Performance Evaluation of SWRO Desalination Plant at Skikda (Algeria)

F. Ammour, R. Chekroud, S. Houli, and A. Kettab

1 Introduction

During the last decades, water resources have been intensively used in Algeria, added to a period of intense drought occurring in the zone, leading to water scarcity (Metiche et al. 2010).

Seawater and brackish water desalination is a strategic option for Algeria which has implemented an ambitious program of desalination of seawater with a production capacity of 2260 million M3 (Metiche et al. 2010; Kehal 2001).

Due to recent developments in membrane technology, the trend in the desalination industry is to use reverse osmosis (RO) for desalting seawater.

One of these plants is investigated in this study. It is an SWRO desalination plant of Skikda, located in the east of Algeria, commissioned in 2009, with a capacity of 100,000 m^3/day.

The most serious problem in BWRO and SWRO plants' operation is the complexity to control membrane fouling and scaling mainly due to frequent variation of quantity/quality of raw water (Arras et al. 2009).

The objective of this paper is to study the performance of the plant and identify the different shortcomings. The plant performance was established from the operation and maintenance data as well as from visits made to the plant.

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Fig. 1 Location of Skikda SWRO plant

2 Plant Description

2.1 Study Site

Skikda SWRO plant is located in the Sonatrach company industrial complex in the east of Algeria (Fig. 1).

2.2 Seawater Intake

The choice of the point of collection was decided after various studies to obtain a good quality of water all year round.

An SWRO desalination plant studied includes an open seawater intake. The water captured at a distance of 1431 m is conveyed gravitationally by canal of 2 m of diameter and collected in a tank.

The intake inlet point is located at a depth of 9 m.

2.3 Raw Water Characteristics

Raw water analysis is presented in Table 1:

Table 1 Raw water composition

Physicochemical analysis	
Ca^{2+} (mg/l)	464.21
Mg^{2+} (mg/l)	1278.94
Na^{+} (mg/l)	12301.65
K^{+} (mg/l)	487.89
Al^{3+} (mg/l)	1
Sr^{2+} (mg/l)	5.12
SiO2 (mg/l)	25.42
Cl^{-} (mg/l)	21611.96
SO_4^{2-} (mg/l)	3087.03
HCO_3^{-} (mg/l)	133.45
F^{-} (mg/l)	1.37
CO_3^{2-} (mg/l)	0.39
Alkalinity (mg/l $CaCO_3$)	110.08
Turbidity (NTU)	1.3
T (°C)	27
PH	6.49
Conductivity (μS/cm)	54463.21
STD (mg/l)	39377.53

2.4 Operating Conditions

Operating conditions at Skikda SWRO desalination plant are shown in Table 2.

2.5 Pretreatment and Posttreatment

The pretreatment has a prevalent importance as well on physicochemical and microbiological qualities of permeate as on the longevity of the membrane.

On arrival at the station, the raw water must undergo disinfection. NaOCl is used at the concentration of 5 ppm. The residual chlorine is then removed by dosing of an average of 1.8 ppm of sodium bisulfite.

Sulfuric acid is dosed as carbonate antiscalant to destroy carbonate/bicarbonate in the feed at the concentration of 37.7 ppm.

Ferric chloride is employed in the coagulation step at the concentration of 6 ppm.

The seawater is filtered through 25 pressure sand filters (the first filtration) to remove suspended solids. Then it passes through 15 anthracite filters (second filtration).

Ten cartridge filters of 5 micron are installed just before the high pressure pumps to protect RO membranes from fouling. This pretreated seawater feed has an $SD1 < 3$.

The quality of the produced permeate does not meet all end-use requirements, hence the need for its additional treatments. The water stabilization and alkalinity

Table 2 Operating conditions

Design capacity (m^3/day)	100,000
Hours of operation per day (h)	24
Hours of operation per year (day)	355
Seawater intake capacity (m^3/h)	8.998
Seawater salinity (ppm)	39.381
Seawater temperature (°C)	24
Volume of rejected water (m^3/h)	4831.56
Recovery (%)	47
The quality of the permeate (ppm)	<400
Pressure OI (bars)	67.8

adjustment is done by the passage of permeate on a bed of dolomite, to increase the pH from 5.03 to 8.08.

Product chlorination is done as a final step to prevent growth of microorganism during water distribution or storage.

2.6 RO Units

Filtered water is aspired by high pressure pumps and is driven back with a pressure of 67.8 bars, before being sent toward the tubes of pressure for the separation of salt and water. Each module contains seven spiral wound polyamide membranes. The minimum salt rejection is 99.45%.

The brine is discharged into the sea, at a distance of 714 m, with insufficient dilution.

The technical characteristics of the high pressure system are shown in Table 3.

3 Plant Performance Evaluation and Improvements

Quality parameters of permeate are grouped in the following table. The product water from this plant is within Algerian potable water standards (Table 4).

As mentioned earlier, the Skikda plant is built with polyamide membranes and utilizes seven elements, per pressure vessel.

Membrane cleaning was carried out four times per year. Chemicals used in cleaning membrane are limited to three: citric acid, soda, and biocide.

Cleaning products must be neutralized before their discharge at sea.

Since Skikda plant commissioning, the membranes have been changed only once. Indeed, the chlorine and bisulfite dosing errors caused serious membrane damages during the first year of the Skikda plant operation. Membranes used in the Skikda plant are very sensitive to chlorine, which should be completely removed, to zero chlorine level, from the feed; otherwise the membranes will be damaged.

Table 3 Technical characteristics of high pressure system

Total pumped water flow	4.317 m^3/h
Number of pumps in operation	5
Minimum temperature of raw water	18 °C
maximum temperature of raw water	27 °C
Seawater density	1.0257
Seawater viscosity	0.9266
Pressure losses in pipings and valves	1.4
Pressure at the inlet of the membranes	66.1 bars
Pressure of aspiration of the pump	2.00 bars
Total pump output pressure	67.8 bars
Pump efficiency	84.5%
Number of membranes by module	7
Type of membrane	Arrollamiento en espirale
Material of membrane	Polyamide aromatique
Maximum specific feed	13.96 $l/m^2/h$

Table 4 Quality parameters of permeate

TDS (mg/L)	<400
Alcalinity (mg/l $CaCO_3$)	65
Hardness (mg/l $CaCO_3$)	50–65
pH	8–8.5
LSI	0–0.4

The Major problem at the Skikda plant is biological fouling of the cartridge filter and the desalination unit. One of these reasons is the reduction of the chlorine dosing due to the incident mentioned above.

The second possible reason for the biological fouling is that the chlorine residence time is insufficient to cause 100% kill of microorganisms, allowing for the passage of some live microorganisms to the cartridge filter and the desalination part of the plant (Ata et al. 1989; Fernandez-Torquemada 2005; Kamel and Chheibi 2001).

This problem can be solved by optimizing the chlorination-dechlorination stage or by replacing chlorine with copper sulphate (CuSO4).

Scaling phenomena, fouling, and chemical degradation affect the performance of the desalination System (Maurel 2001; Ammour 2014):

- Decrease in flow.
- Increase in salinity.
- Increase in pressure losses.
- Reduction of the lifetime of membranes.

The second major problem at the Skikda plant is in the treatment plant, which, in times of flooding, failed to produce the proper SDI, i.e., SD1<3. This deterioration of water quality is due to an increase in turbidity and to the haulage of suspended

Fig. 2 Corrosion in the cartridge filters

sediment and the colloidal matters by the Wadi Safsaf, whose mouth is located near the station. The SDI at the entrance of the membrane increases up to 5, which requires the complete stop of the station in winter.

This problem can be solved by increasing the dose of coagulant and injecting a flocculant.

Another problem encountered in the Skikda plant is material corrosion in pretreatment, especially in the cartridge filters and sand filters, as shown in Figs. 2 and 3.

This corrosion is due to the washing of sand and anthracite filters by the brine and the quality of the material chosen for the joints, fittings, and valves.

4 Conclusions

The pretreatment has a prevalent importance as well on physicochemical and microbiological qualities of permeate as on the longevity of the membrane and equipment. This needs a good operation and maintenance program.

In this paper the performance evaluation of SWRO desalination plant was carried out, and recommendations are suggested to resolve these problems. The plant performance was established from the operation and maintenance data as well as from visits made to the plant.

Fig. 3 Corrosion in sand filters

The SWRO plant supplies a good quality drinking water to Skikda town and Sonatrach company industrial complex. The product water is within Algerian potable water standards.

The first major problem at the Skikda plant is biological fouling of the cartridge filter and the desalination unit. This problem can be solved by optimizing the chlorination-dechlorination stage or by replacing chlorine with copper sulphate (CuSO4).

The second major problem is the deterioration of water quality and the SDI increase up to 5 at the entrance of the membrane, which requires the complete stoppage of the station in winter.

This problem can be solved by increasing the dose of coagulant and injecting a flocculant.

Another problem encountered at the Skikda plant is material corrosion in pretreatment, especially in the cartridge filters and sand filters. This corrosion is due to washing of sand and anthracite filters by the brine and the quality of the material chosen for the joints, fittings, and valves. Also, the plant performance is rated well without serious consequences on equipment and material over the 5 years of operation.

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