Desalination and Water Treatment
www.deswater.com
9 (2009) 54–58

Groundwater treatment by reverse osmosis: Effect of brine recycling on fouling

M. Belkacem*, S. Bakhti, S. Aomraoui

University of Sciences and Technology of H. Boumediene
F.G.M.G.P. Laboratory of Process and Environmental Engineering
B.P. 32 El Alia 35111Algiers, Algeria
Tel./Fax. 213 (21) 24 71 69; email: belkacemed@yahoo.fr

Received 15 September 2008; Accepted 5 November 2008

ABSTRACT

The aim of this study is focused on the efficiency of groundwater treatment by reverse osmosis (RO). The treated water, which is used for beverage industry, must be according with the standard qualities. In this fact, two reverse osmosis modes were studied. The first one without brine recycling, and the second one with partial brine recycling (50%). The treatment is followed by the measurement of the water permeate flow and the treated water conductivity. The results showed that the second mode carry to membrane fouling. However, in spite of this disadvantage, the second mode compared to the first one, allow to decrease the water consumption by approximately 25% in a year.

Keywords: Reverse osmosis; Fouling; Agroalimentary industry; Groundwater; Recycling of brine

1. Introduction

In the last decades, the membrane processes acquired a great development in the water treatment for agroalimentary industry. Reverse osmosis process is usually used to produce drinking water of high quality for beverages industry. This technique can be used effectively to remove salts from the aqueous solutions and to reduce both the organic and inorganic matter concentrations [1,2]. This technique also leads to a better elimination of the total dissolved solids while offering the possibility of retention of all pathogenic microorganisms classes [3].

However, membrane fouling resulting from the foulant accumulation on the membrane surface is the major cause of the RO system failure. RO membrane fouling is a complex phenomenon involving the deposition of organic, inorganic and biological material in the form of particulates or colloidal suspensions [4]. Membrane fouling results in several deleterious effects, including a decrease in water production because of a gradual decline in flux, an increase in applied pressure required for a constant rate of water production, a gradual membrane degradation which results in a shorter membrane life, and finally a decrease in the permeate quality [5].

In addition, the conversion rate, represented by the ratio permeate flow on feed flow, being relatively weak, the quantity of rejected water (brine) is significant.

The present study was carried out on two reverse osmosis plants, in a manufacturing unit for the treatment of beverage industry water. These two units function with different modes: without recycling and with partial recycling of the rejection (brine). In a first stage, the effectiveness of the treatment by reverse osmosis was characterized by studying the variation of the permeate conductivity as a function of time. In a second stage, the evolution of the permeate flow enabled us to carry out a first approach on the parameters having a direct incidence on the membranes fouling.

2. Materials and methods

The primary source of raw water in the beverage industry was local groundwater located in Rouiba

*Corresponding author.

Presented at the Conference on Membranes in Drinking and Industrial Water Production, 20–24 October 2008, Toulouse, France.

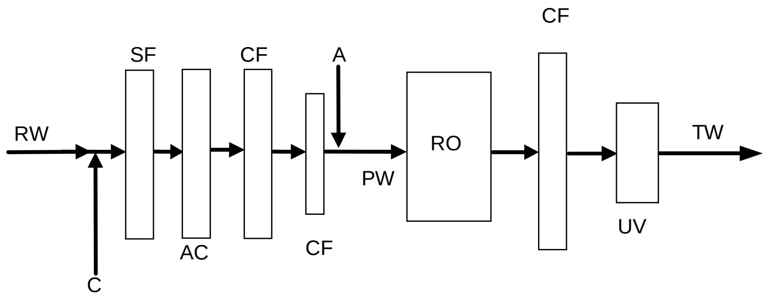

Fig. 1. Pretreatment plant. RW: Raw Water ≡ Groundwater, C: Chlorination, SF: Sand Filter, AC: Activated Carbon, CF: Cartridge Filter, A: Antiscalant addition PW: Pretretead Water, RO: Reverse osmosis unit, UV: Ultra violet TW: treated Water.

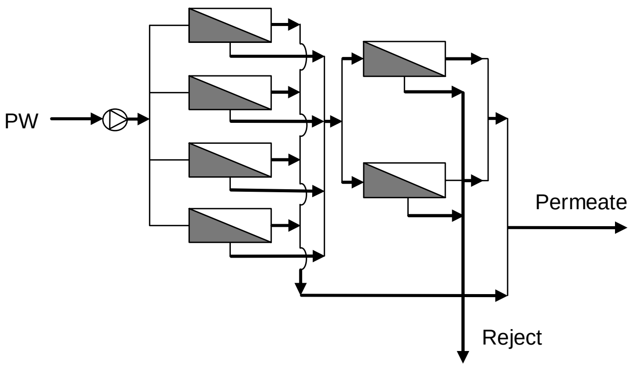

Fig. 2. Reverse osmosis plant, without brine recycling mode (Unit I).

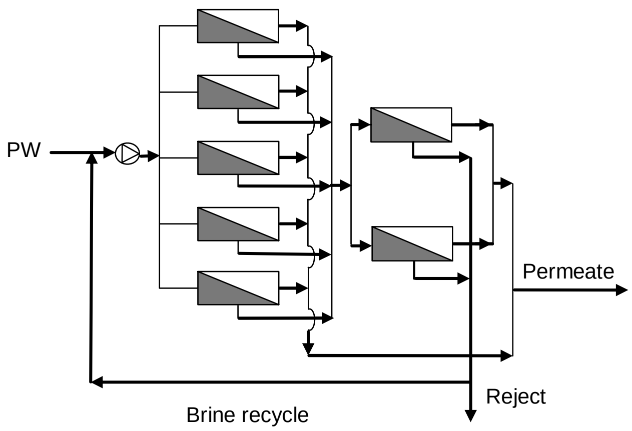

Fig. 3. Reverse osmosis plant, with 50% brine recycling mode (Unit II).

(Algiers). The raw water was pretreated before being supplied to the RO plants (Fig.1).

Water crosses the pretreatment stage, which consists of an injection of sodium hypochlorite as disinfectant, and a series of initial filtration steps to remove particulate matter and colloidal solids from the water, these include sand filters, activated carbon filters, and microfiltration cartridge filter of 10 µm and 2 µm respectively. At the upstream of the RO plant, injection of antiscalant is carried out in order to inhibit precipitation of sparingly solutes at the membrane surfaces. The water stream coming from the pretreatment unit is then processed in the RO plants. Finally, the permeate passes through filters of 1.2 µm, then is disinfected by UV irradiation.

2.1. Without brine recycling mode (Unit I)

The reverse osmosis plant, depicted on Fig. 2, consists of six pressure vessels which were arranged in two stages (Fig. 3), the first one with four vessels and the second with two vessels. The first stage brine is the second stage feed water. Each of the pressure vessels of the RO plant contains five spiral wound polyamide membranes (BW30LE-440 FilmTec) having an active area of 41 m^2. The RO brine of the second stage is continually rejected. The pressures are respectively equal to 16 bars (pretreated water), 1 bar (brine) and 2 bars (permeate).

2.2. With partial brine recycling mode (Unit II)

Seven pressure vessels containing 35 modules are present in the reverse osmosis plant, depicted in Fig. 3, the first one with five vessels and the second with two vessels. The first stage brine is the second stage feed water. Each vessel contains five membrane modules. Part of the RO brine of the second stage is recirculated to the feed of the first stage, whereas the other part is continually rejected. This recirculation mode enabled the recovery of 50% of the rejected brine.

The pressures are respectively equal to 12 bars (pretreated water), 1 bar (brine), 4 bars (brine recycle) and 2 bars (permeate).

3. Results and discussions

3.1. Effectiveness of reverse osmosis treatment

The results of the physicochemical analysis carried out on raw, pretreated, and permeate samples are presented in Table 1 for unit II (with 50% brine recycling mode). The raw water delivered by the groundwater contained significant amounts of solutes and suspended solids (TDS ranging from 757 to 965 mg/L). In addition, the compositions of this water in terms of the most important ionic

Table 1
Composition of groundwater, pretreated water, and permeate.

Parameters	Raw water	Pretreated water	Permeate	Purification
Turbidity (NTU)	1.3	0.167	0	100
Conductivity (µs/cm)	1600	1200	100	95
TH (°F)	49	42	0.6	98.6
Ca^{2+} (mg/L)	159	128	5.79	95.5
Mg^{2+} (mg/L)	23	20	1.6	92
Cl^{-} (mg/L)	218	113	7.93	92.9
SO_4^{-2} (mg/L)	130	140	1	99.3
Na^{+} (mg/L)	92	63	2.53	95.9
K^{+} (mg/L)	1	1	0.07	93.4
NO_3^{-} (mg/L)	33.5	27.68	3.27	88.2
HCO_3^{-} (mg/L)	310.4	271	12.2	95.5
TDS (mg/L)	964	753	25	96.7
pH	7.22	7.71	6.6	-
TA	0	0	0	-

species showed that, the raw water is reach of sulphate, chloride and calcium and highly furring. The quality of water produced from the pretreatment demonstrate that turbidity undergoes the strongest reduction (87%); it was reduced from 1.3 to 0.167 NTU. In addition, we observe that reverse osmosis membranes enables considerably larger rejection of ions of pretreated water, mainly due to the possibilities of RO process. The percentage rejection exceeded 95% for the overall analysed ions. However, the rejection of nitrate was about 88.2%, what is slightly lower that for the other solutes case.

Figure 4 shows the evolution of permeate conductivity versus time. This one fluctuates around a value of 110 µS/cm for unit II. For unit I, the evolution of conductivity show that the reverse osmosis membranes make it possible to preserve conductivity lower than 90 µS/cm. In both cases, conductivity remains lower than standards of ABC Pepsi (150 µS/cm). The conductivity of feed water was about 1600 S/cm for the two units, the reduction is around 95%.

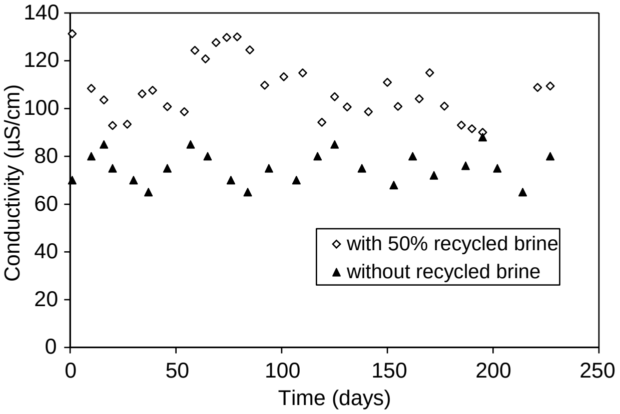

Fig. 4. Evolution of permeate conductivity according to time.

3.2. Removal efficiency of microorganisms

The analyses carried out upstream and downstream from reverse osmosis plants are showed in Figs. 5 and 6 for units I and II respectively.

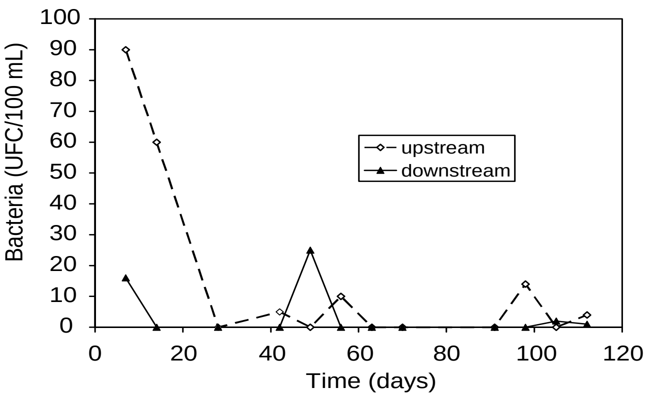

Fig. 5. Bacteria enumeration at the upstream and downstream of the RO installation I (without recycling brine).

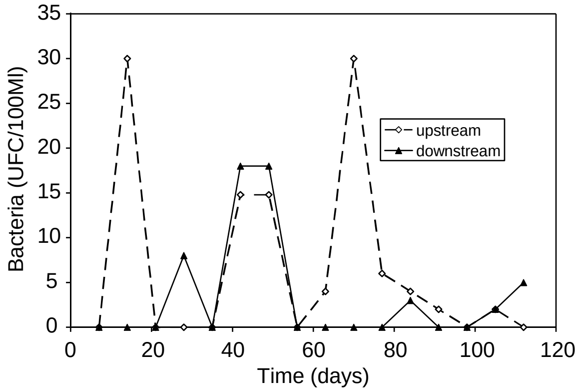

Fig. 6. Bacteria enumeration at the upstream and downstream of the RO installation II.

The membranes reduced the total germs present in the feed water. The average number of bacteria decreased from 6 CFU/100 mL in the upstream to 3.33 CFU/mL at the downstream for the unit I, and from 15.58 CFU/100 mL in the upstream to 3.75 CFU/mL at the downstream for the unit II. It is well known that reverse osmosis membranes reject bacteria with 100% rejection rate. There are sometimes more bacteria in the downstream than in the upstream of the RO units. This can be explained by a bacteria development on the level of the pilot. However, in both cases the bacterial number is in accordance with the beverage industry standards (50 CFU/mL).

In addition, we noted that the produced waters are free from coliforms.

3.3. Brine recycling effect on fouling

The results of average permeate flux for units I and II are plotted in Fig. 7. According to this figure, the average permeate flux remains practically constant during 12 weeks of operation for unit I whereas for the mode with partial recycling, a slow reduction in the flow is noted. After 12 weeks of operation, the reduction reaches 10%. A chemical cleaning was required to restore the flow with its initial value. This observation is in agreement with the study of Gouellec and Elimelech [6] and Gwon et al. [7]. The reduction in flow shows that the recirculation of brine, even if it is partial, already generates the increase in the ionic species present in the feed stream, which supports systematically the membrane fouling.

3.4. Brine recycling effect on conversion rate

The conversion rate of a filtration process is the fraction of current feed entering a membrane module, which crosses the membrane and leaves the module in the form of permeate, it is given as follows:

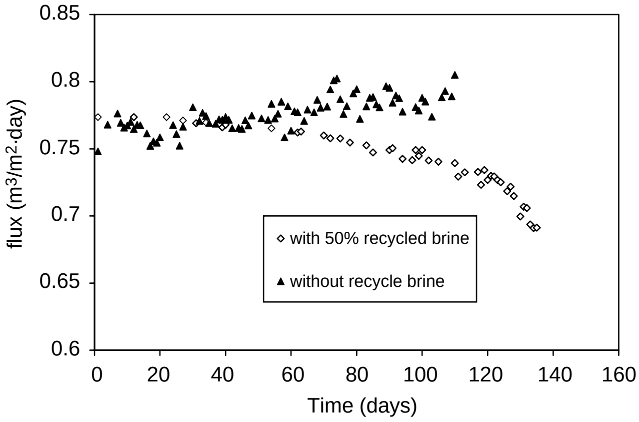

Fig. 7. Evolution of average permeate flux with time.

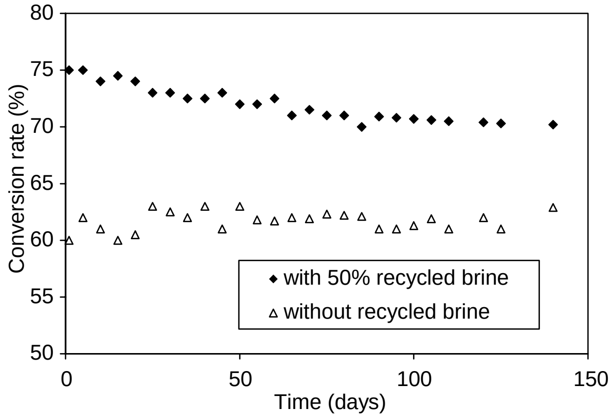

Fig. 8. Evolution of conversion rate with time.

$$Y = \frac{Q_p}{Q_f}$$

Q_p: permeate flow rate (m^3/h)
Q_f: feed flow rate (m^3/h)

The variations of the conversion rate for units I and II are plotted in Fig. 8.

In the case without recycled brine (unit I), the conversion rate ranges between 60% and 65% whereas for unit II, this one accounts for 75% at the beginning of operation and falls to 70% after 3 months of operation. Consequently, the process with 50% recycled brine reduces the water consumption. However this mode of exploitation presents major disadvantages, in particular the significant salinity of recycled water, the fouling of the membranes which leads systematically to chemical cleaning and consequently to the increase in the operating costs of this unit.

4. Conclusion

The treatment of beverage industry water by reverse osmosis is perfectly adapted. Salinity and consequently the osmotic pressure, being relatively low, flow through the membrane is important; this remains valid when the pressures applied are not very high.

Bacteriological quality is in conformity with the standard required. In addition, the retention is higher than 95% for the totality of the ions contained in the feed water, which can be interpreted as a good separation and show that the permeate is in agreement with the necessary standards.

The comparative study of the physico-chemical parameters on the level of the two units showed that fouling for unit I (without recycling) is negligible compared to unit II (50% recycled brine). However, the latter reduces by 25% the water consumption.

References

[1] C. Murray-Gulde, J. E. Heatley, T. Karanfil, J. H. Rodgers, J. E. Myers, Performance of a hybrid reverse osmosis constructed wetland treatment system for brackish oil field produced water, Water Research, 37 (2003) 705–713.

[2] M. Belkacem, S. Bekhti, K. Bensadok, Groundwater treatment by reverse osmosis, Desalination, 206 (2007) 100–106.

[3] K. Karakulski, M. Gryta, A. Morawski, Membrane processes used for potable water quality improvement, Desalination, 145 (2002) 315–319.

[4] J.S. Vrouwenvelder, J.W. N. M. Kappelhof, S. G. J. Heijman, J. C. Schippers, D. Van der Kooij, Tools for fouling diagnosis of NF and RO membranes and assessment of the fouling potential of feed water, Desalination, 157 (2003) 361–365.

[5] H. Y. Ng, M. Elimelech, Influence of colloidal fouling on rejection of trace organic contaminants by reverse osmosis, Journal of Membrane Science, 244 (2004) 215–226.

[6] A. Yann Le Gouellec, M. Elimelech, Calcium sulfate (gypsum) scaling in nanofiltration of agricultural drainage water, Journal of Membrane Science, 205 (2002) 279–291.

[7] E. Gwon, M.Yu, H. Oh, Y. Lee, Fouling characteristics of NF and RO operated for removal of dissolved matter from groundwater, Water Research, 37 (2003) 2989–2997.