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Dissolved Major and Trace Elements in two Contrasting Rivers and Their Estuarine Zones of the White Sea (Karelia, Russia)

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Numerous studies have been devoted to the behavior of trace elements in rivers and estuaries. The collected data have yielded fundamental features of weathering and transport processes in various tropical and temperate zones of the earth surface. In contrast, much less attention have been dedicated to the comportment of trace elements in northern (arctic) organic-rich rivers, and, especially, their estuarine zones. Moreover, compared to large rivers, very little is known about small rivers and watersheds and their mouth zones. In this respect, small estuaries along the White Sea coast represent an ideal area for investigating mixing processes between organic-rich (up to 100 mg Corg/L) fresh and low-saline (max 15) marine waters in sub-arctic environments. Two contrasting Karelian rivers (Kalga and Unduksa) and their estuarine zones in the White Sea (see map, Figure 1) have been sampled in July-August 1999 for dissolved major and trace elements. Both rivers flow through a system of lakes and swamps in a mixed coniferous forest on podzol soils developed on the Proterozoic granitic bedrock. The river Kalga is characterized by relatively low content of dissolved organic carbon (DOC< 10 mg/L), high debit (~100 m^3/sec) and a long estuarine zone (~10 km) formed by several similar rivers. The estuary of Kalga is well mixed without important influence of tidal events. In contrast, Unduksa is a typical "black river" with very high DOC (60 mg/L), low debit (< 10 m^3/sec), and very short (< 500 m) estuary without influence of other tributaries. The Unduksa estuary is characterized by strong temporal variability due to poor mixing and tide inferences. Both of these rivers flow in the region without any industrial or agricultural activities and therefore exhibit the minimal anthropogenic influence. Major and trace elements (TE) were analysed after sample filtering through a 0.22 µm Nylon filter by ICP-MS and atomic absorption technique. Both rivers exhibit similar concentrations of most major elements (Na, Ca, Mg, K, Sr, Ba, Si) and Mn, Co, Ni, Zn, Ga, Ge, Sb, As, Rb, Cs. The concentration of Al, Fe, Y, Mo, Zr, Ti, REE, Th, and U is systematically higher (2 to 10 times) in the organic-rich Unduksa than in Kalga. This shows that complexes of these elements with humic and fulvic acids contribute significantly to their overall transport in small northern rivers. Estuarine profiles for several elements have been also determined in the present study. Rb, Cs, Sr, and Ba exhibit a typical conservative behavior with linear concentration increase with salinity seaward. Concentration of dissolved (<0.2 µm) Al, Fe, and REE decrease with increasing salinity that likely results from the coagulation of the organic colloids bearing these elements to the estuary. For the small estuary of organic-rich Unduksa river, the rate of Al, Fe, and REE concentration decrease with salinity is much slower than in the large estuary of r. Kalga. This can be explained by slow removal of dissolved organic carbon and weak influence of chemical coagulation in a small poorly-mixed estuary compared to a larger one. Overall, our results show the usefulness of studying small rivers and their estuarine zones where chemical mixing and coagulation processes occur within the distances of several meters from the river mouth. The average concentration of many trace elements (such as REE) in small arctic organic-rich rivers is about one order of magnitude higher than that in large temperate rivers. This makes these areas ideal sites for studying the transport of TE organic complexes and the mechanisms of their coagulation. Ultimately, these studies should allows an estimation of the contribution of small organic-rich boreal rivers to the overall transport of TE to the ocean.

Figure 1:Map of the area