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Biogeochemical impacts on soil phosphorus and other macro- and micro elements solubility, ratios and forms during heatwaves

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Increased frequency and amplitude of extreme heat events can affect soil temperature, and biogeochemical processes. High temperatures may have contradicting geochemical and biological effects on essential elements solubility and forms. Endothermic behavior of minerals and oxides results in decreased solubility with increased temperature, while bio-mineralization is stimulated in response to high temperature. To elucidate heatwave impacts on soil biogeochemical processes, we performed a controlled soil incubation experiment and a field survey. Wet and dry alluvial soil sets were incubated at background temperature (33°C) for two weeks and then, a sequence of three heat events was induced (41°C/33°C alternations, five days each) followed by two short events of extreme heat (48°C for two days). Most soil indices changed trends after about 25-30 days. At the first part of the period, P, Al, Fe appeared to reflect endothermic behavior of (hydr)oxides and minerals in the dry soil (i.e., sorbed P was likely dependent on Fe (hydr)oxides dissolution), while trends of Fe/Al in the wet soil followed the dissolved organic C trend. Phosphatases enzymatic activities fluctuated positively with temperature, emphasizing the activity of residual extracellular enzymes sorbed to soil particles (dry soil) in addition to living cells excreted enzymes (wet soil). With the 3rd heatwave, soluble P dramatically fluctuated with temperature, suggesting a sequence of temperature-enhanced bio-mineralization, releasing P to the soil solution, counteracted by geochemical sorption, removing P from solution. Temperature and temperature-cycle significantly (P <0.005) impacted P solubility; the latter implies overall cumulative effects. Nitrogen displayed enhanced solubility after 30 days, and N/P ratios fluctuated strongly throughout the whole period, presenting potentially imbalanced conditions for plant nutrition and soil microbial ecology.

We assume the recorded dynamics are derived from changes in microbial population size and composition at the transient time (in agreement with a decrease in aromaticity of organic C). The field survey was consistent and included a significant increase in P concentrations during August heatwaves compared to July levels, especially in dry exposed soils, followed by simultaneous decrease in temperature and P solubility.

This research demonstrated unstable soil fertility conditions during heatwaves period, governed by biogeochemical processes, involving elemental interlinkages.