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The characteristic evolution of soluble microbial product and its effects on membrane fouling during the development of sponge membrane bioreactor coupled with fiber bundle anoxic bio-filter for treating saline wastewater

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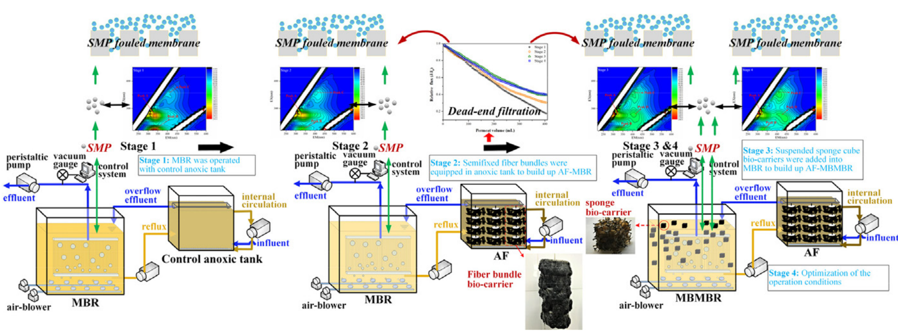
GRAPHICAL ABSTRACT



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ABSTRACT

Membrane fouling mitigation was observed during the development of novel sponge membrane bioreactor coupled with fiber bundle anoxic bio-filter (AF-MBMBR). Soluble microbial product (SMP) was found to be positively correlated with membrane fouling. To further clarify the mechanism of fouling mitigation, the effects of bio-carriers (sponge and fiber bundles) on characteristics and fouling potential of SMP were investigated. Characterization of SMP implied that as a consequence of employing bio-carriers, tyrosine and tryptophan in SMP significantly decreased, instead relative proportions of humic and fulvic acids increased. Meanwhile, batch filtration tests demonstrated that fouling potential of SMP was significantly alleviated, flux decline caused by filtrating SMP decreased from 84.5% to 60.1%. Further analysis on foulants and filtrate revealed that proteins performed high adhesion propensity on membrane while humic and fulvic acids mainly can pass through the membrane; this finding could well explain the mitigation of SMP fouling potential induced by bio-carriers.

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1. Introduction

Membrane bioreactor (MBR) has been widely employed in municipal and industrial wastewater treatment with the notable advantages of high quality of treated water, small footprint, easiness of operation, and less excess sludge (Jang et al., 2013; Moussa et al., 2006; Panswad and Anan, 1999). Particularly because of its excellent capability for biomass retention, which is beneficial to acclimation of biomass to special environment such as high salinity, MBR is becoming increasingly popular in the field of saline wastewater treatment (Luo et al., 2015). However, membrane fouling is still an intractable problem associated with MBR, and this issue could be exacerbated under salinity stress (Lay et al., 2010). High salinity could cause the worsening of sludge characteristics (Deng et al., 2016a) and provoke the production of extracellular polymeric substances (EPS) and soluble microbial products (SMP) which were both main causes responsible for membrane fouling (Di Bella et al., 2013).

Various strategies have been employed to control membrane fouling, including optimizing operating conditions, improving sludge characteristics (Nguyen et al., 2012) and modifying membrane surface property. Recently, using bio-carriers to immobilize biomass and improve mixed liquor properties has attracted more attentions as a promising fouling control strategy for MBR. Guo et al. (2008) studied the effects of sponge bio-carriers on membrane fouling control in a sponge-submerged membrane bioreactor (SSMBR) with sponge volume fraction of 10% and found that suspended bio-carriers significantly mitigated the membrane fouling and improved sustainable flux by two times in comparison with SMBR alone (Guo et al., 2008). Analogously, Duan et al. (2013) reported that compared with MBR without bio-carriers, the moving bed biofilm reactor-membrane bioreactor (MBBR-MBR) with bio-carriers filling ratio of 26.7% exhibited much lower total membrane filtration resistance and almost no obvious detectible fouling during the entire operation (Duan et al., 2013).

Under this circumstance, a sponge moving bed membrane bioreactor coupled with pre-positioned fiber bundle anoxic bio-filter (AF-MBMBR) was designed for saline wastewater treatment (Song et al., 2018). Two different types of bio-carriers, semifixed fiber bundles and suspended sponge cubes were employed in AF and MBMBR, respectively. This novel hybrid system exhibited excellent treatment performance as well as significant membrane fouling mitigation. To clarify the mechanisms of fouling control in the hybrid system, the respective effects of fiber bundle bio-carriers (in AF) and sponge bio-carriers (in MBMBR) on characteristics of mixed liquor were investigated. The results suggested that the reduction of suspended sludge in MBR and the improvement of sludge characteristics (including EPS properties) were important contributors to the mitigation of membrane fouling in hybrid system (Song et al., 2017).

Besides suspended sludge, SMP was another widely recognized fouling contributor in MBR. SMP can be defined as the pool of organic compounds (e.g. humic substances, polysaccharides and proteins) that result from metabolic activity (usually with biomass growth) and biomass decay (Shin and Kang, 2003). They can easily deposit on membrane surface or penetrate into membrane pores due to suction filtration, inducing severe membrane fouling (Deng et al., 2016a). Owing to its important role in development of membrane fouling, SMP has attracted more and more attentions (Tian et al., 2013; Shen et al., 2010). It has been reported that relative contribution of SMP to membrane fouling in MBR reached 26–52% depending on the experimental conditions (Bouhabila et al., 2001). Similar results was reported by (Zhang et al., 2015), who demonstrated SMP had the highest membrane fouling potential when compared with other sludge characteristics (e.g. MLSS, particle size distribution, bound EPS). However, the respective effects of fiber bundle bio-carriers (AF) and sponge bio-carriers (MBMBR) on characteristics and fouling potential of SMP in AF-MBMBR have not been addressed yet.

Although previous researches demonstrated the effects of bio-carriers on membrane fouling mitigation in MBR, most attentions were paid to their improving effects on sludge properties (Zhang et al., 2016) and mechanical scouring effect on membrane surface (Chen et al., 2016), SMP was investigated mainly in term of gross concentration (Luo et al., 2015; Deng et al., 2014; Deng et al., 2016b). Due to the complexity of SMP components and their various properties, more detailed information on SMP characteristics was needed for understanding the effects of bio-carriers on SMP fouling potential. In addition, various types of bio-carriers also probably resulted in different modifying effects on SMP.

Therefore, the objective of this study was to contribute to a better understanding on fouling potential of SMP in AF-MBMBR based on the variations of SMP characteristics due to the modification effects of two types of bio-carriers. To this end, the development of AF-MBMBR was divided into four operation stages; first, the variations of SMP characteristics during each stages was systematically analyzed by concentration measurement, three-dimensional excitation emission matrix (EEM) fluorescence spectroscopy and fourier transform infrared (FTIR) spectroscopy techniques; second, batch filtration tests were conducted for SMP samples from each stages to estimate the variations of their fouling potential; finally, foulants desorbed from membranes fouled in SMPs filtration tests were analyzed to aid the understanding of SMP fouling behavior.

2. Materials and methods

2.1. Staged development of AF-MBMBR hybrid system

The development of AF-MBMBR was divided into four operation stages as shown in Fig. 1. *Stage 1:* MBR was operated with control anoxic tank; *Stage 2:* Semifixed fiber bundles were equipped in anoxic tank to build up AF-MBR; *Stage 3:* Suspended sponge cube bio-carriers were added into MBR to build up AF-MBMBR; *Stage 4:* Optimization of the operation conditions. The detail development process and operation conditions were described in previous reported studies (Song et al., 2018; Song et al., 2017).

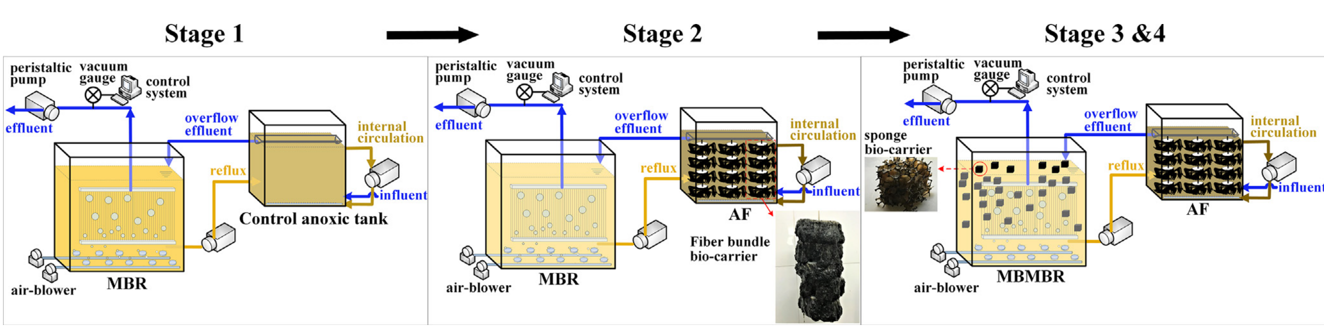

Fig. 1. Schematic diagram of the reactor used in 4 operation stages (Stage 1: MBR was operated with control anoxic tank; Stage 2: fiber bundles were equipped in anoxic tank to build up AF-MBR; Stage 3: sponge bio-carriers were added into MBR to build up AF-MBMBR; Stage 4: optimization of the operation conditions).