Performance evaluation of a flat sheet self-forming dynamic membrane (SFDM) for municipal wastewater treatment containing organic micropollutants

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Abstract
Membrane bioreactors gained increasing interest due to its small footprint and high efficiency. Nonetheless, high capital and operational cost of MBR remains a challenge. With the aim to reduce MBR cost, this study used Dacron mesh to form a dynamic membrane that serves as a substitute to conventional membranes to treat municipal wastewater containing organic micropollutants (OMPs). The SFDM system obtained COD, NH_4-N and PO_4-P removal of 95%, 47% and 14%, respectively.
Keywords: Dynamic membrane, MBR, organic micropollutant, fouling

1. Introduction

High capital and operational cost of membrane bioreactors (MBR) and a decrease in their efficiency due to membrane fouling resulted to alternative processes that have comparable performance but are cost-effective such as self-forming dynamic membrane (SFDM).

SFDM uses low cost mesh such as nylon, Dacron, and ceramic (Fan and Huang, 2002) to deposit solids from the mixed liquor and form the DM. The DM formed mimics conventional membranes and serves as additional biological treatment inside the bioreactor.

While coarse pore sized Dacron mesh has been used as support material for removing conventional contaminants, this study aims to evaluate its performance to treat municipal wastewater containing OMPs.

2. Methodology

2.1. Experimental Setup

The inoculum was collected from a wastewater treatment plant in Salerno, Italy and was acclimatized for 30 days while synthetic municipal wastewater was prepared based on Borea et al. (Borea et al., 2017). Wastewater was continuously fed into a cylindrical bioreactor with an effective volume of 17 L, containing a flat sheet polymer frame made of plexiglass holding the Dacron mesh with pore size of 30 µm and total filtration area of 0.02 m^2. Aeration system was installed to promote good mixing and maintain DO concentration.

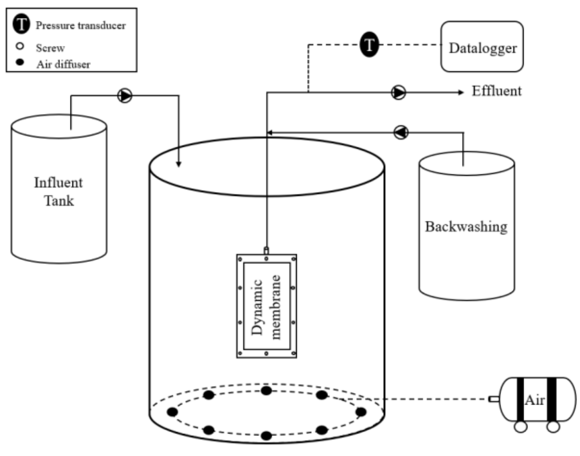

Figure 1. Experimental setup

2.2. Operating Conditions

The SFDM system was operated using a 9 minute filtration cycle (9 mins. Filtration + 1 min. backwashing) with permeate flow rate of 30 LMH. No sludge was withdrawn during the treatment process except for the necessary analysis.

2.2. Analytical Methods

Multiparametric probe (Hanna Instruments, Padova, Italy, HI2838) was used to monitor the pH, temperature, dissolved oxygen (DO) concentration, and redox potential. Standard methods (APAT and CNR-IRSA, 2003) were used to obtain MLSS, MLVSS, COD, and nutrients concentration. TOC analyzer was used to measure the dissolved organic carbon (DOC). Turbidimeter (HACH 2100N) was utilized to measure the turbidity and check DM formation.

Fouling rate was evaluated by monitoring the transmembrane pressure (TMP) and correlating it with fouling precursor concentration. A pressure transducer (PX409-0-15VI, Omega) was used to monitor the TMP and a datalogger (34972A LXI Data Acquisition/ Switch unit, Agilent) obtained the TMP data. Furthermore, heating method (Le-Clech et al., 2006; Morgan et al., 1990) was used to extract SMP and EPS and photometric methods following Frølund et al. and Dubois et al. (DuBois et al., 1956; Frølund et al., 1995) was used to measure the protein and carbohydrate components of EPS and SMP while TEP was analyzed in accordance to the method of Borea et al. (Borea et al., 2017).

Liquid chromatography–mass spectrometry (LC–MS/MS) (Applied Biosystems, Foster City, CA, USA) in electrospray ionization (ESI)-positive mode with a mobile phase composed of A: 0.1% formic acid in water and B: acetonitrile-water (1:1 v/v) solution was used to measure the concentration of OMPs (diclofenac, amoxicillin, carbamazepine, estrone and atrazine) in the influent, bioreactor and effluent samples.

3. Results and Discussion

Dynamic membrane (DM) formation is a crucial step SFDM operation. In this work, DM formation was confirmed by high removal in turbidity. Average COD, NH_4-N and PO_4-P removal of 95%, 47% and 14%, respectively were achieved, comparable to a previous study (Fan and Huang, 2002). This proves that the DM formed was able to retain solids as well as slow growing microorganisms such as nitrifying bacteria while aerobic condition in the reactor did not favor phosphate accumulating organisms (PAO). The results related to organic micropollutants removals are consistent with those found in conventional MBR.

Stable operation of SFDM lasted almost 2 weeks even though high initial concentration of fouling precursors (SMP_p, SMP_c, EPS_p and EPS_c) due to the presence of OMPs was observed. This is higher than 5 days of the control run involving an MBR by Villamil et al. (Villamil et al., 2016). While fouling precursor concentration generally increased, remarkable increase in TMP was observed with the significant increase in the protein components of EPS and SMP. This is consistent with the findings of Hasan et al. (Hasan et al., 2012) where proteins were found to have higher impact on membrane fouling. Chemical cleaning with NaClO solution was required once fouling was reached which indicates the occurrence of irreversible fouling led by foulant accumulation on the Dacron mesh surface.

4. Conclusion

The SFDM used in this study obtained comparable results to conventional MBR in terms of COD, nutrients and OMP removal. Furthermore, the system was able to operate for almost two weeks without membrane fouling even in the presence of OMPs. Dacron mesh was found to be an effective support material for DM formation.

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