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Brackish and Seawater Desalination by a Pilot-scale Reverse Osmosis

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ABSTRACT — Millions of people have no access to a secure source of fresh water. Nevertheless, since many arid regions are coastal areas, Desalination of seawater and brackish water by reverse osmosis is a reasonable alternative.

The main objective of the present work is the study of a reverse osmosis plan operation. We have especially worked on the effect of pressure and salinity on the production and quality of the water produced. The performed work is purely experimental and is part within the framework of improving the profitability of an RO device. During this period of experimentation a physicochemical and bacteriological analysis of the permeate was carried out.

Keywords: Desalination process; reverse osmosis (RO); membrane; pure water.

I.Introduction

Most of the water available on earth has the salinity up to 10,000 ppm whereas seawater normally has salinity in the range of 35,000–45,000 ppm in the form of total dissolved salts. According to World Health Organization (WHO), the permissible limit of salinity in water is 500 ppm and for special cases goes up to 1000 ppm. Excess brackishness causes the problem of health. The annual water availability of 1000 m^3 per capita constitutes the limit below which it will not be possible to guarantee an acceptable living standard as well as economic development [1]. One of the control measures includes supply of water with total dissolved solids within permissible limits of 500 ppm or less. This is accomplished by several water desalination and purification methods.

Algeria has an area of 2,381,741km^2 and a population of about 33 millions. It is the Africa's second-largest country and the eleventh in the word in term of land area. The country is divided into four main physical regions.

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The first region located in the north is the Mediterranean coastline of 1200km in length, where most of the country's population (80%) and industry are concentrated. The second region is the Tell which extends 80–190 km inland from the coast. The next region, lying to the south and southwest is the High Plateau; a highland region of level ground together with the mountains and massifs of the Saharan Atlas of the south region. The fourth region, comprising more than 80% of the country's total area, is the great expanse of the Algerian Sahara [2].

Desalination has become an imperative and inevitable solution for Algeria to overcome its current shortage of potable water. Having exploited seawater desalination largely for industrial use since the sixties, Algeria is now in a hurry to exploit this technology to quench the thirst of its citizens. The total production capacity of the operating plants in Algeria is 661,920 m^3/day. About 47% of it is produced by multistage flash (MSF) and multiple-effect distillation (MED), 44% by reverse osmosis (RO), 5.5% by vapor compression (VC) and 3% by electro-dialysis (ED). More than 67% of the total desalinated water is produced from seawater, 22% from brackish water, 8% from river water and the rest from other sources. The major user of the desalinated water is municipalities with about 49% followed by industries with 45%. The rest is by power, tourist places, military and other sectors [3].

An experimental study has been carried out by the Center of Development of Renewable Energies (CDER). It consists of testing in real conditions of a small reverse osmosis unit coupled to a solar generator. The experimental site is located in the small village of Hassi-Khebbi situated in a desert zone 1400 km southwest ofAlgiers. This installation produces nearly 1000 I/h of fresh water from underground brackish water.[4]

Mohamed et al [5] presented the experimental results of a small seawater RO system, installed at the University of Athens, equipped with an ERD of the Clark pump type.

Fawzi Banat et al [6] presented an design and sizing of the small scale PV-RO unit components for water supply in rural areas.

II. Experimental

In our laboratory we acquired a 100 l / h low reverse osmosis pilot (fig 1). This experimental reverse osmosis system consists of a high pressure pump (PHP) model in stainless steel with variable pressure (plunger pump) which offers a pressure of up to 105 bar. This pump is placed on a 304 stainless steel base connected to a valve that allows to control the inlet pressure. A high-pressure gauge is installed to measure pressure.

The pilot contains two spiral membranes placed in a casing in series so that the concentrate of the first membrane is received by the second. A flow meter placed at the diaphragm outlet is used to control the permeation rate and hence the conversion rate. The various electrical power cables are grouped in an electrical box with an on / off circuit breaker. The high pressure pipes are made of 316L stainless steel. The low pressure pipes are made of polyvinyl chloride PVC. Two filter cartridges for filtering water at 5 microphones are located behind the stainless steel frame which carries all the components of the equipment and others (conductivity meter on the production line, flushing valve, automated panel ... Ect).

Fig1. Reverse Osmosis pilot installed in the DDEMS laboratory

III. Results and discussions

In order to study the effect of salinity on the permate quality we have prepared two different synthetic solution, so for low salinity, we used the well water of UDES characterized by a salinity of 7.7 g/l, to obtain hight salinity a quantity of salt is added to have a salinity of 32 g / l. The water was taken in sterile bottles with a capacity of 0.5 L for bacteriological analysis. The next tables show the corresponding results.

Table 1. permeate microbiological analysis

	Low salinity	**Hight salinity**
Total coliform bacteria	0	0
Fecal coliforms	0	0
E-Coli	0	0
Salmonella	0	0
Clostridium	0	0
streptocoques	0	0

We note from the table 1 that there is absence of any germ after treatment and this for the two different salt concentration.

Table 2. Permeate Physico-chemical analysis

	Low salinity	**Hight salinity**
Temperature(°C)	18.5	18.2
pH	7.74	7.10
Salinity (g/l)	0.00	0.05
Conductivity(ms/cm)	0.397	4.64
MES (mg/l)	1	4
TDS (g/l)	0.53	6.2
Ammonium(mg/l)	0.0139	0.0555
Nitrites(mg/l)	0.0110	0.1017
Nitrates(mg/l)	33.54	1.29
Phosphates(mg/l)	0.0115	0.3416
Chlorides(mg/l)	92.3	0
Carbonates(mg/l)	0.009	0.0097
Sulfates (mg/l)	388.51	346.90

We note from the table 2 that the permeate Physico-chemical parameters are influenced by the salt amount in the feed water

Table3. permeate Volumetric titration

	Low salinity	**Hight salinity**
Cl^- (mg/l)	9.92	9.92
TA/ (mg/l Ca CO3)	0	0
TAC (mg/l Ca CO3)	8	7
Ca^{2+} (mg/l)	1.60	2.40
TH (mg/ l Ca CO3)	10	56

we conclude form table 3 that the produced water is not hard and aggressive and its quality doesn't change with the feed water composition in terms of salinity.

In order to determine the relationship between the salinity and the minimum pression that should be applied to desalinate the water we have prepared solutions at different salt concentrations, the results are shown in fig 2.

It is found that when the salinity increases the minimum operating pressure of the membrane system increases, as shown in figure. Particularly, it is noted that the minimum pressure to desalinate sea water begins at 40 bars for a high salinity 30 g / l.

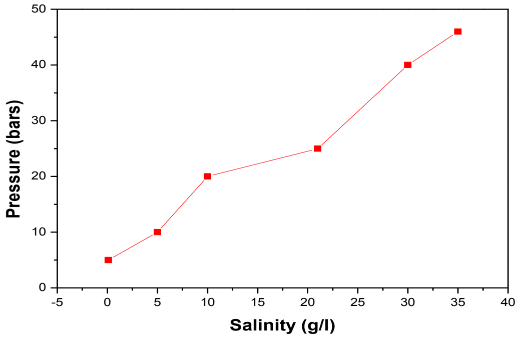

Fig 2. Evolution of pressure versus salinity

IV. Conclusions

We carried out an experimental parametric study of the characteristics of the reverse osmosis system in order to desalinate and treat the well water of the UDES (salinity=7,7 g/l) and a synthetic water (salinity= 32 g/l) by membrane process (OI).The pre-treatment is provided by cartridge filters of 5µm.

The study of the physicochemical and bacteriological quality of water should be carried out regularly and periodically (winter, spring, autumn and summer) in order to control and follow changes in water parameters.

The device is suitable for small and large concentrations and it is noted that the minimum pressure to desalinate sea water begins at 40 bars for a high salinity 30 g / l.

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