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Biofouling in an anaerobic membrane bioreactor treating municipal sewage

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ABSTRACT

At present, considering the availability of reports on aerobic membrane reactor research and full scale experiences, there is a lack of understanding associated to anaerobic membrane bioreactor (AnMBR) applications for low-strength wastewater treatment. In this context, this research aims (1) to evaluate the performance of an AnMBR for municipal sewage treatment at ambient temperature and (2) to contribute to the understanding of AnMBR fouling by characterizing the cake layer with membrane autopsies. Raw sewage was fed at a hydraulic retention time (HRT) of 6 h into an up-flow anaerobic sludge blanket (UASB) reactor (0.849 m^3 volume) coupled to polyvinylidene fluoride (PVDF) external tubular ultrafiltration (UF) modules (100 kDa cut-off; total membrane area of 5.10 m^2). AnMBR permeate was a clear, suspended solids-free effluent with nearly 30 mg L^{-1} of chemical oxygen demand (removal of 93%) without fecal coliforms or parasite ova. Soluble constituents in the UASB effluent were grouped into two predominant fractions (bimodal distribution): higher (144 mg L^{-1}) and lower (89 mg L^{-1}) than membrane nominal cut-off, with an average effluent carbohydrate to protein (C/P) ratio of 0.75. Membrane autopsies were performed on two sections of UF unit, subsequent to a 55-h fouling build-up period (biofouled membrane – BFM – condition). Biofouling characteristics were compared with the fouling layer that remained after a partial (mild) cleaning procedure using chlorine (NaClO at 300 mg L^{-1}, for 30 min). This cleaning practice accomplished a limited removal of fouling mass per unit area (13%). The remnant fouling layer apparently was in part formed by biologically-induced mineralization materials, synthesized in response to cleaning procedure. The resultant biomineralized deposits are an important structural component within the remnant cake layer and may be the basis of irreversible membrane fouling.

1. Introduction

Membrane bioreactors (MBR) are an increasingly common technology for municipal wastewater treatment and, consequently, receive considerable research attention [1]. Capable of producing high-quality effluents that meet water reclamation standards, these mostly aerobic processes have been successfully installed worldwide at full scale [1–3]. However, membrane fouling, an intrinsic phenomenon linked to MBR operation, requires chemical cleaning procedures and operational downtime periods, one of the major drawbacks of this technology. Currently, fouling control is a common goal for many research projects, representing nearly 80% of available MBR technical literature according to MBR-network [4].

Given the inherent advantages of anaerobic over aerobic treatments (lower energy requirements, limited sludge production and methane recovery), recent efforts have focused on the use of membranes coupled with anaerobic process. As a result, anaerobic membrane bioreactors (AnMBR) have been evaluated for industrial and sewage treatments at bench and pilot scales [5]. For municipal wastewater treatment, AnMBR operation near psychrophilic temperature (20 °C) is technically feasible, although sludge retention times (SRT) should be twice those commonly applied in mesophilic operation, resulting in SRTs of 120–180 days [6]. However, given limitations of anaerobic metabolism at this temperature, only partial solid hydrolysis and incomplete conversion of volatile fatty acids to methane are achieved, with a resultant increase in colloidal and soluble solids content in anaerobic effluents [7] and on membrane fouling propensity.

Extracellular polymeric substances (EPS) either free or attached to particulate and colloidal matter, and soluble microbial products (SMP) play a significant role in membrane fouling because their inner pore accumulation (standard blocking) and sorption (complete and intermediate blocking) over membrane surface favors biomass attachment and cake layer formation, resulting in severe fouling [8–10]. Moreover, while some authors have identified dissolved macromolecules (proteins and carbohydrates) as the main cause for flux decrease [11,12], other researchers have reported that

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