Original Article

Water desalination by membrane technology (RO) in southern Iran (Jask city)

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Abstract

Background: Reverse Osmosis (RO) is an increasingly common method of desalination. A full scale water desalination system by membrane technology (RO) evaluated in a southern city (Jask) in Iran.

Methods: First, data collection on water supply and network were performed. Analysis on most of the water quality parameters (Turbidity, pH, EC, Cl^-, Na^+, Alkalinity, Ca, Na, K, No_3, No_2, Fe, Mg, Mn, NH_4, Po_4, HCo_3^-, So_4^{2-} etc.) was performed as standard methods. The membranes of the RO in the desalination system were Poly-Amid (CSM type).

Results: The efficiency of the RO water desalination system was 94.16, 84.12, 92.00, and 96.17% respectively for Turbidity, Na^+, Mg^{2+}, So_4^{2-}. The result shows a significant difference between influent and effluent water of the RO system. The produced water is in agreement with national standard of drinking water. Furthermore, water exited from the RO system for TDS, Ca^{+2}, and Mg^{2+} was less than minimum limit of the guideline.

Conclusion: The quality parameters of the water resource (EC, TDS, Cl^-, Na^+ etc.) were higher than Iranian drinking water standards. The RO technology modified the quality of the water parameters

Keywords: Membrane technology, Reverse osmosis, Water desalination, Southern Iran

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Introduction

Dissolved salts removal from brackish and saline water was difficult and also expensive in the past, so saline water was not as a drinking water source. From 1950s desalination process was considered as an economic option for traditional usage. Isolation of dissolved salts from a saline or brackish water, is called desalination. Every water that contains Total Dissolved Salts (TDS) less than 1000 ppm, is called fresh water (1). Range of TDS for injection to desalination process is vary from 1000 to 60,000 ppm. Usually seawater contain TDS between 30,000-45,000 ppm, which can be removed by Reverse Osmosis (RO) membrane. RO membrane can be applied for TDS variation from 10,000 to 60,000 ppm. TDS ranges from 1000-10,000 ppm (usually related to groundwater resources), can be removed by brackish water RO membrane (2,3). Use of membrane technology in desalination process, increased in recent years (4,5). Recently, different industrial applications, use desalination process by RO membranes. This new technology, increased our potential for improvement of environmental protection and sustainable growth (6,7).

Currently, RO method is considered as the best technology for brackish and seawater treatment and also consumes less energy than the other desalination processes (1,8). Requirement of RO system to energy is less than the other desalination processes. It well ensures the global marketing of RO system (1,9). RO membrane is a basic treatment process for groundwater contaminated with different pollutants (10,11).

Method of treatment for contaminated aquifer by RO process is the same as brackish water RO (14).

Methods

This is an experimental and intermediate study on a full-scale water desalination system in Jask city of southern Iran (Figures 1-3). In this study, a full-scale water desalination system by membrane technology (RO) in a Southern city (Jask) in Iran, has been evaluated. First, data collection on water supply and network was performed. Then, weekly, water samples were taken from inlet and outlet of the system and transferred to the water laboratory of the University and Jask water organization. Analysis on most of the water quality parameters (Turbidity, PH, EC, Cl^-, Na^+, Alkalinity, Ca, Na, K, NO_3 NO_2, Fe, Mg, Mn, NH_4, PO_4, HCO_3^-, SO_4^{2-} etc.) was performed as standard methods. The membranes of the RO in the desalination system were Poly-Amid (CSM type). All experiments and preparation of the solutions were carried out based on the guidelines of a reference book titled "standard methods for water and wastewater experiments" (15).

Results

The Tables 1 and 2 show, the water analysis for the inlet and outlet samples of the RO system. Tables 1 and 2

Figure 2. Full scale MBR system of Jask city - side a

Figure 1. Satellite image of Jask city

Figure 3. Full scale MBR system of Jask city - side b

Table 1. Water analysis for the inlet samples of the RO system

Parameters	Stage											
	1	2	3	4	5	6	7	8	9	10	11	12
Turbidity	0.53	2.240	1.70	1.64	19.100	6.57	1.78	8.32	0.507	0.54	0.47	1.77
pH	7.76	8.33	7.72	7.86	7.50	7.78	7.72	8.130	7.100	7.60	7.47	7.69
TDS	1441	1289	1379	1308	1484	1271.4	1540	1218	1603	1669	1326.5	1340.5
EC	2484	2223	2377	2255	2558	2192	2656	2100	2762.50	2878	2287	2311
T, °C	25	24	23	23	22.80	22.70	22.70	18.50	19	19	15	14.50
Total hardness	546	458	500	544	562	716	740	442	664	643	489	489
Flouride	0.78	0.42	0.48	0.61	0.610	0.570	0.62	0.31	0.92	0.80	0.59	0.46
Chloride	493	369	369	524.60	493	641	404	330	571.60	571.60	385	385
SO_4	515	498	616	240	508	685	500	450	500	520	514	490
CO_3	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3	117.4	113.20	110	127	120.60	119.60	121	126.80	116.20	116.80	130	131
NO_2^-	0.001	_	0	0.012	0	0	0.001	0.001	0.004	0.005	0	0.001
PO_4	0.018	_	0.028	0.025	0.016	0.0068	0.012	0.0135	0.023	0.020	0.0098	0.0079
NO_3	0.485	_	1.260	0.094	0.08	0.58	0.123	0.213	0.394	0.43	0.43	0.711
Ca^{2}	151.5	111.60	124	137.70	153.100	185.200	190	95	164.30	158.30	115	117.50
Mg^{+2}	40.82	43.64	46.41	48.69	43.74	61.70	66.100	49.81	61.73	60.260	49.100	47.50
Na^+	320	275	285	285	340	385	300	250	320	330	300	300
K^+	10	10	9.810	10.180	10.100	11.50	10	12	10.43	10.120	10.200	10
Fe^{+2}	0.039	0.075	0.669	0.146	0.043	0.001	0	0.015	0.354	0.029	0.01	0
Mn^{+2}	0	0.003	0.005	0.015	0.130	0	0.111	0	0.001	0.005	0	0
NH_3	0	0	0.308	0.183	0	0	0	0	0	0		0

Table 2. Water analysis for the outlet samples of the RO system

Parameters	Stage											
	1	2	3	4	5	6	7	8	9	10	11	12
Turbidity	0.278	0.157	0.139	0.493	0.492	0.04	0.140	0.143	0.23	0.145	0.201	0.18
PH	7.61	7.83	7.210	6.56	6.670	7.53	7.050	7.240	7.62	6.95	6.150	7.45
TDS	165	130	144.7	138.60	176	213	232	163	130	110.90	248	236
EC	300	235.70	263	252	319.1	386.60	422.50	297	236	201.6	450.30	429
T,°C	25	14.500	14.500	18.60	18.60	18.50	22.70	22.80	22	23	23	24
Total Hardness	33.200	15.400	39	25	24.20	64.40	46	41	17.40	28.40	45	64.40
Flouride	0.220	0.120	0.23	0.17	0.32	0.18	0.17	0.20	0.21	0.14	0.15	0.12
Chloride	80	59	60	75	58.100	63.130	46	49.54	59.100	42.74	107.8	49.53
SO_4	11	20.400	29.80	14.34	15.84	17.21	15.90	41.040	10.62	9.300	29.070	16.50
CO_3	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3	26.80	16.60	19.60	20	17	25.20	19.80	24.40	18.80	23	20.20	16.50
NO_2^-	0	0.001	0.001	0.008	0.009	0.005	0.001	0.0008	0.013	0.0004	0	_
PO_4	0.014	0.007	0.0063	0.016	0.013	0.007	0.006	0.005	0.013	0.024	0.029	_
NO_3	0.331	0	0.42	0.286	0.394	0.2	0.4	0.3	0.394	0.22	4.918	_
Ca^{+2}	7.300	3.85	11.50	6.090	6.65	43.50	12.80	9.78	4.240	6.250	12.42	16.67
Mg^{+2}	3.64	1.40	2.50	2.38	1.80	10.72	10.40	4.030	1.65	3.010	3.40	5.46
Na^+	50	46	42	50	40	50	46	48	41	34	74	65
K^+	1.620	0.001	1.40	1.120	1.43	2.80	1.200	1.68	2.70	1.190	2.31	1.81
Fe^{+2}	0.231	0	0.02	0.041	0.028	0.03	0	0	0.006	0.147	0.147	0.111
Mn^{+2}	0	0	0	0.001	0.001	0	0	0	0	0.001	0.001	0
NH_3	0	0	0	0	0	0	0	0	0	0.210	0.035	0

and Figures 4-6 indicate, this system can be getting the government standards of drinking water. RO system, inlet and outlet parameters statistical results were indicated in Tables 3 and 4 Efficiency of the RO system that applied in this study, represented in Figure 4.

Range of operating pressures is different for brackish and seawater, 250 to 400 and 800 to 1000 psi, respectively. The quality of feed water is a determining factor to decide on the type of membrane process to use. Surface water (as compared to groundwater) represents the most variable water quality, particularly in terms of particle loadings and turbidity.

Some problems associated with using membranes may include short design life; membrane cleaning (backwashing or chemical treatment); high membrane replacement costs; low resistance to chlorine and lack of resistance to fouling.

As Figure 5 showed, except for nitrogen, phosphorus, iron and sulphate, removal efficiency for other parameters was between 83 to 99.6%. Removal efficiency for turbidity was about 65%. The most efficiency removal related to Mg^{+2} and the minimum was related to Po_4.

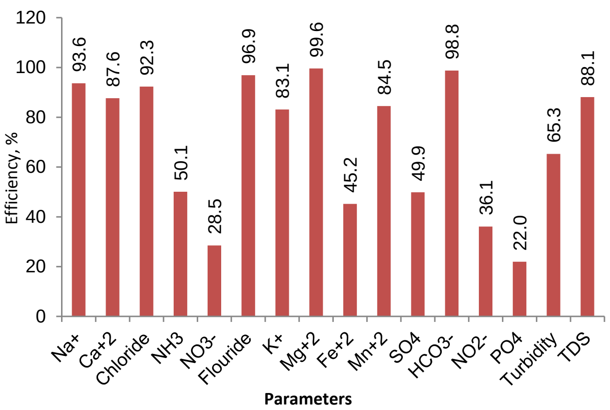

Figure 4. Removal efficiency of different parameters by RO system

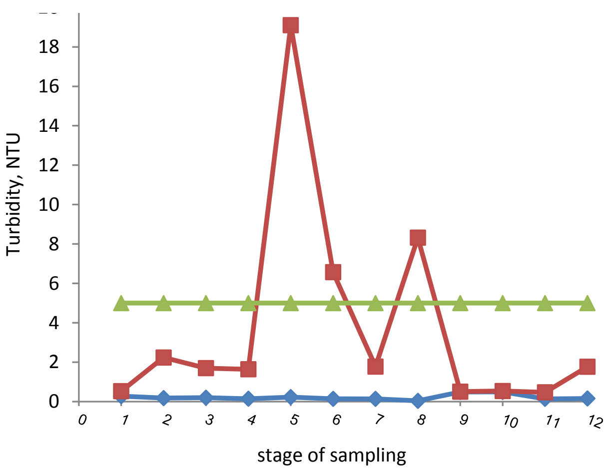

Figure 5. Turbidity status of the RO system in Jask city

Table 3. RO system, inlet parameters statistical results

	Turbidity	pH	TDS	EC	T	TH	F	CL	SO_4	CO_3	HCO_3	NO_2	PO_4	NO_3	Ca	Mg	Na	K	Fe	Mn	NH_3
Number of values	12	12	12	12	12	12	12	12	12	12	12	11	11	11	12	12	12	12	12	12	12
Minimum	0.4700	7.100	1218	2100	14.50	442.0	0.3100	330.0	240.0	0.0	110.0	0.0	0.0068	0.0800	95.00	40.82	250.0	9.810	0.0	0.0	0.0
25% Percentile	0.5325	7.525	1294	2231	18.63	489.0	0.4650	373.0	492.0	0.0	116.4	0.0	0.0098	0.1230	115.6	44.41	285.0	10.00	0.00325	0.0	0.0
Median	1.735	7.720	1360	2344	22.70	545.0	0.6000	448.5	504.0	0.0	120.1	0.0010	0.0160	0.4300	144.6	48.90	300.0	10.11	0.0340	0.0020	0.0
75% Percentile	5.488	7.840	1526	2632	23.00	658.8	0.7400	559.9	518.8	0.0	127.0	0.0040	0.0230	0.5800	162.8	61.34	327.5	10.37	0.1283	0.0125	0.0
Maximum	19.10	8.330	1669	2878	25.00	740.0	0.9200	641.0	685.0	0.0	131.0	0.0120	0.0280	1.260	190.0	66.10	385.0	12.00	0.6690	0.1300	0.3080
Mean	3.764	7.722	1406	2424	20.77	566.1	0.5975	461.4	503.0	0.0	120.8	0.002273	0.01636	0.4364	141.9	51.63	307.5	10.36	0.1151	0.0225	0.04092
Std. Deviation	5.437	0.3127	141.9	244.5	3.489	101.1	0.1724	100.8	103.9	0.0	6.659	0.003636	0.007096	0.3422	30.08	8.490	34.94	0.6741	0.2012	0.04615	0.09921
Std. Error	1.569	0.09027	40.95	70.58	1.007	29.19	0.04976	29.11	29.98	0.0	1.922	0.001096	0.002139	0.1032	8.683	2.451	10.08	0.1946	0.05809	0.01332	0.02864
Lower 95% CI of mean	0.3096	7.523	1316	2268	18.55	501.8	0.4880	397.3	437.0	0.0	116.6	-0.0001697	0.01160	0.2065	122.8	46.23	285.3	9.933	-0.01277	-0.006824	-0.02212
Upper 95% CI of mean	7.218	7.920	1496	2579	22.98	630.3	0.7070	525.5	569.0	0.0	125.0	0.004715	0.02113	0.6663	161.0	57.02	329.7	10.79	0.2429	0.05182	0.1039
Coefficient of variation	144.44%	4.05%	10.09%	10.09%	16.80%	17.86%	28.85%	21.85%	20.65%		5.51%	159.97%	43.36%	78.42%	21.19%	16.45%	11.36%	6.51%	174.86%	205.12%	242.46%
Standard, WHO	5	6.5-8.5	1000	2000	-	500	1.5	250	250	-	-	0.2	-	50	100	60	200	5	0.3	0.05	-
Standard, IRAN	5	6.5-9.0	1500			500	1.5	400	400	-	-	3	-	50	200	-	200	-	-	0.4	

Table 4. RO system, outlet parameters statistical results

	Turbidity	pH	TDS	EC	T	TH	F	CL	SO_4	CO_3	HCO_3	NO_2	PO_4	NO_3	Ca	Mg	Na	K	Fe	Mn	NH_3
Number of values	12	12	12	12	12	12	12	12	12	12	12	11	11	11	12	12	12	12	12	12	12
Minimum	0.0400	6.150	110.9	201.6	14.50	15.40	0.1200	42.74	9.300	0.0	16.50	0.0	0.0050	0.0	3.850	1.400	34.00	0.0010	0.0	0.0	0.0
25% Percentile	0.1408	6.740	132.2	240.0	18.53	24.40	0.1425	49.53	11.84	0.0	17.45	0.0004	0.0063	0.2200	6.130	1.945	41.25	1.193	0.0015	0.0	0.0
Median	0.1685	7.225	164.0	298.5	22.35	36.10	0.1750	59.05	16.20	0.0	19.90	0.0010	0.0130	0.3310	8.540	3.205	47.00	1.525	0.0290	0.0	0.0
75% Percentile	0.2660	7.590	227.3	413.5	23.00	45.75	0.2175	72.03	26.90	0.0	24.05	0.0080	0.0160	0.4000	12.71	5.103	50.00	2.185	0.1380	0.0010	0.0
Maximum	0.4930	7.830	248.0	450.3	25.00	64.40	0.3200	107.8	41.04	0.0	26.80	0.0130	0.0290	4.918	43.50	10.72	74.00	2.800	0.2310	0.0010	0.2100
Mean	0.2198	7.156	173.9	316.1	20.60	36.95	0.1858	62.50	19.25	0.0	20.66	0.003564	0.01275	0.7148	11.75	4.199	48.83	1.605	0.06342	0.0003333	0.02042
Std. Deviation	0.1397	0.5017	47.07	85.60	3.574	16.27	0.05600	18.00	9.458	0.0	3.450	0.004507	0.007850	1.399	10.72	3.180	10.96	0.7621	0.07654	0.0004924	0.06055
Std. Error	0.04034	0.1448	13.59	24.71	1.032	4.698	0.01616	5.196	2.730	0.0	0.9959	0.001359	0.002367	0.4219	3.095	0.9180	3.164	0.2200	0.02209	0.0001421	0.01748
Lower 95% CI of mean	0.1310	6.837	144.0	261.7	18.33	26.61	0.1503	51.06	13.24	0.0	18.47	0.000536	0.007481	-0.2253	4.942	2.179	41.87	1.121	0.01479	2.050e-005	-0.01805
Upper 95% CI of mean	0.3086	7.475	203.8	370.5	22.87	47.29	0.2214	73.93	25.26	0.0	22.85	0.006591	0.01803	1.655	18.57	6.220	55.80	2.089	0.1120	0.0006462	0.05888
Standard, WHO	5	6.5-8.5	1000	2000	-	500	1.5	250	250	-	-	0.2	-	50	100	60	200	5	0.3	0.05	-
Standard, IRAN	5	6.5-9.0	1500			500	1.5	400	400	-	-	3	-	50	200	-	200	-	-	0.4	

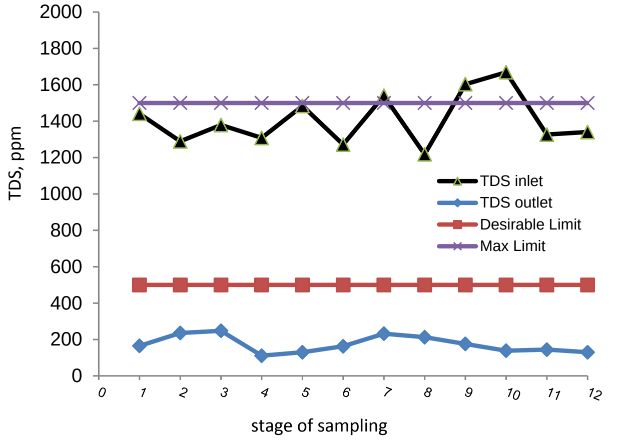

Figure 6. TDS status of the RO system in Jask city

Discussion

RO membrane systems have applied increasingly for seawater and brackish water. Although, permeate flux for brackish water is higher than seawater RO system, operational pressure and salt rejection are lower.

Saudi Arabia and the United States, with 26% and 17% have the first and second ranks in the global desalination capacity, respectively (16).

As the previous researches indicated, rejection of monovalent ions (such as Cl^-, Na^+) and salt rejections by RO membranes, can be higher than 99% (16).

According to WHO and IR standards, the maximum allowable value for the parameters were illustrated in the Tables 3 and 4. As shown in Figure 6, hardness in the feeds of Jask city plant was higher than the allowable limit recommended by WHO and IR standards. Treated water by RO system in the Jask city plant was agreeable with both WHO and IR standards. Moreover, efficiency of RO system for hardness reduction was found 98.5%.

As presented in Tables 3 and 4 the influent and effluent of Jask city plant have lower turbidity, fluoride, magnesium and nitrate concentration levels than WHO and IR standards (17,18).

Applied RO desalination plant in Jask city is for brackish water. As Figure 4 indicates, removal efficiency of different parameters by RO system has an important role to deliver drinking water to the Jask city people.

Applied pressure is the basic agent for driving the RO system. The level of energy requirement for RO system severance is directly dependent on level of the salinity of the solution. Increasing of salinity can cause high-pressure requirement for drinking water production and high energy and cost (19,20). Jask city desalination plant is designed based on brackish water than seawater.

Conclusion

This research indicated that the efficiency of MBR system for removing the pollutants is effectively high and applicable in all seaside cities and other places which encounter with anions and cations so it is suggested that with respect to the deficiency of the water treatment system of this plant, MBR process can practically be used for the water treatment.

Application of this system in water systems with high coloured and turbidity is relatively low. Finally, we can conclude that this system is very suitable and ideal for water treatment with low concentration of color and turbidity such as groundwater.

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Ethical issues

We certify that all data collected during the study is presented in this manuscript and no data from the study has been or will be published separately.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors participated in the design study, data acquisition, and interpretation. RM involved in the analyse and ZY wrote the manuscript.

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