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Fouling characteristics of pressurized and submerged PVDF (polyvinylidene fluoride) microfiltration membranes in a pilot-scale drinking water treatment system under low and high turbidity conditions

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Abstract

Performance and fouling characteristics of two pilot-scale polyvinylidene fluoride hollow fiber microfiltration membranes for drinking water treatment were studied under the same flux and physical cleaning conditions. It is expected that this paper can provide insights into the functions of operation mode (one pressurized and one submerged) of the membrane in process performance and fouling evolution. As a result, it was found that the two membranes showed similar performance in terms of removal efficiencies of organic and inorganic substances. However, the pressurized membrane showed relatively more severe membrane fouling than the submerged membrane because the cake compressibility and thickness seemed to have been increased due to the hard-to-remove cake layer of the pressurized membrane containing relatively large amounts of humic substances, carbohydrate, and Fe than that of the submerged membrane, especially under high turbidity conditions without any pre-treatment. Under low turbidity conditions with pre-coagulation/sedimentation, the two membranes showed similar behaviors for increase of transmembrane pressure. After the chemical cleaning that was carried out after removing the cake layers from the membrane, surface flux restoration of the two membranes was not much different.

Keywords: Polyvinylidene fluoride (PVDF); Pressurized membrane; Submerged membrane; Hard-to-remove cake layer; Pre-coagulation/sedimentation

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1. Introduction

Low-pressure-driven membrane techniques such as microfiltration (MF) and ultrafiltration (UF) have attracted a considerable amount of attention in drinking water treatment for removal of particulates by size exclusion, and usually produce a filtrate free of turbidity and bacteria from river, lake, and underground water sources [1–5]. However, there is often a rapid decline in flux due to membrane fouling, which is caused by natural organic matter (NOM), both colloidal and solutes, as well as inorganic matter [5–7].

To mitigate membrane fouling from these substances, a hybrid membrane system combined with chemical/physical processes such as coagulation/sedimentation, ozonation, chlorination, and activated carbon has been widely adopted [8–12]. Specially, the use of pre-coagulation and pre-coagulation/sedimentation extended the membrane operation period by reducing cake deposits on the membrane and removing NOM including humic substances [4,6,7,12]. Moreover, hybrid membrane systems using chemical or physical activities enhanced the removal of micropollutants and viruses [13,14]. Fiksdal and Leiknes [14] investigated removal of phage MS2 in drinking water by pre-coagulation and filtration through MF and UF membranes in a laboratory-scale unit. As a result, it was reported that the low ($\leq$1–30 pfu ml^{-1}) numbers of infective viruses detected in permeates show that pre-coagulation/flocculation in combination with both loose UF and MF membrane filtration was an effective hygienic barrier against the MS2 virus. However, without pre-coagulation/flocculation, no MF or only a minor UF virus removal was observed.

Polyvinylidene fluoride (PVDF) membranes have recently been adopted due to their tolerance of oxidants during drinking water treatment [10, 15]. The effectiveness of membrane filtration depends on the raw water quality and the operating conditions. Therefore, it is still necessary to study characteristics of performance and membrane fouling of this new membrane under various operating conditions.

Generally, there are two different configurations (i.e. pressurized and submerged modules) of membrane filtration technology. The submerged module has become a major feature in wastewater application of membrane technology. Many researchers reported that this module remarkably reduced the power consumption of recirculation pumps used in a membrane bioreactor [16,17]. From this viewpoint, this research is focused on both process performance and fouling characteristics of pilot-scale pressurized and submerged PVDF membranes for drinking water treatment under low and high turbidity conditions.

2. Material and methods

2.1. Experimental set-up for a pilot-scale membrane filtration system

2.1.1. Raw water

Raw water from the Chitose River surface was obtained from the Kami–Ebetsu water purification plant in Ebetsu, Japan. Although the water quality of the Chitose River changes seasonally, it typically exhibited relatively high turbidity and contained substantial amounts of organic matter, humic and inorganic substances [3,12].

2.1.2. Membranes

Two pilot-scale PVDF hollow fiber membranes having the same nominal pore size of 0.1 µm (Microza®, Asahikasei Chemical, Japan) and the same hollow fibers (surface area, 0.63 m^2; outer diameter, 1.2 mm; inner diameter, 0.7 mm) were evaluated at constant flux under the same operating conditions except for operation mode (i.e. pressurized or submerged). The dimensions of the pressurized module jacket and a tank in which the membrane was submerged were was 38 mm D × 640 mm H and 51 mm D × 570 mm H, respectively.