Development of a Ceramic Monolith Membrane

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Abstract

In order to attain stable filtration of raw water for a long duration using water treatment membranes, it requires an adequate selection of a pretreatment method. In this way, we conducted a membrane filtration test using a large-sized inorganic membrane where river water is used as raw water and a coagulation treatment is adopted for pretreatment.

After adding coagulant to the membrane backwashing drainage, supernatant water obtained as a result of solid-liquid separation at the thickener tank was returned to the receiving tank. More than 99% recovery was attained and stable operation was continued for about six months.

Since there is a difference in membrane surface electric charges between organic and inorganic membranes, what is observed suggests the necessity for a coagulation treatment in the preliminary steps of inorganic membrane filtration treatments.

1 Preface

Generally speaking, the filtration speed of a water treatment membrane slows with the lapse of filtration time. In order to achieve stable filtration for a long time, it is necessary to select an adequate pretreatment method for the raw water. As part of an investigation into the most adequate pretreatment method suitable for the ceramic membranes used to treat raw water taken from a river where the water quality always fluctuates, we conducted a test to examine the filtration characteristics of a small-sized ceramic monolith membrane (small membrane hereafter) in the coagulation system (“System 1”) and a fiber filtration system (“System 2”). Based on our technical knowledge obtained from the above small membrane test, we carried out the filtration test with a large-sized ceramic monolith membrane (“large membrane”). For the improvement of recovery in an overall membrane filtration system, we evaluated the treatment characteristics of the overall system inclusive of a return system for the supernatant water of the thickened waste water. This paper introduces the result of the evaluation from the large membrane test.

2 Outline of Testing

2.1 Small Membrane Test

Fig. 1 shows a flow chart of the testing facility. In System 1, the raw water (river water) was led to the auto-strainer to remove large impurities. According

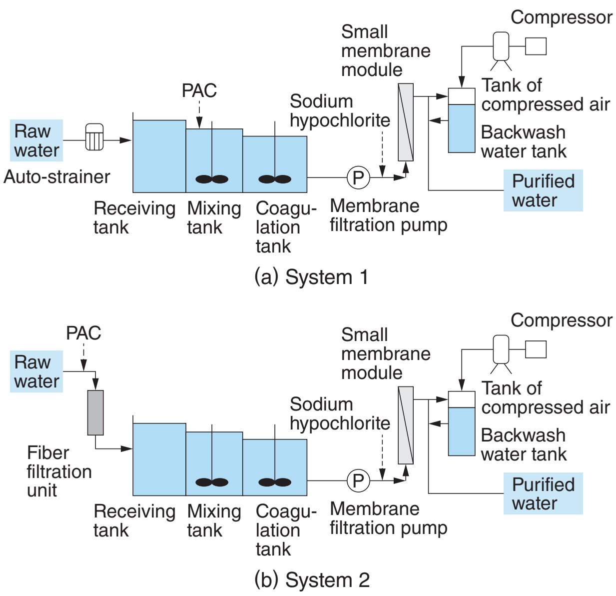

Fig. 1 Flow Chart of Small Membrane Filtration Test

Flow (a) shows a system where coagulation treatment is carried out for pretreatment. Flow (b) shows a system where fiber filtration is implemented for pretreatment.

Table 1 Filtration Testing Conditions for Small Membrane

After pretreatment in Systems 1 and 2, the membrane filtration test was conducted with small membranes.

Membrane surface area	$0.305m^2$
Nominal pore size	$0.1\mu m$
Membrane module size	$\phi 30\times 1000mm$
Filtration time	4 hours
Membrane filtration flux	$1.6m^3/(m^2 \cdot d)$
Filtration system	Internal pressure type dead-end filtration
Recovery	95.6%

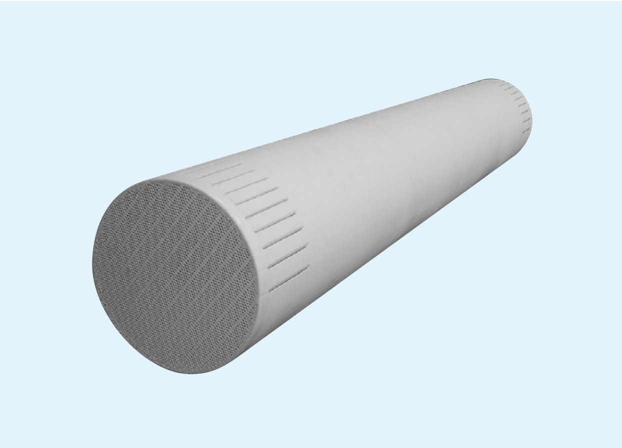

Fig. 2 Large-Diameter Membrane Element

A large-diameter membrane element used for the test is shown with a diameter of 230mm and a length of 1000mm.

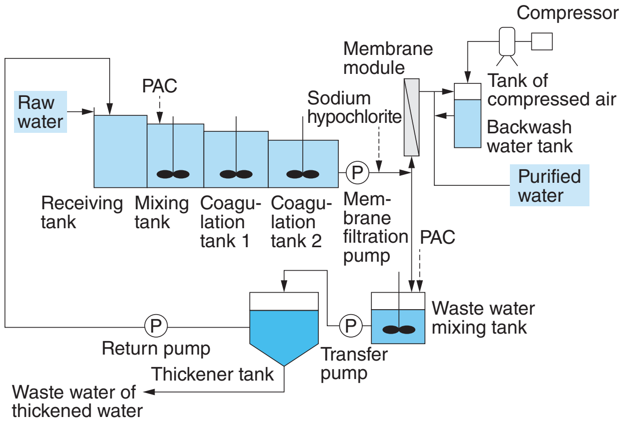

Fig. 3 Testing Flow Chart of Large Membrane Filtration Facility

In order to secure more than 99% of purified water recovery, solid-liquid separation was carried out for the waste water resulting from membrane cleaning and a process of returning supernatant water to the receiving tank was installed.

Table 2 Filtration Testing Conditions for Large Membrane

The recovery of a simple membrane unit was 92%. Since a return system was installed, however, the recovery of an overall membrane system was maintained at 99% or above. After the lapse of 147 days after the start of testing, it was judged that stable operation is possible. As such, the membrane filtration flux condition was changed from 1.2 to $1.5m^2/(m^2 \cdot d)$.

Membrane surface area	$24m^2$
Nominal pore size	$0.1\mu m$
Membrane module size	$\phi 230\times 1000mm$
Filtration time	1.5 hours
Membrane filtration flux	1.2 or $1.5m^3/(m^2 \cdot d)$
Filtration system	Internal pressure type dead-end filtration
Recovery	92% (System recovery 99% or above)

to the grade of turbidity, Polyaluminum Chloride (PAC) used as a coagulant was injected at a rate of 2～30mg/L during the membrane filtration for coagulation treatment. In System 2, membrane filtration was carried out for the water where its turbidity was maintained at approximately 0.3 degrees treated by fiber filtration. In the case of fiber filtration, PAC was injected at the rate of 1～50mg/L according to the grade of turbidity. Table 1 shows the testing conditions for Systems 1 and 2. After the lapse of filtration time, sodium hypchlorite was added and backwashing was performed for the small membrane.

2.2 Large Membrane Test

Fig. 2 shows a large-diameter membrane element and Fig. 3 shows a flow chart of the testing facility. The large membrane came in a size of 230mm in outer diameter, 1000mm in module length, $24m^2$ in membrane area, and $0.1\mu m$ in nominal pore size. The membrane filtration flux test was conducted under the continuous membrane filtration flux conditions: $1.2m^2/(m^2 \cdot d)$ or $1.5m^2/(m^2 \cdot d)$. Table 2 shows the test conditions of a large membrane filtration. The filtration time was 1.5 hours and the recovery of the membrane filtration block was 92%. After cleaning the filtration membrane, PAC was added to the membrane backwashing drainage to separate sludge at the thickener tank and the supernatant water was returned to the receiving tank. In this way, the recovery of the overall system was set at 99%.

3 Test Result and Considerations

3.1 Comparison of Water Quality between Raw Water and Fiber Filtrated Water

Table 3 shows the mean values of the water quality between raw water and fiber filtrated water measured during the test period. At that time, suspended iron, manganese, and other substances generally contained in river water were detected from the raw water. Iron and manganese substances can be said to be removed by fiber filtration because they were detected from fiber filtrated water which amounted to about 10% of those of the raw water. Almost no Total Organic Carbon (TOC) was removed by fiber filtration.

3.2 Comparison of Membrane Filtration Performance among Small Membranes

Fig. 4 shows the compensation Trans-Membrane Pressure (TMP) for Systems 1 and 2. In both of these two systems, the compensation TMP began to rise after the lapse of 100 days from the start of testing. After the lapse of 100 days, the rising speed of compensation TMP was maintained at 0.30kPa/d in System 1. While in System 2, it was 3.3kPa/d (almost ten times the former). The possible reason is that no coagulation treatment was carried out in System 2 even after fiber filtration. According to our previous published report(1), stable filtration is possible without any coagulation treatment after fiber filtration as a pretreatment for an organic membrane. This is because surface charges on the organic membrane are negative at a pH value near the neutral point and it is, therefore, difficult to absorb the turbidity with negative charges. The surface charges on the ceramic membrane, however, are positive at a pH value near the neutral point and membrane fouling tends to go on faster after a long time of operation though the compensation TMP is recovered at an early stage of filtration by the effect of backwashing. The test result therefore suggests that the neutralization of electric charges by coagulation treatment is needed for the filtration with the ceramic membrane even though the turbidity stays around 0.3 degrees in the raw water.

Table 3 Result of Water Quality Analysis for Small Membrane Testing

Iron, manganese, and some other substances attributable to river water were detected from the raw water. About 90% of iron and manganese, however, was removed by the fiber filtration unit.

Water quality items	System 1		System 2	
	Raw water	Membrane filtered water	Fiber filtered water	Membrane filtered water
	Mean value (Max. value)			
Aluminum (mg/L)	0.11	0.04	0.04	0.03
Iron (mg/L)	0.29	Below 0.03	Below 0.03	Below 0.03
Manganese (mg/L)	0.056	0.007	0.005	0.006
TOC (mg/L)	0.62 (0.9)	0.45 (0.8)	0.56 (0.8)	0.48 (0.8)
pH	7.2	7.1	7.1	7.3
Color (degrees)	4	1	1	1
Turbidity (degrees)	2.6 (15)	Below 0.1 (Below 0.1)	0.3 (0.9)	Below 0.1 (0.1)

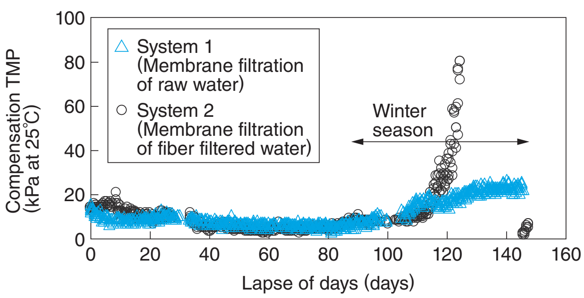

Fig. 4 Transition of Compensation TMP for Small Membrane

This diagram shows that the rising speed of TMP for pretreatment was higher in System 2. In about 100 days after the start of testing, the TMP value began to rise rapidly.

3.3 Membrane Filtration Performance of Large Membranes

In order to investigate the effect of return water upon membrane filtration, quality of thickened water, return water, and membrane filtered water were examined. Table 4 shows the respective mean values. The mean value of aluminum concentration in return water was 2.41mg/L. This is 30 times that of

Table 4 Result of Water Quality Analysis for Large Membrane Testing

This table shows that aluminum, iron, manganese, and turbid substances were removed by membrane filtration.

Water quality items	Raw water	Membrane filtered water	Return water	Thickened water
	Mean value (Max. value)			
Aluminum (mg/L)	0.08	Below 0.02	2.41	273
Iron (mg/L)	0.07	Below 0.03	0.12	16.2
Manganese (mg/L)	0.02	Below 0.005	0.03	5.27
TOC (mg/L)	0.66 (1.0)	0.52 (0.8)	0.83 (1.0)	3.72 (6.7)
pH	7.2	7.0	6.8	6.7
Color (degrees)	2	0	1	63
Turbidity (degrees)	5.4 (86)	Below 0.1 (Below 0.1)	5.8 (12)	755 (2190)

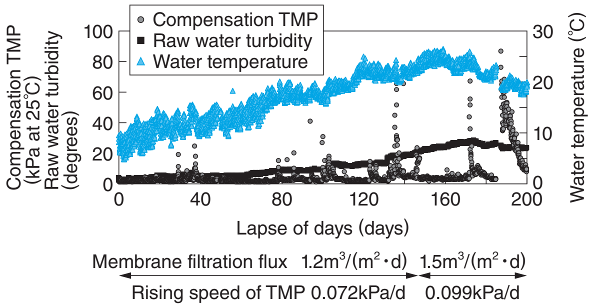

Fig. 5 **Transition of Compensation TMP for Large Membrane**

This diagram suggests that stable filtration was maintained even after the lapse of 200 days after the start of testing. After the lapse of 147 days after the start of testing, the membrane filtration flux was modified from 1.2 to 1.5m^3/(m^2・d). Sudden rise of TMP was not observed.

the raw water. This is because a coagulant was injected in the mixing tank of waste water. In regard to the turbidity and concentration of iron and manganese, no significant change was perceived between raw water and return water. The mean value of TOC in return water was 0.83, which is 1.25 times that of the raw water. Since the return water was diluted into 13.4 times by the raw water, the TOC value of raw water was not greatly increased. **Fig. 5** shows the transitions of compensation TMP for a large membrane. As a result, the rising speed of compensation TMP was settled at 0.04kPa/d and stable filtration can be continued.

4 Postscript

In regard to coagulation of river water and treated water obtained from fiber filtration, we examined filtration performance of ceramic monolith membranes. As a result, more stable filtration performance was confirmed in the system of coagulation treatment. Based on the result of small membrane testing, we implemented the large membrane test where a return process was provided to increase the recovery. Even under the condition of over 99% of recovery, stable filtration performance was demonstrated. In the future, we will continue to seek long-term stable operation capability to treat raw water in higher turbidity.

《Reference》

(1) Sameshima, et al: "Water Purification System in Combination of fiber filtration and membrane filtration," Synopses on Speeches at the 62nd National Waterworks Study Symposium, May 2011