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Biogeochemical mechanisms influencing the bioavailability of P and Fe from vivianite

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The vital element phosphorus (P) invokes two extremes in the environment; (i) scarcity, as a non-renewable resource and as a poorly bioavailable limiting nutrient for plants, and (ii) excess, as cause of eutrophication in surface waters. To tackle both these problems, the inter-relationship between the P and the iron (Fe) cycle is widely discussed with a special interest in the ferrous iron-phosphate mineral vivianite ($\text{Fe(II)}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$). Vivianite forms naturally in sub-/anoxic environments with high Fe(II) and PO_4 concentrations, and is a sink to the dissolved P concentration. On the other hand, vivianite has been proposed as a P source through application as a slow-release Fe-P fertilizer prepared from recycled P. However, vivianite is a metastable mineral under oxic conditions; it readily oxidizes, notably changing color from white to dark blue/purple. This transformation changes the properties of the mineral (surface), and thus its suitability as a fertilizer.

We investigated the oxidation and dissolution of vivianite under different environmental conditions with the aim of developing a mechanistic and kinetic model that relates the oxidation process with dissolution rates. Moreover, the effect of secondary mineral precipitation on the 'net' availability of P and Fe for soil organisms was also studied. Quantifying dissolution rates and secondary mineral formation under environmentally relevant conditions provides the fundamental knowledge needed to assess the suitability of vivianite as Fe and P fertilizer. This information is also paramount to the idea of a circular economy concept: starting with the reduction of P loads of (waste) waters and using the byproduct vivianite as P source for fertilization.