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The influence of hydrolysis induced biopolymers from recycled aerobic sludge on specific methanogenic activity and sludge filterability in an anaerobic membrane bioreactor

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ABSTRACT

The objective of the present study was to evaluate the impact of excess aerobic sludge on the specific methanogenic activity (SMA), in order to establish the maximum allowable aerobic sludge loading. In batch tests, different ratios of aerobic sludge to anaerobic inoculum were used, i.e. 0.03, 0.05, 0.10 and 0.15, showing that low ratios led to an increased SMA. However, the ratio 0.15 caused more than 20% SMA decrease. In addition to the SMA tests, the potential influence of biopolymers and extracellular substances, that are generated as a result of excess aerobic sludge hydrolysis, on membrane performance was determined by assessing the fouling potential of the liquid broth, taking into account parameters such as specific resistance to filtration (SRF) and supernatant filterability (SF). Addition of aerobic sludge to the anaerobic biomass resulted in a high membrane fouling potential. The increase in biopolymers could be ascribed to aerobic sludge hydrolysis. A clear positive correlation between the concentration of the colloidal fraction of biopolymer clusters (cBPC) and the SRF was observed and a negative correlation between the cBPC and the SF measured at the end of the above described SMA tests. The latter implies that sludge filtration resistance increases when more aerobic sludge is hydrolyzed, and thus more cBPC is released. During AnMBR operation, proteins significantly contributed to sludge filterability decrease expressed as SRF and SF, whereas the carbohydrate fraction of SMP was of less importance due to low concentrations. On the contrary, carbohydrates seemed to improve filterability and diminish SRF of the sludge. Albeit, cBPC increase caused an increase in mean TMP during the AnMBR operation, confirming that cBPC is positively correlated to membrane fouling.

1. Introduction

Foulants characterization has been a major research topic related to membrane bioreactor (MBR) technology in recent years. Although many studies claim that extracellular polymeric substances (EPS) are responsible for fouling, no clear relationship between EPS concentration and fouling was found (de la Torre et al., 2008). Taking into account that the

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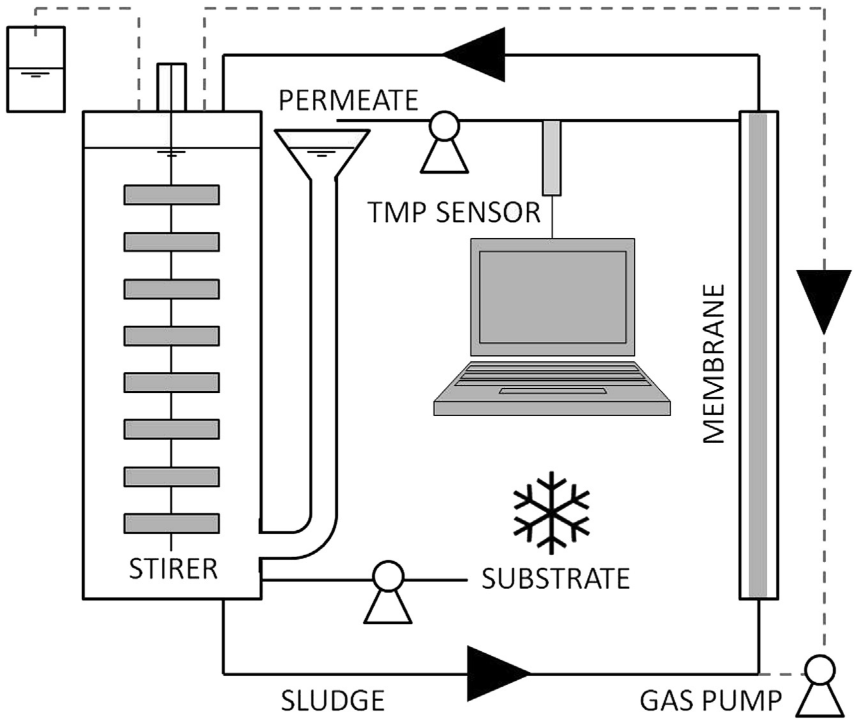

Fig. 1 – Schematic view of the experimental AnMBR set up. The substrate was stored in the fridge at 4 °C to avoid its degradation.

term EPS covers a large range of compounds of different nature, such as microorganisms' secretions, cell lysis products and compounds already present in the influent and adsorbed to EPS matrix, its composition varies depending on the reactor application and operation. In general, these compounds are mainly polysaccharides (PS), proteins, nucleic acids, and humic substances (Drews et al., 2006; Sheng et al., 2010). However, in practice EPS are measured as a sum of the PS and proteins in the sludge. The perceived role of EPS in sludge is twofold. First, the loosely bound or strongly bound EPS is generally linked to binding bacterial cells together, facilitating floc or granule formation, allowing substrate and product transfer, enhancing resistance to toxins, and facilitating intercell communication. Second, EPS that is detached from cells and which is dissolved into the water phase of the mixed liquor is referred to as soluble EPS (Wingender et al., 1999; Laspidou and Rittmann, 2002; Sheng et al., 2010). Both forms of EPS either accumulate on the membrane surface as an effect of filtration, increasing fouling, and/or are decomposed by bacterial cells present in the mixed liquor and membrane cake (Nagaoka and Akoh, 2008).

Another set of compounds commonly used to describe fouling potential are soluble microbial products (SMP). SMP are soluble organic compounds that are released during biomass metabolism and decay. Like EPS, SMP are complex, consisting of proteins, polysaccharides, and some humic-like materials (Azami et al., 2012). Usually this fraction is considered equal to soluble EPS, although some differences were reported that basically derive from the extraction method (Ramesh et al., 2006).

Another category of organic compounds that has been identified in the liquid phase of MBR sludge and in the cake sludge on membrane surfaces consists of biopolymer clusters (BPC) ranging from 2.5 to 60 μm in size. Based on confocal laser scanning microscopy (CLSM) examination, BPC are free and independent organic solutes that are different from biomass flocs and EPS and much larger than SMP (Wang and Li, 2008; Sun et al., 2008). Compared to EPS, BPC contain more polysaccharides and proteins and less humic substances. Wang and Li (2008) state that BPCs are an important foulant that interacts with biomass flocs to form the sludge cake fouling layer on the membrane.

Recent studies showed a clear correlation between the BPC concentration and fouling (Sánchez et al., 2013; Le-Clech et al., 2006; Sun et al., 2008; Wang et al., 2007; Wang and Li, 2008). On the other hand, the source of BPC remains unclear. In order to further elucidate the origin of BPC, Sánchez et al. (2013) studied the influence of excess aerobic sludge recirculation to the anaerobic stage of an integrated UASB-MBR system on the presence of colloidal (less than 0.45 μm) fraction of BPC (cBPC) and membrane performance. The cBPC was measured as the difference between total organic carbon (TOC) of the mixed liquor supernatant and permeate TOC (see Section 2.3). Excess aerobic sludge generated in an aerobic chamber of the MBR stage (also containing a fraction of washed-out anaerobic biomass) was directed to the UASB stage, with the purpose to reduce overall sludge production (and avoid capacity loss of the UASB stage). It was found that apparently due to the hydrolysis of the recycled aerobic biomass, the concentration of cBPC in the effluent of the UASB stage increased, which in turn