



Peculiar arsenic, copper, nickel, uranium, and yttrium-rich stone coatings in a mountain stream situated below an active rock glacier in the Tyrolean Alps (Austria)

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Peculiar coatings rich in arsenic, copper, nickel, uranium, and yttrium were found to cover stones in a high mountain stream located downstream of acidic effluents emerging from the front of an active rock glacier in the Ötztal Alps (Krummgampen, Tyrol, Austria). The hard mineral coatings are characterized by a white color, a x-ray amorphous structure and they showed properties of hydrous aluminum silicates like allophane ($\text{Al}_2\text{O}_3(\text{SiO}_2)_2 \times n \text{H}_2\text{O}$) and/or imogolite ($\text{Al}_2\text{SiO}_5(\text{OH})_4$). Main chemical constituents of these stone coatings are aluminum, silica, and sulfur. Contrary to high concentrations of arsenic, copper, nickel, uranium, and yttrium in stone coatings, these elements are below the limit of detection both in the Krummgampen mountain stream and - except for nickel and copper - also in acidic effluents draining off the rock glacier. White stone coatings do neither occur in rock glacier effluents nor in the Krummgampen mountain stream upstream of the rock glacier, nor in other mountain brooks in the Krummgampen catchment. The acidic effluents of the rock glacier are characterized by high concentrations of dissolved sulfate, calcium, magnesium, silica, aluminum, manganese, and nickel. The stone coatings are interpreted as a precipitate on or an accretion to stone surfaces in the Krummgampen mountain stream at neutral pH values. Some constituents of the stream stone coatings like arsenic, copper, nickel, uranium, and yttrium are present in paragneiss rocks of the Krummgampen rock glacier catchment and this paragneiss is characterized by heavily weathered accessory minerals monazite, xenotime, and pyrite. Bedrock minerals of the Krummgampen rock glacier catchment are therefore considered as a major source of metals in stone coatings of the Krummgampen mountain stream.