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Abstract:

A circular approach to phosphorous recovery: struvite precipitation from biomass waste

The European Commission classifies phosphate rock as one of the 20 Critical Raw Materials, because of its great importance and high supply risk. Phosphorus is in fact a vital element without valid alternatives for the entire global population, but its production is concentrated in only three main countries (USA, China and Morocco). Moreover, phosphorus use efficiency is tremendously low: 80% of P is lost in the supply chain from mine, to crop fertilization, to food production. The main losses end up in water bodies via run off and wastewater, resulting in local accumulation and environmental issues like eutrophication. The transition towards a more circular use of this nutrient has therefore become urgent and inevitable.

A promising approach is to recycle phosphorous from digestate produced during anaerobic digestion of biomass wastes. Digestate is normally separated into solid and liquid fractions. The solid can be further treated by composting or other methods, while the liquid is often disposed of. A smart strategy to avoid N and P discharge in water bodies is to precipitate ammonium and phosphate from the digestate liquid fraction as struvite, a natural mineral with composition $NH_4PO_4Mg{\cdot}6H_2O$, which can be used as slow-release fertilizer. Herein, phosphorous was recovered from the digestate of two different waste materials, yearly produced in huge quantities: livestock waste and the organic fraction of municipal solid waste (OFMSW). When the digestate is separated into solid and liquid fraction, phosphorus normally remains in the solid, while to be recovered as struvite it must be solubilized and moved to the liquid part. Therefore, various pre-treatments can be applied to the initial substrate before anaerobic digestion to solubilize the organic phosphorus, often consisting in strong acidic conditions. In this work, milder enzymatic and physical processes were tested, alone or in combination, aiming to optimize P solubilization and recovery as struvite in a more sustainable way. Different enzymes for organic matter degradation (cellulase, hemicellulose and protease) and phosphate hydrolyses (phosphatase and phytase) were tested, singly or merged with hydrodynamic cavitation. The effects of pre-treatments on the digestate composition were compared and evaluated to optimize the struvite production from the two different biomass wastes. Particular attention was paid both to the quality of the struvite achieved, in terms of yield, purity and slow-release capacity, and to the efficiency of nutrient removal from the digestate liquid fraction. This study aims to contribute to the transition towards a more circular and sustainable use of phosphorus, starting from the valorization of waste materials as a source of this nutrient essential for life.

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