Metal(loid) release from permafrost thaw in the Dawson Range, Yukon

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Permafrost thaw is driving major changes in groundwater hydrology and chemistry within subarctic regions globally. These changes have important implications for groundwater quality including release of naturally-occurring uranium (U) and arsenic (As). Excessive exposure to these and other hazardous metal(loid)s can have serious implications for ecosystem and human health. Metal(loid) contamination is a growing water security concern in Yukon, where groundwater is the primary drinking water source for over 95% of residents. Permafrost thaw increases potential for water-rock interaction in previously frozen sediments and releases organic matter and various inorganic constituents. Although these changes influence metal(loid) mobility, the timing, extent, and mechanisms of metal(loid) release are not known. We performed laboratory column experiments to examine metal(loid) release from composite organic-rich and mineral-rich permafrost samples. We monitored effluent chemistry over time under different post-thaw temperatures that represent future sub-surface conditions (4°C) and near-surface (15°C). Maximum effluent U (> 3000 ug L-1) and As (> 50 ug L-1) concentrations were observed during the initial 1 to 2 pore volumes from the mineral-rich and organic-rich sediments, respectively. Although concentrations decreased substantially with increasing pore volumes, effluent U and As concentrations exceeded water quality guidelines for the majority of the experiments. Synchrotron-based spectroscopy revealed association between U and organic matter in the original permafrost samples, which is consistent with correlation between dissolved U and dissolved organic carbon (DOC) in column effluent. In contrast, As exhibits relationships with iron (Fe), manganese (Mn), and organic matter, which suggest redox reactions are largely responsible for As release. Improving understanding of metal(loid) release mechanisms is critical for assessing groundwater vulnerability to permafrost thaw and, more broadly, to forecasting water security risks associated with climate change in Canada and globally.