Korean Membrane Journal
Vol. 10, No. 1 December, 2008, 33-38

Effect of Periodic Water-back-flushing Time and Period in Water Treatment by Tubular Alumina Ceramic Microfiltration

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(Received October 20, 2008, Accepted November 19, 2008)

Abstract: In this study periodic water-back-flushing using permeate water was performed to minimize membrane fouling and to enhance permeate flux in tubular ceramic microfiltration system for Gongji stream water treatment in Chuncheon city. The filtration time (FT) 2 min with periodic 6 sec water-back-flushing showed the highest value of dimensionless permeate flux (J/J_o), and the lowest value of resistance of membrane fouling (R_f), and we acquired the highest total permeate volume (V_T) of 7.44 L. Also in the results of BT effect at fixed FT 10 min, BT (back-flushing time) 20 sec showed the lowest value of R_f and the highest value of J/J_o, and we could be obtained the highest V_T of 8.04 L. Consequently FT 10 min and BT 20 sec could be the optimal condition in Gongji stream water treatment. Then the average rejection rates of pollutants by our tubular ceramic MF system were 93.8% for Turbidity, 20.7% for COD_{Mn}, 39.2% for NH_3-N and 31.5% for T-P.

Keywords: *microfiltration, ceramic membrane, water treatment, water-back-flushing, tubular*

1. Introduction

According to pollution deterioration of drinking water source due to various organic and inorganic matters, turbidity, and pathogens, both interests and applications of advanced water treatment have increased in order to remove effectively those pollutants of undesirable drinking water source [1]. Recently researches of water treatment by using membrane separation have achieved actively. Fiksdal and Leiknes [2] could remove viruses in drinking water by MF and UF membrane filtration combined with pre-coagulation/flocculation. And Malek *et al.* [3] investigated photooxidation as a pretreatment to break down the natural organic matter in surface water, and could reduce fouling in microfiltration systems for drinking water treatment.

However, the application of membrane process to drinking water treatment has the problem of membrane fouling and decline of permeate flux, and it shortens membrane lifetime. Membrane fouling was made by inorganic particles (e.g. iron, silica and suspended solids) and organic compounds (e.g. humic substances, polysaccharides, proteins and microorganisms) [4,5]. And it caused concentration polarization and gel layer formation on the surface of membranes, and adsorption and pore blockage in the pores inside membranes.

Therefore, many researchers have been accomplished for solving the membrane fouling effectively to maintain high permeate flux during membrane filtration. Then, the membrane back-flushing is a general technology to minimize the membrane fouling, and to maintain a high permeate flux during membrane separation. Many papers related with membrane back-flushing have been published nowadays. Davis *et al.* [6] built up a modeling of concentration and depolarization with high frequency backpulsing. And Kuberkar *et al.* [7] could reduce the fouling resistance of pollutant layer on the membrane by back-flushing in

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Table 1. The Quality of Source Water used in This Study

Items	Effect of BT		Effect of FT	
	Range	Average	Range	Average
TDS (mg/L)	99~118	108	63~83	72
Turbidity (NTU)	0.10~5.56	3.66	0.16~4.72	3.15
COD_{Mn} (mg/L)	0.86~2.47	1.96	1.82~2.96	2.12
NH_3-N (mg/L)	0.009~0.058	0.035	0.009~0.084	0.055
T-N (mg/L)	1.689~4.222	3.838	3.109~4.733	3.903
T-P (mg/L)	0.009~0.058	0.024	0.009~0.058	0.034

the microfiltration of protein cell mixture (BSA, yeast). Then, we published membrane fouling control effects of periodic water-back-flushing using tubular ceramic UF membranes for recycling paper wastewater and lake water treatment [8,9]. Also, we recently investigated the effect of periodic N_2-back-flushing in paper wastewater treatment using multichannels ceramic MF membranes [10].

In this study we performed periodic water-back-flushing using permeate water to minimize membrane fouling and to enhance permeate flux in tubular ceramic microfiltration system for Gongji stream water treatment. And we tried to find optimal operating conditions by investigating effects of water-back-flushing period (FT) and back-flushing time.

2. Theory

The resistance-in-series filtration model in equation (1) was applied to analyze experimental data for calculating filtration resistance and permeate flux (J) in this research. The equation was known well in the application field of membrane separation [1].

$$J = \Delta P / (R_m + R_b + R_f) \quad (1)$$

Where J was the permeate flux through membrane, ΔP was TMP (trans-membrane pressure), R_m the resistance of membrane, R_b the resistance of boundary layer, and R_f the resistance of membrane fouling.

For filtration of pure water, R_b and R_f did not exist because of no boundary layer by concentration polarization and no membrane fouling by pollutants. The equation (1) could be simplified to equation (2).

$$J = \Delta P / R_m \quad (2)$$

Now R_m could be calculated from the experimental data of permeate flux for pure water using equation (2). Then, the plot of $R_b + R_f$ vs. t (operation time) could be obtained from the permeate flux data using wastewater. The intercepting value of y-axis (t=0) in this plot using only initial 2 or 3 data was R_b because of no R_f at the initial time of filtration, and finally R_f could be calculated using equation (1).

3. Materials and Methods

3.1. Membrane and Water Source

Tubular ceramic MF membrane (NCMT-7231) used in the study was coated with α-alumina on supporting layer of α-alumina. We purchased the membrane from Nano Pore Materials Co. in Korea, and its surface area was 47.5 cm^2, its pore size 0.1 μm, O.D. 8 mm, I.D. 6 mm, length 252 mm, and its thickness 1 mm. The source water used here was sampled at Gongji stream located in Chuncheon city, and water quality was arranged in Table 1.

3.2. Experimental Procedures

In this study we performed periodic water-back-flushing using permeate water to minimize membrane

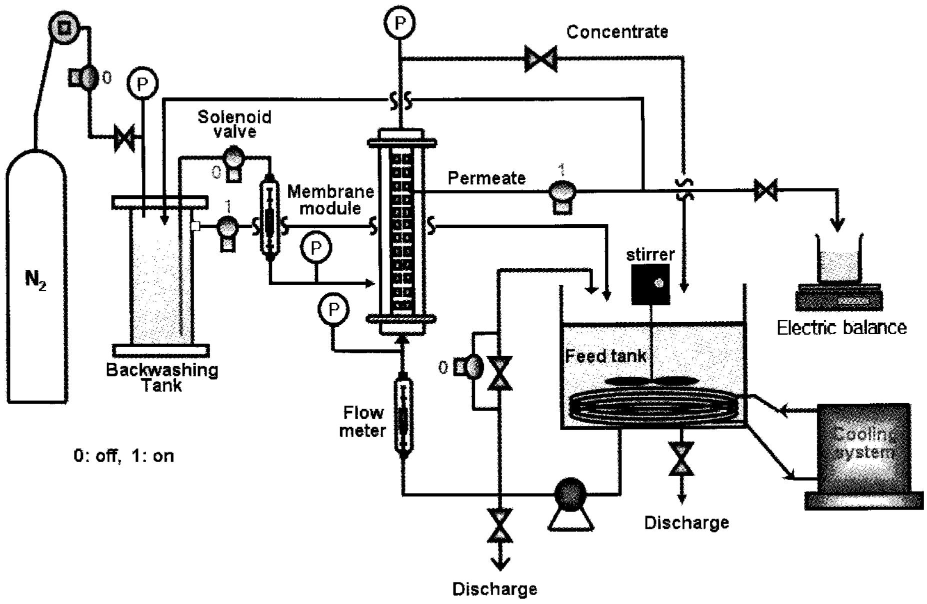

Fig. 1. Apparatus of microfiltration with periodic water-back-flushing system [1].

fouling in tubular ceramic MF system for water treatment of stream source. And crossflow microfiltration with water-back-flushing system used here was shown Fig. 1 [1]. The feed tank was filled with 15 L of source water, and it flowed to the inside of the tubular ceramic membrane. The permeate flow and the concentrate flow were recycled to the feed tank to maintain the concentration of the feeding water almost constant during operation. The source water in the feed tank was continuously mixed with a stirrer. The back-flushing water flowed periodically to the outside of the tubular membrane. And a part of permeated water was automatically filled up the back-flushing water tank using solenoid valves.

Back-flushing time (BT) was fixed at 15 sec and filtration time (FT) was changed as 2, 4, 6 and 8 min to see effect of back-flushing period. Also, FT was fixed at 10 min and BT was changed as 6, 10, 15 and 20 sec to inspect effect of BT. At both two experimental conditions, TMP was fixed at 1.77 bar, water-back-flushing pressure at 1.96 bar, feed flow rate at 1.0 L/min, and feed water temperature at 20°C.

Then, we measured permeate flux (J) during 3 hrs' operation, and calculated resistance of membrane fouling (R_f) using equation (1) and (2). And we could acquired total permeate volume (V_T) by integrating J from starting time to 3 h [10]. And we analyzed TDS (total dissolved solid), turbidity, COD_{Mn} (chemical oxygen demand), NH_3-N, T-N and T-P of supplied and permeate water by standard method of water analysis.

4. Results and Discussions

4.1. Effect of Water-back-flushing Period (FT)

The fouling was investigated according to water-back-flushing period and time in Gongji stream water treatment using tubular ceramic MF membrane. The result of FT effect was given in Fig. 2 at fixed 15 sec back-flushing time. As shown in Fig. 2, the lowest value of R_f was represented at FT 2 min and BT 15 sec. And FT 2 min was the shortest back-flushing period, thus it means that the shorter back-flushing period was more effective to reduce membrane fouling.

Also, the highest value of the permeate flux on time (J) vs. the initial permeate flux (J_o) could be found at FT 2 min, as shown in Fig. 3. J/J_o was 0.339 at this operating condition, but 0.210 at FT 8 min. It means FT 2 min was the most effective back-flushing period

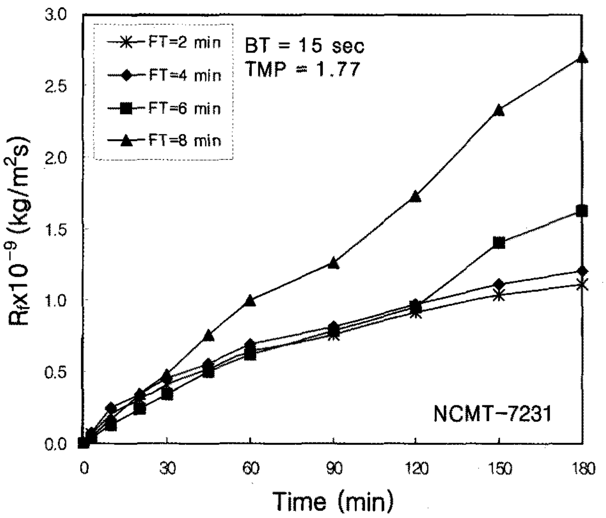

Fig. 2. Effect of water-back-flushing period (FT) on resistance of membrane fouling.

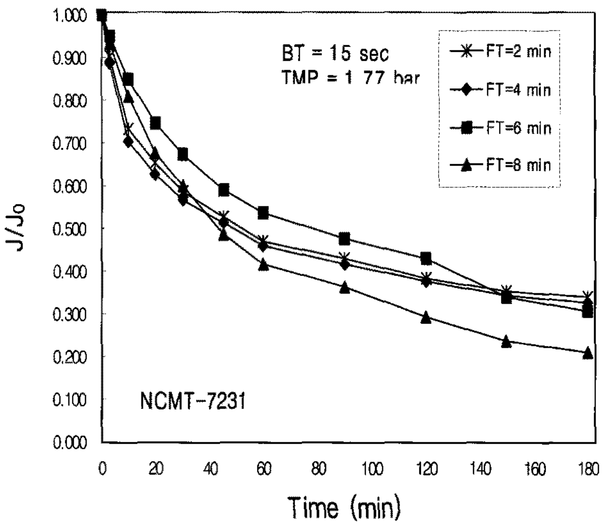

Fig. 3. Effect of water-back-flushing period (FT) on dimensionless permeate flux.

to reduce membrane fouling and to maintain high permeate flux during 3 hrs' operation in our MF system. Then, the highest total permeate volume (V_T) of 7.44 L could be acquired at FT 2 min, as arranged in Table 2. And final J after 3 hrs' operation was the highest value of 10.45×10^{-5} m/s and final R_f was the lowest value of 1.12×10^{9} kg/m^2·s at FT 2 min.

4.2. Effect of Water-back-flushing Time (BT)

At the fixed FT 10 min, which was the longest

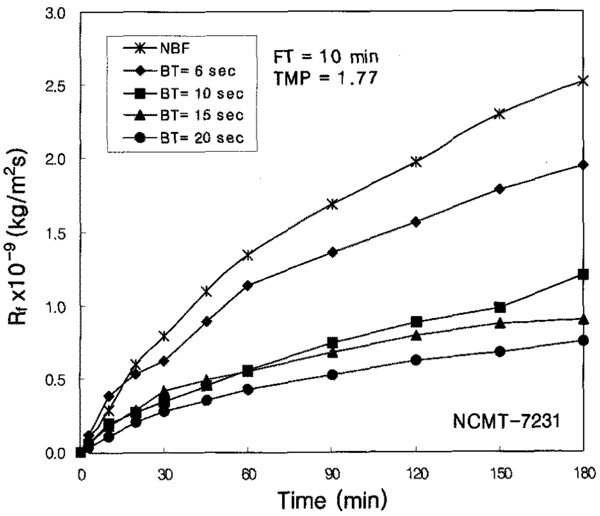

Fig. 4. Effect of water-back-flushing time (BT) on resistance of membrane fouling.

Table 2. Filtration Factors in the Experiments for Effect of Back-flushing Period at BT 15 sec

Effect of FT	2 min	4 min	6 min	8 min
$J_o \times 10^5$ (m/s)	30.84	29.98	24.49	24.59
$R_m \times 10^{-9}$ (kg/m^2 · s)	0.52	0.54	0.52	0.51
$R_{f,180} \times 10^{-9}$ (kg/m^2 · s)	**1.12**	1.21	1.63	2.70
$J_{180} \times 10^5$ (m/s)	**10.45**	9.80	7.51	5.15
$R_b \times 10^{-9}$ (kg/m^2 · s)	0.05	0.05	0.20	0.21
V_T (L)	**7.44**	7.04	6.44	5.18

back-flushing period in our experiment, BT were adopted as 6, 10, 15 and 20 sec to see effect of BT. The lowest value of membrane fouling resistance could be found at BT 20 sec and FT 10 min, in which membrane fouling could decrease to 30.2% of R_f in No back-flushing (NBF) condition, as plotted in Fig. 4. This optimal condition was exactly same as the result [1] for high turbid water source at discharged position of Soyang Dam.

Also, we have got the highest dimensionless permeate flux (J/J_o) value of 0.473 at BT 20 sec, as shown in Fig. 5. It means that the longest BT should reduce the membrane fouling effectively during operation. And as arranged in Table 3, the most V_T of 8.04 L could be obtained at BT 20 sec and FT 10 min.

Finally the experimental results of R_f and V_T at

Table 3. Filtration Factors in the Experiments for Effect of Back-flushing Time at FT 10 min

Effect of BT	NBF*	6 sec	10 sec	15 sec	20 sec
$J_o \times 10^5$ (m/s)	28.62	28.05	28.36	22.62	25.96
$R_m \times 10^{-9}$ (kg/m^2 · s)	0.59	0.55	0.54	0.55	0.53
$R_{f,180} \times 10^{-9}$ (kg/m^2 · s)	2.52	1.95	1.20	0.90	**0.76**
$J_{180} \times 10^5$ (m/s)	5.63	6.85	9.69	10.51	**12.29**
$R_b \times 10^{-9}$ (kg/m^2 · s)	0.03	0.08	0.08	0.23	0.15
V_T (L)	4.83	5.26	7.28	6.57	**8.04**

* NBF : No back-flushing

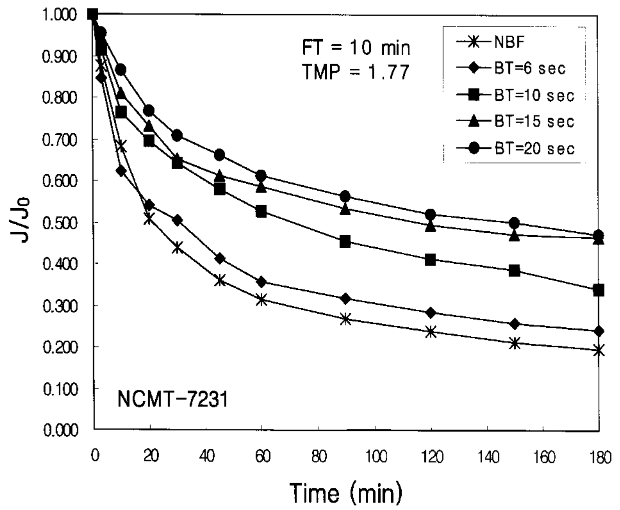

Fig. 5. Effect of water-back-flushing time (BT) on dimensionless permeate flux.

Table 4. Treated Water Quality and Average Rejection Rate of Tubular Ceramic MF System

Pollutants	Effect of BT	Effect of FT
TDS (%)	0.65	1.42
Turbidity (%)	92.9	94.7
COD_{Mn} (%)	27.5	14.0
NH_3-N (%)	38.5	40.0
T-N (%)	4.33	4.93
T-P (%)	24.4	38.6

short and frequent back-flushing of BT 15 sec and FT 2 min were a little worse than those at longer back-flushing and longer period of BT 20 sec and FT 10 min. Therefore, the optimal condition for Gongji stream water treatment by our ceramic MF was FT 10 min and BT 20 sec in the experimental range of this study. Also, this condition was the better than BT 15 sec and FT 2 min to reduce operating costs because of lower back-flushing frequency.

4.3. Water Quality and Rejection Rate of Pollutants

As results of water quality analysis for feed and treated water, average rejection rate of TDS, turbidity, COD_{Mn}, NH_3-N, T-N and T-P were arranged in Table 4. Where the rejection rate of turbidity was very high as 92.9~94.7%, but it of TDS was very low as 0.65~1.42%. And the rejection rates were 13.9~27.5% for COD_{Mn}, 38.5~40.0% for NH_3-N, 4.33~4.93% for T-N and 23.4~38.6% for T-P.

5. Conclusion

In this study, periodic water-back-flushing using permeate water performed to minimize membrane fouling and to enhance permeate flux in tubular ceramic MF system for Gongji stream water treatment. And the optimal conditions were discussed in the viewpoints of permeate flux J, resistance of membrane fouling R_f and total permeate volume V_T. As a result of FT effect, FT 2 min with periodic 15 sec water-back-flushing showed the highest value of permeate flux and J/J_o, and the lowest value of R_f, and we acquired the highest V_T of 7.44 L. Also in the results of BT effect at fixed FT 10 min, BT 20 sec showed the lowest value of R_f and the highest value of permeate flux and J/J_o, and we could be obtained the highest V_T of 8.04 L. Consequently the optimal condition for Gongji stream water treatment by our ceramic MF was FT 10 min and BT 20 sec in the experimental range of this study. Also, this condition was the better than BT 15 sec and FT 2 min to reduce operating costs because of lower back-flushing frequency. Then, the rejection rate of turbidity was very high as 92.9~94.7%, but it of TDS was very low as 0.65~1.42%. And the rejection rates were 13.9~27.5% for COD_{Mn}, 38.5~40.0% for NH_3-N, 4.33~4.93% for T-N and 23.4~38.6% for T-P.

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