Rare Earth Element Chemistry in Surface Waters of Rivers and Streams on the North Slope of Alaska

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Study Area and Methods

Changes in climate on the North Slope of Alaska and other Arctic regions have contributed to physical disturbance and thermal perturbation of permafrost landscapes, changing weather patterns, and altered hydrogeologic processes (Lafrenière and Lamothe, 2019). These impacts can alter the supply of dissolved and colloidal trace elements and organic matter (OM) to surface waters and the transport of these constituents through streams and rivers during the summer season. Trace element and OM cycling, fate, and transport in surface waters is complex and can change as a function of OM degradation, changes in pH, shifts in element:OM ligand equilibria, and aggregation/dissociation with colloids (Gebrit et al., 2006; Pokrovsky et al., 2006). Rare earth elements (REE) have been used as a tracer for element and OM cycling, fate, and transport since dissolved REE concentrations in streams and rivers are linked to the parent geology of the watershed basin and are known to vary with increasing molar mass due to interactions with inorganic and organic colloids and iron and manganese oxyhydroxide coating particle surfaces (Sholkovitz, 1995; Stolpe et al., 2013). This study aims to analyze the REE chemistry of the hydrologic landscape of the North Slope, which transitions between several types of hydrology including permafrost tundra-, mountain-, and lake-sourced streams and rivers, and determine what effects variables such as seasonal landscape changes, precipitation, and river discharge have on the relationship between dissolved OM, organic colloids, and REE concentrations. Data collection for this study was conducted as part of the Alaska North Slope Material Flux Study (AKMFS).

Results

The seasonal shift in the REE signature in each water body is unique to its biogeochemical setting. Comparison of REE weight ratios in transitional tundra streams (SCH01 and HAP01) to upriver and downriver sites on the Sagavanirktok River suggests connectivity between tundra surface waters and the main-stem tributary of Sagavanirktok River (Fig. 4). For Sagavanirktok sites immediately downstream of the confluences with two transitional tundra streams: Schuyler Creek (SCH01) and Happy Valley Creek (HAP01). Samples were not collected from sites SAG041, SAG032, and SAG031 in 2019; SAG04 and SAG03 are shown as upriver and downriver sites in 2019. The relative location of the Ivvik Creek is also shown. The REE weight-ratio plots reveal REE signatures for each water body with distinct shifts in REE spectra over the open water season (Fig. 4). Signatures are similar in all water bodies at the start of the open water season with most shifts occurring in mid-to-late summer. At site HAP01 values were between 0.8-1.1 [REEtotal/REELREE] and 2.5-4.0 [REEtotal/REEHREE], Main-stem Sag sites transitioned to higher ratio values in the later summer months. At SCH01, values were between 1.0-1.3 [REEtotal/REELREE] and 5.0-7.0 [REEtotal/REEHREE] for the majority of the REE season, but more closely resembled HAP01 for some June dates and select dates in August 2019.

Discussion

The shift in the REE signature in each water body is unique to its biogeochemical setting. Comparison of REE weight ratios in transitional tundra streams (SCH01 and HAP01) to upriver and downriver sites on the Sagavanirktok River suggests connectivity between tundra surface waters and the main-stem tributary of Sagavanirktok River (Fig. 4). For Sagavanirktok sites immediately downstream of the confluences with two transitional tundra streams: Schuyler Creek (SCH01) and Happy Valley Creek (HAP01). Samples were not collected from sites SAG041, SAG032, and SAG031 in 2019; SAG04 and SAG03 are shown as upriver and downriver sites in 2019. The relative location of the Ivvik Creek is also shown. The REE weight-ratio plots reveal REE signatures for each water body with distinct shifts in REE spectra over the open water season (Fig. 4). Signatures are similar in all water bodies at the start of the open water season with most shifts occurring in mid-to-late summer. At site HAP01 values were between 0.8-1.1 [REEtotal/REELREE] and 2.5-4.0 [REEtotal/REEHREE], Main-stem Sag sites transitioned to higher ratio values in the later summer months. At SCH01, values were between 1.0-1.3 [REEtotal/REELREE] and 5.0-7.0 [REEtotal/REEHREE] for the majority of the REE season, but more closely resembled HAP01 for some June dates and select dates in August 2019.

Fig. 2 The AKMFS crew on the Ivivik River in August, 2022.

Fig. 3. (a) UCC-normalized dissolved REE concentrations [REE(UCC)] for Schuyler Creek (SCH01) in 2019 and 2022. (b) Ratios of UCC-normalized REE values to mean UCC-normalized values [REE/UCC] versus the ratios of mean UCC-normalized REE values to mean UCC-normalized REE values [REE/UCC] for the same site and year. Dotted lines are where the mean values for each weight category are equivalent.