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Unraveling phosphorus crystallization in animal manure: Defining mechanisms to innovate phosphorus recovery

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Motivation

Europe has the priority of deriving phosphorus (P) from secondary sources to mitigate dependency on phosphate rock. Animal manure (AM) is the largest secondary source of P and contains significant amounts of nitrogen (N) and P [1]. A primary challenge in utilizing AM as a nutrient source is its N:P concentration ratio, where the P content often exceeds crop requirements, leading to runoff and adverse effects on aquatic ecosystems [2]. An understanding of the mechanism that drives calcium phosphate (CaP) precipitation allows for the separation of P from other nutrients, thereby facilitating its targeted application on land and improving the sustainability of agricultural practices.

Research goals

The possible challenges lead to the following research goals:

1. Investigate the effect of calcium addition on struvite dissolution to enhance CaP formation and P recovery.
2. Elucidate the abiotic and biotic conditions that promote or inhibit CaP precipitation and aggregation in AM.
3. Identify and evaluate potential biochemical mechanisms that could induce CaP precipitation and aggregation in AM.
4. Optimize reactor conditions (molar ratio Ca:P, hydrodynamics, temperature, etc) in an anaerobic reactor to maximize P recovery by CaP precipitation.

Each research goal is illustrated schematically in Figure 1.

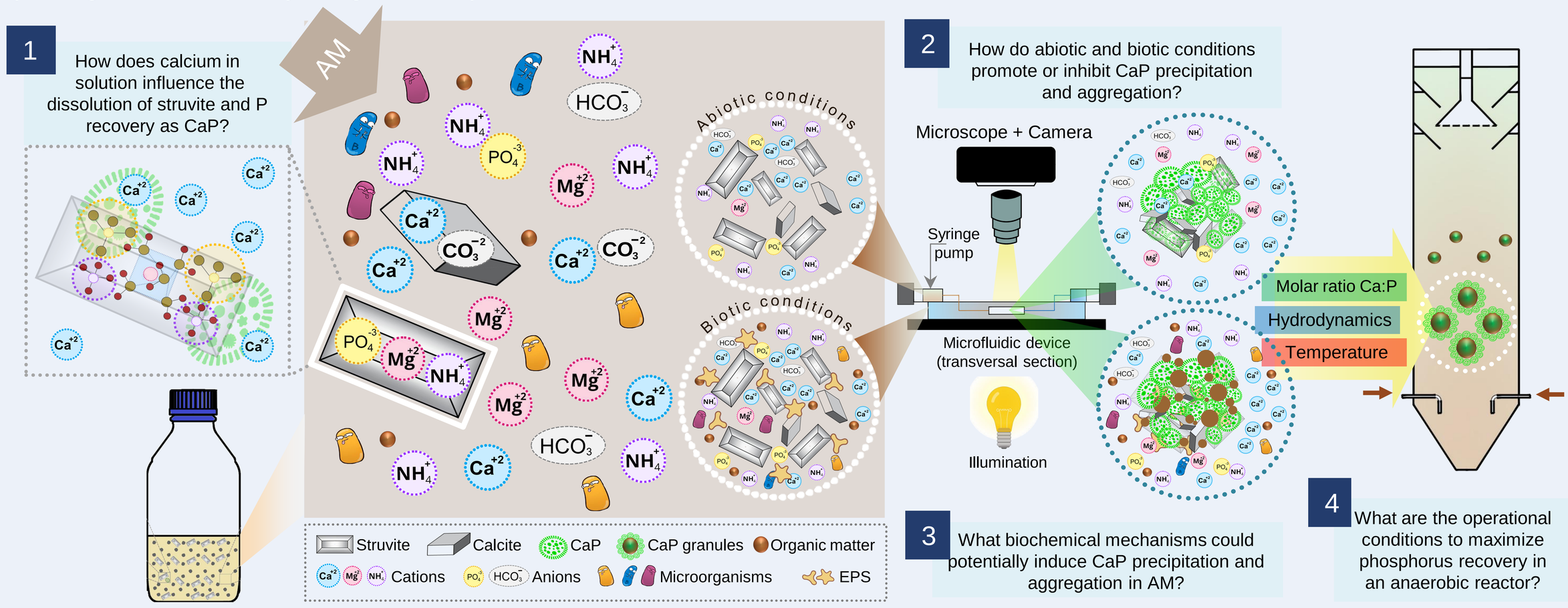

Figure 1. Project overview and schematic approach to achieve the research goals.

Technological challenge

At Wetsus, blackwater (BW) and AM have been investigated for CaP recovery in an Upflow Anaerobic Sludge Bed (UASB) reactor. In BW, microorganisms locally increased the pH within the granules, biologically inducing CaP precipitation in the reactor [3]. In AM, however, P recovery as CaP was more chemically driven. High ammonia levels in pig manure inhibit microbial growth, leading to a more chemical mechanism in which CaP precipitates with calcite [4]. In cow manure, an acidification step before the UASB reactor was required to release ions and enable CaP precipitation [5]. The challenges of recovering CaP from AM arise from the fact that P is mainly in struvite, intense ion competition and varying precipitation kinetics among supersaturated minerals (struvite, CaP, calcite). Additionally, lack of granulation and the production of biopolymers or EPS during substrate degradation, which may promote CaP aggregation and precipitation. These factors have not been thoroughly explored to understand their impact on CaP precipitation in AM.

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