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Membrane autopsy to provide solutions to operational problems of Jerba brackish water desalination plant

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ABSTRACT

Fouling in membrane filtration processes is problematic. Causes are often specific depending on feed water constituents, the membrane and the chemical products used. Some fouling will badly affect membrane performance and cleaning will therefore be necessary. Cleaning can be supported by antiscalant treatments to reduce the risk of membrane fouling. However, some antiscalants may also lead to fouling. This paper presents the major problems of reverse osmosis plant in Jerba Island, namely the influence of antiscalant type on the water characteristics and membrane fouling. This was related to the increase of pressure drop, permeate conductivity and cleaning frequency. To identify the causes of membrane fouling, different investigations were carried out. Membrane autopsy, chemical analysis of feed water, follow-up of the operation parameters. The objective of membrane autopsy, by means of SEM/EDS, was to carry out a destructive analysis on a fouled membrane in order to identify the major causes of fouling. The results show that the film was composed mostly of organic matter, with significant presence of nitrogen, iron and silicates. These findings demonstrate how the antiscalants altered the water characteristics. Thus, the selection of the type of antiscalant should take into account the associated contribution to membrane fouling development.

1. Introduction

Reverse osmosis is a frequently used process in desalination and progressive water treatment. Scaling and fouling are the most serious problems in the efficient operation of reverse osmosis systems. Foulants may be classified into four major categories: sparingly soluble inorganic compounds, colloidal or particulate matter, dissolved organic substances and microorganisms [1,2].

Fouling leads to a loss of membrane performance, for instance, increase of pressure drop, poor product quality and decrease of flux, to a point where it may become necessary to replace the membranes [3].

Inorganic scaling occurs when the product of the concentration of the soluble components exceeds the solubility limit [4]. Particulate fouling is caused by convective and diffusive transport of suspended or colloidal matter [5]. Organic fouling is governed in part by interactions between the membrane surface and the organic foulants and between the organic foulants themselves [6]. Biofouling is caused by attachment and proliferation of microorganisms at the membrane surface [7] leading to the formation of biofilms, which consist of microbial cells implanted in an extracellular polymeric substances matrix produced by the microbes [8].

To characterize fouling development, many parameters, such as permeate flux, permeate conductivity and pressure drop, are measured. However, this method is incomplete for identifying the fouling categories. To identify the types and quantities of the deposit, the membranes have to be examined and autopsied.

Dudley and Darton [9] have adopted a procedure for studying R.O fouling elements which uses chemical analysis and membrane autopsy. They have shown that iron was a significant contributor to the fouling of the membrane. John et al. [10] used many techniques which revealed that the antiscalants were responsible for the fouling of the membrane. Bouguecha et al. [11] demonstrated that the major problems of RO are owed to failure of pretreatment. Ang et al. [12] proved that there is an interaction between antiscalants and substances in the solution and that the antiscalants modify the properties of the foulants in the water as well as the characteristics of the membrane surface. This affects the overall performance and fouling propensity of the membrane separation process.

This paper presents the autopsy results of a spiral membrane of the Jerba brackish water desalination plant and the relationship between the types of antiscalant and membrane performance.

A range of techniques were used in this investigation to identify and

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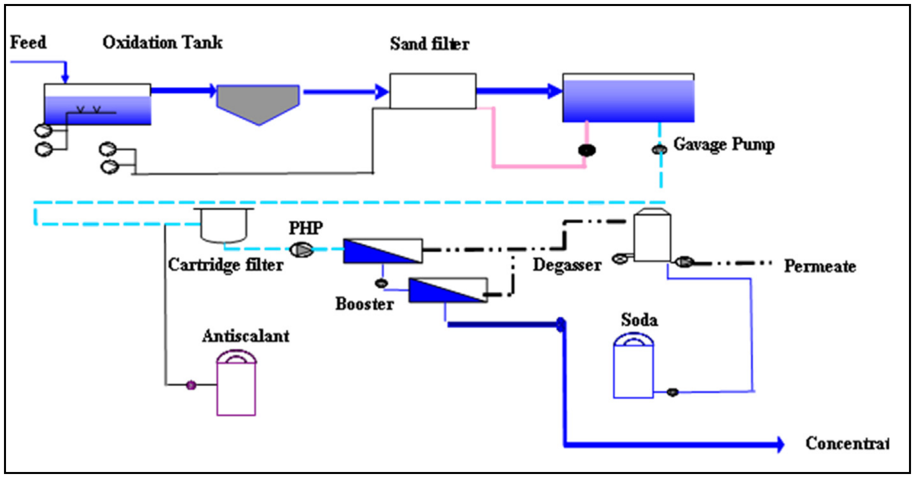

Fig. 1. Process schemes of the Jerba desalination plant (one line).

quantify the membrane foulant, namely chemical analysis of feed water and scanning electron microscopy (SEM). Both the surface and the cross-section of the fouled membrane were analyzed to investigate the nature and the development of the fouling layer.

2. Material and methods

2.1. Plant description

The plant is located on the Jerba Island in Southern east of Tunisia to provide the drinking water for the inhabitants. This Island has developed rapidly due to touristic activity. This unit started to run in 2000 operating continuously with nominal capacity of 15.000 m^3/day, a conversion rate of 75% and a feed water salinity between 5.5 and 6.5 g/L.

It consists of four major components (Fig. 1):

1) advanced pre-treatment in which untreated water to be oxidize and filtered later in sand bed then pumped to the second components; 2) conventional pre-treatment consisting of, micron cartridge to remove fine suspended matter (MES) (5 µm) and anti-scaling to prevent scale formation; 3) reverse osmosis system composed of three units, containing 252 spiral membranes each (hydranautics type); 4) the post-treatment is the final quality control of water supply in which pH permeate is adjusted by the addition of sodium hydroxide (NaOH) and the elimination of CO_2 Operating parameters such feed water conductivity, feed pressure, pressure drop, recovery and permeate conductivity were taken every day.

2.2. Aquifer water

The analysis results of the Mio-Pliocene aquifer water used as feed to the reverse osmosis (RO) plant are given in Table 1.

It consists of about 6.5 g/L total dissolved solids and presents a variable concentration of hydrogen sulfide (H_2S) and iron (fe) reaching respectively 48 and 1.25 mg/L. The basin of oxidation aids in the removal of any iron present in the feed water by converting the soluble ferrous iron (Fe^{2+}) into insoluble ferric iron (Fe^{3+}) which along with suspended matter is removed by the sand bed. The feed water temperature has been quite constant over the 15-year period, i.e. 29 °C.

In Jerba RO plant, two processes have been carried out to overcome the problem of sulfuric water [5]:

- Oxidation: This treatment was tested for a short time and was eliminated for environmental considerations.
- Anaerobic treatment: This process is applied particularly to the first line during short periods. However, this application requires preservation of the anaerobic conditions as well as the use of large quantities of sulfuric acid and soda. The latter is used to neutralize H_2S which is why this process is used only for peak periods.

Table 1
Analysis of brackish water of Jerba Island.

Elements	Concentration
T, °C	28–30
pH	7–8
TDS mg/L	5300–6500
CE µS/cm	7160–8200
TOC mg/L	0–6
HCO_3^- mg/L	94–224
Cl^- mg/L	1500–2200
SO_4^{2-} mg/L	1300–1900
NO_3^- mg/L	0–1
Hardness °F	90–185
Ca^{2+} mg/L	190–340
Mg^{2+} mg/L	95–240
Na^+ mg/L	920–1800
K^+ mg/L	19–28
Fe^{2+} mg/L	0–1.25
F^- mg/L	0.1–1.5
H_2S mg/L	0–48
SiO_2 mg/L	8
Sr^{2+} mg/L	4
Ba^{2+} mg/L	0.001

2.3. Operating data and normalization

2.3.1. Membrane monitoring

Fig. 2 shows the fluctuation of the feed pressure of 3 lines. For example, the feed pressure of first line was around 13 bars at the beginning and increased up to 15.4 bars due to performance decay, especially fouling, scaling and compaction throughout these years [40]. Moreover, during 15 years of operation, the increase in pressure drop presented the main problem. In the first months of operation the increase of pressure drop was acceptable. However, after a long operation period, the increase was significant in the two stages but it was more remarkable in the first stage (Fig. 3).

The feed pressure and the pressure drop decreased in relation to membranes replacements (Table 2) and of course chemical cleaning (Table 3).

2.3.2. Membrane cleaning

Periodic membrane cleaning is very important in water treatment