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RESEARCH ARTICLE

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STUDIES ON WATER DESALINATION USING DOW SW30 – 4040 REVERSE OSMOSIS MEMBRANE UNIT

ABSTRACT:
Experimental investigations have been carried out to obtain pure water from saline water of high salt content. The water is processed through a quartz sand filter, two 5 micron filters and then through an Reverse Osmosis(RO) unit. The RO unit contains four Dow SW30 – 4040 membranes. The effects of applied pressure, feed concentration are determined on outlet pressure, product stream flow rate and product concentration. A useful correlation has been obtained that relates product water concentration as a function of feed water concentration and applied pressure.
Keywords: reverse osmosis; desalination; membrane, water treatment

1. INTRODUCTION:

Now-a-days entire world is facing the challenge of scarcity of potable waters. It is well known that the distribution of potable water sources across the globe is not as per the needs of the population. As a result, in many parts of the world, treatment of available water is necessary to convert that into potable purpose. In this regard many techniques are being employed worldwide. Widely used techniques are water distillation, electrodialysis, reverse osmosis, chlorine treatment, ozone treatment, UV treatment, coagulation, flocculation, sand filtration, activated charcoal adsorption etc [1-3]. These methods are employed either alone or in combination with other methods.

Shannon et al [4] extensively reviewed various aspects of water treatment such as disinfection, decontamination, desalination, reuse and reclamation. The review presented that, in the present day among the global installed capacity of water purification plants, more than 50% installed capacity is through Reverse Osmosis Technology. Further, the installed capacity utilizing this technology is growing very rapidly since the RO technology addresses almost all aspects of the water purification criteria.

The health effects caused by the presence of arsenic in drinking waters and its removal from waters have been studied extensively over the years and the corresponding technologies and health effects have been thoroughly reported [5-7]. Similarly, studies on the presence of mercury in drinking waters its ill effects and its removal have been presented in detail by Thiem et al [8] and Huang and Blankenship [9]. A thorough review of the hazardous effects of heavy metals such as zinc, copper, nickel, cadmium, lead and chromium in drinking waters and the available technologies to remove them have been reviewed by Fu and Wang [10].

Several health issues have been recorded worldwide due to the presence of lead in drinking waters. Apart from other sources, lead is also a minor constituent in kitchen utensils, hence the presence of lead in the earlier days was inevitable. Research investigations due to the hazardous effects of lead on humans have been carried out extensively and two reviews in this regard have been recently published by Papanikolaou et al[11] and Hu et al [12].

Similar investigations have been reported globally on the hazardous effects of cadmium [13-15], chromium [16-18], fluorides [19-24], nitrates [25-27], nitrites [28-29] etc. Several treatment methods are available for the removal of contaminants from drinking waters. Latest trend in water purification technology is the usage of membranes. Several investigations [30-36] have been reported on the usage of different membranes for removal of various contaminants. The use of membranes now-a-days is also proved to be economical in producing commercial drinking waters. However, a close examination of the literature revealed that there is no specific study that has been carried out on the effect of pertinent variables such as pressure, concentration, temperature and flow rates on the discharge rates and concentration levels of the product waters. To the best knowledge of the author, so far no such work has been reported in the literature by employing Dow Chemical Company's SW30-4040 membrane. In view of this the present work is taken up.

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In recent past for purification of waters either commercially or domestically, reverse osmosis technique is being used along with UV treatment and activated charcoal filtration. When necessary only, pretreatment is being employed especially in commercial drinking water plants. Among the available membranes, it is well established that Dow Company membranes are of the best quality. For reverse osmosis applications, different types of Dow Filmtec membranes are available. A large number of membranes are there in use in these applications. In view of this, in the present investigation, a DOW RO membrane obtained from trade, SW30-4040 has been chosen and its performance against various operating variables of the process has been investigated. The range of variables covered in the present investigation is compiled and presented in Table.1.

S.No.	Parameter Studied (units)	Minimum	Maximum	Maximum/Minimum
1.	Pressure (MPa)	4.0	5.0	0.8
2.	Flow Rate (Lpm)	1.4	18.72	13.3
3.	Membrane Surface area(m^2)	7.4	29.6	4.0
4.	Concentration (ppm)	950	32000	33.6

Table.1: Range of variables covered in the present study

2. DESCRIPTION OF EXPERIMENTAL SETUP:

The schematic representation of the experimental test rig employed in the present investigation is shown in Fig.1. The equipment essentially consists of three storage tanks, one feed water pump, two numbers of 5 micron filters and membrane battery consisting of 4 membrane units in series. T1 is the feed water tank. T2 is the permeate tank that contains the product water i.e., purified water where as T3 is the rejected water tank. Filters F1 and F2 are five micron filters in the sense the pore size is about 5 microns. Only impurities lower than 5 microns can only pass through these filters. The filtered water is then passed through the membrane battery. Here 4 numbers of Dow SW30-4040 membranes are available. The onnections are flexible, in the sense, any number of membranes can be used in the water line and they can be joined either in series or in parallel arrangement [37]. The equipment is operated as per the instructions of the manufacturer [38].

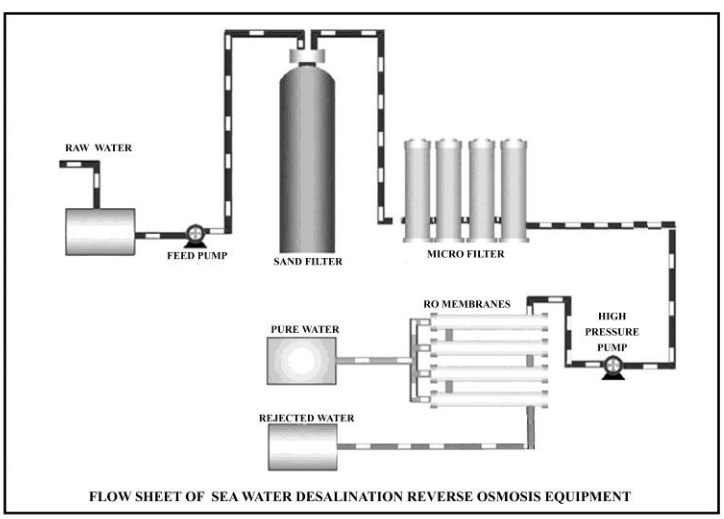

Fig.1. Schematic of the experimental unit

3. RESULTS AND DISCUSSION

In this chapter the effect of applied pressure and feed concentration on product stream concentration has been discussed in detail.

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3.1.Effect of feed concentration on outlet pressure

When the inlet pressure at the entrance of the membrane module is fixed at 5.0 MPa, data on the variation in outlet pressure i.e., pressure measured at the exit of last membrane were obtained against time for a given feed water concentration of 31000 ppm. The inlet and outlet pressures thus obtained were shown in Fig.2. A close examination of the plots of the graph revealed that the inlet pressure was maintained almost constant about 5.0 MPa where as the outlet pressure is maintained almost constant around 3.6 MPa. The reason for the decrease in the pressure can be attributed to the usage of high pressure energy for reverse osmosis operation which allowed permeation of pure water through the membranes.

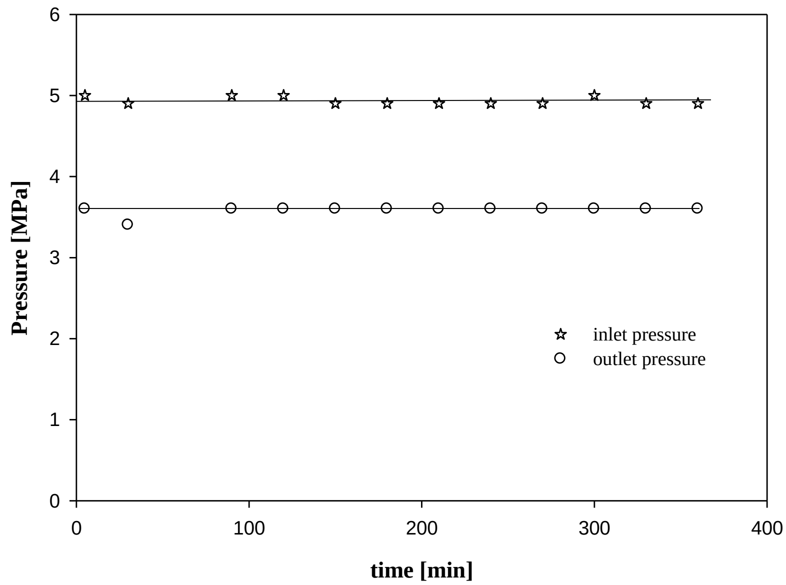

Fig.2. Inlet and outlet pressures for feed water concentration of 31000 ppm

In the present study the feed concentration is varied from 1000 ppm to 31000 ppm. For the inlet pressure of 4.0 MPa, the variation in the outlet pressure is depicted for all these concentrations and shown in Fig.3. A close look at the plots of this figure revealed that the influence of feed concentration seems to exhibit an interesting behaviour on outlet pressure.

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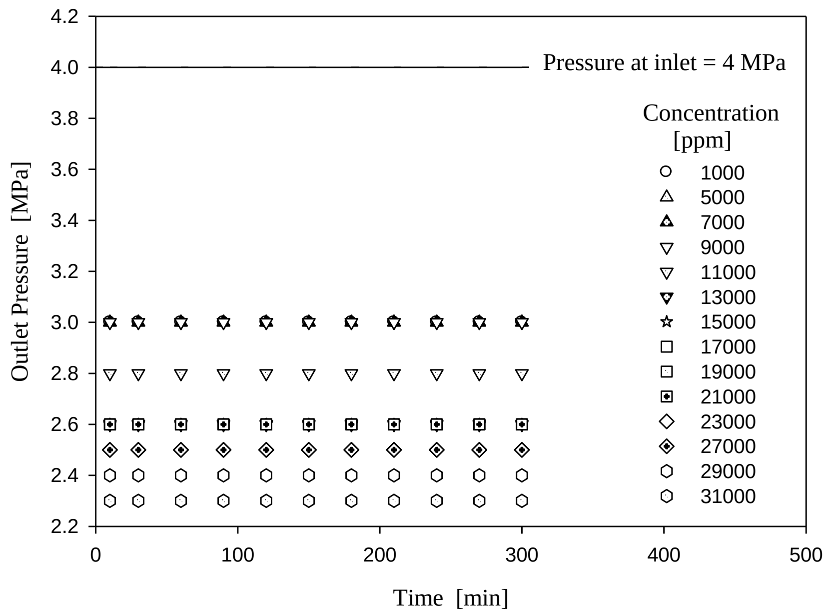

Fig.3. Effect of concentration on outlet pressure for applied pressure = 4.0 MPa

In order to have a clarity of this influence, corresponding to a time of 60 min, a cross-plot was obtained for outlet pressure drawn against feed concentration and is shown depicted in Fig,3a. A close examination of the plot of this figure revealed that the outlet pressure remained constant initially when the feed concentration is varied from 1000 ppm to 10,000 ppm. This implies that upto this concentration the membrane surface available for solvent permeation is not influenced by the solute presence in the solvent. Further increase in feed concentration upto 15,000 ppm resulted in a decrease in outlet pressure. The reason can be attributed to the occupation of membrane surface with solute molecules. Further increase from 15,000 ppm to 21,000 ppm, the influence of the solute molecules on available membrane surface remains marginal. However, further increase in feed concentration resulted in a decrease in outlet pressure.

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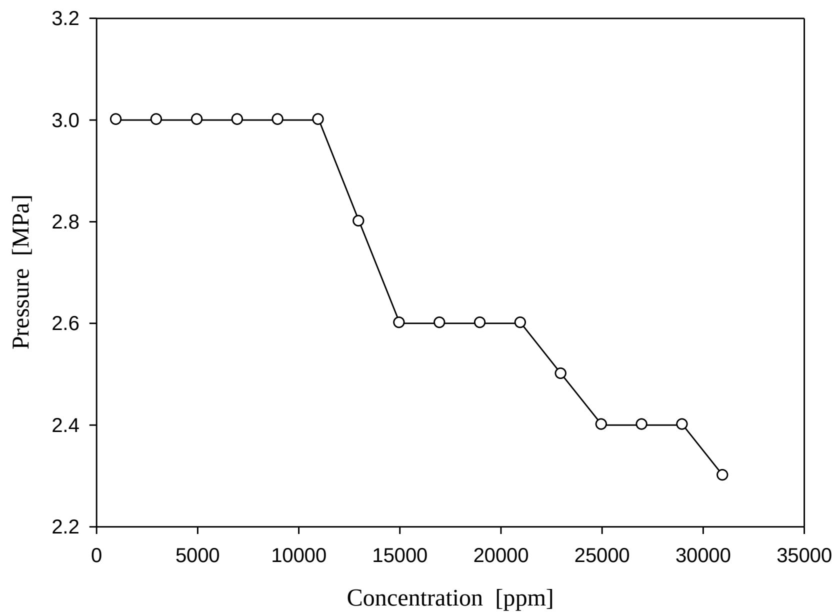

Fig.3a. Variation of outlet pressure with feed concentration at an inlet applied pressure of 4.0 MPa

3.2.Effect of feed concentration on pure water flow rate

In order to understand the influence of salt concentration in feed waters on flow rate of purified water, data on pure water flow rate were collected and plotted against time for the concentrations of salt in feed waters varying from 11000 ppm to 29000 ppm and shown in Fig.4. The inlet pressure in this case is maintained constant at 4.0 MPa. One can anticipate that the flow would decrease with increase in salt concentration of feed waters. This is because the salt molecules occupy some surface of the membrane and as the salt concentration increases the surface occupied by the salt molecules increases and hence the area of membrane that is available for flow of solvent molecules i.e., water molecules would become less. Hence an increase in salt concentration will decrease the flow rate of pure water when the pressure is maintained constant. The plots of the figure indicate same trend.

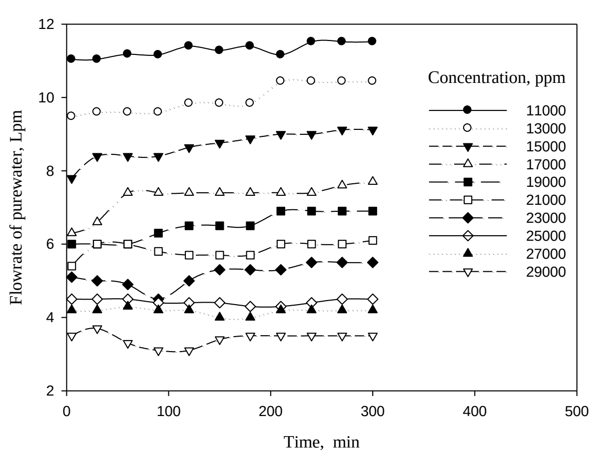

Fig.4. Effect of concentration of flowrate of pure water, pressure 4 MPa

3.3.Effect of inlet pressure on pure water flow rate

One can expect that an increase in applied pressure at the inlet of the membrane will definitely cause an increase in the flow rate of permeate. To examine such behavior plots were drawn for permeate flow rate against time for three applied inlet pressures considered in the present study viz., 4.0, 4.4 and 5.0 MPa for a given concentration of 17000 ppm. The plots were shown in Fig.5. By inspecting the plots of this graph, one can deduce that an increase in inlet pressure resulted in an increase in permeate flow rate.

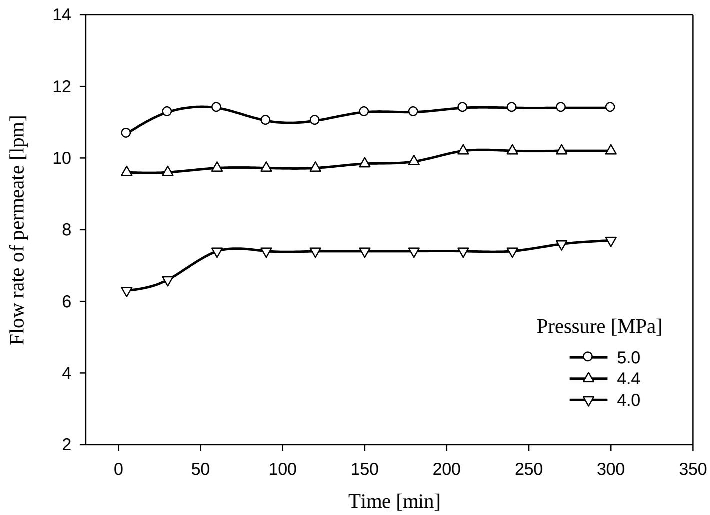

Fig 5. Effect of Pressure on flowrate of permeate at a feed concentration of 17000 ppm

3.4.Effect of membrane length on pure water flow rate

One can expect that an increase in the length of the membrane will definitely yield an increase in the flow rate of permeate. To examine such behavior, in the present experimental study, it was arranged in such a way that only one membrane unit (I Stage), 2 units (II Stage), 3 units (III Stage) and four units (I V Stage) were arranged for each of the experiment and data were obtained for permeate flow rate against time at a given feed concentration and a specified applied pressure. Fig.6 represents data for 9000 ppm of feed concentration at an applied pressure of 4.0 MPa. A close look at the plots of the figure revealed that as the number of stages are increased the permeate flow rate also increased.

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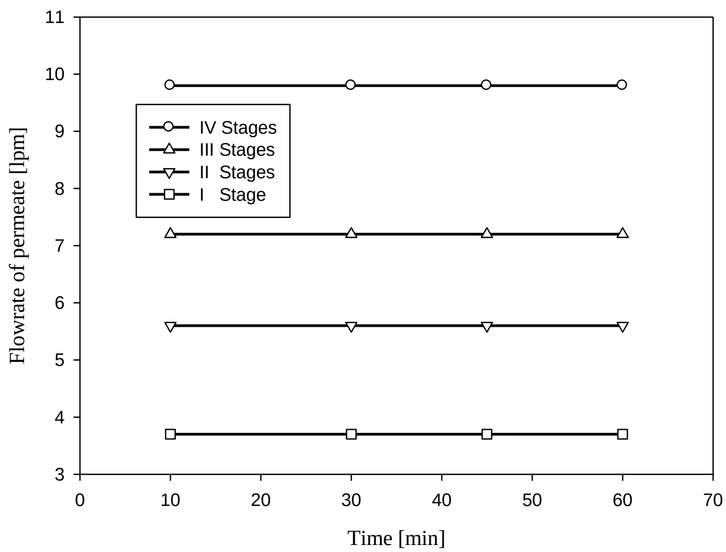

Fig.6. Effect of Membrane length on flowrate of permeate, with feed concentration of 9000 ppm and applied pressure of 4.0 MPa

3.5.Effect of feed concentration on pure water

It can be expected that an increase in feed concentration would cause an increase in the TDS levels of the permeate water. Because more salt molecules gets trapped in the membrane pores and due to applied pressure some of them may move into the pure water stream. To examine this, for the case of 4.0 MPa applied pressure, the effect of feed concentration on pure water stream concentration has been drawn and shown in Fig.7. The graph contains three plots viz., permeate concentration, feed concentration and rejectate concentration. As expected the permeate concentration is very less and the rejectate concentration is obviously more than the feed water concentration.

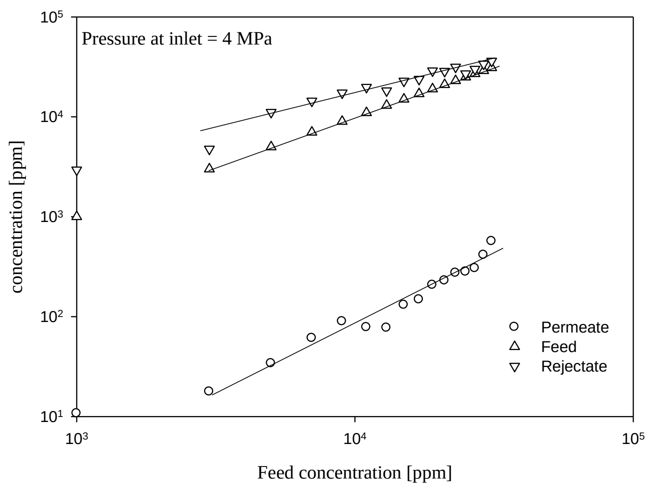

Fig.7. Effect of concentration on outlet pressure for applied pressure = 4.0 MPa

Fig.7. Effect of concentration on outlet pressure for applied pressure of 4.0 MPa

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3.6. Development of correlation

The entire data obtained in the present study has been correlated to predict pure water stream concentration as a function of feed water concentration and applied pressure.

Let C_P = Pure water stream concentration, ppm
C_F = Feed water concentration, ppm
P = Applied pressure, MPa.

By Least Squares Regression analysis, the correlation equation can be found as

$$C_P = 0.004 C_F^{1.113} P^{0.139} \qquad \ldots(1)$$

Average deviation = 7.05 percent; Standard deviation = 13.58 percent.

The correlation graph according to eqn.(5.1) is shown in Fig.8.

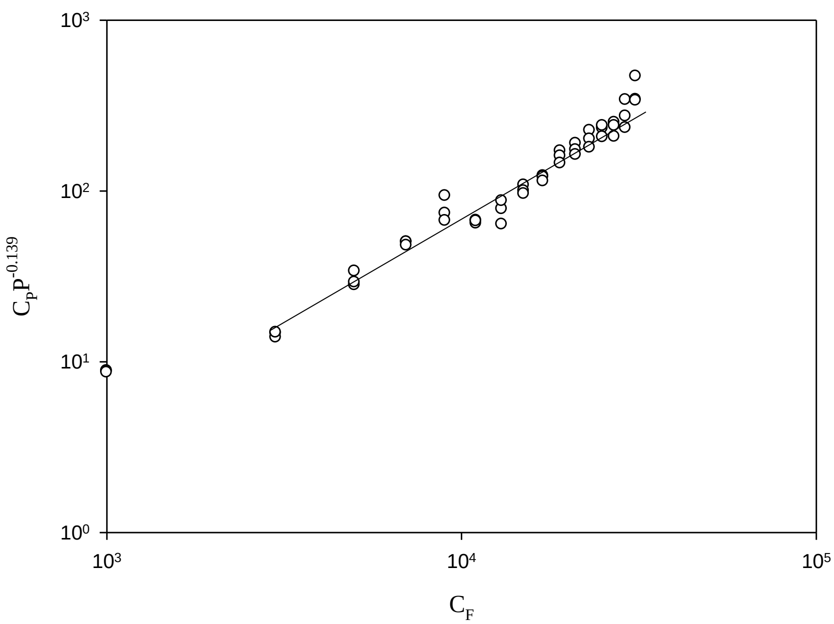

Fig.8. Correlation plot in accordance with eqn.(1)

4. CONCLUSIONS:

Experiments were conducted to obtain purified water from salt waters using a DOW SW30-4040 Reverse Osmosis membrane. From the present investigation the following conclusions were drawn.

Feed concentration was varied from 1000 to 31000 ppm whereas the applied pressure is varied from 4.0 to 5.0 MPa. The feed concentration was found exercise considerable influence on outlet pressure which was measured at the exit of the RO unit. An increase in feed concentration resulted in a decrease in outlet pressure. An increase in feed concentration caused a decrease in product stream flow rate. An increase in applied pressure resulted in an increase in flow rate of product stream. An increase in membrane length resulted in an increase in permeate flow rate. An increase in feed concentration yielded an increase in product stream and rejectate stream concentrations. A correlation has been developed to predict pure water concentration as a function of feed concentration and applied pressure.

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