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Influence of External Reflector on The Efficiency of The Conical Solar Still (CSS) in Basra City

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ABSTRACT

This research, a conical solar still was constructed under various atmospheric conditions of Basra city, Iraq, Latitude 30° 33' 56.55"N, Longitude 47° 45' 5.86"E. The Basra city well-knows of plentiful of solar radiation intensity. The still contains a basin with total area of (314 cm^2). In addition, one of stills was provided with external reflector, in order to reflect the direct sunlight to the absorber surface. The solar still was prepared from available local materials. The experimental results showed the thermal efficiency arrived to (58 %) for conical solar still with external reflector of the day 23 August 2023, and the solar radiation arrived to (6271 w/m^2) at same date. Aim of the research, a mathematical simulation was conducted to calculate the rate of production per hour for solar still, and the results of these calculation were compared to the productivity which found experimentally.

Keywords: water; saline water; solar still; vertical solar still; external reflector; desalination

INTRODUCTION

Water is the source of life, it is the basic element for the development and growth. Since ancient times mankind's were looking after water source and lived beside it. All lived and flourished ancient civilizations were found where the water is found. It is well known that the world is facing an increasingly current shortage in the quantities of fresh water needed to meet essential needs in the various aspects of civilized life. This is due of the limited sources of fresh water and the successive demands for it. Now a days, all the world is looking after a new sources of fresh water such as that extracted from sea water and brackish water, to fulfill the mankind demand of fresh water [1]. The presence of fresh water gives the life on the earth the opportunity to continue, since about 10,000 to 20,000 people die every day due to diseases that transferred by polluted water [2].Saline water (sea 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%), which in turn people still cannot benefit it totally because of the difficulty of access [3-8]. The remote arid warm places in the Middle East and North Africa and other regions in the world are suffering a sharp shortage of fresh water. These regions are characterized by high salinity of ground water, lack of rains and a good solar energy. It is a globally problem, and the best solution is using solar energy for desalination of salt water [9].

Sun produces a radiation form of energy falls on earth called electromagnetic radiation, a wave propagating at speed of light having associated with it an oscillating electric field and magnetic field both mutually perpendicular to each other and to the direction of propagation. The rate of solar energy per unit area which falling on a subject surface perpendicular to the path of the solar radiation outside the earth's atmosphere casing is called the solar constant and equals to ((1370 W/m^2)) [10-11].

Vertical solar stills may be conveniently used in places where land area is expensive or sufficient horizontal space is not available for installation of basin type solar stills. Very few papers have appeared concerning the vertical solar stills. In 1958 a vertical solar still was designed and built for operation in temperate zones. This still had a vertical structure with four trays, placed one above the other, in a glass greenhouse; the total area of the trays was 1 m^2 and the ground area occupied by the still was 0.3 m^2. The trays did not need thermal insulation being surrounded by still air. During the test it was possible to obtain appreciable amounts of distilled water also in the months in which the [12]. In 1975, Cofey [13], studied experimentally deferent concepts of vertical solar stills, such as ground suction and floating stills. In 1980 [14], Wibulswas, studied a cylindrical solar still having a vertical absorbing, evaporating surface of 0.1 m diameter and 1 m height inside a cylindrical cover of 0.3 m diameter. The annual average daily rate of distillation was about 1.7 $1/m^2$ of the vertical surface. In 1983[15], studied Ramli and Wibulswas, constructed a tow-sided vertical solar still. The annual average daily rate of distillation was about 2 $1/m^2$ of the vertical surface. In 2004, M. Boukar, A. Harmim[16], studies Parametric study of a vertical solar still under desert climatic conditions. The daily still productivity varied from 0.5 to 2.3 kg/m^2 on the sponged cloth area. In 2005, M. Boukar, A. Harmim[17], studies Performance evaluation of a one-sided vertical solar still, tested still yield varies from 0.2 75 to 1.31 l/m^2.d for a corresponding energy varying from 8.42 to 14.71 MJ and daily overall efficiency ranging from 7.85 to 21.19%. In 2009, Hiroshi Tanaka [18], studied Experimental study of vertical multiple-effect diffusion solar still coupled with a flat plate reflector. The overall daily productivity of the proposed still with 6-effect and 5 mm diffusion gaps was about 13.3 kg/m^2 day at maximum when the global solar radiation on a horizontal surface was 13.4 to 15.7 MJ/m^2 day and radiation on the glass cover was 20.2 to 22.9 MJ/m^2 day.

Aim of the research, a mathematical simulation was conducted to calculate the rate of production per hour for solar still, and the results of these calculation were compared to the productivity which found experimentally.

MATERIALS, METHODS AND FILLERS

A Conical Solar still has been constructed and its performance has been evaluated under different atmospheric circumstances of Basra city (Iraq) (Latitude 30° 33' 56.55"N, Longitude 47° 45' 5.86"E). Conical solar still has been built of transparent glass with a thickness of (4 mm) and have the same dimensions of the measurement. still consists of conical basin of (134 cm^2) is made of aluminum. Figure 1 (a) shows the schematic diagram of the still, and the figure 1(b) shows a photograph picture of this still. Figure 2 shows a photograph picture of the reflectors has been constructed to concentrated sun light.

FIGURE 1: photographic picture of the Conical Solar Still (CSS).

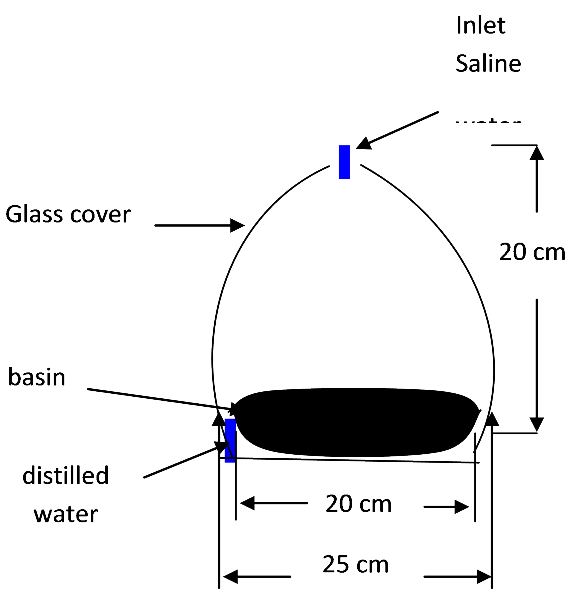

FIGURE 2: A schematic diagram of the Conical Solar Still (CSS).

FIGURE 3: A photographic picture of the concave mirror [19].

RESULTS AND DISCUSSION

The principles of operation for solar stills. The basin of the still is filled with brackish or seawater, the incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface (basin) which contains the salt (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 product water was measured every hour by calibrated beaker of 1-liter volume. The productivity of the still with respect to the solar radiation has been studied. Experimental hourly productivity of the Conical solar still of the day 23 August 2023 are shown in Figure (3), and the experimental hourly productivity of the Conical solar still of the day 26 August 2023 shown in Figure (4). It is clear from the figures that the productivity of the still has the same behavior with the solar radiation.

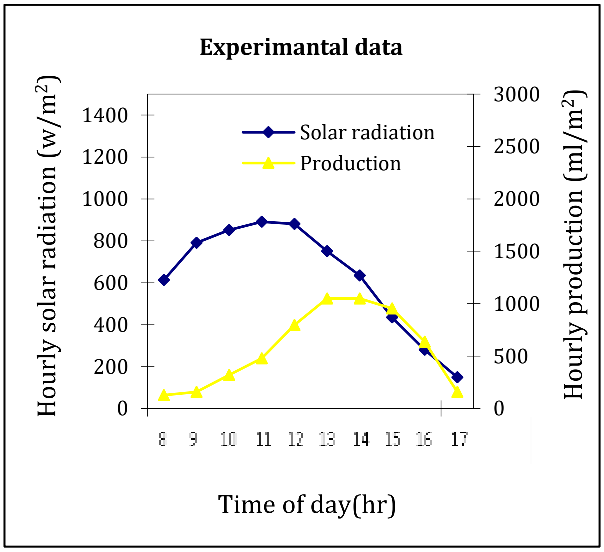

FIGURE 3: Experimental hourly productivity of the conical solar still and solar radiation during the day of 23 August 2023.

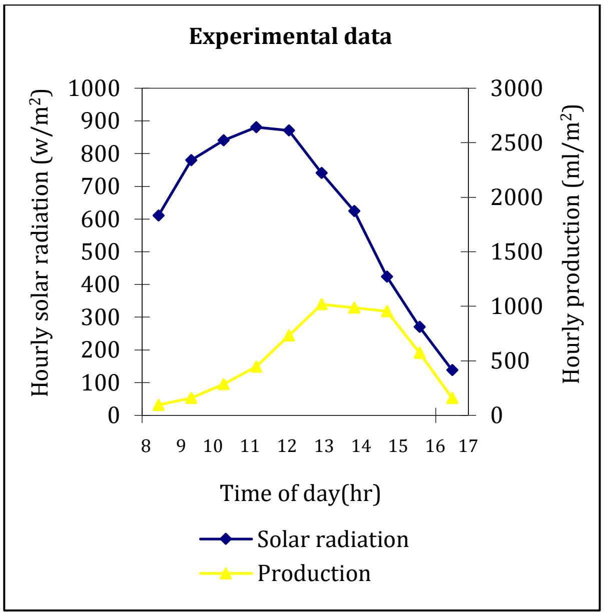

FIGURE 4: Experimental hourly productivity of the conical solar still solar radiation during the day of 26 August 2023.

The hourly production was measured experimentally and calculated mathematically using the following in equation [20].

$$P_h = (q_{ew} / L) \times 3600 = [h_{ew}(T_w - T_g) / L] \times 3600$$

$$q_{ew} = h_{ew}(T_w - T_g)$$

Where;
Ph: The hourly productivity.
L: The latent heat of evaporation of water (kJ/ kg).
hew: Evaporative heat transfer coefficient (Wm−2 K−1) can be found throughout the following equation:

$$h_{ew} = 16.273 \times 10^{-3} h_{cw}(P_w - P_g) / (T_w - T_g)$$

hcw: Convective heat transfer coefficient (Wm−2 K−1) can be found through the following equation:

$$h_{cw} = 0.884[(T_w - T_g) + (P_w - P_g)(T_w + 273) / (268.9 \times 10^3 - P_w)]^{1/3}$$

Where;
Tw: Water temperature (K).
Tg: Glass temperature (K).
pw: Partial pressures of the moist air is functions of water temperatures (N2 / m).
pg: Partial pressures of the moist air is functions of cover temperatures (N2 / m).

pw and pg are calculated using the following relation:

$$P = 7235 - 431.43T + 10.76T^2$$

The hourly distillate output of the stills and the hourly solar radiation on the glass covers are recorded in the Table 1 and Table 2). Shows the mathematically calculated of the hourly productivity of the conical solar still of the days (23 and 26) August 2023 in Figure 4, Figure 5.

TABLE 1: The production of the solar still evaluated through the Experimental and mathematical simulation for Conical solar still during the day of 23 August 2023.

Time of day (hr.)	T_a (C°)	T_g (C°)	T_w (C°)	Water production (ml/m²/hr.)		I(W/m²)
				Exp.	Math.Sim.	
9.00	47	55	60	127.2	15.1	612.48
10.00	48	56	65	159	52.9	790.21
11.00	49	57	68	318	82.9	850.61
12.00	50	58	70	477	102.2	890.78
13.00	52	60	79	795	288.3	880.7
14.00	52	61	80	1049.4	294.1	750.3
15.00	52	60	75	1049.4	172.4	634.57
16.00	51	58	70	954	102.2	433.77
17.00	49	52	65	636	104.9	280.15
18.00	48	49	60	159	67.3	148.3
Sum				5724		6271.87

TABLE 2: The production of the solar still evaluated through the Experimental and mathematical simulation for Conical solar still during the day of 26 August 2023.

Time of day (hr.)	T_a (C°)	T_g (C°)	T_w (C°)	Water production (ml/m²/hr.)		I(W/m²)
				Exp.	Math.Sim.	
9.00	46	54	60	95.4	21.4	610.48
10.00	47	55	65	159	64.5	780.21
11.00	48	56	68	286.2	97.5	840.61
12.00	50	57	70	445.2	118.6	880.78
13.00	51	57	79	731.4	374.8	870.7
14.00	51	60	80	1017.6	322.7	740.3
15.00	50	60	75	985.8	172.4	624.57
16.00	49	57	70	954	118.6	423.77
17.00	48	52	65	572.4	104.9	270.15
18.00	47	49	60	159	67.3	138.3
Sum				5406	1462	6179.87

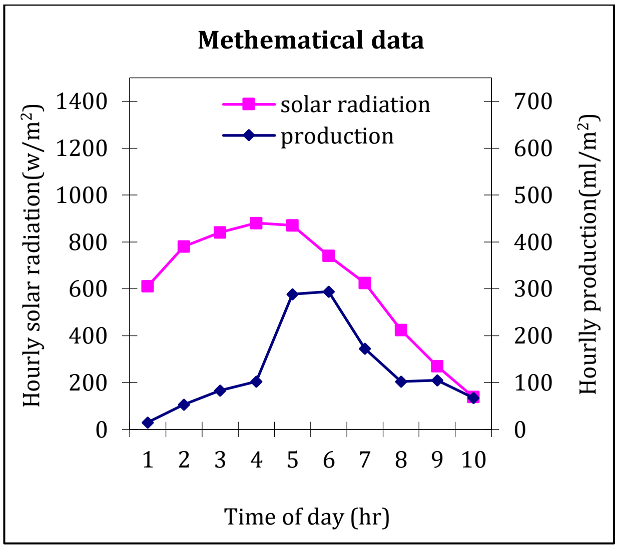

FIGURE 5: Mathematical hourly productivity of the conical solar still of the day 23 August 2023.

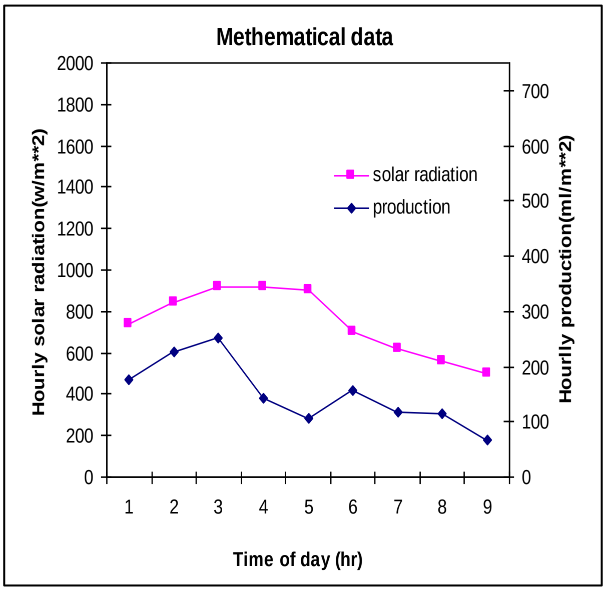

FIGURE 6: Mathematical hourly productivity of the Vertical solar still of the day 26 August 2023.

The thermal efficiency (E) of the stills was calculated for the through some days of (August 2013) using the following equation[21] :

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

Where:
E: thermal efficiency.
P: Daily output of distilled water.
L: latent heat of water evaporation (KJ / Kg).
I: daily solar radiation (W / m^2. Day).
Ab: area of the solar still (m^2).

Table (3) shows the results of the thermal efficiency of the conical solar stills through some days of (August 2013).

TABLE 3: Thermal efficiency of the conical solar stills through some days of (August 2013).

Number of Days	Production ($ml/m^2/day$)	Solar radiation (w/m^2)	Thermal efficiency%
227	3657	5970	39
231	3943	5980	42
235	5724	6271	58
238	5406	6230	55

CONCLUSIONS

Main observations and conclusions from the results of this work are the following: Clean drinking water remains one of the most international health issues of today, and the solar distillation is one of the important solutions in facing potable water needs especially in remote arid zones where no fresh water is available.

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 distillate production can be increased when the temperature of the brackish water increases. The thermal efficiency arrived to (58 %) for Conical solar still of the day 23 August 2023, and (39 %) for conical solar still of the day 26 August 2023. The hourly variation behavior of yield is similar to that of solar intensity.

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