PREVENTION OF SCALE DEPOSITS IN DESALINATION: PRE-TREATMENT OF FEED SEAWATER BY SALTS PRECIPITATION

Aiman E. Al-Rawajfeh

Tafila Technical University (TTU), Department of Chemical Engineering,
P.O. Box 179, 66110 Tafila, Jordan. Tel.: +962-3-22 50 034, Fax: +962-3-22 50 431,
e-mail: aimanr@yahoo.com

ABSTRACT

In this work, salt precipitation at percentage of 0 to 100% pre-treatment was investigated. The precipitation process, includes reduction of sulfate and/or elimination of calcium and magnesium ions, has the following advantages: (i) reduction, or indeed elimination of the scaling problem on the heat exchanger surfaces, if a thermal desalting device is used by heating the feed water up to higher temperatures, or fouling on membranes surfaces if RO is used. This reduces maintenance and extends the materials and membranes life span, (ii) the compounds used in this process are safe and biodegradable, and (iii) the precipitates are valuable minerals and can be used in industrial and agricultural processes or can be used in post-treatment fresh water production. Top Brine Temperature (TBT), at which sulfate scale begins to precipitate, is shifted to higher temperatures with increasing the pre-treated portion. For 100% SP-treated feed, TBT reached 170^{o}C.

Keywords: Pretreatment; Salt precipitation; Divalent ions removal; Scale reduction.

INTRODUCTION

Pre-treatment of the feed water entering a desalination unit such as MSF involves reduction of salinity and hence reducing or in some cases eliminating scale forming species to a certain extent. This will increase the efficiency of the process, reduce the pumping power (in RO systems), reduce or eliminate the scale and consequently reduce the cost. In this work, two different methods of pre-treatment will be investigated and compared to apply the most applicable one or may be a combination of them. The first one is precipitation (Al-Rawajfeh and Al Zarooni, 2008) and the second is nanofiltration (Hussain and Al-Rawajfeh, 2009). The percentage of pre-treated feed will change from 0 to 100%. Precipitation process deals with supersaturating the saline solution by addition of chemical reagents which results in the precipitation, up to 80% or higher, of some of the salts in seawater. The purpose of co-precipitation process is to reduce the concentration of dissolved salts (solutes) in the feed water (solution), such as seawater, brackish water or industrial brine solutions so that it can be more effectively desalinated and higher percentage of fresh water can be recovered from it.

EXPERIMENTAL

For precipitation (Hussain and Al-Rawajfeh, 2009), each 1kg of the feed needs to be treated in two steps (Fig. 1):

1. In the first step, 2.8 g/kg feed of CaO are added to the precipitation tank and stirred for 5-10 minutes and then the mixture is permitted to settle. The clear water is filtered or simply decanted. The pH of the solution reaches 7.5. A white precipitate of mixed $CaSO_4$ and $Ca(OH)_2$ forms.
2. In the second step, (21.5 g/kg of Na_2CO_3 + 12.5 g/kg of NaOH) are added to the filtered or decanted water. After 5-10 minutes agitation and then settling, the gelatinous white precipitate of $MgCO_3$, $Mg(OH)_2$, $NaHCO_3$ and NaCl is removed by either filtration or decantation. The pH of the solution reaches 10. About 85% of the original water can be recovered.

PRECIPITATION PRE-TREATMENT

Fig. 1 illustrates the precipitation pre-treatment process. The feed water may be filtered first to remove sediments, marine life, and other solids. A sufficient amount of an alkaline salt; sodium hydroxide, sodium carbonate, potassium hydroxide, potassium carbonate, calcium hydroxide, calcium carbonate, aluminum hydroxide, aluminum sulfate, aluminum potassium sulfate (Hussain, 2007) calcium chloride (Jodand and Peron, 2000), or mixture of them is added to the sea water to bring its concentration up to about 60%, whereby a precipitate forms in the water.

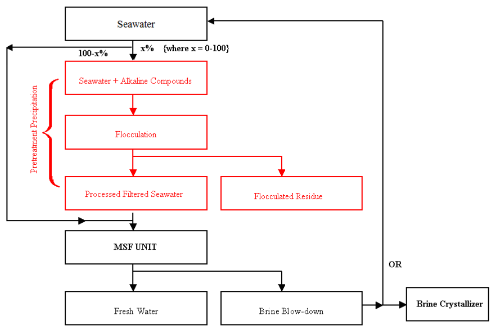

Fig. 1: Illustration of the precipitation pre-treatment process.

The feed water is then separated into two streams: processed filtered steam and flocculated residue stream. The processed filtered seawater is then desalinated using a suitable desalting device such as MSF, RO, or any other process (Hussain, 2007) to produce fresh water and concentrate discharge to the sea. The brine blow-down can be either fully or partially recycled and added to the feed water. If nanofiltration (NF) membrane is used (Jodand and Peron, 2000), the concentrate, in which salts are supersaturated up to 80%, is subjected to the following steps: crystallization-coagulation treatment, flocculation, and finally settling. It is advantageous to recycle the brine blow-down because of the following reasons: (i) make use of the remaining initially-added compounds, (ii) discharging it to the ocean has high environmental impact and can damage the marine life, and (iii) if a thermal process is used, the heat can be recovered during recycling.

The precipitation process, includes reduction (Hussain, 2007) or indeed elimination (Jodand and Peron, 2000) of calcium and magnesium salts, has the following advantages:

- reduction, or indeed elimination of the scaling problem on the heat exchanger surfaces, if a thermal desalting device is used by heating the feed water up to higher temperatures, or fouling on membranes surfaces if RO is used. This reduces maintenance and extends the materials and membranes life span
- the compounds used in this process are safe and biodegradable
- the precipitates are valuable minerals and can be used in industrial and agricultural processes or can be used in post-treatment fresh water production.

The effect of different percentage precipitation pretreatment was investigated. Table 1 shows the concentrations of the different species in the pretreated feed.

Table 1: The concentrations of the different species in the pretreated feed.

		% PPT-treated feed					
Ion	**Original**	**20**	**40**	**60**	**80**	**100**	**% Red. of the 100%**
Ca^{2+}	600	482.4	364.8	247.2	129.6	12	-98
Mg^{2+}	1550	1243.1	936.2	629.3	322.4	15.5	-99
K^{+}	500	507	514	521	528	535	+7
Na^{+}	14840	20063.68	25287.36	30511.04	35734.72	40958.4	+176
HCO_3^{-}	128	102.912	77.824	52.736	27.648	2.56	-98
CO_3^{2+}	38	70.072	102.144	134.216	166.288	198.36	422
Cl^{-}	26253	23312.66	20372.33	17431.99	14491.66	11551.32	-56
SO_4^{2-}	3440	3054.72	2669.44	2284.16	1898.88	1513.6	-56
TDS	47367	42061.9	36756.79	31451.69	26146.58	20841.48	-56

Fig. 2 shows Skillman index of the sulfate scale potential for seawater with 0 to 100% precipitation-treated make-up in BR-MSF reference plant. The scale potential increases with increasing temperature and decrease with increasing the percentage of 100% precipitation-treated feed. For 100% precipitation-treated feed, TBT can reach as much as 170^{o}C as shown in Fig. 3.

Techno-economic feasibility and commercial viability would require further simulation, evolution and pilot or, if possible, actual plant testing.

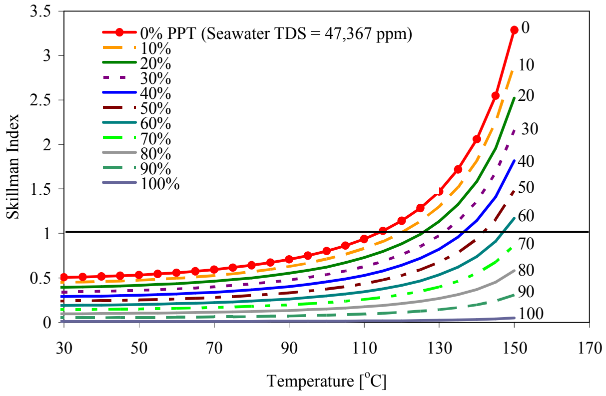

Fig. 2: Influence of precipitation pretreatment on sulfate scale potential in BR-MSF plant.

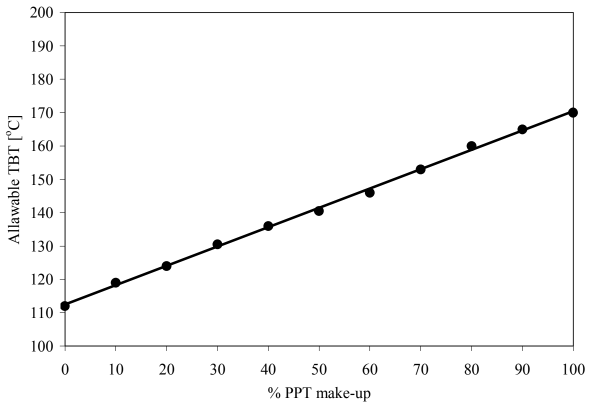

Fig. 3: Shifting the maximum TBT by precipitation pretreatment.

CONCLUSIONS

The sulfate scale potential is analyzed and modeled for integrated salt precipitation (SP) with multi-stage flash (MSF) evaporators. The scale potential increased with increasing temperature and decreased with increasing the percentage of precipitation-treated feed.

Consequently, the top brine temperature (TBT) is shifted to higher temperatures with increasing the pre-treated portion. For 100% SP-treated feed, TBT reached 170°C. Techno-economic feasibility and commercial viability would require further simulation, evolution and pilot or, if possible, actual plant testing.

REFERENCES

Al-Rawajfeh, A. E. and M. Al Zarooni. 2008. New Processes in Seawater Desalination. *Rec. Patents Chem. Eng.* 1: 141-150.

Hussain, A. A. and A. E. Al-Rawajfeh. 2009. Recent Patents on Nanofiltration Applications in Oil Processing, Desalination, Wastewater and Food Industries. *Rec. Patents Chem. Eng.* 2: 51-66.

Hussain, A. H.: US007198722B2 (2007).

Jogand, H. L. A., Peron, P. A. J. H.: US0060368667A (2000).