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Impact of nanoparticles and colloids on glacial meltwater: A comparative study of rare earth elements in glacial meltwater rivers and terminal lakes in Iceland and New Zealand

Nathalie Tepe (1,2) and Michael Bau (1,2)

(1) Earth and Space Sciences, School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany, (2) Integrated Environmental Studies, School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

Global warming accelerates the retreat of glaciers in both polar and temperate climatic regions and enhances the input of glacial meltwater and its load of particulates, colloids and nanoparticles into the ocean. In addition to the worldwide trend imposed by global warming, enhanced glacial melting in Iceland is occasionally caused by high geothermal heat flux and/or sub-glacial eruptions related to volcanic activity. This might even cause catastrophic melting events.

We here report results of geochemical studies of meltwater rivers from southern Iceland sampled between 2010 and 2013 and of glacial terminal lakes and one meltwater river from the Southern Alps in New Zealand's South Island from 2013. In addition to the dissolved concentrations of Rare Earths and Yttrium (REY) in 200 nm-filtered waters, we also studied the respective filter residues (particles >200 nm). The REY are highly particle-reactive and show low solubilties, and therefore only a small fraction of the total REY concentration determined in 200 nm-filtered freshwaters is truly dissolved, whereas the majority is associated with colloids and nanoparticles. Nevertheless, in 200 nm-filtered water samples the REY are often below the lower limit of quantification even by sensitive analytical techniques such as ICPMS.

The chemical composition of glacial meltwater rivers in Iceland is affected by volcanic eruptions due to the input of (colloid- and nano-) particles from volcanic ashes, whereas the chemical composition of glacial terminal lakes and meltwater rivers in New Zealand is affected by particles derived by erosion of rocks in the respective catchment. In marked contrast to Iceland, single events do play a minor role in New Zealand.

In Iceland, all studied meltwater rivers display the same shale-normalized REY patterns with pronounced depletion of light and heavy REY relative to the middle REY (LaSN/GdSN: 0.41-0.45; GdSN/YbSN: 1.70-2.44). They show positive Eu anomalies, but no La, Ce or Y anomalies. Comparison of the trace element distribution of river particulates (200 nm-filter residues) to that of the respective glacial meltwater (200 nm filtrates) reveals very close similarities, suggesting that REY bound to colloids and nanoparticles dominate the dissolved trace element distribution in these meltwater rivers. Meltwaters in New Zealand show similar REY patterns, although the heavy REY depletion is less pronounced (LaSN/GdSN: 0.35-0.75; GdSN/YbSN: 1.19-1.99) and they do not show positive Eu anomalies. As in Iceland, comparison of filter residues and dissolved REY concentrations reveals close similarities.

Our results suggest that the dissolved REY distribution in glacial meltwater rivers and lakes is controlled by colloids and nanoparticles smaller than 200 nm. Hence, the REY distribution in the REY pool delivered via glacial meltwater rivers to estuaries depends on catchment lithology which will, therefore, also control the Nd isotopic signature of REY input into seawater. In contrast, REY concentrations and REY distribution in the dissolved riverine REY flux into seawater will be affected by estuarine removal and remineralization processes, and may strongly differ from those observed in the waters before they enter the estuaries.