Strategies for optimizing the scalable microbial synthesis of vivianite

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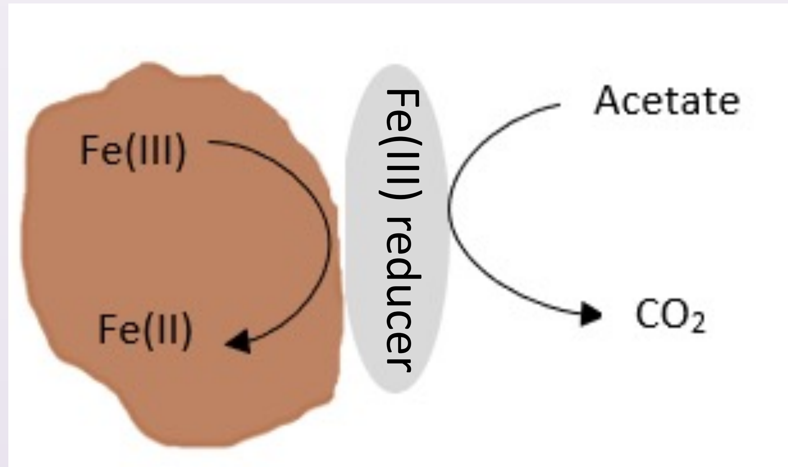
BACKGROUND

Microbial reduction of Fe(III) oxides can immobilize phosphorus from paddy soils, aquatic sediments, wastewater treatment plants etc. [1-4] by forming a stable precipitate, vivianite *($Fe_3(PO_4)_2{\cdot}8H_2O$)* through reaction with biogenically produced Fe(II).



Phosphorus (P) is a plant-limiting nutrient, a scarce and non-renewable resource and a major contributor to eutrophication in water bodies.

Aim of the study: To develop strategies to transform waste phosphorus-containing Fe(III) oxyhydroxides into useful agricultural fertilizers using Fe(III)-reducing bacteria.

Importance of the study: Trapping phosphorus as bio-vivianite can serve as both an iron and phosphorus fertilizer for plants grown in calcareous soils, thereby reducing the overdependence on commercial P fertilizers.

BIOSYNTHESIS OF Fe(II) BIOPRODUCTS

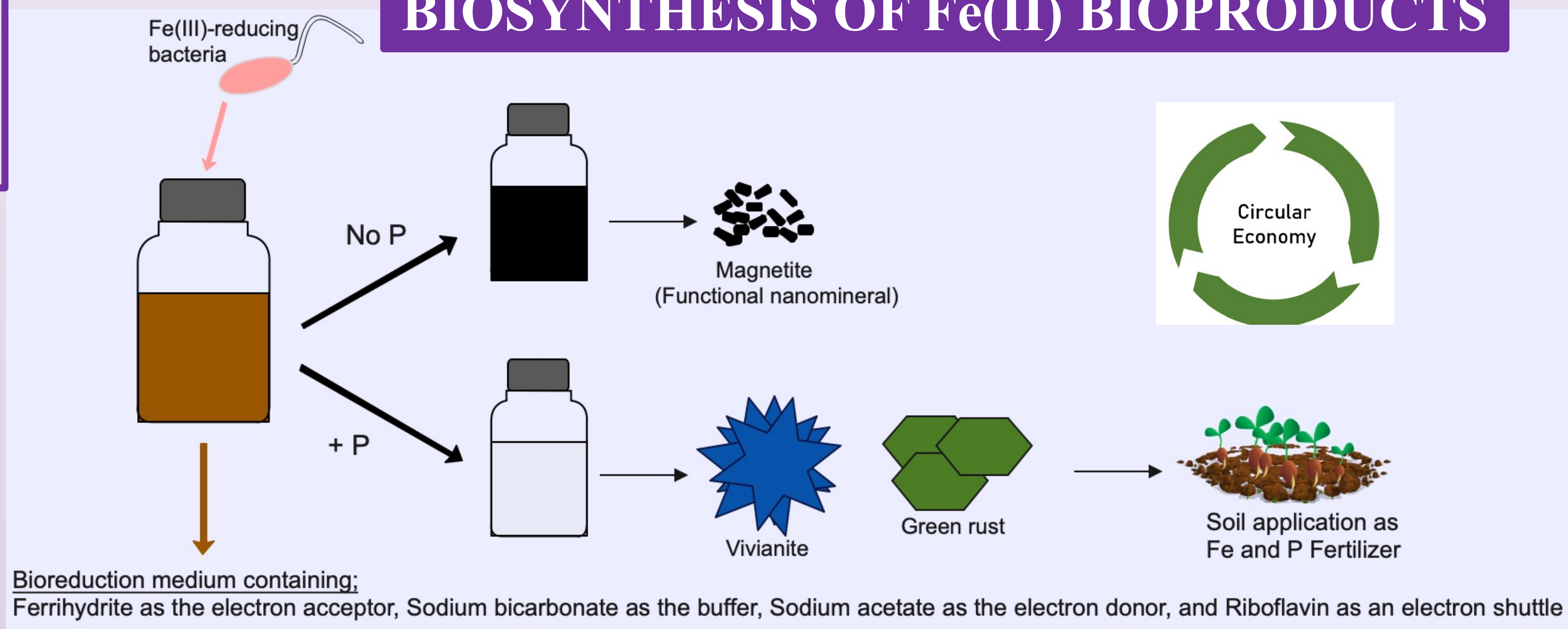


Figure 1: Schematic illustration of the bioreduction of ferrihydrite with and without phosphate to produce functional Fe(II) minerals, including vivianite, using the subsurface bacterium Geobacter sulfurreducens

RESULTS: Effect of phosphate and type of Fe(III)-reducing bacteria on Fe(III) bioreduction

Effect of phosphate

- The presence of phosphate and an electron shuttle (AQDS) influenced the rate and extent of Fe(III) reduction by *G. sulfurreducens*.
- Fe(II) production was higher in phosphate-amended treatments than in zero-phosphate treatments (Fig. 2).
- Vivianite and green rust 2 (GRII) were identified in all phosphate-amended treatments (both shuttle and non-shuttle treatments) irrespective of the initial phosphate concentration.
- Magnetite was mainly dominant in the zero-phosphate treatments.

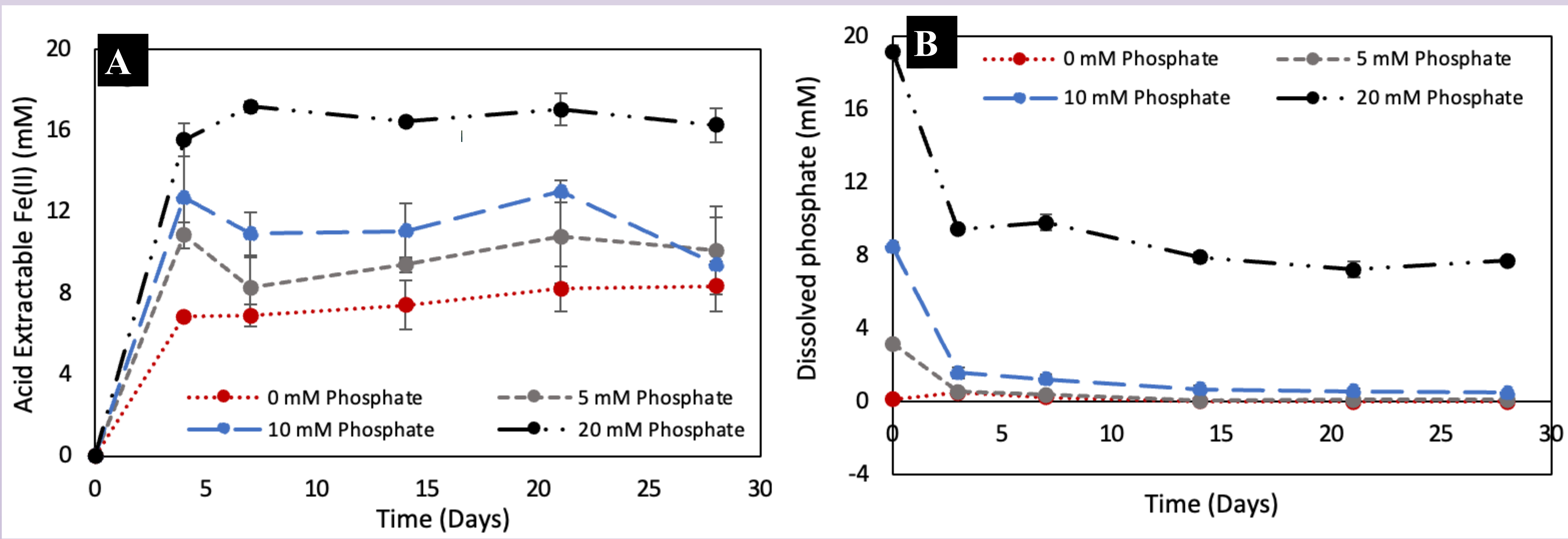
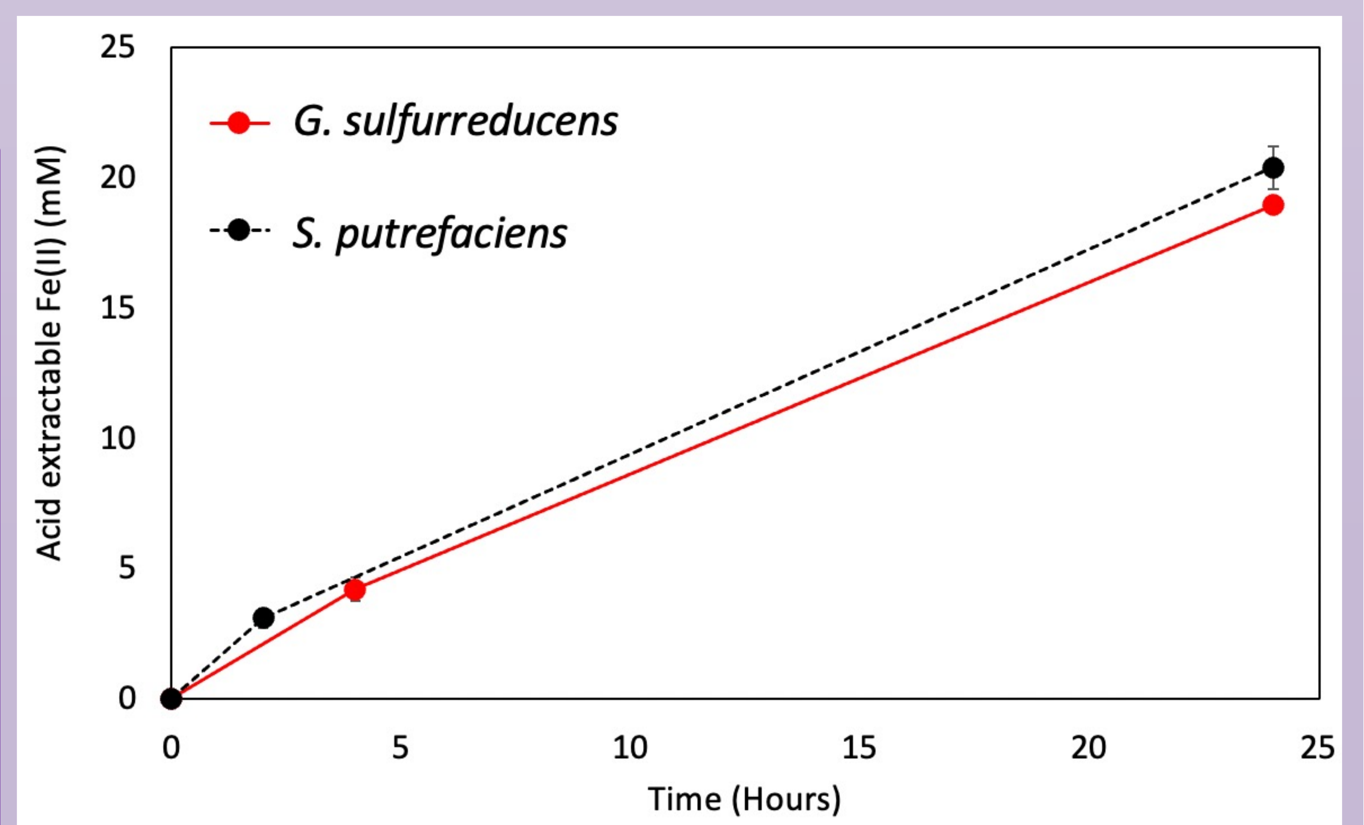


Figure 2: Acid extractable Fe(II) produced (A) and dissolved phosphate (B) measured after Fe(III) bioreduction at varying phosphate concentrations.

G sulfurreducens vrs *S. putrefaciens*

- Complete Fe(III) bioreduction was observed in both treatments after 24 hours.
- Vivianite and green rust 2 were identified as the dominant minerals in treatments with *G. sulfurreducens* and *S. putrefaciens,* respectively.



CONCLUSIONS

- The supply of Fe(II) and the presence of phosphate were the main factors controlling vivianite formation. The presence of phosphate at pH between 5 and 7 promoted Fe(II) production which enhanced vivianite formation.
- The study gives insight into the fate of phosphate–loaded Fe(III)-oxyhydroxides in systems that experience anaerobic conditions. The formation of Fe(II) in such systems impacts the biogeochemistry of iron and consequently, the immobilization of contaminants.
- The microbially-mediated vivianite produced in this study has been tested as an iron and phosphorus fertilizer for plants grown in a calcareous medium.
- This optimization study used synthetic Fe(III) substrates, and follow-on work focuses on revalorizing waste Fe(III)-phosphate sources from water treatment systems.

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