

# Performances of electro dialysis process in desalination of brackish waters at various salinities and voltage

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## Abstract

In the south Mediterranean countries and especially the North Africa, the water demands, since many decades, have increased while the conventional water availability has decreased dramatically. These trends continue. The obligation to use other non-conventional water resources such as desalinating water or waste water reuse becomes a necessity.

Electrodialysis is a membrane process that competes with reverse osmosis for desalination and the removal of specific inorganic contaminants

The experiments for desalination were carried out of various synthetic brackish waters containing 2, 4, 6, 8 and 10 g/l NaCl in order to determinate the operating conditions of electro dialysis process. The pilot used supplied by the Tokuyama Corp. The influence on the desalination performances of many running parameters such as voltage and salinities was investigated.

These studies demonstrated that the electro dialysis is an effective method of being used to desalinate brackish water as well as water with higher salt concentrations up to about 10 g/L NaCl.

**Keywords:** Electrodialysis, Performances, Membrane, Voltage, Salinities, Intensity.

## 1. Introduction

The shortage of drinking water is a major problem in the southern communities of Morocco. In these regions, the precipitations are insufficient to meet the demand for water and it is, therefore, necessary to resort to underground resources. However, the salinity content of these aquifers is largely exceeded the acceptable standards of drinking water.

Electrodialysis is one of the membrane processes that proved reliable and efficient in many application especially the production of drinking water from brackish and seawater [1], [2], also the treatment of industrial effluents [3], [4], the recovery of useful materials from effluents and salt production [5], [6] The basic principles of ED have been reviewed in the literature [7]. Figure 1 shows the charge transport in a conventional electro dialysis system for NaCl solutions. The ionic separation in this process takes place under the effect of an electric field. [8], [9].

The focus of the present study is to determine the performances of ED for the desalination of synthetics brackish waters containing a various salinities of NaCl. The removal of the chloride and the sodium were carried out under various running conditions such as the applied voltage and the initial salt concentration.

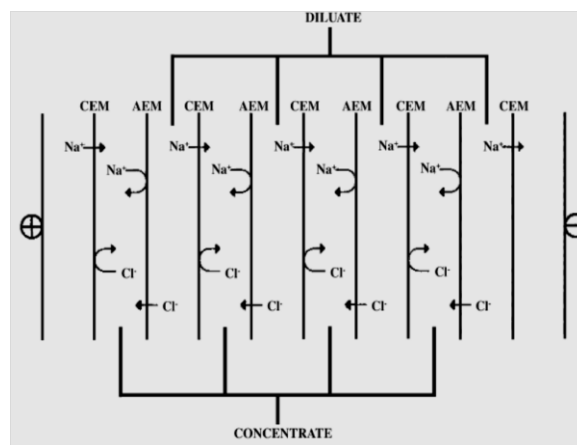


Fig. 1: Charge transport in the electro dialysis stack.

## 2. Materials and methods

### 2.1. Electro dialysis plant

The electro dialysis operation was carried out on a laboratory pilot plant (figure 2). This apparatus was a batch electro dialysis unit composed of ten compartments alternatively separated by cation and anion exchange membranes. The two electrode compartments are separated from the others to prevent a modification of the composition of the solution, which could be caused by electrode reactions. The circulation of water through the dilute, concentrate and electrode rinse compartments was assured by pumps. The used membranes were a conventional cationic exchange mem-

brane CMX and an anionic exchange membrane AFN manufactured by Tokuyama Corp. The stack design characteristics of the electro dialysis pilot plant are given in Table 1.



Fig 2: Electro dialysis pilot plant

Table 1: Stack design

Membrane area (cm <sup>2</sup> )	200
Cation exchange membrane	CMS Tokuyama Corp.
Anion exchange membrane	ACS Tokuyama Corp.
Number of cell pair	10
Separator	PE + PP
Electrode	DSE
Flow of dilute and concentrate compartments (l/h)	180 - 200
Flow of electrode compartment (l/h)	150
Current max (A)	9
Maximum voltage (V/Cell)	1.5
Polarity Reversal	Manual

To prevent the scaling and fouling membranes, the polarity of the direct current was reversed at the end of each test, and the stack was flushed periodically with an acidic solution.

## 2.2. Characteristics of feed water

The experiments were carried out on synthetic water prepared from distilled water doped with NaCl at various concentrations: 2, 4, 6, 8 and 10 ppm. Table 2 gives the characteristics of the feed water.

Table 2: characteristics of the feed water

Salinities (g/l)	pH	$\chi$ (mS/cm)	Cl (ppm)	Na <sup>+</sup> (ppm)
2	6,19	4,01	789,87	1203,58
4	6,02	7,82	1464,37	2482,396
6	6,3	11,4	1908,12	3272,22
8	6,44	14,98	2440,62	4983,59
10	6,62	18,46	3017,5	5641,8

## 2.3. Analytical methods

During the tests, water samples are taken periodically and the ion concentrations were determined analytically. The content of sodium (Na<sup>+</sup>) and chloride (Cl<sup>-</sup>) were determined analytically following standard methods [10], [11]. The values of conductivity (mS/cm) were converted to NaCl concentration from the following equation:

$$NaCl_{concentration} (ppm) = \frac{EC \times 89.4}{1.8}$$

With:

EC: Electrical conductivity ( $\mu$ S/cm)

The total energy consumption is the sum of energy applied to the electrodes and power hydraulic pump for circulating diluate, concentrate and rinse. The calculation of energy applied to the electrodes is determined by the following relation [12]:

$$E_{elec} = V \times \sum_{i=0}^{n-1} \frac{I(t_i) + I(t_{i+1})}{2} \times \Delta t$$

With:

V : Applied voltage,

I (t<sub>i</sub>): intensity,

$\Delta t$  : time (s).

The pumping energy is given by the following relation [12]:

$$E_{pump} = \frac{q \times \Delta P}{\eta}$$

With:

q : flow rate (en m<sup>3</sup>/s),

$\Delta P$  : pressure (Pa),

$\eta$  : Efficacy of the pump.

## 3. Results and discussion

In this work, the performances of electro dialysis membranes in salt removal are compared for various running conditions such as the initial salinities and of applied voltage. The studies were carried out on an industrial pilot plant.

### 3.1. Influences of applied voltage on desalination

In the first step, desalination experiments using ED were undertaken to determine the performance of the system at three applied voltages; 5, 10 and 15 Volts and for a salinity of 6g/l. Figures 3, 4, 5 and 6 give the variation of intensity, conductivity and NaCl concentration versus times for three applied voltage.

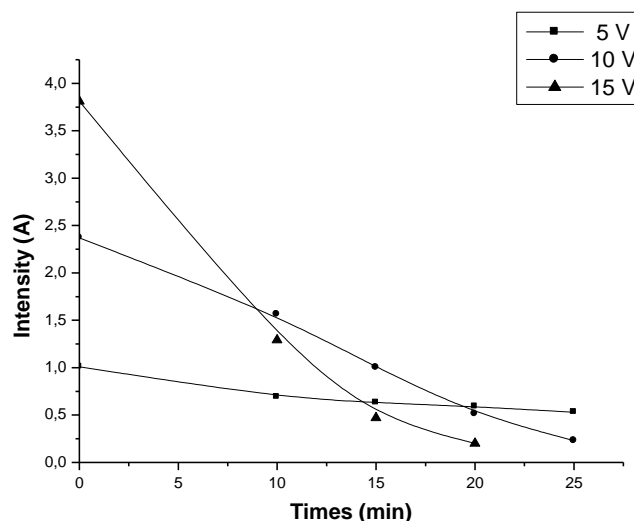


Fig. 3: variation of intensity versus time for three applied voltage

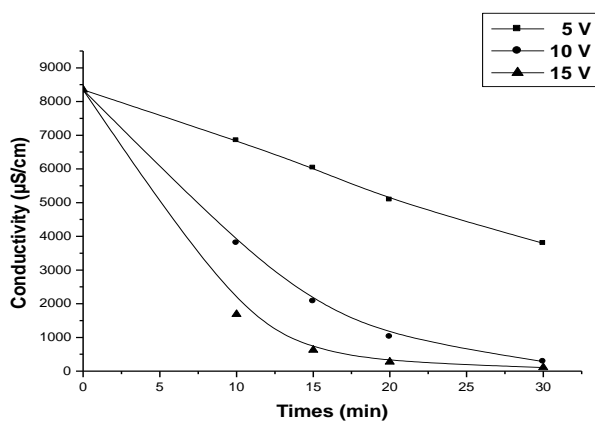


Fig. 4: variation of conductivity versus time for three applied voltage

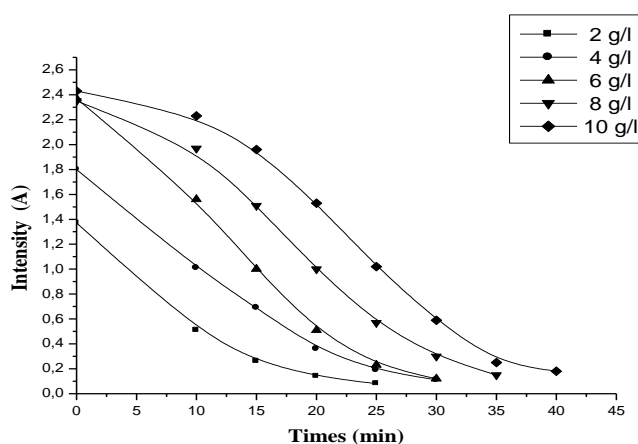


Fig. 6: Variation of intensity versus time for a different salinities.

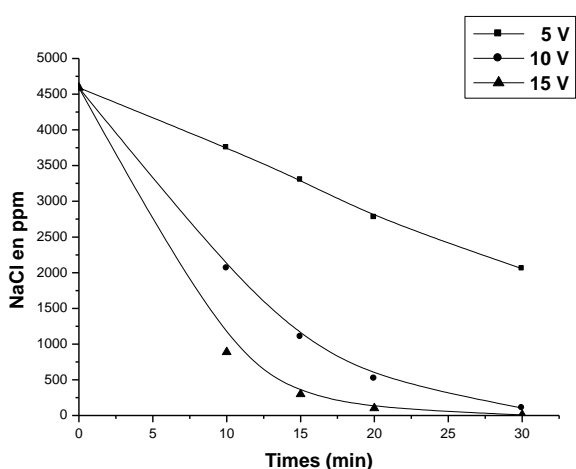


Fig. 5: variation of NaCl concentration versus time for three applied voltage.

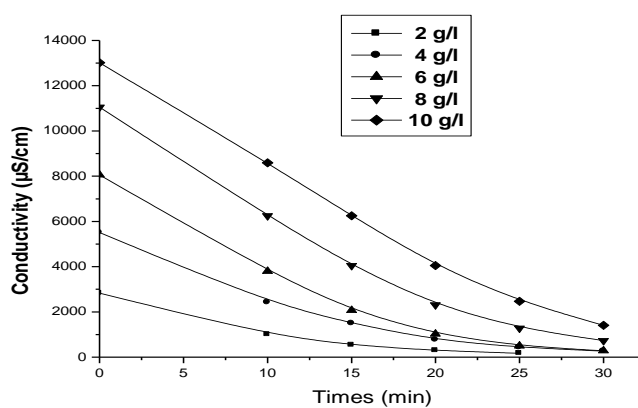


Fig. 7: Variation of conductivity versus time for a different salinities.

The analysis of the results show that the intensity, the conductivity and the NaCl concentration in diluate compartment decreases within the initial 10 min. After this point the decrease in salt concentration slowed down and an accompanying smaller incremental decrease in the current between the two electrodes within the stack was noted.

This can be explained by the phenomenon of the concentration and the polarization in the membrane boundary layer as well as depletion of electron carriers in the diluate. For desalination to occur in the electrodialysis there needs to be sufficient current between the cathode and anode.

Table 3: gives the evolution of demineralization energy, pumping energy and total energy consumption versus three applied voltage.

	5 V	10 V	15 V
Demineralization energy (kWh/m <sup>3</sup> )	-	2.837	4.364
Pumping energy (kWh/m <sup>3</sup> )	-	6 10 <sup>-6</sup>	6 10 <sup>-6</sup>
Total energy consumption (kWh/m <sup>3</sup> )	-	2.837	4.364

### 3.2. Influences of initial salinities on desalination

To study the impact of initial salt concentration the desalination process experiments were carried out with salt concentrations of 2, 4, 6, 8 and 10 g/l NaCl at an optimum applied voltage of 10 V. Figures 6, 7, 8 and 9 give the variation of intensity, conductivity and NaCl concentration, energy consumption versus time for a different salinities.

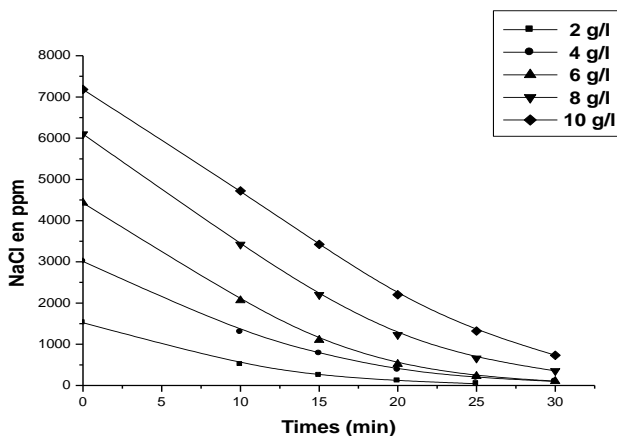


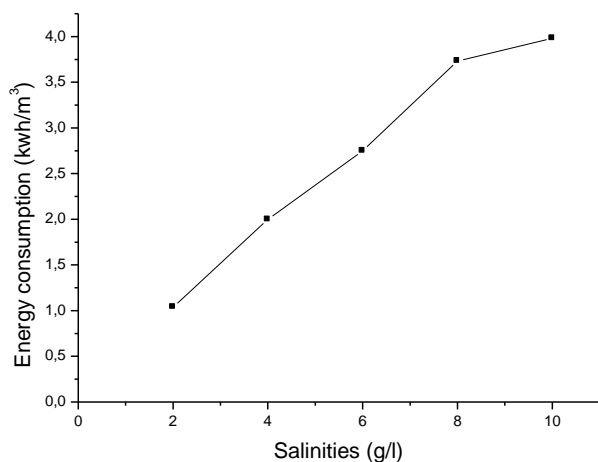
Fig. 8: Variation of NaCl concentration versus time for a different salinities.

For the different tested salinities. The several parametrs such as intensity, conductivity and NaCl concentration decreases versus time.

The NaCl guideline value for drinking water (500 ppm) was reached only in the experiments with an initial salt concentration of 2, 4, 6, 8 g/L NaCl, but it was not reached with an initial salt concentration of 10 g/l NaCl, however a removal of 97.5% NaCl was achieved, after 30 min the desalination becomes marginal. Table 4 gives the values of time and the removal rate of NaCl for each tested salinities where the guide value of NaCl was reached (500 ppm).

**Table 4:** Performances of ED processes at a various tested salinities.

Initial salinities	2	4	6	8	10
NaCl guideline (ppm)	500	500	500	500	500
Times (min)	10	17	20	30	....
Removal rate of NaCl (%)	74	87	91	93	....

**Fig. 9:** Variation of energy consumption versus time for a different salinities.

The analysis of results show that the energy consumption increases linearly versus salinities of up to 8 g / l, after this point the increase in energy consumption slowed forming a bearing. This can be explained with the phenomena of concentration polarizations in the membrane boundary layer. In this case the desalination becomes marginal.

## 4. Conclusion

The results of this study show that the electro dialysis is capable of being used to desalinate brackish water. However, for a lower concentrations of NaCl (2, 4 et 6 g/l), the reduction of NaCl is remarkable before 20 min in order to obtain the concentration of 500 ppm of NaCl in permeate water (value declared in the drinking water standards). But for higher concentration of NaCl (8 and 10g/l) the reduction of is remarkable that after 30 min. Moreover, further work is required to determine fouling mechanisms for electro dialysis process.

## Acknowledgement

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