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The roles of various sludge fractions in the cake layer formation during the filtration of MBR mixed liquor

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1. Introduction

Since MBR(membrane bioreactor) mixed liquor includes living microorganisms and their metabolites, the fouling mechanism is even more complex than that of conventional membrane separation processes. Many researchers have focused their attentions on the fouling mechanism in MBR systems. It has been reported that biomass concentration, sludge characteristics, and the amount and composition of microbial products are the key factors in membrane fouling. In addition, membrane fouling may be directly influenced by properties of the membrane and the hydrodynamic conditions of the membrane process, most notably, permeation drag and back transport.

Recently, several studies have attempted to quantify the degree and character of fouling caused by each fraction of the activated sludge, namely, suspended solids, colloids, and solutes. The results are, however, so conflictive as to deepen the controversy. Bouhabila *et al.* speculated that those differences could be derived from the nature of the substrate, physiological characteristics of the biomass, fractionation method, and membrane materials. By reviewing most of the previous relevant literature, we can extend the hypothesis that fouling contributions from various fractions of the activated sludge may be variable, and change according to membrane materials, hydrodynamic conditions, and the physiological properties of the biomass.

The objectives of this study were to investigate the roles of various sludge fractions to membrane fouling, and also to evaluate the effects of the membrane material and the hydrodynamic condition on the behaviors of the aforementioned sludge constituents. The results of this study should help us elucidate the fouling mechanism of membranes in MBR systems.

2. Experimental

The activated sludge used in this study had been cultivated in a submerged MBR plant with synthetic substrate. Glucose, $(NH_4)_2SO_4$, and KH_2PO_4 were used as carbon, nitrogen, and phosphorus sources, respectively. Additional nutrients and alkalinity ($NaHCO_3$) were also supplied to the reactor. MLSS concentration was maintained at levels between 3,500 and 4,000 mg/l. Sludge retention time was about 20 days, and the organic loading rate was 0.16~0.17 gCOD/gMLSSday.

UF membranes used in this study were prepared using the phase inversion method. Cellulose acetate (CA CA398-3, Eastman-Kodak), polyethersulfone (PES; Ultrason E, BASF), and polysulfone (PSf; Udel-P 3500, Amoco) were used as membrane materials, and solvent was N-methyl-2-pyrrolidone (NMP, Aldrich). Cosolvent for CA membrane was acetone (Aldrich), and polyvinylpyrrolidone (PVP; MW 10,000, Aldrich) was used as an additive for PES and PSf membranes.

Flux decline behavior in the cross flow system was measured using membrane cells, the membrane surface area of which was 18.1 cm^2. Filtration tests of the UF membranes were performed at 100 kPa and 20±2℃. Cross flow velocity was controlled at 1.2 m/s, and the flow rate was 2.5 l/min. The UF membranes were tested simultaneously with the same feed, and air was supplied to the biomass in the feed tank during the filtration tests. Flux was determined by weighing the permeate on a top-loading balance at desired time intervals. Stirred batch cell (Amicon) was used for dead end filtration experiments under different conditions.

In this study, we assumed that the activated sludge consisted of solutes, colloids, and suspended solids, and that these components independently contribute to membrane fouling, that is to say, we neglected any coupling or synergistic effects which might occur among the components. Therefore, the resistance of the activated sludge can be considered to be equal to the sum of the resistances of the suspended solids, colloids, and solutes. The resistance of the activated sludge could be measured from the activated sludge filtration, and calculated by the following equation

$$R_{AS} = R_{ss} + R_{col} + R_{sol} = R_t - R_m = \frac{\Delta P_T}{\eta \cdot J_{AS}} - R_m$$

where R_{AS} is the resistance of the activated sludge, R_{SS} is the resistance of the suspended solids, R_{col} is the resistance of the colloids, and R_{sol} is the resistance of the solutes.

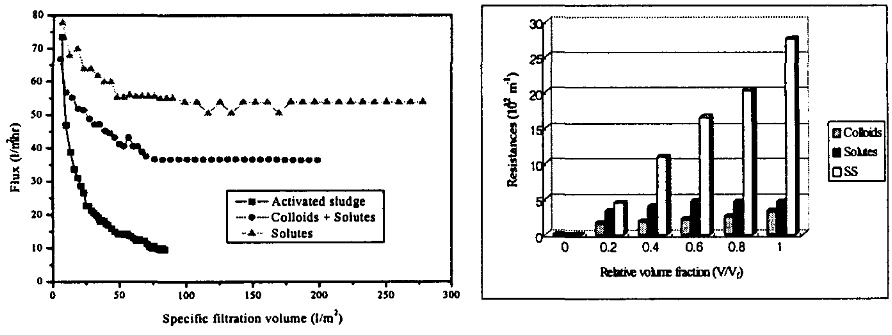
Colloids and solutes could be obtained by extracting the supernatants generated after 4 hours of gravitational sedimentation of the activated sludge mixed liquor. Finally, the soluble fraction was acquired via the filtration of the supernatant with a 0.45 ㎛ microfiltration membrane.

3. Results and discussion

The fouling contribution of each sludge fraction appeared to depend on particle size, as both permeation drag and back transport velocity are particle size-related functions. Solutes played a significant role in the initiation of cake layer formation, because they were deposited onto the membrane surface and pore wall immediately upon initial filtration, but were dislodged only in small amounts by cross flow. Suspended solids were consistently deposited onto the membrane surface, until flux reached a steady state and colloids exhibited characteristics commensurate with an intermediated state between solutes and suspended solids.

The deposition of large particles can be controlled by the creation of conditions of low permeation drag and high shear rate, but more solutes will then be directly deposited onto the membrane surfaces and pore walls without the protective effects of the cake layer. As a result, the main fouling contributor shifted from the suspended solids to the solutes.

The main fouling feature was the formation of cake layer on the membrane surfaces regardless of membrane materials. Hydrophobic membranes exhibited greater fouling than hydrophilic membrane, mainly due to the significant increase in colloidal adsorption.



(a) (b)

Fig. 1 Flux decline of CA membrane and filtration resistance behaviors of each sludge fraction according to the relative filtrate volume.

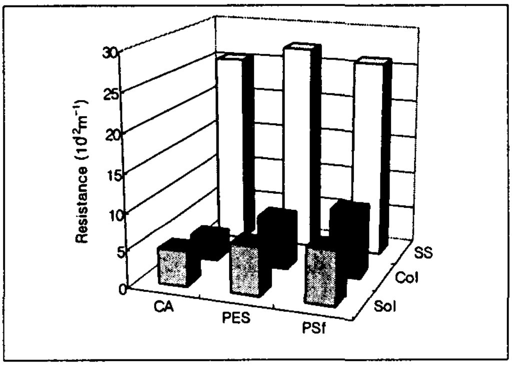


Fig. 2 Filtration resistance behaviors of each sludge fraction.

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