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A new membrane performance index using flow-field flow fractionation (fl-FFF)

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Abstract

A new application of flow-field flow fractionation (fl-FFF) method was developed to quantify the interfacial interactions. The fl-FFF method was designed so as to characterize a new membrane performance index (MPI-FFF), which represents not only fouling resistibility of a membrane for a specific foulant, but also the removal capability for the foulant. Three commercial ultrafiltration (UF) and nanofiltration (NF) membranes and two foulants including organic and colloidal materials, were tested to verify MPI-FFF in lab-scale membrane fouling tests. Higher values of MPI-FFF mean better performance of membranes for a specific foulant in terms of rejection and fouling resistibility. According to the fouling tests, combinations of foulant and membrane with higher MPI-FFF values showed lower fouling and higher rejection characteristics, which means the MPI-FFF is a useful parameter to account for membrane performance. In addition, MPI-FFF values can be easily and quickly obtained for membranes and the foulants in the feed water for the selection of membrane with high performance.

Keywords: Flow-field flow fractionation (fl-FFF); Membrane performance index using fl-FFF (MPI-FFF); Fouling; Ultrafiltration (UF); Nanofiltration (NF); Organic fouling; Colloidal fouling

1. Introduction

Membrane filtration technologies have became more popular due to the demand for high-quality water through the world [1], and these are considered as a promising process to supply efficient performance for drinking water treatment, wastewater reclamation, and seawater desalination [2–4]. It is very important to select suitable membranes for the membrane

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water treatment processes. The target material size and the water permeability were generally used as criteria for the membrane selection. However, the fouling resistibility should be also considered for better performance of the process. Fouling has always been an inevitable problem and the most interested issue for membrane process engineers and researchers. Membrane fouling causes subsequently high operation cost by inducing low permeability or high trans-membrane pressure drop [5]. Therefore, much effort has been made to minimize membrane fouling and as fouling indices, silt density index (SDI) and modified fouling index (MFI) have been most widely used for estimation of fouling potential of feed water [6,7].

Although SDI and MFI are relatively easy to conduct and exhibited practical use, it has been reported that feed water with low SDI and MFI caused unexpected severe fouling in practice [8,9]. This failure of estimation for fouling potential is likely that both methods basically use 0.45 μm filter resulting in inadequately dealt with colloid and organic matter which are smaller than pore size of filter. In addition, there was a report that particles smaller than 0.05 μm were considered as significant cause for flux decline of the reverse osmosis membrane [10]. Although recently MFI-UF and MFI-NF have been investigated to improve these limitations of fouling indexes [9,11,12], these up-graded types of MFI still have fundamental limitations for prediction of nanofiltration and reverse osmosis membranes. First of all, selection of standard membrane for up-graded MFI is not simple because fouling mechanisms are involved in various factors such as solution chemistry, inorganic and organic colloids, characteristics of natural organic matter, and characteristics of membrane. In addition, NF or RO are operated in cross-flow mode in water treatment, fouling index obtained by dead-end filtration type might not proper to apply [9].

Fundamentally the fouling occurs from interfacial interactions; i.e., the foulant–membrane adhesion and the foulant–foulant interactions. Thus, the two interactions will be good parameters to predict fouling in the membrane processes. An extended version of the Derjaguin Landau Verwey Overbeek theory (a.k.a XDLVO theory) can be used to describe these interactions and it worked well to predict colloidal and organic fouling [13–18]. However, this method is difficult to use in field application because it needs a lot of membrane and foulant characterization data and complex procedure of the interaction force calculation using these data.

In this study, we propose a new membrane fouling potential estimation method using flow-field flow fractionation (fl-FFF) method. The fl-FFF is one of flow-assisted separation technique with capacity to separate colloids ranging in size from 1 nm to 50 μm [19]. The liquid flow in fl-FFF is the same as the typical cross-flow membrane filtration mode and fl-FFF can be regarded to investigate membrane–solute interaction which is important fouling mechanism [20,21]. It can investigate direct fouling potential depending on not only feed water but also membrane by applying different membrane. In addition, we found out another application of fl-FFF to measure membrane performance, i.e., fouling resistibility and removal efficiency. The distinction of the new method from the previous methods [20,21] is whether the flow field is on (for the previous methods) or off (the new method) during the measurement.

2. Materials and methods

2.1. Membrane, reagents, and foulants

The UF and NF membranes used in this study were designated by the manufacturer as PW (GE Osmonics, UF), NE70 (Woongjin Chemical, NF), and NF90 (Dow Filmtec, NF). Humic acid (HA) from Aldrich and spherical