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# Effects of cationic polyelectrolyte on filterability and fouling reduction of submerged membrane bioreactor (MBR)

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ABSTRACT

Organic and inorganic polyelectrolytes are commonly used as coagulants or flocculants in membrane bioreactor to enhance the filtration properties of membranes. The main objective of this study was to determine the effectiveness of organic cationic polyelectrolyte (CPE) addition on filterability of various membranes and to investigate the influences on fouling of membranes. First, batch tests were performed to determine the optimum polyelectrolyte concentration at which the highest soluble microbial products (SMPs) removal was observed. Then, short-term filtration test were conducted. Cellulose acetate, polyethersulfone, mixed ester, polycarbonate (CA, PES, ME, PC) membranes with two different pore sizes (0.45–0.40 and 0.22–0.20 μm) were used in submerged MBR experiments. Permeate flux decline at constant vacuum was observed with time. Protein and carbohydrate analysis were performed in the permeate samples. Filtration resistances were determined for each membrane. Cake resistance was observed to be the most significant fouling mechanism for all membranes. Polyelectrolyte addition decreased the cake resistance. The effect of polyelectrolyte on pore resistance was relatively insignificant. The results showed that addition of polyelectrolyte had significant impact on sustainable filtration time.

## 1. Introduction

Submerged membrane bioreactors (SMBRs) for wastewater treatment and water reuse applications have received significant interest in recent years as they offer operational and design benefits by eliminating the need for a secondary settling tank. They also require smaller reactor volume and produce smaller quantities of sludge. However, membrane fouling is one of the major operational concerns of MBRs. To understand membrane performance in relation to system parameters have been extensively investigated. Extracellular polymeric substances (EPSs) or soluble microbial products (SMPs) are reported to be major compounds to cause membrane fouling [1,2]. They are large molecular weight compounds that are released by bacteria. They consist of proteins, polysaccharides, lipopolysaccharides, lipoproteins or complex mixtures of these biopolymers with a variety of functional sites including carboxyl, amino and phosphate groups. In recent years, research on EPS in either soluble form (i.e., SMP) or bound form have gained increasing interest [3–8]. However, the current understanding of membrane fouling mechanisms and membrane performance in relation operational parameters in SMBRs are still limited. EPS plays an integral part of the biofilm structure and development especially for attachment, detachment, mechanical strength, and protection against environmental stress factors. The bioadhesive characteristics of EPS alter the original surface properties rendering hydrophobic surfaces to become hydrophilic. Once the EPS deposit on surfaces, they can provide sources of nutrition for bacteria, and create the conditions necessary for bacterial attachment [9,10]. The removal of soluble foulants like SMP in the activated sludge is very important since they may potentially cause internal fouling of membranes, and thus decreased membrane filterability [6].

Most research efforts have been focused on identification of the key biomass parameters leading to membrane fouling in MBR. Recently, application of antifouling agents such as diatomaceous earth, powdered activated carbon, $Fe^{3+}$ or $Al^{3+}$ salts, inorganic polymeric substance, organic poly-electrolytes, natural organics in MBR for alleviation of membrane fouling has been reported in several publications [11–14]. Flocculants are mostly used in water and wastewater treatment for removing colloidal and soluble organic matters. Since addition of polyelectrolytes in MBR could modify the properties of mixed liquor through inducing complex change among soluble, colloidal and solid fractions, it is important to understand filtration performance and membrane-fouling characteristics in the polyelectrolytes added MBRs [15]. Iversen et al. [16] have shown that some of the tested additives were able to significantly reduce the concentrations of SMP. Furthermore, they indicated that the additives may also affect the porosity of the

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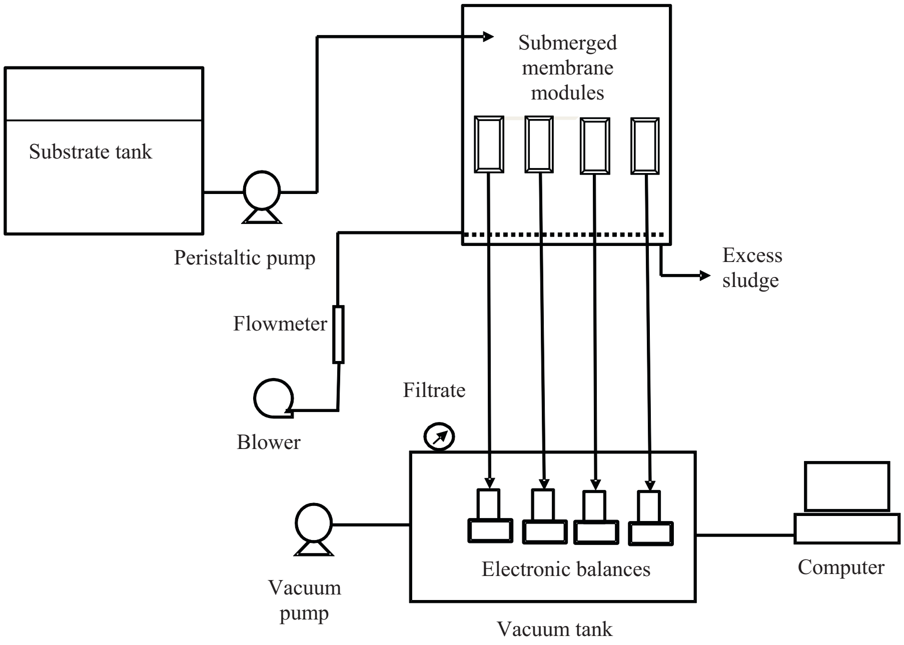

**Fig. 1.** The schematic diagram of the SMBR experimental set up.

cake through formation of larger flocks. Similarly, Hwang et al. [17] reported that the cake layer dosed with polymeric additive exhibited a 1.3 times greater porosity than that in the control reactor.

It is apparent that the filtration additives improve filtration performance by changing the properties of the mixed liquor (e.g., reduction in SMP). The effects of these changes on various membrane materials and pore sizes are expected to be different since the morphology and the properties of the membrane surfaces are different. The effects of polyelectrolyte addition to the filtration characteristics of different membrane materials and various pore sizes have not been investigated in the literature. The objective of this study was to improve the filtration performance of various membranes by using a cationic polyelectrolyte and to identify the effects of the polyelectrolyte addition on the fouling of membranes with different type and pore sizes. Cellulose acetate, polyethersulfone, mixed ester, polycarbonate (CA, PES, ME, PC) membranes with two pore sizes (0.45–0.40 and 0.22–0.20 μm) were used in submerged MBR experiments. Initially, batch tests were performed to determine the optimum polyelectrolyte dosage for SMP removal. Filtration tests were conducted to determine the effects of polyelectrolyte addition on filtration properties by observing flux. Protein and carbohydrate analysis were conducted in permeate samples.

## 2. Materials and methods

### 2.1. Membrane filtration experiments

Membrane filtration experiments were performed with a custom made submerged membrane filtration system. The schematic representation of the experimental setup is shown in Fig. 1. The MBR system was operated with synthetic wastewater to control the operating conditions and evaluate the system performance in a systematic manner. Influent wastewater was fed to the bioreactor with a peristaltic pump (Cole Parmer Masterflex). Compressed air at 8–10 L/min was supplied by a membrane diffuser which was placed at the base of the bioreactor. The air supplied by the diffuser provided mixing of suspension in the bioreactor and scouring of the membrane surface. The dissolved oxygen concentration in the bioreactor was 4.6 ± 1.1 mg/L. A sedimentation tank was placed after mixing tank to maintain constant hydraulic retention time (HRT). During filtration experiments effluent out of sedimentation tank decreased by the amount of filtrate collected from the membranes. HRT was kept constant at 12 h, and sludge retention time (SRT) was 10 days. Excess sludge was withdrawn daily at a rate of 5 L/day from the bioreactor to maintain the concentration of mixed liquor suspended solids (MLSS) at 3780 ± 45 mg/L at 10 days. The sludge temperature was controlled at 22.4 ± 1.9 °C with an electric heater. All experiments were run at a feed water temperature of 22.0 ± 0.5 °C and were repeated at least once. The activated sludge inoculum was obtained from a wastewater treatment plant in Gebze, Turkey. The sludge was firstly acclimated at batch study for 7 days and then the bioreactor was operated at continuous-mode. Activated sludge system was operated more than a month to reach constant MLSS values prior to the membrane experiments. New membrane was used for every filtration experiment.

The flat sheet membrane modules, made of polypropylene, had a total area of 50 $cm^2$. Short-term (24 h) mixed liquor filtration tests were conducted in constant pressure mode (−140 ± 5 mmHg). Filtration tests were also conducted without the addition of polyelectrolyte for comparison purposes.

The synthetic wastewater was prepared using glucose, urea/$(NH_4)_2SO_4$, and $KH_2PO_4$/$K_2HPO_4$ as a source of carbon, nitrogen, and phosphorous, respectively. The influent contained 650 mg/L glucose, 50 mg/L peptone, 100 mg/L urea, 50 mg/L $(NH_4)_2SO_4$, 50 mg/L $KH_2PO_4$, and 5 mg/L $K_2HPO_4$. $NaHCO_3$ was used as a buffer to adjust the influent pH to about 7.3 ± 0.2. Required trace metals derived from $CaCl_2$ (10 mg/L), $MgSO_4{\cdot}7H_2O$ (50 mg/L), NaCl (50 mg/L), KCl (10 mg/L), $CuSO_4{\cdot}5H_2O$ (0.1 mg/L), $FeCl_3{\cdot}6H_2O$ (10 mg/L), $ZnCl_2$ (0.25 mg/L), $CoCl_2{\cdot}6H_2O$ (0.45 mg/L), and $MnSO_4{\cdot}7H_2O$ (7 mg/L) were provided to the system. All reagents were analytical grade.

### 2.2. Polymer and membranes characteristics

Four types of membranes cellulose acetate, polyethersulfone, mixed ester, polycarbonate (CA, PES, ME, PC) membranes with two different pore sizes (0.45–0.40 and 0.22–0.20 μm) were used in submerged MBR experiments. All membranes were obtained from