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The Potential Use of Nanofilters to Supply Potable Water in Persian Gulf and Oman Sea Watershed Basin

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***Abstract*—**In a world worried about water resources with the shadow of drought and famine looming all around, the quality of water is as important as its quantity. The source of all concerns is the constant reduction of per capita quality water for different uses.

Iran With an average annual precipitation of 250 mm compared to the 800 mm world average, Iran is considered a water scarce country and the disparity in the rainfall distribution, the limitations of renewable resources and the population concentration in the margins of desert and water scarce areas have intensified the problem.

The shortage of per capita renewable freshwater and its poor quality in large areas of the country, which have saline, brackish or hard water resources, and the profusion of natural and artificial pollutant have caused the deterioration of water quality.

Among methods of treatment and use of these waters one can refer to the application of membrane technologies, which have come into focus in recent years due to their great advantages. This process is quite efficient in eliminating multi-capacity ions; and due to the possibilities of production at different capacities, application as treatment process in points of use, and the need for less energy in comparison to Reverse Osmosis processes, it can revolutionize the water and wastewater sector in years to come. The article studied the different capacities of water resources in the Persian Gulf and Oman Sea watershed basins, and processes the possibility of using nanofiltration process to treat brackish and non-conventional waters in these basins.

***Keywords*—**Membrane processes, saline waters, brackish waters, hard waters, zoning water quality in the Persian Gulf and the Oman Sea Watershed area, nanofiltration.

I. Introduction

ALL methods based on membrane technology are in fact a type of filtration. These processes prevent a number of targeted particles from passing through the membrane. The membrane technologies can be used to substitute the conventional treatment processes.

Membrane filters can be divided into the two general categories of permeable (micro & ultra filtration) and semi-permeable (nano-filtration and Reverse Osmosis). Microfiltration and ultrafiltration processes are applied when the intention is to eliminate suspended solid particles, but the nano filters and Reverse Osmosis (RO) process are used to eliminate salts dissolved in water.

The nanofiltration and RO processes do not function as per orifice principles, instead they separate particles using penetration principles, and the pressure needed for the purpose in these processes resembles the pressure applied in micro and ultra filtration methods [1]. Fig. 1 shows the different limits of application of each of the membrane systems.

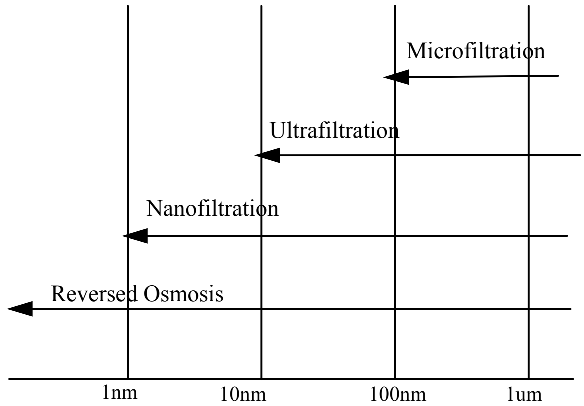

Fig. 1 The different filtering applications according to particle sizes [1]

As observed nanofiltration is appropriate for high removal of organic matters, and medium elimination of minerals.

Nowadays nanofilters are applied in different treatment processes including softening, and removal of color and biological pollutants. The industries also use nanofilters to remove different substances such as pigments from water.

The most common applications of nanofilters are:

- Softening and removal of 2 or more capacity ions from water
- Removal of heavy metals for reuse of water
- Reducing the salt concentration in saline and brackish waters
- Removal of pesticides from ground waters
- Recycling industrial and agricultural effluents

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- Reduction of nitrogen concentration, etc [2,3]

Given the potential of nanofiltration in improving the quality of brackish and non-conventional water, through identification and zoning the water resources in the Persian Gulf and Oman Sea watershed basin on quality and quantity basis, we can evaluate the feasibility of using nanofilters for supply of potable water in the region.

II. Classification of Watershed Basins in the Persian Gulf and Oman Sea Region

According to the latest results of classification and codification of watershed basins by the Codification Committee of the Department for Basic Research and Studies of the Water Resources Management Company, the national watershed areas are divided into 6 main watershed basins or grade 1 and 30 grade 2 basins. The Persian Gulf and the Oman Sea basins are graded 2 and include the main western, southwestern and southern sections of the heights and slopes of Zagros chains, as well as the southern slopes of Beshagard mountains, and all the rivers in this area flow either directly or from Iraq to the Persian Gulf and the Oman Sea. The Persian Gulf and the Oman Sea watershed basin includes 9 grade 2 sub-basins [4,5].

TABLE I
Classification of the main Persian Gulf and Oman Sea watershed area and its secondary sub-basins (code 2) and the number of areas studied in the basin [6]

Main watershed basin	Grade 2 basins	Code of grade 2 basins	Area (Km^2)	No. of grade 2 basins studied
Persian Gulf and Oman Sea watershed basin (code 2)	Western frontier rivers	21	39,667	24
	Karkheh River	22	51,643	35
	Greater Karoon River	23	67,303	42
	Jarahi & Zohreh rivers	24	40,788	24
	Heleh River and the small seasonal rivers on either side	25	21,773	13
	Mand River and the Karian & Khanaj basins	26	47,654	48
	Mehran rivers, southern seasonal rivers and islands	27	62,918	42
	Rivers between Bandar Abbas and Sadij	28	44,747	22
	South Baluchistan rivers between Sadij and Pakistan frontier	29	48,551	15
	The Abarghoo Desert (Sirjan)	44	57,196	19
	Hamoon Jazmoorian Basin	45	49,390	21
	The Loot Desert	46	206,220	36
	The Central Desert	47	226,523	50
	The Siahkouh, Rig Zarin and Degh Sorkh Deserts	48	48,912	11
	Daranjir and Saghand Deserts	49	50,508	12

The classification according to salinity is presented in Table II.

TABLE II
Water Classification according to Salinity [5]

Group name	Salt concentration (mg/l)	Electrical conductivity (µS/cm)
Fresh	<500	<700
Marginal	500-1500	700-2500
Brackish	1500-5000	2500-8000
Saline	5000-8000	8000-12000
Very saline	8000-13000	12000-20000
Hyper saline	>13000	>20000

III. Analysis of the Quality and Quantity of Saline and Brakish Ground Waters in the Studty Area in the Persian Gulf and Oman Sea Watershed Basin

The amount of intake and the potential for expansion in the study area of Persian Gulf and Oman Sea watershed basins having saline and brackish waters are shown in Table III:

TABLE III
The status of groundwater resources in the Persian Gulf and Oman Sea Watershed Basins [7,8]

Basn code	Basin name	Curret intake from aquifer (million m^3)	No. of ares studied	No. of overexploited basins	No. of basins with brackish and saline waters	Curret volume of intake from brackish and saline basins (millin m^3)	No. of areas with potential for expansion from brackish and saline zones	The expandae volume from the brackish and saline zones (million m^3)
2	Persin Gulf and the Oman Sea	1167	265	19	96	2274	70	598

IV. Materials and Methodology

In the context of studying the capacity of applying the nanofiltration process for treating the saline and brackish waters in this watershed basin, after assessing the saline and brackish water reserve, the appropriate membrane for different qualities of water was selected with the assistance of a software application.

V. Data Processing Method

The ROSA software was used to select the appropriate nanofilters for treating the ground waters of different quality. The parameters measured in the study area of the Persian Gulf and Oman Sea watershed basin included the concentrations of calcium, magnesium, sulfate, carbonate, bicarbonate, chlorine, TDS, etc. Given the fact that in this watershed basin the scope of changes in electrical conductivity (EC) and total dissolved solids (TDS) concentration varies to a great degree, the basin was divided into 2 or 3 different sub-basins according to water quality, which were then processed separately using the software. Therefore in some sub-basins, two or more different types of nanofilters were recommended to reduce the TDS.

VI. The Rosa System

ROSA is a tool for evaluating an approved design for a special RO of Nanofiltration system during the design stage or similar conditions of considered water quality. The proposed design is used by the system on the basis of the components of apparent design of the Filmtec elements. During the design of a real system, errors of approximately +15% might occur [9].

VII. The Design Stages Using Rosa

1- Specification of raw water resource, the quality and concentration of pollutants in water, the flow rate and the outflow quality standard considered.
2- Selection of the condition and the mode of flow and the number of production lines.
3- Selection of the considered membrane.
4- Selection (or design) of the average membrane passing pressure.
5- Calculation of needed elements.
6- Calculation of the needed pressure vessels.
7- Selection of the number of levels (stage series)
8- Selection of membrane ratio in each stage (or level)
9- Balancing the rate of outflow [2,9]

VIII. Review of Results

The following outputs in the form of charts were obtained from the analysis of ROSA system:

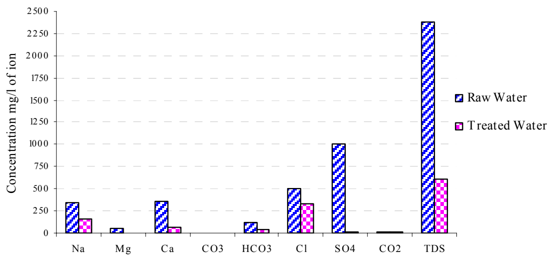

Fig. 2 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code (21)1- Western frontier rivers' basins (code 21)- 1st condition

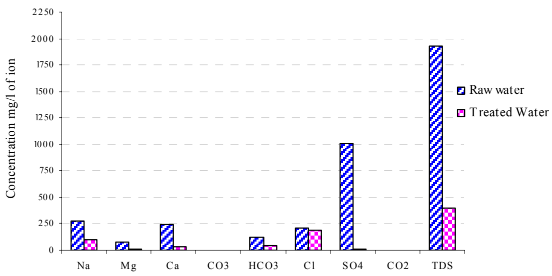

Fig. 3 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code (21) 2- Western frontier rivers' basins (code 21)- 2nd condition

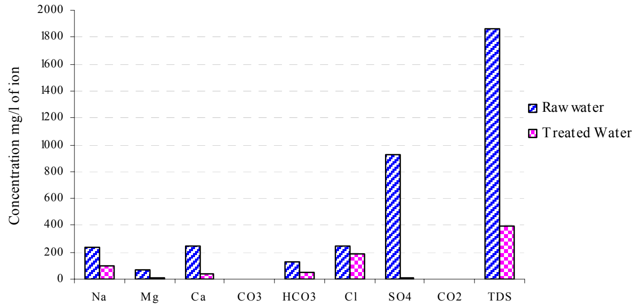

Fig. 4 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code 22- Karkheh river basin (code 22)

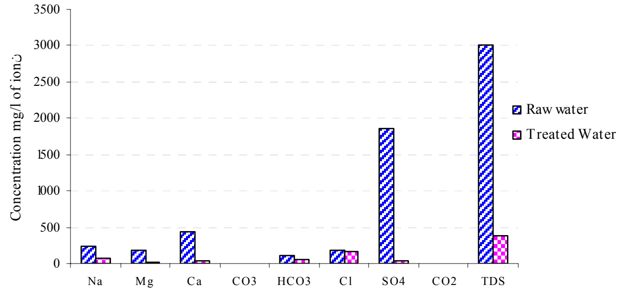

Fig. 5 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code 23-Greater Karoon River Basin (code 23)

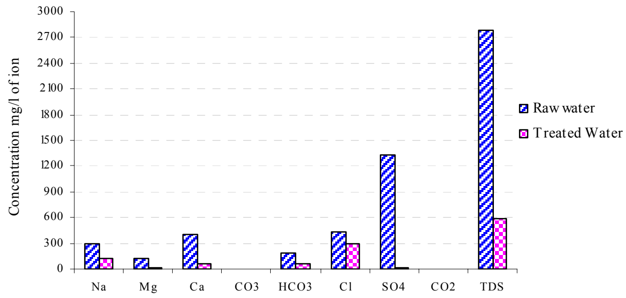

Fig. 6 Changes in concentration of water parameters using the 200-4040 nanofilter in sub basin code 24- Jarahi and Zohreh rivers basins (code 24)

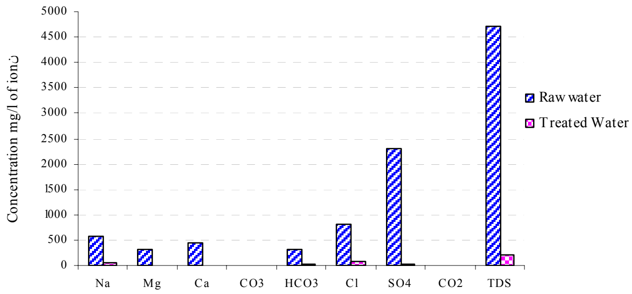

Fig. 7 Changes in concentration of water parameters using the 90-4040 nanofilter in sub basin code 25- Heleh basin & seasonal rivers on either bank (code 25)

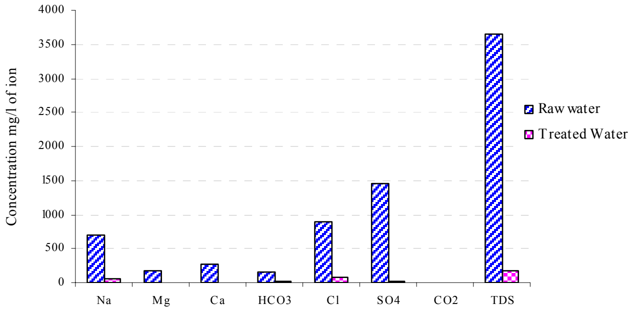

Fig. 8 Changes in concentration of water parameters using the 90-4040 nanofilter in sub basin code 26(1)- Mand River and Basteh Heram, Karian& Khanj basins (code 26) – 1st condition

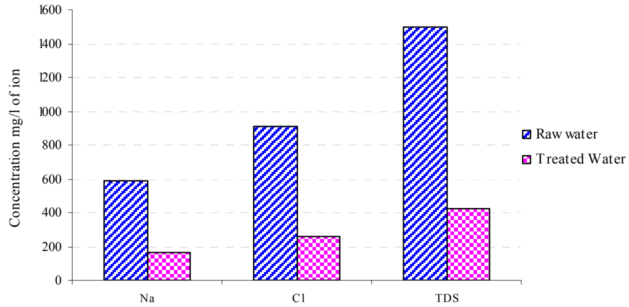

Fig. 9 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code 26(2)- Mand River and Basteh Heram, Karian& Khanj basins (code 26) – 2nd condition

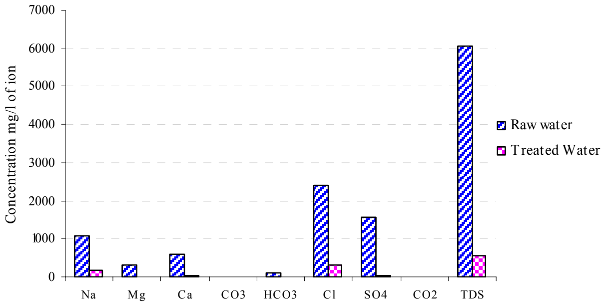

Fig. 10 Changes in concentration of water parameters using the 90-4040 nanofilter in sub basin code 27(1)- Kol, Mehran, south rivers and islands basins (code 27) – 1st condition

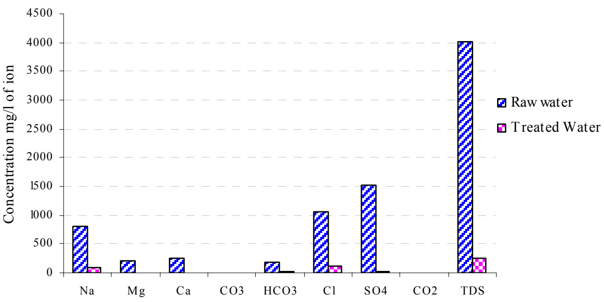

Fig. 11 Changes in concentration of water parameters using the 90-4040 nanofilter in sub basin code 27(2)- Kol, Mehran, south rivers and islands basins (code 27) – 2nd condition

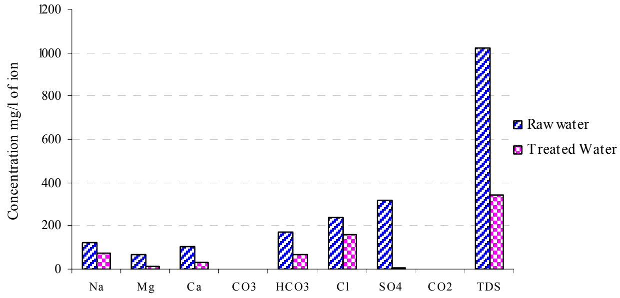

Fig. 12 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code 27(3)- Kol, Mehran, south rivers and islands basins (code 27) –3rd condition

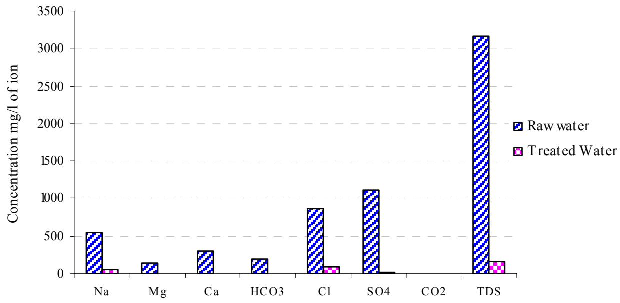

Fig. 13 Changes in concentration of water parameters using the 90-4040 nanofilter in sub basin code 28(1)- Bandar Abbas and Sadij river basins(code 28) – 1st condition

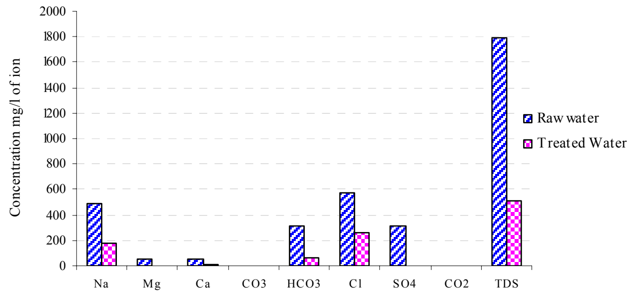

Fig. 14 Changes in concentration of water parameters using the 200-4040 nanofilter in sub basin code 28(1)- Bandar Abbas and Sadij river basins(code 28– 2nd condition

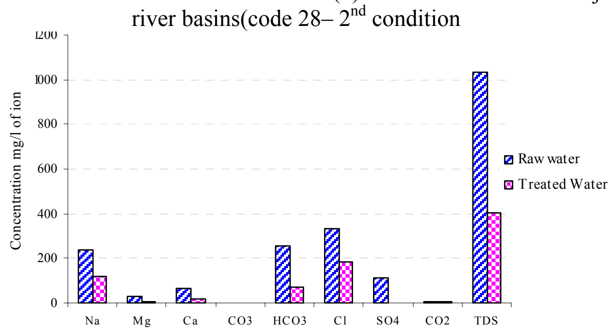

Fig. 15 Changes in concentration of water parameters using the 270-4040 nanofilter in sub basin code 29(1)- South Baluchistan river basins, between Sadij& Pakistan border (code 29)

IX. The Level and the Number of Modules Needed in the Persian Gulf and Oman Sea Watershed Basin

Based on mentioned issues, the total surface area of the considered membrane and the number of necessary modules can be calculated based on the current and future (expansion) volumes of operation in the Persian Gulf and the Oman Sea basins, the type of nanofilter suited for softening, desalination and reduction of TDS down to standard levels, the active surface area of the considered membrane and the average flux across it (obtained from computer analysis) in this watershed basin.

TABLE IV
Surface Area and the Number of Modules Needed for the 90-4040, 200-4040 And 270-4040 Nanofilters in the Persian Gulf and Oman Sea Sub-Basins

No. of modules	*Total membrane surface*	*Expandable volume*	*Current operational volume*	*Average flux*	*Active surface of membrane*	*Nanofiltr type*	*Code**
	Sq. meters	*l/h*	*l/h*	*l/h/m²*	*Sq. meters*		
6,559	99,951.60	502,283.11	1,666,666.67	21.70	15.24	200-4040	21(1)
13,764	209,763.03	2,009,132.42	6,666,666.67	41.36	15.24	270-4040	21(2)
	597,245.07	3,995,433.79	21,118,721.46	42.05	15.24	270-4040	22(1)
	963,964.16	16,552,511.42	19,634,703.20	37.54	15.24	270-4040	23(1)
	678,526.22	7,305,936.07	6,963,470.32	21.03	15.24	200-4040	24(1)
	1,680,887.70	7,420,091.32	24,315,068.49	18.88	15.24	90-4040	25(1)
	2,014,345.38	5,650,684.93	36,872,146.12	21.11	15.24	90-4040	26(1)
	1,136,062.81	5,650,684.93	36,872,146.12	37.43	15.24	270-4040	26(2)
	4,131,654.55	5,194,063.93	36,700,913.24	10.14	15.24	90-4040	27(1)
	1,055,554.98	2,308,472.86	16,311,517.00	17.64	30.47	90-4040	27(2)
	525,157.66	2,885,591.07	20,389,395.25	44.32	30.47	270-4040	27(3)
	607,919.47	0.00	12,985,152.82	21.36	30.47	90-4040	28(1)
	850,688.99	0.00	18,179,223.74	21.37	15.24	200-4040	28(2)
	153,752.41	6,506,849.32	913,242.01	48.26	15.24	270-4040	29(1)

** Numbers in brackets depict the different TDS concentrations in the sub-basins*

X. Conclusion

Based on the above table, in the event of applying the nanofiltration and nanofilter membranes, the total volume of saline and brackish waters, the number of membrane modules and the required total surface area in the Persian Gulf and the Oman Sea basins would be as below:

- ✓ For the purpose of softening, desalination and reduction of TDS concentration in 147.76 million m^3 of saline and brackish waters per year, 568,168 membrane modules using the 90-4040 nanofilters would be needed at a total surface area of 9,490,362.1 square meters.
- ✓ For the purpose of softening, desalination and reduction of TDS concentration in 34.62 million m^3 of saline and brackish waters per year, 106,901 membrane modules using the 200-4040 nanofilters would be needed at a total surface area of 1,629,166.81 square meters.
- ✓ For the purpose of softening, desalination and reduction of TDS concentration in 143.20 million m^3 of saline and brackish waters per year, 218,074 membrane modules using the 270-4040 nanofilters would be needed at a total surface area of 3,585,945.14 square meters.

References

[1] Fazeli. Rashidi, 2000, "Water treatment and methods for improving the quality of potable water," Power and Water University of Tehran.
[2] Dow Liquid Separations "FILMTEC Membranes," Products and Specification Guide, tap water, seawater and brackish water elements for commercial, industrial and municipal applications, published May 2002, Dow Europe Official Building.
[3] EPA 815-R-06-009, "Membrane filtration guidance manual," November 2005, Environmental Protection Agency, United States.
[4] Archive of reports published by Iran Water Resources Management Company,2005.
[5] Moshaver Yekom Consulting Engineers, 2003, Bureau for Basic Studies of National Water Resources, 2002, Study of national saline and brackish water resources.
[6] Bureau for Basic Studies of National Water Resources, 2002, Classification and coding the national watershed basins .
[7] Jamab Consulting Engineers, 1985-1999, the National Water Master Plan.
[8] Bureau for Basic Studies of National Water Resources, 2002, Annual report on the condition of national ground waters.
[9] http://www.filmtec.com, (2006), "FILMTEC Membranes".