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**Original Article**

# Performance Study of Reverse Osmosis Plants for Water Desalination in Bandar-Lengeh, Iran

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**Abstract**

**Introduction**: Reverse osmosis (RO) is best known for its use in desalination (removing the salt from seawater to get fresh water), but since the early 1970s it has also been used to purify fresh water for medical, industrial, and domestic applications. The aim of this research was the performance study of reverse osmosis plants for water desalination in Bandar-Lengeh, Iran.

**Materials and Methods**: In this study the concentrations of a number of physical, chemical and biological quality parameters in raw and treated water of Bandar-Lengeh water Desalination Plants were determined and Performance of RO plants for seawater and costal groundwater desalination were studied. There are two desalination plants in Bandar-Lengeh. Water from these plants are used for municipal supply. Total production capacity of the two RO desalination plants is 8000 $m^3$/d.

**Results**: The results of this study showed average values of TDS, Sodium, Chloride and Sulfate in seawater were 37749 mg/l; 9715 mg/l; 22020 mg/l and 3067 mg/l and in treated water were 1233 mg/l; 436 mg/l; 710 mg/l and 58 mg/l, respectively. Also the results showed average values of TDS, Sodium, Chloride and Sulfate in coastal ground water were 37131 mg/l; 9303 mg/l; 21072 mg/l; 3745 mg/l; and in treated water were 687mg/l; 253 mg/l; 389 mg/l; 19 mg/l, respectively.

**Conclusion**: The results showed the quality of feed water and pretreatment plays an extremely important role in operational problems such as fouling of RO systems.

***Keywords***: Osmosis; Seawater; Plants; Fresh Water; Water Pollutants, Chemical/chemistry

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## Introduction

Explosive population growth and industrial activities have been causing huge consumption of water resources and water pollution, nowadays insuring enough quality water is one of the most serious issues in the world [1, 2]. The extreme shortage of potable water has made countries rethink their potable water supply policies. A method exploited in many arid countries is desalination of seawater or brackish water. Seawater is freely available and exists close to coastal lands, hence desalination of seawater can be an attractive and logical option for alternative potable water supply [3]. Membrane processes are designed to carry out physical or physicochemical separations. In Reverse Osmosis (RO), the applied pressure is the driving force for mass transfer through the membrane [4]. RO has advanced rapidly since the 1980s [2]. Membrane technology development as a whole began with the first high performance reverse osmosis membrane produced in the early 1960s, which led to the installation of large seawater desalination plants in arid regions of the world [5]. Especially in recent years, RO solutions have won in international bids for tenders of seawater desalination, due to its low capital investment, low energy consumption, low operation cost and shorter construction period [2].

The exponential growth of desalination can be illustrated by the fact that in 1971 total worldwide capacity was only 1.5 million cubic meters per day. In 1976 the total was 4 million cubic meters per day and in 1995 it was 20 million cubic meters per day. In the last 10 years, worldwide capacity grew from 12 to about 22 million cubic meters per day. Middle Eastern countries are the biggest users of desalination technology, with about 50% of the world’s capacity installed in this region. In Hormozgan province, in the southern part of Iran, most of the fresh water for the cities and islands is produced from the sea water or brackish through water desalination processes [6]. In the Kingdom of Saudi Arabia there is a large number of RO desalination plants of various sizes for both brackish water and seawater and several smaller size RO plants (0.6–1.2 MGD) in operation on both the Persian Gulf and the Red Sea [7].

One of the important cities of Hormozgan province is Bandar-Lengeh with more than 1710 ha. It is located to the west of Bandar-Abbas. Bandar -Lengeh has a population of more than 40000. Weather of Bandar-Lengeh is hot and dry. The yearly average temperature is 26.6$^{o}$C and humidity is 64%. The most and the least sunny days are respectively in June and February. Average sunny hours in a year are 3264. The maximum and minimum evaporation rates are 208 mm in May and 68.3 mm in June [8]. The aim of this research was to study the Performance of Reverse Osmosis Plants for Water Desalination in Bandar-Lengeh.

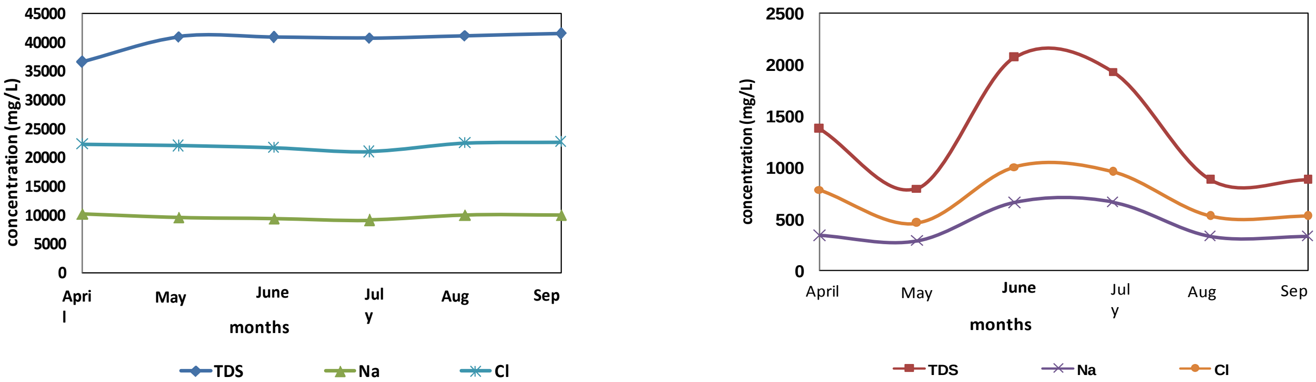
## Materials and Methods

This research was a descriptive – analytical study of the performance of RO plants for seawater and costal groundwater desalination in Bandar-Lengeh. There are two desalination plants in Bandar-Lengeh and water from these plants provide municipal supply. The total production capacity of RO desalination plants is 8000 $m^3/d$. The plants are designed to use seawater and costal groundwater as feed water and produce water with a TDS< 200 mg/L and a recovery of 35-45%. Grab sampling was done weekly during spring and summer of 2012 and the total numbers of samples were 96. In this study, sampling, handling and analysis of raw and treated water were done by the methods mentioned in the standard methods for the examination of water and wastewater [9] and the concentrations of a number of physical and chemical quality parameters such as TDS, pH, $Na^+$, $Cl^-$ and $SO_4^=$ were determined in raw and treated water (permeate). In order to evaluate the performance of reverse osmosis systems, raw and treated water experiments results were analyzed by descriptive statistics and the results in terms of mean values, standard deviation and removal efficiency were reported.

## Results

In these RO plants, the raw sea and costal groundwater are first chlorinated to protect against biological fouling of the membranes, and then the residual chlorine is eliminated by the addition of sodium metabisulfite in order to protect the membranes from oxidation.

The pretreatment consists of: (1) storage tank and prechlorination (2) sand-filter of graded quartz for removal of turbidity and dissolved iron. Sand filter reduces turbidity of the ground water to less than 0.5 NTU, this may be called as the macro filtration (3) Granular Activated carbon (4) Check Filter (also called micro filter or cartridge filter) which traps residual particles above 5 microns from sand filtered water before it enters the RO assembly. Acid proof polypropylene thread is woven around this tube, to prevent entry of particles above 5 microns. Pretreated water from micro filter is pumped to the RO membrane unit through a high pressure pump at a pressure of 65 bars and the reject water from RO plants is discharged into the sea.




**(a)** **(b)**

**Figure 1**. Sea water and RO1 desalted water quality variations in Bandar Lengeh in the first half 2012

The figures 1,2 and tables 1,2 give the raw water and treated water quality in Bandar-Lengeh RO desalination plants in the first half 2012.

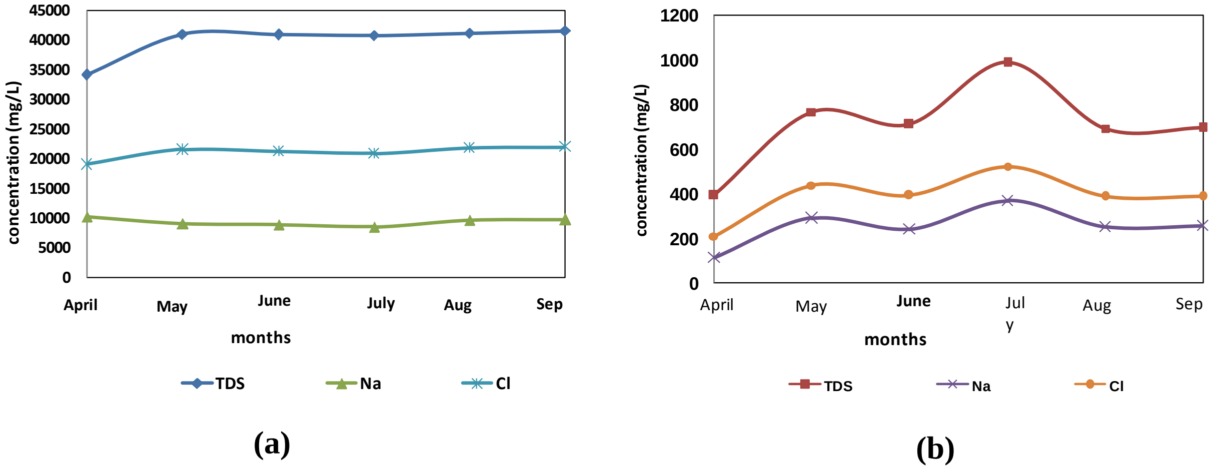



**Figure 2**. Coastal groundwater and RO2 desalted water quality variations in Bandar-Lengeh in the first half 2012

According to Fig 1and 2, the values of TDS, $Na^+$ and $Cl^-$ during the first half of 2012 had little changes in sea water and groundwater quality, while RO1 and RO2 treated water had quality variations. As the most values of these parameters in RO1 desalted water were measured in June and in RO2 desalted water were measured in July.

**Table 1.** Comparison of RO1 and RO2 feed water (The first half 2012)

| Quality Parameter | Unit | RO1 Feed Water Mean | RO1 Feed Water S.D | RO2 Feed Water Mean | RO2 Feed Water S.D | P-value |
|---|---|---|---|---|---|---|
| EC | µS/cm | 58075 | 1470 | 57124 | 2101 | 0.14 |
| Turbidity | NTU | 9.3 | 3.3 | 0.7 | 0.2 | 0.06 |
| pH | - | 7.6 | 0.2 | 7.3 | 0.1 | 0.08 |
| TDS | mg/L | 37749 | 848 | 37131 | 823 | 0.0 |
| Total Hardness | mg/L | 7522 | 565 | 7622 | 562 | 0.23 |
| $Ca^{2+}$ | mg/L | 416 | 64 | 446.5 | 46 | 0.08 |
| $Mg^{2+}$ | mg/L | 1581 | 45 | 1587 | 127 | 0.89 |
| $Na^+$ | mg/L | 9715 | 414 | 9303 | 634 | 0.0 |
| $K^+$ | mg/L | 588 | 136 | 556 | 130 | 0.0 |
| $Fe^{2+}$ | mg/L | 0.1 | 0.04 | 0.3 | 0.03 | 0.11 |
| $Cl^-$ | mg/L | 22020 | 617 | 21072 | 692 | 0.72 |
| $F^-$ | mg/L | 54 | 10 | 48 | 15 | 0.01 |
| $SO_4^=$ | mg/L | 3067 | 150 | 3745 | 276 | 0.15 |
| $HCO_3^-$ | mg/L | 273 | 15.2 | 193 | 8.3 | 0.0 |
| $PO_4^{3-}$ | mg/L | 0.04 | 0.02 | 0.03 | 0.0 | 0.02 |
| $NO_3^-$ | mg/L | 33 | 11 | 37 | 8 | 0.20 |
| $NO_2^-$ | mg/L | 0.2 | 0.001 | 0.01 | 0.001 | 0.0 |

The results of this study showed average values of TDS, Sodium, Chloride and Sulfate in seawater were 37749 mg/l; 9715 mg/l; 22020 mg/l and 3067 mg/l and in treated water were 1233 mg/l; 436 mg/l; 710 mg/l and 58 mg/l, respectively. Also the results showed average values of TDS, Sodium, Chloride and Sulfate in coastal ground water were 37131 mg/l; 9303 mg/l; 21072 mg/l; 3745 mg/l; and in treated water were 687 mg/l; 253 mg/l; 389 mg/l; 19 mg/l, respectively.

**Table 2.** Comparison of RO1 and RO2 desalted water (The first half 2012)

| Quality Parameter | Unit | RO1 desalted water | | RO2 desalted water | | |
|---|---|---|---|---|---|---|
| | | Mean | S.D | Mean | S.D | P value |
| EC | μS/cm | 1953 | 978 | 1058 | 345 | 0.61 |
| Turbidity | NTU | 0.2 | 0.6 | 0.1 | 0.05 | 0.15 |
| pH | - | 6.9 | 0.02 | 7.1 | 0. | 22 |
| TDS | mg/L | 1233 | 607 | 687 | 190 | 0.17 |
| Total Hardness | mg/L | 140 | 21 | 31 | 20 | 0.23 |
| $Ca^{2+}$ | mg/L | 5.7 | 3.5 | 3.5 | 2.7 | 0.27 |
| $Mg^{2+}$ | mg/L | 31 | 4.5 | 5.5 | 4.7 | 0.42 |
| $Na^{+}$ | mg/L | 436 | 175 | 253 | 83 | 0.39 |
| $K^{+}$ | mg/L | 14.6 | 6 | 8 | 2 | 0.69 |
| $Fe^{2+}$ | mg/L | 0.03 | 0.01 | 0.04 | 0.01 | 0.005 |
| $Cl^{-}$ | mg/L | 710 | 239 | 389 | 102 | 0.89 |
| $F^{-}$ | mg/L | 0.4 | 0.3 | 0.3 | 0.3 | 0.15 |
| $SO_4^{=}$ | mg/L | 58 | 51 | 19 | 7.5 | 0.51 |
| $HCO_3^{-}$ | mg/L | 12.5 | 1.7 | 8 | 0.8 | 0.13 |
| $PO_4^{3-}$ | mg/L | 0.02 | 0.007 | 0.02 | 0.007 | 0.04 |
| $NO_3^{-}$ | mg/L | 0.22 | 0.2 | 0.64 | 0.35 | 0.91 |
| $NO_2^{-}$ | mg/L | 0.06 | 0.001 | 0.002 | 0.001 | 0.01 |

## Discussion

According to the results the removal efficiency of TDS, Sodium, Chloride and Sulfate in RO1 were 96.7%, 95.5%, 96.7%, 98.1% and in RO2 were 98.1%, 97.2%, 98.1%, 99.5%, respectively. The results of Ghaneian et al [10] study about performance of RO Plants for Seawater Desalination at Hormozgan Province, showed average value of TDS, Sodium, Chloride and Sulfate in seawater were 32331.1, 9136.3, 19572.3, 3549.2 mg/l and in treated water were 436.2, 137.9, 229, 17.5 mg/l, respectively. So the removal efficiency of these parameters were 98.6%, 98.4%, 98.8% and 99.5%, respectively.

In this research the membranes can operate over a pH range of 2 to11 and temperatures up to 45 $^{0}$C. The average life of RO membranes is three years. Membranes are cleaned by chemicals with an injection pressure of 1.5–4bar periodically to avoid fouling. The fouling of membranes affects adversely on the quantity and quality of product water. Membrane fouling occurs in nearly all reverse osmosis system, the frequency of fouling varies from one unit to the next and depends on a number of variables, including system recovery rate, RO feed water characteristics, pretreatment and system operation. Fouling may occur as frequently as every week or as infrequently as once a year. In any case, it is important to have a good understanding of what membrane fouling are, how they occur and accumulate on the membrane, and when and how they may be most effectively removed. There are four major categories of membrane fouling agents (dissolved solid, suspended solids, biological organisms and non-organics) which may be classified by their physical type and their location on the membrane.

In the studied Reverse Osmosis plants in Bandar-Lengeh we found that in most of the time, membrane biological fouling occurred more than the other norms and have more influence on RO systems efficiency. The results of Pearce's study (2007) showed UF/MF pretreatment in SWRO provides an excellent treated water quality, since it provides an absolute barrier to particles, which provides consistent treated water quality from a variable feed source [11].

For efficient and dependable water supply to areas like Bandar-Lengeh, at which potable water is scarce, RO desalination plants offer the practical option. The most important factors affecting the RO membrane process are membrane fouling/ scaling, resulting in a higher operational cost. Membrane fouling/scaling causes a permeate flux decrease during constant operating conditions[12].

## Conclusion

The results showed the quality of feed water and pretreatment plays an extremely important role in performance and operational problems such as fouling of RO systems. Also the operating parameters of RO system are mainly affected by feed water quality such as salinity and temperature.

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