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Research article

Mathematical Simulation for the Pyramidal Solar Still (PSS) production

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Abstract

This research a pyramidal solar still (PSS) 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).An experimental investigation was carried out on solar still under the same conditions. The pyramidal solar still consists of a basin area of (0.025 m^2). Several additions have been made and examined in order to increase the performance of the solar still and the outcomes as thermal efficiency account to solar still. A mathematical simulation has been conducted to calculate the rate of production per hour for all solar stills and the results of these calculation have been compared to the productivity that was found experimentally. The maximum efficiency of the experimental still varies from (44%) pyramidal solar still.

Keywords: Water; Saline Water; brackish water; Solar Still; Pyramidal Solar Still; Desalination.

1. 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 very small fraction [1–5]. 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 day's all the world are looking after a new sources of fresh waters such as that extracted from sea water and brackish water, to fulfill the mankind demand of fresh water [6]. In thermal desalting the sea water is vaporized and the pure water is condensed, so this requires a lot of energy for the boiling of the water, other mechanisms for desalting non thermal processses include membrane (in which the seawater is forced through a desalting membrane by high pressure generated by electric power [7]) and chemical processes [8], as shown in Fig. 1. In this work, a mathematical simulation has been conducted to calculate the rat of production per hour.

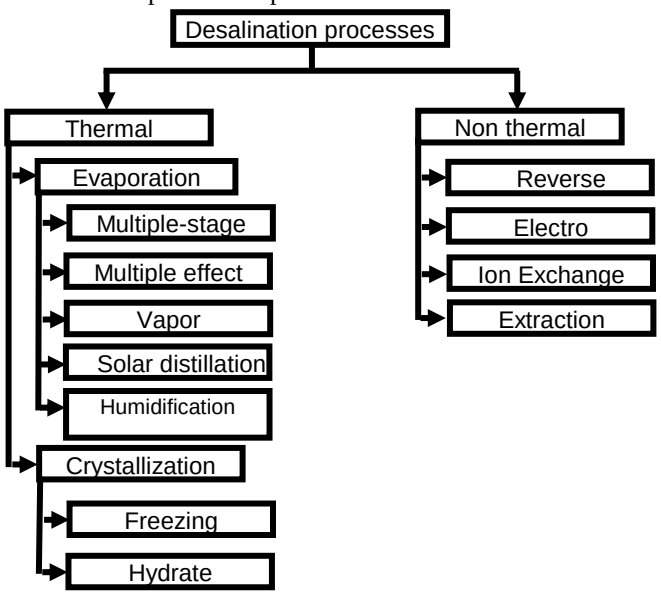

Fig. 1. Categories of desalination processes [9].

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2. Materials and Methods

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) has been built of transparent glass with a thickness (4 mm) and has 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. This plate in still is made of aluminum with surface area (0.14 m^2), Fig. 2 shows the schematic diagram of the still. Figs. 3 show a photograph picture of the still.

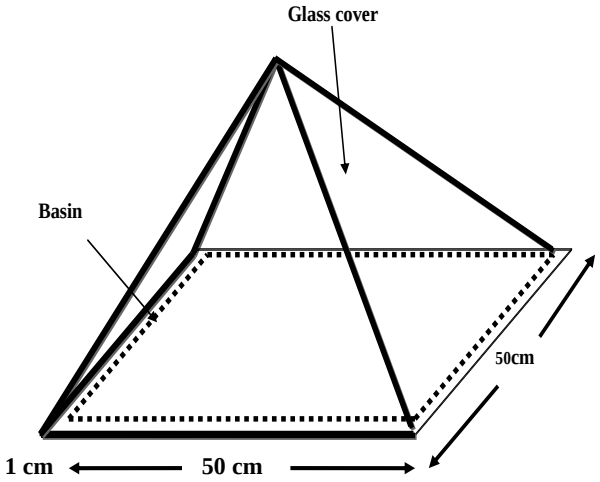

Fig. 2. Schematic diagram of the pyramidal solar still (PSS)

Fig. 3. Photograph picture of the pyramidal solar still (PSS) with external reflector.

An external reflector (dish covered with aluminum paper) was used to reflect and concentrate sunlight onto the basin. The dish is mounted on the basin manually to reflect the highest percentage of sunlight possible onto the basin show in Fig. 4 [10].

Fig. 4. Schematic diagram of the dish covered with aluminum paper [10].

3. Results and Discussion

The product water is measured every hour 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 7 May 2014 are shown in Fig. 5. It is clear from the figure that the productivity of the still has the same behavior with the solar radiation.

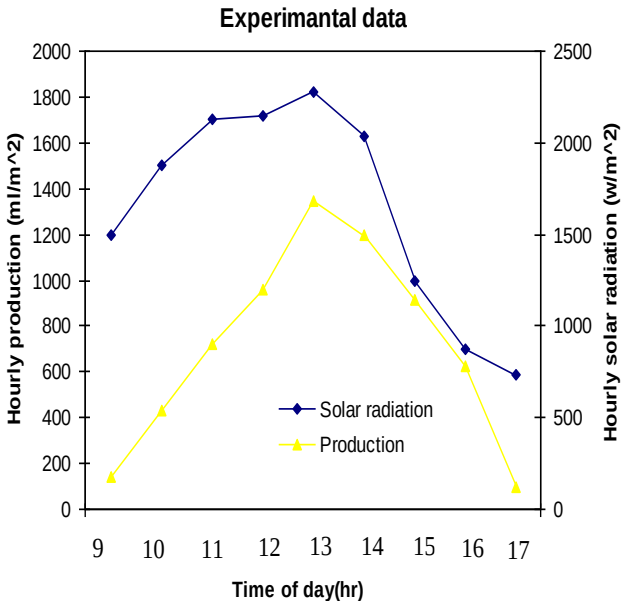

Fig. 5. Experimental hourly productivity of the Pyramidal solar still & solar radiation during the day of 7 May 2014.

The hourly production was measured experimentally and calculated mathematically using the following in equation [11].

$$P_h = (q_{ew} / L) \times 3600 = [h_{ew}(T_w - T_g) / L] \times 3600 \quad (1)$$

$$q_{ew} = h_{ew}(T_w - T_g) \quad (2)$$

where: -
P_h: The hourly productivity.
L: The latent heat of evaporation of water (kJ/kg).
h_{ew}: Evaporative heat transfer coefficient(Wm−2 K−1)can be found through out the following equation:

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

h_{cw}: Convective heat transfer coefficient (Wm−2 K−1)can be found through the following equation:

$$h_{cw} = 0.884[(T_w - T_g) + (P_w - P_g)(T_w + 273)/(268.9 \times 10^3 - P_w)]^{1/3} \quad (4)$$

where: -
T_w: Water temperature (K).
T_g: Glass temperature (K).
p_w: Partial pressures of the moist air is functions of water temperatures (N/m^2).
p_g: Partial pressures of the moist air is functions of cover temperatures (N / m^2).
p_w and p_g are calculated using the following relation:

$$P = 7235 - 431.43T + 10.76T^2 \quad (5)$$

Fig. 6 shows the mathematically calculated of the hourly productivity. Fig. 7, shows the experimental results and mathematically simulation of the hourly productivity of solar still.

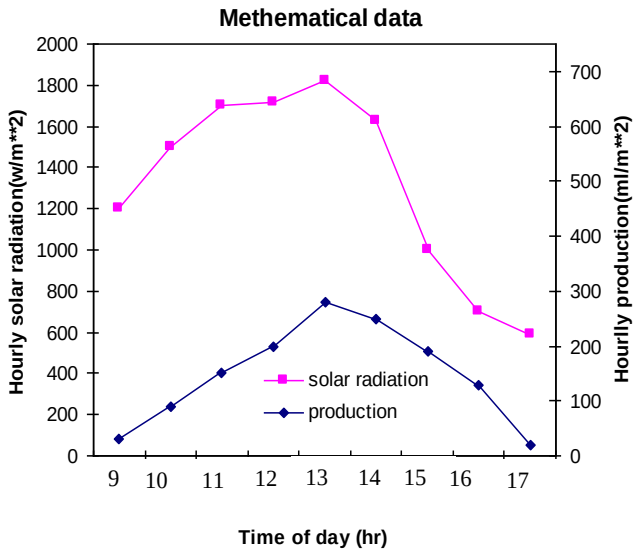

Fig. 6. Mathematical hourly productivity of the Pyramidal solar still & solar radiation during the day of 7 May 2014.

The hourly distillate output of the stills and the hourly solar radiation on the glass covers are recorded in the Table 1.

Table 1 The production of the solar still evaluated through the Experimental and mathematical simulation for pyramidal solar still during the day of 7 May 2014.

Time of day (hr)	T_w (C°)	T_g (C°)	T_a (C°)	Water production (ml/m^2/hr) Exp.	Math.Sim.	I(W/m^2)
9:00	39.5	31	39	180	30	1200
10:00	43.5	33	39.5	540	90	1500
11:00	48	35	40	900	150	1700
12:00	52.5	36	40	1200	200	1720
13:00	57.5	38	40.5	1680	280	1820
14:00	60	39	42	1500	250	1630
15:00	63	40	43	1140	190	1000
16:00	59	34	37	780	130	700
17:00	53.5	33	33	120	20	590
18:00						
Sum				8040	1340	11860

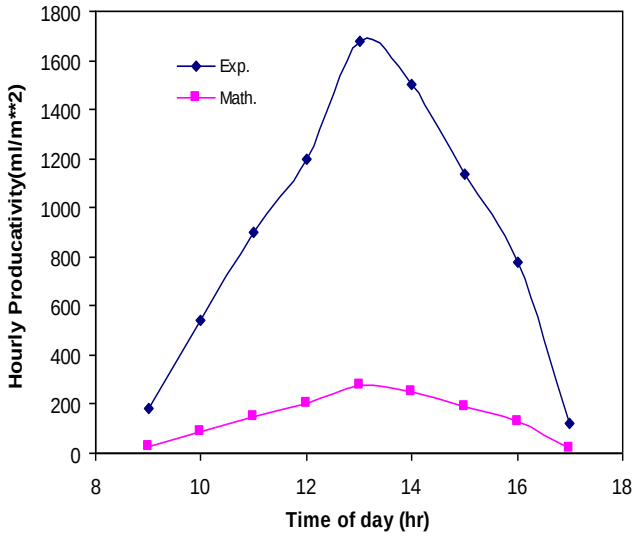

Fig. 7. The exp. and math. of the hourly productivity of solar still at 7 May 2014.

It is clear from Fig. 7 that there is a difference between the experimental and the simulation results, this difference come from the improvements that were added to the stills reflector who are working to increase the temperature of the water basin solar still, which lead to increase the difference between the temperature of the basin solar still and temperature of the

cover condensation (glass cover) which is an important factor in increasing the productivity of solar still, The simulation result for the solar still can be agreed with the experimental result if we multiplying the equation (1) by modifying factor of (6) for the Pyramidal solar still.

The thermal efficiency (E) of the stills was calculated for the same day 7 May 2014 using the following equation [12]:

$$E_{bsn} = P \text{ x } L / I \text{ x } A_b \quad (6)$$

Where:
E_{bsn}: 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 2 show the thermal efficiency of the Pyramidal solar still.

Table 2 Thermal efficiency of the Pyramidal solar still.

The Still	Production ($ml/m^2/day$)	Solar radiation (w/m^2)	Thermal efficiency %
Pyramidal solar still	8040	11860	44

4. Conclusion

The main observations and conclusions that can be drawn from the results of this work are the following:

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 hourly variation behavior of yield is similar to that of solar intensity. The maximum for the thermal efficiency arrived to (44 %) Pyramidal solar still for the day (7 May 2014).

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