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Evaluation of the five years operating data of a RO brackish water desalination plant in Las Palmas, Canary Islands, Spain: a historic case

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ABSTRACT

The reverse osmosis (RO) brackish water desalination plant described in this article has been operating without acid in the pretreatment and only using two types of antiscalants (this was the first experience of 40,000 operating hours in Canaries). This work describes the graphical evolution of all the daily operating information of the first five years. A study of the normalization and standardization of the information about the five years of the evolution of the plant for fixed feedwater conditions, operating pressure, and system recovery is shown too, so that the performance evaluation of the plant can be indicated correctly. Likewise, this article describes the graphic evolution of thse brine Langelier saturation index (real and theoric values). The conclusions of this study and the operating experience are intended to get a practical and optimum design method of RO brackish water desalination plants.

Keywords: Brackish water; Reverse osmosis; Desalination plants; Operating data; Normalization

1. Introduction

This article constitutes a second part of the paper ''Graphic Evolution of the 24,000 h…'', prepared for the International Desalination Association World Congress and presented in Kuwait [1]. It constitutes one part of the doctorate thesis that the author (*) did at the University of Las Palmas de Gran Canaria, Faculty of Industrial and Civil Engineering (Analysis of the membrane processes. Brackish water desalination, November 2011).

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The capacity of this reverse osmosis (RO) brackish water desalting plant was 370 m^3/day and from January 1986 to June 1993 and it was in operation with a Langelier saturation index (LSI) in the brine of about 2.2 without using acid in the pretreatment and only using Flocon 100 [2] and EL 5600 [3] antiscalant products (this was the first experience of seven years in brackish water desalting plants in Canary Islands).

The RO system (1 pass and 2 stages) was equipped with 5 pressure vessels. The arrangement was 3 + 2. The element number by pressure vessel was 4. A total of 20 (12 + 8) Filmtec BW30-8040 RO elements [4] were placed. This work describes the evolution and evaluation of the first five years of operation.

The operating conditions of any reverse osmosis desalination plant such as pressure, recovery, and feedwater conditions can vary, causing permeate flow and salt rejection to change. Normally, the actual (real) operating data are generated at different conditions (Figs. 1–4). To evaluate plant performance, it was necessary to compare permeate flow and salt rejection data at the same operating conditions (Figs. 5 and 6). The objectives of this work were as follows:

(1) To indicate the graphical evolution of the operating data of this RO BW desalination plant, details of the design conditions and data can be found in [1].

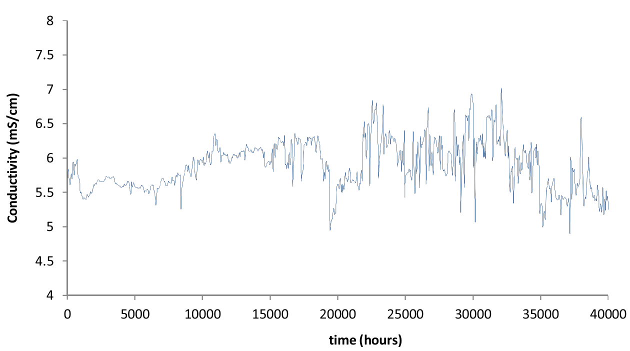

Fig. 1. Feedwater conductivity.

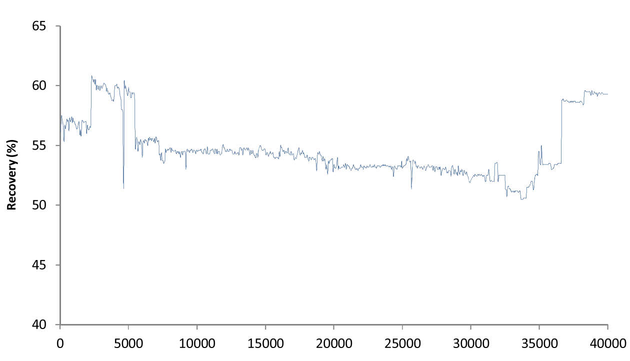

Fig. 2. System recovery.

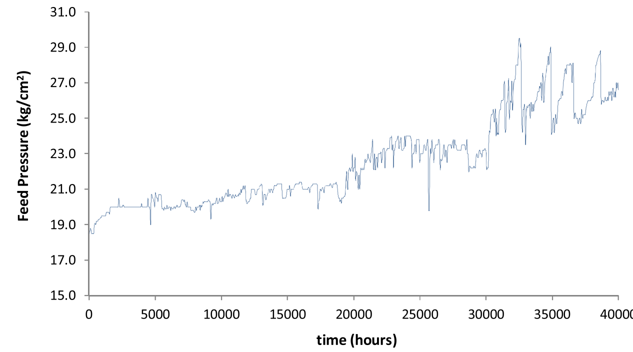

Fig. 3. Feed pressure.

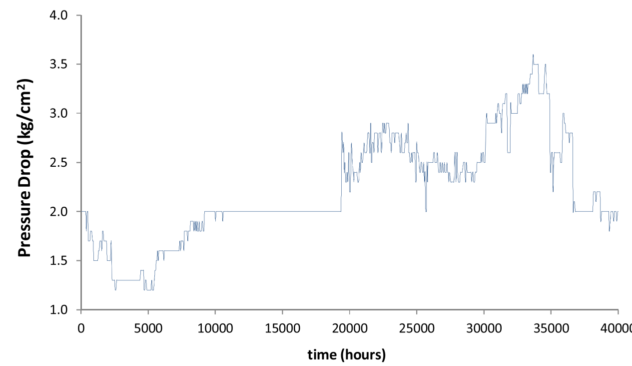

Fig. 4. Total pressure drop.

(2) To show the evolution of the product flow and the salt rejection normalized by application of the american society for testing and materials (ASTM) method [5], the operating data of the 17 different samples of the feed, product and reject water were used in this study (Table 1). To obtain the most accurate standardization, the standard conditions were closed to the average actual conditions (Sample 9). The first three samples were not considered because in this operating time the RO desalination plant was modified and had an irregular performance [1].

(3) Through the analysis of these samples, the real and theoric brine LSI [6,7] were computed to compare the different values (Fig. 7).

2. Graphic evolution of the operating data

All the information on which the graphs of the evolution of the operating parameters are based was obtained every day. Four graphs of the evolution of the plant through the first five operating years are shown to indicate versus operating time (hours) the performance of the following parameters:

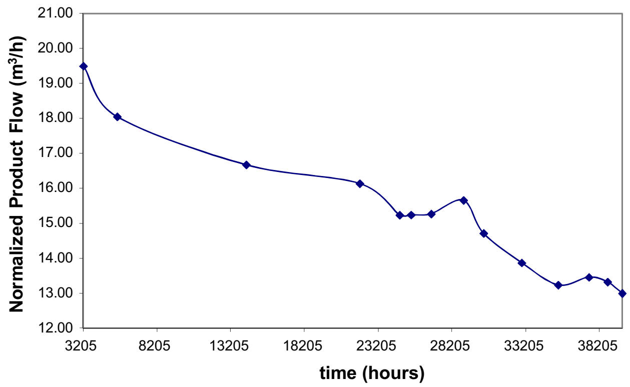

Fig. 5. Product flow.

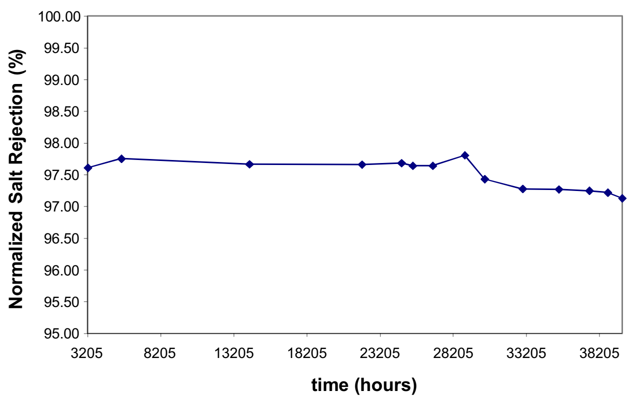

Fig. 6. Normalized salt rejection.

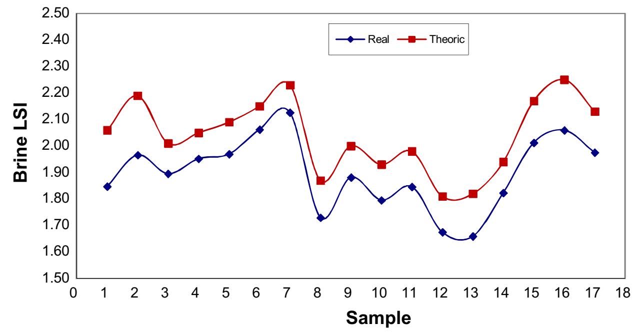

Fig. 7. Brine LSI.

As it can be seen from the corresponding graphs, the cycles of chemicals cleaning have been each 2–3 months of operation. According to the membranes manufacturer instructions [8], the following chemical products in solution with product water ($t = 22$°C) were used:

(a) First 3 operating years:

- Citric acid to the 2% and pH approximately of 2.5.
- Sodium carbonate to the 1% and pH of 10.5–11.
- In both cases, the time used for cleaning was 40 min.

Table 1
Operating conditions of the samples

Sample	Operating time (h)	Recovery (%)	SDI_f	TDS_f (mg/l)	pH_f	pH_r	Antiscalant type	Antiscalant dose (mg/l)
1	49	56.20	2.7	4,396	7.79	7.94	Flocon 100	7
2	852	57.40	2.7	4,365	7.85	8.00	Flocon 100	7
3	1,394	57.00	2.5	3,914	7.72	7.98	Flocon 100	9
4	3,205	60.22	2.4	4,254	7.65	7.96	Flocon 100	12
5	5,501	54.76	2.4	4,209	7.77	8.00	Flocon 100	12
6	14,253	54.00	2.3	4,601	7.80	8.05	Flocon 100	12
7	21,955	53.40	2.3	4,889	7.87	8.10	Flocon 100	12
8	24,659	53.30	2.4	4,417	7.47	7.67	Flocon 100	12
9	25,420	54.10	2.4	4,182	7.61	7.83	Flocon 100	12
10	26,789	53.20	2.4	4,760	7.52	7.72	Flocon 100	12
11	28,986	52.80	2.3	4,363	7.60	7.80	Flocon 100	12
12	30,343	52.50	2.4	4,550	7.43	7.62	Flocon 100	12
13	32,931	51.20	2.4	4,354	7.49	7.65	Flocon 100	12
14	35,408	53.40	2.5	4,086	7.59	7.81	Flocon 100	12
15	37,487	58.70	2.4	4,212	7.63	7.86	EL-5600	5
16	38,754	59.20	2.4	4,141	7.70	7.90	EL-5600	5
17	39,745	59.30	2.4	4,052	7.60	7.84	EL-5600	5

(b) Fourth and fifth operating years:

- Hydrochloric acid: 0.5% and 2–2.5 pH.
- Phosphoric acid: 0.5% and 2.5 pH.
- Sodium salt of dodecylsulfate: 0.1% and 11–11.5 pH.
- The time used for cleaning was 40 min in all the cases.

3. Standardizing method

The method used for standardizing RO performance data was the ASTM. The main equations incorporated with this method are:

(1) Standardization of permeate flow.

$$A = \left(P_{fs} - \frac{PD_{fbs}}{2} - P_{ps} - OP_{fbs} + OP_{ps}\right)TCF_s \quad (1)$$

$$B = \left(P_{fa} - \frac{PD_{fba}}{2} - P_{pa} - OP_{fba} + OP_{pa}\right)TCF_a \quad (2)$$

$$Q_{ps} = \frac{Q_{pa}ATCF_s}{BTCF_a} \quad (3)$$

(2) Standardization of salt passage.

$$\%SP_s = \frac{\%SP_a BC_{fbs}C_{fa}}{AC_{fba}C_{fs}} \quad (4)$$

Table 2
Operating time factor

Operating time	F_t
1 year	0.9
3 years	0.8
5 years	0.7

Table 3
Average ionic permeability coefficients at 25°C

Ion	Salt rejection (%)	Salt pass (%)	K_j (m/day)
Ca	99.30	0.70	0.00303
Mg	94.44	0.56	0.00242
Na	97.30	2.70	0.01117
K	96.30	3.70	0.01600
HCO_3	98.61	1.39	0.00601
SO_4	99.93	0.07	0.00030
NO_3	90.34	9.66	0.04707
Cl	98.13	1.87	0.00809
SiO_2	99.41	0.59	0.00255

4. Operating conditions and results

Seventeen representative samples of the plant evolution have been taken. The operating data as well as the dose of antiscalant are shown in the correspondent table (Table 1). In all the cases, the feed water temperature was 22°C. The results obtained are shown in Figs. 5–7.

5. Conclusions

If we take into account the concentration polarization over the membrane surface, we will deduce that the brine LSI values of the last RO elements are between 1.8 and 2.25.

The results (Fig. 7) indicate a relation between theoric and real brine LSI values of about 1.08 (4–11%). This relation is quite conservative to appear that the application of the theoric LSI values to design RO brackish water (BW) desalination plants will be a good practice [6–8].

The normalized product flow and salt rejection of the plant appear to indicate a normal level of compaction [10,11] and a stability of the membrane performance versus time. It seems clear that a 6–7 years operating life is a reasonable projection for these operating conditions and for this FT30 RO element.

The data shows that it is a reasonable possibility to design and to operate RO BW desalination plant with a LSI in the brine of about 2–2.5 without using acid in the pretreatment stage. These RO systems with little maintenance can offer the guarantee of a continuous operation with a long-time limit and with a minimum of deterioration of its operational characteristics.

Despite the time elapsed, the analysis has been useful. From the results of the normalized product flow (Fig. 5), the following practical values of the compaction and fouling correction factor or fouling factor [12] or operating time factor (F_t) (Table 2) have been deduced:

Likewise, from the normalized salt rejection graph (Fig. 6), we can deduce that if it is not exists some kind of physical or chemical degradation of the RO membranes or the RO modules, the salt rejection is almost constant along the operating time. From the previous work, we have deducted the average ionic permeability coefficients at 25°C (kJ) [9] [12], of the RO membrane utilized (Table 3):

The previous values (Tables 2 and 3) will be useful to design the RO system using spiral wound RO elements similar to the type FILMTEC FT30 considered.

The desalination plant, which we have used to do this work, has the following configuration since May 2005: 1 pass, 2 stages with 3:2 arrangement, 6 RO elements per pressure vessel so it has 30 RO elements (18 + 12). The RO element installed after that date (nowadays in operation after 7 years) is the BW30-400 (Filmtec). This plant currently has about 58,000 h of operation and we are still taking data, hoping to complete them, analyze them and publish them in due course.

Symbols

BW, bw	—	brackish water
C_f	—	feed concentration (mg/l NaCl)
C_{fb}	—	feed-brine concentration (mg/l NaCl)
CFCF	—	compaction and fouling correction factor
FF	—	fouling factor (idem CFCF)
F_t	—	operating time factor (idem CFCF)
K_j	—	average ionic permeability coefficients at 25°C
LSI	—	Langelier saturation index
OP_{fb}	—	feed-brine osmotic pressure (kPa)
OP_p	—	permeate osmotic pressure (kPa)
P_f	—	feed pressure (kPa)
P_p	—	permeate pressure (kPa)
PD_{fb}	—	feed-brine pressure drop (kPa)
RO, ro	—	reverse osmosis
SDI	—	silt density index
SP	—	salt passage
T	—	feed water temperature (°C)
TCF	—	temperature correction factor

Subscripts

a	—	actual (real) conditions
b	—	brine
f	—	feed
p	—	product, permeate
r	—	reject
s	—	standard conditions
i, j	—	ion/component

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