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Bio-dissolution of iron and phosphate from coal fly ash by Trichodesmium

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Marine productivity is often limited by the availability of phosphate and iron to surface seawater. In some marine settings, atmospheric deposition of iron and phosphate rich particles does not suffice, due to low solubility and bioavailability of nutrients from these sources. It has been demonstrated that trichodesmium, a marine nitrogen fixing cyanobacteria, applies bio-dissolution mechanisms, with the aid of epibiotic bacteria, to dissolve iron from dust particles. Specifically, two mechanisms, reduction and ligand promoted dissolution have been proposed by Basu and Shaked (2018).

Here we demonstrate, through alkaline-phosphatase activity, that phosphate from coal fly ash is utilized by trichodesmium cultures. We propose that reduction and ligands promote phosphate dissolution as well as iron dissolution from coal fly ash. In industrialized regions, coal fly ash is estimated as a major source of atmospheric P. Additionally, due to its high phosphate content, coal fly ash serves as a convenient model for testing the effect of these mechanisms geochemically in none-biogenic incubation experiments.

In incubation experiments of coal fly ash in seawater with ascorbate as a reducing agent, we observed enhanced dissolution of iron and phosphate from ash, both as a function of increasing ascorbate concentration and with time. Initially different dissolution rates were observed, converging towards similar rates during the course of a few days. Ligand promoted dissolution was tested by incubations of ash in in seawater with desferrioxamine B (DFB) as a model ligand. Iron dissolution was immediate, reaching maximal values by the second day, regardless of ligand concentration. The release of phosphate, however, was slower, and reached maximal concentrations after four days. Final phosphate concentrations increased almost linearly with ligand concentrations. Our maximum phosphate values in both experiments exceed those reported by Weinberger et al. (2016) for the same coal ash sample as the acid leachable phosphate.

We suggest that both mechanisms, of reduction and ligands, enhance the dissolution of iron and phosphate separately, and may explain the way these nutrients are made bio-available for marine primary producers.