Prospects for phosphorus recovery from mainstream: experimental and modelling studies.

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The new paradigm in wastewater treatment states that wastewater treatment plants (WWTP) should evolve to water resource recovery facilities where as much as energy and materials are recovered from water. Among all the potential resources to recover, phosphorus (P) arises as a perfect candidate since i) P is essential for our society in the production of fertilizers and ii) the main source of P is a non-renewable source which is envisaged to be depleted in the next 50-100 years (Chowdhury et al., 2017; Cordell et al., 2009)

The most accepted strategy for P recovery nowadays is the P precipitation as struvite ($NH_4MgPO_4·6H_2O$) (Li et al., 2019). Struvite is a slow-release rate fertiliser with nitrogen and magnesium and has been reported to be a good option for agricultural uses. High concentrations of P, NH_4^+ and Mg^{2+} are needed so that struvite crystallisation becomes technologically viable. Thus, precipitation in the tertiary step is not viable. Nowadays, the most common option seems the digestate of anaerobic digestion since high ammonia concentrations could be found there. If the WWTP contains Enhanced Biological Phosphorous Removal (EBPR), the system becomes much more efficient since the sludge entering anaerobic digestion contains up to 20 times more P as Poly-P that could be easily released in the digestate. EBPR is based on the enrichment of the microbial community in polyphosphate-accumulating organisms (PAO), which have a metabolism capable of accumulating P intracellularly as polyphosphate (Poly-P) when alternatively exposed to anaerobic/ aerobic (or anoxic) conditions. In EBPR systems, P is removed within the biomass purge at the end of the aerobic stage, when the sludge has the maximum amount of Poly-P accumulated. Typical values of P recovered by anaerobic liquor precipitation are about 12% of the entering P in the influent ((Remy and Jossa, 2015). In fact, undesired struvite precipitation that clogs pumps and pipes is a major issue when combining anaerobic digestion and bio-P sludge.

P-recovery via struvite precipitation requires high concentration of P in order to reach the solubility equilibrium. The same high P concentrations are also neeed when P is recovered through other minerals, such as hydroxyapatite (HAP). The other location in the plant where phosphorus is high is the anaerobic reactor effluent just after the PAO have uptaken most of VFA and, thus released P to the bulk liquid. Recovering P from this location, would be very beneficial since P could be recovered from mainstream leading to important equipment savings, reducing the nitrogen load into the plant and avoiding any undesired struvite precipitation though the plant.

Hence, this work has three main objectives:

1. Critically review the few proposed alternatives to recover P from the mainstream. For example, the BCFS® process (Biological–chemical phosphorus and nitrogen removal) proposed 20 years ago (Barat and van Loosdrecht, 2006; van Loosdrecht et al., 1998). Shi et al., (2012) proposed a new process, named anaerobic-anoxic-nitrifying induced crystallization (A2N-IC). This process integrated a chemical precipitation of phosphorus from a side stream obtained at the end of the anaerobic stage. Kodera et al., (2013) proposed a novel system for P-removal with a modified trickling filter enriched in PAO, which was exposed to alternating anaerobic-aerobic conditions. Some other configurations will be revised and compared from a performance and practical point of view.
2. Discuss the experimental work conducted in a SBR where EBPR was integrated and the anaerobic liquid was extracted in view of P- recovery. A main goal is to evaluate the maximum amount of P that could be extracted from the system without affecting EBPR performance. The SBR was operated more than one year under different influent COD/P ratios. It was observed that up to 60% of the P could be extracted without a deleterious effect on biological phosphorus removal. The system could even operate at very high COD/P ratio (7.5) with high activity. All the different scenarios were tested in a long-term basis and the comparison will be based on the amount of P-recovered per week under each configuration. Moreover, experimental results will be presented on the possibility of anaerobic purging besides anaerobic liquid extraction. Purging sludge from the anaerobic phase could be beneficial since anaerobic sludge contains higher PHA levels, which could result in increased methane production when submitted to anaerobic digestion.

3. Gain a deeper understanding of the mechanisms involved through the process modelling. Baeza et al., (2017) proposed a new configuration of the SBR cycle to allow the recovery of P from the water line in a model-based study. The SBR included a settling phase after the anaerobic step resulting in an anaerobic/ settling/ aerobic/ settling sequence. Part of the anaerobic supernatant was extracted for P-recovery by chemical precipitation. The simulations performed were able to describe the experimental results and showed that, with an extraction volume ca. 4% of the reaction volume, more than 60% of the P in the influent can be recovered in compliance with the legal limits for organic matter, P and N.

The integration of EBPR into a P-recovery scenario has attracted the attention of many researchers within the framework of the circular economy and we think our comprehensive evaluation of the P-recovery possibilities from the mainstream would be very interesting form the researchers attending the conference.

CONFERENCE TOPICS: Circular economy, Biological treatment techniques (composting & anaerobic digestion), Recycling & Resources Recovery, Water circular economy, Recovery of materials from wastewater & sludge, Energy saving

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