

# Review of membrane distillation for the production of fresh water from saline water

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**ABSTRACT:** One of the new ways for sweetening or desalination of saline water is use of membrane distillation. This method is based on the partial vapor pressure difference caused by a temperature gradient across the hydrophobic porous membrane. In this study, seawater desalination process using membrane distillation, based on condensation mechanism of that has been segmented into four categories direct contact membrane distillation (DCMD), Air Gap Membrane Distillation (AGMD), Sweeping Gas Membrane Distillation (SGMD), and membrane distillation under vacuum (VMD) and has been checked. Advantages and disadvantages of a membrane distillation has been titled and in continue direct contact membrane distillation, has been studied as an example. In this case study, the parameters such as capable of reproducing the MD results of the laboratory scale, the effect of salt concentration and temperature of the feed, have been evaluated.

**Keywords:** Desalination; Membrane Distillation; Saline Water

## INTRODUCTION

Persian Gulf region has minimal rain and limited fields of water. Desalination of sea water is the dominant technology for solving the problem of water scarcity in the region, especially with the growth of the project. Thermal processes, membrane and hybrid desalination are the preferred choices in this region. Thermal desalination units, drain large volumes of saline waters with temperatures between 5 and 10 ° C above the temperature of the sea water. Membrane distillation can be used for redosalination of hot saline water and can use the waste heat with the present low quality in the powerhouse to add to supplier of fresh water in this area. This process leads to the reduction of environmental impacts of concentrated warm salty water is discharged into the sea (Adham et al.,2013).

### **Membrane Distillation**

Membrane distillation is just one example of the membrane contactor where the driving force is associated with transmission of the temperature gradient across the membrane. Used membranes were hydrophobic and the feed stream is as an aqueous solution. In this case, the hydrophobic membrane was separated two aqueous solutions (feed and naked flow), by imposing a temperature difference across the membrane (feed solution is heated and naked solution is cooled) and a partial pressure gradient is caused from the warm place to the cold. Along this gradient, molecules of water has evaporated and has migrated from the hot place of membrane and through the pores of the membrane and after cooling percolates in there.

### **Types of Membrane Distillation**

This process according to condensation mechanism has been divided into four categories (Alkhudhiri et al.,2012).

#### **Direct contact membrane distillation (DCMD):**

This approach is the simplest type of membrane distillation in which hot and cold fluid, are directly in contact with the membrane and it is a suitable method for Concentration and desalination (Imdakhm and Matsuura,2005),.

**Air Gap Membrane Distillation (AGMD):**

In this method, there is a gap between the membrane and the surface of condensation that the vapor diffusion passes through the gap and with contact is connected with surface cooling and is condensed. The advantage of using this method is transfer of less heat from the feed section to the condensation part, as a result the temperature gradient is maintained over time and efficiency of membrane is not impaired (Alklaibi and Lior2005). (Khayet and Cojocar,2012).

**Sweeping Gas Membrane Distillation (SGMD):**

In this case, a penetrated inert gas accompanied self and in a condenser container turns to the liquid. The existence of gas flow makes the boundary layer resistance is reduced and the mass flux increases. This method is suitable for removing a volatile liquid from the system (Khayet et al.,2006).

**Vacuum Membrane Distillation (VMD):**

In this method the existence of vacuum causes to remove trapped gas in the pores and therefore resistance against penetration reduced. Despite the high costs of creating a vacuum, using this distillation is still growing (Nagaraj et al.,2006).

**Advantages and disadvantages of membrane distillation**

Membrane distillation compared to other desalination processes have advantages and disadvantages as follows:

**The advantages of membrane distillation**

- To achieve a pure product
- Energy efficiency
- Less cost to avoid clogging
- Do not use chemicals
- Simple and versatile membrane structure

**Disadvantages of Membrane Distillation**

- High initial cost
- Down performance with time
- Sediment clogging
- Reduce power penetration in the effect of sediment

**RESULTS AND DISCUSSION**

**Capability of reproduction of MD results of laboratory scale**

The initial phase of testing is focused on the capability of reproduction of the flux profiles generated by single DCMD, using different parameters under experimental conditions. Figure 1 (I) and (II) shows data from two identical experiments using synthetic water with the sodium chloride ion concentration respectively 0.1g / l and 15g / l. The data show a good degree of ability to reproduce, but also for the other membranes and other salt concentrations were observed.

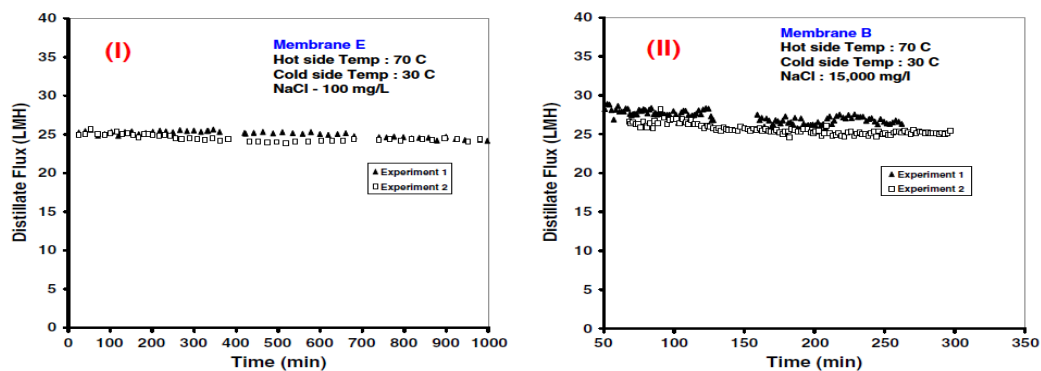


Figure 1. The experimental results reproducible of membranes E/B. (Warm or cold flow rate: 1.8 l/min)[1]

**Effect of feed temperature**

MD units operate in 70 and 50 degrees C feed temperature (Figure 3), while the cold side is kept constant at 30 ° C which respectively leads to the temperature difference 40 and 20 ° C across the membrane. As expected, the data showed that the feed temperature and  $\Delta T$  across the membrane has a great effect on membrane flux which is also consistent with other articles.

Based on the Antoine equation, vapor pressure values are calculated for each of the conditions presented in Figure 2. It was found that the distillate flux increased due to the higher difference between the hot and the cold vapor pressure, but the relationship was not directly proportional. Slight deviation was attributed from a direct connection to polarization potential temperature and hydrophobicity condition of the membrane surface.

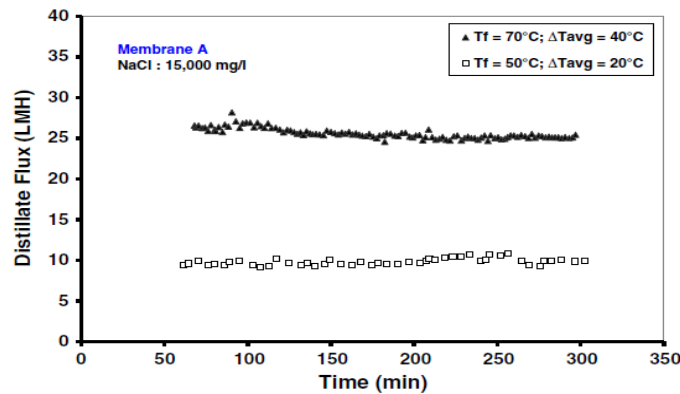


Figure 2. Effect of feed temperature on the performance of the MD. (Hot and cold flow rate: 1.8 l/min)[1]

**Effect of salt concentration**

After confirmation of reproducible data generated by DCMD unit under test conditions, additional experiments were conducted to evaluate the effect of salt concentration on the MD process. For these experiments, synthetic saline water, were prepared (removed deionized water with various concentrations of sodium chloride). Figure 3 (I) and (II) show that flux about 25 LMH remains constant and there is no significant difference in flux over the salt concentration range tested (15-60 g / l). However, when the salt concentration above 70 g / l increased (Fig. 3 (III)), the values of flux slightly lower (20 MLH) were obtained, Which can be related to changes in water vapor pressure and water viscosity that can affect the thermal conditions in boundary layer membrane. These results are consistent with other articles.

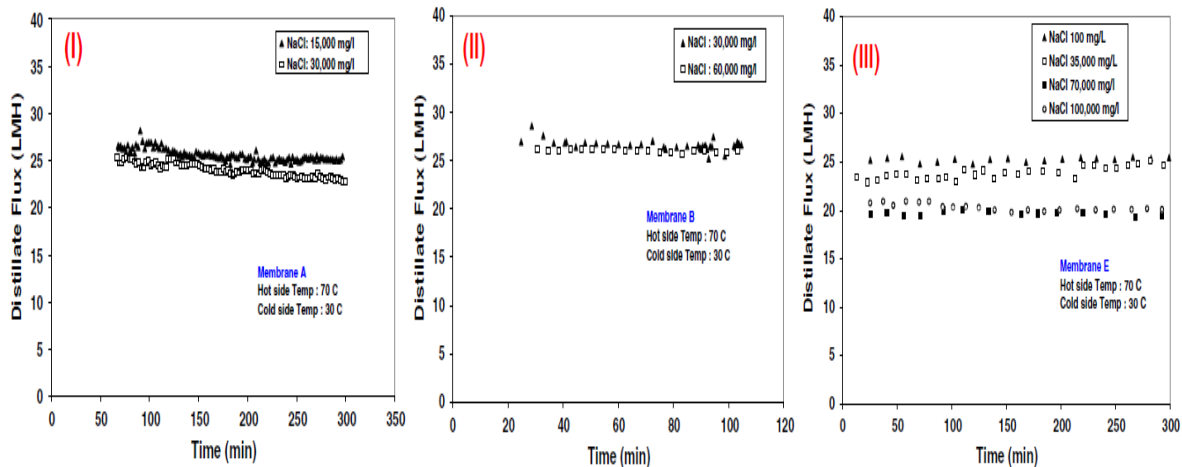


Figure 3. Effect of salt concentration on the MD (hot and cold flow rate: 1.8 l / min)[1]

### Figures

Figure 1	The experimental results reproducible of membranes E/B. (Warm or cold flow rate: 1.8 l/min)[1]
Figure 2	Effect of feed temperature on the performance of the MD. (Hot and cold flow rate: 1.8 l/min)[1]
Figure 3	Effect of salt concentration on the MD (hot and cold flow rate: 1.8 l / min)[1]

### Abbreviations

AGMD	Air Gap Membrane Distillation
DCMD	direct contact membrane distillation
SGMD	Sweeping Gas Membrane Distillation
VMD	vacuum membrane distillation

### CONCLUSION

The main objective of this study was to evaluate different membrane methods for desalination of saline water and the advantages and disadvantages of these methods. In continue the direct contact membrane distillation as an example of above methods were discussed that following results were obtained.

MD for desalination of saline water result of desalination units are possible and can produce consistently distillate with a high quality (<10  $\mu\text{s} / \text{cm}$  conductivity).

The salt concentration more than 70 g / l, the membrane flux (25 LMH), is not influenced by the salt concentration. In salinities above 70 g / l, a decrease of flux has been observed 20%. Under all salinities tested, no flux abnormalities were noted and membrane was stable.

Feed temperature and  $\Delta T$  across the membrane had a great effect on the flux membranes and the production process.

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