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Permafrost degradation reshapes soil physicochemical conditions releasing metals and organic carbon in soil pore water

ELÉONORE DU BOIS D'AISCHE[1,2], FRANÇOIS JONARD[2], MAËLLE VILLANI[1], MAXIME THOMAS[1], CÉCILE OSY[1], JORDAN BATES[2], PHILIPPE ROUX[1], JUSTIN LEDMAN[3], SÉBASTIEN LAMBOT[1], KRISTOF VAN OOST[1], VEERLE VANACKER[1], EDWARD A.G SCHUUR[3] AND SOPHIE OPFERGELT[4]

[1]UCLouvain
[2]ULiège
[3]Northern Arizona University
[4]Earth and Life Institute, UCLouvain

Permafrost degradation in high-latitude environments is accelerating due to rising air temperatures, making previously frozen soil organic carbon (OC) susceptible to mineralization and the release of greenhouse gases. However, 30–80% of permafrost OC is stabilized through interactions with metals, particularly iron (Fe), manganese (Mn), and aluminum (Al) either as oxides or as complexes. These interactions are sensitive to redox fluctuations driven by changes in soil hydrology following permafrost thaw. This study investigates the influence of permafrost thaw on the solubilization of Fe, Mn, Al, and the associated OC released in soil pore water. Along a natural permafrost degradation gradient at Eight Mile Lake (Healy, Alaska, USA), elevation, active layer depth, soil water content, and redox potential were continuously monitored for 17 days in September 2023 and linked to the chemical composition of soil pore water. Results show that permafrost thaw progressively exposes deeper soil layers, including mineral horizons with limited OC stabilization capacity. Increasing soil moisture lowers redox potential, promoting the dissolution of Fe oxides such as ferrihydrite, releasing previously adsorbed dissolved organic carbon (DOC). This mobilized DOC can undergo mineralization or be transported to aquatic systems, where it may contribute to greenhouse gas emissions through microbial or photodegradation processes. Understanding the processes modulating the OC release from soils is critical for predicting permafrost carbon feedbacks in a warming climate.