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# Recovery Increase by Recycling Backwash Residuals in Microfiltration System

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## Abstract

With the rise in membrane applications, residuals management has become a growing challenge for membrane system. The primary residuals of MF/UF (microfiltration/ultrafiltration) system results from the wastes generated during backwashing. Many regulatory agencies, utilities, and water process engineers are unfamiliar with the characteristics and methods for treatment and disposal of membrane residuals. Therefore, this study was performed to investigate the backwash residuals water quality from the pressurized system with and without pre-coagulation, and to suggest approaches for the backwash residuals treatment. Pressurized MF system was installed at Guui water intake pumping station and operated with raw water taken from the Han River. We compared performances with and without the recycling backwash residuals at flux conditions, 50 LMH and 90 LMH with and without pre-treatment (coagulation). Based on the results, recycling of backwash residuals in pressurized system with pre-coagulation showed applicability of backwash residuals managements. Moreover, the recovery rate also increased up to over 99%.

Key words : Backwash residuals, Coagulation, Microfiltration, Pressurized.

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# I. INTRODUCTION

In the 1990s, low-pressure membranes [microfiltration (MF) and ultrafiltration (UF)] emerged for treatment of surface waters and the application of membrane processes to drinking water treatment is constantly expanding to achieve high quality drinking water production[1]. However, with the rise in membrane applications, residuals management has become a growing challenge for membrane system. Many regulatory agencies, utilities, and water process engineers are unfamiliar with the characteristics and methods for treatment and disposal of membrane residuals. Discussion of cost-effective implementation of microfiltration (MF) and ultrafiltration (UF) treatment systems often highlight the optimization of net flux rates, energy use, and cleaning chemicals. As with conventional treatment systems, management of residual waste streams can present some of the key challenges for cost-effective implementation of MF/UF treatment systems[11].

Operation of MF/UF treatment systems can result in the production of several different types of waste streams that need to be treated and/or disposed of, including backwash and chemical cleaning residuals and concentrate. The types of residuals that are generated vary. The specific characteristics and volumes of these residuals waste streams are site- specific; however, they can be grouped into three general categories as non- chemical cleaning ("backwash") wastes, chemical cleaning wastes, and residual solid wastes. Backwash residuals typically represent the largest quantity of waste produced from MF/UF treatment systems[6,11].

As a general rule of thumb, waste streams produced during backwashing of MF/UF treatment system typically have dissolved constituent concentrations that are similar to the membrane system feed water and suspended solids concentrations that are approximately 10 to 20 times higher greater than that of the feed water[8,11]. Although MF/UF systems remove approximately the same types of feed water constituents as conventional media filters, the volume and characteristics of the residuals may be significantly different. In addition, disposal of coagulant- and polymer-free MF/UF backwash residuals may be less problematic[1,6]. One of solids handling management that has been employed extensively is gravity (or dissolved air) thickening[5,11].

On-site treatment options for MF/UF backwash residuals are also similar to those that might be used with conventional media filtration, and include clarification, sedimentation lagoon, gravity thickening, centrifuging, belt filter presses, or a combination of these processes. If sedimentation process is used to treat MF/UF backwash residuals, the addition of a coagulant may be necessary to improve the settling characteristics of the solids if coagulant is not already applied in the MF/UF pretreatment process [1,6,11].

Therefore, this study was performed to investigate the backwash residuals water quality from the pressurized system with and without pre-coagulation, and with and without recycling backwash residuals, and to suggest approach for the backwash residuals treatment.

## II. MATERIALS AND METHODS

The pilot system was installed at Guui water intake pumping station and operated with raw water taken from the Han River. The water was fed into both the bench-scale and the pilot scale plant of MF membrane system (UNV-3003, Asahi-Kasei, Japan). The material of membrane was poly-vinylidene fluoride (PVDF). Operating conditions of pilot plants were shown in Table. 1. The range of operating pressure of pressurized system is 0 to 0.15 Mpa. The schematic of MF membrane system in the pilot scale is shown in Figure 1. The MF membrane module was operated in cross flow mode, and the flow stream through fibers outside to inside. It was operated in constant flow mode. Free chlorine concentration in the backwashing water is ranged from 2 to 5 mg/l. And air bubbling step was operated at the same time with reverse filtration, with 1.43 $Nm^3/hr$ of air flow. These tests provide the opportunity to compare performance of recycling backwash residuals and without recycling it. When the backwash residuals were recycled, the backwash residuals from membrane system were sent to the gravity thickener. After 25min, the supernatant returned to the raw tank. Several water quality parameters were measured as follows: turbidity, particles, and organic matters including total organic carbon (TOC) and dissolved organic carbon (DOC), the ultraviolet absorbance at 254nm (UV254) and the specific UV absorbance (SUVA). In addition, the concentration of suspended solids was examined for mass balances

Table 1. Operating conditions of pressurized MF membrane system.

| Parameter | Flux (LMH, $L/m^2/hr$) | Feed Flow Rate ($m^3/hr$) | Reverse Filtration Flow Rate ($m^3/hr$) | Discharge /Flushing Flow Rate ($m^3/hr$) | Recovery rate (%) |
|---|---|---|---|---|---|
| | 50 / 90 | 0.67 / 0.97 | 0.56 / 1.01 | 0.75 | 91.4 / 92.9 |
| CIP | ■ When the TMP reaches to about maximum pressure, chemical cleaning is performed<br>■ 1st Chemical Solution (6~8 Hr) - Rinse - 2nd Chemical solution (1Hr) - Rinse | | | | |
| | Chemical : 1st : 3,000ppm Cl + 0.5% NaOH<br>2nd : 2% Citric acid | | | | |

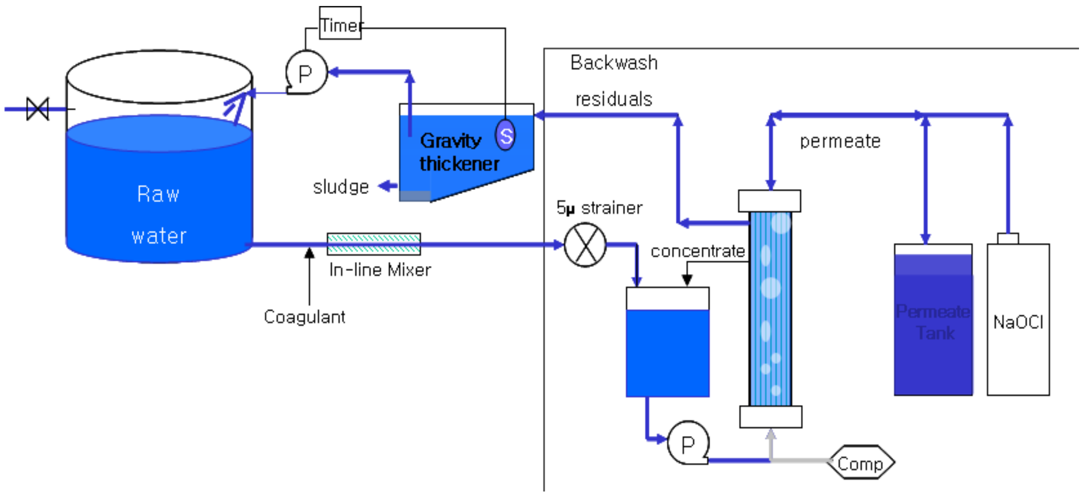


Fig. 1. The schematic diagram of MF system.

# Ⅲ. RESULTS AND DISCUSSION

## 1. The coagulant-free system

As shown in Figure 2, the pressurized systems were operated at 50 LMH and 90 LMH. The raw water was directly filtered by microfiltration without pre-coagulation. At 50 LMH, there was no significant increase in transmembrane pressure (TMP), and no difference between the two systems with and without recycling. However, in the case of 90 LMH, the TMP sharply increased in both systems. Expecially, in case of recycling supernatant of backwash residuals, after exceeding critical pressure, the TMP increased more rapidly than without recycling it. TMP increased when the flux was increased beyond a certain value.

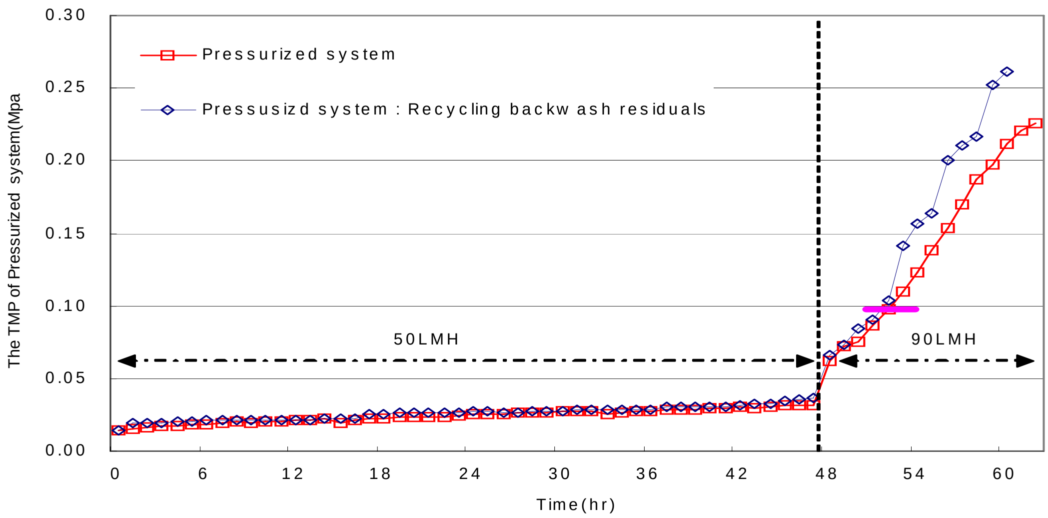


Fig. 2. The variation of TMP of pressurized MF system at 50, 90 LMH.

Table 2. shows the water qualities of raw water, backwash residuals and

supernatant during the pressurized filtration without pre-coagulation.

Table 2. The water quality of the MF membrane system without pre-coagulation.

| | Raw water | | Raw water* | | Backwash* | | Settled* | | Permeate | | Permeate* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH |
| Turbidity (NTU) | 3.2 | 3.7 | 5.9 | 8.6 | 36.7 | 82 | 28.5 | 45.1 | 0.19 | 0.20 | 0.41 | 0.42 |
| TOC (mg/L as C) | 1.90 | 1.85 | 2.22 | 2.03 | 10.5 | 24.5 | 5.2 | 12.6 | 1.47 | 1.67 | 1.75 | 1.65 |
| DOC (mg/L as C) | 1.58 | 1.84 | 1.74 | 1.86 | 7.5 | 21.8 | 4.5 | 8.1 | 1.38 | 1.32 | 1.35 | 1.41 |
| $UV_{254}$ ($cm^{-1}$) | 0.028 | 0.035 | 0.038 | 0.038 | 0.053 | 0.177 | 0.044 | 0.071 | 0.018 | 0.017 | 0.020 | 0.021 |
| SUVA | 1.77 | 1.90 | 2.18 | 2.04 | 0.71 | 0.81 | 0.98 | 0.88 | 1.23 | 1.21 | 1.33 | 1.35 |
| SS (mg/L) | 5.5 | 10 | 16 | 24.5 | 97.9 | 167 | 42 | 121 | - | - | - | - |

Raw water* : mixed raw water with backwash residuals
Backwash* : backwash residuals
Settled* : supernatant of backwash residuals after 25min. settling
Permeate* : permeate of mixed raw water

Backwash residuals of MF treatment typically have suspended solids concentrations that are approximately 10 to 20 times higher than that of raw water[11)]. Table 2 also shows that the suspended solids of backwash residuals varied from 6 to 18 fold higher than that of raw water depending on recycling. In case of recycling supernatant of backwash residuals, raw water blended with the supernatant has high values of turbidity, organic character (TOC, DOC and UV254) and suspended solids. These results caused TMP increase at 90 LMH. Permeate of TOC and DOC also had high value. Direct-pressurized MF filtration without coagulation was not very efficient in removing natural organic matter. With and without coagulation TOC and DOC were removed by about 20 %. The TOC and DOC removal was generally similar to the microfiltration membrane systems. UV254 removal is often higher than that of DOC removal for a direct-MF process[3)]. This study also shows that UV254 removal was higher than that of DOC removal. Figure 3~4 show the total inorganic matter and dissolved inorganic matter concentration, respectively. Calcium concentration was highly detected in all of samples. Calcium might be bound chemically with natural organic matter. However, in the case of Fe, Mn and Al, they were detected by a minor concentration in raw water, backwash residuals and supernatant, respectively.

## 2. The coagulant-add system

The membrane filtration without pre-coagulation caused relatively rapid TMP increase compared with that with pre-coagulation as previous studies[2,4,10,)].

The optimal dosage of coagulant has to be pre-tested. The coagulant dosage wasdetermined by addition of varying

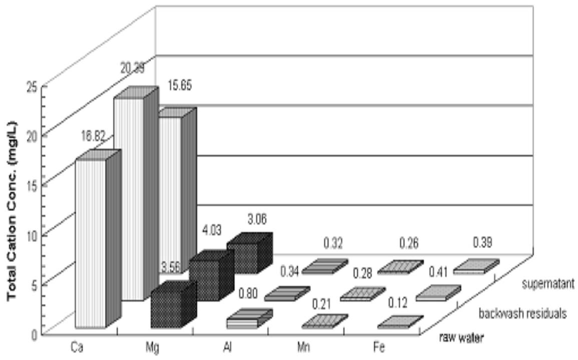


Fig. 3. Total cation concentrations. <coagulants-free>

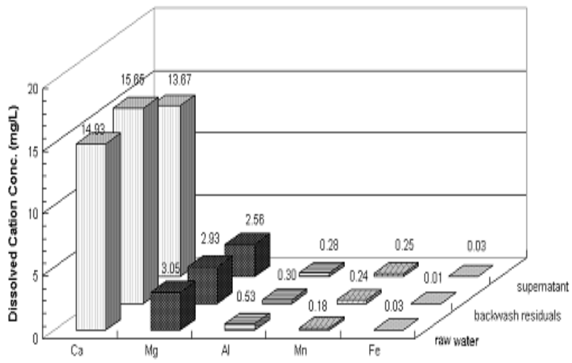


Fig. 4. Dissolved cation concentrations. <coagulants-free>

coagulant (PACl) dose 0, 5, 10, 15, 20 ppm (v/v), during the operation of microfiltration with a in-line mixer using 17% polyaluminum chloride as a coagulant. Comparing permeate turbidity, the optimal coagulant dose was 10 ppm (v/v). In this study, in-line mixer was used for rapid-mixing. It has also been reported that aggregates produced under sweep floc conditions were more compressible than charge neutralization conditions, resulting in compaction when the membrane filtration system was pressurized. The low dose of pre-coagulant addition as in-line mixer does not only successfully remove foulants but also stabilize the membrane filtration[9,10]. Figure 5 shows TMP variations at 50 LMH, and 90 LMH. At 50 LMH, there was no difference the both cases. And, the TMP in both cases increased slightly. So, filtration of blended raw water with backwash residuals didn't become worse than filtration without recycled backwash residuals.

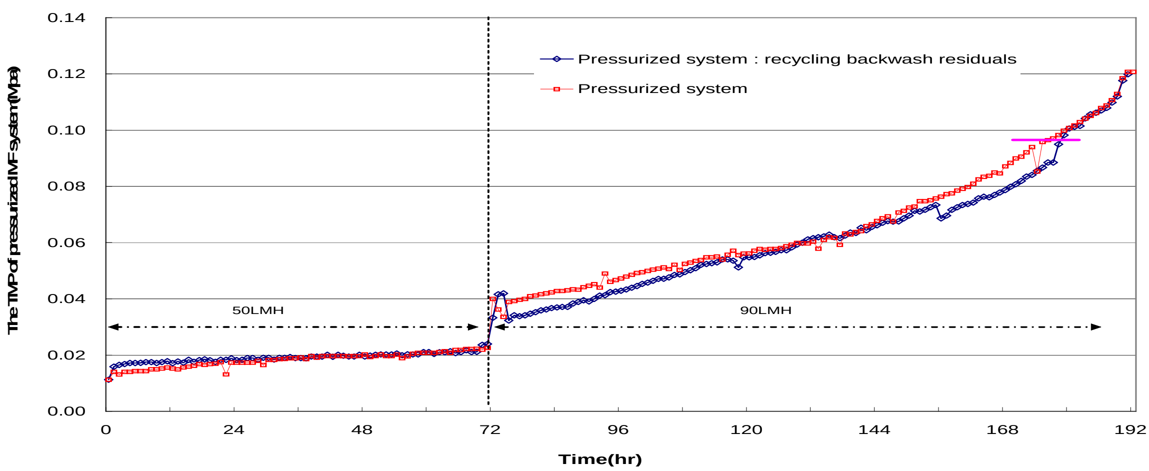


Fig. 5. The variation of TMP of pre-coagulation MF system at 50, 90LMH.

Table 3. presents the profiles of water quality data. This water quality of backwash residuals was high values than that of coagulant-free. But, the qualities of settled water after 25 minutes were similar to those of raw water.

Table 3. The water quality of the MF membrane system with pre-coagulation.

| | Raw water | | Raw water* | | Backwash* | | Settled* | | Permeate | | Permeate* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH | 50LMH | 90LMH |
| Turbidity (NTU) | 3.04 | 7.62 | 6.25 | 9.97 | 178.70 | 294.5 | 3.58 | 4.16 | 0.32 | 0.26 | 0.24 | 0.32 |
| TOC (mg/L as C) | 2.01 | 2.21 | 2.83 | 3.23 | 12.4 | 29.4 | 2.7 | 2.9 | 1.02 | 1.41 | 1.41 | 1.64 |
| DOC (mg/L as C) | 1.36 | 1.05 | 145 | 1.72 | 2.3 | 2.7 | 1.7 | 1.5 | 0.98 | 1.02 | 1.21 | 1.44 |
| $UV_{254}$ ($cm^{-1}$) | 0.02 | 0.022 | 0.026 | 0.022 | 0.039 | 0.040 | 0.034 | 0.026 | 0.017 | 0.019 | 0.020 | 0.019 |
| SUVA | 1.47 | 2.16 | 1.79 | 1.28 | 1.70 | 1.48 | 2.00 | 1.73 | 1.73 | 1.81 | 1.65 | 1.32 |
| SS (mg/L) | 9.0 | 16.1 | 12 | 17.1 | 251.7 | 428.5 | 14 | 17 | - | - | - | - |

Raw water* : mixed raw water with backwash residuals
Backwash* : backwash residuals
Settled* : supernatant of backwash residuals after 25min. settling
Permeate* : permeate of mixed raw water

Preceding experiments have shown that coagulated floc particles were dis-aggregated in the subsequent pumping. However charge-neutralized particles easily re-coagulate on the membrane surface in cross-flow[12]. So, re-aggregated particles were easily eliminated on the membrane surface during backwashing. With this view, it is assumed that the backwash residuals could be settled well in gravity thickener. The TOC, DOC and UV254 removals of backwash residuals in gravity thickening were 98.0, 78.2, and 26.1 % at 50 LMH and 98.6, 90.1, and 44.4 % at 90 LMH, respectively. It caused that the TMPs of both cases weren't different a lot. Table 3 shows that pre-coagulation increased the TOC removal, but recycling supernatant backwash residuals didn't effect the TOC removal. And, the $UV_{254}$ removal is higher than that of DOC removal since coagulation is more efficient to remove UV254.

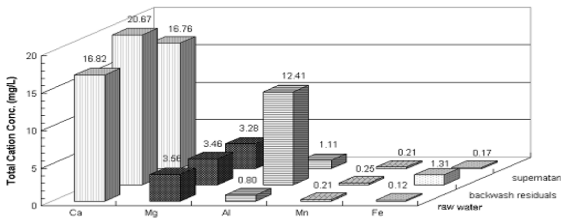


Fig. 6 Main cation concentrations.
: coagulants-add.

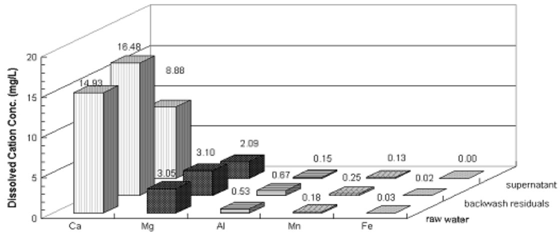


Fig. 7 Dissolved cation concentrations.
: coagulants-add.

The Inorganic fouling is due to metal ions. As shown in Fig. 6~7, Ca and Al concentrations were highly detected in backwash residuals. Al (12.41 mg/L) in backwash residuals is much higher than that in raw water. This was due to addition of aluminum coagulant. And, Al concentration in supernatant was 1.11

mg/L (91.01 % removal in gravity thickener). Fe and Mn were detected by a minor concentration in raw water, backwash residuals and supernatant, respectively. And, the dissolved Al concentrations of backwash residuals and supernatant were 0.67 mg/L, 0.15 mg/L, respectively. Most of Al in backwash residuals exists in particulate form. Coagulation modifies characteristics of NOM with the formation of complexes between organic compounds and metal cations. Coagulation parameters control the properties of these complexes and so have a good influence on MF performance[7]. So, TMP for pre-coagulated increased slightly compared to direct-MF filtration without coagulation.

# IV. CONCLUSIONS

As with conventional treatment systems, management of residual waste streams can present some of the key challenges for cost-effective implementation of MF/UF treatment systems. This study provides the opportunity to compare performance of systems with and without recycling backwash residuals. When the MF system was operated at 50 LMH and 90 LMH without pre-coagulation, the TMP was stable in both recycling options. However, at 90LMH, in case of recycling supernatant of backwash residuals, after exceeding critical pressure, the TMP increased more rapidly than without recycling it. The TMP showed no difference in both recycling options. And, the TMP in both case increased slightly when the MF system was operated at 50 LMH and 90 LMH with pre-coagulation. The impact of coagulation condition in cross-flow is less than in dead-end filtration. It shows treatment applicability of recycling backwash residuals. The recovery rate of recycling backwash residuals was increased over 99 %. Therefore, the recycling backwash residuals by gravity thickening increased the recovery rate and could have economical efficiency.

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