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The effect of different surface conditioning layers on bacterial adhesion on reverse osmosis membranes

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HIGHLIGHTS

- MBR permeate & synthetic foulants water were used to form conditioning layers.
- The presence of conditioning layers increased bacterial attachment.
- Biopolymers were found to be the main contributor in the conditioning layer.
- Bacterial attachment was highly influenced by the change in AFM adhesive force.
- Pretreatment with UF was better than MF to reduce biopolymers & bacterial attachment.

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ABSTRACT

Reverse osmosis (RO) biofouling is a problem of biofilm development which is initiated by bacterial attachment to the membrane surface following the surface conditioning. In this study, the impact of the initial fouling layers on bacterial attachment was investigated. Both model foulants and MBR permeate water were used to simulate conditioning layers on RO membranes by performing fouling experiments at constant flux and crossflow velocity. Analysis of the properties of different conditioning layers included zeta potential, contact angle, roughness, and adhesive force. Results in this study show that the bacterial attachment was greater on pre-conditioned surfaces and the load of attached bacteria was closely correlated to the change of adhesive force rather than to the change of zeta potential and hydrophilicity. Additionally, the amount of the pre-conditioning layer also influenced the bacterial attachment. Differences in surface roughness were found to be unimportant. To examine the effect of pretreatment bacterial attachment tests were performed on a secondary effluent filtered by microfiltration or ultrafiltration. The UF pretreatment showed significantly less attachment. Results in this study confirm the role of the initial conditioning layer and highlight which surface characteristics of the conditioning layer are the most important for the initial bacterial attachment.

1. Introduction

Water production using reverse osmosis (RO) is becoming more popular. In places where surface and ground water are limited, RO has been very successful in providing a fresh water solution through wastewater reclamation and seawater desalination. In spite of the successes of RO, the technology has been disturbed by the phenomenon of fouling, which is a deposit of unwanted materials on the membrane and in the membrane module which causes several adverse impacts including elevated energy requirement, lower product quality, and increased costs [1].

Among the different types of RO membrane fouling, biological fouling (biofouling) is one of the major problems in RO processes. Biofouling is defined as the development of biofilms in the membrane module, which may cause increases of pressure drops across the membrane (trans-membrane pressure, TMP) and along the membrane channel (channel ΔP) [2]. Several studies have shown that biofilm development on surfaces is a series of successive events which can be separated into five stages: i) surface conditioning; ii) initial bacterial attachment; iii) initial release of extracellular polymeric substances (EPS); iv) biofilm development; and v) planktonic detachment/release [3,4].

Based on the knowledge of the biofilm development process above, bacterial attachment following the conditioning of membrane surface appears to be one of the key events contributing to the biofouling problem in RO. One of the earliest studies on bacterial attachment

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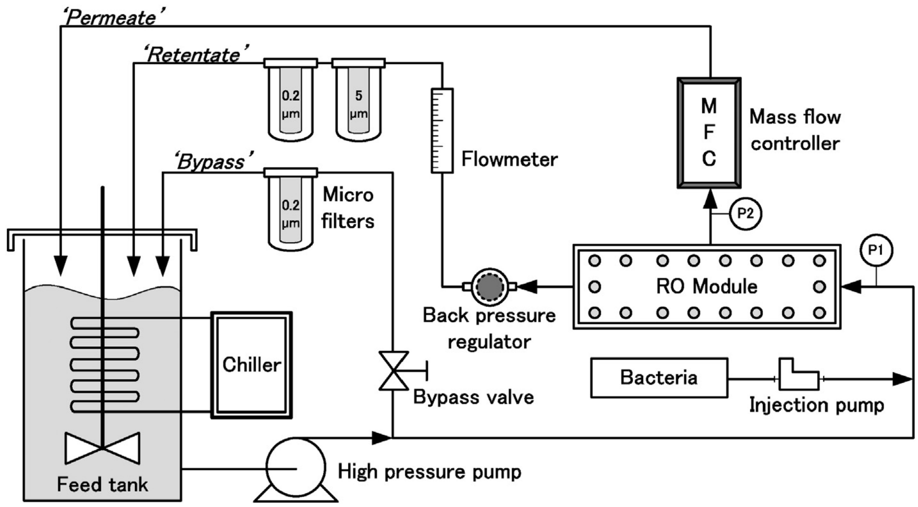

Fig. 1. Diagram of reverse osmosis fouling set-up.

onto the membrane surface was done by Ridgway et al. [5]. Through a series of non-flux-driven experiments they showed the importance of hydrophobics interaction where more hydrophobic bacteria tended to adhere more strongly to cellulose acetate (CA) membranes. The impact of surface conditioning on bacterial adhesion was also shown in a study by Sadr Ghayeni et al. [6]. Although the system in their study did not include flux and the impact of the conditioning layers varied with bacterial strains, the study clearly showed the impact of different conditioning layers on bacterial adhesion. The membrane surface charge, measured as zeta potential, which affects the electrostatic repulsions, and the water permeation (i.e. flux) which induces higher convective force were also shown to influence the bacterial attachment on membrane surfaces [7,8]. The same convective force is also the main contributor for the deposition of the initial conditioning layer on the membrane surface due to the phenomenon of concentration polarization (CP).

Organic components (i.e. biopolymers, humic substances) coming from the feed water are understood to be the main composition in the conditioning layer [9,10]. Several attempts to understand the impact of organic conditioning on RO membranes have utilized model foulants and changes in the surface characteristics were shown including zeta potential, hydrophobicity, and roughness [11–14]. More advanced observations using the atomic force microscope (AFM) further suggested that the deposition of organics may also be correlated with the adhesive force between the foulant and the surface where a higher adhesive force can cause more severe fouling [15,16]. The impact of the organic conditioning layer on biofouling was also reported by Baek et al. where greater bacterial attachment and EPS were observed on a membrane pre-fouled with synthetic nutrient-rich water compared to a clean membrane [17].

RO membranes are commonly used to treat water from various sources including seawater, surface water, and wastewater. Since the mixture of organics in actual water sources is more complex and the impact of conditioning layers formed in these systems on the initial bacterial attachment can also be quite complex. In previous bacterial attachment studies using different types of conditioning layer solutions from a two-stage MF-RO process it was found that the conditioned membranes had changed the pattern of bacterial attachment, although it only showed a relatively weak impact which may be due to the non-filtration (i.e. no flux) nature of the experiment [6]. In a recent study using a quartz crystal microbalance (QCM), it was observed that a

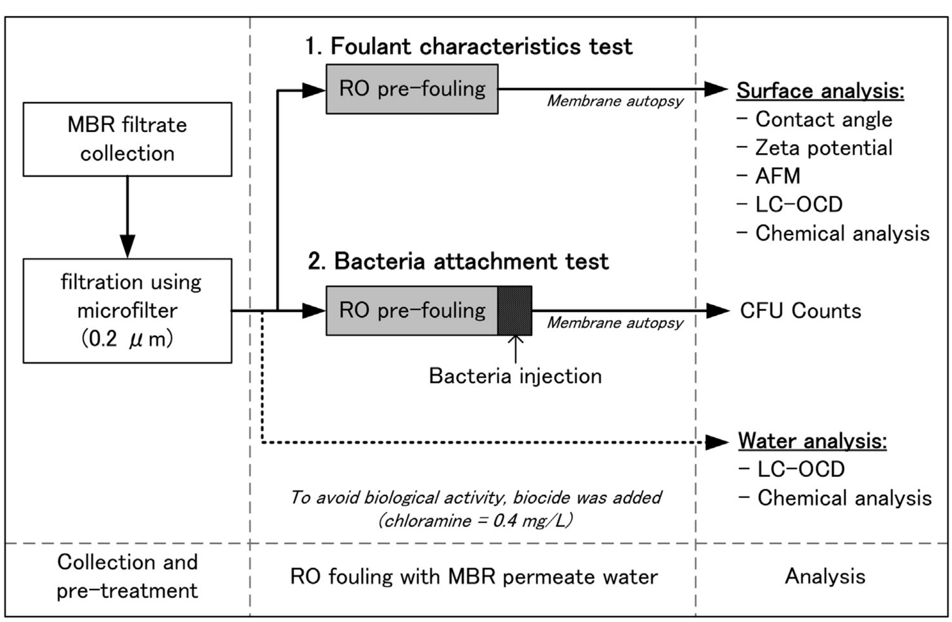

Fig. 2. Diagram of experimental protocol for conditioning tests with MBR permeate as feed solution.