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Hydrochemical- and isotopic-based assessment of surface-groundwater interactions in the continuous permafrost area of Rankin Inlet (Nunavut, Canada)

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Assessing surface-groundwater interactions in continuous permafrost environments using geochemical tracers is inherently challenging. However, resolving meteoric versus subpermafrost groundwater contributions is essential for understanding solute transport pathways and predicting water-quality responses to lake talik development, permafrost thaw and resource/infrastructure development. An under-ice water column profiling and sampling campaign was conducted in April 2024 across five lakes near Rankin Inlet, Nunavut (Canada). Major ions, stable water isotopes (δ^2H–$\delta^{18}O$), tritium (^3H), and dissolved radon (^{222}Rn) were analyzed to evaluate whether combined ionic, isotopic, and gaseous tracers can resolve groundwater–lake connectivity during winter stratification. A two-endmember mixing framework integrating ^3H and ^{222}Rn was applied to assess the relative influence of modern meteoric lake water and potential subpermafrost groundwater inflow. Stable isotope compositions exhibited minimal vertical variability, indicating a largely homogeneous, modern meteoric water column beneath ice cover. Major-ion chemistry was dominated by Ca–HCO_3 and Na–Cl facies, reflecting catchment lithology and legacy marine influence. Most near-bottom samples cluster near the meteoric endmember (~10 TU, low ^{222}Rn), suggesting limited groundwater influence during late winter. However, two sites display modest ^3H depletion combined with elevated ^{222}Rn, consistent with localized and minor subpermafrost groundwater inputs. These findings demonstrate both the utility and the limitations of established hydrochemical and isotope tracers for detecting low-magnitude groundwater fluxes in continuous permafrost systems, and highlight the importance of integrating complementary tracer systems and quantitative mixing approaches to better constrain groundwater–lake connectivity in Arctic environments.