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Study of efficiency for the pyramidal solar still (PSS) in Basra city, Iraq

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ABSTRACT

A pyramidal solar still (PSS) and a single basin solar still (SBSS) having been built of transparent glass with a thickness (4 mm) and have the same dimensions of absorber plate which contains the Saline water, and have been constructed under different atmospheric circumstances of Basra city (Iraq). An experimental investigation was carried out on two solar stills under the same conditions. The still has consists from the basin total area of 0.25 m^2. We found in this experimental study that the efficiency of the single basin solar still (SBSS) is (55%) and increases to (66.5 %) of the pyramidal solar still (PSS).

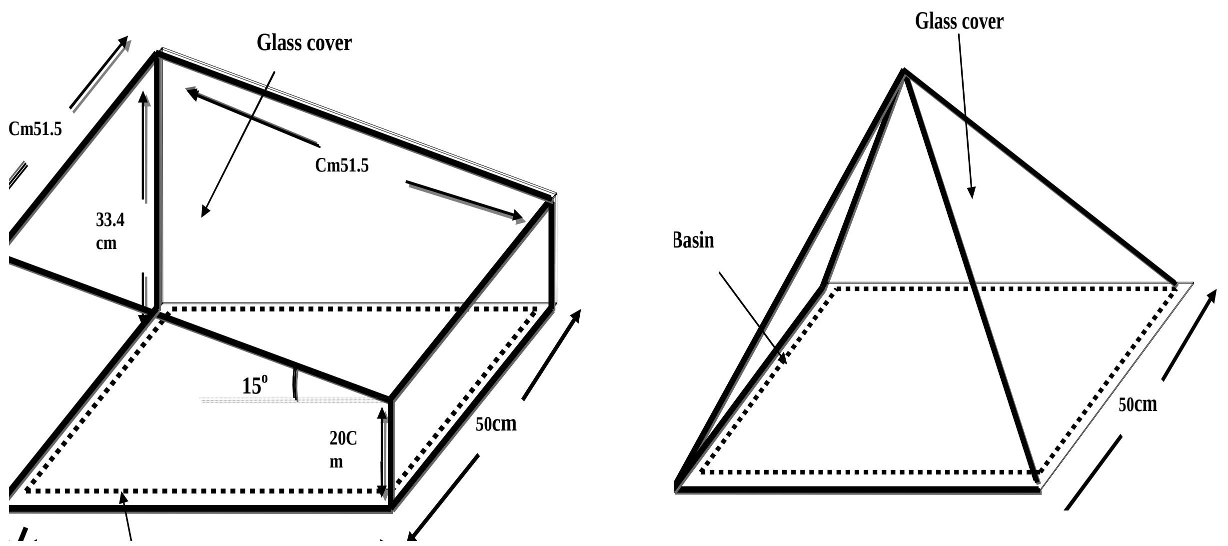
Key words: Water, Saline Water, Solar Still, Pyramidal Solar Still, Desalination.

INTRODUCTION

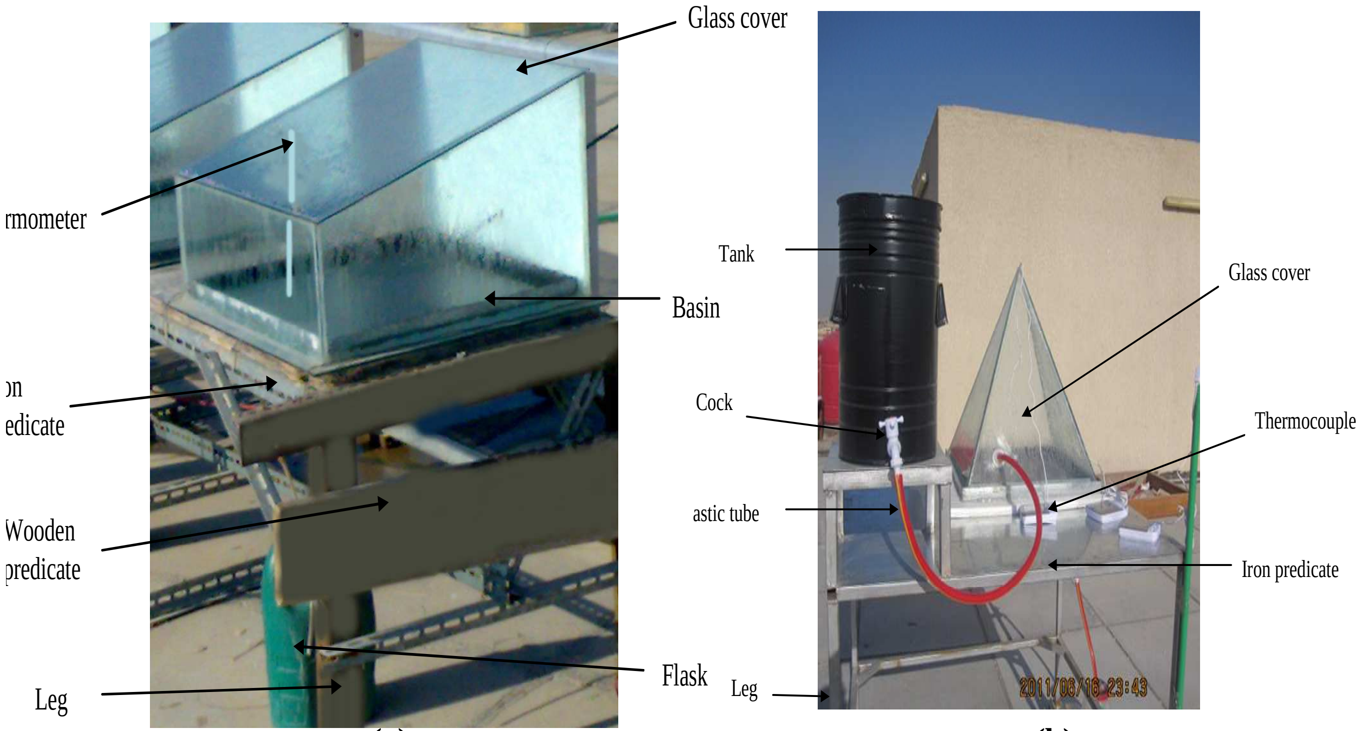
Water is important to life. Man has been dependent on rivers, lakes, and underground water for his requirements. About 97% of the earth water is salty and only 3% of earth water is potable. Due to increase in population and rapid industrial growth, the consumption of fresh water is increasing day by day. With water scarcity problem, men and animals are suffering a lot.

Apart from this, water pollution is also a major problem for water scarcity. Desalination is the best solution for the above said problem. In existing desalination method, for mass production, fossil fuels are used. But availability of fossil fuels in the world is very limited. A solar still is widely used in solar desalination process to produce potable water. Such kind of system is suitable for low productions and particularly applicable in rural areas. It consists of an airtight basin of rectangular shape, made from galvanized iron (zinc coated iron to prevent corrosion) and a glass to trap the solar energy inside the still. The yield of the single basin type solar still is very less. To enhance the productivity of the solar still, a plastic solar water purifier [1], a regenerative solar desalination unit [2], asymmetric greenhouse type solar still with some mirrors [3,4], a specially shaped reflector with corrosion free absorbers [5], a solar still integrated with a flat plate collector [6,7], a wick type solar still [8],a triple-basin solar still [9], a flat plate collector coupled with a single basin still [10], solar distiller with capillary film [11], an air blown multi effect solar still with thermal energy recycle [12], solar still coupled with solar collector and storage tank [13,14,15], a solar still with black rubber or black gravel [16,17], a solar still with sponge cubes [18], single and double slope stills [19], solar still with multi source and multi use environment [20], solar still coupled with electrical blower [21], and solar still with baffle suspended absorber [22] were designed.

The general objective of this work is to design a pyramidal solar still and measure its efficiency in comparison with a single basin solar still.



(a) (b)



(a) (b)

Fig.(1): (a) Schematic diagram of the single basin solar still(SBSS), (b) Schematic diagram of the pyramidal solar still(PSS)
Fig.(2): (a) Photograph picture of the single basin solar still (SBSS), (b) Schematic diagram of the pyramidal solar still(PSS)

MATERIALS AND METHODS

1- System Description

A pyramidal Solar still has been constructed and it's performance has been evaluated under different atmospheric circumstances of Basra city (Iraq) (Latitude 30° 33' 56.55''N, Longitude 47° 45' 5.86''E) .

The pyramidal solar still (PSS) and a single basin solar still (SBSS) having been built of transparent glass with a thickness (4 mm) and have the same dimensions of absorber plate which contains the Saline water, an absorber plate and glass cover that creates a cavity. The cavity length, width and height for the pyramidal solar still are 0.5 m, 0.5 m and 0.67 m and for the single basin solar still are 0.5 m, 0.5 m and 0.334 m. This plate in two stills is made of aluminum with surface area (0.25 m^2), the surfaces were coated with black paint to absorb the maximum amount of solar radiation incident on them. The brackish water is fed to the both stills through the hollow screw (double ended screw pipe) of (8mm) diameter on the side glass at height 5 cm and join with rubber tube to the tank of saline water with capacity 30 liter. The condensed channel in both stills lies between the absorber plate and the glass cover with width 1cm and height 2cm. The absorber receives solar radiation from both sides. Flowing water gets heated and evaporation starts from absorber plate. The evaporated water was condensed on condensed channel, it has been developed by putting hollow screw (ended screw pipe) of (8mm) diameter on the channel to get distilled water linking transparent rubber tube in this screw, goes to the distilled water collecting flask , diameter of the plastic tube (1cm).

The bases of the both stills are insulated with pieces of wood (wood block) of (1cm) thickness to avoid the thermal losses to the external ambient, proven the basin on the base by silicon rubber. Fig.(1) shows the schematic diagram of the both stills. Fig.(2) shows a photograph picture of the both stills.

2- Testes

The pyramidal solar still and single basin solar still directed to the south geographic, the direction geographical advantage from solar radiation and to be the first side towards the sunrise and the other side heading towards the sunset.

The experiments on the stills were carried out during some days of (December 2012, April 2013 and June 2013) to study their performance under different field conditions.

In each experiment, the hourly amount of distilled water and the insulation are monitored for both stills. The total daily amount of distillate water was recorded.

RESULTS AND DISCUSSION

Fig.(3) shows the daily production of the both solar still for some days of (December 2012, April 2012 and June 2013), and the solar radiation intensity values for the same days .It was seen from this figure that daily production of the maximum value arrived to (7368 ml/m^2) at (20 June 2013) for the PSS and (5570 ml/m^2) at (20 June 2013) for the SBSS, where the sky is clear, where the production of the solar still has been depending on the intensity of solar radiation, while the less value of production to (1640 ml/m^2) on the day of (20 December 2013) where the sky is not clear but partly cloudy. Fig.(4) shows the results of experimental hourly productivity of PSS and SBSS at 20 December 2012, solar radiation recorded every hour using the solar integrator device [23] .

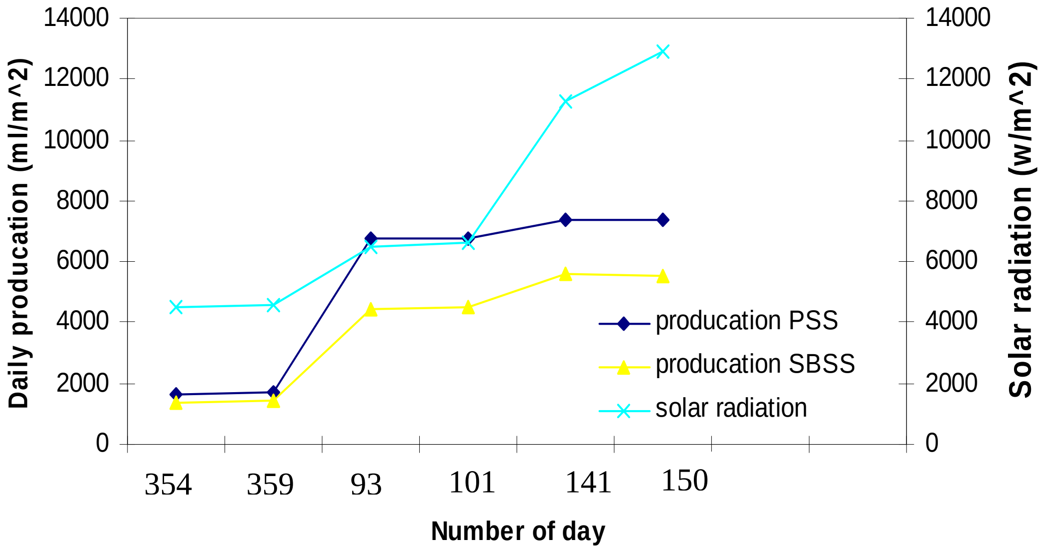


Fig.(3): Daily production of the both solar still with the solar radiation from days of December 2012, April 2013 and June 2013.

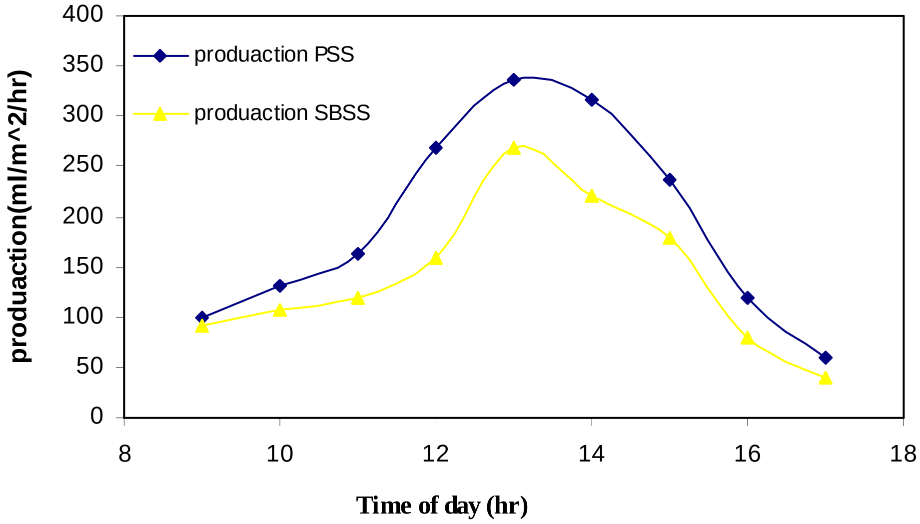


Fig. (4) Experimental hourly productivity of PSS and SBSS at 20 December 2012.

It is clear from Fig.(4) that the hourly production of the two stills have the same behavior, and there is a significant increase in the productivity of (PSS) due to the effect of the pyramidal solar still . A maximum production is one at the first and the end day hours arrived to (336 ml/m^2/h) of (PSS), and (240 ml/m^2/h) of (SBSS), while the lower at mid-day to (120ml/m^2/h) of (PSS), and (80 ml/m^2/h) of (SBSS), because the solar radiation is vertical at midday. The temperature of water basin for (PSS), (SBSS) and ambient air was recorded continuously for one hour at 20 December 2012 show in Fig. (5).

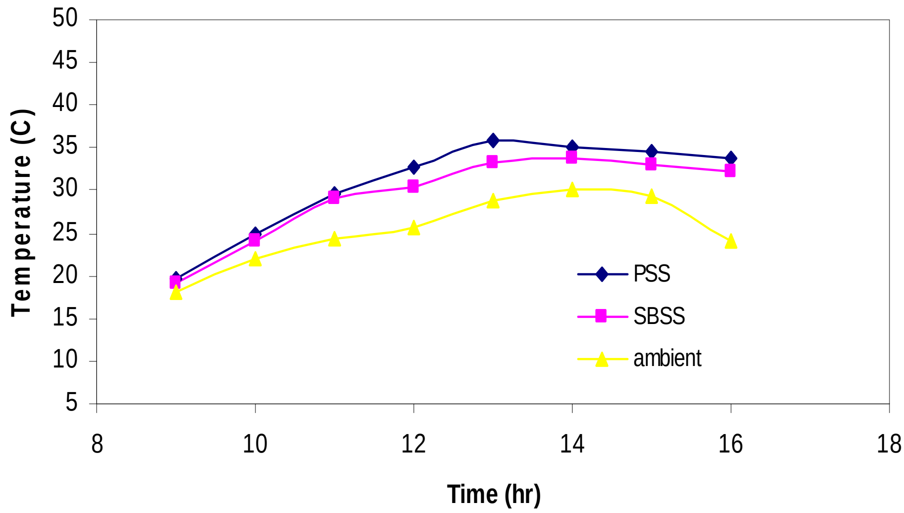


Fig. (5): The change in the temperature of the water basin along the daily hours at 20 December 2012.

From Fig.(5) we observe that the water temperature for the PSS has a highest value at mid day ,this is because of the effect of pyramidal solar still, also the maximum value of the temperature water basin arrived to (36^o)for the PSS. The thermal efficiency (E) of the stills was calculated for the same day (December 2012, April 2013 and June 2013) using the following equation [24]:

$$E = \frac{P \times \mathrm{L}}{\mathrm{I} \times \mathrm{A_b}}$$

Where:
E: Thermal efficiency.

P: Daily output of distilled water.
L: Latent heat of water evaporation (KJ / Kg).
I: Daily solar radiation (W / m². Day).
A_b: Area of the solar still (m^2).

Table (1, 2) shows the results of the thermal efficiency of the pyramidal solar still (PSS) and the single basin solar still (SBSS) respectively.

Table(1): Thermal efficiency of the pyramidal solar still (PSS).

Date	Production (ml/m^2/day)	Solar radiation(w/m^2)	Efficiency %
20/12/2012	1640	4500	23.3
25/12/2012	1692	4600	23.5
2/4/2013	6768	6500	66.5
10/4/2013	6740	6600	65.2
20/6/2013	7368	11300	43.6
29/6/2013	7365	12900	38.1

Table(1): Thermal efficiency of the single basin solar still (SBSS).

Date	Production (ml/m^2/day)	Solar radiation(w/m^2)	Efficiency %
20/12/2012	1400	4500	19.9
25/12/2012	1420	4600	19.7
2/4/2013	4405	6500	43.3
10/4/2013	4480	6600	43.4
20/6/2013	5570	11300	31.5
29/6/2013	5550	12900	27.5

CONCLUSION

The main observations and conclusions that can be drawn from the results of this work are the following:
1. The largest part of distillate production was seen to take place between noon and sunset, where the productivity was increased with the increase of solar radiation.
2. The high distillate production of the pyramidal solar stills occurred in June, which was related to the high incident radiation.
3. The thermal efficiency arrived to 66.5 % for the pyramidal solar still (PSS) while 55 % for the single basin solar still (SBSS).
4. The pyramidal solar still (PSS) is the best design appropriately in Basra region in this work.
5. The hourly variation behavior of yield is similar to that of solar intensity.

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