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Sustainable membrane distillation coupled with solar pond

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Abstract

The necessity for fresh water is at the top of the international schema of serious issues. As the fresh water shortage becomes an issue, the application of desalination plants is rapidly rising on a large scale. Also, membrane technologies are gaining high importance for their great performance and their economic viability. Membrane distillation as a novel thermally-driven separation process can be adapted for water desalination, due to its simplicity and ability to couple with a sustainable source of energy. In this paper, study was conducted to develop a Sustainable Water Desalination (SWD) system by combining direct contact membrane distillation with solar ponds. A brief explanation of the solar pond concept and the concept of the membrane distillation (MD) system was illustrated. Additionally, the possibility of desalinating high saline water with zero brine discharge was investigated. Moreover, an alternative source of energy which is from the heat stored in the lower zone of the solar pond was investigated by using the combination of MD and salinity gradient solar pond (SGSP). In this work, the idea of using the surface of the solar pond as heat sink for the permeate water was considered, by introducing floating cooling pipes that are also acting as wave suppressors to reduce the surface mixing in solar pond caused by wind-driven currents. Furthermore, the present understanding and contribution to the research efforts to build a SWD technology system was analysed. In addition to the concept illustration, an indoor study was also conducted about the performance of MD with variation of the feed temperature. It concluded that as the feed temperature increases, the heat flux, mass flux, heat transfer coefficients and evaporation efficiency will increase as the temperature polarization coefficient decreases.

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1. Introduction

The demand for fresh water is rapidly growing; however that demand cannot be met using the conventional desalination processes such as Reverse Osmosis and multi stage flash especially in arid area since it requires high amount of energy that cannot be supplied in such area. There are three categories for the desalination systems. First is a phase changing process which is thermally-driven such as Multi-Stage Flash and Multi-Stage Effect; the second system is considered to be a membrane process such as Reverse Osmosis and Electrodialysis, these two processes desalinate water by using a certain type of membrane; the third and last system is called Membrane Distillation (MD), it is thermally-driven and considered a hybrid system as it combines two processes, the membrane technology and the phase change [1]. This process is very advantageous as it can be operating in low pressure and temperature which makes it possible to couple it with sustainable energy, also it has a low heat loss and high rejection of salt and ions compared to other conventional processes [2]. According to previous studies thermal desalination consumes approximately 1.3 KWh electricity and 48.5 KWh heat per each m^3 of desalinated water [1]. Therefore, environmental friendly solution should be found to deal with the energy consumption and the brines such as sustainable energy to reduce carbon footprint as well as the cost of it. Also zero liquid discharge (ZLD) system which recycles and treats the brine could be a better option to manage produced water, as it saves more money and does not damage the environment [1]. As mentioned earlier, MD can be coupled with solar energy; this energy can be used to produce the thermal energy necessary for the feed liquid [3]. For instance, solar ponds can store large amount of solar energy in the lower convective zone (LCZ) which has a high level of salinity. This energy can be used to heat the feed water, also waste brine can be reused as a source of salt for the lower convective zone in the solar pond [3]. Since the last two decades, many studies and researches had been done to study the ability of coupling solar energy and desalination [3]. This paper will discuss the combination of membrane distillation with solar pond. Membrane distillation combined with solar pond is considered to be the most convenient solar desalination in terms of cost and the ecology concern [4]. The impact of this combination is very advantageous for two reasons, it is the least expensive way for the heating required, and also no more waste products would be left to be injected back to the sea, as it can be used as a basis to build the pond [4].

Nomenclature

MD	Membrane Distillation
UCZ	Upper Convective Zone
NCZ	Non Convective Zone
LCZ	Lower Convective Zone
EE	Evaporation Efficiency

2. Membrane Distillation

There exist variations of MD configurations utilised to allow vapour molecules to migrate through the hydrophobic membrane pores, but the particular process that has been used in research is Direct Contact Membrane Distillation (DCMD); this particular process is the simplest and most used in the industry [5-7]. The both sides of the hydrophobic membrane come in direct contact with feed water and cold water. Water vapour from the feed side travels through the hydrophobic membrane, due to pressure difference across the membrane resulted from the temperature difference, and then condensation of water occurs in the cold side when the vapour molecules come into contact with the cold water stream. Fig. 1 shows the configuration sketch and thermal layers of DCMD.