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Antiscalant cost and maximum water recovery in reverse osmosis for different inorganic composition of groundwater

A. Ruiz-García[a,*], J. Feo-García[b]

[a]*Department of Mechanical Engineering, University of Las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain, Tel. +34 928 451888, Fax +34 928 451879, email: alejandro.ruiz@ulpgc.es*
[b]*Department of Electronic and Automatic Engineering, University of Las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain, Tel. +34 928 451963, email: jose.feo@ulpgc.es*

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ABSTRACT

Groundwater sources play a very important role in the Canary Islands. In fact the 80% of the reverse osmosis desalination plants in Gran Canaria are to treat brackish water. In water desalination processes, water recovery is one of the most important indexes for RO system design. But this is not always the most convenient from the point of view of the operating costs. This article aims to estimate the antiscalant/dispersant specific costs considering the maximum recovery levels for reverse osmosis systems. The products (Antiscalant A and B) have been evaluated as these sorts of products are most commonly used considering the inorganic composition of the different groundwater bodies in this island. The silica, calcium carbonate and calcium sulfate are the most commonly found salts in the groundwater of Gran Canaria. In most cases, silica had the highest effect on the antiscalant/dispersant specific costs, followed by calcium carbonate.

Keywords: Brackish water; Reverse osmosis; Desalination plants; Recovery; Scaling; Antiscalant.

1. Introduction

The source water quality of a desalination plant has an impact on the treatment needed, costs and on the quality of the permeate. The inorganic composition of the feedwater is a key component of the operation and maintenance (O&M) cost, for example in terms of antiscalant type and dosing. The formation of mineral deposits (scaling) on the surface of a RO membrane is caused by the precipitation of sparingly soluble mineral salts (e.g., silica (SiO_2), calcium carbonate ($CaCO_3$), calcium sulfate dihydrate (denoted simply as $CaSO_4$), barium sulfate ($BaSO_4$), strontium sulfate ($SrSO_4$) and calcium fluoride (CaF_2)). As plant recovery increases, more salts in the feedwater are likely to exceed their solubility and they begin forming crystals on the membrane surface and cause mineral membrane fouling. Therefore, the RO desalination systems face a threshold of maximum water flux recovery at which the scaling process destabilizes the membrane performance.

As one of the main limiting factors in RO despite the advancements in antiscalant chemistry [1–7], scaling has been studied by many authors [8–15]. Generally, the silica and calcium carbonate are the main "problem" in this region [16–18]. There are some interesting pretreatments to separate the silica from feedwater. Den et al. [19] studied electrocoagulation pretreatment showing removal efficiency up to 80% for initial concentrations of dissolved silica between 80 mg/L and 200 mg/L. Sanciolo et al. [20] showed the possibility to decrease the silica concentration in RO concentrate to levels that would allow an overall water recovery of 90–95% using 10 g/L of regenerable activated alumina adsorbent. Cob et al. [21] tested several methods to remove silica, a. Precipitation of silica with $Fe(OH)_3$, $Al(OH)_3$ and silica gel was investigated, and also the removal of silica using a strongly basic anion (SBA) exchange resin, they concluded that a removal of 94%

*Corresponding author.

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could be achieved depending on the feed water quality. These pretreatments should be also studied from the economic point of view in order to carry out an assessment of the permeate specific cost in terms of pretreatment and antiscalant products. The close circuit desalination has been showed to be a promising technology to increase water flux recovery [22,23].

Antiscalants are used to minimize the potential for forming scale on the surface of an RO membrane. They have the ability to keep supersaturated salts in solution changing the crystal shapes and having non-adherent scales. They impart a highly negative charge to the crystal keeping them separated to avoid propagation. BWRO flux recoveries are in a range from 60 to 90%, depending on feed water salinity and composition. Most cases, these recoveries are achievable using antiscalants taking part in the O&M costs.

The aim of this paper was to calculate and assess the antiscalant cost in different regions of Gran Canaria. As the most limiting factors are usually the silica and calcium carbonate, two specific antiscalant products for these salts were considered. The maximum flux recovery in a BWRO desalination plant is key for its viability. An economic assessment of the two above mentioned antiscalant products was made considering maximum flux recovery and dosing ratio.

2. Material and methods

2.1. Groundwater inorganic composition

The Gran Canaria Island was separated in different groundwater bodies (Fig. 1). It was possible to get a water analysis from different groundwater wells in Gran Canaria. All information about groundwater inorganic composition was given by public administration ("Consejo Insular de Aguas de Gran Canaria").

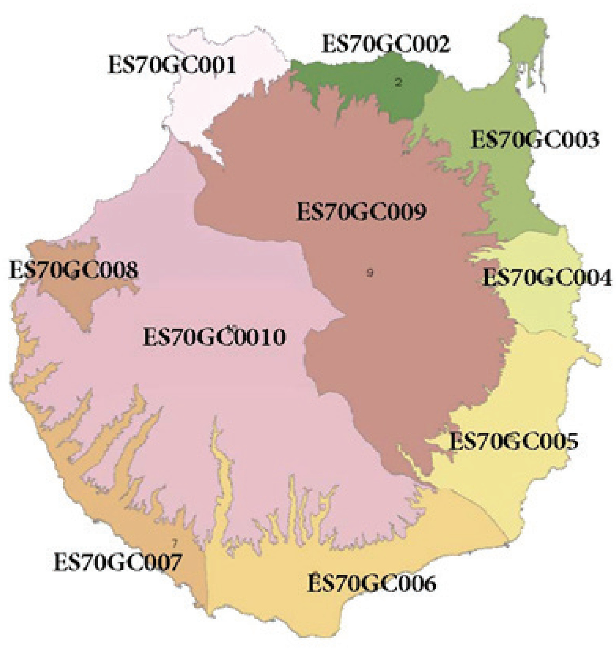

Fig. 1. Groundwater bodies in Gran Canaria [24].

The inorganic composition of groundwater is shown in Table 1 (wells located in different groundwater bodies). The samples were collected and analysed in 2009 (Gran Canaria). The inorganic composition of groundwater can vary considerably due to location. The total dissolved solids (TDS) concentration are in a range of 79.1–16,933 mg/L. Some chemical analyses in Gran Canaria Island were not taken into account due to no silica concentration determination or inconsistent values. The fluorine concentration was not collected in Gran Canaria. A temperature range of 20–24ºC was considered due to the unavailability of the data.

2.2. Antiscalants

The characteristics of the considered antiscalant are in Table 2. Most of BWRO desalination plants have a production capacity below 1,000 m^3/d [24] so the antiscalant product is usually supplied in pails of 23 kg. Considering the location, taxes, etc, the price for each antiscalant was 6.30 €/kg and 4.26 €/kg for the antiscalant A and B respectively. The software of the antiscalant manufacturer was used to estimate the antiscalant dosage for the different products and feedwaters. As it is a theoretical study, the limits established by the manufacturer were used.

3. Results and discussion

The maximum water recoveries using different antiscalant products are shown in Table 3. In general, due to high concentration of silica, the appropriate scale inhibitor to get the higher maximum water recovery was the antiscalant A. It inhibits silica scaling at higher concentrations than antiscalant B. This antiscalant is specific for $CaCO_3$ allowing a LSI < 3, while using antiscalant A, a LSI < 2 could be achievable as it is shown in Table 2. Due to high concentrations of silica, low recoveries were estimated for antiscalant B and as consequence low dosage. Depending on water needs, this option could be interesting from the cost point of view or in combination with other pretreatment.

In general, the dosage is higher for the antiscalant A than for antiscalant B, and more expensive which makes the antiscalant A to have a higher specific cost spite of getting a higher water flux recovery (Fig. 2).

Fig. 2 shows the decline trend of the specific cost with the water flux recovery increase for both antiscalants. Only when the water flux recovery is close to 80%, the

Table 1
Antiscalant characteristics

Salt	Theoretical power of inhibition	
	Antiscalant A	Antiscalant B
$CaCO_3$	LSI ≤ 2.5	LSI ≤ 3
$CaSO_4$	$3.5 \cdot K_{sp}$	$3.5 \cdot K_{sp}$
$BaSO_4$	$105 \cdot K_{sp}$	$105 \cdot K_{sp}$
$SrSO_4$	$20 \cdot K_{sp}$	$20 \cdot K_{sp}$
CaF_2	$1,000 \cdot K_{sp}$	$1,000 \cdot K_{sp}$
SiO_2	2·Saturation	120 ppm

Table 2
Inorganic composition of groundwater in Gran Canaria [24]

Groundwater body	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	SiO_2	Fe	Mn	TDS	pH
ES70GC001	175.00	168.00	652.00	25.00	1,293.00	325.00	169.00	792.00	71.00	–	–	3,598.00	7.2
	65.00	90.00	365.00	17.00	635.00	281.00	204.00	255.00	85.00	–	–	1,911.00	6.8
	556.00	556.00	1,085.00	44.00	602.00	750.00	195.00	3,322.00	64.00	–	–	7,434.00	7.3
	217.00	118.00	144.00	26.00	1,098.00	97.00	–	281.00	107.00	–	0.90	1,671.60	6.8
	175.00	150.00	365.00	20.00	1,342.00	134.00	67.00	439.00	112.00	–	0.54	2,317.00	6.4
ES70GC002	388.00	499.00	1,461.00	58.00	509.00	650.00	60.00	3,662.00	86.00	–	0.01	7,287.00	6.2
	186.00	141.00	437.00	25.00	246.00	517.00	201.00	833.00	53.00	–	–	2,587.00	7.8
	99.00	59.00	371.00	31.00	376.00	164.00	–	600.00	57.00	–	0.65	1,699.00	7.8
	67.00	72.00	338.00	43.00	455.00	248.00	168.00	370.00	73.00	0.02	–	1,747.20	6.8
ES70GC003	162.00	186.00	862.00	37.00	1,045.00	325.00	36.00	1,397.00	108.00	–	0.09	3,969.70	6.5
	127.00	102.00	543.00	44.00	383.00	384.00	198.00	818.00	47.00	–	–	2,779.00	7.7
	93.00	77.00	177.00	48.00	221.00	338.00	172.00	229.00	49.00	–	–	1,332.10	7.5
	33.00	19.00	574.00	39.00	756.00	351.00	77.00	334.00	67.00	–	0.28	2,023.70	6.5
	51.00	72.00	475.00	20.00	732.00	210.00	62.00	471.00	73.00	–	–	2,336.00	6.9
	151.00	150.00	863.00	49.00	762.00	344.00	54.00	1,429.00	103.00	–	–	4,109.00	7.4
	47.00	87.00	941.00	34.00	637.00	294.00	50.00	1,255.00	64.00	–	0.01	3,433.50	7.4
ES70GC004	83.00	77.00	378.00	20.00	481.00	436.00	107.00	336.00	84.00	–	–	1,780.80	7.2
	37.00	27.00	139.00	16.00	183.00	157.00	118.00	79.00	84.00	–	–	756.00	7.6
	942.00	920.00	1,389.00	83.00	359.00	728.00	127.00	5,665.00	64.00	0.02	0.01	11,683.00	6.8
	32.00	38.00	306.00	19.00	370.00	139.00	72.00	324.00	71.00	–	–	1,365.70	7.3
	28.00	30.00	257.00	14.00	342.00	79.00	26.00	281.00	89.00	–	–	1,057.00	7.4
	87.00	91.00	169.00	18.00	976.00	43.00	18.00	92.00	86.00	–	–	1,493.00	6.5
	70.00	70.00	360.00	22.00	390.00	218.00	125.00	451.00	73.00	–	–	1,801.80	7.4
ES70GC005	829.00	763.00	509.00	36.00	183.00	412.00	16.00	4,064.00	86.00	–	–	8,288.00	7.5
	31.00	26.00	102.00	9.40	298.00	24.00	6.80	101.00	100.00	–	–	598.00	8.2
	510.00	401.00	330.00	27.00	187.00	201.00	8.40	2,258.00	94.00	–	–	3,922.00	7.6
	227.00	145.00	214.00	21.00	196.00	126.00	84.00	900.00	55.00	–	–	1,913.00	7.9
	563.00	477.00	757.00	32.00	1,051.00	706.00	18.00	2,480.00	77.00	–	0.22	6,084.00	7.4
	39.00	26.00	93.00	8.90	266.00	52.00	6.10	89.00	65.00	–	–	579.00	8.1
	113.00	181.00	859.00	33.00	439.00	634.00	152.00	1,362.00	43.00	–	–	3,772.00	8.1
ES70GC006	228.00	97.00	1,462.00	36.00	112.00	331.00	6.90	2,623.00	40.00	–	0.02	4,896.00	7.6
	88.00	59.00	168.00	11.00	366.00	38.00	1.50	363.00	4.60	–	–	1,095.00	7.3
	46.00	20.00	621.00	13.00	87.00	151.00	5.00	973.00	48.00	–	0.03	1,915.00	7.3
	14.00	11.00	320.00	4.80	497.00	109.00	7.10	194.00	41.00	–	–	1,157.00	8.5
	76.00	47.00	233.00	9.80	304.00	167.00	85.00	310.00	52.00	–	–	1,299.20	8.0

(Continued)

Groundwater body	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	SiO_2	Fe	Mn	TDS	pH
	54.00	53.00	277.00	17.00	176.00	87.00	7.60	514.00	63.00	0.03	–	1,442.00	8.0
	65.00	36.00	280.00	9.60	201.00	103.00	9.00	467.00	53.00	–	–	1,171.00	7.8
	60.00	52.00	482.00	21.00	289.00	194.00	11.00	738.00	48.00	–	–	1,847.00	7.7
	89.00	119.00	534.00	22.00	336.00	341.00	73.00	861.00	110.00	–	–	2,375.00	7.6
	26.00	16.00	161.00	5.60	165.00	64.00	19.00	204.00	44.00	–	–	660.00	7.9
	105.00	98.00	634.00	21.00	304.00	445.00	93.00	923.00	40.00	–	–	2,623.00	8.1
	88.00	65.00	218.00	13.00	394.00	57.00	2.60	418.00	98.00	–	0.01	1,254.00	7.4
	59.00	39.00	226.00	13.00	129.00	83.00	3.60	446.00	57.00	–	0.01	997.00	7.8
	16.00	15.00	306.00	12.00	337.00	64.00	1.40	320.00	63.00	–	–	1,070.00	8.1
	55.00	36.00	236.00	12.00	126.00	80.00	4.30	441.00	63.00	–	–	992.00	7.4
	20.00	16.00	272.00	12.00	241.00	60.00	2.10	339.00	61.00	–	–	962.00	8.1
	252.00	121.00	1,141.00	28.00	118.00	305.00	6.30	2,203.00	40.00	–	–	4,173.00	7.5
ES70GC007	80.00	60.00	664.00	16.00	171.00	234.00	32.00	1,049.00	51.00	–	–	2,777.60	7.8
	70.00	58.00	197.00	6.60	196.00	61.00	2.50	445.00	66.00	–	–	1,262.80	7.3
	65.00	44.00	411.00	18.00	173.00	125.00	13.00	690.00	55.00	–	–	1,896.30	7.8
	106.00	96.00	251.00	13.00	253.00	213.00	65.00	529.00	67.00	–	–	1,750.00	7.8
	33.00	43.00	166.00	23.00	170.00	104.00	31.00	276.00	47.00	–	–	985.60	8.1
	83.00	65.00	464.00	17.00	150.00	156.00	14.00	868.00	59.00	–	–	2,215.50	7.5
	36.00	40.00	106.00	3.30	245.00	65.00	32.00	125.00	83.00	–	–	652.00	8.0
	124.00	161.00	212.00	6.80	275.00	365.00	247.00	420.00	81.00	–	–	1,812.00	8.0
	104.00	118.00	206.00	5.70	448.00	203.00	107.00	358.00	76.00	–	–	1,549.00	8.0
	55.00	39.00	318.00	18.00	157.00	104.00	7.00	568.00	62.00	–	–	1,444.10	7.9
ES70GC008	224.00	146.00	349.00	15.00	241.00	642.00	231.00	654.00	46.00	–	–	2,502.00	7.4
	113.00	101.00	447.00	14.00	290.00	265.00	25.00	836.00	36.00	–	–	2,090.00	7.8
	232.00	254.00	461.00	9.20	403.00	670.00	304.00	959.00	63.00	–	–	3,293.00	7.8
ES70GC009	216.00	175.00	153.00	16.00	1,164.00	367.00	4.80	250.00	137.00	–	6.00	2,345.00	6.4
	29.00	31.00	253.00	14.00	537.00	114.00	21.00	134.00	89.00	–	–	1,133.00	7.3
	51.00	62.00	289.00	12.00	354.00	193.00	40.00	342.00	35.00	–	–	1,343.00	7.8
	17.00	8.70	39.00	6.60	112.00	19.00	28.00	28.00	57.00	–	–	258.00	7.6
	18.00	10.00	30.00	8.30	95.00	13.00	31.00	34.00	71.00	–	–	238.00	7.8
	70.00	34.00	68.00	11.00	515.00	32.00	3.60	22.00	40.00	–	0.01	755.00	7.8
	14.00	12.00	13.00	2.50	96.00	6.40	5.10	16.00	69.00	–	–	166.00	7.9
	59.00	45.00	369.00	31.00	1,159.00	147.00	–	85.00	92.00	–	0.11	1,896.00	7.5
	20.00	9.70	28.00	9.00	127.00	12.00	16.00	25.00	49.00	–	–	246.00	8.0
	11.00	8.20	41.00	7.80	120.00	35.00	1.90	21.00	40.00	–	–	245.00	8.1
	25.00	19.00	27.00	6.80	204.00	12.00	7.10	19.00	92.00	–	0.10	320.00	7.1
	55.00	52.00	96.00	11.00	580.00	23.00	12.00	64.00	98.00	–	–	79.10	6.0
	15.00	10.00	15.00	3.80	98.00	5.80	13.00	19.00	70.00	–	–	171.50	7.5

Groundwater body	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	SiO_2	Fe	Mn	TDS	pH
	13.00	7.80	28.00	6.20	92.00	14.00	17.00	24.00	75.00	–	–	199.50	7.7
	6.00	2.80	37.00	4.70	98.00	5.90	8.40	17.00	33.00	–	–	179.00	8.1
	52.00	34.00	82.00	13.00	354.00	44.00	13.00	87.00	103.00	–	–	623.70	6.2
	4.70	8.90	12.00	32.00	1.20	25.00	52.00	91.00	50.00	0.06	–	187.00	8.2
	8.30	9.10	49.00	5.10	110.00	11.00	20.00	43.00	55.00	–	–	255.00	7.8
	112.00	46.00	108.00	19.00	774.00	51.00	11.00	44.00	92.00	–	2.00	1,165.00	6.6
	23.00	15.00	61.00	7.00	177.00	21.00	27.00	51.00	74.00	–	–	382.00	8.0
	15.00	11.00	15.00	3.20	95.00	4.00	12.00	17.00	82.00	–	–	172.00	7.8
	31.00	21.00	42.00	10.00	202.00	26.00	31.00	36.00	82.00	–	0.04	399.00	7.5
	9.10	5.00	19.00	3.30	50.00	4.00	14.00	23.00	56.00	–	–	127.00	8.1
	17.00	10.00	27.00	6.30	79.00	15.00	32.00	34.00	74.00	–	–	231.00	7.5
	60.00	45.00	110.00	13.00	445.00	28.00	9.00	137.00	101.00	–	0.01	847.00	7.3
	11.00	6.80	22.00	4.50	67.00	5.00	23.00	24.00	66.00	0.02	–	163.10	7.6
	76.00	44.00	48.00	14.00	549.00	6.80	7.60	27.00	95.00	–	2.00	630.00	6.0
	22.00	16.00	37.00	6.30	82.00	40.00	46.00	45.00	82.00	–	–	310.80	7.6
	67.00	69.00	53.00	6.60	640.00	12.00	12.00	35.00	80.00	–	0.01	895.00	7.2
	19.00	8.00	41.00	18.00	218.00	5.70	4.00	11.00	83.00	–	–	325.00	7.7
	22.00	9.80	47.00	8.20	144.00	22.00	24.00	36.00	53.00	–	–	312.00	7.5
	143.00	68.00	65.00	24.00	976.00	12.00	–	19.00	99.00	–	0.87	1,307.00	6.4
	38.00	20.00	76.00	13.00	409.00	6.30	4.80	20.00	72.00	–	0.02	441.70	8.2
	8.50	7.90	12.00	4.00	78.00	4.00	5.10	12.00	53.00	–	–	131.00	7.7
	85.00	53.00	558.00	62.00	1,790.00	189.00	–	137.00	72.00	–	1.00	2,873.00	6.6
	67.00	37.00	35.00	9.40	476.00	5.70	–	23.00	107.00	–	0.29	534.80	6.2
	50.00	30.00	73.00	5.90	315.00	82.00	7.80	56.00	56.00	–	0.16	618.00	7.3
ES70GC0010	36.00	21.00	166.00	9.50	245.00	118.00	90.00	112.00	52.00	–	–	784.70	7.7
	15.00	6.50	204.00	5.30	311.00	36.00	2.00	168.00	74.00	–	0.23	748.00	7.7
	388.00	499.00	1,461.00	58.00	509.00	650.00	60.00	3,662.00	86.00	–	0.01	7,287.00	6.2
	186.00	141.00	437.00	25.00	246.00	517.00	201.00	833.00	53.00	–	–	2,587.00	7.8
	99.00	59.00	371.00	31.00	376.00	164.00	–	600.00	57.00	–	0.65	1,699.00	7.8

Table 3
Maximum water flux recovery and dosage for each antiscalant.

Groundwater body	Water flux recovery (%)		Dosage (mg/L)	
	Antiscalant A	Antiscalant B	Antiscalant A	Antiscalant B
ES70GC001	62	39	16.49	3.18
	64	28	5.40	2.00
	65	45	13.96	2.68
	54	10	12.17	2.98
	54	7	8.70	2.33
ES70GC002	65	28	5.40	2.00
	73	56	4.05	2.00
	75	53	3.75	2.00
	69	38	4.65	2.00
ES70GC003	55	10	6.75	2.24
	75	61	3.90	2.00
	79	59	3.15	2.00
	71	44	4.35	2.00
	69	36	4.65	2.00
	56	10	6.60	2.62
	73	44	4.05	2.00
ES70GC004	64	27	5.40	2.00
	65	27	5.25	2.00
	73	44	8.84	2.00
	70	38	4.50	2.00
	62	22	5.70	2.00
	64	28	5.40	2.00
	69	36	4.65	2.00
ES70GC005	71	40	4.35	1.00
	64	25	5.40	2.00
	58	17	6.30	2.09
	71	54	4.35	2.00
	48	33	22.31	4.58
	73	46	4.05	2.00
	65	64	3.28	2.00
ES70GC006	81	67	2.85	2.00
	84	85	5.25	2.00
	80	58	3.00	2.00
	75	66	3.60	2.00
	75	57	3.75	2.00
	73	48	4.05	2.00
	82	56	3.30	2.00
	80	60	3.00	2.00
	54	6	6.90	2.37
	81	63	2.85	2.00
	70	67	4.50	2.00
	58	16	6.30	2.19
	76	53	3.60	2.00
	73	48	4.05	2.00
	73	46	4.05	2.00
	74	49	3.90	2.00
	82	67	2.70	2.00
ES70GC007	78	58	3.30	2.00
	72	44	4.20	2.00
	77	54	3.45	2.00
	72	44	4.20	2.00
	80	61	3.00	2.00
	75	50	3.75	2.00
	65	31	5.25	2.00
	66	33	5.10	2.00
	68	37	4.80	2.00
	74	48	3.90	2.00
ES70GC008	79	60	3.15	2.00
	76	70	2.75	2.00
	66	48	5.10	2.00
ES70GC009	70	41	4.50	2.00
	75	67	4.04	2.00
	71	43	4.35	2.00
	61	20	5.85	2.37
	79	59	3.15	2.00
	83	67	2.55	2.00
	61	20	5.85	2.00
	61	18	6.15	2.04
	71	39	4.35	2.00
	68	38	4.80	2.00
	86	73	2.10	2.00
	57	14	6.45	2.00
	79	58	3.15	2.00
	77	54	3.45	2.00
	50	23	7.50	2.52
	69	38	4.65	2.00
	72	32	5.10	2.00
	67	30	5.10	2.00
	86	53	4.00	2.00
	71	37	6.45	2.21
	57	14	6.30	2.00
	76	45	5.70	2.00
	62	21	7.50	2.00
	69	30	5.10	2.00
	66	32	5.10	2.00
	70	31	5.25	2.00
	78	54	3.30	2.00
	58	18	6.42	2.05
	70	40	4.50	2.00
	78	56	3.30	2.00
	69	40	6.45	2.06
	55	11	6.75	2.20
	76	51	3.60	2.00
	78	57	3.30	2.00
	69	38	4.65	2.00
	64	40	5.40	2.00
	70	39	4.50	2.00
ES70GC0010	70	39	4.50	2.00
	62	39	16.49	3.18
	64	28	5.40	2.00
	65	45	13.96	2.68
	54	10	12.17	2.98

specific cost of each antiscalant is very close. This difference in terms of specific cost between both antiscalant should be taken into account in the specific pre-treatments to reduce silica. From the experimental data and after removing some points which showed dosages outside "standard trend", two correlative equations were obtained:

$$SC_{\text{anti-A}} = 3.06 \cdot 10^{-5} \cdot R^2 - 6.30 \cdot 10^{-3} \cdot R + 0.33 \quad (1)$$

$$SC_{\text{anti-B}} = 1.50 \cdot \left(\exp\left(\frac{0.83}{R}\right) - \exp\left(\frac{0.19}{R}\right) \right) \quad (2)$$

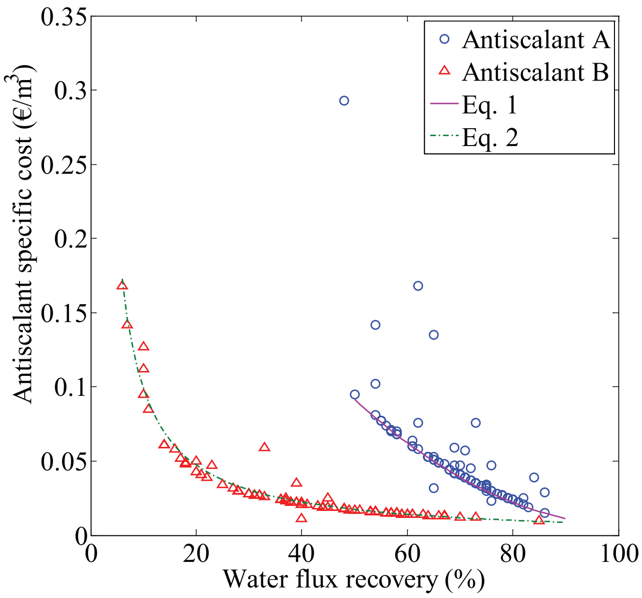

Fig. 2. Antiscalant specific cost vs. water flux recovery

where $SC_{anti\text{-}A}$ and $SC_{anti\text{-}B}$ are the specific costs for the antiscalants A and B respectively, and R is the water flux recovery in percentage. These equation estimates the antiscalant cost knowing recovery for the type of brackish water studied. The difference in terms of specific cost between the antiscalant products went from 0.074 €/m³ at R = 50% to almost 0 €/m³ from R~93%.

Considering a BWRO desalination plant with a typical production capacity of 500 m³/d in Canary Islands, working with R = 70%, the cost difference between using antiscalant A or B would be 410 €/month approximately. A silica mitigation pretreatment would be interesting in this region. For example if a BWRO desalination plant owner is using the antiscalant A, the use of a silica pretreatment that allow to use the antiscalant B would be interesting if the cost of this pretreatment is below 410 €/month.

4. Conclusions

Maximum water recoveries of different groundwater bodies in Gran Canaria were calculated. Silica was the most limiting compound in water flux recovery, so the antiscalant A was the most appropriate to reach higher recoveries. On the other hand, the price and dosing of the antiscalant A are higher than antiscalant B being necessary to evaluate the specific cost in both cases. The antiscalant specific cost for both products were evaluated providing two estimating equations related with the water flux recovery for both antiscalants. The results showed that the antiscalant A had a higher specific cost that antiscalant B for a wide range of recoveries. At very high recoveries (>90%), the difference is negligible. The specific silica removal pretreatments would be an option when the silica concentration in the feedwaters is very hight. The silica removal pretreatments should be taken into account in two situations:

- When the desired water flux recovery is not attainable with the antiscalant products available.
- For example if the specific cost of these processes plus the dosing of antiscalant B would be more cost effective than antiscalant A dosing.

In cases concerning the second situation, an economic assessment of the silica removal pretreatments is essential to determine whether pretreatment is viable or not in this region.

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