

## An attempt to solar still productivity optimization; solar still shape, glass cover inclination and inner surface area of a single basin solar still, optimization

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### Abstract

Solar energy utilization in five different shape of solar stills is considered. Also, four solar still with similar specification but different in inclination angle, and another four with similar specification but different in inner surface areas have been investigated in an attempt to optimize solar still productivity. It is found that the best solar still is that which has symmetric double slope, the best inclination angle is  $45^\circ$  and that the lesser inner surface area ( $11645 \text{ cm}^2$ ) give the best productivity.

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### 1-Introduction

Water is the primary source of life and it is essential to life. Next to oxygen, fresh water is the most important substance for sustaining human life, and it's a key for life. Water shortage is a worldwide problem, where 40% of the world population is suffering from water scarcity [Abdullah *et al* 2008]. Although 75 percent of the earth is covered with water, 97 % of Earth's water is too salty for us to use. 3% of Earth's water is fresh water; only one-third is accessible at the lakes and rivers [Bowers 2006]. So the fact that 97% of the earth's surface is covered with saline water has been an important catalyst for developing water desalination technologies [Purohit *et al* 2006 and Klausner *et al* 2002].

All desalination methods require fossil fuel or electrical energy but solar distillation is one of many processes that can be used to produce fresh water by using the heat of the

sun directly in a simple equipment to purify water. The equipment, commonly called a solar still [Tiwari and Tiwari 2007]. Solar distillation process, which occurs in the still, is similar to natural evaporation of water from the sea, which creates clouds. The result is fresh water. Solar desalination could be one of the most successful applications of solar energy in most of the hot climate countries having limited resources of fresh water [Argaw 2001].

Although solar distillation at present cannot compete with oil-fired desalination in large central plants, it will surely become a viable technology within the next 100 years, when oil supplies will have approached its end. When that day arrives, the primary question will be, "which method of solar distillation is the best" [Gordes 1985].

Solar still is most simple device to get potable/fresh distilled water from impure

water using solar energy as fuel. Solar stills can be easy to construct and maintain. Depending upon their size, they can provide water for many uses. A solar still is very useful in desert areas where, sunshine is plentiful and there isn't fresh water.

A conventional solar still consists of the following basic components: (1) a basin, (2) support structures, (3) glazing, (4) a distillate trough (channel), and (5) insulation. In addition to these, other components may include like: (a) Sealants, (b) piping and valves, (c) tank for storage, (d) an external cover to protect the other components from the weather and (e) a reflector to concentrate sunlight [Gordes 1985]. The optimum inclination of the glazing inner surface mainly depends on the location, glazing material and the season. It has been observed experimentally by various investigators that the minimum inclination of the glass cover should be at least  $10^\circ$ , to avoid the drop back of the condensate [Meukam *et al* 2004].

The Principles of operation are the same for all solar stills. The basin of the still is filled with brackish or sea water, the incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface (basin) which contains the brackish water. Thus the water is heated and gives off water vapor. The vapor condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air, If the glass cover is tilted, the formed condensation drops will start running down the cover by gravitational forces, and may then be collected in a channel to go out the side of the still to a storage tank.

The daily collection rates can vary from 1 to 5 l/m<sup>2</sup> with a thermal efficiency of 50% [Ktmze 2001]. This rate depends on weather conditions and the amount of solar energy available.

Solar stills are simple in operation and non-requirements of highly skilled for maintenance. The only maintenance required is the cleaning of the plant, especially of the glass cover. As such, it can be used at any place without many problems.

The solar distillation systems are classified into two groups; Passive and active solar stills, Fath [Fath 1998] reviewed the various designs of solar stills and studied the suitability of solar stills for providing potable water.

In this paper we have studied the productivity of fresh water by solar distillation using five different shapes of stills under the climatic conditions of Iraq at Basrah city(longitude 47°45' 06.45"E, latitude 30°33' 56.26"N) to select the best shape, then using four solar stills with the same shape but in different glass cover inclination to select the best inclination angle and then using five solar stills with same inclination angle but with different inner surfaces areas to find the optimum inner surface area of the still to be designed.

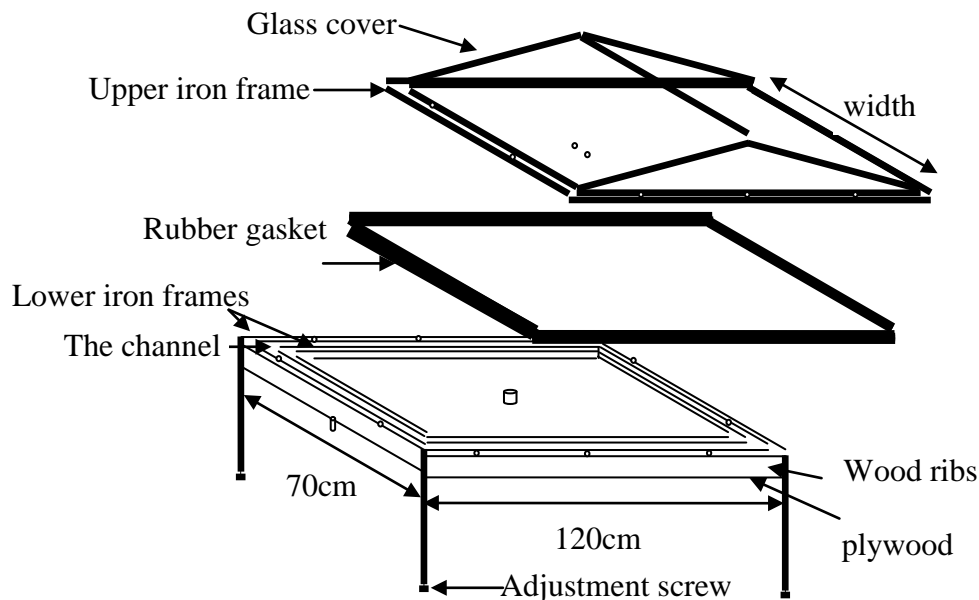
### **Experimental set-up**

To select the best shape of the solar still, five different configurations of basin-type solar stills were designed from locally available materials and locally manufactured components. All solar stills have been constructed in same steps for comparison purposes where; each one have a basin area of

0.5 m<sup>2</sup> was made of 1.5 mm aluminum plates, and covered with 4 mm transparent glass which fixed on the iron frame. The supported structure for each stills made from iron (angel shape cross section of 1.25"). A rubber gasket has been placed between the upper and the lower iron frames to prevent leakage. The basins of the stills were left without paint, the bottom of the five stills were insulated from outside only with plywood of 4 mm thickness to minimize the heat loss with the surrounding. Whole assemblies of the stills are made air

tight with the help of rubber gasket and rubber silicon. Each still provided with four Adjustment screws to rest it horizontally on the ground as shown in figure (1).

The solar still's glass covers were tilted at an angle of 15°. The water in the basin was kept in the depth of 2 cm for all stills. The distillate yield was measured by scaled flask every day. The present stills have a top cover and walls made of glass to allow to the solar radiation to pass through onto the basin.



**Fig.(1): Schematic diagram of the solar still**

The glass cover allows the solar radiation (shortwave) to pass into the still. The water begins to heat up and the moisture content of the air is trapped between the water surface and the glass cover, thus the glass cover traps the solar energy inside the still. The basin also radiates energy in the infrared region (long wavelength). The heated water evaporates from the basin and condenses on the inside of the glass cover. In this process the salts and microbes that were in the original

water are left behind. The condensed water trickles down the inclined glass cover to an interior collection trough and is delivered to a storage bottle. The still is filled each morning with the brackish water, and the total water production for the day is collected in the morning of the next day, all stills have the same quantity of brackish water.

Photographic picture of the five stills are shown in figure (2) which have been installed.



**Fig. (2): A photographic picture of stills Nos.1-5 during measurements.**

The characteristics of the stills 1-5 (figure (2)) are as follows; Solar still No.1(SS.No.1): this still has been manufactured with the following specifications: It is as a rectangular shape of  $(120 \times 70) \text{ cm}^2$ , the area of the basin is  $0.5 \text{ m}^2$  and made from aluminum plate with thickness of 1.5 mm, the glass cover has been inclined in a single slope of  $15^\circ$ , the width of the incline glass cover is 112cm, the basin without paint, there isn't any insulation except plywood under the basin. (SS. No.2): this still has been manufactured with the same specifications of SS.No.1 except the width of the incline glass cover is 62cm. (SS.No.3): this still has been manufactured with the same specifications of SS.No.1 except the glass cover has been inclined in a double slope of  $15^\circ$  and the width of the incline glass is 112cm. (SS.No.4): this still has been manufactured with the same specifications of SS.No.3 except the width of the incline glass is 62cm and (SS.No.5 ): this still has been manufactured with the following specifications; It is as a

pyramid shape, its basin of  $(70.7 \times 70.7) \text{ cm}^2$  and the top of  $(20 \times 20) \text{ cm}^2$  with slope of  $15^\circ$ , the area of the basin is  $0.5 \text{ m}^2$ , the glass cover has been inclined in a single slope of  $15^\circ$  to the four sides, the width of the incline glass is 70.7cm in each sides, the basin without paint and there isn't any insulation except plywood under the basin.

To select the best inclination angle of the still's glass cover, four of symmetric double slope basin-type solar stills (Nos.4,6-8) with similar specification but different in glass covers inclination were designed. The solar stills glass covers were tilted at angles of  $15^\circ, 25^\circ, 35^\circ$  &  $45^\circ$  in order to find the optimum angle for glass cover inclination as shown in figure (3). And to select the optimum inner surface areas, all stills(Nos.4,9-11) were inclined at the same angle while the inner surface area are differs as shown in figure (4). The depth of water in the basin was maintained at 2cm. The distillate yield was measured by scaled flask every day.

In order to find the best angle for glass covers inclination which gives the high productivity, the stills were operating at the same time after putting equal quantities of brackish water in each of them, and under the same conditions. The stills were provided with a brackish water in the morning and were left for one day in order to calculate the daily

production of each one of them. Figure (3) shows a photographic picture of the stills (4,6-8), where all stills have been manufactured with the same specifications of (SS.No.4) except they differ in the inclination angle of the glass cover, where the glass cover of the stills No.6, No.7 and No.8 were tilted with angle of  $25^\circ$ ,  $35^\circ$  and  $45^\circ$  respectively.



**Fig.(3): A photographic picture of stills Nos.4,6-8.**

In order to find the best inner surface area of the still which gives the high productivity, the mentioned four solar stills have been rebuilt to become similar in the slope of the glass cover, each one of  $15^\circ$ , but they differ in the inner surface area of the condensing chamber.

Solar stills Nos.4,9-11 were installed as shown in figure (4), where: the inner surface area of (SS.No.4) is of  $10510 \text{ cm}^2$ , (SS.No.9) has been manufactured in the same

specifications of solar still No.4 except the inner surface area has been increased by increasing the high of the four sides of the glass cover by 5 cm, where the inner surface area is  $12780 \text{ cm}^2$ . It is the same inner surface area of (SS.No.6). (SS.No.10) has inner surface area of  $15987 \text{ cm}^2$ , it is the same inner surface area of (SS.No.7). while (SS.No.11) has inner surface area of  $20324 \text{ cm}^2$ , it is the same inner surface area of (SS.No.8).

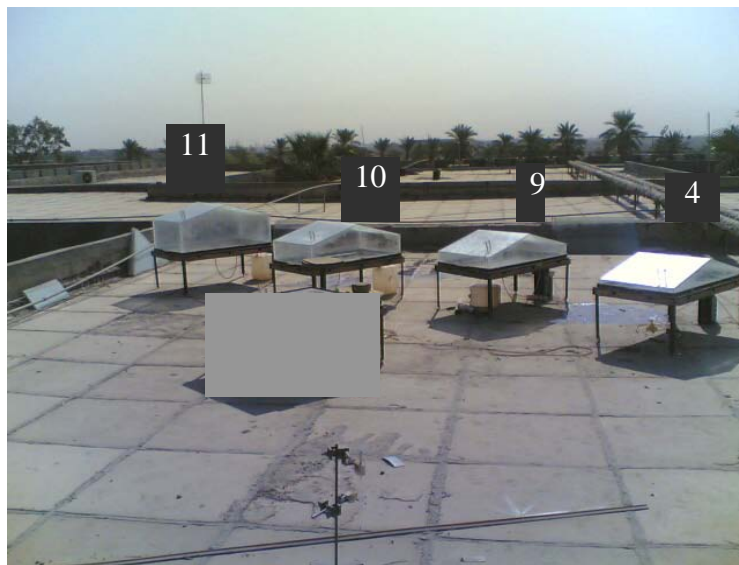


Fig.(4): A photographic picture of the stills Nos.4,9-11.

**Results and discussion**

The comparison of the productivity of fresh water between the five types of stills

(Nos.1-5) for the period from 22 May 2007 to 25 June 2007 is shown in figure (5)

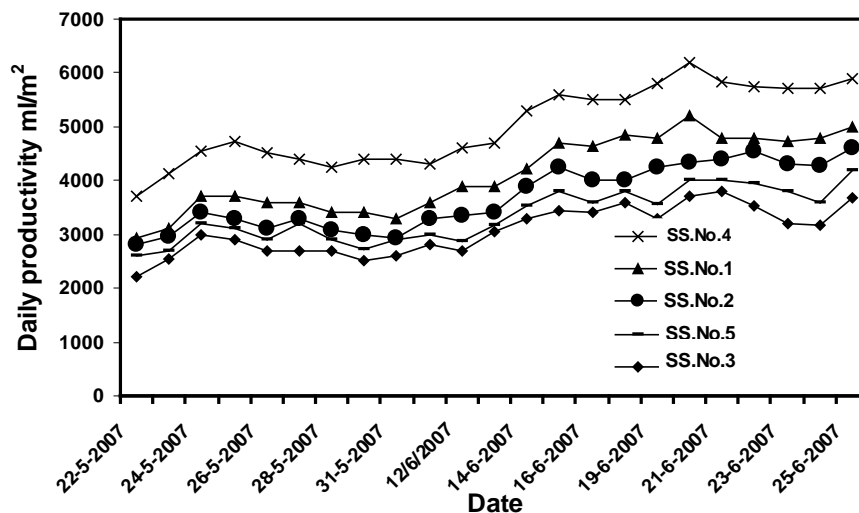


Fig.(5): The daily productivity of the solar stills Nos. 1-5.

Its clear that the production of the double inclination still No.4 is the higher than that of the others stills, this maybe due to the less losses in the condensing water on the inner surface of the glass as compared with the other stills. In the other stills some of the heavy water drops may fall again in the basin leading to a decrease in their productivity.

It is also clear that the averages productivity per a day of the still No. 4 is higher than the productivity of the other stills No.1, No.2, No.3 and No.5 by 22%, 36%, 64 % and 50% respectively.

The stills Nos. 4,6-8 were operating for the period from 26 June 2007 until 14 Aug. 2007. The results are shown in figure (6).

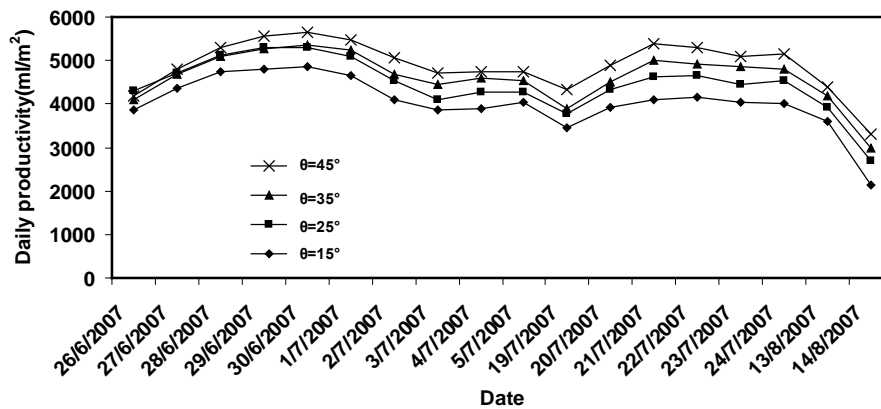


Fig.(6): The daily productivity of the solar stills Nos. 4,6-8.

From figure (6) its clear that the productivity increase with the increasing of the glass cover inclination angle, because the high angle enhanced the drops of condensing water to flow to the channel and decrease the loses which come from falling in the basin. It is also clear from figure (6) that the average

productivity per a day of still No.8, is higher than the productivity of stills No.7, No.6, and No.4 by 6%, 10% and 21% respectively.

Figure (7) shows the relation between the daily productivity and the inclination angles.

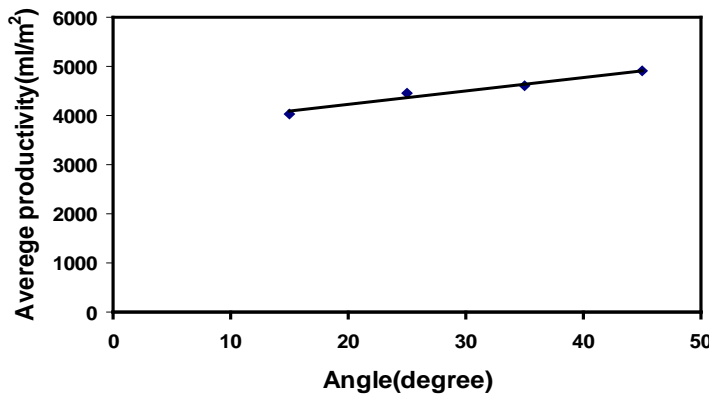


Fig.(7): The relation between the daily productivity and the inclination angles.

It is obvious that the best still is still No. 8, which has a glass cover slope of 45°. It is worth nothing that [Samee 2007] find 15 degrees is a best cover inclination. This maybe due to several reasons such as the area allocated to condensing will be increases, so the area of the glass (condenser) will be a

larger, which allows a better exchange of heat between the cover and the ambient air, thus; the difference between the water temperature and the glass temperature will be increase so that the condensation increase. In addition, the condensed drops on the inner surface of the glass are going to drain channel without falling

at the basin again, because of higher gradient of the glass inner surface. However, for the large angle some disadvantages for design, such as the large size increased cost of the solar still. If one says that this result is logical, where production increase because the area of condensing increase, we will examine the following confirmation on 15 degree angle,

according to which we are theoretically increase the inner surface area and fixed the angle at 15 degree to cheak the differences.

Solar stills Nos. 4,9-11 were installed and operating at the same time under the same conditions for the period time from 8 Sep. 2007 until 4 Oct. 2007 and the results were obtained are shown in figure (8).

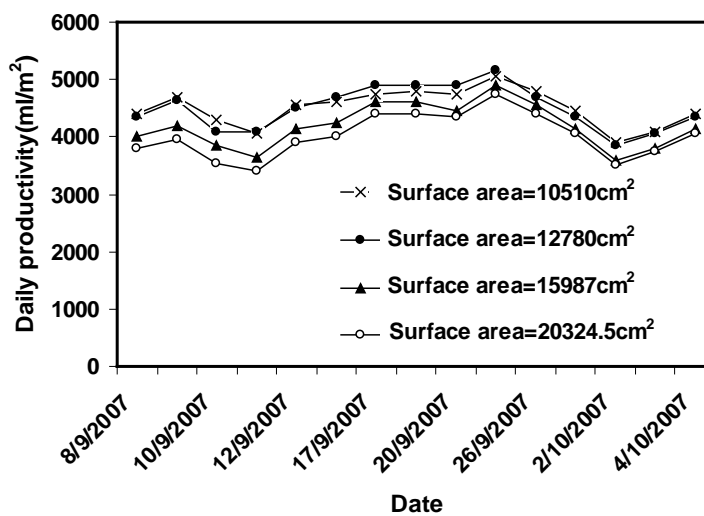


Fig. (8): The effect of inner surface area on stills productivity.

It is clear from the figure (8), that the larger the inner surface area the lower is the productivity and the stills No.4 and No.9 have

the better productivity, due to their relatively smaller inner surface area see table below:

	SS.No.4	SS.No.9	SS.No.10	SS.No.11
Average productivity of the operation days( ml / m <sup>2</sup> )	4503.333	4506.666	4193.333	4016.666
inner surface area (cm <sup>2</sup> )	10510	12780	15987	20324

Therefore, in the past experience the angle of the glass cover has a major effect by reducing the condensing water losses, where a large angle help to accelerate the drop to the channel without fall again in the basin. However, for economic reasons and design the stills No. 4 & 6 in this experiment are better

than angle was 45°, because of their small size, where the condensing glass cover and walls are near for the vapor. Therefore, the optimum inner surface area of the still can be selected as of 11645 cm<sup>2</sup>, which is the average inner surface area of the stills 4&9.

## Conclusion

Solar stills are useful due to their simplicity, ability to supply fresh water to remote areas where no fresh water is available, and its environmental friendliness makes it attractive technology in future.

The results in the present study indicated that the double inclination solar still No.4 with glass cover inclination of 15° and inner surface area of 11645 cm<sup>2</sup> is the best suited among the five models which have been constructed and installed, to the climate of the Basrah city (south of Iraq).

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محاولة لتحقيق أفضل شكل وأفضل زاوية للغطاء الزجاجي وأفضل مساحة سطحية  
للمقطر الشمسي ذو الحوض المفرد

عقيل يوسف هاشم      جاسم مهدي الأسدي      واثق أيوب طه الرمضان  
المعهد التقني في البصرة      جامعة البصرة كلية التربية      جامعة البصرة كلية العلوم قسم الفيزياء  
قسم الفيزياء

الخلاصة

تم استخدام الطاقة الشمسية في خمسة أشكال مختلفة من المقطرات الشمسية، وكذلك في أربعة مقطرات أخرى متشابهة لكنها مختلفة في زاوية انحدار الغطاء الزجاجي ولخمسة مقطرات أخرى متشابهة في زاوية الانحدار للغطاء الزجاجي لكنها مختلفة بالمساحة السطحية الداخلية للمقطر الشمسي وتبين إن أفضل المقطرات هو ذو الشكل الذي غطاءه الزجاجي مائل من الجهتين وبشكل متناظر وأفضل زاوية إمالة للغطاء الزجاجي هي 45 درجة عن الأفق وأفضل مساحة سطحية للمقطر هي 11645 سم<sup>2</sup>.