Improvement of Water Recovery Rate after NF Membrane Treatment of Contaminated Raw Water

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Abstract: The Nanofiltration (NF) membrane treatment is useful for purification of polluted raw water. However, with concentrated water generated, there is a problem of increased cost due to sewage discharge of it, and a decrease in the recovery rate. In order to solve this problem, we improved the water treatment method. And even if 1/2 of the concentrate is returned to the raw water after ion exchange resin treatment, and others, we confirmed that it will not affect treatment performance and operation management. Besides, as a result of cost estimation assuming a water treatment plant (10,000 m^3/day), it was suggested that the 1/2 of the concentrate returned can improve the recovery rate by 6 points and reduce the cost by 3% compared with all sewage discharge. The new treatment method shown in this study can be expected to contribute sufficiently to the realization of sustainable water supply in many areas where raw water quality is deteriorating.

Keywords: NF membrane; concentrated water; ion exchange resin; activated carbon

Introduction

The Training and Technical Development Center is taking water from the downstream part of the river running through a densely populated area. Since there is a large amount of treated wastewater flowing into this river, concentrations of nitrate nitrogen (NO_3-N) and dissolved organic carbon (DOC) tend to be higher than other water systems. In addition, a decrease in water temperature, typically increasing the concentration of NO_3-N and ammonia nitrogen (NH_3-N). For this reason, we have conducted studies and experiments on the Nanofiltration (NF) membrane treatment to remove NO_3-N, the highly purified water treatment (ozone + biological activated carbon) to remove DOC, and the process of completely removing NH_3-N which reacts with chlorine to produce chlorinous odor.

However, Microfiltration (MF) and Ultrafiltration (UF) membranes which have become common in recent years cannot effectively remove trace contaminants. Y. Wang, et al. reported the applicability of a system combining UF membrane and activated carbon for water purification treatment [1)]. Furthermore, our experimental results demonstrated that NF membrane filtration could not completely remove NH_3-N in raw water [2)]. Also, the NF membrane treatment system generates concentrated water, and has a characteristic that the recovery rate is lower than that of other filtration treatment. In order to improve the recovery rate and reduce the cost, we developed a method of removing part of DOC and ions in concentrated water and returning it to raw water.

The influence and effect of NF membrane filtration treatment of polluted surface water and the return of raw water of concentrated water are considered to be useful for other water operators who are considering introduction of the membrane filtration facilities. In this study, we propose a method to improve both recovery rate and cost reduction in NF membrane processing.

Method and Result

The developed water treatment method is characteristics in terms of, by processing a part of the concentrated water and returning it to the raw water, improving the recovery rate and reducing the sewage charge under the metered system. Specifically, after filtering the raw water with a strainer, we performed filtering using fibrous filter materials (biological carrier), MF and NF membranes. We returned concentrated water to before the fibrous filter material (biological carrier) after untreated, treated with ion exchange resin or granular activated carbon and ion exchange resin (**Fig. 1**).

(1) In the case of un-treatment

When 1/4 of concentrated water was returned, the transmembrane pressure (TMP) of the MF and the NF membranes was almost constant. However, when the total amount of concentrated water was returned, the TMP rapidly increased (**Fig. 2**). Furthermore, the TMP continued to increase even after the return of concentrated water was discontinued. Thereafter, the TMP decreased due to exchange of the NF membrane (**Red arrow in Fig. 2**).

(2) In the case of treatment with ion exchange resin

When 1/2 of the concentrated water was treated with ion exchange resin and returned, the TMP of the MF and the NF membranes was almost constant regardless of the high or low water temperature phase, allowing a stable operation (**Fig. 3**).

(3) In the case of treatment with granular activated carbon and ion exchange resin

When 1/2 of the concentrated water is treated with granular activated carbon and ion exchange resin and returned to raw water, the TMP of the MF membrane and the NF membrane was almost constant at the high water temperature period, allowing a stable operation (**Fig. 3**).

During the low water temperature period, an increase in TMP occurred in the inorganic MF membrane. This is partly due to the aggregating property of the coagulants (iron(III) chloride) which lowers during the low water temperature phase. This phenomenon occurs at a low water temperature regardless of whether concentrated water is returned or not.

Discussion and Conclusion

In this study, we studied the ion exchange resin treatment and the granular activated carbon treatment as a method of returning the concentrated water to raw water. As a result, with the 1/2 amount, either of the treatments did not adversely affect the removability of NH_3-N and DOC and the TMP. Therefore, it is suggested that treatment with only ion exchange resin is enough if 1/2 of the concentrated water is returned.

Based on the results of this study, we assumed a water treatment plant with a capacity of 10,000 m^3/day equivalent to about 29,000 people in the water supply population, and estimated the cost under the following three conditions: (1) all amount of the concentrated sewage water is discharged, (2) 1/2 of the concentrated water is treated using ion exchange resin method and returned, (3) 1/2 of the concentrated water is treated using granular activated carbon and ion exchange resin and returned. The cost was lowest in (2), and the recovery rate was the highest in (3). In comparison with condition (1), it is estimated that the cost is reduced by 3% in (2) and the recovery rate can be improved by 6 points in (3) (**Table 1**).

Based on the above calculations and results, both the improvement of recovery rate and cost reduction can be achieved by returning the concentrated water. Moreover, by further promoting the application of the NF membrane treatment to contaminated raw water, we can expect that it will contribute to the realization of sustainable water supply in areas where raw water quality is deteriorating.

Reference

1) Y.Wang, J.Hu.C.Chen and X.Zhang "Feasibility study of using a SPAC/PAC-UF Hybrid System for Emerging Organic Pollutants Removal in a Lake Water", Water Quality, Safety and Human Health, Micropollutant Treatment Technologies I, ((Day), October,2016)
2) Sato, T., Iwanami, A., & Ishida, N. (2015), Study and Experiment for Building NF Membrane Processing System, Training and Technical Development Center, Research and Development Briefing Session, Tokyo, Japan.

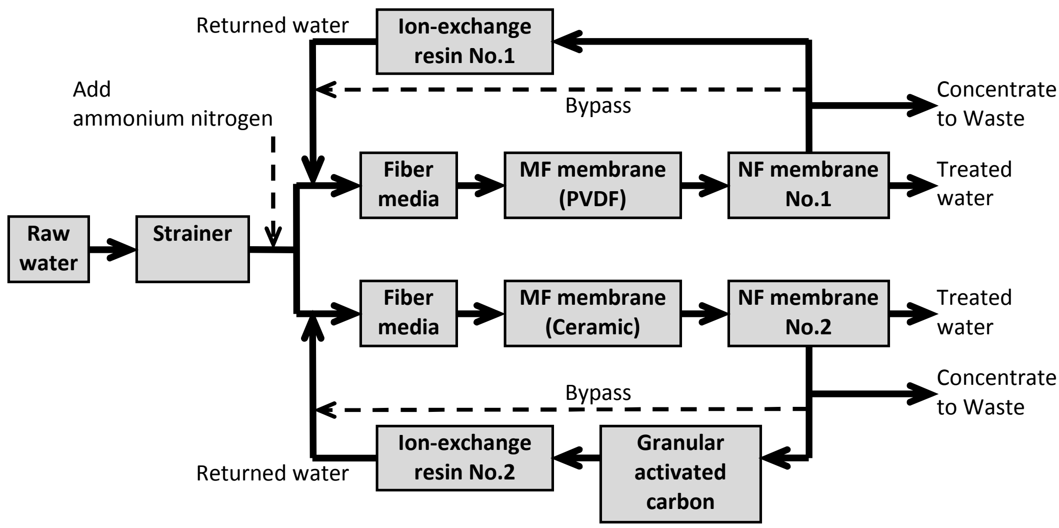

Fig. 1 The scheme of experimental apparatus

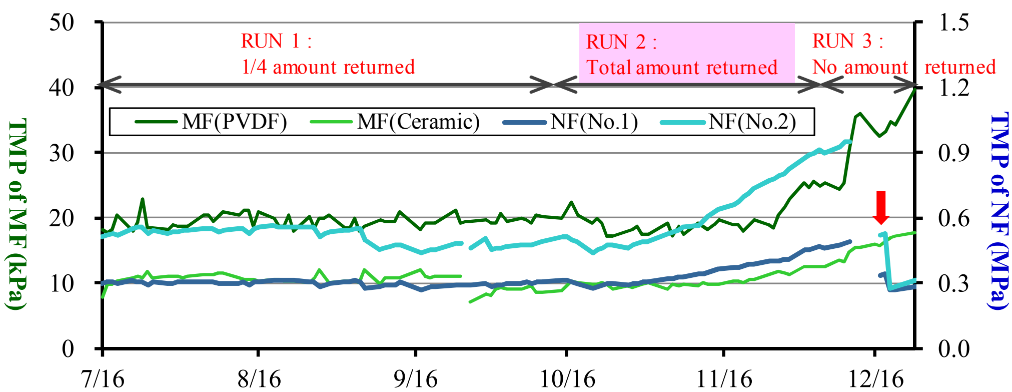

Fig 2 Transition of transmembrane pressure differential in 2013

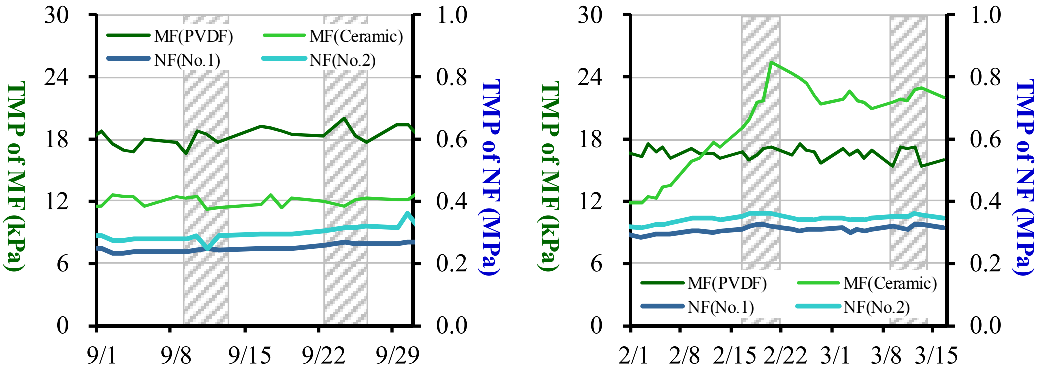

Fig. 3 Transmembrane pressure differential in 2014
Left: High water temperature period
Right: Low water temperature period
*The shaded area indicates the period for returning concentrated water.

Table 1 Cost Estimate

<table>
<tr><th colspan="2">Case / Evaluation items</th><th>(1)
All sewage amount of the NF membrane concentrated water discharged</th><th>(2)
1/2 amount of the NF membrane concentrated water returned (treated using ion exchange resin method)</th><th>(3)
1/2 amount of the NF membrane concentrated water returned (treated by ion exchange resin and granular activated carbon)</th></tr>
<tr><td rowspan="2">Fiber filtration column</td><td>Construction fee</td><td colspan="3">98.2 million yen/year</td></tr>
<tr><td>Maintenance and operation fee</td><td colspan="3">89.4 million yen/year</td></tr>
<tr><td rowspan="3">MF + NF membrane</td><td>Construction fee</td><td colspan="3">56.7 million yen/year</td></tr>
<tr><td>Maintenance and operation fee</td><td colspan="3">151.3 million yen/year</td></tr>
<tr><td>Sewage amount discharged</td><td>2,000 m³/day</td><td>1,000 m³/day</td><td>1,000 m³/day</td></tr>
<tr><td rowspan="2">Granular activated carbon column</td><td>Construction fee</td><td>---</td><td>---</td><td>13.3 million yen/year</td></tr>
<tr><td>Maintenance and operation fee</td><td>---</td><td>---</td><td>3.9 million yen/year</td></tr>
<tr><td rowspan="3">Ion exchange resin column</td><td>Construction fee</td><td>---</td><td>5.6 million yen/year</td><td>5.3 million yen/year</td></tr>
<tr><td>Maintenance and operation fee</td><td>---</td><td>67.4 million yen/year</td><td>62.1 million yen/year</td></tr>
<tr><td>Sewage amount discharged</td><td>---</td><td>141 m³/day</td><td>129 m³/day</td></tr>
<tr><td colspan="2">Sewage service charge</td><td>247.6 million yen/year</td><td>140.9 million yen/year</td><td>139.4 million yen/year</td></tr>
<tr><td colspan="2">Total cost</td><td>643.1 million yen/year</td><td>609.4 million yen/year</td><td>619.5 million yen/year</td></tr>
<tr><td colspan="2">Recovery rate</td><td>80.0 %</td><td>86.0 %</td><td>86.2 %</td></tr>
<tr><td colspan="2">Cost / m³</td><td>220.2 yen/m³</td><td>212.5 yen/m³</td><td>215.7 yen/m³</td></tr>
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