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# Productivity Enhancement of Conventional Solar Stills Using Water Sprinklers and Cooling Fan

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## Abstract

Conventional solar still is a simple device uses solar energy to produce fresh water from brackish or sea water. It is regarded by many investigators as one of the important methods of utilizing solar energy to solve water scarcity problems, especially in remote areas and on a small scale production. The enhancement of solar stills performances and improving their productivity are the main goals of the investigators in recent years. The aim of the present research is to study and evaluate the effect of wind speed and the use of water sprinklers to cool down the outside surface of the inclined glass cover. Therefore, three identical conventional, single slope solar stills were designed, constructed, and tested under the actual environment of Kuwait city during the month of August. The water depth inside the stills was automatically controlled and fixed at 1 cm level and the stills' glass cover's tilted angle was fixed at 32.5º. Cooling fans have been used to vary and control wind speed. The results of this investigation indicated that increasing the wind speed from an average natural value of 1.2 m/s to 3 m/s and 4.5 m/s has the effect of increasing the production rate by 8% and 15.5% respectively. Cooling the glass cover was carried out using water sprinklers at preset intervals of 20 min and 10 minutes respectively. It had the effect of increasing the production rate by 15.7% and 31.8% for the two situations respectively.

**Keywords**; **Solar still; solar distillations; solar still productivity; wind speed; sprinkler.**

## 1. Introduction

Fresh water availability is a basic human need. Out of a world population of six billions, one billion does not have access to drinking water. More than two-thirds of the earth is covered by sea out of which less than 2.5% of fresh water is available in the earth's soil in the form of ice in

Antarctic-Green Land (El-Zahaby et al., 2011). Most of human populations consume water from rivers, lakes and underground sources that contribute to less than 1% of the total water available (Boubekri and Chaker 2011). Historically, a strong relationship always existed between the availability of the drinkable water and the density of population per square kilometer throughout all eras. Due to the continuous and rapid growth of populations and fast industrial developments around the world that pollute many resources of fresh water supplies, the scarcity and the demand has even further increased (Ahmed et al., 2012; El-Zahaby et al., 2010). Drinkable water is produced on large scale by several desalination methods, such as vapor compression, electro dialysis, and reverse osmosis. The costs of these methods are still too high and it has a side effect of increasing the pollutions that is already running in high levels. Furthermore, these thermal desalination techniques are not suitable to be downscaled to serve remote areas and small scale demand of drinkable water (Muller-Holst, 2007).

The Gulf Region, the Middle East and North Africa are blessed with huge solar energy which is available in most of the calendar of the year. This abundant availability of solar power could be used effectively to produce fresh water by installing solar still plants and the water obtained could be used as a supplement to the existing water storage plants in these regions (Dev et al., 2011). Distillation techniques utilizing solar energy have been known and used long time ago. The use of solar stills for producing fresh water dated back to the 16th century (Abu-Hijleh and Rahaba'h 2003). Solar stills use a relatively an easy and simple technique to produce distilled fresh water from brackish or sea water. It implements and simulates the green house effect using the basic principles of heating, evaporation and condensation. It is easy to fabricate and require low maintenance demand (Varun, 2010; Ighodalo and Ebhodaghe, 2011). It requires an energy input as a heat, which is taken from the sun rays. The brackish water acts as a heat absorber and an evaporator. The glass cover acts as a condenser (Ben Bacha et al., 2007). The aim of research conducted over the years was toward improving and enhancing the daily distillate output of solar stills (Rajamanickam and Ragupathy 2012).

Most of the investigations about the wind speed effect on still productivity have been performed in the last century. Very little research can be found in recent literature about the wind speed effect. Tiwari et al. (2009) pointed out that there are conflicting results about the effect of wind speed on solar still productivity. Some investigators concluded that the increase in wind speed causes an increase in still productivity; while others indicated that an increase in wind speed causes a decrease in stills productivity. He also pointed out that some investigators reported that the wind speed has no significant effect on still productivity. Maalej (1991) reported that the increase of wind velocity from 0 to 3.6 mph yielded a slight reduction of 2% in the solar still performance. He recommended that the best performance of the solar still was achieved when the solar stills operate at a minimal wind speed. Aburideh at al. (2012) also reported that wind decreases relatively the rate of the distilled water production. El-Sebaii (1998); El-Sebaii (2000) reported that the daily productivity of some designs of single and double basin solar stills as well as for a vertical solar still increases with the increase of wind speed up to a typical value. This value was found to be independent on the still shape and the heat capacity of brine but it shows some seasonal dependence. The author proposed empirical correlations relating the stills daily productivity with the wind speed for different masses of basin water up to 200 kg. El-Sebaii (2004) calculated that the critical value of wind velocity, beyond which its effect became insignificant, was 8 m/s and 10 m/s for typical winter and summer days respectively. Yousef and Abu-Arabi (2004) reported that the wind speed affects the cover temperature. At higher wind velocity the convective heat transfer from the cover to the atmosphere increases due to the increase in convective heat transfer coefficient between the cover and the atmosphere. This effect increases the condensation and evaporation rates and consequently the still productivity. Abu-Hijleh (1996) reported that the single basin, single slope solar still productivity is found to increase by 35% on increasing the wind speed from 2.7 to 5 m/s. Badran (2007) studied numerically the effect of introducing a water film cooling on the efficiency of the conventional solar still. The investigator used different water film cooling methods to modify the glass cover temperature and to provide preheated makeup water to the solar still. The results show that using the appropriate combination of water cooling film parameter, the solar still efficiency can be increased by up to 6%. On the other hand, a poor choice of the parameters resulted in a reduction in still efficiency. Lower film cooling thickness gave a better efficiency up to a certain value, beyond which the still efficiency decreases.

The investigator also reported that the still efficiency with water film cooling was not sensitive to the wind speed. Abu-Hijleh and Mousa (1997) also performed a numerical investigation on the effect of introducing water film cooling onto the glass cover of a conventional single basin solar still. It was found that in the case of the still that with the using the of appropriate water film cooling parameters, the still efficiency could be increased by up to 20%. They also reported that the presence of the water cooling film neutralizes the effect of wind speed on still efficiency. Madhlopa and Johnstone (2009) reported that the wind speed has a marginal effect on distillate production. They found that the levels of production for three different wind speeds (2 m/s, 4 m/s and 6 m/s) are not significantly different from morning (6:00 h) till about 15:00 h. After that, the cumulative distillate slightly decreased as the wind speed increased. El-Sebaii (2011) used a computer simulation program to investigate the effect of wind speed on the daily productivity of solar stills. Based on the assumption that the inner and outer glass cover temperatures are not equal, the author reported that the still productivity was found to be less dependent on wind speed for all investigated values of mass of basin water. Abu-Hijleh (1996) reported that introducing a water sprinkler (cooling film) onto the outer surface of the glass cover will enhance the conventional still productivity by 22%. Al-Garni (2012) found that using external cooling fan on a double slope solar still will decrease the still productivity buy 4% and 8 % for wind speeds of 7 m/s and 9 m/s, respectively.

The aim of the present research is to experimentally evaluate the effect of reducing the volumetric space, the wind velocity and using a sprinkler to cool down the glass cover of the conventional, single base, single slope solar still under the climate of the city of Kuwait during the month of August 2011.

## 2. Experimental facilities

Three identical conventional single slope basin type solar stills were designed and constructed from durable aluminum with a thickness of 4 mm and a net basin effective area of 1 m² (1x1m). Each still has a 3 mm glass cover. The whole structure is held together by using GI Angles for durability and strength. The glass cover is rubber lined and rests on a GI frame structure, completely sealed by using superior silicon sealants. All stills insides were painted black using Black Epoxy in order to increase the suns rays' absorptions efficiency and also to eliminate any possible corrosion to the metal surfaces. The three stills were given an insulating cladding (bottom and sides) material of flex – nitrile rubber insulator of 15 mm thickness, which has superior insulating properties of 0.037 W/m² K.

An aluminum trough was used to collect the condensate water running down the glass cover of each solar still. The troughs were fixed with a slight slope in order to facilitate a smooth flow of condensation to the plastic jars where the collected condensed water can be measured in a graduated flask. The detailed schematic diagram is shown in Fig. 1, and the solar still setup is shown in Fig. 2.

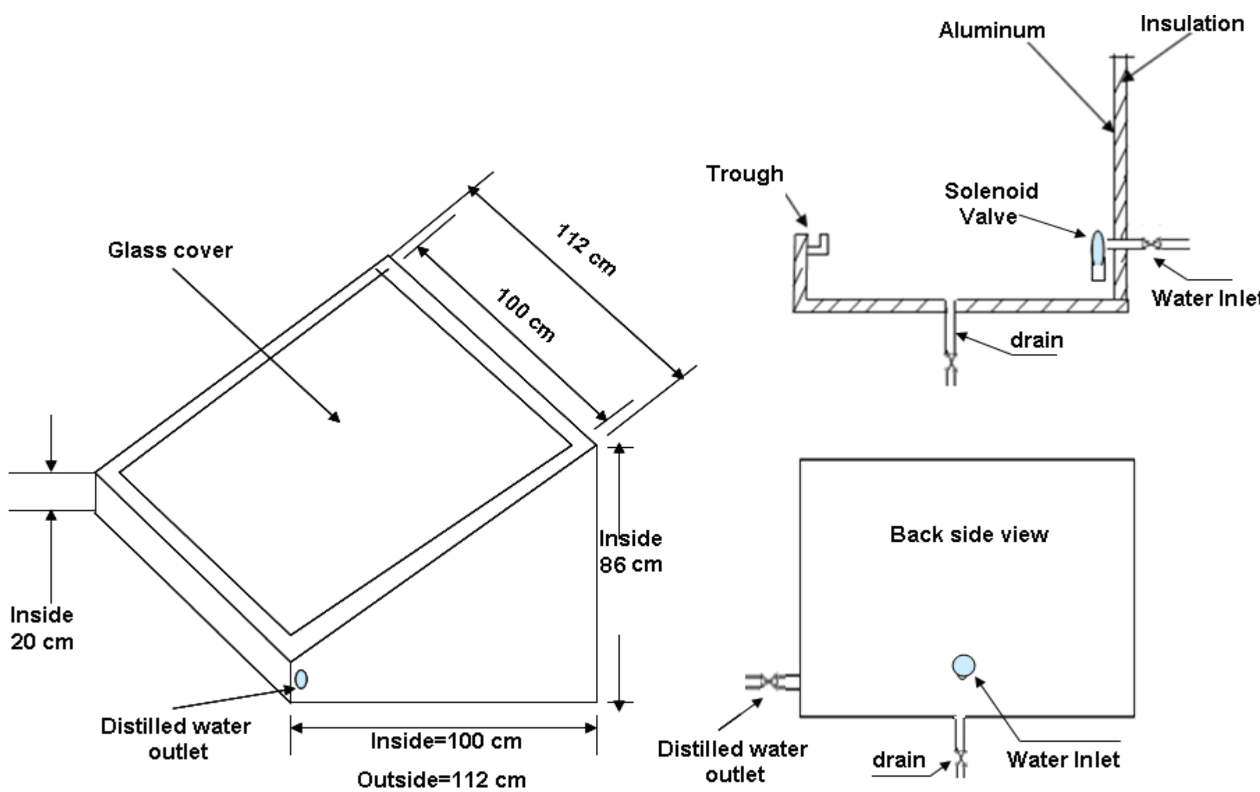


Fig.1. detailed schematics diagram of solar still

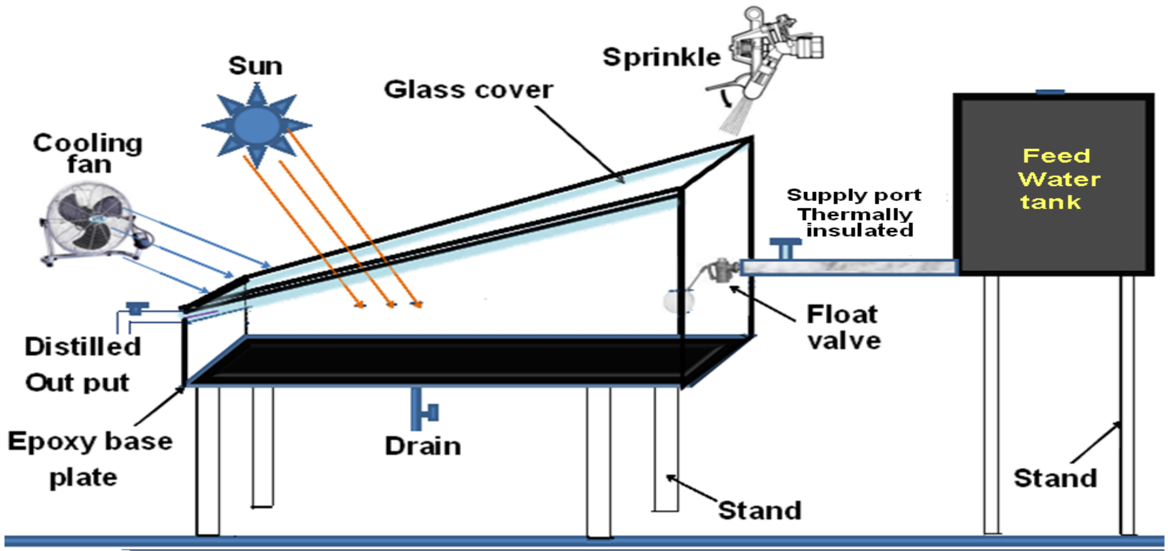


Fig.2. Solar still schematics diagram setup

A half inch hole was made in the lower part of the back of each still with a drop down pipe for inlet water. The pipes were connected to a feed water tank fixed at higher level next to each solar still. The water level was controlled and maintained at 1 cm height by means of an electronic float linked to a solenoid valve shown in Fig. 3. The float operation was tested and proved to be very accurate. Another hole of the same size fitted with a pipe was fixed at the base of each solar still for drainage and flushing during maintenance. A manual sprinkler system was installed and operated to study the effect of glass cover cooling on solar still yield as shown in Fig. 4.

Fig.3. Solenoid valve for water level control

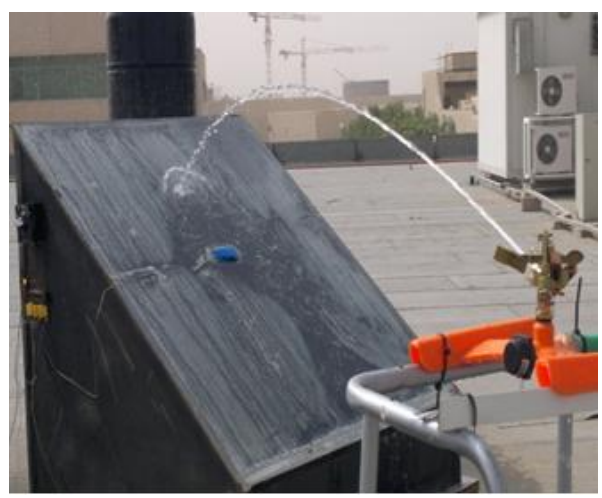

Fig. 4. Water sprinkler system

Water line pressure was developed from an elevated tank filled with tap water. The water output was controlled by using a manual gate valve which was opened and closed manually at fixed time intervals and for certain periods as per the experimental requirement. Suitable fans were used to vary and control the wind speed at the desired level. This can be seen in Fig. 5.

Fig.5. Fans used to vary and control wind speed

An anemometer was used to measure wind speed, a humidity meter was used to measure the ambient humidity, and a solar intensity meter was used to measure the solar radiation intensity in $W/m^2$ (its range from 0-1.999 $kW/m^2$). K-type thermocouples were used to measure the ambient temperature, the water inlet temperature, the basin water temperatures, the basin metal temperatures, the glass cover inside and outside temperatures and the still's inside temperatures.

The experiments were carried out on days with clear sky in a location 10 km to the west of the city of Kuwait (32.4º E 26.1º N) during the month of August 2011. Preliminary tests were conducted for one day to make sure that the system was ready. Then the experiments were carried out for another two days and the average values taken. The three stills were positioned on a suitable steel structure, next to each other facing south as shown in Fig. 6

Fig.6. the three solar stills set up in situ.

All experiments were carried out for 12 hours, which started at 7:00 am and lasted till 7:00 pm local time; Measurements were taken and recorded on an hourly basis

## 3. Results and Analysis

Comprehensive tests were performed implementing three identical basin type, single slope solar stills to evaluate the effect of wind speed and the use of water sprinklers to cool down the still covers. The three stills worked simultaneously. All parameters were recorded on an hourly basis from 7:00 am till 7: 00 pm.

### 3.1. Wind speed effect

The wind speed was controlled by using suitable fans. The first still was used as a reference where the natural wind speed recorded and the average value was found to be around 1.2 m/s. it yielded a total daily production rate of 2805 ml/m²/day. On the second still, the forced wind was set up and controlled at an average value of 3 m/s. It was found to yield 3030 ml/m²/day, which represented an increase in production rate of 8 %. On the third still, the forced wind was setup and controlled to an average value of 4.5 m/s. it was found to yield 3240 ml/m²/day, which represented an increase in production rate of 15.5%. The effect of wind speed on accumulated and hourly based stills' productivity is shown in Figs. 7 and 8 respectively. The increase in production rate is obvious as the wind speed increased. This is due to the decrease in still cover outside temperature which enhanced condensation on the inner cover surface of the still. This can be seen when the covers of the three stills, outside and inside temperatures compared as shown in Figs. 9 and 10 respectively.

### 3.2 Sprinkler cooling effect

The same three stills were used to evaluate the effect of implementing an external water sprinkler to cool down the outside glass cover surface. The first basic still was used without external sprinkler cooling. The second still was used with the water sprinkler operated manually for 30 seconds at 20 minute intervals. The third still was used with the water sprinkler operated for 30 seconds, and at 10 minute intervals. Again the experiments were conducted over a 12 hour period and all the three stills were operated simultaneously.

It has been found that the total daily productivity of the three stills was 3230 ml/m²/day, 3737 ml/m²/day and 4259 ml/m²/day respectively. These represent an increase in the daily still's productivity of 15.7% and 31.8% respectively. The effects of wind speed on accumulated and on hourly based stills' productivity are shown in Figs. 11 and 12 respectively.

## 4. Conclusions

Outdoor experimental tests were conducted to study the effect of wind speed variations and the effect of introducing water sprinklers to cool down the outside of the glass cover of a conventional, basin type, single slope solar still.

It was found that increasing the wind speed from 1.2 m/s (the average measured wind speed), to 3 m/s and to 4.5 m/s (the average values were taken) has the effect of increasing the still productivity by 8% and 15.5 % respectively.

Cooling down the outside glass cover of the solar still using water sprinklers for 30 seconds and at 20 minute intervals increases the stills productivity by 15.7%. Decreasing the interval to 10 minutes, increase the stills productivity to 31.8%.

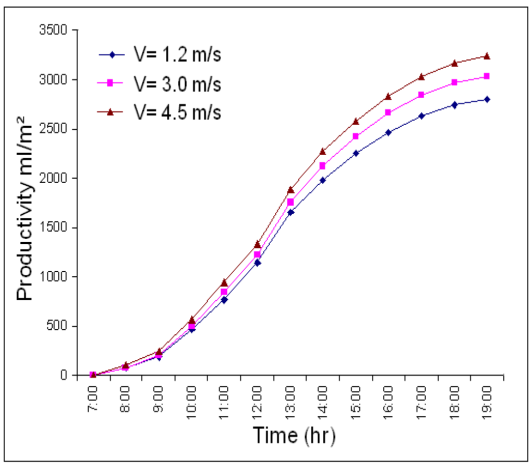


**Fig. 7.** Effect of wind speed on stills accumulated productivity

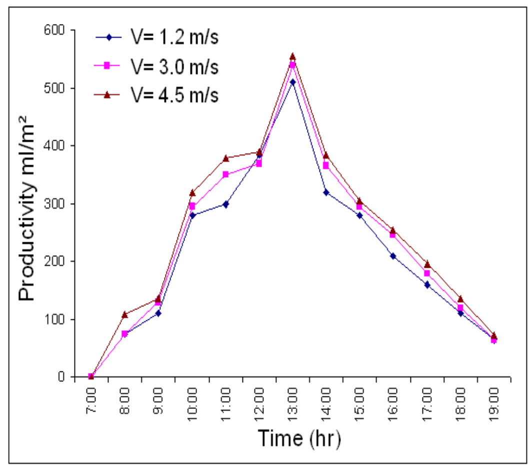


**Fig. 8.** Effect of wind speed on stills hourly based productivity

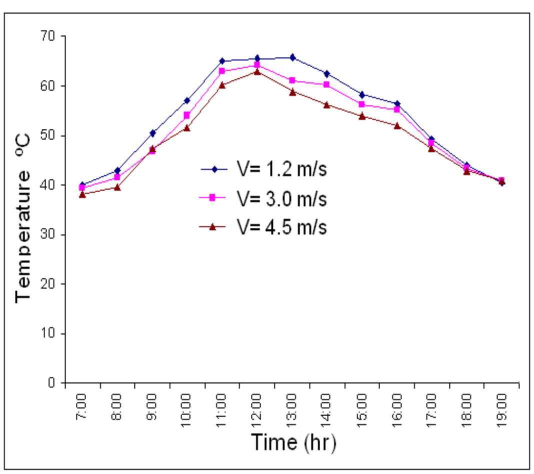


**Fig. 9.** Effect of wind speed on the covers

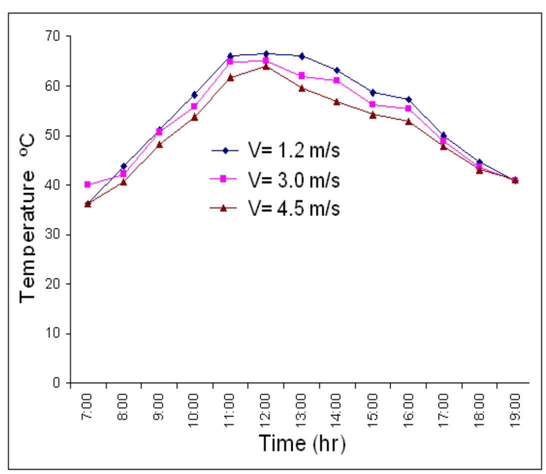


**Fig. 10.** Effect of wind speed on the covers

outside temperatures

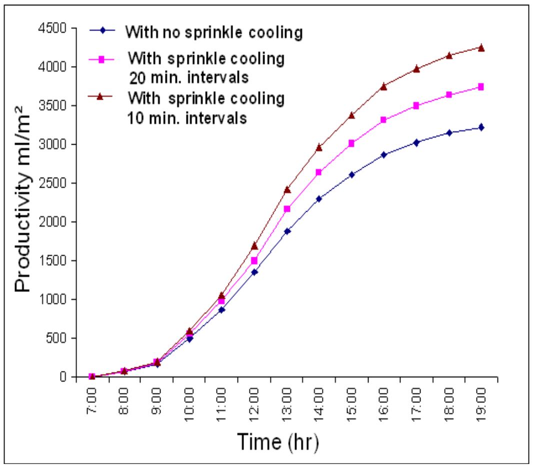


**Fig. 11.** Effect of water sprinkler on stills hour accumulated productivity

inside temperatures

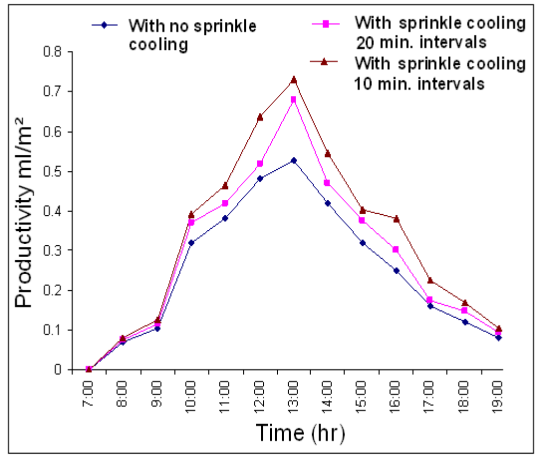


**Fig. 12.** Effect of water sprinkler on stills based productivity

## References

Abu-Hijleh, B., and Rababa'h, H. M. (2003). Experimental study of a solar still with sponge cubes in basin. Energy Conversion and Management, 44, 1411–141.

Abu-Hijleh, B., and Mousa, H. A. (1997). Water film cooling over the glass cover of a solar still including evaporation effects. Energy, Volume 22, Issue 1, Pages 43-48.

Abu-Hijleh, B. A. (1996). Enhanced solar still performance using water film cooling of the glass cover. Desalination 107, 235-244.

Aburideh, H., Deliou, A., .Abbad, B., Alaoui, F., Tassalit, D., and Tigrine, Z. (2012). An Experimental Study of a Solar Still: Application on the sea water An Experimental Study of a Solar Still: Application on the sea water. Procedia Engineering 33, 475 – 484

Ahmed, H. M., Al Taie, A., and Alme, M. (2012). The Comparison between Solar Water Distillation with and without a Cooling Tube. Journal of Energy and Power Engineering 6, 195-200.

Al-Garni, A Z. (2012). Productivity Enhancement of Solar Still Using Water Heater and Cooling Fan.. Sol. Energy Eng. Volume 134, Issue 3, 031006 (8 pages).

Badran, O. O. (2007). Experimental study of the enhancement parameters on a single slope solar still productivity” Desalination, Volume 209, Issues 1-3, Pages 136-143.

Ben Bacha, H., Maalej, A. Y., and Ben Dhia, H. (2007). A Methodology to Predict Operation of a Solar Powered Desalination Unit. NATO Security through science series, Solar Desalination for 21st Century Page 69-82.

Boubekri, M., and Chaker, A. (2011). Yield of an improved solar still: numerical approach. Energy Procedia, Volume 6, Pages 610-617.

Dev, R., Abdul-Wahab, S. A., and Tiwari, G. N., “Performance study of the inverted absorber solar still with water depth and total dissolved solid” Applied Energy, Volume 88, Issue 1, Pages 252-264, (2011).

El-Zahaby, A. M., Kabeel, A. E., Bakry, A. I., El-Agouz, S.A., Hawam, O. M., (2010). Augmentation of solar still performance using flash evaporation. Desalination, Volume 257, Issues 1-3, Pages 58-65.

El-Zahaby, A. M., Kabeel, A. E., Bakry, A. I., El-Agouz, S. A., and Hawam, O. M. (2011). Enhancement of solar still performance using a reciprocating spray feeding system—An experimental approach. Desalination, Volume 267, Issues 2-3, 15, Pages 209-216.

El-Sebaii, A. A. (1998). Parametric study of a vertical solar still. Energy Convers Mgmt., 39:1303–15.

El-Sebaii A. A. (2000). Effect of wind speed on some designs of solar stills” Energy Convers Mgmt 2000; 41:523–38.

El-Sebaii, A. A., (2004). Effect of wind speed on active and passive solar stills” Energy Conversion and Management 45, 1187–1204.

El-Sebaii, A. A., (2011). On effect of wind speed on passive solar still performance based on inner/outer surface temperatures of the glass cover. Energy 36, 4943-4949.

Ighodalo, O. A., and Ebhodaghe, F. A. (2011). Performance Evaluation of a Solar Still for Salty Water. Desalination. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (2): 338-341, (ISSN: 2141).

Maalej, A. (1991). Solar still performance. Desalination, Volume 82, Issues 1–3, 197-205.

Muller-Holst, H. (2007). Solar Thermal Desalination Using the Multiple Effect Humidification (MEH)-Method” NATO Security through science series, Solar Desalination for 21st Century Page 215-225.

Madhlopa, A., Johnstone, C., (2009). Numerical study of a passive solar still with separate condenser” Renew. Energy 34, 1430–1439.

Rajamanickam, M. R. Ragupathy, A. (2012): Influence of Water Depth on Internal Heat and Mass Transfer in a Double Slope Solar Still" Energy Procedia 14, 1701 – 1708. 2nd International Conference on Advances in Energy Engineering (ICAEE2011).

Tiwari, G.N., Dimri, V., Chel, A., “Parametric study of an active and passive solar distillation system: Energy and exergy analysis” Desalination, Volume 242, Issues 1–3, June 2009, Pages 1-18, (2009).

Varun, A.K. (2010). Solar stills: A review”. Renewable and Sustainable Energy Reviews 14, 446–453.

Yousef, H., and Abu-Arabi, M. (2004). Modeling and performance analysis of a regenerative solar desalination unit. Appl. Therm. Eng. 24,1061–1072.