

## Desalination of sodium chloride solution by air gap membrane distillation

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### Introduction

Membrane distillation (MD) for water desalination is a membrane technique for separating water vapor from a liquid saline aqueous solution by transport through the pores of hydrophobic membranes, where the driving force is the vapor pressure difference created by temperature difference across the membrane [1,2]. MD has many significant advantages, such as high system compactness, possibility to operate at low temperatures ( $\approx 30\text{--}90^\circ\text{C}$ ) which makes it amenable for use with low temperature heat sources, including waste or solar heat, and, when compared with say reverse osmosis or electrodialysis, the simplicity of the membrane which allows it to be manufactured from a wide choice of chemically and thermally resistant materials, and much larger pores than of reverse osmosis membranes that aren't nearly as sensitive to fouling.

The membrane distillation is carried out in various modes differing in a way of permeate collection, the mass transfer mechanism through the membrane, and the reason for driving force formation. Various types of MD are: direct-contact MD (DCMD), air gap MD (AGMD), sweeping gas MD (SGMD), vacuum MD (VMD) and Osmotic MD (OMD) [3].

The main application of MD process is the production of a high purity water and successfully applied to the concentration of several non-volatile solutes in aqueous solutions like salt, sugar, fruit juices, blood, waste water treatment, etc. In the recent year, MD is applied for the separation of volatile compounds from aqueous mixtures, continuous removal of alcohol produced by fermentation, breaking of azeotropic mixture, and concentrating of the various acids [1].

The effect of various operating parameter such as feed and cooling temperature, feed flow rate, feed concentration and air gap thickness were studied with 3.5% NaCl solution. The coolant of water was flow co-current with feed solution. Each experimental result was obtained after the system reaching the equilibrium time of about 4hr between the membrane and feed solution. The experiment was also conducted in the recycle mode of various operating conditions.

### Experimental methods

The AGMD experiments were performed with a membrane module as shown schematic diagram in fig. 1. The membrane modules consist of feed, cooling and permeate compartments. In the feed compartment, nitric acid solution was directly contacted with membrane. Water was passed in the

cooling compartment that contact with condensing plate. The condensing plate was made of stainless steel. The feed and permeated compartments were separated by hydrophobic microporous (PTFE) membrane. The stainless steel grid was used as a membrane support to avoid membrane bending and wrinkling. The effective area of the membrane is 13.68 cm<sup>2</sup>. The vapour was diffused through the membrane and condensed by means of condensing plate. The permeated collected in the measuring cylinder with regular interval of time. The inlet temperature of the 3.5% NaCl solution in the hot feed and water in the cooling side was maintained constant throughout the experiment.

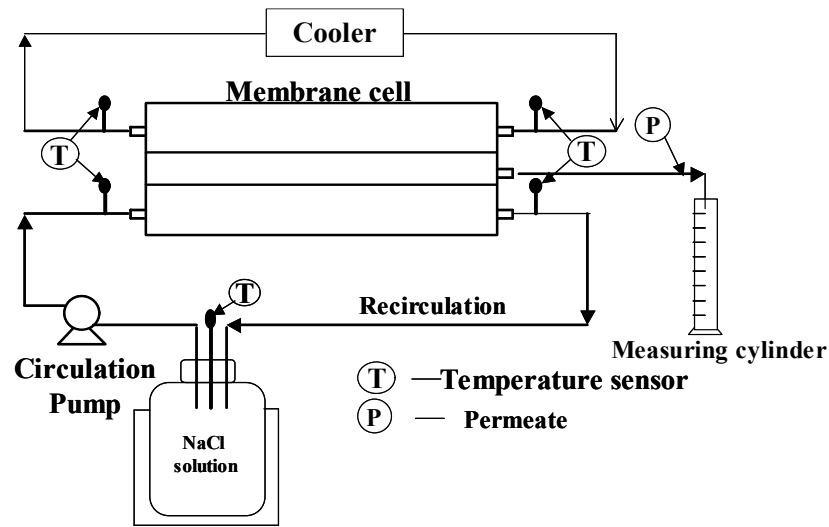


Fig. 1: Schematic Diagram of Air Gap Membrane Distillation (AGMD)

The cooling water was maintained at 15°C by means of chiller and recirculated. The outlet temperatures of the hot side and coolant side were continually monitored. The samples were collected regular interval of time and analyzed. The effects of various operating parameters such as feed temperatures, feed flow rates and feed concentration were studied under a steady state operation with co-current (with cooling water) mode. The experiments were conducted in the recirculation mode of specific operating conditions like fixed initial temperature and flow rate. The salt contented in the permeate was measured by conductivity.

### Membrane

The flat sheets membrane made of polytetrafluorethylene (PTFE) (Teflon) porous membrane was used to conduct the experiment, which is from Millipore FGLP. A membrane with the average pore diameter of 0.22 μm, diameter of membrane ~ 142 mm, thickness ~ 175 μm, porosity ~ 70% and tortuosity factor ~ 2 was tested for permeation flux and separation factor of water.

The permeate flux was obtained by measuring the volume of the liquid collected in the permeate side during a fixed time.

$$J = \frac{Q}{AT} \quad \dots (1)$$

Where  $J$  is permeate flux ( $L/m^2h$ ),

$Q$  is volume of permeate collected (L),

$A$  is effectiveness area of membrane ( $m^2$ )

$T$  is operating time (hr)

### Result and Discussion:

The experiments were studied the effect of permeate flux and conductivity of permeate water by means of changing the hot feed temperature at various flow rate of feed solution and fixed coolant temperature and flow rate of coolant water. Permeate flux was increased with increase feed solution temperature. The results were shown in the fig. 2 & 3. The conductivity of permeate water was within range of 6-10  $\mu s/cm$ , which is the drink water quality.

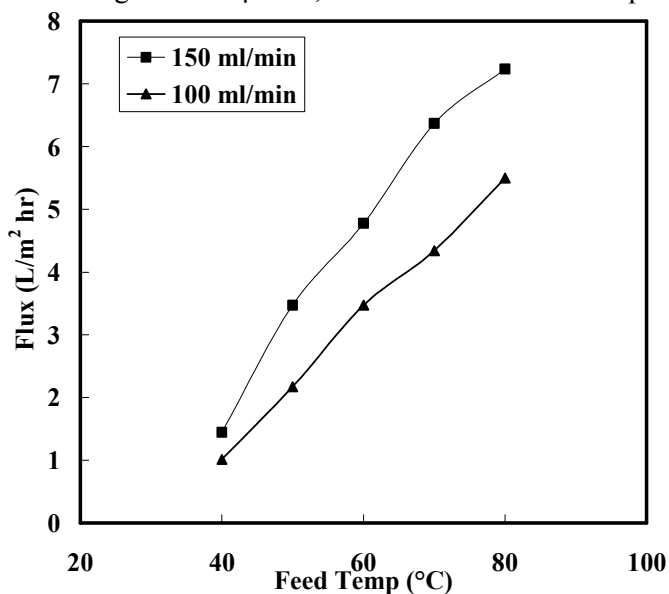


Fig. 2: Effect of feed temperature on flux permeate at different feed flow rate

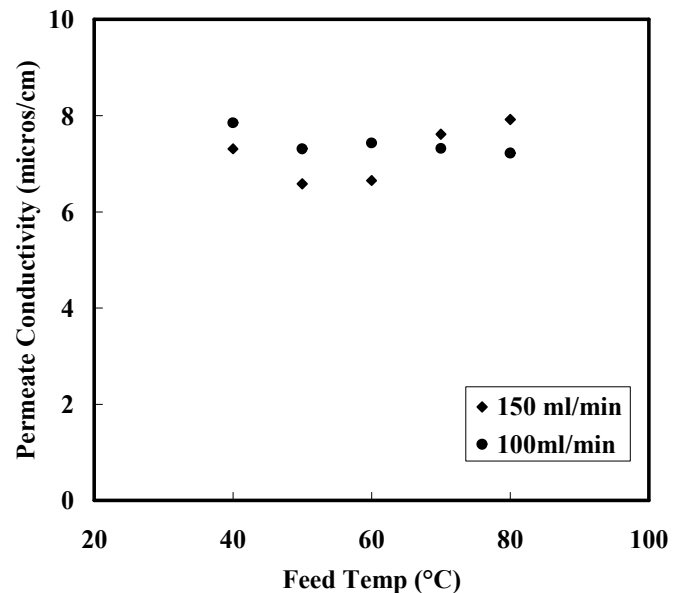


Fig. 3: Effect of feed temperature on conductivity at different

At constant temperature, the permeate fluxes increase rapidly with the feed flow rate, and they reach maximum values asymptotically for higher feed flow rates. At a given feed flow rates, we observed that an increase in temperature was accompanied with increasing mass flux.

Fig. 4 represents the variation of permeate flux vs. temperature difference between the feed temperature solution and condensate plate ( $T_f - T_c$ ). The permeate flux increase sensitively with  $\Delta T$ . At 45 K, the flux varies sensitively with the  $Re$  number or the feed flow rate. We noted that the transmembrane temperature increases as function of feed flow rate and the conductivity of the permeate remains invariable around 6-10  $\mu s/cm$ .

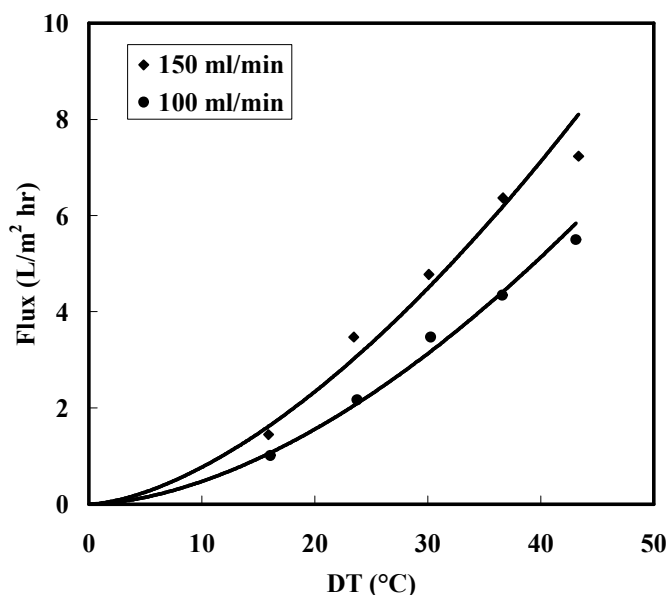


Fig. 4: Effect temperature difference on the flux at different feed flow rate

### Conclusions

Air gap membrane distillation is a promising desalination process because it is the most efficient MD process. The system was designed to minimize capital cost and pre-treatment cost of high fouling feed streams. The studied process allows for the use of feed waters like seawater and formation water without pre-treatment giving constant fluxes in time and producing high quality water in a single step. Solar energy could very much help this process in countries which are very sunny due to the reduction of energy costs; and thus membrane distillation could become competitive relative to other processes--reverse osmosis or distillation, for instance.

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