or two community members in our field program that will occur over a 7-10 day interval in mid-August 2026. Recruitment will occur through consultation with community members of Rankin Inlet via the Kangiqliniq Hunters and Trappers Organization.

## Methodology:

Work is being conducted in two separate areas over the 3-year life cycle of this activity: the central Northwest Territories (completed) and the Kivalliq region of Nunavut, specifically the area surrounding Rankin Inlet. We aim to collect and analyze lake sediment cores collected in triplicate from 5 lakes identified for detailed study through consultation with the Kangiqliniq Hunters and Trappers Organization and the KIA. We are also analyzing 2 peat cores (collected as monoliths from the active layer using a cut-block method in 2024 by Agnico Eagle Mines from sites near Meliadine Lake) from the Kivalliq region of Nunavut. Lake sediment coring will occur from a helicopter equipped with floats (gravity coring), although other options are available.

This project builds on existing partnerships with the the Tłı̨ch̨ Government, Government of the Northwest Territories, Aurora Research Institute, Carleton University, University of Calgary, University of Alberta, University of Łódź, Queen's University, Belfast, Agnico Eagle Mines, and is aiming to develop new collaborations with KIA and the Kangiqliniq Hunters and Trappers Organization.

From 2009 to 2022, our team collected sediments from lakes spanning 55.5 to 64.4 °N from northern Alberta and through the central Northwest Territories along the proposed Grays Bay Road (Galloway et al. 2023). Currently we have in-hand 211 near-surface sediment samples, three permafrost peat cores, 29 lake sediment freeze cores, and data from their analyses from the central Northwest Territories. We used this latitudinal dataset to statistically explore how vegetation, permafrost, limnology, catchment area, lake area, bedrock geology, and climate influence biogeochemical processes for Hg and other elements of concern (Galloway et al., 2024). We aim to combine knowledge gained from this meta-analysis with collection of new lake sediment and peat cores from high-priority sites in the Kivalliq region of Nunavut where Hg is known to be increasing. This targeted approach will help to characterize sources and sinks for Hg and the processes controlling its mobility in an area where it is reported to be increasing by the KIA and Agnico Eagle Mines. This region is also prospective for gold and critical minerals, and thus this project should help inform environmental assessments for future mineral resource development in addition to supporting informed land-use decision making by community organizations and members.

Analyses on the newly collected lake sediment (planned for 2026) and peat (2024) will include organic (programmed pyrolysis; organic petrology) and inorganic (ICP-MS, Hg) geochemistry, age dating (AMS<sup>14</sup>C, <sup>210</sup>Pb), grain size determinations and endmember mixing analysis, and/or plant macrofossil, charcoal, palynological, micropaleontological (testate amoebae, diatoms, and/or biogenic silica, pigments), and stable isotope analyses. Characterization of lacustrine sediments and/or peatlands will be used to determine the: 1) distribution of Hg and other elements of interest; 2) climatic history; 3) fire history; 4) hydrological history (e.g., changes in water table depth, timing and magnitude of freshet); 5) vegetation history; and, 6) changes in primary productivity. These data will be synthesized to understand the cumulative effects of paleoenvironmental changes on biogeochemical processes that affect the mobility and fate of Hg in northern lakes to better understand drivers of recent changes to environmental baselines for Hg.

GSC-Atlantic's Inorganic Geochemistry Lab (co-proponent Dr. Michael Parsons) will provide low-level, total Hg analysis of samples using a Milestone DMA-80 evo Direct Mercury Analyzer. New ICP-ES/MS analyses will be contracted to commercial labs (e.g., Activation Laboratories). Given the importance of organic matter (OM) in the environmental cycling and fate of Hg, the Organic Geochemistry and Petrology Lab at GSC-Calgary (co-proponent Dr. Omid Ardakani) will provide total organic carbon (TOC) content and OM fraction analyses of samples using programmed pyrolysis. Reflected light and fluorescence microscopy (petrology) will provide information on the maceral composition of sediments and the quality, quantity, and source of OM.

Budget permitting, various organic geochemical techniques may be used to evaluate the chemical composition of OM in peats, possibly including GC-MS (GSC-C) and Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR-MS; U of Calgary; co-proponent co-proponent Dr. Omid Ardakani). The Delta-Lab at GSC-Québec (co-proponent Dr. Jason Ahad) may conduct light stable isotope analyses of organic material, particularly plant fractions, to characterize changes in climate and hydrology over time and the effect on element cycling. Polycyclic aromatic hydrocarbons (PAHs) will be determined to reconstruct fire history together with the charcoal data. GSC-Calgary's PaleoLab (Primary Investigator Dr. Jennifer Galloway) will coordinate sample curation, Sample Management System-database support, and, possibly processing and analyses of samples for palynology and microscopic charcoal to reconstruct vegetation and regional fire history. Carleton University (co-proponent Tim Patterson, and PhD candidate Natasha Cavanaugh) will conduct micropaleontological (testate amoebae, diatoms) and particle size analyses. Queen's University, Belfast (co-proponent Graeme Swindles) will collaborate on statistics (e.g., Bayesian modelling, transfer functions). University of Łódź (co-proponent Mariusz Gałka) will lead the plant macrofossil analyses for AMS<sup>14</sup>C age dating and interpretation of peatland permafrost and fire dynamics based on vegetation and macroscopic charcoal reconstructions in peat cores. Agnico Eagle Mines will provide environmental monitoring data and have provided in-kind support for field collection of peat cores in 2024.

Our communication and knowledge transfer strategy will occur throughout the life of the project and will include workshops in the community of Rankin Inlet, and production of Open Files, peer-reviewed manuscripts, and uploading of data to Polar Knowledge Canada's Polar Data Catalogue, an open-source database. Although GEM-GeoNorth funding for this activity end March 31, 2027, we are hopeful that funding for ongoing work will become available in the following years.

References:

Galloway, J.M., Palmer, M.J., Parsons, M.B., Nasser, N.A., Falck, H., Roe, H.M., and Patterson, R.T., 2023. Mercury concentrations in near-surface lake sediments of the Yellowknife area, Northwest Territories, Canada; Geological Survey of Canada, Open File 8949, 27 p. <https://doi.org/10.4095/331434>

Galloway, J.M., Parsons, M.B., Ardakani, O.H., Falck, H., Fewster, R.E., Swindles, G.T., Sanei, H., Palmer, M.J., Nasser, N.A., Patterson, R.T. 2024. Organic matter is a predominant control on total mercury concentration of near-surface lake sediments across a boreal to low Arctic tundra transect in northern Canada. *Science of the Total Environment* 954, 176466. <https://doi.org/10.1016/j.scitotenv.2024.176466>

## Data management:

Data produced by this project will be numerical. Geospatial representation of data is accounted for in our budget. Primary Investigator Dr. Jennifer Galloway will oversee data management and will use the Geological Survey of Canada's Sample Management System Database for curation of samples. All samples will be on loan (with formal agreement) by the Government of Nunavut for the duration of their analyses, and eventually repositioned at the Canadian Museum of Nature.

Open geoscience is a core initiative of our data and knowledge transfer strategy and will include open-source published reports and databases, including Natural Resource Canada's OSTR repository (open-source) and the POLAR Data Catalogue, an existing federal open-source data management framework.

Indigenous language and knowledge organization will be considered in our data management and knowledge exchange strategy. Community presence and workshops based in Rankin Inlet are central to our knowledge transfer strategy to ensure knowledge sharing in its proper cultural context. Use of interpreters will promote retention of Indigenous linguistic context and cultural meanings and social environments. Insofar as is possible and relevant, we will translate English language written knowledge products to Indigenous languages.

Our project will ensure Inuit data sovereignty by managing western science data in the open access platform POLAR Data Catalogue, hosting workshops in communities on how to access and use the POLAR Data Catalogue, and sharing and receiving data and knowledge in ways and places that Inuit would like to provide and to receive it. Inuktitut will be used in data platforms and information management where possible. Western science practitioners and their institutions are herein attempting to partner with Inuit and community organizations to ensure consent and guidance about the political and social context of research outputs and any potential impacts of sharing/publishing those data. All team members will be coauthors on peer-reviewed journal articles and government publications.

## Research outputs:

Research outputs will include academic theses (1 PhD thesis by Natasha Cavanaugh, Carleton University), peer-reviewed publications, presentations at conferences, presentations at community workshops, Open File reports, and plain language summaries translated into Inuktitut. Data will be uploaded to the POLAR Knowledge Catalogue.

Knowledge products will be shared with community members at workshops (annual), and by other means requested (e.g., one-pagers, radio).











