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Assessing Mercury Sources to Arctic Soils in the Mackenzie River Delta

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Long-range atmospheric transport has resulted in the ongoing buildup of mercury (Hg) across Arctic soils, ice, and aquatic systems, with permafrost recognized as one of the largest surface reservoirs of Hg globally. As temperatures rise, Hg stored within permafrost and active soil layers becomes increasingly vulnerable to release due to thawing. Furthermore, these landscapes are becoming more hydrologically linked to downstream environments. Consequently, Hg dynamics in Arctic aquatic ecosystems are expected to be driven more by landscape transformations than by shifts in external Hg inputs, though the effects on bioavailability and bioaccumulation remain uncertain.

In this study, we analyzed Hg concentrations and isotopic compositions in northern soils from the Mackenzie River Delta, spanning the region between Inuvik and the Arctic coastline, including one retrogressive thaw slump (RTS) site. Overall, higher Hg concentrations were associated with soils containing greater organic carbon and moisture, indicating that plant-derived organic matter is a significant contributor to Hg accumulation. However, substantial variability in Hg concentrations among organic-rich samples suggests that additional factors also influence Hg levels. Soil depth profiles revealed patterns in both Hg concentrations and isotopic signatures with surface soils containing more organic matter, elevated Hg concentrations, and more negative odd-mass independent fractionation (MIF) values. In contrast, deeper layers were characterized by lower organic content, lower Hg concentrations, and no odd-MIF values. The presence of negative odd-MIF values near the surface supports that Hg in upper layers primarily originates from vegetation-associated organic matter. This Hg likely results from plant uptake or adsorption of atmospheric gaseous elemental mercury (GEM, Hg^0), with possible additional direct adsorption of GEM to soils. In deeper soil horizons, the absence of MIF suggests a predominantly geogenic or bedrock-derived Hg source. Minimal even-MIF across all samples indicates that deposition of oxidized Hg^{2+} species is not a major contributor to these soils. At the thaw slump site, no clear trends in Hg concentration or isotopic composition were observed. Mercury levels remained relatively uniform with negligible odd-MIF, even in surface layers. This pattern suggests that vegetation-derived mercury may have been preferentially lost, leaving geogenic Hg behind.