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The effect of seawater quality on reverse osmosis operational problems in Hormozgan Province, Iran

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Introduction

Population explosion and human industrial activities have been causing huge consumption of water resources and water pollution, and now insuring enough quantity and quality of 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. Seawater is freely available and exists close to coastal lands, hence desalination of sea water 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 transport 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 by in the early 1960s**,** which led to the installation of large seawater desalination plant in arid regions of the world (5). Especially in recent years, RO has won in international bids for tenders for seawater desalination, due to its low capital investment, low energy consumption, low operation cost and shorter construction period(2).

Material and Methods

In this work, the operational problems of RO plants for seawater desalination at Hormozgan Province, Iran were studied. Hormozgan province with a coast-line of nearly 900 km is situated in the south in Iran. There are 13 desalination plants in Hormozgan province and water from this plants provide municipal supply. The total production capacity of RO desalination plants is 23000 m^3/d, use membrane units of different sizes. The plants are designed to use seawater as feed water and produce product water having TDS < 200 mg/L with a recovery of 35-45%. The concentrations of a number of quality parameters such as TDS, pH, Na^+, Cl^-, $SO_4^=$ and biological microorganisms were determined in seawater and treated water (permeate) by the methods mentioned in the standard methods for the examination of water and wastewater (6).

Results and Conclusions

In this study seawater reverse osmosis plants product flow range were 20–6000 m^3/d; pressure range max. 852 psi were used. In these SWRO plants, the raw seawater from an open intake is first chlorinated to protect against biological fouling of the membranes, and then the residual chlorine is eliminated by the addition of sodium metabisulphite in order to protect the membranes from oxidation.

The pretreatment consists of: (1) storage tank and prechlorination (2) sand-filter of graded quartz sand for removal of turbidity and dissolved iron. Sand filter reduces turbidity of the ground water to less than 0.5 unit. This may be called as the macrofiltration. (3) Granular Activated carbon (4) Check filter, is also called as microfilter or cartridge filter and 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 microfilter is pumped to the RO membrane unit through a high pressure pump under pressure of 55-60 bar. Reject water from RO plants is discharged into the sea.

The membranes can operate over a pH range of 2 to11 and temperatures up to 45 ^{0C}. The average life of RO membranes is three years. RO membranes are cleaned by chemicals with an injection pressure of 1.5 – 4 bar periodically to avoid fouling.

The fouling of membranes affects adversely, the performance of plants, 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 variable, 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.

Dissolved solids are scale-forming materials such as calcium and barium, which are soluble in feed waters. They are either cations or anions, which may complex and precipitate in the brine stream as their concentrations increase in the RO. Examples of such precipitated cation/anion compound include calcium carbonate, calcium sulfate and barium sulfate.

Suspended solids maintain their suspension through a process of repulsion by a double layer of charge. Examples of suspended solids include colloidal forms of metal oxides such as iron, aluminum or silica. The charge-repulsion characteristics of suspended solids also stabilize particulates such as carbon fines which may inadvertently leak from mixed media or carbon filters. Suspended solids tend to agglomerate and settle onto the membrane surface when concentrated past the point of their charge related stability.

Biological foulants are aerobic and anaerobic living organisms such as bacteria, fungus, algae and the metabolic waste they generate. Such foulants tend to be present in low concentrations and literally grow into massive quantities that effectively block flow through the membrane surface.

Non-biological organic foulants are substances that contain carbon-based chemical structures, but which are not living organisms. Examples non-biological organic foulants are materials such as oil, plant materials, cationic surfactants and hydrocarbons.

In the suspected on the Reverse Osmosis plants for Seawater Desalination in Hormozgan Province it was definited that in the most conditions, membranes biological fouling occurred more than the other ones and have more influence on RO systems efficiency .

The tables 1-2 give the seawater and desalted water quality in Hormozgan RO desalination plants.

The results of this study were showed average values of TDS, Sodium, Chloride and Sulfate in seawater were 36554 mg/l; 10200 mg/l; 22254.5 mg/l; 3305 mg/l and in treated water were 432.5 mg/l; 138.4 mg/l; 230.6 mg/l; 17.1 mg/l, respectively. The results were showed the quality of feed water and pretreatment plays an extremely important role in performance of RO systems.

Table 1. Seawater quality influent in Hormozgan RO desalination plants

Item	Unit	Seawater
TDS	mg/l	36554
pH	-	7.8
Alkalinity	mg/l	129
Total Hardness	mg/l	8020
Ca^{2+}	mg/l	541.8
Mg^{2+}	mg/l	1620
Na^{+}	mg/l	10200
K^{+}	mg/l	357
CL^{-}	mg/l	22254.5
$So_4^{\ 2-}$	mg/l	3305
Fe	mg/l	0.8
Po_4^{3+}	mg/l	0.013
No_3^{-}	mg/l	0.6
Diatoms	N/100ml	3600
Chlorophyceae	N/100ml	1500
Cyanophycia	N/100ml	280
Protozoa	N/100ml	100
Rotifer	N/100ml	1
Crustacea	N/100ml	2
Nematode	N/100ml	Not observed

Table 2. Desalted water quality in Hormozgan RO desalination plants

Item	Unit	Desalted water
TDS mg/l		262
Na+ mg/l	RO1	74
CL- mg/l		128.3
$So_4^{\ 2-}$ mg/l		20
TDS mg/l		340.5
Na+ mg/l	RO2	127
CL- mg/l		219
$So_4^{\ 2-}$ mg/l		23
TDS mg/l		386
Na+ mg/	RO3	110.6
CL- mg/l		210.8
$So_4^{\ 2-}$ mg/l		27.2
TDS mg/l		348
Na+ mg/l	RO4	112
CL- mg/l		184.6
$So_4^{\ 2-}$ mg/l		6.1
TDS mg/l		305.4
Na+ mg/l	RO5	94
CL- mg/l		158
$So_4^{\ 2-}$ mg/l		5.7
TDS mg/l		232
Na+ mg/l	RO6	85
CL- mg/l		115
$So_4^{\ 2-}$ mg/l		5.4
TDS mg/l		227.2
Na+ mg/l	RO7	75.6
CL- mg/l		125.17
$So_4^{\ 2-}$ mg/l		4.1
TDS mg/l		842
Na+ mg/l		295
CL- mg/l	RO8	502
$So_4^{\ 2-}$ mg/l		68

TDS mg/l		884
Na+ mg/l		312
CL- mg/l	RO9	490
So$_4^{2-}$ mg/l		8
TDS mg/l		350.7
Na+ mg/l	RO10	82
CL- mg/l		230.5
So$_4^{2-}$ mg/l		28.5
TDS mg/l		904
Na+ mg/l		311.2
CL- mg/l	RO11	496
So$_4^{2-}$ mg/l		7.4
TDS mg/l		240
Na+ mg/l	RO12	59
CL- mg/l		91
So$_4^{2-}$ mg/l		9
TDS mg/l		300.6
Na+ mg/l	RO13	62
CL- mg/l		47
So$_4^{2-}$ mg/l		10

For efficient and dependable water supply to areas like Hormozgan, 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. The results showed the quality of feed water and pretreatment plays an extremely important role in performance of RO systems.

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