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Nanofiltration innovation: performance of new DuPont™ FilmTec™ NF270-440 element in municipal wastewater operation

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ABSTRACT

With more stringent water quality standards, advanced treatment solutions to ensure delivery of reliable, safe water at premium quality are essential. The FilmTec™ NF270-440 nanofiltration element presents an ideal solution for utility managers and operators seeking a technology that removes a high percentage of dissolved organic pollutants from source water while maintaining a suitable level of minerals. Energy efficiency is also of utmost importance for any water treatment facility. Our latest nanofiltration (NF) innovation enables end-users to reduce CAPEX of nanofiltration systems and simplify the overall systems design by offering a 10% more active membrane area, thus reducing their energy consumption. FilmTec™ NF270-440 is also able to deal with challenging feed water. These benefits were highlighted while in operation in a pilot plant installed in the Vilaseca municipal wastewater treatment plant (Tarragona, Spain). Significant reductions in feed-side pressure drop, fouling resistant properties and reduced energy consumption were observed throughout the trial.

Keywords: Nanofiltration; Wastewater; Pollutants; Antifouling; Energy

1. Introduction

Reduction of energy consumption is one of the challenges in nanofiltration (NF) systems operation [1]. Element design can be optimized by increasing the active area and/or by reducing the feed-concentrate pressure loss. These modifications will cause a boost in permeate productivity by more membrane area and higher available net driving pressure. The reduction of element pressure drop has also positive effects in the control of biofouling and is associated with a decrease in the number of cleanings-in-place (CIP) [2]. Biological fouling effects are caused by the growth and accumulation of micro-organisms and their respective extracellular polymeric materials (EPS) inside the feed channel of the spiral wound RO element [3]. Overall, biofouling and frequent cleanings will affect energy and chemical consumption, element lifetime, water productivity and cost of water produced. FilmTec™ NF270-440 is designed to operate at low energy consumption. These elements are equipped with advanced fouling-resistant and cleanability features, helping plants reduce the number of cleanings, while maintaining low energy usage [4]. Its additional benefits are high total organic carbon removal capacity for municipal drinking water application and high biofouling resistance.

2. Materials and methods

2.1. Experimental set-up

Due to pilot plant requirements, the nanofiltration elements used needed to be in 4-inch configuration. Thus, prototypes were configured with the same element construction. The pilot plant is installed in the Vilaseca wastewater treatment plant (Spain), treating 63,300 m^3/d of

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municipal wastewater. The feed water used for the test is ultrafiltrate water taken from the secondary sedimentation basin. Both lines received the same water quality summarized in Table 1.

The pilot plant has two independently controlled high pressure pumps through which conditions for each line can be adjusted. Up to six elements in series can be installed in each line. A basic diagram of the experimental plant is shown in Fig. 1.

The experimental conditions used were equal recovery and flux for both NF270-400 and NF270-440 elements. Given that active area is 10% higher for the NF270-440 train, permeate production rate was 10% more. To operate both lines at the same recovery, feed flow was adjusted, as shown in Table 2.

Cleaning protocol used for the cleaning in place (CIP) included recirculation with NaOH (pH 11) at 35°C, followed by recirculation with HCl (pH 2.5) at 25°C.

3. Results and discussion

3.1. Operational performance

Results are reported as accumulated days of operation to compact operational data range and simplify visualization of trends. As shown in Fig. 2, during summer period, feed water temperature increases to more than 30°C. This caused a high biofouling potential, as it can be observed in the aggressive pressure drop build-up in the cartridge filters.

As previously described, feed and permeate flow were adjusted to keep recovery rate and flux constant for both lines (Fig. 3).

It can be observed in Fig. 4 that initial water permeability was higher for NF270-440 prototype (around 20% more than NF270-400 initial permeability). This might be attributed to potentially higher element efficiency and lower concentration polarization (better mixing). Water permeability and the advantage of NF270-440 configuration remained stable throughout the first 100 d of operation, including after completion of the first CIP (day 55).

Pressure drop evolution for the side-by-side test (Fig. 5) showed the advantage of the low pressure drop spacer of the NF270-440 prototype (more than 30% lower

Table 1
Ultrafiltrate quality

Parameter	Concentration
TDS (mg/L)	1,800
Ammonia (mg/L as N)	30
Alkalinity (mg/L as $CaCO_3$)	420
Calcium (mg/L)	130
Magnesium (mg/L)	50
Chloride (mg/L)	550
Sulfate (mg/L)	270
Sodium (mg/L)	340
Potassium (mg/L)	20
TOC (mg/L)	7.5
pH	7.5

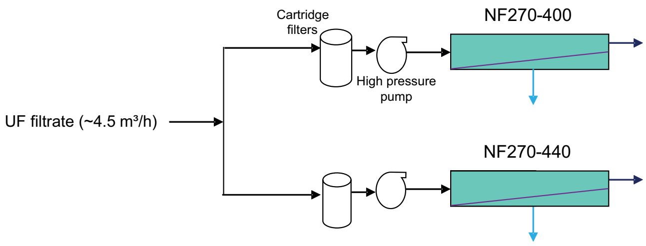

Fig. 1. Scheme of pilot plant layout used for side-by-side testing.

Table 2
Operating conditions during testing

Line	NF270-400	NF270-440
Elements per vessel	6	6
Flux (LMH)	21	21
Permeate (m^3/h)	0.90	0.99
Concentrate (m^3/h)	1.00	1.10
Feed (m^3/h)	1.90	2.10
Recovery (%)	47	47

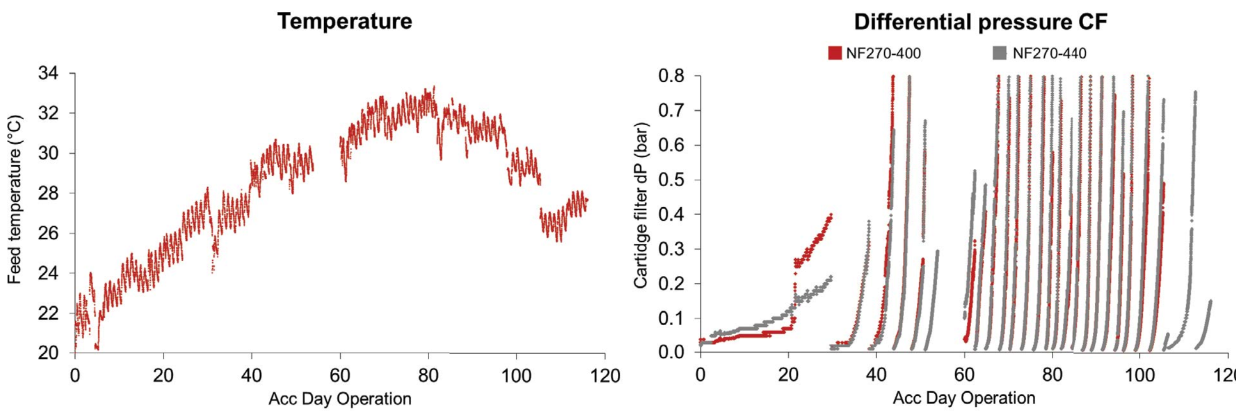

Fig. 2. Feed water temperature and cartridge filter pressure drop.

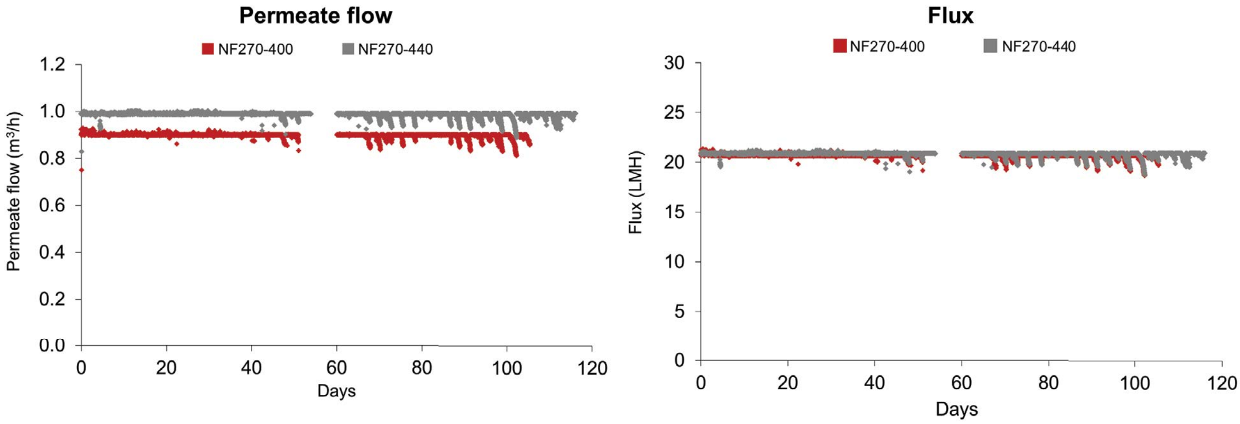

Fig. 3. Feed and permeate flow rate.

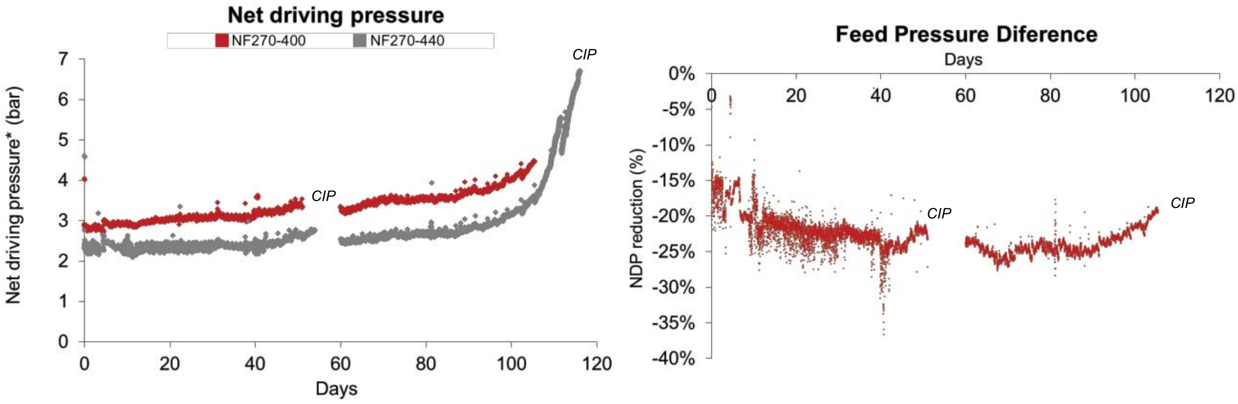

Fig. 4. Normalized water permeability comparison.

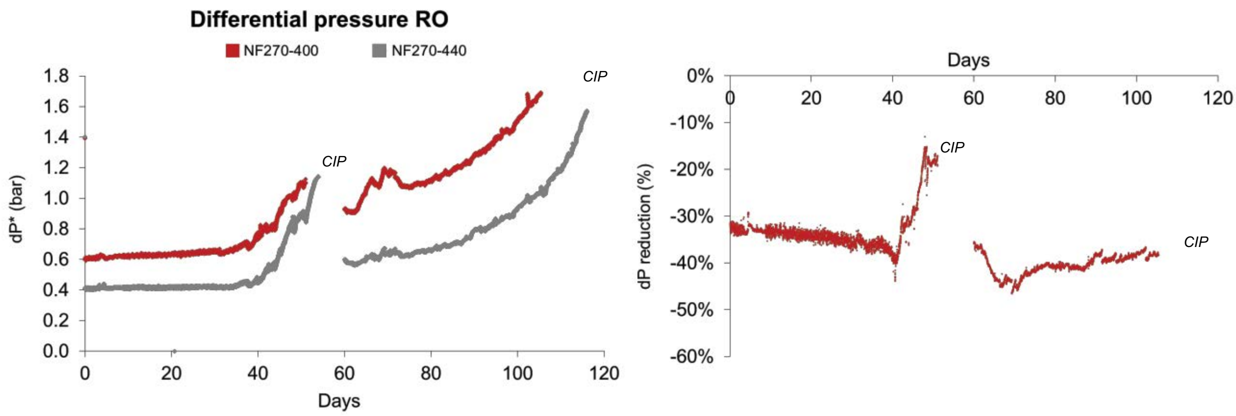

Fig. 5. Normalized pressure drop comparison.

initial pressure drop than NF270-400). This is more significant if it is taken into consideration than the feed flow of NF270-440 line is 10% higher than NF270-400.

3.2. Permeate quality

Since both elements share the same base membrane chemistry, the permeate quality produced by NF270-440 and NF270-400 is expected to be equivalent. Laboratory analysis of individual ions was used to assess and monitor the permeate quality of nanofiltration elements.

The main characteristic of nanofiltration elements is that it allows a relatively high passage of monovalent ions. Sodium and chloride passage are a representative example of monovalent performance. As shown in Fig. 6, the average passage rate of monovalent ions is the range of

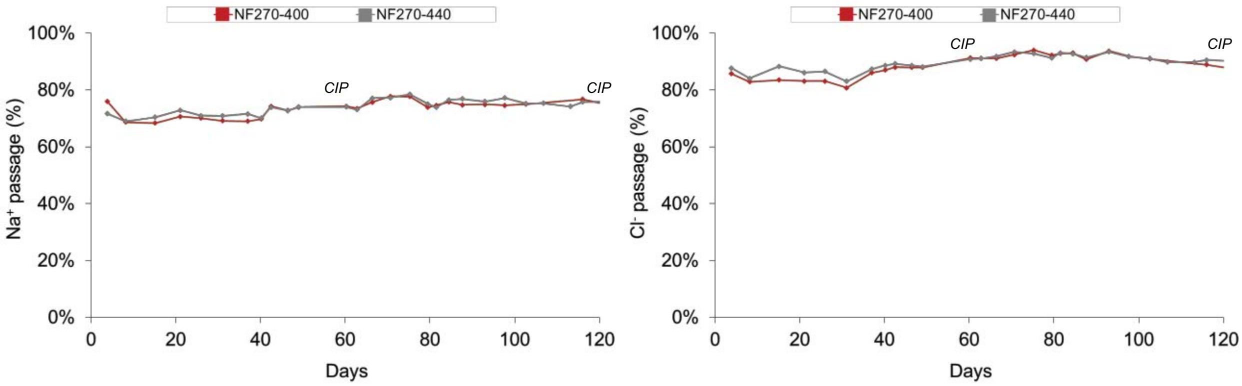

Fig. 6. Monovalent passage tendency.

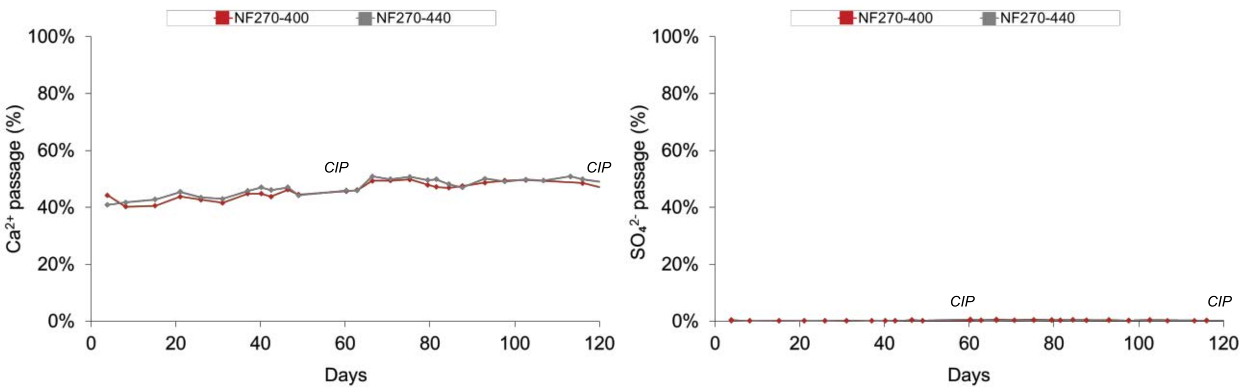

Fig. 7. Divalent passage tendency.

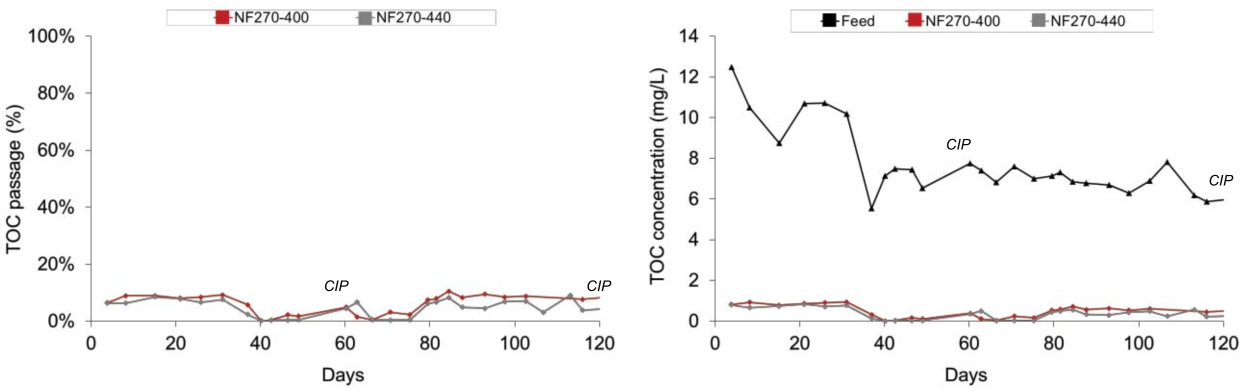

Fig. 8. Organics passage tendency.

70%–85%, with no statistical difference between NF270-440 and NF270-400.

NF270 chemistry provides a significantly lower passage of divalent ions compared to monovalent ions. As shown in Fig. 7, Sulfate passage was extremely low, with concentrations in the permeate of less than 1 mg/L on average. This is a positive effect for permeate quality since high sulfate content can influence the corrosion potential of water and its taste. Calcium passage was significant (around 40%–45%), but still much lower than monovalent passage reported. Again, the permeate quality of NF270-440 and NF270-400 regarding divalent composition was equivalent. The chemical cleanings performed did not impact the salt permeability properties of the membrane, even the most aggressive conditions used towards the end of the test.

Another important parameter for water purification is the ability to separate organic compounds present in the water to be treated. Total organic carbon (TOC) was used to evaluate the overall efficiency in preventing the passage of organic contaminants to the permeate water. It can be observed in Fig. 8 that passage was always lower than 10% and in average was 5%. This demonstrates that even at feed concentration of more than 10 mg/L of TOC, the TOC of the permeate remained below 1 mg/L. A marginally lower TOC passage was observed for NF270-440, giving it a slight advantage over NF270-400 in this parameter.

4. Conclusions

FilmTec™ NF270-440 nanofiltration element enables end-users to reduce CAPEX of nanofiltration systems and simplify the overall system design. It offers 10% more active membrane area, reducing its energy consumption. NF270-440 nanofiltration element is also able to deal with fouling prone feed waters, thanks to new module construction. The pilot tests results using municipal wastewater highlighted the advantages of NF270-440 compared side-by-side with NF270-400.

Higher productivity and permeability, combined with reduced pressure drop, helped to achieve more sustained operation. Permeate quality obtained by NF270-440 is equivalent to NF270-400, removing a high percentage of dissolved organic pollutants from source water while keeping a suitable level of minerals.

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