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Intact rock glaciers as weathering reactors: influence on spring water quality

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During the last decades, most glaciers have been retreating and losing mass in all high-mountain regions, where permafrost has also undergone warming, degradation, and ice loss. In this context, rock glaciers, a visual indication of the presence of mountain permafrost, have gained attention because they host shallow groundwater resources. Hence, rock glaciers could represent a contributor for future water supply, especially in arid and semi-arid mountain areas and/or during dry periods. However, a growing body of literature, mostly composed of local scale studies, has reported high concentrations of solutes, including trace elements, in rock glacier-fed waters, with negative implications on water quality. Therefore, the potential for rock glaciers to function as safe sources for drinking water supply may be questioned, although the main drivers of solute export from rock glaciers are still little understood. Here, we investigated how geographical and geological settings, together with cryospheric conditions, influence the water chemistry of intact (containing internal ice) and relict (without internal ice) rock glaciers, and assessed the potential

implications for water quality. To do this, we assembled an unprecedented dataset on 201 rock glacier springs from mountain ranges across Europe, North and South America, and we applied a combination of machine learning, multivariate and univariate analyses, as well as geochemical modelling. Several intact rock glacier springs had higher concentrations of sulphate and trace elements (e.g., Ni, Al, U) than relict ones. Accordingly, one third of springs issuing from intact rock glaciers had a water quality that did not meet the requirements of drinking water standards, with respect to only 5 % of relict rock glacier springs. The ice presence combined with specific lithologies (e.g., paragneisses) enhanced solute concentrations in rock glacier springs, due to intense oxidation of sulphide minerals that was also responsible for the elevated trace element concentrations. Since rock glaciers are emerging as key mountain water resources as well as potential threats to water quality, we call for an international effort to investigate the hydrochemistry of rock glacier springs across the globe, especially in understudied mountain ranges (e.g., Himalayas, Caucasus) and where these springs are used for drinking purposes.

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