



Optimization of Membrane Desalination Process Along With Products Recovery

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ABSTRACT

Development of desalination technologies in recent years, especially in the case of reverse osmosis process, enables now the massive production of drinking water with a moderate cost, providing flexible solutions to different necessities within the fields of population supply, industry and agriculture. The development of reverse osmosis (RO) technology has been a consequence of several factors such as reduction in energy consumption and decrease in membrane cost. The best option is to concentrate the brine by reverse osmosis up to the technical limit of the process. In this paper the concentrate obtained from RO is further treated in evaporator in which additional freshwater is obtained. The thick liquor from the evaporator is further processed into crystallizer where salt is obtained and the mother liquor is recycled back to crystallizer. In this way by concentrating the reject from RO freshwater is recovered and by using crystallizer valuable product such as salt is obtained. From the experimentation/analysis the results obtained are positive as discussed in the paper. The possibility of producing water from brackish groundwater using reverse osmosis processes is studied. Brackish groundwater samples were taken and characterized in terms of pH, conductivity and hardness. The objective of this paper is to concentrate the reject from RO (brine) by means of evaporator to obtain additional freshwater. The product is processed in crystallizer to obtain crystals.

INTRODUCTION

Due to introduction of membrane desalination and the major technological advancements that have been made in the last 10-15 years in the field, desalination is becoming more and more commercialized and increasing the spectrum of suitable and possible applications for it. The only aspect of desalination that has been relatively neglected is the environment. Solution for brine disposal should be in more focus than it is today. For brine disposal, the methods used are vital. There are two completely different scenarios regarding brine disposal, which is determined by the location of the plant. The most suitable disposal methods from the environmental and economical perspective have to be evaluated site-specifically. Methods like Deep aquifer injection and discharge to inland surface have their own disadvantages (Mickley 2001, Lu et al. 2000). An alternative approach is to further process the reject to extract all the salts. In this paper the process is being optimized by using RO followed by evaporator and crystallizer.

MATERIALS AND METHODS

The possibility of producing water from brackish groundwater using reverse osmosis (RO) process has been studied. The spiral wound polyamide RO module has been used for experimentation. Brackish

groundwater samples were taken and characterized in terms of pH, conductivity, hardness and inorganic matters. The reject from RO (brine) was concentrated by means of evaporator by which additional freshwater was obtained. Concentrated brine was further treated in crystallizer to recover the brine in the form of crystals thus, leading to zero liquid discharge (Ahmed et al. 2002).

Brackish groundwater has about 5000 mg/L common salt, which was fed into the feed tank. The feed was pumped into the micron filter for pretreatment. The pretreatment was important in RO because the feed water must pass through very narrow passage during the process. Suspended solids must be removed from the water so that salt precipitation or microorganism growth does not occur on the membrane. The high pressure pump supplies the pressure needed to enable the water to pass through the membrane and have the salt rejected. The membrane used here was spiral wound membrane, made up of polyamide material. Different inlet and outlet pressures for RO membrane at certain time intervals were measured. Simultaneously, samples of permeate and concentrate were taken for measuring concentration of salts. The concentrate, which was collected finally was taken and fed to the evaporator, which was calendria type. Concentrate was heated in the evaporator by directly passing the steam at about 1.5 bar. The steam entering the chest may be superheated. Flow rate of feed should be constant. The vapours generated at the evaporator were cooled in condenser; this condensate usually leaves the steam chest somewhat subcooled below its boiling point. Here, additional freshwater in terms of condensate is obtained. The thick liquor was then fed into hating type crystallizer. Hot water was fed to the jacket. Continuous stirring was given to the solution. As soon as the saturation point was reached, stirrers were stopped. Sudden cooling is given to the crystallizer by supplying cold water (tap water). Crystals formed were weighed and % yield was calculated. The schematic diagram of experimental set up is shown in Fig. 1.

RESULTS AND DISCUSSION

Brackish water of 120 L having 5000 mg/L common salt was taken as feed. This quantity of feed was processed into the reverse osmosis plant. Different pressures of reverse osmosis, flow rate of permeate and retentate or concentrate are given in Table 1. At about 95% rejection, 101 L of permeate

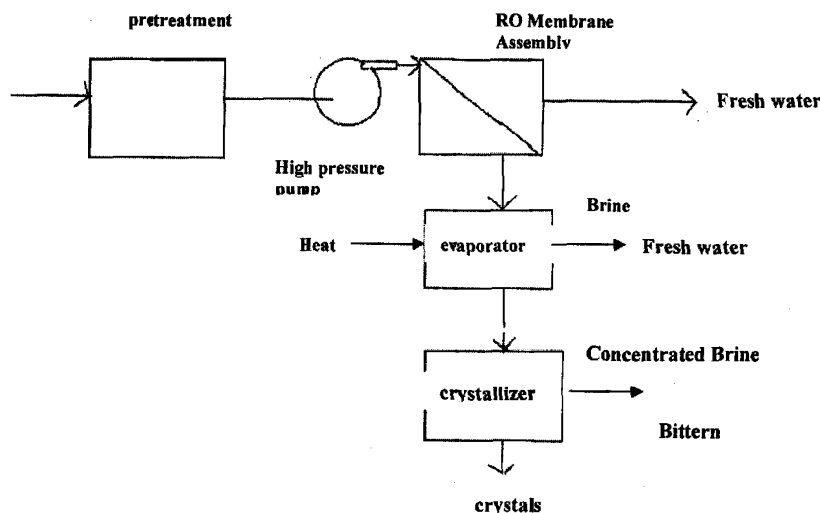


Fig. 1: Schematic diagram of experimental set up.

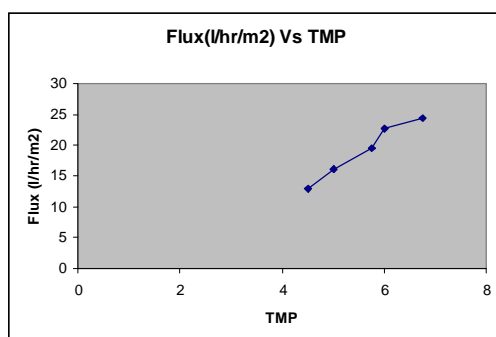


Fig. 2: Flux Vs TMP.

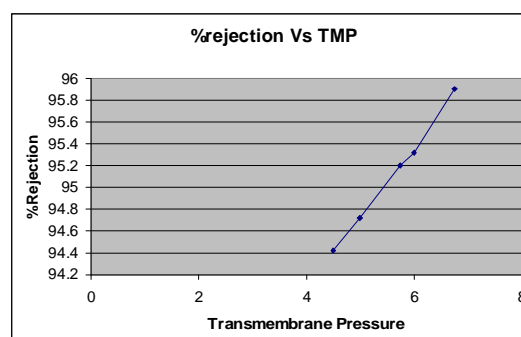


Fig. 3: %Rejection Vs TMP.

Table 1: Pressure for RO, and flow rate and conductivity of permeate and retentate, concentrate for 5000 mg/L of salt.

Sr. No.	Pressure (kg/cm ²)		Flow in LPM		Conductivity (mS/cm)		
	Feed	R.O.	Permeate	Concentrate	Feed	Permeate	Concentrate
		Retentate					
1	5.5	3.5	0.4	16	15.9	0.9	10.3
2	6	4	0.5	15.5	16	0.5	10.3
3	6.5	5	0.6	15	15.6	0.4	10.8
4	7	5.5	0.7	14.5	15.2	0.3	11.5
5	7.5	6	0.75	14.5	15.25	0.1	12

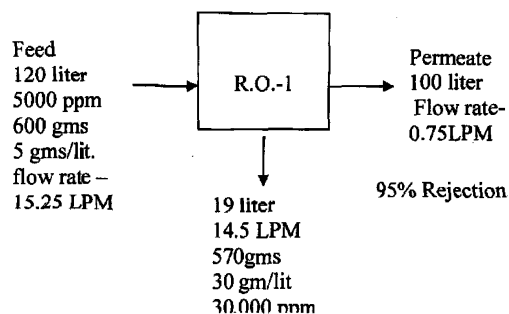


Fig. 4: Material balance For 5000 mg/L feed solution.

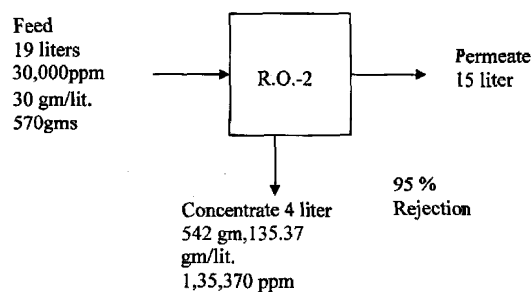


Fig. 5: Material balance for 30000 mg/L feed solution.

having 0.5 g/L of salts is obtained. The permeate recovery is about 84%. The permeate which is obtained is a usable resource.

About 19 L of concentrate was obtained. The TDS value of concentrate was about 30,000 mg/L, the value is much similar to seawater. This shows that concentration increased from 5000 mg/L to 30000 mg/L, which means 6 times increase in concentration. The concentrate obtained was again processed in RO for more recovery of permeate with pressures and flow rates as given in Table 2. After processing from RO with 95% rejection, 15 litre of permeate and 4 litre of concentrate were obtained. The recovery of permeate was 78% with formation of concentrate of 1,35,500 mg/L.

Flux (l/hr/m²) Vs. TMP was studied (Fig. 2, Table 3) and it is seen that with the increase in transmembrane pressure, flux is increased. %Rejection Vs. TMP (Fig. 3, Table 3) shows that with the increase in trans-

Table 2: Pressure for RO, and flow rate and conductivity of permeate and retentate, concentrate for 30,000 mg/L of salt.

Sr. No.	Pressure (kg/cm ²)		Flow in LPM		Conductivity (mS/cm)		
	R.O. Feed	Retentate	Permeate	Concentrate	Feed	Permeate	Concentrate
1	20	19.5	0.01	13.5	13.05	2.5	31.75

Table 3: Calculated values for 5000 mg/L feed solution.

Sr. no	Flux (l/hr/m ²)	% Rejection	Transmembrane pressure (Δp) kg/cm ²	Concentration (mg/L)	
				Permeate	Concentrate
1	12.97	94.42	4.5	279	6250
2	16.21	94.72	5	264	8750
3	19.45	95.2	5.75	210	10000
4	22.70	95.32	6	208.8	11250
5	24.32	95.9	6.75	201.6	12500

membrane pressure, rejection is also increased. The material balance for RO for 5000 mg/L and 30,000 mg/L solids is shown in Figs. 4 and 5 respectively. The reject from the RO plant is generally discharged into the sewage or directly onto the land. This results in increase in the salinity and it is hazardous from agricultural point of view. To get rid of this, an alternative method is to extract the total salt from concentrate. For this the concentrate is further processed into the evaporator.

In evaporator, the concentrate, which is obtained from RO having 1,35,500 mg/L, is fed and heated by superheated steam at a pressure of 1.5 kg/cm². 40% freshwater is recovered from the concentrate and there is no salt content present. This water may be used for generating steam in evaporator. Thick liquor of about 2.4 litre having concentration of 2,26,000 mg/L solids is obtained. To obtain crystals or to extract the salt, it is further processed into crystallizer of heating type. Thick liquor is heated into the crystallizer with continuous stirring. The heating is done at about 96°C. As soon as the saturation level is reached, stirring is stopped and sudden cooling is given to the solution to obtain crystals of salt. % yield was found to be 44%. The mother liquor is recycled back to the crystallizer. The material balance for 1,35,000 mg/L solids feed solution in evaporator is shown in Fig. 6.

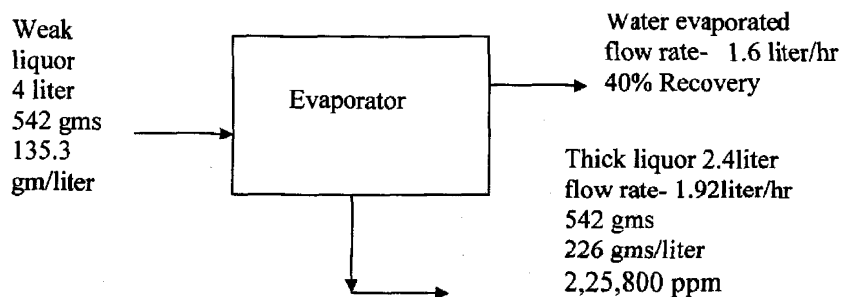


Fig. 6: Material balance For 1,35,500 mg/L feed solution in evaporator.

CONCLUSION

The above experiment shows that from RO process, usable water is obtain and the concentrate is again processed into the evaporator to obtain freshwater, and followed by crystallizer to obtain salt. In the case of brackish water desalination, brine management can be specially critical if the plants are placed far from the coast and far from any public channel or water treatment plant where brine can be discharged. The best option in this case is to concentrate the brine by reverse osmosis up to the technical limit of the process and after that continue concentrating by means of evaporator to obtain additional freshwater.

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INNOVATIONS, NEW ENVIRONMENTAL TECHNOLOGIES

Technologies on Offer

The National Chemical Laboratory (NCL), Pune, along with other laboratories under the Council of Scientific and Industrial Research (CSIR) are attempting to chart a new course in technology development, and commercialization of scientific research. With past models of engagement with industry on transfer of technology having outlived their usefulness, and a sea-change in the environment in which the institutes operate, the pressure has been on the industrial research laboratories to better serve industry. In response, the laboratories are attempting to evolve participatory, risk-sharing models of technology transfer and development, to better serve Indian industry. Indian industry today has a much wider access to technology – although, perhaps, not state-of-the-art.

At the same time, businesses themselves have ramped up their in-house R&D spends considerably – at least in select sectors – in recognition of the fact that innovation can be a powerful driver for sustainable growth. Similarly, several Indian pharmaceutical companies now each spend a few hundred million dollars in R&D efforts ranging from process development and scale-up to development of alternate, more efficient routes to synthesis; and on development of new chemical entities and formulations.

As a pioneering experiment, NCL has created the ‘NCL Innovation Park’ and a ‘Venture Center’ therein, that aims to create the ecosystem necessary to nurture an idea from the laboratory and take it through the stages that will eventually see it emerge as a successful technology serving a market need. Designated as a technology business incubator, its focus is currently on the chemical, biochemical and material sciences – all areas in which NCL has significant research programs.

NCL is now open to multiple modes of engagement with industry, including sponsored research projects, consulting and technology transfer. While exclusive or non-exclusive technology transfer through licensing was the preferred route in the past, the laboratory is now in a position to part with its knowhow and intellectual property even for equity in existing or start-up companies. The choice of the model depends on the nature of knowhow, intended markets and industry scenario; the stage of technology readiness; stage at which the commercialization partner enters; IPR and knowhow strength and ownership position; and the type of relationship desired (transactional or partnership).

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