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Evaluating thermal efficiency of Hemispherical Solar Still (HSS) (circular basin) in Basra city-Iraq

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Abstract

In this research Hemispherical Solar Still (HSS) has been constructed and their 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 Hemispherical solar still consists of a basin area of (0.025 m^2). This small measurement has been adopted in the size (0.20 m) for the size of the hemispherical glass cover and the difficulty of obtaining the larger measurement, this measurement is considered to cover a hemispherical as the largest size for the manufacturing in the South Oil Company in Basra-Iraq. The maximum experimental efficiency of the experimental still varies from(19% -23%) for the Hemispherical solar still.

Keyword :Water, Saline Water, Solar Still, Hemispherical Solar Still, Desalination.

Introduction

Saline water (brackish water) represents very high percentage of the total water on the surface of the earth, (97% - 97.5%), and the rest is fresh water (3% - 2.5%), so the fresh water which is available for use is a very small fraction [1-6].The remote arid warm places in the Middle East and North Africa and other regions in the world are suffering from a sharp shortage of fresh water. These regions are characterized by high salinity of the ground water, lack of rains and a good solar energy. It is an international problem and the best solution, is the use of solar energy for desalination of salt water [7]. Desalination processes require significant quantities of energy to achieve the separation of salts from seawater [8]. The desalination of saline waters requires a great amount of energy, so due to the energy crisis, new alternatives which are based on sustainable energy are essential to supplement the required energy of desalination processes. Over the years, solar energy has been used to purify water and numerous solar desalination devices have been developed. Solar stills directly utilize solar energy to desalinate brackish water and do not need other expensive and unsustainable energy sources such as fossil fuel. Therefore, they can be the best suitable solar desalination units to be used as low-capacity and self-reliant water supply systems [9]. In oil-rich countries, about 95% of all freshwater is already supplied by desalination technologies using fossil fuels (oil or gas). In view of future oil shortages, desalination must, however, be driven by renewable energy [10].

The 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 is commonly called a solar still [11]. Solar distillation is one of the available methods to produce potable water. This process has the advantage of zero fuel cost but requires more space (for collection) [12-13].

G.Gowrisankar and R.Jayaprakash study a design of spherical solar still with the charcoal absorber and get a maximum efficiency which is (18%) for still without charcoal and (25.34%) for still with charcoal absorber [14].

The aim of this work is to study the performance of newly designed spherical solar still, the distilled water output and the still efficiency of all the results were compared to the results of a single slope solar still studies.

Experimental set-up

A Hemispherical solar still has been constructed and their performance has been evaluated under different atmospheric circumstances of Basra city (Iraq) (Latitude 30° 33' 56.55"N, Longitude 47° 45' 5.86"E). Figure(1) shows the pictorial view of Hemispherical Solar Still. Figure (2) shows the schematic diagram of hemispherical solar still. The still has consisted of a circular basin with the area of (0.0125 m^2), the total height of the still is about 0.20 m. This small measurement has been adopted in the size (0.20 m) for the size of the hemispherical glass cover and the difficulty of obtaining the larger measurement, this measurement is considered to cover a hemispherical as the largest size for the manufacturing in the South oil Company in Basra-Iraq. The still consists of the circular basin of diameter 0.18 m, which is made up of Aluminum. The circular absorber basin is coated with black paint for maximum absorption of incident solar radiation.

The circular basin is fixed on the base which is made up of aluminum, the distance between the basin and glass cover (1cm) was used to collect the distilled water. The evaporated water is condensed on the top cover creeps down towards the distilled water collection channel. It has been developed by putting a hollow screw of (8mm) in diameter on the channel to get distilled water linking transparent rubber tube in this screw, going to the distilled water collecting flask, a diameter of the plastic tube (1cm). The base of the still is insulated with pieces of wood (wood block) with the (1cm) thickness to avoid thermal losses to the external ambient, the basin was put and restricted on the base by silicon rubber. The experiments on the stills were carried out during some days of (September 2013) to study their performance under different field conditions. During each experiment, the hourly amount of extracted distilled water and the insulation were monitored for both stills. The total daily amount of distillate water was recorded.

Figure 1: A photographic picture of the Hemispherical Solar Still (HSS)

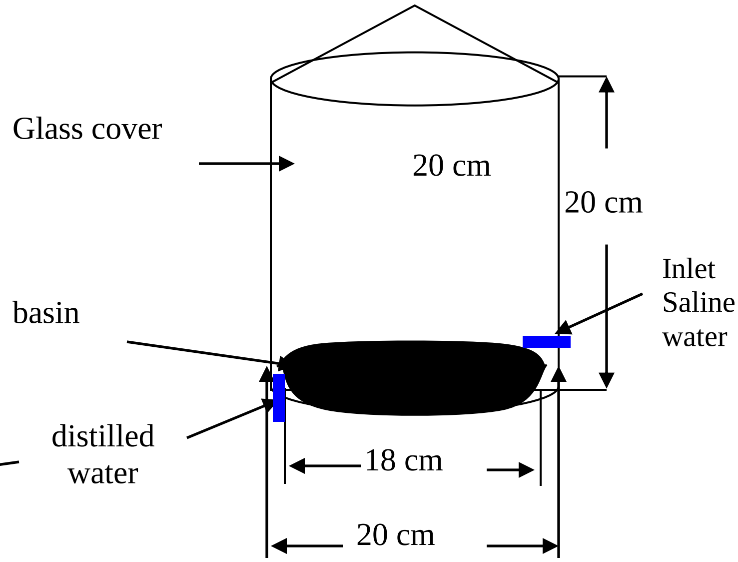

Figure 2: A schematic diagram of the Hemispherical Solar Still (HSS)

Results and discussion

Figure (3) shows the daily production of distilled water of the hemispherical solar stills throughout some days of September 2013. This figure shows that the daily production of the maximum value arrived to (3400 ml/m^2)for day (16/9/2013)where the sky is clear and the air does not contain the dust ,where the production of the solar still has been depending on the intensity of solar radiation ,while the less value of production to (3000 ml/m^2) on the day of (21/9/2013) where the sky is not clear but partly cloudy and the weather does contain on dust. Table (1) concludes the percentage increase in the daily productivity for the daily productivity of hemispherical solar still.

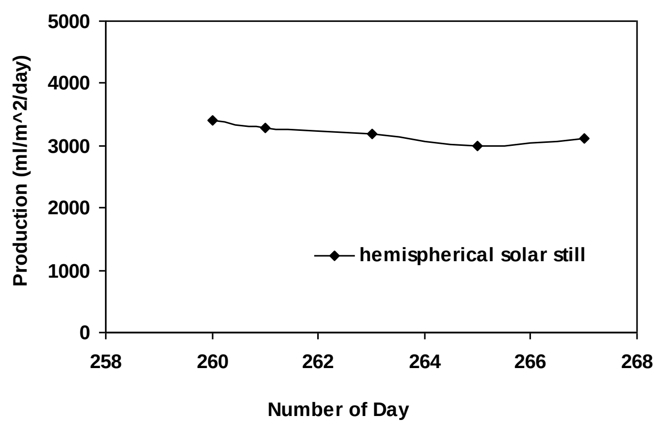

Figure 3: Daily productivity for the hemispherical solar still throughout some days of September 2013

Table 1: The percentage of increase in daily productivity of hemispherical solar still

Number of day	Daily productivity hemispherical solar still (ml/m^2)	Percentage increase %
260	3400	35
263	3280	20.5

The product water is measured hourly by calibrated beaker of 1 liter volume. The productivity of the still with respect to the solar radiation has been studied. The results of the day 16 of September, 2013 are shown in figure (4). The average daily production of the hemispherical solar still has the same behavior and the variation in its productivity from one day to another depending on the variation in solar radiation and the other meteorological factors like clouds. It is clear from the figure that the productivity of the still has the same behavior with respect to the solar radiation behavior. A maximum production is at midday while a lower one is at the first and the end day hours, but there is a significant increase in the productivity of the hemispherical solar still at the later hours of the day because the inner surface is hemispherical and has a wide area. Also at the first hours the inner surface of the hemispherical enhances to quick the condensation of the vapor which arises from the horizontal basin on it because of its lower temperature. Productivity of the solar still has been increased due to increase in temperature difference between water surface and inner surface of condensing glass cover. The maximum value arrived to (490 ml/m^2) in the hour (13 pm) while lower value arrived to (150 ml/m^2) in the hour (16 pm).

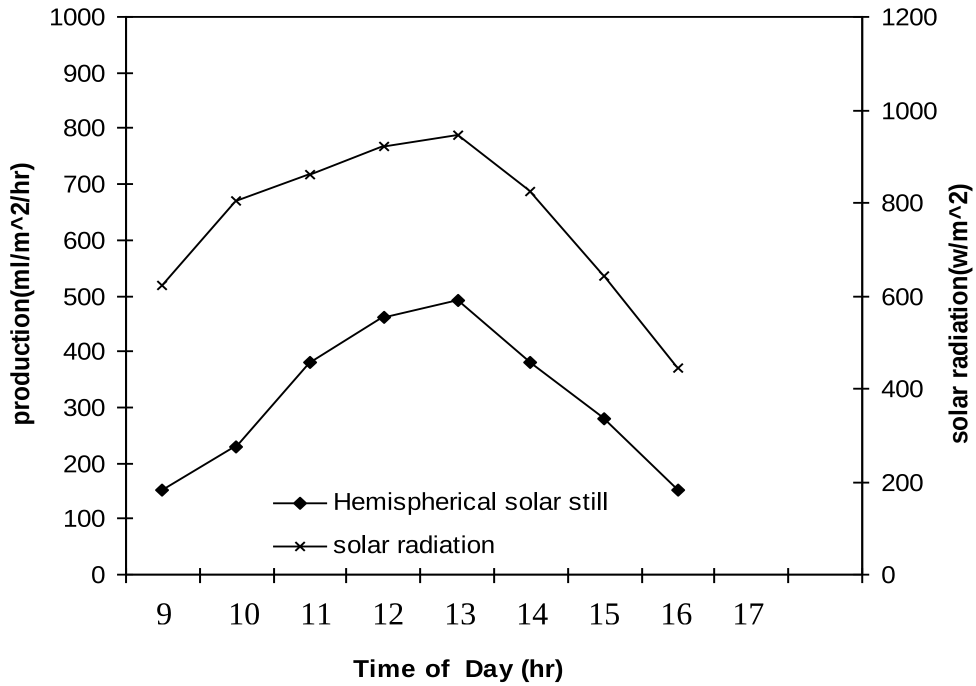

Figure 4: Hourly productivity of the hemispherical solar still during the day of 16 September 2013.

Figure (5) shows the daily production of distilled water of the hemispherical solar still with the solar radiation through some days of (September 2013). This figure shows that the daily production has a maximum value arrived to (3400 ml/m^2)for the hemispherical solar still the day 16 September 2013, where the sky is clear (there is no dust) ,where the production of the solar still has been depending on the intensity of solar radiation.

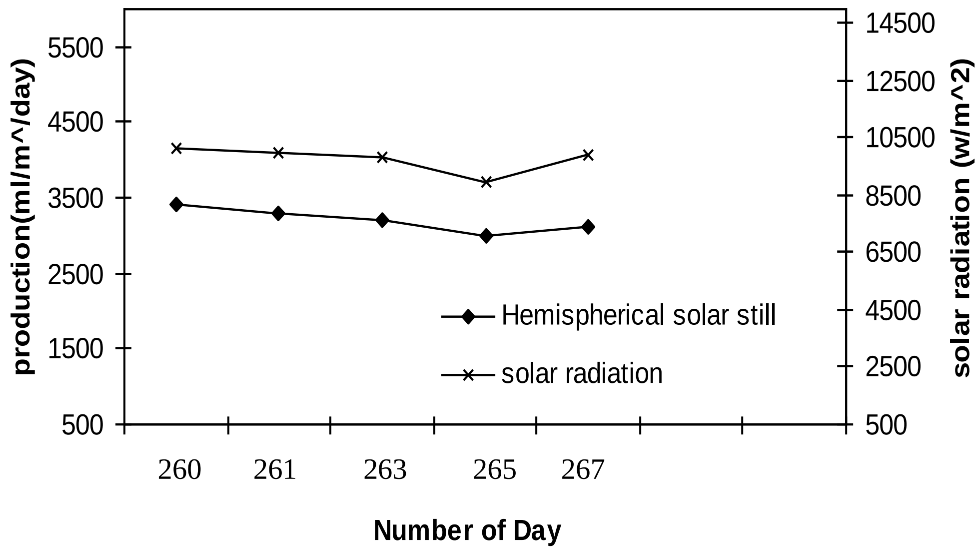

Figure 5: Daily productivity for the hemispherical solar still with the solar radiation through some days of (September 2013).

The thermal efficiency (E) of the still was calculated for some days using the following equation [15] .

$$E_{bsn} = \frac{P \times \mathrm{L}}{\mathrm{I} \times \mathrm{A_b}} \times 100\%$$

Where:

E_{bsn}**:** Thermal efficiency.

P**:** Daily output of distilled water.

L**:** Latent heat of water evaporation (KJ / Kg).

I**:** Daily solar radiation (W / m^2. day).

A_b**:** Area of the basin if the still (m^2).

Figure (6) shows the thermal efficiency (E) for the hemispherical solar still and through some days of (September 2013). The maximum thermal efficiency arrived at (23%) for hemispherical solar still while a less value (45.6 %) for the day 16 September 2013.

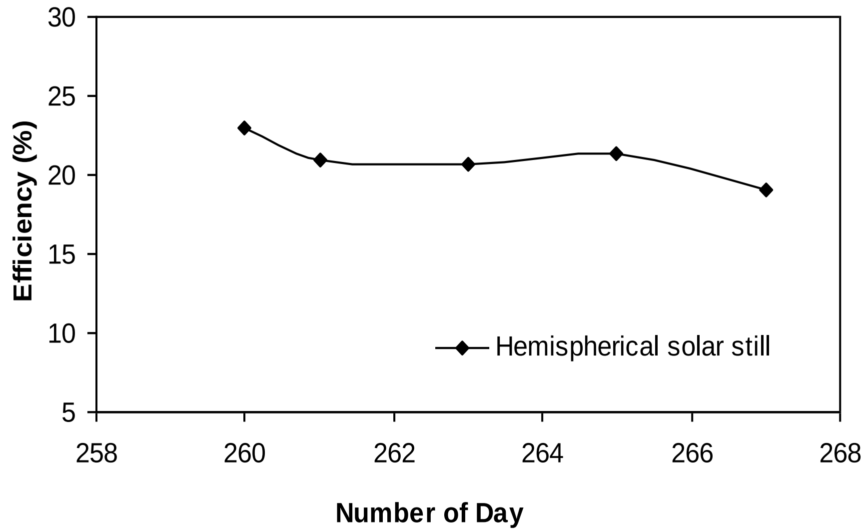

Figure 6: Thermal efficiency of the spherical solar still and single slope solar still through some days of (September 2013).

conclusions

The main observations and conclusions that can be obtained 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. The average daily production of the hemispherical solar still has the same behavior and the variation in its productivity from one day to another depending on the variation in solar radiation and the other meteorological factors like clouds.
2. The maximum thermal efficiency arrived at (23%) hemispherical solar still for the day 16 September 2013.
3. The distillate production can be increased when the temperature of the brackish water increases.

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تقييم كفاءة المقطر الشمسي النصف كروي (ذو القاعدة الدائرية) في مدينة البصرة - العراق

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المستخلص:

في هذا البحث، تم بناء المقطر الشمسي النصف كروي ذو الحوض الدائري، وتم وتقييم أدائه تحت الظروف الجوية لمدينة البصرة (العراق)الواقعة على (خط عرض N '33 °30 ، خط طول E '45 °47) يتكون المقطر النصف كروي من حوض مساحته ($0.025\ m^2$)، وقد اعتمد هذا القياس في الحجم وهو (0.20 m) للغطاء الزجاجي النصف كروي وذلك لصعوبة الحصول على قياس اكبر حجما، ويعتبر هذا القياس للغطاء النصف كروي كأكبر قياس للتصنيع في شركة نفط الجنوب فرع نهران عمر في البصرة، وتم حساب الإنتاجية العملية والكفاءة الحرارية للمقطر الشمسي وقد أظهرت نتائج التجارب العملية بان وكفاءة المقطر الشمسي النصف كروي هي تتراوح بين (19% - 23%).

الكلمات المفتاحية: الماء ، الماء المالح ، تحلية الماء ، المقطر الشمسي ،المقطر الشمسي النصف كروي.