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Phosboucraa desalination plant for the phosphate industry — optimization of process unit and RO performance

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ABSTRACT

The phosphate industry is a big consumer of water. In Morocco, water consumption by the phosphate industry located in the southern region represents approximately 14% of the national industrial consumption. To solve the problem of water shortage in that region, the Cherifian Office of Phosphates have been using desalinated water. After a brief presentation of the genesis of desalination at the Phosboucraa site, the paper reports on the new RO desalination plant. The performance of the plant and the results of the optimisation operations are described. The advantages of desalination by reverse osmosis compared with multi-stage-flash or thermal compression are presented.

Keywords: Desalination plant; Phosphate washing; Reverse osmosis; Optimization; Performances

1. Introduction

Water shortage is among the most severe problems that Morocco is facing in this 21st century. Several sectors of economic activities suffer from scarcity of fresh water. The phosphate industry is among these sectors. It is one of the first economic resources in Morocco. The phosphate industry is exclusively managed in Morocco by the Cherifian Office of Phosphates (OCP). The group is present in five geographical zones of the country, three mining sites and two chemical transformation sites. OCP offers a varied range of products: raw phosphate, phosphoric basic acid, cleansed phosphoric acid and fertilizers [1,2].

The phosphate industry is a big consumer of water. The consumption is estimated to 0.5 to 2 m^3/T of produced phosphate. In Morocco, the water consumption by the phosphate industry exceeds 60 million m^3/year. It represents approximately 14% of the national industrial consumption. The principal uses are in washing processes, flotation, the phosphoric acid industry, cooling, dilution and evacuation of phosphogypsum and in power production [3].

To solve the problem of the water shortage, the Cherifian Office of Phosphates, has for a long time been using non-conventional water resources such as wastewater reuse in Khouribgua (central Morocco) or desalination (in Laayoune, south Morocco).

In 2006, OCP built a desalination plant to produce some 1,200,000 m^3/year of desalinated water with salinity lower than 20 ppm for phosphate washing. This plant substituted the former thermo compressor (TC) plant. Indeed, the high content in chlorides in the raw phosphate of the mining site of Boucraa, requires a

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wash with desalinated water to meet the requirements of the international market [4].

2. Water requirements for Phosboucraa site and the genesis of the desalination

The phosphate treatment in Phosboucraa site requires an annual need in fresh water of about 1,200,000 m^3 with salinity lower than 20 ppm. The produced ultra-pure water is mainly used in rinsing the washed phosphates with the sea water and to supply the boilers of the vapor groups.

Figure 1 presents the process of phosphate rinsing. It consists of:

- desalinated water supply,
- conveyor of rinsing phosphates for drying, and
- two spherical tanks with two rectangular tanks for separation, sedimentation and for the recycling of filtrates.

Desalination at Phosboucraâ started in 1973. The first plant was a MSF thermal process. In 1989 the MSF plant was replaced by a thermo compressor (TC) plant. The installation of the desalination plants was accompanied by an effort to optimize the consumption of desalinated water for phosphate rinsing. The optimization concerned:

- Management of the water consumption according to the quality required by the customer, particularly the chlorine content of the rinsing product.
- Stabilization of washing and rinsing lines and consequently the filter line.
- Improvement of the regulation buckle of the rinsing water flow.
- Improvement of the filter performances.

These operations reduced the consumption of the rinsing water by more than 50%. It was reduced from 0.8 to 0.45 m^3 per ton of produced phosphate. Figure 2 gives the results of the optimization during the period 1995–2004.

In spite of these efforts, the energy cost of the desalination remained high, in particular with the increase in the fuel prices which doubled in some years. After several studies and consultations, the OCP decided in 2004 to use reverse osmosis (RO) a less energy-consuming technology for desalination. The first phase of 2000 m^3/d started in 2006. The second of the same capacity started six months later. Table 1 summarizes the desalination history of the studied site.

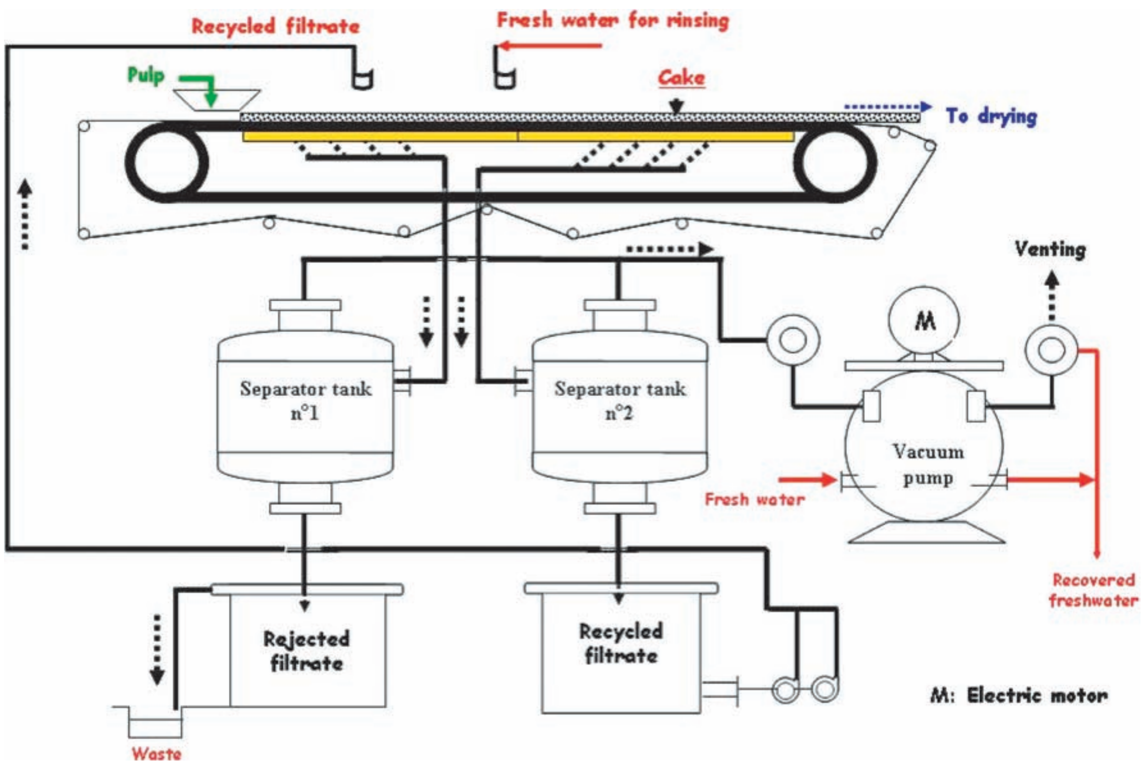

Fig. 1. The phosphate rinsing process. M: Electric motor.

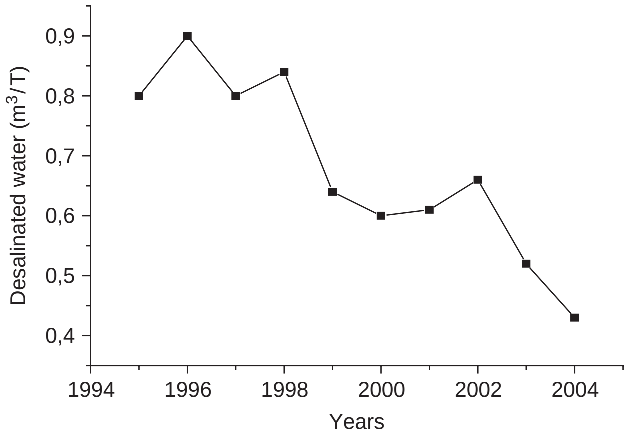

Fig. 2. Optimization of the consumption of desalinated water for rinsing of phosphates.

Table 1
Desalination history of Phosboucraa site.

Process	Multi Stage Flash MSF	Thermo Compressor TC	Reverse Osmosis RO
Produced capacity (m^3/d)	2 × 3,500	3 × 2,000	2 × 2,000
Produced water quality (ppm)	< 10	< 15	< 20
Period	1973–1988	1989–2005	Since 2006

3. Phosboucraâ RO desalination overview

Figure 3 gives the overview of the Phosboucraa RO desalination plant which was manufactured by Veolia Corporation (France). It consists of four main stages:

1. Seawater intake
2. Pre-treatment
3. Reverse osmosis
4. Storage and distribution

The sea water intake is located around the plant. Seventeen beach wells were prepared. The average depth of every beach is of 40 m and the diameter is of 14 thumbs. The capacity of each well is 280 to 320 m^3/h.

The raw water is characterized by a relatively good bacteriological quality and a very low organic content. The total dissolved solids (TDS) are about 37,000 mg/l.

The pretreatment was planned to conform the pre-treated water to the RO membrane requirements. After pre-chlorination at the plant entry, coagulation and flocculation are operated using polymer flocculants and ferric chloride, followed by a sand filtration through ten (5 × 2) sand filters of OFFSY type to remove suspended solids from the feed water. The sand filters are periodically backwashed with raw water and air to ensure the good permanent quality of the feed water. The following stage of the pretreatment is the injection of sulfuric acid to attenuate the precipitation of calcium carbonate and an antiscalant agent to ensure the

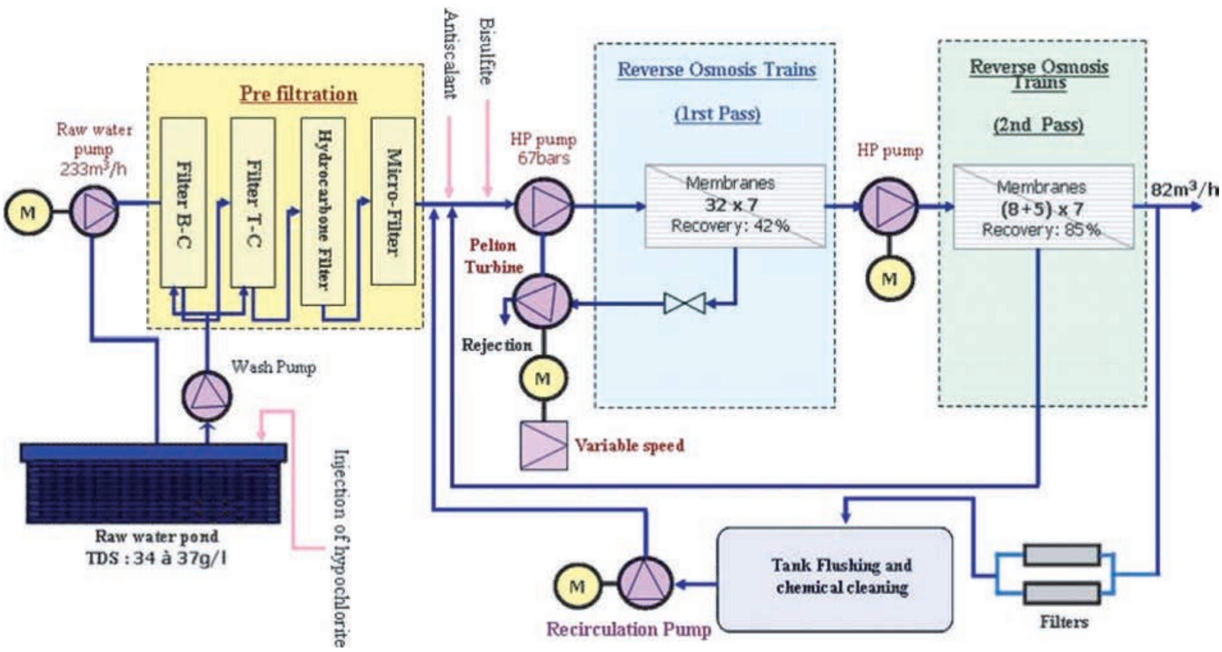

Fig. 3. Schematic overview of the Phosboucraa desalination plant. HP pump: Haute pressure pum, M: Electric motor.

inhibition of sulfate salt and eventually iron scaling. All the operations are ensured automatically.

The pretreated water was dechlorinated by sodium bisulfate and sent through a 5 µm microfilter to ensure a final safety filtration to protect high pressure pumps and RO membranes. The pretreatment and RO section of the plant are divided into two independent lines, A and B, each with a capacity of 2,000 m^3/d (83 m^3/h). To ensure the lower salinity of the produced water, the plant was designed in double pass.

Each line was equipped with a high pressure pump for the first pass, that boosts the pressure of the feed water at around 60 bars and another pump for the second pump that boosts the pressure of the permeate of the first pass at around 15 bars. The high pressure pumps of the first pass are coupled to turbines for brine energy recovery. The plant is equipped with a pressure regulator to compensate automatically the change in membrane permeability.

The first pass of each line consists of 2 trains, each equipped with 112 elements SWHR320 Filmtec membranes with a recovery rate of 42%. The second pass of each line is equipped with 91 elements BW30-400 Filmtec membranes with a recovery rate of 85%.

The trains of the second pass have two stages (56 elements in the first stage and 35 in the second). The salinity of the produced water is less than 20 mg/l. The produced brine by the second pass (3–4mg/l) is much lower than the sea water. It is recycled in the entry of the first pass.

The produced water by the plant is used directly for phosphate washing without any post-treatment. The RO system is equipped with a flushing tank filled with the permeate of the first pass for flushing the membranes and with a cleaning system for cleaning the membranes. The brine is rejected directly in the sea.

All the stages of the plant are followed and controlled automatically by software and control systems.

4. Plant operations

Line B started in August 2005 and line A in June 2006. The plant was commissioned in 2007 and it reached its full capacity in January 2007.

It was observed after three months of functioning that the quality of feed water remained good and constant. Consequently the coagulation and flocculation stages were eliminated. During the six first months, the line B of the plant functioned following the contractual parameters. From the seventh month, the pressure increased slightly and reached maximal values after 12 months. The decrease of the permeability was compensated at the beginning by the increase of the pressure, but from the tenth month, it began perceptible because the pressure reached maximal values. The second pass seemed not affected by this phenomenon. The pressure did not vary significantly but the flow decreased owing to the reduction of the flow of the first pass.

Figure 4 gives for line B (first pass), the variations of the applied pressure at the entry of the trains of membranes and the permeability of the membranes of the first pass, during the first year of the plant functioning.

The increase of the pressure was attributed to membrane biofouling. The inspection of the equipment upstream of the membranes of the first pass showed the existence of gelatinous matter. The biofouling was attributed to the possible bacterial proliferation after the chlorine neutralization by sodium bisulfate and to antiscalant injection post. It was proved that bacteria can resist to the chlorination effect and after neutralization a very important development happened on the microfilter which was used as support for bacterial development [5]. Moreover a greenish thick of mold was observed in the container of antiscalant injection indicating bacterial proliferation. This was attributed to the non renewal of the antiscalant periodically. To overcome these phenomena, the SBS injection point was moved from upstream to downstream and the container of the antiscalant was cleaned and the product was renewed periodically. Before these actions, a cleaning operation using a commercial product on the basis of hydroxide was conducted following the constructor recommendations in November 2006. The cleaning operation allowed for the recuperation of more than 90% of the initial performances of the plant.

Figure 5 gives the variations of the pressure and of the permeability of the membranes of the first pass of the line A during the first year of the plant functioning.

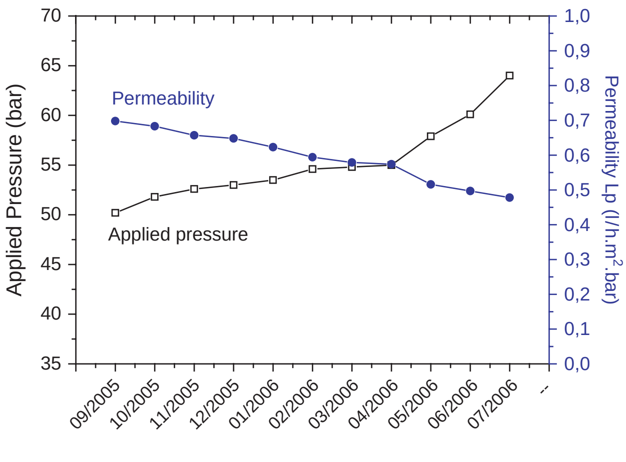

Fig. 4. Variations of the applied pressure (bar) and the permeability Lp (l/h.m^2.bar) for line B (first pass).

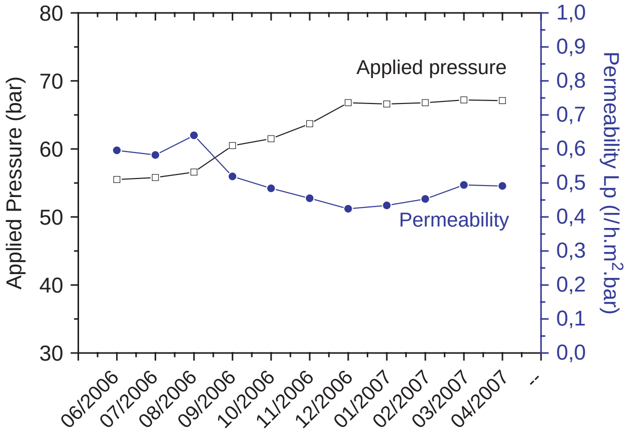

Fig. 5. Variations of the applied pressure (bar) and the permeability Lp (l/h.m2.bar) for the line A (first pass).

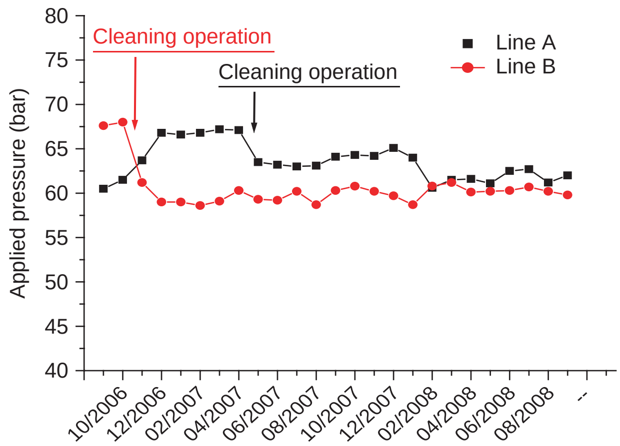

Fig. 6. Variations of the applied pressure (bar) at the entry of the lines A and B (first pass).

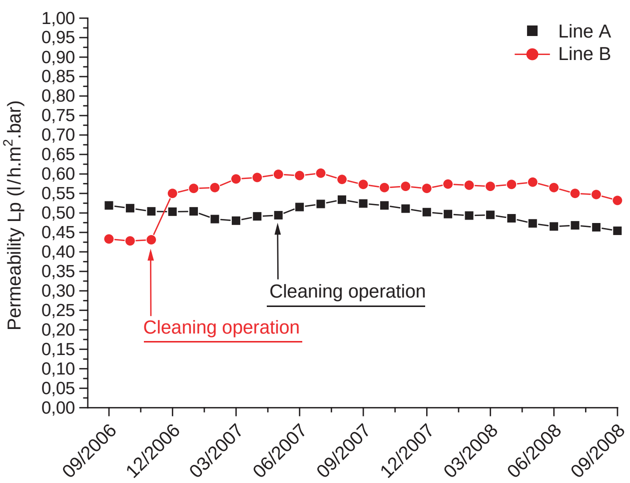

Fig. 7. Variations of the applied pressure (bar) at the entry of the lines A and B (first pass).

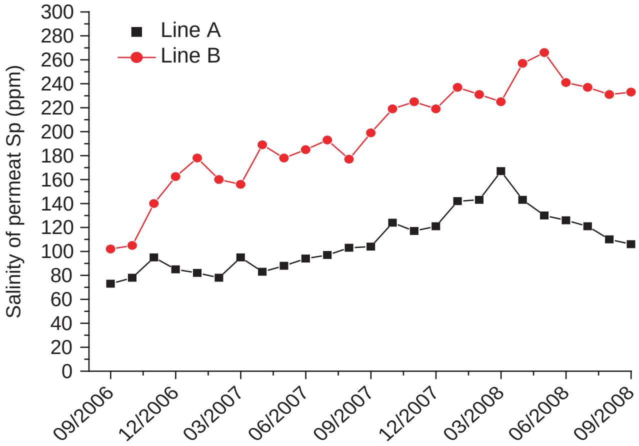

Fig. 8. Variations of the salinity (ppm) of the permeate for the lines A and B (first pass).

Table 2
The mean performances of the desalination plant.

Parameter	Mean performance
Conversion rate first pass	41–42 %
Conversion rate second pass	84–86 %
Pressure	53–67 bars
Flow rate first pass	92–100 m^3/h
Flow rate second pass	78–84 m^3/h
Producted TDS first pass	150–200 ppm
Producted TDS second pass	5–20 ppm
Energy consumption	5 kWh/m^3

The same phenomena as for the line B were observed. The biofouling occurred and the maximal pressure was reached after seven months. The cleaning was operated after one year of functioning. It was not necessary to make it before because the produced quantities were widely enough for the phosphates wash. After cleaning the same actions as those conducted for line B, were carried out for the line A.

Figures 6, 7 and 8 give the variations of the pressure, of membrane permeability and of salinity of the permeate of the line A and B (first pass) since the cleaning operations and during two years. The performances of the plant remained practically the same since the cleaning operations. Table 2 gives the mean performances of the plant.

5. Conclusion

Despite some problems that appeared in the beginning, Phosboucraa SWRO plant is in good operating conditions since 2 years. After 3 years and owing to

Table 3
Comparison of TC and RO processes.

Process	TC	RO
Produced capacity (m^3/day)	6,000	4,000
Water quality (ppm)	TDS < 10	TDS ≈ 5 ppm
Used energy	Fuel-oil and electricity	Electricity
Fuel-oil consumption (kWh/m^3)	10	0,00
Electricity consumption (kWh/m^3)	2.16	4–5
Production cost ($/$m^3$)	4–5	1.4–1.6

some optimization actions, the plant performances meet the contractual requirements and some time better. There was no replacement yet in two lines and just one operation cleaning of line B and line A.

The replacement of TC process by RO had the following advantages (Table 3):

1. Reduction of the production cost of desalinated water.
2. Elimination of fuel dependence (heavy logistics, costs of storage, and fluctuation in the market).
3. Simple maintenance and exploitation.
4. Improvement of the working conditions.
5. Cleaning process because no emission of toxic gas.

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