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Phosphorus recovery by struvite crystallization in WWTPs: Influence of the sludge treatment line operation

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ABSTRACT

Phosphorus recovery by struvite ($MgNH_4PO_4 \cdot 6H_2O$) crystallization is one of the most widely recommended technologies for treating sludge digester liquors especially in wastewater treatments plants (WWTP) with enhanced biological phosphorus removal (EBPR). In this paper, phosphorus recovery by struvite crystallization is assessed using the rejected liquors resulting from four different operational strategies of the sludge treatment line. Phosphorus precipitation and recovery efficiencies of between 80–90% and 70–85%, respectively, were achieved in the four experiments. The precipitates formed were mainly struvite, followed by amorphous calcium phosphate and, in some experiments, by calcite. The highest global phosphorus recovery taking into account both the sludge line and the crystallizer was achieved when mixed thickening and high elutriation were carried out (8.4 gP/kg treated sludge). However, low struvite content was obtained in the crystallizer with this operation scheme due to the high calcium content in the elutriation stream. Therefore, if the final purpose is to obtain struvite, the reduction of the elutriation flowrate is widely recommended in the case of high water hardness.

1. Introduction

Phosphorus recovery by struvite ($MgNH_4PO_4 \cdot 6H_2O$-MAP) crystallization is one of the most widely recommended technologies for treating sludge digester liquors (von Münch et al., 2001; Battistoni et al., 2002; Parsons and Doyle, 2004) especially in wastewater treatments plants (WWTP) with enhanced biological phosphorus removal (EBPR).

In the EBPR process, phosphates and other ions (i.e., Mg^{2+}, K^{2+}) are taken up and stored as polyphosphates (Poly-P) inside the bacterial cells. During the anaerobic digestion process, these polyphosphates are released to the liquid phase (Wild et al., 1997) increasing notably the phosphate, magnesium and potassium concentration. Moreover, ammonium concentration increases significantly as proteins are degraded, and dissolved magnesium, phosphorus, calcium and potassium concentrations increase due to the cell lysis. Therefore, the rejected liquors from digested sludge dewatering show high phosphorus, ammonium and magnesium concentrations which make these streams very appropriate for recovering phosphorus as struvite in a crystallization process. The thickener supernatant could also be used in the crystallizer since Poly-P hydrolysis can take place in the gravity thickener.

Other studies have shown that the product obtained by struvite crystallization can be used as an effective slow release fertilizer in agriculture (de-Bashan et al., 2004; Shu et al., 2006); hence, an economical benefit can be obtained. The use of struvite as fertilizer allows not only the recovery but also the

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Nomenclature

$\%P_{MAP}$	Percentage of phosphorus fixed as MAP
ACP	Amorphous calcium phosphate
ALK_P	Bicarbonate alkalinity
HAP	Hydroxyapatite
MAP	Struvite
NH_4-N	Ammonia nitrogen
PO_4-P	Orthophosphate
P_T	Total phosphorus
Q	Volumetric flowrate
$w_{P\ AV}$	Mass of available phosphorus per mass of treated sludge
$w_{P\ LOST}$	Mass of phosphorus lost per mass of treated sludge
$w_{P\ prec}$	Mass of phosphorus precipitated per mass of treated sludge
$w_{P\ rec}$	Mass of phosphorus recovered per mass of treated sludge
$w_{P\ rec\text{-}MAP}$	Mass of phosphorus recovered as struvite per mass of treated sludge
$w_{P\ TOT}$	Mass of total phosphorus (AV + LOST) per mass of treated sludge
w_P	Mass of phosphorus per mass of treated sludge
α	Thickener supernatant volume/Centrate volume

reuse of nutrients, thereby increasing the sustainable management of the WWTP.

Accumulation of struvite ($MgNH_4PO_4 \cdot 6H_2O$) on pipe walls and equipment surfaces of anaerobic digestion and post-digestion processes significantly increases operational problems and maintenance costs of WWTPs (Ohlinger et al., 1998; Parsons and Doyle, 2004). This uncontrolled precipitation reduces phosphorus concentration in the sludge liquors. Therefore, in order to guarantee phosphorus rich streams and thereby obtain high struvite production in the crystallization process, the uncontrolled phosphorus precipitation in the digester should be reduced.

In a previous work (Martí et al., 2008a), four operational strategies were tested in a pilot plant in order to minimise uncontrolled phosphorus precipitation in the digester and to increase the phosphorus to be recovered. In the present work, phosphorus recovery as struvite crystallization is assessed using the rejected liquors resulting from these four operational strategies. Finally, this study evaluates the global phosphorus recovery by struvite crystallization in the system taking into account both the sludge line and the crystallizer.

2. Materials and methods

2.1. *Pilot plant description*

The pilot system used in this work was composed of different elements: a primary sludge settler/fermenter, a biological nutrient removal system, an anaerobic digester for the stabilization of primary and secondary waste sludge, and a crystallization reactor. All of them are located in the Carraixet WWTP (Valencia), except the crystallizer (which is located in the Environmental Technologies Laboratory of the University of Valencia). A detailed description of these three pilot plants can be found at Bouzas et al. (2007), García-Usach et al. (2006) and Martí et al. (2008b), respectively.

The crystallization pilot plant (Fig. 1) is composed of the crystallization reactor, three stainless steel injection tubes for the influent and reactants, two peristaltic pumps, one membrane pump, and two balances. The reactor is a stirred tank reactor that is composed of two parts: a reaction zone and a settling zone that prevents fine particles from being driven out with the effluent. The reactor was equipped with

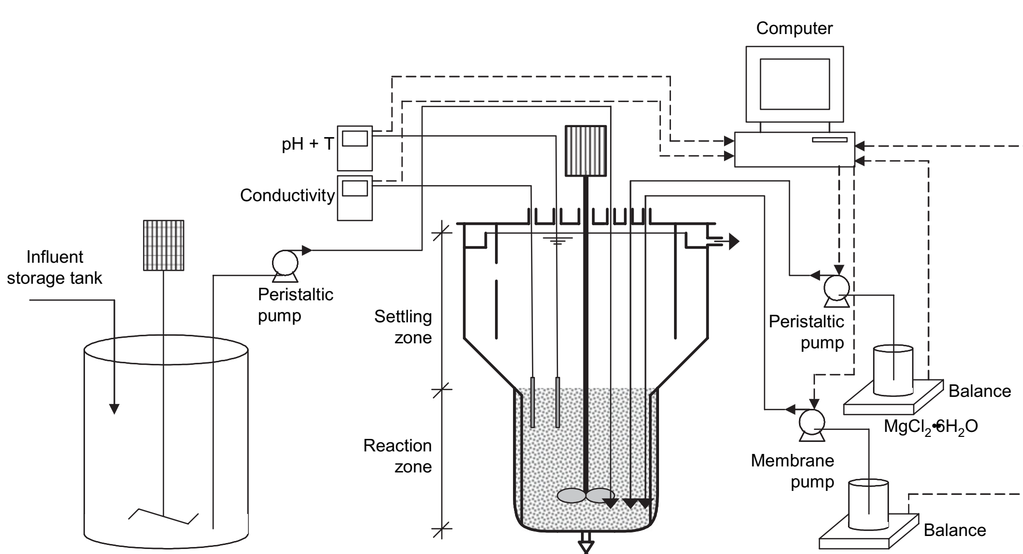

Fig. 1 – Layout of the crystallization pilot plant.