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Short Communication

Effect of support material pore size on the filtration behavior of dynamic membrane bioreactor

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ABSTRACT

The effect of support material pore size on the filtration behaviors during start-up and stabilized stages in the dynamic membrane bioreactors (DMBR) was studied. Before the dynamic membrane (DM) was formed, the turbidity at 50-μm could be more than 250 NTU, while it was less than 40 and 10 NTU at 25- and 10-μm, respectively. After the DM was formed, the stabilized stage lasted for 61 days with low transmembrane pressure < 0.6 kPa and the 5-, 10-, and 25-μm filters had similar effluent turbidity (< 1 NTU) and chemical oxygen demand. However, their averaged flux was 66.4, 25.1, and 3.5 $L \cdot m^{-2} \cdot h^{-1}$, respectively, suggesting that the 25-μm filter had significantly lower filtration resistance. Consequently, to avoid unallowable high effluent turbidity during start-up or after membrane cleaning and to achieve high flux with low pressure filtration, a mesh size of ~25 μm is more suitable for DMBR.

1. Introduction

To ensure the membrane bioreactors (MBRs) work properly, complicated operations are needed, e.g., backwashing and chemical cleaning, which lead to significant higher operation cost (Salerno et al., 2017). As a result, the application of MBR is still limited and the new installations of MBRs for large-scale wastewater treatment plant became decreasing since 2010 (except the situation in China) (http://www.thembrsite.com/). Some studies have focused on the development of dynamic membrane bioreactor (DMBR), which replaces the microfiltration or ultrafiltration membranes with cheap materials, e.g., stainless steel grids and polyester mesh (Chu et al., 2010; Hu et al., 2017; Huang et al., 2015). During the operation, an in-situ sludge cake layer or biofilm, named dynamic membrane (DM), will formed on the support material, which can achieve effective solids rejection at low transmembrane pressure (TMP) of 0.01–0.1 m water head loss (Hu et al., 2017). The DMBR has the major advantages of MBR, while it can achieve low pressure gravimetric filtration and the fouled membrane can be easily cleaned.

Previous studies on DMBR mainly focused on support materials with large pore sizes, generally ranging from 30 to 200 μm (Fan and Huang, 2002; Kiso et al., 2000; Li et al., 2012). The large pore size support materials could deteriorate the effluent quality during start-up stage or after membrane cleaning (Chu et al., 2008; Chu and Li, 2006; Fan and Huang, 2002; Kiso et al., 2000; Wang et al., 2012). They also required a relatively longer time, e.g., 0.3–24 h, to form an effective DM (Chu and Li, 2006; Liu et al., 2009; Wang et al., 2012). Due to the high SS in the initial effluent, the filtrate was necessary to be recycled back to the reactor before an effective DM was formed. The DMBR using large-pore support material could also have another problem of unstable effluent quality once the DM was detached. Above-mentioned problems may be resolved by using smaller pore size support materials (1–25 μm), which can possibly achieve both low pressure filtration and low effluent SS before DM is formed.

The objective of this study was to determine the effect of support material pore size (from 1 to 50 μm) on the filtration behaviors and effluent quality during start-up period (DM not formed) and under the stabilized conditions (DM formed).

2. Materials and methods

2.1. Filter design and reactor setup

The filter was made of stainless steel and wrapped with nylon mesh (Fig. 1(a)). Its outer diameter was 25 mm. Five mesh filters with averaged pore sizes of approximately 1, 5, 10, 25, and 50 μm were prepared. The lab-scale reactor (Fig. 1(b)) had five effluent outlets with flanged fitting on the reactor wall. The filters were submerged into the

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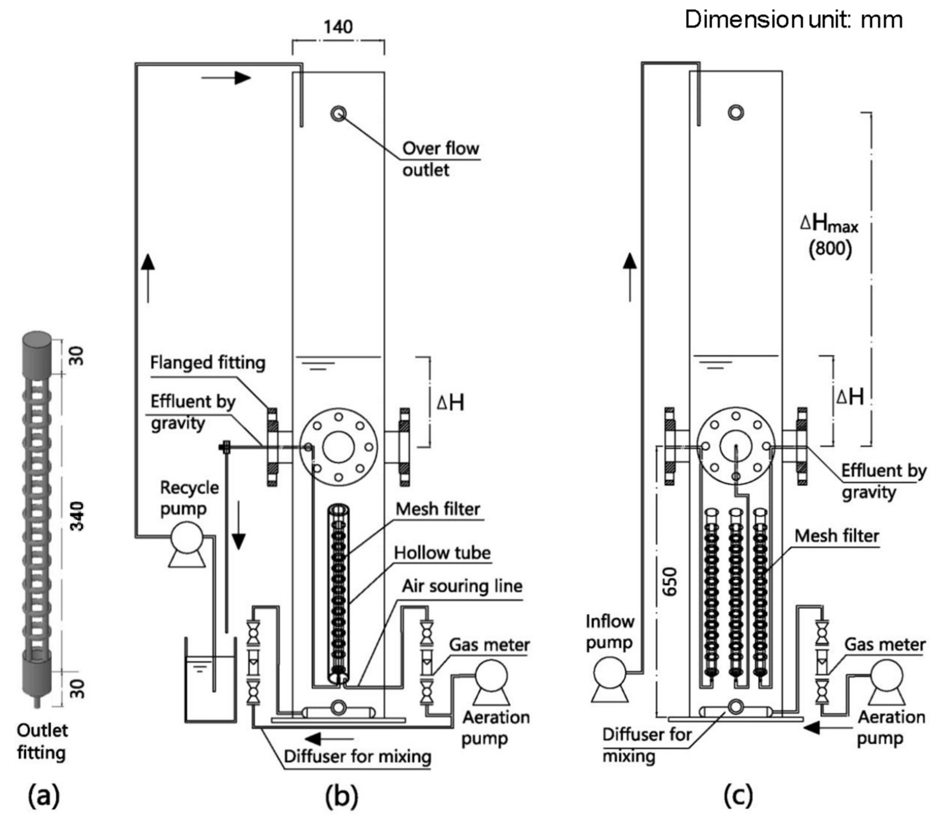

Fig. 1. (a) Frame of the mesh filter, (b) reactor setup for the screening test, and (c) reactor setup for the long-term test.

bioreactor and connected to the inner side of effluent outlet. The filtration process was driven by the water head loss between the bioreactor water level and the outlet (ΔH).

2.2. Screening test

A screening test was carried out to quickly evaluate the effect of pore size on the filter behavior during DM forming stage. As shown in Fig. 1(b), the mesh filter was inserted into an organic glass tube with inner diameter of 36 mm. At the bottom side of the hollow tube, there was an air tube outlet. This setting allowed the air scouring to be controlled more accurately and effectively. The five filters were installed into the reactor at the same level and connected to the five reactor effluent outlets with flanged fitting, respectively. So the performance of each filter could be evaluated independently under the same conditions.

A fresh activated sludge sample collected from a local municipal wastewater treatment plant was used for the screening test. Once the sludge sample was loaded, the effluent flow rate and turbidity from each filter were monitored with time. The effluent was returned back to the reactor immediately to maintain a constant water head loss of 5 cm. In this test, the MLSS was 3000 mg/L, the air scouring strength was 400 mL/min, and the temperature and pH were approximately 23 °C and 7–7.5, respectively.

2.3. Long-term test

According to the screening test results, the 5-, 10-, and 25-μm mesh filters were selected for the long-term test. The reactor setup was shown in Fig. 1(c). Once the reactor was seeded, it was fed continuously with synthetic wastewater at a constant flow rate of approximately 42 mL/min, which contained chemical oxygen demand (COD) and ammonia nitrogen (NH_3-N) concentrations of 180 mg/L and 33 mg-N/L, respectively. The COD and ammonia in the influent were provided with glucose and ammonium bicarbonate, respectively. Trace elements were added into the influent as well (Liu and Wang, 2015). The water temperature varied at 20–25 °C and DO was greater than 2 mg/L. The solids retention time (SRT) was controlled at approximately 40 days through daily biomass discharge.

The outflow rate and the turbidity from each filter and the water head loss were monitored daily. The effluent concentrations of COD and ammonia and the MLSS in the reactor were measured regularly. Along with membrane fouling, the water level in the reactor would increase to provide a greater TMP. Once the operation pressure reached 7.84 kPa, the long-term test ceased. Analytical methods for MLSS, COD and ammonia were described previously (Liu and Wang, 2012).

3. Results and discussion

3.1. Screening test results

During the screening test, the initial flux (the averaged flux in the first 0.5 h) for the 10-, 25-, and 50-μm filters were approximately 600 $L \cdot m^{-2} \cdot h^{-1}$ (Fig. 2(a)). For the 1- and 5-μm filters, however, the initial flux was only approximately 75 and 55 $L \cdot m^{-2} \cdot h^{-1}$, respectively. This suggested that when the pore size decreased from 10 to 5 μm, the filtration resistance increased dramatically. As shown in Fig. 2(b), the initial turbidity (the averaged effluent turbidity in the first 0.5 h) for the 50-μm filter was approximately 260 NTU. According to the correlation of SS and turbidity (SS = 1.463 × turbidity) (Fuchs et al., 2005), the initial SS was 380 mg/L. For the 25-μm filter, the initial effluent turbidity was only about 38 NTU. For the 10-, 5-, and 1-μm filters, very low initial turbidity of less than 10 NTU was detected, indicating that most of the particulates in the wastewater could be rejected at pore size below 10 μm without the formation of DM. With a pore size of 50 μm, however, the DM was needed to achieve effective solids rejection.

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