8. Biogeochemical response to extreme events

Increasing frequency of heavy rains accelerates recovery of the Tatra Mountain lakes from acidification

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Ongoing changes in climate characteristics can reverse trends of decreasing calcium plus magnesium (Ca+Mg) leaching to surface waters recovering from acidification and increase their concentrations of phosphorus (P) and organic nitrogen (ON) in granitic alpine regions.

Despite decreasing concentrations of strong acid anions (–1.6 μeq/L/yr), the average Ca+Mg concentrations increased (1.3 μeq/L/yr), together with increased terrestrial export of bicarbonate (HCO_3; 2.5 μeq/L/yr) in 25 non-acidic alpine lakes in the Tatra Mountains (Central Europe) during the mid-2000s to 2022. The elevated terrestrial export of Ca+Mg from catchments thus reversed the Ca+Mg trends, which had originally decreased in parallel with decreasing strong acid anions after their continuously reduced atmospheric deposition since the late 1980s. The percent increase of the in-lake Ca+Mg concentrations was significantly and positively correlated with proportion of scree (areas of broken rocks and gravel without any vegetation except lichen) in the lake catchments and negatively correlated with extent of vegetated soil cover.

Leaching experiments with 12 freshly crushed samples of granodiorite (the dominant bedrock in the study area) showed that accessory calcite was an important source of Ca, Mg, and HCO_3. Moreover, fresh apatite [$Ca_5(PO_4)_3(F,Cl,OH)$] in the crushed granodiorite was a P source under acidic soil conditions, especially in the presence of chelating organic acids. Increasing soil pH due to liberated HCO_3 and decreased acidic deposition decreased soil ability to adsorb phosphate. The elevated P input from catchments stimulated biological activity in lakes and increasing ON concentrations. The increasing ON concentrations then represented the most sensitive indicator of the changes in the lake water nutrient composition.

We hypothesize that elevated terrestrial export of Ca+Mg, HCO_3, and P resulted from increased mechanical weathering of rocks due to elevated climate-related forces during the last 30+ years. The forces include increasing frequency of days with > 30 mm day^{-1} precipitation causing more creep of scree and erosion, and more frequent air temperatures fluctuating through 0 °C, creating more mineral and rock fractures.

These climatic effects on water chemistry are especially strong in catchments dominated by scree areas where fragmented rocks are more exposed to weathering, and their position is less stable than in soil.

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