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Optimisation of sludge line management to enhance phosphorus recovery in WWTP

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ABSTRACT

The management of the sludge treatment line can be optimized to reduce uncontrolled phosphorus precipitation in the anaerobic digester and to enhance phosphorus recovery in WWTP. In this paper, four operational strategies, which are based on the handling of the prefermented primary sludge and the secondary sludge from an EBPR process, have been tested in a pilot plant. The separated or mixed sludge thickening, the use of a stirred contact tank and the elutriation of the thickened sludge are the main strategies studied. Both the reduction of phosphorus precipitation in the digester and the supernatant suitability for a struvite crystallization process were assessed in each configuration. The mixed sludge thickening combined with a high flowrate elutriation stream reduced the phosphorus precipitation in the digester by 46%, with respect to the separate sludge thickening configuration (common practice in WWTP). Moreover, in this configuration, 68% of the soluble phosphorus in the system is available for a possible phosphorus recovery process by crystallization (not studied in this work). However, a high Ca/P molar ratio was detected in the resultant supernatant which is pointed out as a problem for the efficiency of struvite crystallization.

1. Introduction

Eutrophication of water bodies caused by an increased input of inorganic phosphorus is a major worldwide problem (de-Bashan and Bashan, 2004). Among the different methods developed, the enhanced biological phosphorus removal (EBPR) process appears as a feasible technology to remove phosphorus in wastewater treatment plants (WWTP). In contrast to conventional plants, the phosphorus content of activated sludge in EBPR processes reaches values of up to 7% (Jardin and Pöpel, 1994) due to polyphosphate (Poly-P) storage by polyphosphate accumulating organisms (PAO).

On the other hand, phosphorus recovery and reuse has become important in recent years since phosphorus is a limited resource. After human consumption, most of the phosphorus remains in wastewaters. For this reason, phosphate recovery from wastewaters is considered to be a suitable method to promote phosphorus recycling.

In the sludge treatment line, especially in the anaerobic digestion process, phosphorus from Poly-P hydrolysis and from organic matter degradation is released, increasing the orthophosphate content in the system and, therefore, the potential for phosphorus precipitation. The concentration of other ions such as ammonium, potassium and magnesium also increases in the digester. Furthermore, the hardness of influent wastewater also controls precipitation processes of phosphorus inside the digester since it determines Ca^{2+} and Mg^{2+} concentrations in the wastewater.

According to the literature (Wild et al., 1997), different phosphate compounds are likely to precipitate in the sludge

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Nomenclature

ACP	Amorphous calcium phosphate
ALK_P	Bicarbonate alkalinity
ALK_T	Total alkalinity
HAP	Hydroxyapatite
m	Sludge mass flowrate
MAP	Struvite
NH_4-N	Ammonia nitrogen
OLR	Organic loading rate
PAO	Polyphosphate accumulating organisms
MP	Mixing power
PO_4-P	Orthophosphate
PP	Potential phosphorus
PPS	Prefermented primary sludge
SGP	Specific gas production
SRT	Solid retention time
TCOD	Total chemical oxygen demand
TP	Total phosphorus
TS	Total solids
TVS	Total volatile solids
VFA	Volatile fatty acids
w_P	Mass of phosphorus per mass of treated sludge
Q	Volumetric flowrate
% P-MAP	Percentage of phosphorus fixed as MAP
% P-HAP	Percentage of phosphorus fixed as HAP
% P-ads	Percentage of phosphorus adsorbed

Subscripts

av	available
elut	elutriation
fix	fixed
lost	lost
ORGrel	release from organic matter degradation
PAOrel	release from Poly-P hydrolysis
prec	precipitated
rem	removal
TOTrel	total release

treatment system causing significant operational problems that lead to an increase in maintenance costs. Accumulation of struvite ($MgNH_4PO_4 \cdot 6H_2O$) on pipe walls and equipment surfaces of anaerobic digestion and post-digestion processes has been reported as a frequent problem in the wastewater treatment industry (Ohlinger et al., 1998; Parsons and Doyle, 2004). Struvite precipitation occurs when the combined concentrations of Mg^{2+}, NH_4-N and PO_4-P exceed the struvite solubility product. Since specification of these components is a pH function, struvite solubility also varies with pH. As pH increases, struvite solubility decreases. Therefore, anaerobic digestion and post-digestion processes, which show a higher pH value than the previous stages of the wastewater treatment, are more susceptible to struvite formation.

Phosphorus precipitation in the sludge line also determines the dissolved phosphorus concentration in the return liquor stream, which causes variations that might affect the efficiency of the EBPR process. Therefore, in order to assure a successful nutrient removal process, recirculated liquors to the wastewater treatment should be treated.

Phosphorus recovery by struvite crystallization is one of the technologies developed for treating sludge digester liquors. The product obtained, struvite, is a valuable slow-release fertiliser for agriculture and, hence, an economical benefit can be obtained. In order to guarantee P-rich streams and thereby to obtain a high struvite production in the crystallization process, the uncontrolled phosphorus precipitation in the digester should be reduced. Other factors, such as the calcium concentration in the crystallizer influent stream, can significantly affect the production of struvite (Pastor et al., 2007). Therefore, suitable characteristics of the supernatants treated by crystallization should be guaranteed.

A simple methodology to assess phosphorus precipitation in anaerobic digesters based on routine experimental analysis and mass balances was developed in a previous work (Martí et al., 2008). This methodology was successfully applied in an anaerobic digestion pilot plant treating prefermented primary sludge and secondary sludge from an EBPR process and in a full-scale WWTP in Murcia, Spain (Barat et al., in press).

In this work, the above methodology has been applied to optimise sludge treatment line management in order to minimise uncontrolled phosphorus precipitation in the digester. Hence, operational costs associated to the formation of deposits can be reduced and the phosphorus recovery can be enhanced. Four operational strategies, which are based on the management of the prefermented primary sludge and the secondary sludge from an EBPR process, were tested in a pilot plant.

2. Materials and methods

2.1. Anaerobic digestion pilot plant

The anaerobic digestion pilot plant treats the prefermented primary sludge (PPS) generated in a fermentation/elutriation pilot plant and the waste activated sludge from an EBPR pilot-scale process (EBPR sludge). The three plants are located in the Carraixet WWTP, which is near the city of Valencia (Spain). A detailed description of the anaerobic digestion pilot plant can be found in Martí et al. (2008).

2.2. Process schemes

The four operational configurations studied are based on the separated or mixed sludge thickening, the use of a contact tank, the elutriation of the thickened sludge and the flowrate of the elutriation stream. Table 1 summarizes the main characteristics of each configuration. Fig. 1 outlines the four

Table 1 – Operational characteristics of the configurations tested

Configuration	Sludge thickening	Elutriation	Secondary sludge settling	Contact tank
C1	Separated	No	No	No
C2	Mixed	Yes	Yes	No
C3	Mixed	No	Yes	Yes
C4	Mixed	Yes	No	No