Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2021.26745

225 (2021) 350–355
June

Water production by reverse osmosis for the manufacture of paint in the automotive industry

F.A. León[a,]*, A. Ramos-Martín[b]

[a]*Institute of Intelligent Systems and Numerical Applications in Engineering (SIANI), University of Las Palmas de Gran Canaria, Campus Universitario de Tafira, 35017 Las Palmas de Gran Canaria, Spain, Tel. 0034686169516; email: federico.leon@ulpgc.es*
[b]*Department of Process Engineering, University of Las Palmas de Gran Canaria, Campus Universitario de Tafira, 35017 Las Palmas de Gran Canaria, Spain, Tel. 0034928451933; email: alejandro.ramos@ulpgc.es*

Received 30 August 2020; Accepted 1 November 2020

ABSTRACT

Reverse osmosis (RO) is the most extensively used technology in seawater and brackish water desalination. This technology is used in many applications, one of which is the manufacture of automotive paint. In this work, 2 y of operating data of a brackish water reverse osmosis (BWRO) desalination plant were analyzed. The feedwater was taken from groundwater well. The desalination plant had sand and cartridge filters with antiscalant dosing as pre-treatment. The RO system comprised two stages, with 40 pressure vessels (PV) in the first stage and 20 in the second stage, and 6 BWRO elements per PV. Feedwater conductivity ranged between 680 and 2,100 μS/cm, and feedwater pH between 6.05 and 7.55. Feed pressure increased from 11 to 28 bar due to membrane fouling along the operating period. The RO system had a recovery rate of around 75%, with an approximate production of 7,200 m^3/d. Plant performance over the two study years was evaluated through the calculation of the characteristic parameters of the membrane, including average ionic and water permeability coefficients.

Keywords: Brackish water; Reverse osmosis; Desalination plants; Long-term; Operating data

1. Introduction

In Spain, the high-quality process water that is needed in the manufacture of automotive paint and paints for industrial use is commonly obtained using reverse osmosis (RO) technology, the most widespread technology in seawater and brackish water desalination [1–3].

In this article, an analysis is undertaken of 2 y of operating data of a brackish water reverse osmosis (BWRO) desalination plant (Fig. 1) used to produce high-quality water for the manufacture of automotive paint. The feedwater was taken from a brackish well. The main objective of this process is water quality as opposed to desalination plant efficiency [4,5]. In the production of automotive paint, the permeate conductivity rate, which can be affected by temperature, should be lower than 50 uS/cm. As the feedwater comes from the city pipeline network and permeates conductivity can increase in the summer due to the higher temperatures, special attention needs to be paid to the permeate conductivity rate in this kind of process [6,7].

Fig. 1 shows a schematic representation of the process followed to obtain the required high quality permeate water. There is a groundwater well with a feedwater tank and pump before the chemical pretreatment (with antiscalant only) and the physical pretreatment with sand filters and cartridge filters. After the pretreatment equipment comes to

---

* Corresponding author.

To be presented at Desalination for the Environment: Clean Water and Energy, 16–20 May 2021, Las Palmas de Gran Canaria, Spain

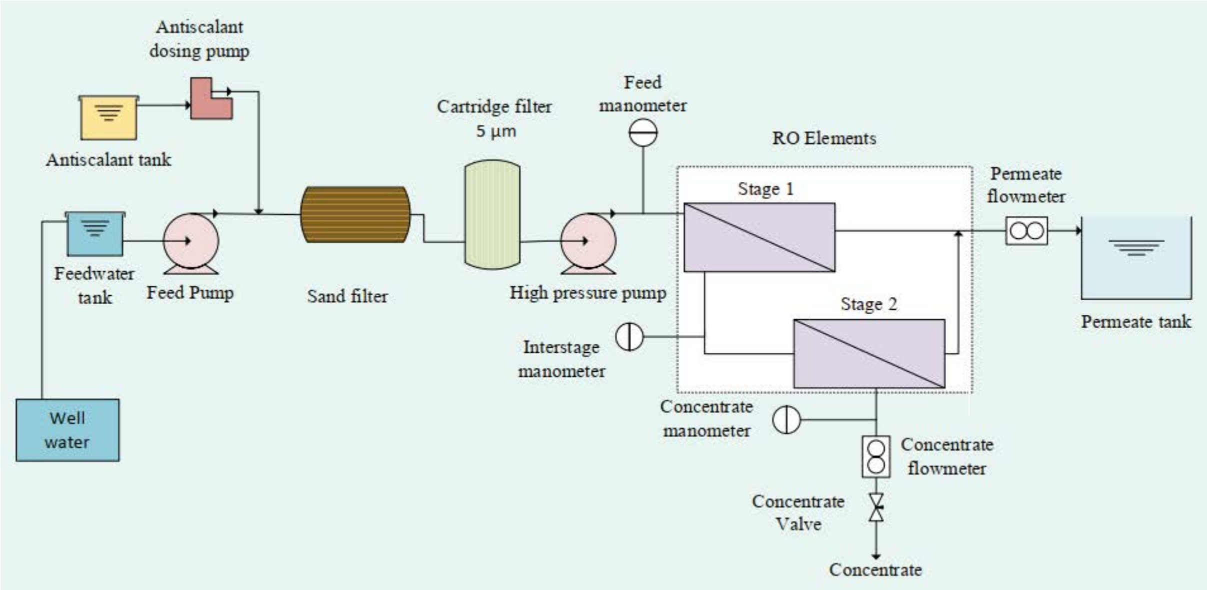

Fig. 1. Brackish water reverse osmosis desalination plant.

the high-pressure pump followed by the actual RO system, which is divided into two stages. The brine from the first stage goes directly to the second and is finally removed from the system through a concentrate valve. The permeate water goes to a permeate tank. With respect to instrumentation, there are manometers to measure feed and brine pressure and flow meters for the feed and permeate. The process is that of a standard BWRO desalination system [8–10].

2. Material and methods

The desalination plant had sand and cartridge filters with antiscalant dosing as pre-treatment. The RO system consisted of two stages, with 40 pressure vessels (PV) in the first stage and 20 in the second-stage and 6 BWRO elements per PV.

A significant amount of operating data was collected over 17,000 operating hours in order to evaluate the performance of this BWRO desalination plant, working under the specific conditions described above [11–13].

3. Results and discussion

Feedwater conductivity ranged between 680 and 2,100 μS/cm (Figs. 2 and 3) and feedwater pH between 6.05 and 7.55 (data not shown). Feed pressure increased from 11 to 28 bar due to membrane fouling over the operating period. According to the technical specifications of the membrane, the maximum feed pressure for this type of element is 42 bar. However, given the continuous operation of the plant, it is considered that this feed pressure increment from 11 to 28 bar is the maximum that is acceptable. The RO system had a recovery rate of around 75%, with a production of 7,200 m^3/d. Most of these results are shown in Figs. 4–12.

Fig. 2 shows the feedwater conductivity of train 1, which was not very stable and ranges between 680 and 2,000 μS/cm. Due to this, the average feed conductivity was around

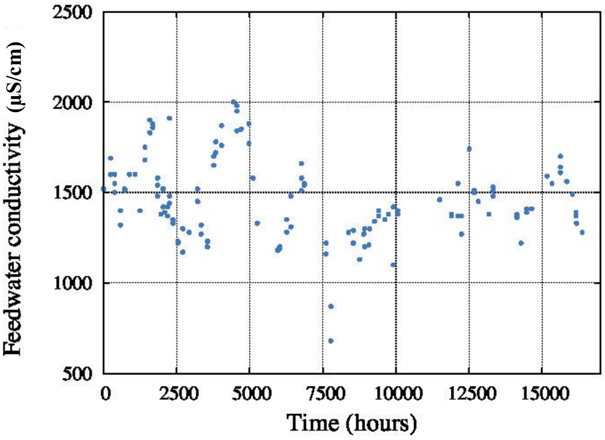

Fig. 2. Feed conductivity train 1.

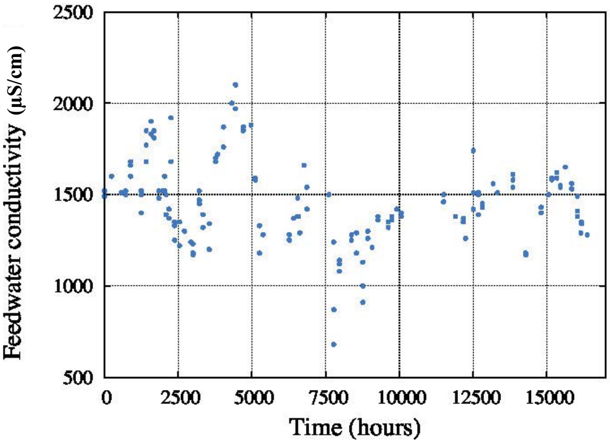

Fig. 3. Feed conductivity train 2.

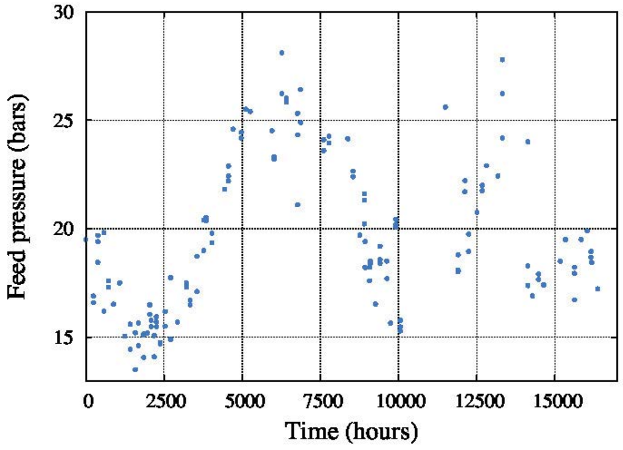

Fig. 4. Feed pressure train 1.

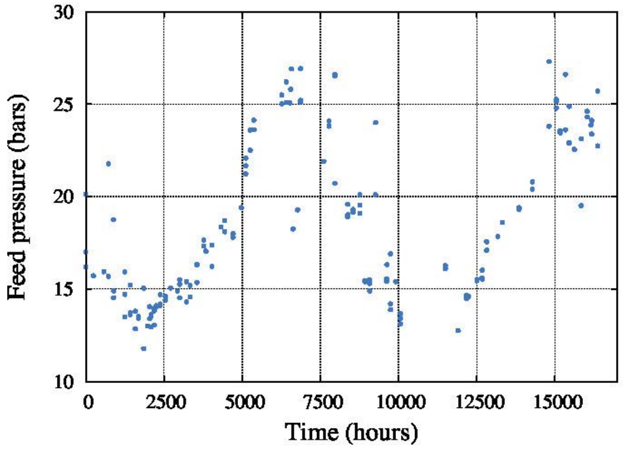

Fig. 5. Feed pressure train 2.

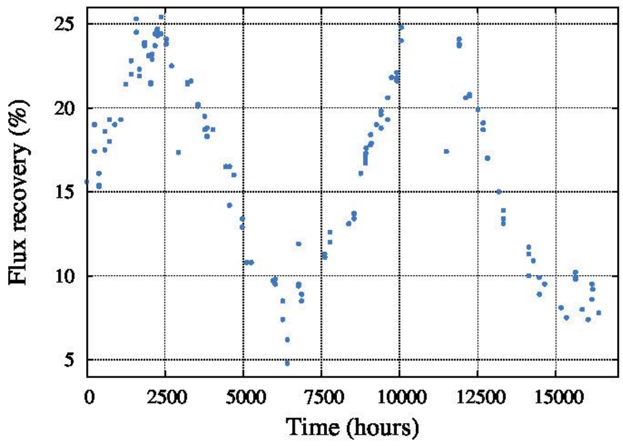

Fig. 6. Flux recovery train 1.

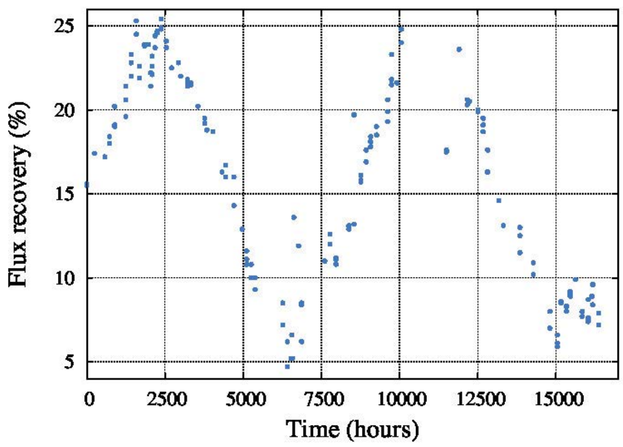

Fig. 7. Flux recovery train 2.

1,500 µS/cm. This instability can result in different feed pressure values and the varying energy consumption of the system.

The feedwater conductivity of train 2 (Fig. 3) was very similar to that of train 1, but with an even higher maximum conductivity value of 2,100 µS/cm. The average feed conductivity was approximately the same, around 1,500 µS/cm.

Fig. 4 shows how the feed pressure of train 1 decreased after 7,500 operating hours, which was due to the decrease in feedwater conductivity. The energy consumption of the system also decreased. After 10,000 operating hours, the feed pressure increased again with the rise in feed conductivity. This increase is also due to the effect of aging of the RO elements.

The feed pressure pattern of train 2 (Fig. 5) was quite similar to that of train 1, due to the same decreases and increases in feedwater conductivity. That is the feed pressure and the energy consumption of the system change depending on the feedwater conductivity values and the aging of the RO membranes.

Figs. 6 and 7 show the flux recovery rates of trains 1 and 2. As both are very similar due to the virtually same feedwater conductivity and feed pressure rates, the flux recovery rates for trains 1 and 2 are considered together.

Fig. 8 shows how the permeate flow of stage 1 in train 1 remained very stable over time. The feedwater, which comes from the city pipeline network, produces fouling on the surface of the membranes of the first stage. Consequently, after 12,500 operating hours, a basic chemical clean-in-place (CIP) was performed with NaOH and pH 11–12 in order to improve the permeate flow rate.

Fig. 9 shows how the permeate flow of stage 2 in train 1 increased a little after 7,500 operating hours due to the decrease in feedwater conductivity in train 1 (Fig. 2). Between the operating hours 7,500–10,000 the feed conductivity of train 1 ranged between 700 and 1,400 us/cm which was much lower than at the start. Due to this, the brine conductivity of the first stage in train 1, which is the feed to the second-stage, decreased and permeate flow of the second-stage consequently increased. This effect was more pronounced in the second bank, as the feed of this stage is the brine from the first bank. Therefore, a decrease in this feed conductivity is quite significant in the desalination system due to the high salinity values.

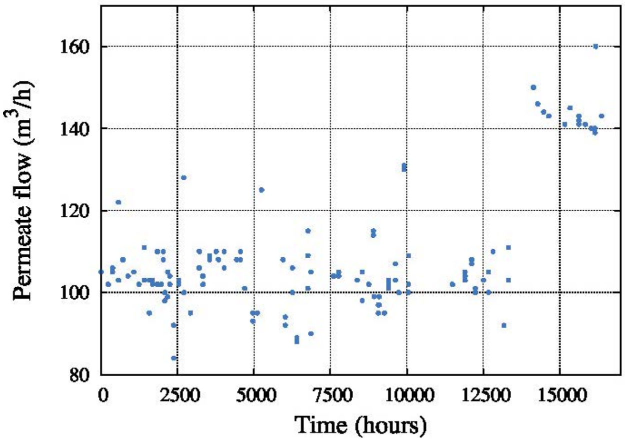

Fig. 8. Permeate flow of stage 1 in train 1.

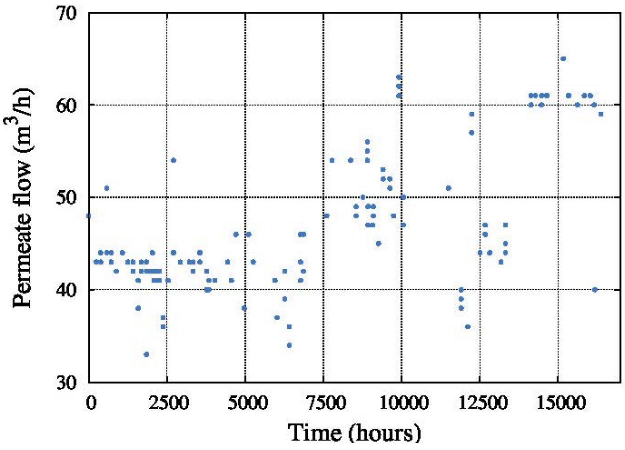

Fig. 9. Permeate flow of stage 2 in train 1.

Figs. 10 and 11 show the permeate flow of the first and second-stages in train 2. Both were very stable, even with the aging of the RO elements. Moreover, after 7,500 operating hours when feedwater conductivity decreased, the permeate flow of both banks increased. This effect is more significant in stage 2 because salinity is higher than in the first stage. Consequently, permeate flow increased between 7,500–10,000 operating hours.

Fig. 12 shows how the permeate conductivity of train 1 remained very stable over time, as is also the case in train 2. In train 1, after 12,000 operating hours, permeate conductivity started to climb due to the aging of the elements and the increase in feedwater salinity. The increase in feedwater conductivity also caused an increase in permeate water conductivity, though not excessive. Aging of the elements and fouling are the most important factors. Fouling produced a considerable increase in permeate conductivity over time and was most notable after 12,000 operating hours.

As can be seen in Fig. 13, the permeate conductivity in train 2 was even more stable, with just a slight decrease in permeate conductivity between 7,500–10,000 operating hours due to the decrease in feedwater conductivity. A similar effect in train 1 can also be seen in Fig. 12.

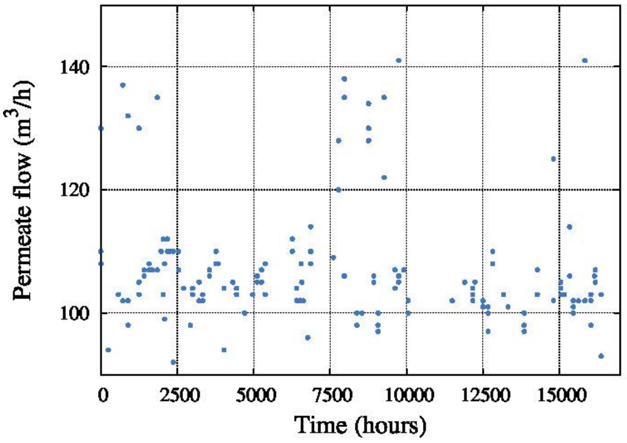

Fig. 10. Permeate flow of stage 1 in train 2.

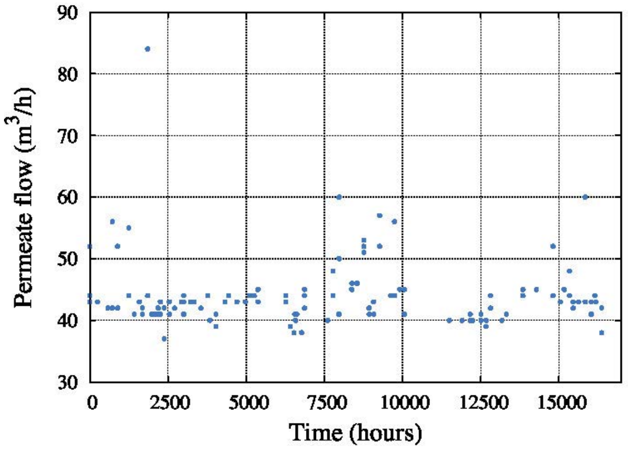

Fig. 11. Permeate flow of stage 2 in train 2.

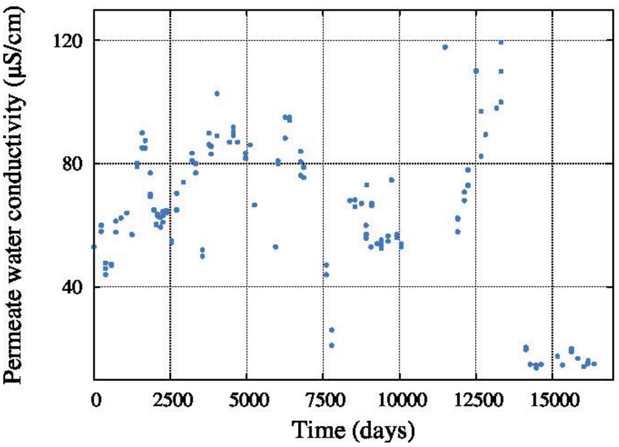

Fig. 12. Permeate conductivity train 1.

Figs. 14 and 15 show the pressure drops of the first and second-stages of train 1. Both were very stable. In the first bank, the pressure drop started a bit high and later stabilized at around 1.5 bar. The pressure drop of stage 1 was high in the early stage due to the special design and because stabilization with this type of element takes time. Initially, the pore of the membrane is slightly closed and starts to open up with the operation of the plant, so at the early stage the pressure drop was a bit high and after 2,500 h gradually began to stabilize.

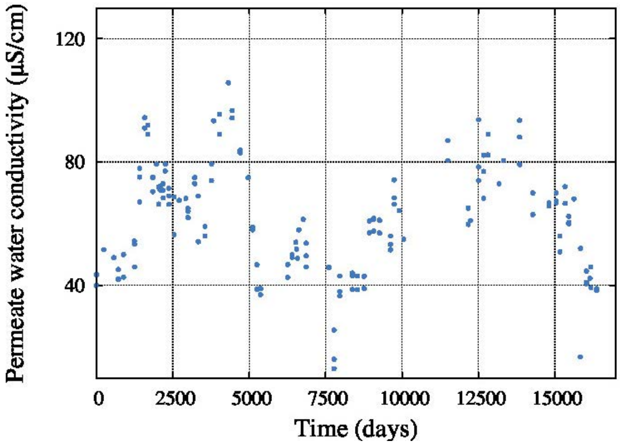

Fig. 13. Permeate conductivity train 2.

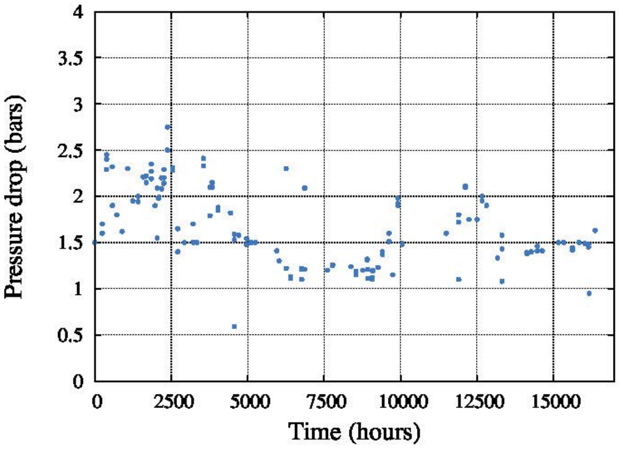

Fig. 14. Pressure drop of stage 1 in train 1.

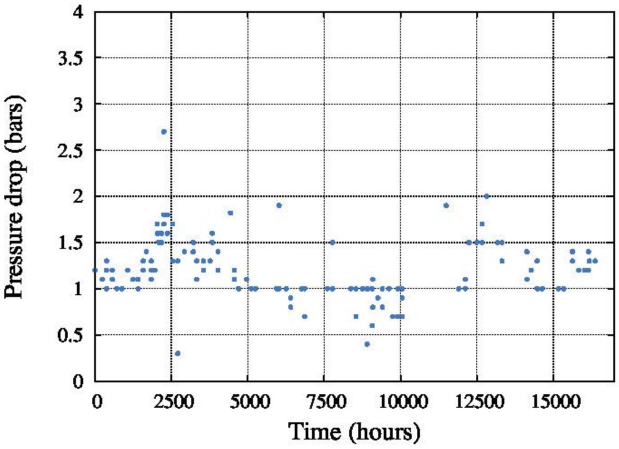

Fig. 15. Pressure drop of stage 2 in train 1.

In the case of the second bank, the average value of 1.2 bar was lower than in the first. In reality, the pressure drop remained very stable in both stages of train 1 over the 16,000 operating hours.

Fig. 16 shows the pressure drop of train 2, which was also very stable. As in train 1, it started a bit high but later stabilized at around 1.5 bar. The pressure drop of train 2 remained virtually constant over the 2 y of operation.

Fig. 17 shows how the feedwater silt density index (SDI) values of train 1 remained below 4 throughout the 17,000 h and below 3 during 83% of the period. The SDI remained quite stable over the 2 y study period, increasing a little in the second year of operation. The feedwater SDI values for train 2 are shown in Fig. 18, with a few values close to or above 4 but 99% below this value and 83% below 3. It is therefore concluded that the feedwater SDI is acceptable in both trains.

4. Conclusions

Reverse osmosis technology is required to obtain the high-quality process water that is needed for the

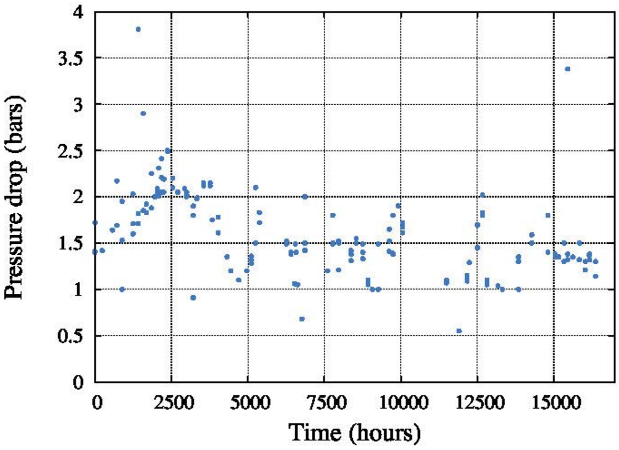

Fig. 16. Pressure drop train 2.

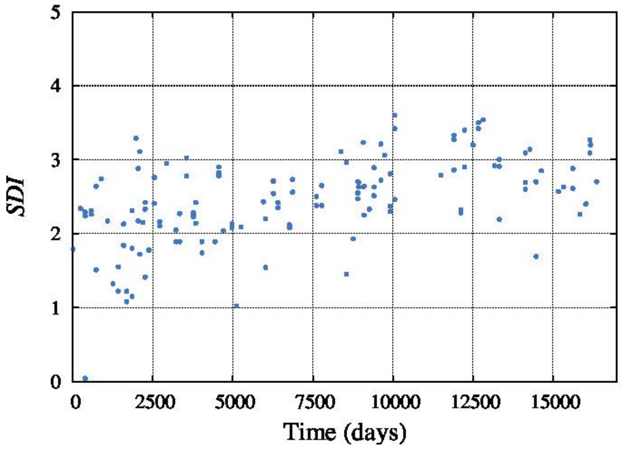

Fig. 17. Feed silt density index train 1.

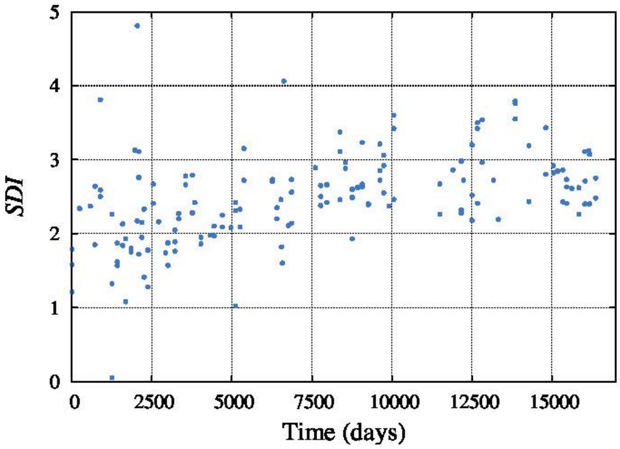

Fig. 18. Feed silt density index train 2.

manufacture of automotive paint, with electrical conductivity values below 50 µS/cm.

The BWRO desalination plant considered in this study requires a conventional pre-treatment with sand filters, cartridge filters and antiscalant dosing to avoid fouling and scaling.

A significant amount of operating data was collected over 17,000 operating hours in order to evaluate the performance of the plant.

The average feed conductivity was found to be around 1,500 µS/cm. The feed pressure and the energy consumption of the system changed depending on the feed conductivity values and the aging of the RO membranes.

The feedwater, which comes from the city pipeline network, produces fouling on the surface of the membranes of the first stage, and so basic chemical cleaning processes (pH 11–12) need to be periodically undertaken in order to improve the permeate flow rate.

The increase in the permeate water conductivity was due to fouling, aging of the elements and the increase in feedwater conductivity.

Acknowledgments

This research was co-funded by the INTERREG V-A Cooperation, Spain-Portugal MAC (Madeira-Azores-Canarias) 2014–2020 program and the MITIMAC project (MAC2/1.1a/263).

References

[1] D.W. Song, Y. Wang, S.C. Xu, J.P. Gao, Y.F. Ren, S.C. Wang, Analysis, experiment and application of a power-saving actuator applied in the piston type energy recovery device, Desalination, 361 (2015) 65–71.

[2] E. Dimitriou, E.Sh. Mohamed, C. Karavas, G. Papadakis, Experimental comparison of the performance of two reverse osmosis desalination units equipped with different energy recovery devices, Desal. Water Treat., 55 (2015) 3019–3026.

[3] E. Dimitriou, E.Sh. Mohamed, G. Kyriakarakos, G. Papadakis, Experimental investigation of the performance of a reverse osmosis desalination unit under full- and part-load operation, Desal. Water Treat., 53 (2015) 3170–3178.

[4] F.J. García Latorre, S.O. Pérez Báez, A. Gómez Gotor, Energy performance of a reverse osmosis desalination plant operating with variable pressure and flow, Desalination, 366 (2015) 146–153.

[5] J. Kheriji, A. Mnif, I. Bejaoui, B. Humrouni, Study of the influence of operating parameters on boron removal by a reverse osmosis membrane, Desal. Water Treat., 56 (2015) 2653–2662.

[6] J. Schallenberg-Rodríguez, J.M. Veza, A. Blanco-Marigorta, Energy efficiency and desalination in the Canary Islands, Renewable Sustainable Energy Rev., 40 (2014) 741–748.

[7] N. Dow, S. Gray, J.-d. Li, J.H. Zhang, E. Ostarcevic, A. Liubinas, P. Atherton, G. Roeszler, A. Gibbs, M. Duke, Pilot trial of membrane distillation driven by low grade waste heat: membrane fouling and energy assessment, Desalination, 391 (2016) 30–42.

[8] N.M. Mazlan, D. Peshev, A.G. Livingston, Energy consumption for desalination – a comparison of forward osmosis with reverse osmosis, and the potential for perfect membranes, Desalination, 377 (2016) 138–151.

[9] N.R.G. Walton, Electrical conductivity and total dissolved solids—what is their precise relationship?, Desalination, 72 (1989) 275–292.

[10] S. Boerlage, N. Nada, Algal toxin removal in seawater desalination processes, Desal. Water Treat., 55 (2015) 2575–2593.

[11] T. Bilstad, E. Protasova, A. Simonova, S. Stornes, I. Yuneizi, Wind-powered RO desalination, Desal. Water Treat., 55 (2015) 3106–3110.

[12] V. Gnaneswar Gude, Desalination and sustainability – an appraisal and current perspective, Water Res., 89 (2016) 87–106.

[13] F. León-Zerpa, A. Ramos Martín, Analysis of high efficiency membrane pilot testing for membrane design optimization, Desal. Water Treat., 73 (2017) 208–214.