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# Enhancement of filterability in MBR achieved by improvement of supernatant and floc characteristics via filter aids addition

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ABSTRACT

Reduction of membrane fouling in membrane bioreactors (MBR) by addition of three typical filter aids (aluminum sulfate ($Al_2(SO_4)_3$), polymeric ferric sulfate (PFS) and Chitosan) was investigated. The effects of filter aids on membrane pore blocking, gel layer and cake layer resistance were analyzed respectively. Significant improvement of the sustainable filtration was demonstrated in the filter aids added MBRs. The membrane fouling rate of the MBRs operated under 20 L/m$^2$ h flux was in the order of Control MBR (no filter aid added) > $Al_2(SO_4)_3$ added MBR > Chitosan added MBR > PFS added MBR. Membrane inner fouling due to pore blocking was analyzed by means of Fourier-transform infrared microscope (FTIR). Compared to the control MBR, significantly low protein and carbohydrate concentrations were measured in the membranes of the filter aids added MBRs, indicating that filter aids could effectively alleviate membrane pore blocking. Gel Permeation Chromatography (GPC) analysis suggested that both the concentration and molecular weight distribution of the macromolecules in supernatant play an important role in gel layer formation and loss of membrane porosity. The reduction of fouling rate in the filter aids added MBRs could be attributed to lower concentration and reduction in molecular weight of macromolecules in supernatant. The specific cake resistance ($\alpha_c$), mean floc size ($d_p$) and fractal dimension of the flocs (df) in the filter aids added MBRs were also investigated. It was demonstrated that $\alpha_c$ decreased with the increase of $d_p$ and with the decrease of df, which is in consistent with the model prediction.



## 1. Introduction

The emergence of membrane bioreactor (MBR) by the combination of the widely used activated sludge treatment with the sophisticated membrane separation offers many advantages over conventional wastewater bio-treatment process. However, membrane fouling remains a bottleneck for the widespread application of MBR. Membrane fouling in MBR is due to the complex interactions between the membrane material and the components of activated sludge mixed liquor. Investigation on fouling alleviation has been conducted since the initial stage of the research and application of MBR. Generally, the approaches on membrane fouling control can be classified as: (1) optimization of operating parameters; (2) improvement of membrane characteristics; and (3) modification of mixed liquor characteristics (Le-Clech et al., 2006). Research

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on method 3 is especially unique for MBR since the activated sludge mixed liquor in MBR is generally much more complex than the mixed liquor in the conventional microfiltration or ultrafiltration processes. With the inclusion of activated sludge, the mixed liquor in MBR features a very complex fluid consisting of planktonic bacteria, microbial aggregates, microbial metabolism products, organic and inorganic solute, colloidal and particles. According to settleability, the composition of the mixed liquor in MBR can be classified into floc and supernatant. It was reported that floc could play major role in cake resistance once the cake was formed on the surface of membrane (Deferance et al., 2000). Supernatant, consisting of colloidal and soluble substances, can be classified into three groups according to the relative size: (1) far smaller than the size of membrane pores, (2) close to the size of membrane pores, and (3) larger than the size of membrane pores. The first group of macromolecule substances could pass through membrane pores and have a minor influence on membrane filtration process. The second group of macromolecule substances could enter membrane pores and are likely to deposit in the pores. Pore blocking can lead to reduction of pore size and permeability of membrane. Although pore blocking resistance may not dominant in total filtration resistance, control of pores blocking is very crucial because it can result in irreversible membrane fouling and severe damage on membrane. The last group of macromolecule substances cannot enter membrane pores but may deposit on membrane surface to form a gel layer. The gel layer could further promote the formation of cake layer on top of it by providing adsorption sites and possible nutrient source for the attached growth of microorganism, which could eventually lead to significant increase in membrane filtration resistance (Rosenberger et al., 2005). Therefore, better understanding of the impact of mixed liquor properties on membrane fouling in the multi-component MBR system could be favorable to the development of effective solution for membrane fouling alleviation.

Some studies have reported that membrane fouling in MBR can be alleviated by improvement of mixed liquor properties resulted from the addition of some so called anti-fouling agents (Akram and Stukey, 2008; Sagbo et al., 2008; Zhao and Gu, 2006). Most of these anti-fouling agents, including substances like powdered activated carbon, diatomaceous earth, zeolite and perlite, functioned mainly by physical interaction with the mixed liquor in MBR (Roux et al., 2005). However, their actual application in MBR is still not available due to limited improvement and gradual loss of effectiveness with the time of operation.

Recently, Wu et al. (2006) reported that addition of $Fe^{3+}$ and $Al^{3+}$ coagulants could control membrane fouling by reducing the initial trans-membrane pressure (TMP) and TMP increase rate. Study by Lee et al. (2007) also indicated that the addition of membrane fouling reducer (MFR), a type of cationic polymer, to a conventional MBR led to improvement in membrane filterability through flocculating activated sludge. These information show that flocculants can be considered as filter aids used in MBR for fouling control. It is different from the conventional purpose of flocculants for removal of colloid and fine suspended solid from water or for excessive sludge dewatering (Roux et al., 2005). Adoption of flocculants as filter aids seems quite favorable since they are usually cheap, low toxic and widely used in wastewater treatment for many decades. However, comprehensive assessment on the effects of addition of different types of flocculants on flux enhancement, the effective duration of each type of flocculant as well as the intrinsic mechanism of fouling control in MBR has not been well explored.

According to their chemical composition, flocculants could be classified into three types: inorganic monomer, inorganic polymer and organic polymer. In this study, three typical flocculants (monomer: $Al_2(SO_4)_3$, inorganic polymer: polymeric ferric sulfate (PFS) and macromolecular organic polymer: Chitosan) were selected to comprehensively evaluate the effect of filter aids addition on sustainable filtration flux and time. Investigation had been conducted on soluble and colloidal foulants as well as floc foulants. Analyses on the mechanism of flux enhancement had been made from various aspects such as the concentration and MW distribution of organics in supernatant, the FTIR spectrum of the fouled membrane, the correlation among floc size, fractal dimension and specific cake resistance, and the effect of the dosage of filter aids on specific cake resistance. The aim was to assess the applicability of different flocculants as filter aids in MBR operation and to explore how filter aids affect mixed liquor properties and thus alleviate the membrane fouling.

## 2. Materials and methods

### 2.1. *Experimental set-up and operating modes*

#### 2.1.1. *Submerged MBR*

Fig. 1 shows the schematic diagram of the submerged membrane bioreactors. Four identical reactors were operated simultaneously with one reactor as the control (without adding filter aid) and the other three reactors with addition of $Al_2(SO_4)_3$, PFS and Chitosan, respectively, for comparison. All reactors were inoculated with the same activated sludge and run in parallel under the same operating conditions.

Compressed air was supplied continuously through diffusers at the bottom of each reactor to provide dissolved oxygen for biomass and create a turbulence flow along membrane

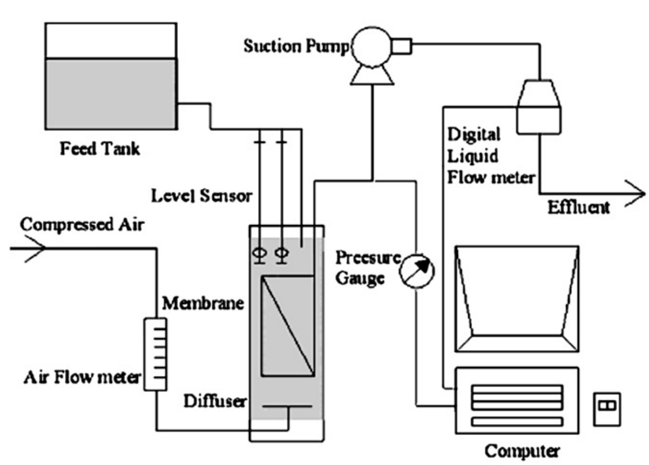


**Fig. 1 – Schematic diagram of the submerged membrane bioreactor.**