Desalination of Brackish Water using Solar Energy

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Abstract- The aim of the paper is to enhance the performance of membrane supported water desalination techniques to reduce the consumption of energy by employing solar energy. Development of the pilot plant in the laboratory has been carried out to desalinate the brackish water using PV collector. Experimental study was carried out and report the effect of temperature, time and flow rate on permeates flux. Results show that permeates flux increases with increase in temperature. Also the analysis of the well water has been performed by various techniques and reported. It was found that vacuum membrane distillation using solar energy provide better quality of water in comparison to other treatment techniques. This study provides an idea for the application of renewable energy in the field of desalination of water on a small scale.

Keywords Desalination, VMD, Permeate Flux, Solar Energy, Water Quality Analysis.

1. Introduction

Global problem of fresh water supply is increasing due to arise in population growth, contamination of available fresh water supplies and public policy. According to the United Nations, one third of the world's population is living in the regions where the annual water supply is less than 1700 m^3 per person which is expected to approach two thirds of the world's population by 2025 [1,2,3]. Per-capita water use in the developed world is decreasing due to more efficient agricultural, industrial and personal practices. The stress on the water resources will increase due to economical development of China and India. Of the total water available, about 97.5% is saline and 2.5% is fresh water of which 70% found in the form of icecaps and the remaining 30% in underground aquifers [4]. A small fraction of the freshwater available (less than 1% of total freshwater) in rivers, lakes and reservoirs is readily accessible for direct human use [5,6]. The water challenge faced by the world can be overcome by the use of new developments in the field of desalination of water. Proper utilization and conservation of fresh water can be an effective way for ensuring water for all. Desalination technology along with utilization of renewable energy can provide unlimited fresh water in remote area affected by saline water [7,8]. This paper discusses the vacuum membrane desalination technology using renewable energy for desalination of water.

1.1Methods for membrane distillation

A number of methods are used for the desalination of saline/brackish water. Some of them are direct contact membrane distillation (DCMD), air gap membrane distillation (AGMD), sweep gas membrane distillation (SGMD) and vacuum membrane distillation (VMD). The table 1 shows the merits and demerits of the different membrane distillation processes.

1.2 *Principle of vacuum membrane distillation*

Thermal energy has been applied in vacuum membrane distillation process for transfer of mass due to convection. Driving force for this process is the vacuum which keeps the vapour pressure to the other side of the membrane in equilibrium. The vapour liquid phase is supported by the membrane and the selectivity of the VLE is not affected by the membrane [9]. The table 1 shows the advantages of VMD in comparison to other separation [10]. VMD can used at low temperature of about 60~90°C which proved to be an advantage for supply of energy for evaporation. In comparison to other separation techniques such as pervaporation, VMD is found to be cost effective [11]. The different applications of VMD have been shown in table 1[12,13].

2. Design of Pilot Plant

The experimental set-up has been designed for a laboratory scale and is shown in the figure1. It comprises of various parts such as membrane module, flow pump, peristaltic pump, tank of fresh water, etc. This design is set up for the production of 25 L/day fresh water.
The design of solar collector field will depend upon efficiency of heat exchanger, the weather condition, recovery of energy from distillate, etc. The choice of module of the membrane depends on physical and chemical membrane characteristics, pass number in module, costs, fouling of membrane, etc.. The plate heat exchanger is composed of a set of corrugated metal plates. The number of plates is determined by the flow, fluid properties, pressure and temperature. The required thermal energy is supplied by a 5 m^2 solar thermal collector field. Electrical energy is supplied by a 75 W PV-module.

2.1 Cost estimation

The total cost occurs in the design of the process for desalination of 25L/day is approximately 90,000/- Rupees (India).

Table 1. Advantages & Disadvantages of Membrane Distillation processes

S.No.	Process	Advantages	Disadvantages	Application
1.	DCMD	Permeate flux is high Recovery of heat can be possible	Heat conduction losses is high Polarization effect is high	Desalination Nuclear industry Textile industry Chemical industries
2.	AGMD	Heat losses due to conduction is low Polarization effect is low Recovery of heat can be possible	Permeate flux is low	Desalination and water treatment Food industry Chemical industry
3.	SGMD	Heat losses due to conduction is low Permeate flux is high	Gas sweeping is difficult to control Recovery of heat is a problem	Desalination and water treatment Chemical industry
4.	VMD	Heat losses due to conduction is low Permeate flux is high	Wetting of pore is a problem Recovery of heat is a problem	Desalination and water treatment Food industry Textile industry Chemical industry

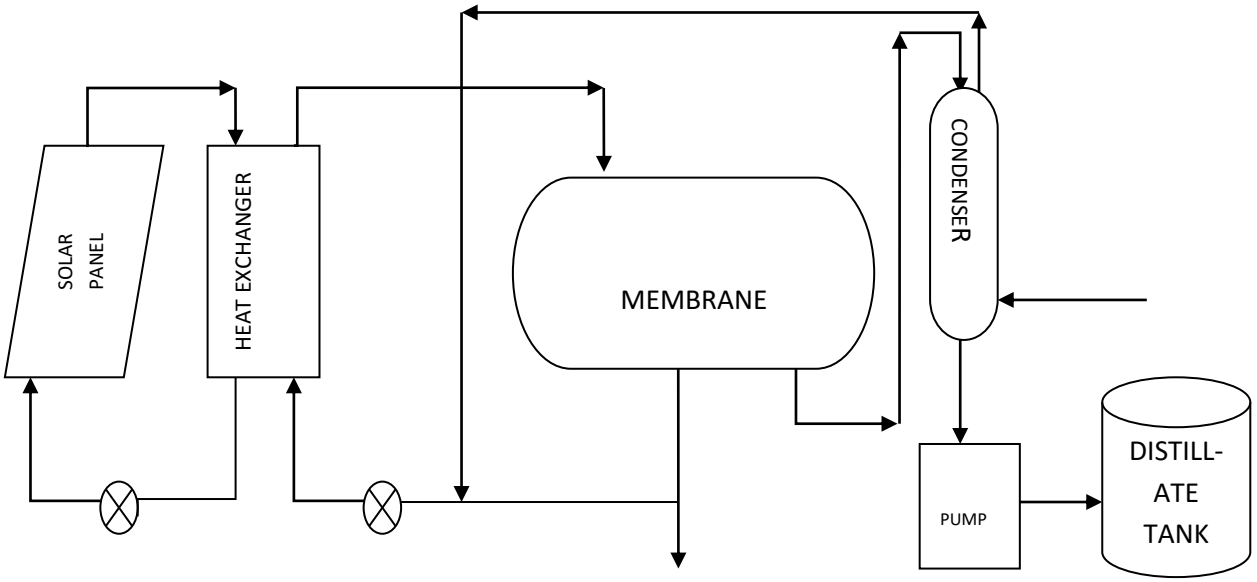

Fig.1. Line diagram of experimental set-up

Table 2. Analysis of water quality

S.No.	Parameters	Well Water	RO Treated water	Solar V MD treated water
1.	pH	7.7	7.9	7.2
2.	TDS (ppm)	380	10	9
3.	Total Hardness (ppm)	270	8.4	6.5
4.	Sodium (ppm)	20	0	0
5.	Electrical Conductivity (mho/cm)	625	15	12

3. Results and Discussion

3.1 Effect of temperature on flux

Figure 2 shows that the permeate flux increases with increase in temperature. Various studies have performed and reported the same effect. The permeation flux of VMD process increases with increasing of feed liquid temperature at the same operational condition due to the pressure difference across membrane in VMD process. Increase in the feed temperature increases the vapour pressure of gas liquid interface on liquid feed side results in increase of the mass transfer driving force [14,15]. Also the thickness of the membrane increases this flux [16].

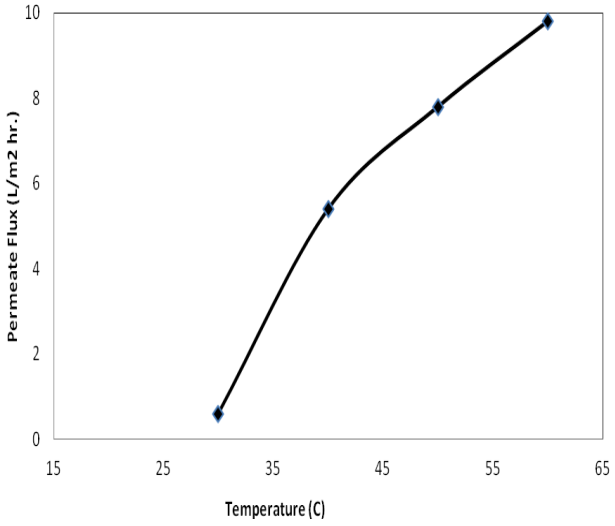

Fig.2. Effect of temperature on permeate flux

3.2 Effect of Time

The effect of time on distillate flow rate was shown in figure 3. The figure shows that the distillate flow rate increases gradually with the time and have a maximum value in between the time 12.30 and 13.30h and then it decreases. This behavior of the figure was due to the energy received form solar absorbance which was high during the period of 12.30 to 13.30 h. The same behavior was reported by [17].

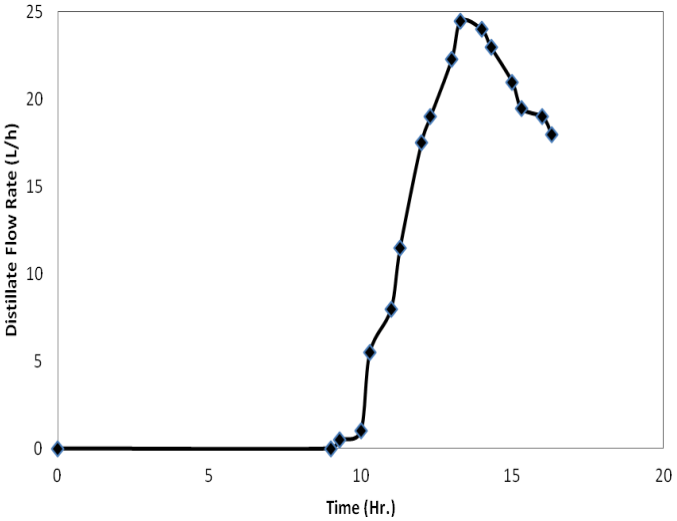

Fig. 3. Effect of time on distillate flow rate

3.3 Effect of Temperature

The results in figure 4 generally show a linear increase of distillate output as the feed temperature increases. This increase in the feed temperature increases the mass transfer driving force due to increase in the vapour pressure of liquid feed side. The same behavior was reported by [16].

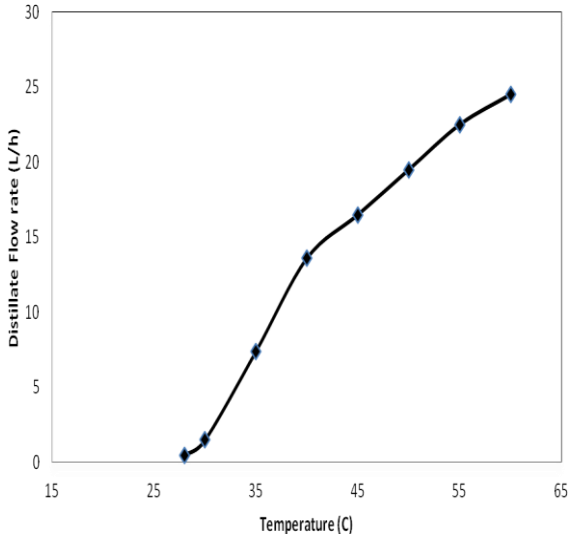

Fig. 4. Effect of temperature on distillate flow rate

3.4 Water Quality Analysis

The analysis of quality of well water was performed and compared with RO and Solar vacuum membrane distillation techniques. It was found that Solar VMD treated water have better water quality in comparison to other process. The results were given in table 2.

4. Conclusion

Vacuum membrane distillation along with solar energy proved to be a better technology for the desalination of brackish water on small scale. The treated water from this technology has significant benefit over other techniques in terms of the quality of water. This technology using solar insolation can be advantageous for the people residing in remote areas affected from problem of saline water since it can fulfill their needs at a low cost in comparison to other technology.

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