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Microfiltration of microalgae in the presence of rigid particles

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ABSTRACT

This study investigated the microfiltration of microalgae, *Chlorella* sp., in the presence of polymethylmethacrylate (PMMA) under dead-end and cross-flow modes. The concentration of microalgae was 10 mg/L, while PMMA concentration varied from 10 to 40 mg/L. Flux increased with increasing concentration of PMMA in dead-end microfiltration, and the specific cake resistance decreased as PMMA concentration increased under three different trans-membrane pressure (TMP) of 20, 40, and 60 kPa. The cake compressibility decreased in the presence of PMMA. In cross-flow microfiltration of microalgae in the presence of PMMA, the flux increased as cross-flow velocity increased, and the effect became more pronounced as PMMA concentration increased. It was because the rigid PMMA particles rendered the distribution of local specific resistance more uniform along the cake thickness. In addition, the cake growth became more containable by increasing cross-flow velocity when more PMMA particles were present, and resulted in higher steady flux under both laminar and turbulent flow conditions.

1. Introduction

Microalgae in excess amount in surface water are known to cause trouble in sedimentation basin and shorten filter run in rapid sand filtration unit in water treatment plants [1]. Cyanotoxins, such as microcystin, pose risks to human health and its removal is challenging although various technologies have been examined [2]. Furthermore, microalgae also lead to taste, odors, formation of disinfection by-products, and higher coagulant demand by the presence of algogenic organic matter (AOM) [3]. Unfortunately, the conventional water treatment processes are not adequate for the removal of algal cells, while additional unit may be costly [4]. The use of membrane-based technologies in water treatment have been shown to be reliable and capable of producing high-quality water.

Microalgae have gained enormous attention due to their potential for various applications, such as biofuel and wastewater treatment [5]. And membrane filtration is considered as an alternative method for microalgae harvesting [6]. However, membrane fouling is an important issue encountered in the membrane processes for water treatment as well as for algae harvesting, and extensive research has been carried out to elucidate the fouling mechanisms. Both algae size and extracellular organic matter (EOM) are critical factors in membrane fouling [7]. Deposition of microalgae started to occur even at a very low permeate and would eventually result in severe fouling in cross-filtration of *Chlorella sorokiniana* [6]. In microfiltration of algal suspension, EOM significantly increased the resistance [8]. Hung and Liu [9] pointed out that the dissolved polysaccharide-like substances derived from EOM cause remarkable increase in fouling resistance of the hydrophobic membrane via adsorption on membrane surfaces. Characteristics of AOM as affected by different nutrient conditions and subsequent influences on microfiltration membrane fouling have been investigated [10].

It is noted that microalgae may not the only fine particles in nature water. There are plenty of inorganic particles present in water, such as clay. Contrary to microalgae that are compressible, clays are rigid and incompressible in terms of their structures. The filtration of microalgae in the presence of incompressible particles needs to be investigated from water treatment viewpoint. Understanding the influence of rigid particles on the microfiltration of microalgae will be beneficial for developments in water treatment technology and microalgae harvesting method. In the current study, the filtration of microalgae in the presence of rigid polymethylmethacrylate (PMMA) particles at mass ratio of microalgae to PMMA at 1:0, 1:1, 1:2, and 1:4, were examined, respectively. The main reason for choosing PMMA as surrogate of clay is because, similar to clay, it is negatively charged in a wide pH range. Its possible electrostatic interaction with microalgae will thus be similar to that of clay. Both dead-end and cross-flow microfiltration were conducted at different trans-membrane pressure (TMP) and cross-flow velocity. The specific cake resistance and cake compressibility were assessed. Furthermore, the resistances-

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in-series model was used to assess the fouling mechanisms during microfiltration.

2. Materials and methods

2.1. Materials

The microalgae species, *Chlorella* sp., was cultivated in the laboratory. The procedure for microalgae cultivation and the subsequent cleaning are described in our previous work [9]. The mean diameter of *Chlorella* sp. is 3.8 μm. The commercial PMMA particles (Soken, MX-300) with a mean diameter of 3.68 μm were used to mimic incompressible particulates in natural water. The stock suspension of PMMA (1000 mg/L) was first prepared using 1-L ultrapure water. After stirring for 24 h, the suspension was filtered with a 0.45 μm GF/C membrane. The retained PMMA particles were again suspended with 1-L ultrapure water. Aforementioned procedures were repeated twice to clean PMMA particles. The concentration of microalgae was controlled at 10 mg/L for all experiments with PMMA concentration of 0, 10, 20, 40 mg/L, respectively. The size distribution of microalgae with PMMA was measured with a small-angle light scattering instrument (Malvern, Mastersizer 2000) as shown in Fig. 1. The hydrophilic mixed cellulose ester membrane (Corning, Membra-Fil) with a nominal pore size of 0.22 μm was utilized in this study.

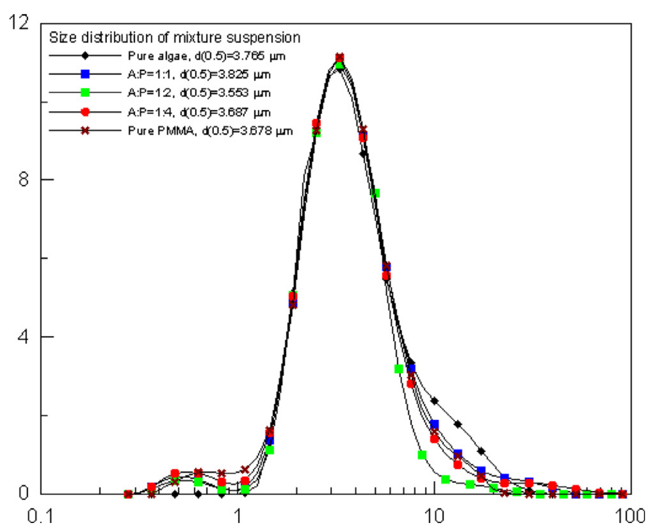

Fig. 1. Size distribution of microalgae with various concentration of PMMA.

2.2. Apparatus and procedures

2.2.1. Dead-end microfiltration

The experimental apparatus for dead-end microfiltration is shown in Fig. 2. The 2-L microalgae suspension was poured into the tank, which was kept at 25 °C throughout the process. The membrane module made of acrylic with the effective filtration area of 4 cm^2 was submerged into suspension. As filtrate began to flow into the receiver while the vacuum pump (Gast, DOA-P104-AA) was switched on to create negative pressure. Trans-membrane pressure (TMP) for dead-end microfiltration was set at 20, 40, and 60 kPa, respectively. The weight of filtrate was recorded as a function of operation time by the personal computer that acquired data from the electronic balance (Ohaus, adventurer). The procedure for the classification of hydrodynamic resistances, such as membrane resistance ($R_{m,b}$), fouling resistance ($R_{m,f}$), cake resistance (R_c), and total resistance (R_t) is illustrated in the previous work [9].

2.2.2. Cross-flow microfiltration

The equipment of cross-flow microfiltration used in the current study was described in our earlier work [9]. It was a customer-made plate and sheet type module which measures 4 cm in length, 1 cm in width, and 2 mm in height. The 2-L microalgae suspension was first placed in the thermostatic tank. The peristaltic pump (Cole-Parmer, Masterflex) not only accounted for transportation of suspension but also provided trans-membrane pressure (TMP) as the driving force for filtration. The rotameter (Aalborg, P11A2) prior to filter module was used to monitor cross flow velocity, which was controlled at 0.43 and 1.11 m/s, respectively, in order to assess laminar and turbulent flow conditions. Two pressure gauges were used to examine the TMP, which was kept at 20, 40 and 60 kPa, respectively. The technique used for recording permeate weight as a function of time was the same as that for dead-end microfiltration. The desired level of the overall particle concentration was monitored using turbidimeter (Merek, Turbiquant-1500T) and kept via supplementing ultrapure water, so that the solid

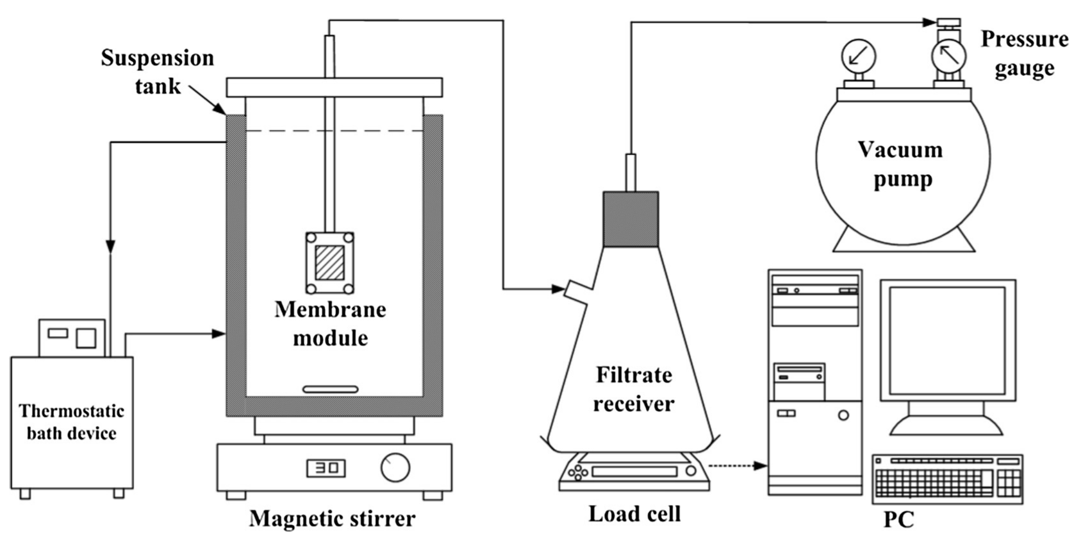

Fig. 2. Equipment of dead-end microfiltration system.

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