DESALINATION

Desalination 221 (2008) 298–302

www.elsevier.com/locate/desal

Water produce for pharmaceutical industry: role of reverse osmosis stage

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Received 19 December 2006; accepted 3 January 2007

Abstract

The aim of this work is the performance study of the various stages of groundwater treatment in a pharmaceutical industry. We were particularly interested in the influence of the reverse osmosis on the data processing sequence. The water quality was evaluated in terms of conductivity; the performances of RO treatment were evaluated in terms of rejection of different species in the groundwater. Also, fouling potential of groundwater was investigated.

Results indicate that the reverse osmosis process is well adapted for this treatment; the retention is more than 99% for the totality of solutes. The conductivity of water to be treated decreases by 1770 µs/cm to 15 µs/cm.

To be in agreement with the standards of pharmaceutical industry, a deionizer placed at the exit of the osmosor allows decreasing the conductivity down to 0.5 µs/cm.

Keywords: Reverse osmosis; Deionizer; Fouling; Groundwater; Membrane; Pharmaceutical industry

1. Introduction

When the standards quality are not very constraining, the traditional treatments are sufficient to purify groundwater for industrial applications.

In many cases, for pharmaceutical and food industries, it is necessary to remove the mineral and organics micro pollutants to obtain water as close as possible to the "ultra pure water" element.

The membranes technologies, nanofiltration and reverse osmosis, seem to be the technology of the future for this type of separation. These techniques have the following advantages:

- Reduction of the operating costs,
- Small overall dimensions,
- Possibility of automatic exploitation of the process.

Although this technique has an industrial development, its rise is slowed down by intrinsic

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Presented at the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.

doi:10.1016/j.desal.0000.00.000

phenomena with the membrane techniques: polarization of concentration and fouling [1].

Membrane fouling resulting from the foulant accumulation on the membrane surface is the major cause of 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 [2,3]. Membrane fouling results in several deleterious effects, including a decrease in water production due to gradual decline in flux [4].

Fouling refers to pore plugging and external pore blocking, resulting from deposition of particles and colloids on the membrane surface and precipitation of smaller dissolved materials within the membrane pores and on the membrane surface [5]. Pore blocking is important in the fouling mechanisms of ultrafiltration (UF) and microfiltration (MF) membranes by colloids and macromolecules, but its role is insignificant in reverse osmosis (RO) and also nanofiltration (NF) membranes. RO membrane fouling also has arisen as precipitate fouling or fouling by biological growth [6,7].

In this study, a follow up was conducted for six month of groundwater RO operation plant at the pharmaceutical industry. The performances of RO treatment were evaluated in terms of rejection of different species in the groundwater.

2. Materials and methods

2.1. Brief description and operation of the plant

The primary source of raw water was a local groundwater located in Algiers. The experiments were carried out at the pharmaceutical manufacturing unit SAIDAL Dar El Baida, Algeria.

The raw water was pre-treated before being feed to the RO plant (Fig. 1). Water passed to the pre-treatment section, which consists of settling tank (ST), an injection of sodium hypochlorite as a disinfection aid, a passage through a series of initial filtration steps to remove particulate matter and colloidal solids from the water, these included sand filters (SF), activated carbon filters, and microfiltration cartridge filter (CF1) of 10 μm. A softener (SR1) and microfiltration cartridge filter (CF2) of 3 μm close the pre-treatment.

The water stream coming from the pre-treatment unit was then processed in a RO plant operating according to the scheme illustrated in Fig. 1.

Six modules constitute the reverse osmosis plant depicted in Fig. 1. They are arranged in two stages in serial, which two modules in every stage (Fig. 2). Each of the pressure vessels of the RO plant containing a spiral wound polyamide membranes (BW30LE-440 FilmTec) having a surface area of 35 m^2.

The permeate is stored in 12 m^3 tank (TS1) which also serve as storage tank. From this tank,

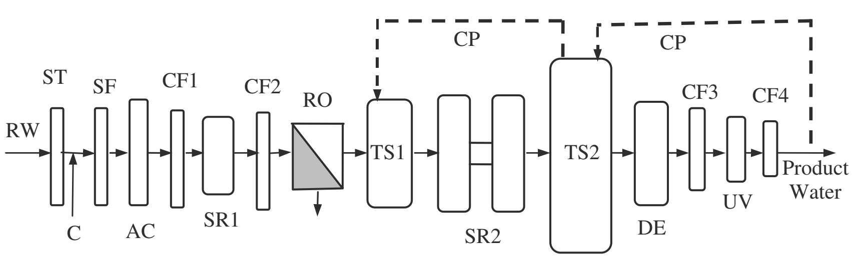

Fig. 1. Scheme of the full scale treatment plant. RW: raw water ≡ groundwater, SR: softener, ST: settling tank, RO: reverse osmosis, C: chlorination, TS: tank storage, SF: sand filter, DE: deionizer, AC: activated carbon, UV: ultraviolet irradiation, CF: cartridge filter, CP: cleaning phase.

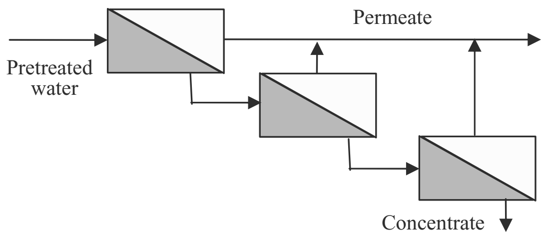

Fig. 2. Reverse osmosis scheme.

a pump sends water in a softening unit (SR2) Elite Pro Duo 310.

After storage in a tank, the permeate passed trough final processing circuit which includes a deionizer (DE), a microfiltration cartridge filter (CF3) of 1 μm, a generator with UV and microfiltration cartridge filter (CF4) of 0.2 μm. Finally treated water is delivered to the different dies of production and washing.

2.2. Water quality characterization

Produced waters were characterized by measuring water quality parameters prior to treatment, following pre-treatment step and finally, treatment with reverse osmosis and deioniser. Total dissolved solids and the electrical conductivity were measured using a 6 p ultra meter (Myron L Company). Alkalinity was measured by titration according to AFNOR norms. Calcium, sodium, potassium, sulphate, iron, chloride, and nitrate were measured using atomic absorption technique.

3. Results and discussion

3.1. Physicochemical analysis

The results of the physicochemical analysis, summarized on Table 1, showed that the raw water delivered by the groundwater contained significant amounts of solutes and suspended solids. In addition, the compositions of this water in terms of the most important ionic species showed that, the raw water is rich of chloride, calcium and magnesium.

The quality of water produced from the pretreatment demonstrate that turbidity undergoes the strongest reduction, on the level of sand filter (SF) it was reduced from 0.46 NTU to 0 NTU.

The chlorine, introduced during chlorination is completely eliminated on the level from the activated carbon module.

Table 1
Physicochemical analysis

Parameters	RW	ST	SF	AC	SR1	RO	SR2	DE
Turbidity (NTU)	0.46	0.41	0	0	0	0	0	0
Conductivity (μs/cm)	1644	1662	1477	1689	1770	15	0.61	0.59
PH	7.52	7.38	7.41	7.26	6.48	6.76	5.91	5.57
TH (°f)	27	27	27	27	0	0	0	0
Ca_2^+ (°f)	16	16	16	16	0	0	0	0
Mg_2^+ (°f)	9	9	9	9	0	0	0	0
HCO_3^- (°f)	32.5	32.5	32.5	32.5	32.5	2.5	0.4	0.4
Na^+ (mg/L)	100	83	83.3	83.3	133	3.4	0.2	0.2
Cl_2 (mg/L)	0	0.7	0	0	0	0	0	0
K^+ (mg/L)	1	1	1	1	0.05	0.03	0.01	0.01
DBO (mg/L)	5	3	3	1	1	1	1	0
DCO (mg/L)	0	0	0	0	0	0	0	0

The ions Ca^{++} and Mg^{++} are totally eliminated on the level from the softener, which decreases the furring capacity of water.

In addition, we observe that reverse osmosis membranes enable considerably larger rejection of the rest of ions, mainly due to the possibilities of RO process. The percentage rejection exceeded 95% for the overall analysed ions; the conductivity is equal to 15 μs/cm.

At the exit of deionizer, the latter decreases up to 0.59 μs/cm, which leads have a pharmaceutical water of process in conformity with the standards.

3.2. Effectiveness of reverse osmosis treatment

Before the installation of the RO unit, the regeneration of the deionizer was made once per week; when the pharmacopoeia norms required conductivity lower than 1 μs/cm it was made two to three times per day. This situation has the following disadvantages:

- The saturation of the resins being done too quickly, successive regenerations did not allow any more one production of sufficient deionised water.
- Increase in the consumption of the reagents of regeneration.
- The successive rinsing, rejection of acids and basic solution in the natural environment, have a negative impact on the environment.

In order to limit the number of cycles of regeneration, water supply at the entry of the deionizer must have a lower conductivity, to achieve this objective an RO unit was installed with the upstream of the deionizer.

A deionizer is necessary in chains of water treatment for pharmaceutical industry; the conductivity of water at the exit of the RO unit (15 μs/cm) is higher than the standards of the pharmacopoeia (conductivity lower than 1 μs/cm).

3.3. Permeate flux

The average permeate flux is the most commonly used parameter to indicate the performance of a RO process. The average permeate flux in full-scale RO can be easily measured by dividing the total permeate flow rate by the total membranes surface area.

The results of average permeate flux are plotted in Fig. 3. It can be seen from this figure, that the average permeate flux remains roughly constant during 12 weeks of operations.

In previous studies, we showed that the principal reason of the reduction in permeate flux be the fouling of the membrane by the ions Ca^{++} and Mg^{++} which lead in a layer of sediment to the surface of the membrane in $CaCO_3$ and $MgCO_3$ forms [8]. For this case, constant flow is explained by the fact that these ions were completely eliminated on the level from the softener.

3.4. Permeate conductivity

Fig. 4 represents the variations of the permeate conductivity versus time for each stage. The shape of the curves is the same one but with higher values for stage 3. This is due to the fact that the feed of the third stage is charged, the concentration

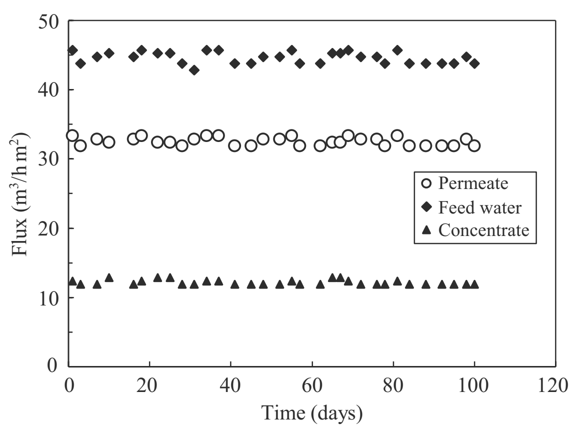

Fig. 3. Evolution of flux with time.

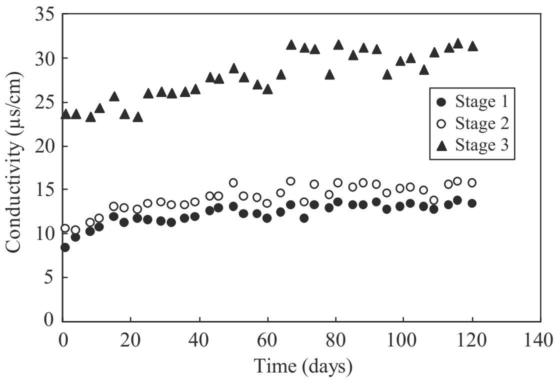

Fig. 4. Evolution of conductivity with time.

of the feed having a direct influence on the selectivity of the membrane.

For each stage, one notes a weak reduction in the rate of retention according to time, which leads to a reduction in the selectivity.

Although in the literature there are few data characterizing these phenomena during the treatment of a groundwater, the majority of the authors consider that fouling influence in a very significant way the retentive properties of the membranes.

During our tests fouling being negligible, the reduction in the selectivity remains however weak for 12 weeks of operation, what did not lead to a significant variation of conductivity at the exit of the deioniser.

4. Conclusion

The results obtained show that reverses osmosis plant is perfectly adapted for the groundwater treatment in a pharmaceutical industry.

The RO unit limits the regeneration cycles of deionizer, consequently, the chemicals used at the time of the regeneration are less, which preserve environment.

At one hand, salinity and consequently the osmotic pressure are relatively low, the permeate flux is important. At the other hand, treatment achieved by reverse osmosis unit effectively decreased conductivity of the groundwater more than 95% for the totality of ions.

At the exit of deionizer, the latter decreases up to 0.59 μs/cm, which leads have a pharmaceutical water of process in conformity with the standards.

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