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Practical experience of backwashing with SWRO permeate for UF fouling control

Sheng Li[a,b,*], S.G.J. Heijman[a], J.Q.J.C. Verberk[a], G.L. Amy[a,b], J.C. van Dijk[a]

[a]*Delft University of Technology, P.O. Box 5048, 2600 GA Delft, The Netherlands*
Tel. +31(0)152784282; email: s.li@tudelft.nl
[b]*Water Desalination and Reuse Research Center, 4700 King Abdullah University of Science and Technology, Thuwal 23955-6900, Kingdom of Saudi Arabia*

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ABSTRACT

Effectiveness of seawater reverse osmosis (SWRO) permeate backwash on fouling control of seawater ultrafiltration was investigated at a pilot scale. A standard membrane module was used in this pilot to represent full-scale desalination plants. Results of the pilot show a good reproducibility. When the UF permeate was used for backwash, the frequency of chemically enhanced backwash (CEB) was around once per day. However, results of the pilot show that SWRO permeate backwashing could significantly reduce the CEB frequency.

Keywords: Ultrafiltration; Backwash; SWRO permeate

1. Introduction

In our previous studies, backwashing with demineralized water (the DEMIFLUSH concept) has been proven to be successful on controlling fouling of ultrafiltration (UF) for both surface water and seawater treatments [1–3]. The absence of cations in demineralized water establishes a cation-free environment near the negatively charged UF membrane surface during backwashes, eliminating the charge screening effect formed during filtration. Therefore, a restored repulsion force between negatively charged membranes and natural organic matter compounds is achieved, enhancing the backwash efficiency.

However, this concept has not been tested with standard modules used in full-scale plants. Membrane modules used in the previous experiments include modules with a surface area of 3.75×10^{-3}, 7×10^{-2} and $2.4\,m^2$. All these modules are much smaller than the surface area of standard modules ($40\,m^2$). In order to show that the DEMIFLUSH concept can also improve the fouling control in a realistic situation, tests with standard modules were conducted at a pilot scale. Since the quality of seawater reverse osmosis (SWRO) permeate is similar with demineralized water in terms of the low concentration of cations, SWRO permeate was applied for backwashing in this study. Furthermore, because, with the settings of small-scale experiments, too much SWRO permeate is required which makes the DEMIFLUSH concept not economically feasible, the consumption of SWRO permeate is optimized in this study as well. Although the consumption optimization can be conducted at experiments of all scales, the bigger the scale the more demineralized water/SWRO permeate consumes in

*Corresponding author.

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Table 1
Water qualities of the seawater

	pH	Ca (mg/l)	Na (mg/l)	DOC (mg/l)	Conductivity (μS/cm); 20℃
October–November	8.11	360	8,500	1.8	43,000
January–February	8.09	350	8,300	1.7	40,000-42,000
May–June	7.92	360	8,234	1.9	43,000

the pipe line system. Therefore, it is better to optimize the SWRO permeate consumption with standard modules at a scale representing full-scale plants.

Although both seawater and surface water applications of the DEMIFLUSH concept need to be investigated at this pilot scale, seawater application is considered first in this study. That is because the DEMIFLUSH concept is more convenient and economically feasible to be implemented in a desalination plant with both UF and RO system.

In this study, the authors experimentally determined the effectiveness of DEMIFLUSH concept on standard modules.

2. Material and methods

Pilot tests were conducted near a desalination demonstration plant of Evides Water Company in the Netherlands, Oosterschelde, North Sea estuary. Raw seawater was taken by pumps to the demonstration plant and passed through a 50-micron strainer. The strained seawater was used for the DEMIFLUSH pilot as UF feed water (same as the desalination plant), so that the results between the pilot and the desalination plant are comparable.

2.1. Feed water

Strained seawater was continuously taken from the desalination demonstration plant of the Evides Company within three periods: October–November 2010, January–March 2011, and May–June 2011. The 50-micron strainer was used to remove the big particles, and then water was delivered to the DEMIFLUSH pilot by gravity. The water qualities of the seawater are shown in Table 1.

2.2. Backwash water

Two types of backwash water were compared: (1) demonstration plant SWRO permeate and (2) pilot UF permeate. The water qualities are shown in Table 2.

2.3. Membrane

Standard XIGA (brand name of one type membrane) modules (equipped with UFC M5 0.8 fibers) from Norit X-Flow were used in this study. The characteristics of this membrane fiber are same as modules used in the previous studies, which have been described in details in those studies [1–5]. These membranes are made of a mixture of polyethersulfone with a small amount of polyvinylpyrrolidone. The dimensions of a standard XIGA module are shown in Table 3.

2.4. Chemical cleaning

Alkaline chemical cleaning was applied in the DEMIFLUSH pilot: 200 mg/l NaOH and 250 mg/l NaOCl. After a 2.5-min chemical backwash at 60 l/(m^2 h) flux, the membrane was soaked in chemical cleaning solution for ten minutes. After soaking, the membrane was rinsed with SWRO permeate for 2 min at a flux of 165 l h^{-1} m^{-2}.

Table 3
Dimensions of a standard XIGA module

Diameter of module (cm)	19
Length of module (m)	1.5
Surface area (m^2)	40

Table 2
Water qualities of backwash water for seawater treatment

	pH	Ca (mg/l)	Na (mg/l)	DOC (mg/l)	Conductivity (μS/cm); 20℃
UF permeate	7.92	360	8,500	1.7	N/A
SWRO permeate	5.84	1	18	<0.1	205

Table 4
Operational details of different tests

	Feed media	Filtration flux (l/(m^2 h))	Filtration time (min)	Backwash media	Backwash flux (l/(m^2 h))	Backwash time (s)
1	Strained seawater	55	45	UF permeate	275	120
2	Strained seawater	55	45	SWRO permeate	275	90
3	Strained seawater	55	50	SWRO permeate	275	60

2.5. DEMIFLUSH pilot and filtration protocol

In this pilot, there are five possible operation phases: (1) forward flush with raw water, (2) forward flush with SWRO permeate, (3) filtration with raw water, (4) backwash with UF permeate, and (5) backwash with SWRO permeate. In addition to the fouling control with DEMIFLUSH, in-line coagulation is also incorporated in this pilot, but was not used during current experiments. Therefore, the combination of coagulation and DEMIFLUSH can be utilized when it is desired. This pilot is fully automated and remote controllable.

All experiments were carried out in a dead-end operation mode. Depending on the experiments conducted, different operation conditions were applied. Each fouling experiment, with one type of backwash medium (either UF permeate or SWRO permeate), consisted of more than one operational cycle. Each cycle was composed of filtration and backwash (details shown in Table 4). When the permeability of the membrane decreased to 200 l/(h m^2 bar), a chemically enhanced backwash was conducted (same as the desalination demonstration plant).

Experiments focused on comparing the SWRO permeate backwash and UF permeate backwash.

3. Results

3.1. Reproducibility of results from the DEMIFLUSH pilot

In order to ensure the reproducibility of results gaining from the DEMIFLUSH pilot, UF permeate backwashing experiments were continuously conducted from January to March 2011, except for the periods with shortage of seawater supply.

Fig. 1 shows the permeability as a function of date. for UF permeate backwashing. All experiments were conducted between the permeability of 200 and 400 l/(h m^2 bar). Although the starting point for each experiment is not exactly the same, the permeability decline rate (the slope of each line) is similar for all experiments. The two experiments conducted around

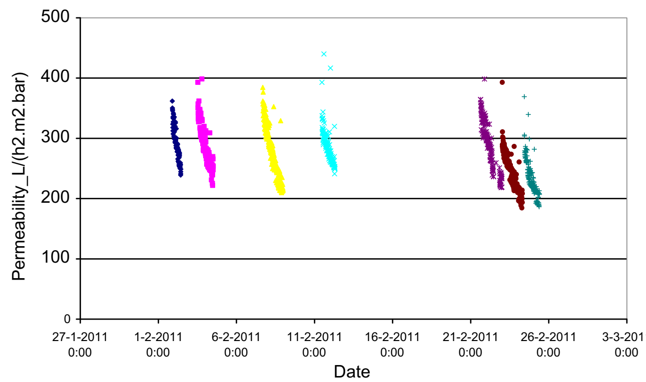

Fig. 1. Permeability as a function of date for the experimental runs of the DEMIFLUSH pilot conducted from January to March 2011.

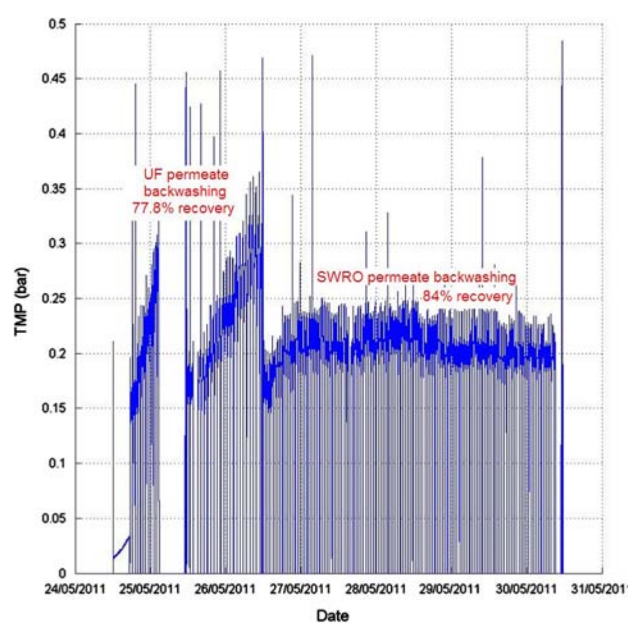

Fig. 2. TMP as a function of date for experiments with UF and SWRO permeate backwashes (UF permeate backwashing experiments were conducted at 77.8% recovery, with 45 min filtration at 55 l/(m^2 h) flux and followed by 2 min backwash at 275 l/(m^2 h) flux; SWRO permeate backwashing experiment was conducted at 84% recovery).

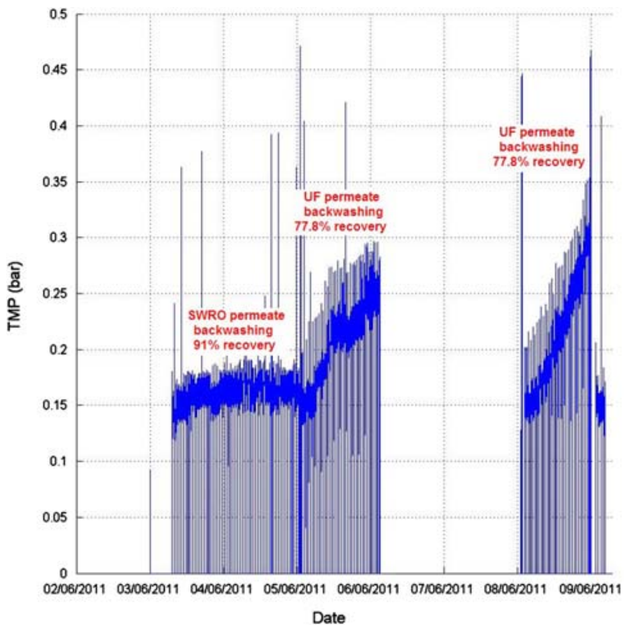

Fig. 3. TMP as a function of date for experiments with UF and SWRO permeate backwashes (UF permeate backwashing experiments were conducted at 77.8% recovery, with 45 min filtration at 55 l/(m^2 h) flux and followed by 2 min backwash at 275 l/(m^2 h) flux; SWRO permeate backwashing experiment was conducted at 91% recovery).

26 February 2011 showed a lower initial permeability, but that is probably because of the insufficient chemical-enhanced backwash.

3.2. Improvement of SWRO permeate backwashing

Figs. 2 and 3 show the experimental results of pilot tests in the high fouling period (from May to June of 2011). As shown in these two figures, the recovery of UF for UF permeate backwashing was 77.8%, which means 22.2% of UF permeate was used for backwashing. When the membrane was backwashed with UF permeate, TMP increased sharply all the time. On the other hand, the recoveries of UF for the SWRO permeate backwashing in Figs. 2 and 3 are 84 and 91%, respectively. At these two recoveries, less amount of water (SWRO permeate) was used for backwashing, but the fouling control efficiencies were still satisfactory (stable TMP after a small initial increase). These two figures indicated that the SWRO permeate (almost demineralized water) backwashing can control the UF fouling in high fouling period. In terms of the usage of SWRO permeate, the amount can be reduced to 9% of the production of UF until this moment (91% recovery). Unfortunately, because the high fouling period is gone after June 2011, further optimization could not be continued. The consumption of SWRO permeate may be reduced further. This should be investigated in the high fouling period next year at the same location.

In high fouling period, the Evides plant had to incorporate in-line coagulation to control the UF fouling. If the consumption of SWRO permeate can be optimized to a low level, the DEMIFLUSH concept probably can replace in-line coagulation as a fouling control method. When the SWRO permeate is used for backwash, the waste sludge of backwash contains only salt and organic substances originally from the sea. Therefore, it should be possible to discharge it back to the sea, and thus, the coagulant dosing and waste sludge treatment facilities are not necessary any more. Both capital and maintenance cost can be saved in this case, making the application of DEMIFLUSH more economically feasible. Of course, it depends on the consumption of SWRO permeate as well. If too much SWRO permeate is required, then it is still not cost-effective. However, application of the DEMIFLUSH concept is still environmentally friendly, concerning the elimination of disposal of backwash waste sludge.

4. Conclusions

Results in the previous studies with small scale-membrane modules are confirmed again with a standard UF membrane module. SWRO permeate (having similar qualities as demineralized water) backwash substantially improves the seawater UF fouling control. The effectiveness of SWRO permeate backwash on UF fouling control is still obvious at a UF recovery of 91%. Therefore, the application of this technique is more feasible in terms of cost. However, there is still space for further optimization, so tests should be continued to find out the lowest SWRO permeate consumption in which the good UF fouling control is still effective.

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