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Design of Reverse Osmosis Water Treatment Unit Using Lanxess Lewaplus2

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Abstract

Basrah is the richest town and the economic capital of Iraq. It suffers from lack of drinking water. This project is a dream to supply drinking water to Basrah citizens within WHO standards. Water should pass sedimentation and filtration stages before interring reverse osmosis unit. The design is carried out using Lewaplus2 software. Several parameters should be selected in the design step membrane type, number of stages, number of element in each stage, and the recovery percentage. An optimization is carried out using Minitab ver. 18 for the acceptable limit of TDS and minimum cost and it was found that the optimum conditions were 52% for first stage, the numbers of vessels are 20 for both the first and second stage. In addition, results showed that the pressure and the total dissolved solid increase with increasing the recovery while parameters like the feed flow rate per vessel, the power, and the cost are decreasing with the recovery. Mathematical model described the cost was conducted and statistical study was also done to ensure the results.

Keywords: Reverse Osmosis, Design, Minitab, Lanxess, LewaPlus2.

1. Introduction

Reverse osmosis is a membrane processes which is applied in many fields of industry such as desalination of seawater and brackish water [1], power generation treatment of municipal and industrial wastes [2], concentration of food products like dairy products [3, 4], Tomato paste products [5], pharmaceuticals [6], and many other applications comprising the semi-conductor industry, and recovery of important materials in chemical and petrochemical industries [7]. Most reverse osmosis treatment systems include pretreatment units, pressurizing units, membrane unit's ant post treatment. Pretreatment is required to control the scaling and fouling, as well as enhancing the performance of the RO treatment units. pressurization unit is required to maintain the operating pressure which is related to the feed water salinity, temperature and recovery, membrane filtration and post-treatment. RO recovery efficiencies are influenced by three factors and water analysis, the type of membrane water pressure [8, 9]. The recovery of system has to optimize the membrane performance and process economics [10]. Recovery depends on the number of reverse osmoses stages, for one stage, it does not exceed (50 %), for two stages (75-80%) and for three stages (85-90%) [11, 12]. Seawater reverse osmosis systems are designed for recovery (40-45%) in the first stage. The average permeate flux should be between (11.9-13.51 l/m2-hr). Many studies referred to the pH reduction for the water produced from RO system. Stabilization required to adjust the pH to meet the drinking water specifications [9]. the recommended value of pH by US Environmental Protection Agency is 6.5–8.5 for the produced water [13]. Design of Reverse osmosis unit operation is tedious, many researchers and designers use approximations and assumptions to treat such puzzles. Different correlations for osmotic pressure seen. The osmotic pressure depends on the concentration of impurities. As these concentrations being high in sea water, Solutions behaviour tend to non-ideal characteristics, one should calculate the activities instead of mole fractions. Using the water activity provides a better correlation of experimental data than the classical Van't Hoff equation [14].

LewaPlus2 software is provided by Lanxess Deutschland GmbH, Leverkusen, Germany. It is a comprehensive software design tool for ion exchange resins (IX) and reverse osmosis (RO) membrane systems was used in this work. The allows for design of IX and RO systems under a variety of system configurations. The first important thing is to enter the analysis of water. The software directly calculates the summation of cations, anions, TDS, conductivity, the osmotic pressure and the Ionic strength. According to

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the water analysis, one should select the configuration of the plant, Failure in calculation occurs at:

a) Osmotic pressure is higher than the feed pressure.
b) The requested recovery has not achieved.
c) Maximum number of iterations should not be exceeded.

2. Case study (Arab gulf water RO unit)

Water analysis of Arabian Gulf based on data in reference [15]. The Data are shown in Table 1. According to analysis entry, the software gives a summary of water analysis as shown in Fig. 1. Water analyses were input to the analysis menu; plant basis is 1500 m3/day production. The software allow designer to select design basis, either based on feed flow rate or system permeate flow. Select membrane type, number of stages, numbers per element each stage and the recovery percentage. Recoveries are selected with 40% as a minimum value.

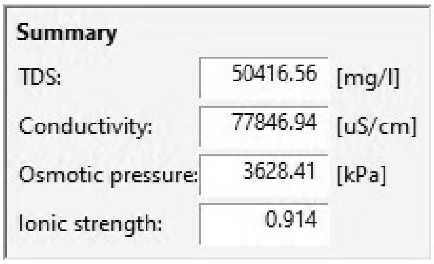

Figure (1): Summary of water analysis

Table (1): Analysis of the raw water.

Constituent	*ppm*
Cl^-	23000
Na^+	15850
$SO4^{--}$	3200
Mg^{++}	1765
Ca^{++}	500
K^+	460
HCO_3^-	142
Br^-	80
TDS : calc.	50417.49

3. Results and discussions

Simulation results for various recoveries and various numbers of vessels, is shown in Table 2, number of elements in each vessel was fixed two eight, it was recommended by the manufacturing company to select the number within (8-10) for large units. Data are collected from multi runs carried out on Lewaplus. From Table 2, increasing no of vessels reduces the cost extent, that is true because the productivity increased with increasing the recovery but the specification of the produced water should remain within the acceptable limits, Figs 2-7 show how the specification of RO system changes with increasing the recovery for (20 ,20) vessels in the two stages.

The increase of rejection ratio causes an increase in the concentrate flow per vessel. So increasing the number of vessels solve the problem. Increasing number of vessels above such extent increasing the feed pressure and that led to increase in pumping cost or may be doubled it. Decreasing the rejected rate also increase the feed flowrate per vessel was selected to reduce pressure for elements that are characterized by low permeability. The cost calculation includes the capital cost and the annual running costs. The project life is assumed to be 20 years.

The relation between recovery and pumping pressure takes a polynomial relationship as shown in Fig.3 and the relation of the recovery with feed flow for vessel is inversely related. It was found an inverse relationship between water conductivity and applied pressure, and pH levels slightly decreased at high pressures. Furthermore, the most effective parameter on the optimum values was the recovery rate. Optimization done by surface response analysis using MinitabV.18. Data calculated by Lewa Plus 2.0 entered for response surface analysis, the variables was number of vessels and the recovery as percent of feed flow. The response is the calculated Lewa plus cost. Accurate prices and running costs are roughly, they are subjected to feasibility studies. Results of response surface analysis are shown in Table 2, while Fig.8 shows the optimum values. Also, response surface analysis, was carried out to predict the impact of recovery, TDS, conductivity, and power, the responses are statistically significant for all the selected factors as shown in Table 3.

Table (2): Simulation results for changing recovery and No. of vessels.

R	N1	N2	APF	P1	fv	TDS mg/l	COND µS	pH	Power kW	Cost $
40	11	9	11.9	7131	17.75	24.71	50.3	5.7	504.72	14,177,182
42.5	11	9	11.9	7354	16.71	25.64	52.14	5.7	490.38	13,652,936
45	11	9	11.9	7618	15.78	26.69	54.22	5.7	480.25	13,224,137
47.5	11	9	11.9	7930	14.95	27.88	56.55	5.7	473.91	12,596,047
50	11	9	11.9	8275	14.2	29.18	59.11	5.7	470.11	12,879,333
40	12	11	10.4	7082	16.27	28.36	57.5	5.7	501.75	14,199,406
42.5	12	11	10.4	7308	15.31	29.45	59.64	5.7	487.87	13,681,663
45	12	11	10.4	7576	14.46	30.68	62.06	5.7	478.12	13,258,323
47.5	12	11	10.4	7891	13.7	32.07	64.78	5.7	472.12	12,918,361
50	12	11	10.4	8238	13.02	33.59	67.76	5.7	468.57	12,638,653
40	15	15	7.96	6783	13.02	37.99	76.34	5.7	482.29	14,072,938
42.5	15	15	7.96	7029	12.25	39.58	79.43	5.7	470.93	13,591,069
45	15	15	7.96	7314	11.57	41.37	82.91	5.7	463.32	13,198,263
47.5	15	15	7.96	7644	10.96	43.38	86.8	5.7	459.13	12,883,931
50	15	15	7.96	8011	10.41	46	91.1	5.7	457.43	12,630,621

40	20	20	5.97	6563	9.76	52.8	104.98	5.7	468.83	14,096,582
42.5	20	20	5.97	6827	9.19	55.2	109.59	5.7	459.63	13,645,489
45	20	20	5.97	7128	8.68	57.88	114.74	5.7	453.8	13,277,947
47.5	20	20	5.97	7471	8.22	60.87	120.47	5.8	451.05	12,984,132
50	20	20	5.97	7854	7.81	64.2	126.84	5.8	450.83	12,751,928
52	20	20	5.97	8198	7.51	67.17	132.5	5.8	452.73	12,611,380

R: recovery, N1: number of vessels in stage 1, N2: number of vessels in stage 2, APF: average permeate flux, P1 Pump1discharge pressure for stage1, fv flow per vessel, TDS: total dissolved solids, COND: conductivity, pH: acidity.

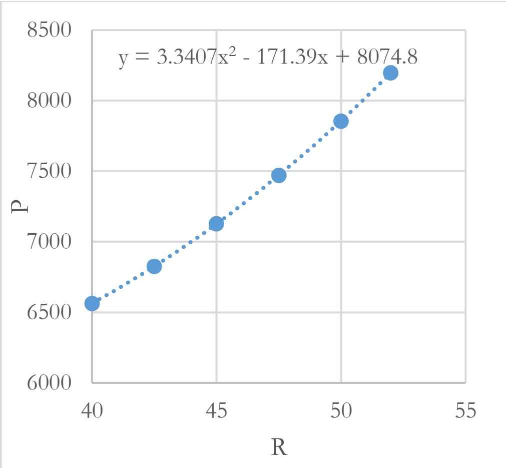

Figure (2): Pressure vs. recovery

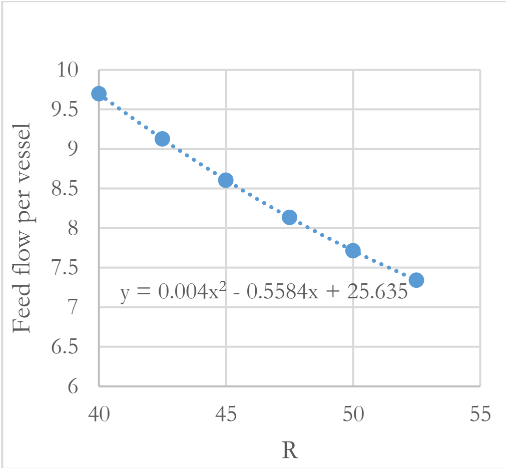

Figure (3) Feed flow per vessel VS. recovery

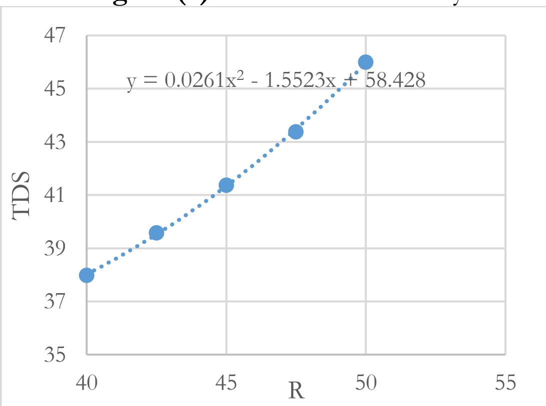

Figure (4): TDS vs. Recovery

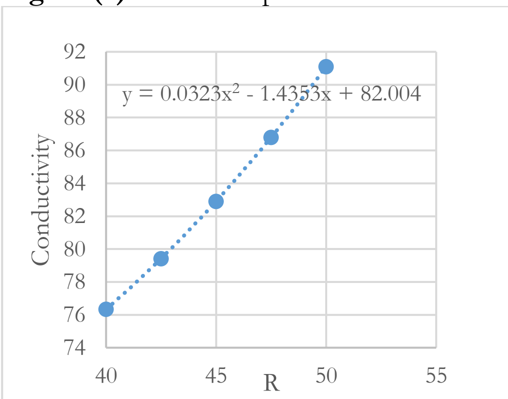

Figure (5): Conductivity. Recovery

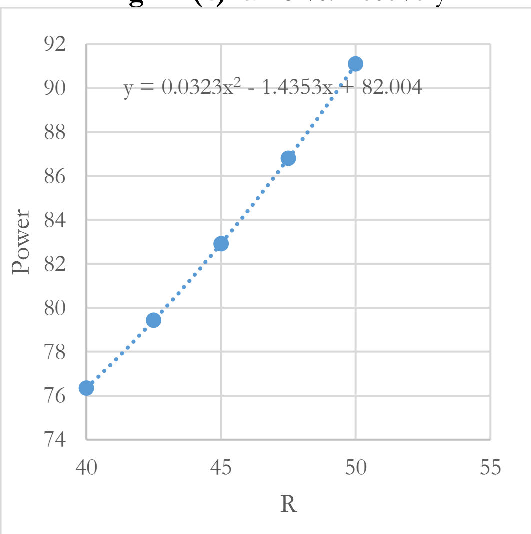

Figure (6): Power vs. Recovery

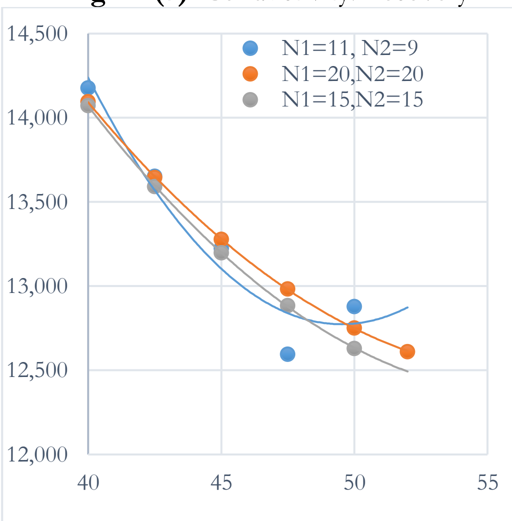

Figure (7): Total Predicted Cost vs. Recovery

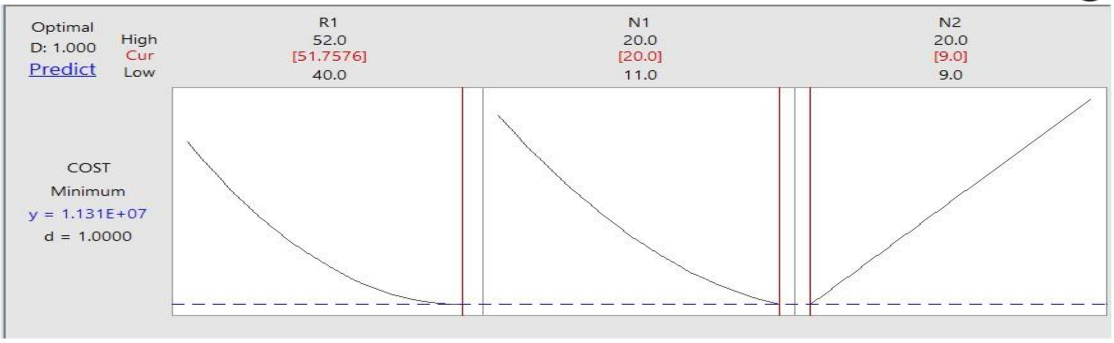

Figure (8): Minitab plot shows the optimum values.

Table (3): Analysis of variance table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	20	6.04890E+12	3.02445E+11	0.00	*
Linear	6	64828362052	10804727009	0.00	*
R1	1	5634813252	5634813252	0.00	*
N1	1	15393722417	15393722417	0.00	*
N2	1	2993912357	2993912357	0.00	*
TDS	1	8924385490	8924385490	0.00	*
COND	1	6583621787	6583621787	0.00	*
POWER	1	7261791629	7261791629	0.00	*
Square	5	44167649490	8833529898	0.00	*
R1*R1	1	91308893	91308893	0.00	*
N1*N1	1	2195215464	2195215464	0.00	*
TDS*TDS	1	32746377	32746377	0.00	*
COND*COND	1	173919739	173919739	0.00	*
POWER*POWER	1	9832387658	9832387658	0.00	*
2-Way Interaction	9	1.25312E+11	13923571389	0.00	*
R1*N1	1	4510306465	4510306465	0.00	*
R1*N2	1	1109939423	1109939423	0.00	*
R1*TDS	1	4155166247	4155166247	0.00	*
R1*COND	1	3987042948	3987042948	0.00	*
R1*POWER	1	21231113	21231113	0.00	*
N1*TDS	1	297591122	297591122	0.00	*
N1*COND	1	1595165	1595165	0.00	*
N1*POWER	1	372229072	372229072	0.00	*
N2*TDS	1	2996843891	2996843891	0.00	*
Error	0	*	*		
Total	20	6.04890E+12			

The predicted model is:

Regression Equation in Uncoded Units

Cost = -12807049434 + 14996090 R1 + 157614664 N1 - 57576363 N2 - 1112555238 TDS + 481827592 Cond + 34609290 Power + 160720 R1*R1 + 9856502 N1*N1 - 925994 TDS*TDS + 633387 Cond*Cond - 28080 Power*Power + 12462583 R1*N1 - 1215696 R1*N2 + 22568133 R1*TDS - 11780619 R1*Cond + 5587 R1*Power - 19787407 N1*TDS + 762865 N1*Cond + 51388 N1*Power + 10647278 N2*TDS

4. Conclusion

LewaPlus 2 is a good assistant software to the chemical engineers who are working in the field of water treatment plant design, it helps to jump over tedious calculations or assumptions in the design of reverse osmosis units. Minitab helps the decision maker for choosing the optimum design from cost view and the water quality. Cost may be decreased in more percentages, that is shift the balance from quality. Good design offers the control of such parameters in a suitable range. otherwise operation problems occurred if the operation span is narrowed. From response surface analysis, it is concluded the impact of recovery, TDS, conductivity, and power, the responses are statistically significant.

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