Construction of Solar Distiller to Study Its Performance Under Environmental Conditions in Mosul City

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Abstract:

Water is a basic necessity for human being along with food and air. Desalination of water by using solar energy is suitable for potable water production from brackish and sea water. This article includes constructing the double inclined roof model and study its performance under the open environmental conditions of Mosul – Iraq. The solar distillation unit consist of two main components: transparent glazing cover of 0.004m thickness inclined at 40^o in order to obtain extra solar energy, and steel basin had dimension of 0.98m length,0.76m width and 0.15m height. The study includes the still performance in terms of the still efficiency (η), the coefficient of performance (C.O.P.) and heat losses from the solar still were also considered.

بناء مقطر شمسي لدراسة أدائه تحت الظروف الجوية لمدينة الموصل

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ملخص البحث:

الماء ضرورة أساسية للحياة ، فضلا عن الغذاء والهواء. وعملية تقطير المياه باستخدام الطاقة الشمسية وسيلة مناسبة لتحويل الماء العكر والماء المالح إلى ماء صالح للشرب. تم في هذا البحث بناء نموذج ذي وجهين مائلين ودراسة أدائه للظروف المناخية لمدينة الموصل في العراق . تتكون وحدة التقطير الشمسي من جزأين أساسيين : الغطاء الزجاجي الشفاف بسمك 0.004m ومائل بزاوية 40^o لتحصيل أكبر مقدار من الطاقة الشمسية، الحوض المعدني بطول مقداره 0.98m ، عرض 0.76m و ارتفاعه 0.15m. تضمن البحث دراسة أداء

الحوض بدلالة كفاءة الحوض (η) ومعامل أدائه (C.O.P.)، وحساب الخسائر الحرارية من الحوض الشمسي أيضا.

Introduction:

There is an urgent need for clean, pure drinking water in many countries. Often, water sources are brackish and / or containing harmful bacteria and therefore it cannot be used for drinking. In addition, there are many coastal locations where sea water is abundant but potable water is not available. Pure water is also needed in some industries, hospitals and schools. Solar distillation is one of many processes that can be used for water purification. Solar radiation can be used as the source of heat energy where brackish or sea water is evaporated and is then condensed as pure water.

Water to be cleaned (purified) is poured into the still to partially fill the basin. The glass cover allows the solar radiation to pass into the still, which is mostly absorbed by the base. Water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The heated water vapor 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. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle.

The solar still is the most suitable one as it is most economic, easily constructed, and does not require any continuous watch or special experience. So, continuous efforts have been done all over the world to improve the coefficient of performance of this type of stills by investigating the several factors which affect it. In the following paragraphs, some of the international and national developments and researches will be given through the factors affecting the productivity of solar stills. Van Steenderen (1975) investigated the use of solar distillation for the desalination of brackish water or seawater in south west Africa, the double inclined roof still was chosen for evaluation under local climatic conditions. Abdel Dayem (2010) designed inclined wick solar distiller, constructed, tested and numerically simulated for moderate latitudes, Cairo 30 ^{0}N. Afrand et al.(2010) presented a theoretical study of solar distillation in a single basin under the open environmental conditions of Chabahar- Iran. El-Sebaii et al.(2009) presented transient mathematical models for a single slope- single basin solar still with and with out phase change material under the basin liner of the still. Mehta et al. (2011) have devised a model which will convert the dirty / saline water into pure / potable water using the renewable source of energy (i.e. solar energy) . Radwan et al.(2009) investigations, were carried out under the open environmental conditions of Egypt on single slope solar still inclined 20^o of one direction (I-20^o OD). Ahamed et al.(2008) has studied the effect of preheating inlet water supplied to a single effect solar water still on its production and its performance and also the effect of glass cover cooling by air and water flow on its production and performance. Tarawneh M. S.((2007) has evaluated the effect of water depth in the basin on the water productivity , in the same time , the effect of the design and operational parameters on the solar desalination process were investigated.

The aim of this article is to study the still performance in terms of the still efficiency (η), the coefficient of performance (C.O.P.) and heat losses from the solar still were also considered.

System Description:

Investigations on a double inclined roof solar still were carried out under the open environmental conditions at the Physics Department of the Sciences College, Mosul University , throughout the period from June 2010 until April 2011. The experimental units setup is presented in figure (1 and 2).

Solar distillation experimental unit composed three main components: steel basin, transparent glazing cover of 4mm thickness and wood box. Rectangular Aluminum metal distiller with basin dimensions of 0.98m length, 0.76m width, 0.15m height. Two Aluminum channels 4 cm width were mounted in each basin side with enough slope to allow the distilled water to run outside the unit in the container. Collected fresh water volume and its brackish were determined.

Wood box generally provides rigidness to the still. Technically it provides thermal resistance to the heat transfer that takes place from the system to the surrounding.

Methodology:

1- Thermal analysis:

The solar still operation is governed by various heat and mass transfer modes occurring in the system. Within the solar still the following heat transfer modes can be distinguished :

- Convection from water surface to the inner glass cover surface can be calculated from the equation (Cooper 1973 & Sayigh 1974) :

$$Q_c=0.884[(T_w-T_g)+\frac{(Pw-Pg)\times Tw}{268\times 10^3-Pw}]^{1/3}[(T_w-T_g)\text{…………(1)}$$

Where:

T_w : still film water average temperature, ^oK
T_g : average temperature of the glass cover, ^oK
P_w and P_g : are the partial pressures in (N/m^2) for water vapor at water and the interior glass surface temperatures within the still which are given by the equation (Radwan et. al. 2009) :

$$P_w = \exp[25.317 - (\frac{5144}{Tw})] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$P_g = \exp[25.317 - (\frac{5144}{Tg})] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

- Evaporation from water surface to the inner glass cover surface. Can be estimated as follows (Cooper 1973 & Sayigh 1974) :

$$Q_e = 4.52*10\text{-}3\ [Q_c \frac{Pw - Pg}{Tw - Tg}] \quad \ldots\ldots\ldots\ldots\ldots(4)$$

- Radiation from water surface to the inner glass cover surface calculated from the equation (Cooper 1973 & Sayigh 1974) :

$$Q_r = \varepsilon_w\, \sigma\, (T_w^4 - T_g^4) \quad \ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

Where:
ε_w : The emissivity of the water is equal 0.9 (Ahamed et al. 2008).
σ : is the Stefan – Boltzman constant taken as $56.7*10^{-9}\ Wm^{-2}\ K^{-4}$.

2- Still Efficiency:

The experimental steady state efficiency (η) of the solar still calculated from the following equation, using the measured values of parameters obtained from this work (Radwan et. al. 2009) :

$$\eta = \frac{m \times Lw}{G \times A \times \Delta t} \quad \ldots\ldots\ldots\ldots\ldots(6)$$

Where :
m : is the mass condensate and collected in a time interval (gm).
L_w : water latent heat of evaporation (cal/gm).
G : hourly solar radiation flux (w/m^2).
A : the still area (m^2).
Δt : the time interval (sec).

The daily efficiency (η_d) can be given in the following formula (El-Sebaii et. al. 2009) :

$$\eta_d = \frac{\sum m \times Lw}{\sum A \times G \times t} \quad \ldots\ldots\ldots\ldots\ldots(7)$$

3- The Coefficient of Performance (C.O.P.):

The Coefficient of Performance (C.O.P.) was determined to investigate the specific design parameter and its effect on the still performance. It can be determined by using the equation (Radwan et al. 2009) :

$$C.O.P = \frac{Y \times \rho w \times Lw}{G \times t} \quad \text{................(8)}$$

Where :

Y : solar still productivity rate.

ρ_w : water density .

Results and Discussion:

Data set were taken each hours around the representative days within the experiments. It includes the measured weather conditions, i.e. global incident solar radiation on tilled surface of glass cover, still productivity, air temperature inside still, ambient air temperature, basin temperature and outer glass cover temperature.

Figure (3) presents the measured hourly solar radiation values on tilled surface ($\beta = 40^o$) on the 25th day of April . As shown that solar radiation was maximum mount at noon time.

Four thermometer are distributed on the solar still at different locations measuring the water temperature distribution to demonstrate the heat transfer inside the still. Temperature profiles are shown for one day in figure (4) of the still components. According to these figures, variation of temperatures matches with variation of solar radiation.

Hourly productivity of the distilled water values are presented in figure (5) , which shows that maximum of productivity of the distilled water is occurred at noontime . Variation of productivity of the distilled water matches with variation of solar radiation. Total still productivity in Liter/m^2.day for each month was determined for June, September, October, November and December, were (1.98, 1.66, 1.3, 1.24 and 0.88) Liter/m^2.day, respectively as shown in table (1) .

The hourly variation of the still efficiency for 25th of April is shown in figure (6), which indicates the efficiency of the distiller increase gradually from sunrise until it reaches certain maximum value at solar noon time then decreased until reached to minimum value at sunset time. Table (1) represents the total still efficiency for each month by using equation (7) .

Table (1): Monthly average productivity ,efficiency and C.O.P. for solar distiller under the open environmental conditions.

Month	June	Sept.	Oct.	Nov.	Dec.
Still productivity Liter/m^2.day	1.98	1.66	1.3	1.24	0.88
Efficiency %	17	18.4	20.19	27.02	27.3
C.O.P.	.0493	0.063	0.0765	0.113	0.12

The monthly average still efficiency was found in June less than other investigated months as it can be seen from the represented data in table (1). Regardless of increasing the solar radiation caused an overheating the glass cover as a result of absorbed part of the incident solar radiation also all energy transferred by the water vapor during condensation, in addition to different heat flows (by convection, radiation and evaporation) going up to the glass, the mounts of heat lost from glass cover to the air at September and other months is higher than of June. Therefore, the reduction of the glass cover temperature increases the condensation process and then increases the efficiency of the still. The monthly average coefficient of performance investigated in the open environmental conditions is presented in table (1).

From figure (7), it is noticed that, the radiation, convection and evaporation energy transported from surface water in the solar basin to glass cover increase gradually from sunrise until it reaches certain maximum value at noon and after noon by about an hour respectively and then decrease until they reach to minimum values at sunset.

Conclusions:

1- The hourly solar radiation values on tilled surface was maximum in a mount at noon.
2- The variation of temperature profile for the still components, the productivity of the distilled water and the still efficiency matches with variation of the local time.
3- The radiation, convection and evaporation energy transported from surface water in the solar basin to glass cover matches with variation of local time.
4- The monthly average still efficiency decreased in hot months due to overheating the glass cover because of increasing the solar radiation.
5- The monthly average still efficiency increased in cold months due to lower atmosphere temperature which kept the glass cover colder.

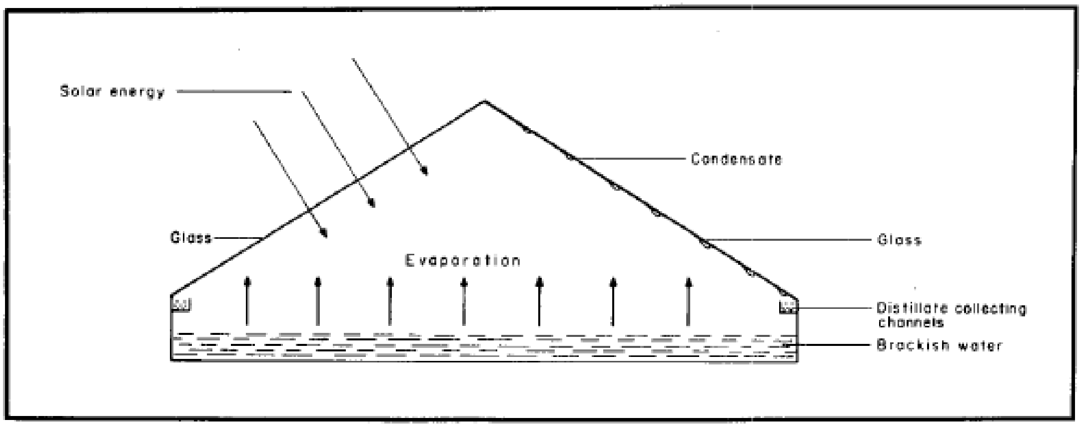

Figure (1): Schematic sketch of the solar distillation.

Figure (2): Photograph of the solar distillation.

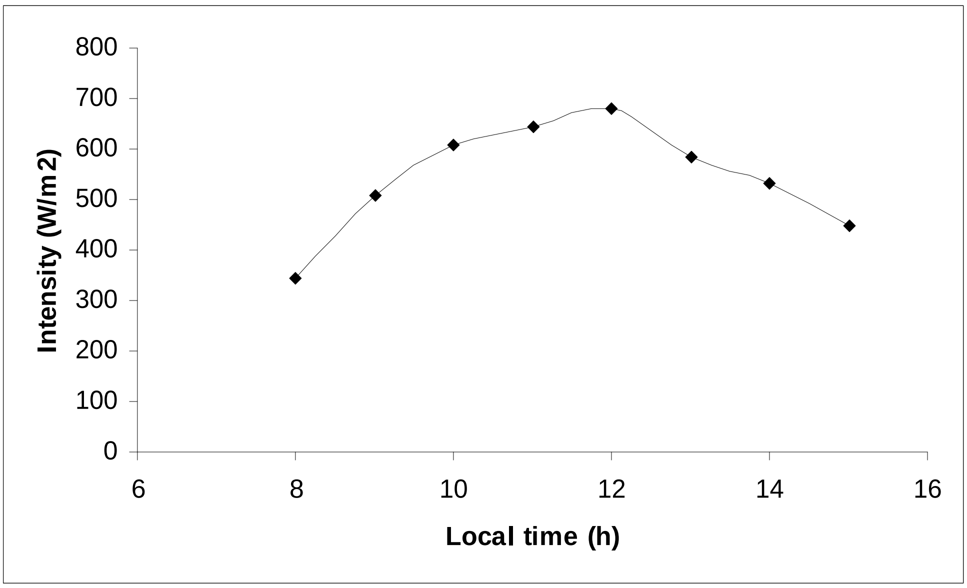

Fig.(3) : Hourly solar radiation values on tilled surface on (25^{th} of April).

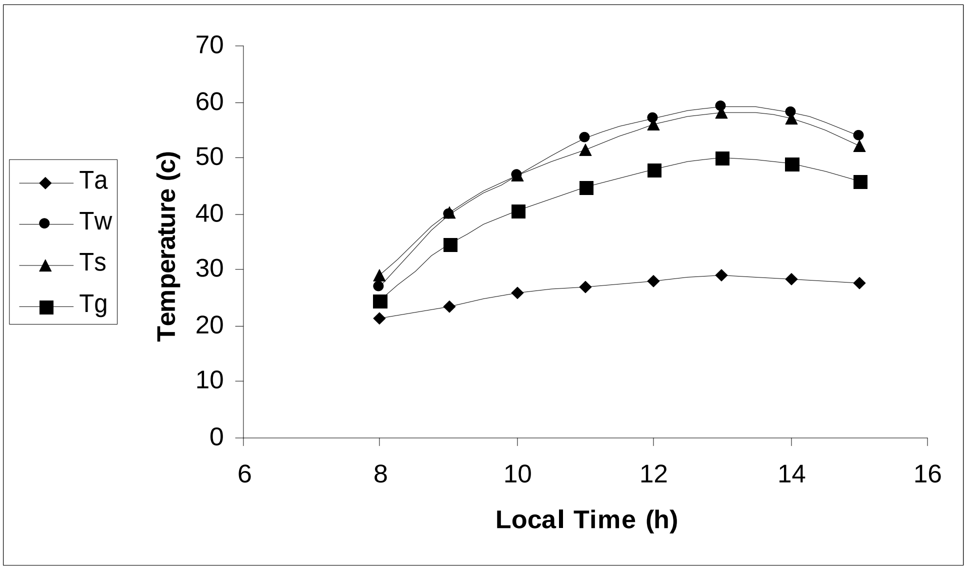

Fig.(4): Hourly variation of temperatures values on solar still (25^{th} of April).

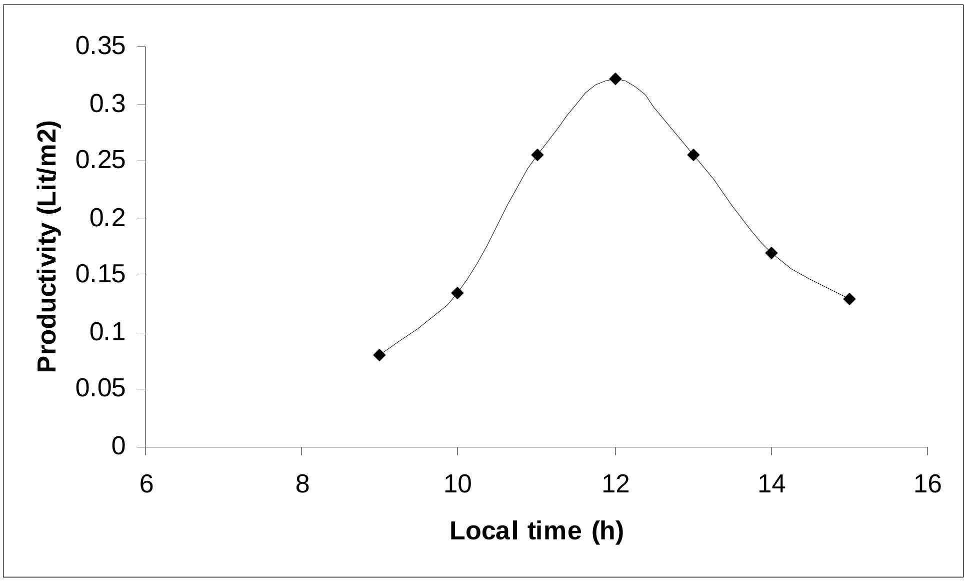

Fig.(5): Hourly productivity of the distilled water values (25^{th} of April).

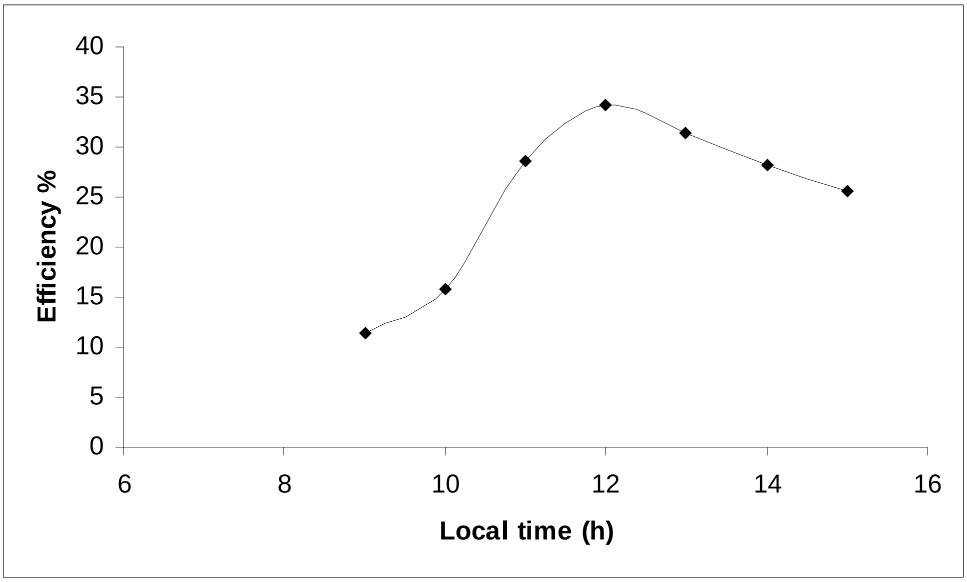

Fig.(6): Hourly variation of the still efficiency (25th of April).

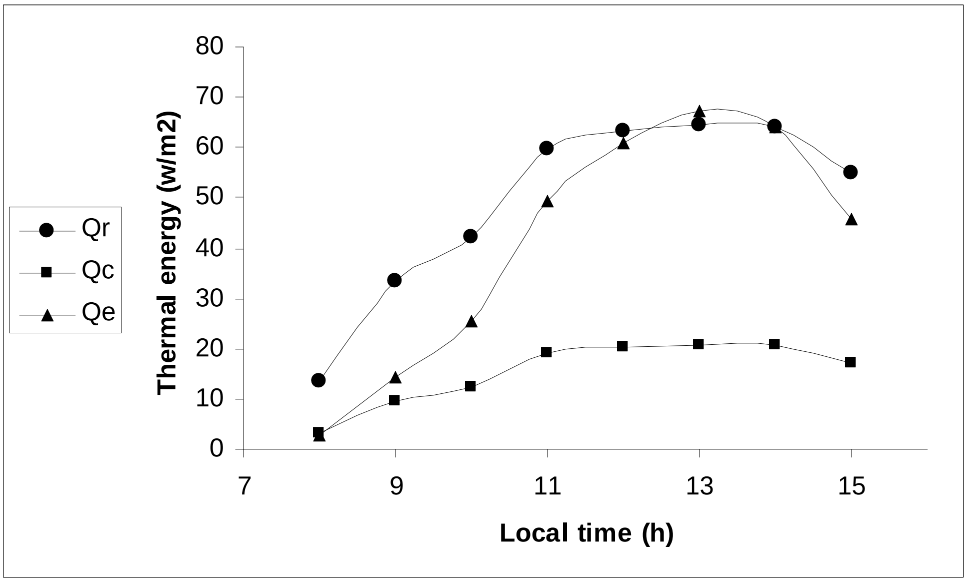

Fig (7): Thermal energy (heat) transported from water to glasses .

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