Comparison of Performance and Membrane Fouling Characteristics between Pressurized and Submerged PVDF Microfiltraion Membranes

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1. Introduction

As a means of complying with current and anticipated regulations, membrane technologies have been widely adopted in the world. Especially, the low-pressure driven membrane techniques such as microfiltration (MF) and ultrafiltration (UF) have attracted a considerable amount of attention in drinking water treatment to remove particulate and colloidal matters and usually produce a filtrate free of turbidity and bacteria from river, lake, and underground waters (Hagen, 1998; Klijn et al., 2000; Kimura et al., 2004). Recently, a polyvinylidene fluoride (PVDF) membrane having high permeability and strength has been developed for drinking water production (Kurihara et al., 2004).

There are two different configurations (i.e. pressurized and submerged modules) of the 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. However, there were no available reports comparing the pressurized and submerged membrane modules in drinking water treatment. Therefore, this study was focused on comparison of process performance and fouling characteristics between pressurized and submerged PVDF (nominal pore size = 0.1 ㎛, microza®, Asahikasei Chemical co., Japan) hollow fiber membranes.

2. Material and methods

For this study, Chitose River having relatively high turbidity, inorganic matter, and humic substances in Ebetsu, Japan was used as raw water. Two pilot-scale membrane filtration systems (i.e. pressurized and submerged modules) were evaluated under the same operating conditions (flux of 0.65 m/d, recovery rate of 92%, and physical cleaning using permeate and the compressed air for 90 s) without any pre-treatment and chemical addition.

3. Results and discussion

As shown in Table 1, turbidity (100%), Al (> 84%), and Fe (> 95%) were removed very well by both membrane modules. However, humic substances (E260) and Mn were not effectively removed by the membranes. On the other hand, different fouling characteristics of the two membranes were observed during the experimental period (Figure 1). Membrane fouling of the submerged membrane could be effectively mitigated by backwashing and air scrubbing during the experimental period. In contrast, in case of the pressurized membrane, transmembrane pressure (TMP) of the membrane was gradually increased but it could not be easily recovered by backwashing and air scrubbing once it increased rapidly at the 40th days.

Table 1. Process performance of two pilot-scale membrane filtration systems

	Raw water	Permeate of the pressurized membrane	Permeate of the submerged membrane
Temperature (^{o}C)	11.6 ± 2.6	11.1 ± 4.5	10.8 ± 3.9
Turbidity	11.5 ± 6.3	0 (100%)*	0 (100%)*
pH	7.3 ± 0.2	7.3 ± 0.2	7.4 ± 0.2
E260 (1/cm)	0.10 ± 0.04	0.07 ± 0.03 (30%)*	0.07 ± 0.04 (30%)*
TOC (mg/l)	1.7 ± 0.8	1.1 ± 0.5 (35%)*	1.1 ± 0.5 (35%)*
DOC (mg/l)	1.3 ± 0.5		
Total-Al (ppb)	133.4 ± 109.8	20.9 ± 13.0 (84%)*	21.8 ± 12.7 (84%)*
Total-Mn (ppb)	75.1 ± 32.2	46.8 ± 17.6 (38%)*	55.0 ± 14.9 (27%)*
Total-Fe (ppb)	603.1 ± 254.6	29.5 ± 16.9 (95%)*	30.9 ± 13.7 (95%)*

*( ): removal efficiency

Keywords: drinking water treatment; pressurized and submerged modules; PVDF; process performance; membrane fouling
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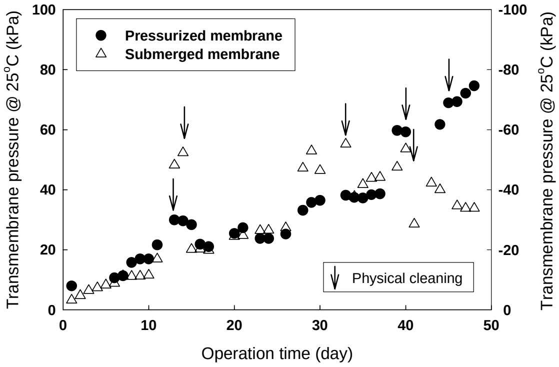

Figure 1. Variation of TMPs in two pilot-scale membrane filtration systems

Focused on this point, characteristics of various foulants in both membranes were studied. As a result, as shown in Figure 2, it was observed that relatively large amounts of organic matter (especially carbohydrates and humic substances) and Fe were extracted from the cake layer of the pressurized membrane than those of the submerged membrane. Moreover, as shown in Table 2, from a scanning probe microscopy (SPM) analysis showing surface characteristics of cake layer, it was found that the cake layer formed on the pressurized membrane surface was intensely smoother and thicker than that formed on the submerged membrane surface. Finally, it was recognized that interaction between organic matters and Fe in the pressurized membrane improved significantly the cake compressibility and stability deteriorating membrane fouling.

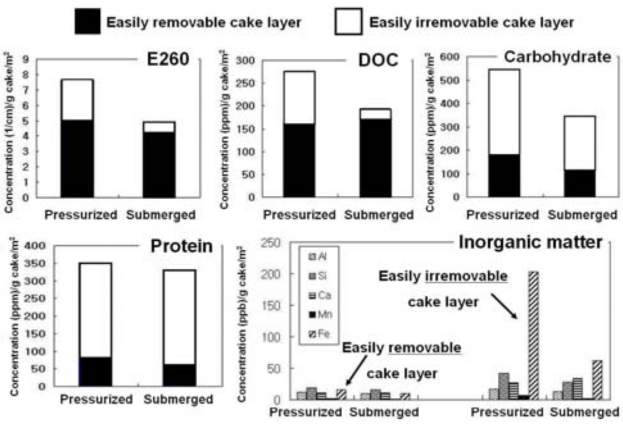

Figure 2. Characteristics of the extracted foulants from the cake layer in two PVDF membranes

Table 2. Parameters of cake layer surface morphology obtained from SPM images for two PVDF membranes

Membrane	Root mean square Rq (nm)	Power spectral density (nm^2)	Average mean height (㎛)
Before use (new)	155	0.41	0.8
Pressurized	363	1.06	3.0
Submerged	341	2.53	2.1

4. Conclusions

The pressurized and submerged membranes treating Chitose River water having relatively high turbidity, inorganic and humic substances showed similar performance in terms of removal efficiencies of turbidity, humic substances, TOC, and inorganic matters. However, the submerged membrane did better than the pressurized membrane in terms of membrane fouling as relatively large amount of organic matters and Fe in the latter improved significantly the cake compressibility and stability deteriorating membrane fouling.

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