Parametric analysis of (One Stage with Two Pressure Vessel) Brackish Water Reverse Osmosis System

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Abstract: - Reverse Osmosis System Analysis (ROSA) model is used to simulate a brackish water desalination system under different feed flow and number of membrane elements. The design is one stage with two pressure vessel configuration to provide at least 35 m^3/day of drinking water for 110 households in Mersing, Johor, Malaysia. The design showed highest permeate flow of 45.08 m^3/d, minimum specific energy of 1.6kWh/m^3, and maximum recovery of 58.55% with permeate TDS of 346.51mg/l and desalination cost of 0.19$/ m^3. These design results are found at feed flow of 77m^3/d, feed pressure of 27bar and by using 8 elements of membrane in each pressure vessel.

Key-Words: - desalination, Brackish water, reverse osmosis; single stage, two pressure vessels, 3 kW load; ROSA software, parametric analysis

1 Introduction

About 1.76 billion people live in areas already facing a high degree of water stress [1]. ''Water stress'' is at the top of the international agenda of critical problems, at least as firmly as climate change [2]. As a result, the need for desalination is increasing, even in regions where water supply is currently adequate. Increasing demand for water is a big problem[3].

Reducing the salt content in brackish water and sea water to turn them in drinkable supply, a process called "desalination". Brackish water is water that has more salinity than fresh water, but not as much as seawater [4, 5].

Reverse osmosis (RO) technology is ranked among the most appropriate in desalination systems [6]. Reverse osmosis (RO) desalination is a treatment process for production of fresh, low salinity potable water from saline water source (sea or brackish water) via membrane separation. The mineral/salt content of the water is usually measured by the water quality parameter named total dissolved solids(TDS), concentration of which is expressed in milligrams per liter (mg/L), or parts per thousand (ppt). The World Health Organization (WHO) has established a maximum TDS concentration of 500 mg/L as a potable water standard. This TDS level can be used as a classification limit to define potable (fresh) water [7].

RO systems consist of the following basic components: Feed water supply unit, pretreatment system, high pressure pumping unit, membrane element assembly unit, instrumentation and control system, permeate treatment and storage unit, and cleaning unit [8, 9].

In this paper, one stage configuration with two pressure vessel is designed. In each pressure vessel numbers of elements are assumed 6-8. (See Figure 1).

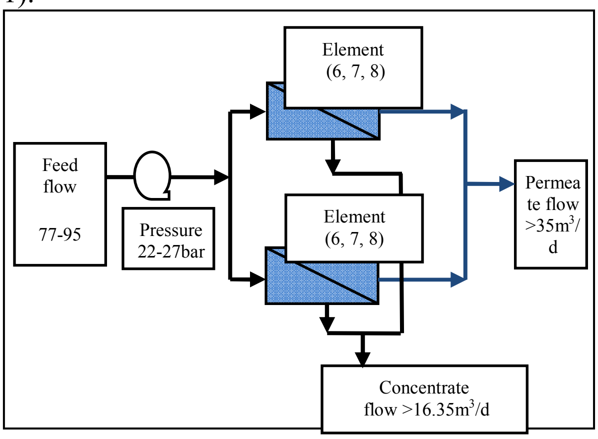

Figure 1 Schematic diagram of one stage BWRO with two pressure vessels

2 Material and Method

2.1 Brackish water salinity/type of membrane

Sample of water source is from Mersing, Johor, Malaysia with altitude 1°22' N and longitude 103°59' E. Most of residents in Mersing are near 4 to 7 km from the sea. Testing the TDS of water sample by conductivity meter showed that the TDS content in the water is 13,400 mg/L. This sample is categorized as brackish water, because according to National Research Council (2004), TDS content in brackish water is between 1000 mg/L to 15.000 mg/L.

The water demand is assumed for 110 households. According to [11], the average freshwater demand is about 0.32 m^3 / household/day. Determined RO designs will be capable to produce more than 35 m^3/day of freshwater. The type of membrane that used in this research is BW30-4040.

2.2. ROSA (Reverse Osmosis System Analysis)

The optimum simulation results can be decided with considering highest permeate flow, lowest pressure and specific energy, maximum recovery and acceptable permeate TDS). Table 1 shows the simulation results of one stage with two pressure vessels of 3 kW BWRO system. The range of permeate flow is 37.75-45.08(m^3/d), permeate TDS is 242-346(mg/L), Specific energy is 1.6-2(kWh/m^3), recovery is 30-58.5% and desalination cost is 0.18-0.2($/$m^3$). Figures (2-5) below show the effect of feed flow and number of membrane elements on the output of permeate flow, permate TDS, specific energy and system recovery. Figure 2 shows the effect of feed flow on permeate flow with different number of element. The highest permeate flow is 45.08 m^3/d at 77 m^3/d feed flow with 8 membrane element of each pressure vessel. Increasing feed flow (77-87m^3/d) shows slow reduce in the permeate flow. Increasing number of membrane elements is more significant than increasing feed flow.

Reverse Osmosis System Analysis (ROSA) model is a sophisticated RO design program that predicts the performance of membranes and energy requirements for desalination systems. The ROSA model has been used for designing desalination plants in different parts of the world [10]. Input data of desalination cost is shown in table 1. The optimum RO design will be evaluated based on the output of permeate flow (m^3/d), perm TDS (mg/L), specific energy (kWh/m3), Recovery (%), and the desalination cost ($/$m^3$) at different range of feed flow, feed pressure and number of membrane elements.

3 Design assumptions

1. One stage RO design with two pressure vessel
2. The load of the RO unit is 3kW only.
3. The type of membrane that used in this research is BW30-4040.
4. The permeate TDS is as high as possible but less than 500ppm.

4 Result and discussion

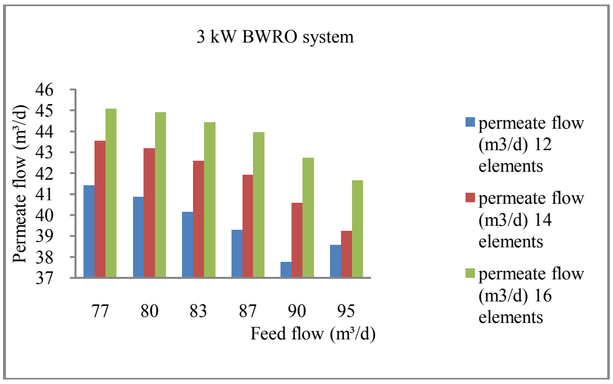

Figure 2 Effect of feed flow and membrane elements on permeate flow

Figure 3 shows the effect of feed flow and number of membrane elements on permeate TDS. Increasing feed flow will reduce the permeate TDS. While increasing number of elements will increase the permeate TDS.

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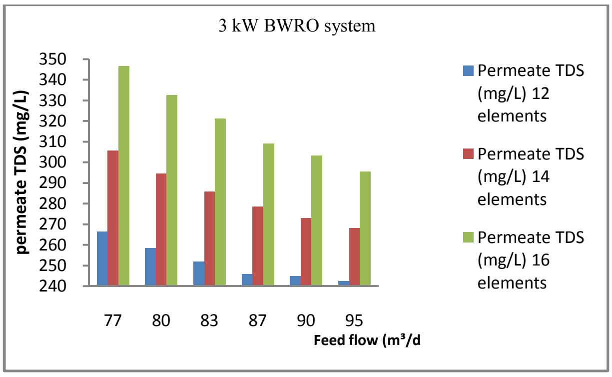

Figure 3 Effect of feed flow and membrane elements on permeate TDS.

Figure 4 shows the effect of feed flow and number of membrane elements on specific energy. Increasing the feed flow will increase the specific energy. While increasing the number of membrane elements will decrease the specific energy.

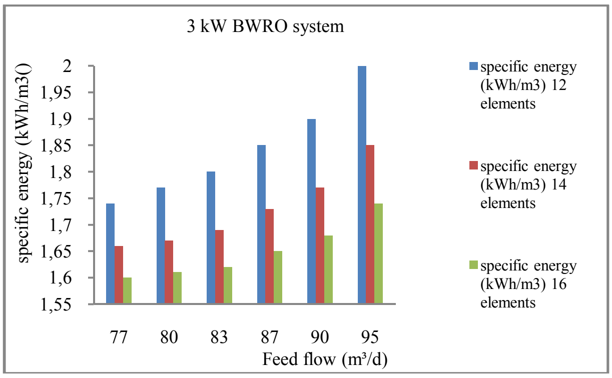

Figure 4 Effect of feed flow and membrane elements on specific energy

Figure 5 shows the effect of feed flow and number of membrane elements on system recovery. When feed flow increase, the recovery will decrease. Also, increasing number of elements will increase the recovery.

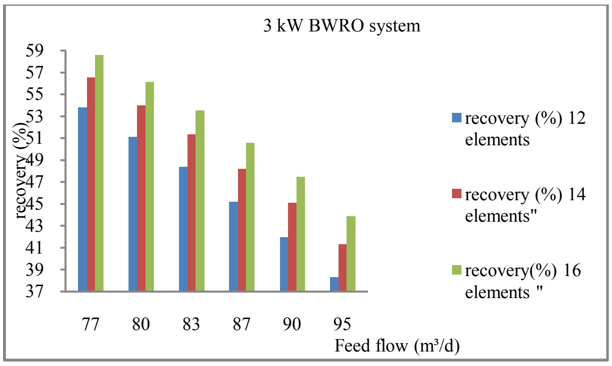

Figure 5 Effect of feed flow and membrane elements on system recovery

Table 1 simulation result of the Studied RO system

Feed flow (m³/d)	Number of element	Pressure (bar)	Perm. flow (m³/d)	Conc. flow (m³/d)	Perm TDS (mg/L)	Power (kW)	Specific energy (kWh/m^3)	Recovery (%)
77	12	27	41.42	35.58	266.29	3.01	1.74	53.79
80	12	26	40.88	39.12	258.2	3.01	1.77	51.1
83	12	25	40.14	42.86	251.98	3	1.8	48.36
87	12	24	39.29	47.71	245.69	3.02	1.85	45.16
90	12	23	37.75	52.25	244.73	3	1.9	41.95
95	12	22	38.58	56.42	242.3	3.01	2	30.29
77	14	27	43.54	33.46	305.51	3.01	1.66	56.54
80	14	26	43.19	36.81	294.44	3.01	1.67	53.98
83	14	25	42.59	40.41	285.64	3	1.69	51.32
87	14	24	41.93	45.07	278.48	3.02	1.73	48.19

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90	14	23	40.59	49.41	272.94	3	1.77	45.1
95	14	22	39.25	55.75	268.2	3.01	1.85	41.32
77	16	27	45.08	31.92	346.51	3.01	1.6	58.55
80	16	26	44.9	35.1	332.48	3.01	1.61	56.12
83	16	25	44.44	38.56	321.05	3	1.62	53.55
87	16	24	43.96	43.04	308.96	3.02	1.65	50.52
90	16	23	42.73	47.27	303.28	3	1.68	47.48
95	16	22	41.65	57.35	295 53	3.01	1.74	43.84

5 Conclusion

Under 3kW RO load and brackish water of TDS 13,400mg/L, feed flow and number of membrane element affected significantly the design of BWRO system.

The best design showed highest permeate flow of 45.08 m^3/d, minimum specific energy of $1.6kWh/m^3$, and maximum recovery of 58.55% with reasonable permeate TDS of 346.51mg/l and desalination cost of 0.19$/ m^3. These design results are found at feed flow of $77m^3/d$, feed pressure of 27bar and by using 8 elements of membrane in each pressure vessel.

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