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RESEARCH ARTICLE

SUITABILITY OF SOLAR MIRRORS FOR WATER DESALINATION SYSTEM IN WINTER

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ABSTRACT

The objective of this study is to check the possibility of producing potable water from seawater using low cost technique depends on concentrated solar rays by mirrors specially in autumn and winter seasons. The study erected a pilot plant in Faculty of Eng. pilots open site, ASU. The system used 3 concave mirrors and directed to let mirrors receives sunrays and concentrated it on the pilot for the whole sunny period. The measurements for quantities, temperature and TDS for the inlet and outlet waters were made with the measuring of air temperature and sunshine period among the day. The tests covered three months between autumn and winter to be in the worst climate for the system operation that depends mainly on sun and temperature. The results were good for product quantity and quality. The study shows that the fresh water quantity is proportional with air temperature and its TDS is between 20-40 ppm even how much the salinity of the influent seawater that ensure the system high efficiency to remove salts.

INTRODUCTION

Water resources in Egypt are limited to the Nile River, rainfall and flash floods, deep groundwater in the deserts and Sinai, and potential desalination of sea and brackish water. Each resource has its usage limitation, whether these limitations are related to quantity, quality, space, time, or exploitation cost (Periodical Report, 2014). With the construction of Ethiopian Renaissance Dam the Egypt water share in River Nile will decrease. Also the population growth increases with the increase in water needs for industrial and agricultural needs. So, in the near future Egypt will suffer from water shortage. For the shortage of water resources in Egypt and Arab countries, A need to develop low cost technology to deal with seawater as water resource are increased. The objective of this work is to study the possibility of producing potable water from seawater using low cost technique depends on concentrated solar rays by mirrors under the worst climatic conditions for such system in autumn and winter in Egypt.Solar desalination using humidification and dehumidification is a promising technique for producing freshwater, especially in remote and sunny regions. It has the potential to make a significant contribution to providing humans with fresh water using a renewable, free and environmentally friendly energy source (Mahmoud Shatat and Saffa B. Riffat, 2012). Solar-powered desalination processes are generally divided into two categories, direct and indirect systems (Paul Guyer, 2010). The direct systems are those where the heat gaining and desalination processes take place naturally in the same device. The basin solar still represents its simplest application, the still working as a trap for solar radiation that passes through a transparent cover as illustrated in Figure (1).

In indirect solar system, the plant is separated into two subsystems, a solar collector and a desalination unit as presented in Figure (2). The solar collector can be a flat plate, evacuated tube or solar concentrator and it can be coupled with any of the distillation unit types described previously which use the evaporation and condensation principle, such as MSF, VOC, MED and MD for possible combinations of thermal desalination with solar energy. Systems that use PV devices tend to generate electricity to operate RO and ED desalination processes (Mahmoud Shatat and Saffa B. Riffat, 2012). In 2002 Dr. El Nadi proposed an idea of a low cost desalination unit that depends on solar rays concentrations by concave mirrors (Meshaly 2007). Meshaly (2007) in his M.Sc. thesis made a model for that unit and proved that this idea is applicable.

The study covered the main elements affected the unit operation and obtains its best values for the system success. The study proved the suitability of the system for water desalination due to the achievement of fixed quantity and good quality for produced desalinated water. Deduced the optimum area for the used mirror and the best methodology for humidifier condenser and the saline water internal channel path length. The system achieved low power consumption compared to other desalination systems for 1 m3 production. The initial cost, operation cost are minimized compared to other systems.

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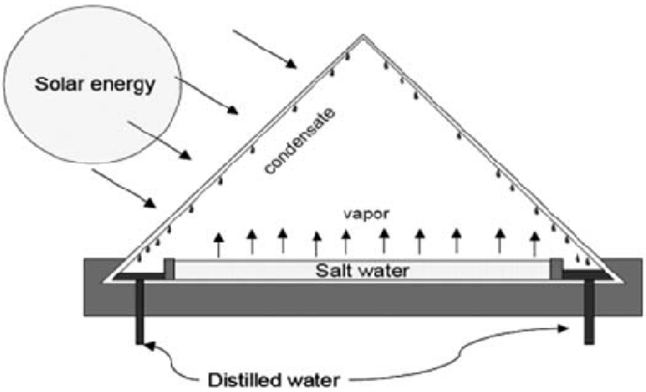


Fig.1. Direct Solar Desalination
(Mahmoud Shatat and Saffa B. Riffat, 2012)

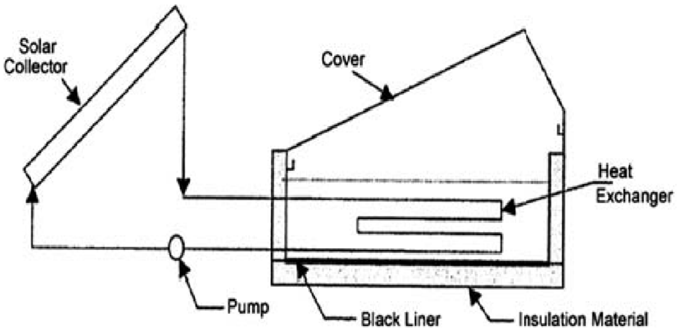
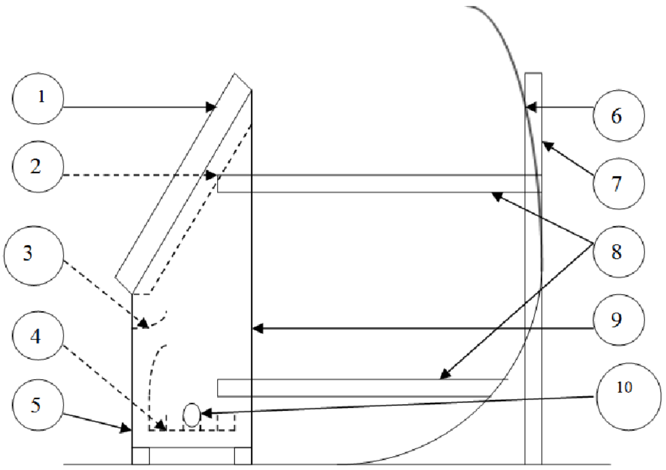


Fig.2. Indirect Solar Desalination
(Mahmoud Shatat and Saffa B. Riffat, 2012)



1. Solar collector.
2. Condenser humidifier.
3. Fresh water channel.
4. Inside Sea water channel.
5. Plant body
6. Mirror surface.
7. Vertical fixed.
8. Horizontal fixed (arms).
9. Glass face.
10. Open out for saline.

Fig. 3. Pilot Plant Model (Meshaly, 2007)

The system saves about 70% of the needed area, 75 % of the initial costs and 40 % of the running costs when compared with old solar desalination system. El Hosseiny (2009) continued the experimental work on the previous solar plant model. The study was divided into two phases first experimental work by operating the plant in the site under several climatic conditions and the second was identifying design criteria for the plant. The study deduced the design equations and reached a fresh water flow of 25 l/d/m^2 as minimum in march and increased to 180 l/d/m^2 as maximum in July.

El Sergany (2009) had continued her study on the same pilot plant to study the factors controls a low cost technique for water desalination by concentrated solar rays. The study covers the effect of the deflector mirrors area, the cool of condensing surface, the length of raw sea water channel inside the plant, the air pressure inside the plant and the climate conditions as air temperature and sunshine rate. The study concluded that the climate conditions: air temperature and sun shine rate are affecting the system efficiency by big effect that the summer production is more than 180% of winter production and about 100% more than the average production. The mirror surface area proportional gradually with the production rate. Also the shape of this mirror and the convection angle affects the fresh water production. The optimal convection angle was 15° and the area should not less than the plant open side area to get the maximum production value at summer period.

Fig.4. Used Pilot Plant Front View (El Hosseiny, 2009)

El Sergany (2009) proposed for further researches the selection of more appropriate materials for the plant, optimization of unit design criteria equations. Study the other factors that's not included in this study as TDS, evaporation rate, internal pressure on inside sea water surface, inside sea water depth and inside sea water velocity. El Nadi *et al*. (2011) suggested applying this plant all over coastal places in Egypt and other hot countries and some modification on the plant to be applied such as using multiple longer mirrors, increasing the length and the number of channels and studying the K factor in different locations, thus to increase the plant's efficiency.

MATERIALS AND METHODS

A pilot plant unit designed taking into consideration the suggestions of El Sergany (2009) and El Nadi *et al.* (2011). The designed pilot unit was consisting of the following:

1. A sloped back box made from transparent acrylic sheets with dimensions of (200 cm length * 70 cm width * 100 cm height).
2. Three serial seawater channels, erected inside the box, The seawater channels are divided into 2 series V-Shaped

channels each of dimensions (200 cm length * 9 cm width (upper surface) * 9 cm depth).
3. Two fresh water channels
4. The seawater channels is exposed to indirect sun rays using concentrating mirrors as shown in Figures (5) and (6).
5. The sloped back is used to condensate the evaporated water which is then collected into fresh water channel.
6. On the sloped back lays a solar collector, red copper pipes, to reduce the temperature of the sloped back to increase the efficiency of condensation.
7. A foam sheet was used cover the solar collector to protect it from direct contact with sun radiations thus, avoiding raising its temperature.
8. Mirrors are made from chrome sheet of total surface area 2 m2 and divided to 3 mirrors each of dimensions (200 cm length * 33 cm width).
9. The mirrors are fixed by wooden frame and each mirror angle can be adjusted according to the sun rays direction. Each mirror is directed to a certain channel.
10. in the pilot to concentrate sun rays on each channel indirectly.
11. Dosing pump is used to feed the pilot plant with the required flow from raw seawater tank.
12. A fresh water tank, brine water tank and raw seawater tank.
13. Connecting pipes between units and arrangements are from polypropylene and erected.

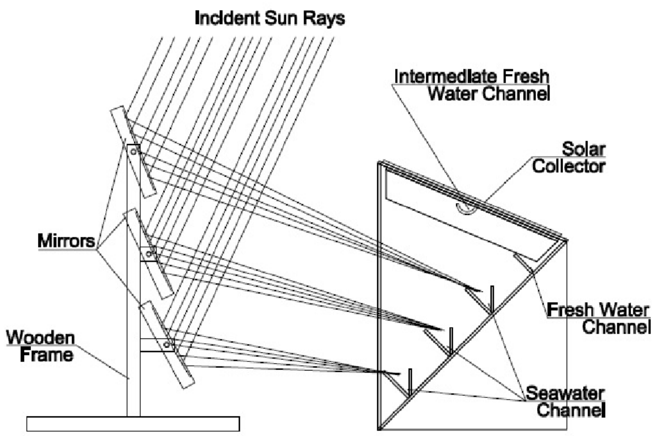


Fig.5. Sketch for Proposed System

Fig.6. Pilot Plant

Operation program

The operation program for the study was as follows:
1. The period of study was conducted on three months of work covers the wrest climatic period for such technique to measure the performance of the pilot plant.
2. Air temperature measured several times during operation day and the average calculated to simulate the day air temperature
3. The volume of raw seawater is recorded daily before and after operation.
4. Fresh (desalinated) water volume and brine volume are recorded after operation.
5. Working hours of the operation is recorded to calculate the flow rate of raw seawater, desalinated water and brine.
6. Samples are taken daily from three different locations to cover the raw seawater, the produced fresh water and the brine water to measure the describing parameters which are pH value, water temperature and TDS. Analysis were made according to standard methods (Rice *et al*., 2012).

RESULTS AND DISCUSSION

From the study results several observations are raised. Generally, the rates of fresh water decrease as the air temperature decrease and sunshine period decrease. That confirms the workability of the system in most of the year as shown in Figure (7). The air temperature is the main parameter affecting the rate of fresh water, the flow rate is increased by 4 times while the increase in air temperature is about 1.6 time, Figure (11) shows the relation between air temperature and the fresh water flow rate. The increase in sunshine period lead to the increase of product fresh water, Figure (9) shows the relation between sunshine period and product fresh water.

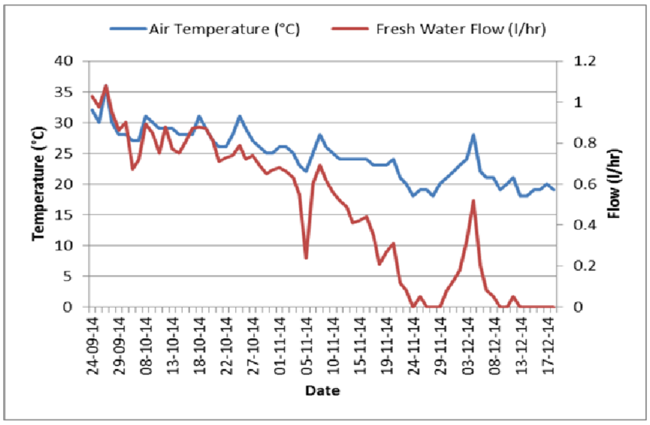


Fig.7. Air Temperature versus Fresh Water Flow during the Study Period

The results show a sudden drop in fresh water flow even though it's at high sunshine period, this due to unstable weather conditions such as low air temperature or that day being cloudy. Also the sudden rise in fresh water flow is because of heat wave at that period of study. The resulted fresh have low TDS, which insures that the pilot work and have high efficiency on TDS removal and the TDS values for fresh water ranges from 20ppm to 40ppm and is not affected the product flow rate or the raw water TDS, Figure (10) shows the relation between raw water TDS and fresh water TDS during the study period.

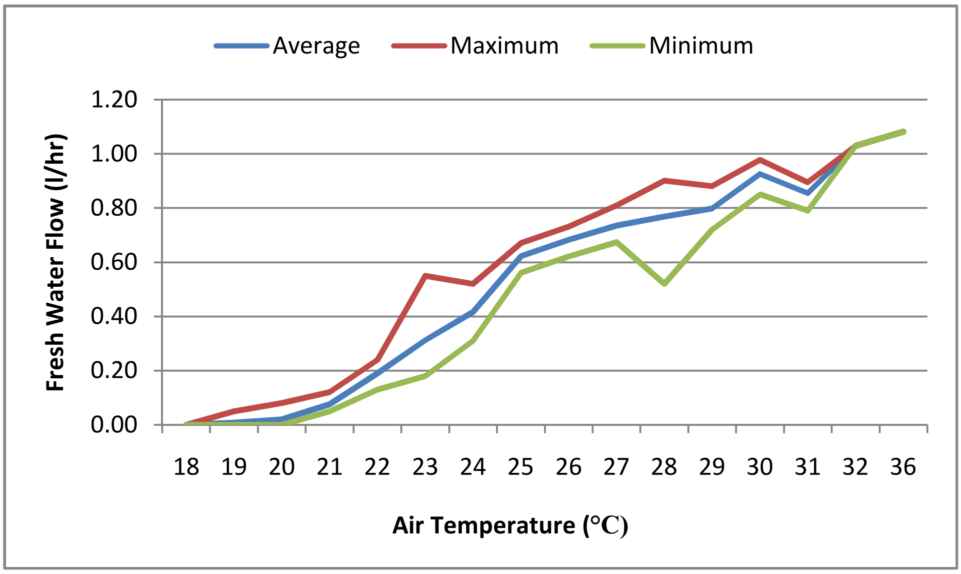


Fig.8. Air Temperature versus Fresh Water Flow Rate

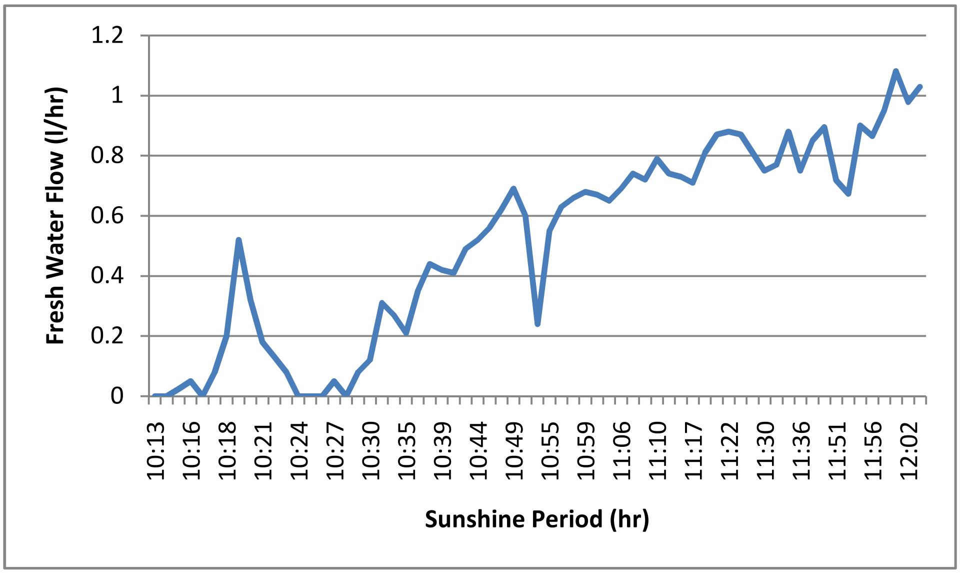


Fig.9. Sunshine Period versus Fresh Water Flow Rate

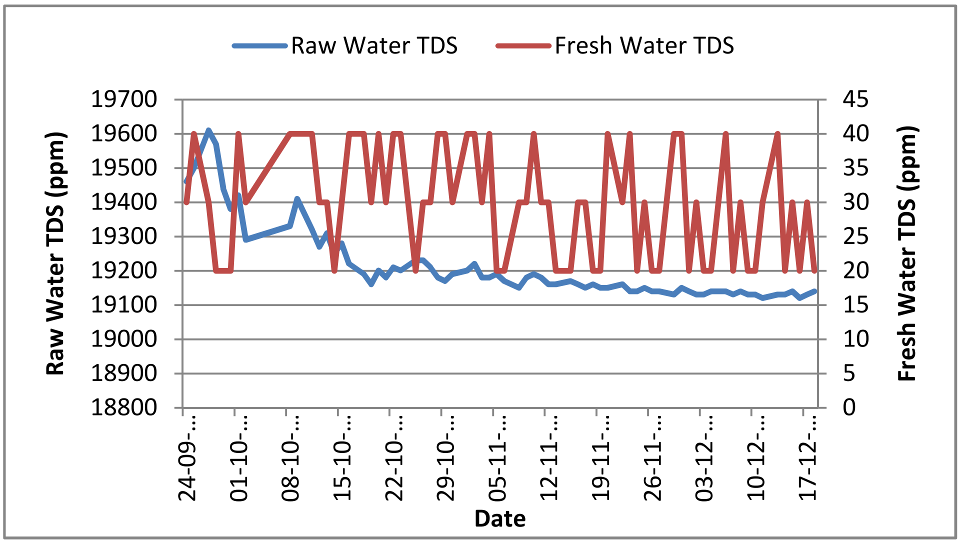


Fig.10. Raw and Fresh Water TDS during the Study Period

Conclusion

Due to the discussion of the study results and from the conducted data we could conclude the following:

1. The rate of fresh water is directly proportional to the air temperature.
2. The studied system is stable in producing fresh water with minimum production during cloudy days.
3. The sunshine period affects the rate of fresh water, as the sunshine period increases the fresh water flow rate increases, but not as effective as air temperature.
4. Increasing the number of channels and their length increased the retention time in the pilot thus increasing the produced fresh water flow rate.
5. The reflecting mirrors surface area should be maximized to increase solar rays concentrated on the raw seawater channels and there orientation should be adjusted according to the sun position.
6. The resulted fresh water TDS varies from 20ppm to 40ppm which confirms the high efficiency of the system in TDS removal regardless to the influent TDS.
7. The stability of pH value of the resulted fresh water.

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