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Microbially Mediated Struvite Precipitation: Mechanisms, Kinetics, Morphology and Applications

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Formation of magnesium ammonium phosphate hexahydrate ($MgNH_4PO_4 \cdot 6H_2O$) as struvite is widely recorded in various environmental and industrial settings; and microbial activities have been playing a significant role in its formation (1). This biomineral tends to form in environments rich in organic matter where conditions support the decomposition of nitrogenous compounds (2). Biogenic struvite exhibits unique morphologies, including coffin and dendritic forms, differing from those formed under purely inorganic conditions. Recently there has been a growing interest in this phosphate based mineral due to its ability to form in low pH environments and biocement with minimal environmental footprint due to ammonia capture (3). Phosphate biocement therefore offers a range of environmental and engineering applications for mining/construction; but very little is known about the reaction kinetics, precipitation mechanism, role of organics & phosphate source and role of microbes in this complex biomineral formation.

In this study, we investigated the properties of struvite formed under biogenic and abiogenic conditions. Three different microbial cultures with varying ureolytic, alkaline phosphatase, Extracellular Polymeric substance production (EPS) ability and surface properties were used to investigate the impact of microbial activity on struvite precipitation. Comparison with abiogenic controls was made. Precipitates were analysed for their morphological, mineralogical and elemental composition along with crystal phase, quantity of biomineral and reaction kinetics via Scanning Electron Microscopy (SEM), Energy dispersive X ray spectrum (EDS), Raman spectroscopy and X-ray Diffraction (XRD). The outcome of the study revealed notable differences between crystal orientation patterns, size, shapes of struvite formed under different biogenic conditions (Fig. 1). Microbial extracellular enzyme production (alkaline phosphatase, urease), EPS, cell surface properties and reaction kinetics had a major impact on the quality and quantity of struvite crystals. The outcome of this study can help unpin fundamental knowledge in crystal formation, behaviour and its related properties; and also pave the way towards exploration of phosphate-based biomaterials for different applications in construction, mining and environmental engineering.

References:

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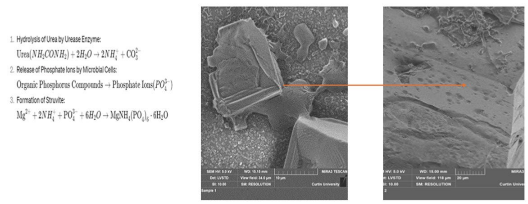

Fig 1. (a) Enzymatic hydrolysis of urea leading to struvite formation (b) Biogenically formed struvite in association with microbial Extra Polymeric Substance (EPS) (c) Microbial imprints and cells on the surface of struvite crystal demonstrating the sites of nucleation during crystal precipitation.