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Comparative study of a preheating and non-preheating solar-still production

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Abstract

Over 70% of the planetary surface is covered by water from whish 97.5% is salted water and thus is improper for human, in industrial and agriculture use. Soft water represents only, 2% of existing water. Solar desalination may be considered as an alternative to the drinking water production, which seems interesting for some areas of the planet, but represent disadvantage in terms of daily production which is still low.

The efficiency of solar still depends on the temperature gradient existing between the water temperature in the basin (Evaporation surface) and the glass cover (Condensation surface), in our case we have chosen a solar collector as a pre-heating system in order to increase the temperature of the basin water.

The obtained results highlight the effect of the performance parameters such as the water thickness , the ambient temperature, the inclination angle as well as the effect of pre-heating system (thermal solar collector) on the system performance (distiller production). In this optic we carry out a comparison, in terms of production; between a pre-heating and non-pre-heating solar stills.

Keywords: solar desalination, solar collector, solar still, Performance;

Nomenclature

A	Surface (m^2).
Cp	Mass heat by constant pressure (J/kg.°C).
Q_{cd}	Density of the wasted thermal flow by tub conduction.
$Q_{c:e\_v.i}$	Density of the thermal flow by convection between the water film and the glass (W/m^2).
$Q_{c:v.e\_a}$	Density of the wasted thermal flow by convection in the glass to the outside (W/m^2).
$Q_{c:b\_e}$	Density of the thermal flow by convection between the tub bottom and the water film (W/m^2).
$Q_{cond.b\_i}$	Density of the thermal flow by conduction between the tub and the thermal insulator (W/m^2).
Q_{evap}	Density of the thermal flow by condensation-evaporation between the water film and the glass (W/m^2).

$Q_{r:e\_v.i}$	Density of the thermal flow by the raying between the film of water and the glass (W/m^2).
$Q_{r:v.e\_ciel}$	Density of the wasted thermal flow by the glass in raying to the outside (W/m^2).
λ_v	Thermal conductivity of the glass (W/m°C).
δ	Depth of the glass (m).

1. *Introduction*

Solar desalination of brackish water and sea water is a common used process in arid areas at the small scale villages or even individual houses. Several types of solar still were invented based on of green hose effects, which are characterized by their simplicity, easy to realize and not costly. However, their productivity is lower. Several techniques have been carried out In order to increase the water temperature in the basin and decrease it at glazing cover [1-5].

1.1. *Techniques of water desalinations:*

There are two types of water desalination technology:

- Thermal technologies and membrane technologies [7].
- Thermal technologies are those using evaporation processes to produce pure water. They are scarcely used for distilling brackish water having less than 10.000 mgs per 1 suspended matter, where it is not useful to apply this process. Thermal technologies contain the following processes:
  - Multi stage flash (MSF) distillation.
  - Multiples effect distillation (MED).
  - Distillation by Vapor compression (VC).

The membrane technologies deal with thin membranes that use semi permeable membrane supplied by flows with different concentration; and where in the process of desalination the supply comes from sea water or brackish one.

1.2. *Solar distillation:*

This procedure consists of heating water, that exists in a closed chamber and covered by glasses, directly from the solar radiation produced from this process is simple reliable and does not need maintenance. However, its efficiency is relatively low (5 Liters/day.m^2). However, there are two types of manufacturing solar still [8]:

Modular product, which generally refers to a tank (plastic, wood, steel …), insulated at the bottom and glazed at the top. Many solar stills can be supplied simultaneously in order to from a distillation unit. The number of still-solar depends on the ability of producing water. This model is only used small capacities (tens of liters per day). It is useful when the need for distilled water is not important (laboratory needs). However, there are many varieties, from which, we can quote solar still plan with multiple effects, spherical, with waterfall, and with lock.

When the need for water is important (hundreds of liters per day), solar still are built en masonry concrete with large glazed basins, the surface depends on the amount of the distillated water. Some applications are carried out in rural areas where surfaces (on the ground) are available.

2. *Theoretical study of the model:*

The theory of a simple solar still with a greenhouse effect "Fig. 1," illustrates different heat exchanges which take place in solar still. It is founded with few heat exchanges. In a transient regime, the equations governing the thermal exchange, at each component of the solar still, are as follows: [9]

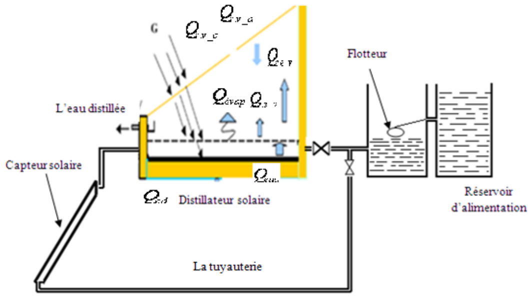

Fig. 1 A pre-heating solar still System [5].

- Outside the glass face

$$\frac{M_v Cp_v}{2\times A_v}\frac{dT_{ve}}{dt}=\left(\frac{\lambda_v}{\delta_v}\right)(T_{vi}-T_{ve})-Q_{r:v.e\_ciel}-Q_{c:v\_a}+\frac{P_v}{2}, \quad (1)$$

- Inside the glass face

$$\frac{M_v Cp_v}{2\times A_v}\frac{dT_{v.i}}{dt}=-\frac{\lambda_v}{\delta_v}(T_{vi}-T_{ve})+Q_{r:e\_v.i}+Q_{c:e\_v.i}+Q_{evap}+\frac{P_v}{2}, \quad (2)$$

- water surface

$$\frac{M_e Cp_e}{A_e}\frac{dT_e}{dt}=Q_{c:b\_e}-Q_{c:e\_v}-Q_{evap}-Q_{r:e\_v.i}+P_e, \quad (3)$$

- absorbante surface

$$\frac{M_b Cp_b}{A_b}\frac{dT_b}{dt}=P_b-Q_{c.b\_e}-Q_{cd:b\_iso.i}, \quad (4)$$

- Inside insulator face

$$\frac{M_i Cp_i}{2\times A_i}\frac{dT_{iso.i}}{dt}=Q_{cd:b\_iso.i}-\frac{\lambda_i}{\delta_i}(T_{iso.i}-T_{iso.e}), \quad (5)$$

- Outside insulator face

$$\frac{M_i Cp_i}{2\times A_i}\frac{dT_{iso.e}}{dt}=\frac{\lambda_i}{\delta_i}\left(T_{iso.i}-T_{iso.e}\right)-Q_{r:iso-soll}-Q_{c:iso-a}, \tag{6}$$

The equations for the heat transfer with a preheating system are similar to those indicated for a non-preheating system.

$$\frac{M_e Cp_e}{A_e}\frac{dT_e}{dt}=Q_{c:b\_e}-Q_{c:e\_v}-Q_{evap}-Q_{r:e\_v.i}+m_d\times Cp_e\times\left(T_{e.appoint}-T_e\right)+P_e, \tag{7}$$

3. *Numerical resolution:*

For our study we elaborate a calculating code based on MATLAB (version 6.5). Simulations are carried out depending on data recorded in the area of Constantine (east of Algeria), their characterized coordinates are:

Latitude 37°.17 to the north, a longitude 6°.62 to the east, and a time difference of one hour. The simulation is carried out at the initial instant "t_0" for each solar still component with time-step of one hour. The 17^{th} of July is selected as a simulation day (reference day).

The study is carried out on solar still plan having an absorbing surface (bassin) "A_b" of $1m^2$, and a thickness "δ_b" of 0.004m, a brackish water bed "δ_w" of 0.02m, a glassing area "A_v" of 0.005m, and an isolated thickness "δ_{iso}" of 0.05m, and an area "A_i" of 0.015m.

The solar still is inclined to the south with an inclination angle of 30°.

In the case of the preheating system, we use a thermal solar collector connected, where the mean velocity is 0.08 m/s.

The wind velocity is constant and equal to 4m/s for both systems (without preheating):

- The first step consists of comparing the different thermal exchanges which are independent of the temperature.
- We assume that the different solar still components are at an ambient temperature, except the temperatures at the brine and the basin which are higher, and then we carry out computation at the initial temperatures. The temperature of the brine is equal to the temperature at the collector outlet for the preheating system.
- The resolution of the equation is carried out by using the iterative method of GAUSS-SEIDEL.
- Re-computation with The obtained temperatures.

4. *Interpretation and discussion of the results:*

The effect of brine thickness on the production (efficiency). Of a plan solar still is highlighted in "Fig. 2. (a)," it shows clearly the diminution of the water thickness layer for each case; this leads to improve solar still characteristics. The obtained experimented results by BADRAN [5], shows also an increase of the water layer thickness reveal to a decrease of the production of the distillated water.

For a such solar still, the increase on the ambient temperature increase the production "Fig. 2. (b),". In fact, the ambient temperature has an effect on temperatures issued from all the distiller components, and its decrease will lead to the decrease of the brine temperature. These results seen in agreement with certain experimented results [1,3,4 and 5].

We observe through the "Fig. 3," that the increase on the glass inclination decreases the production. However, the production becomes better at the inclination angle within 0° and 30°.

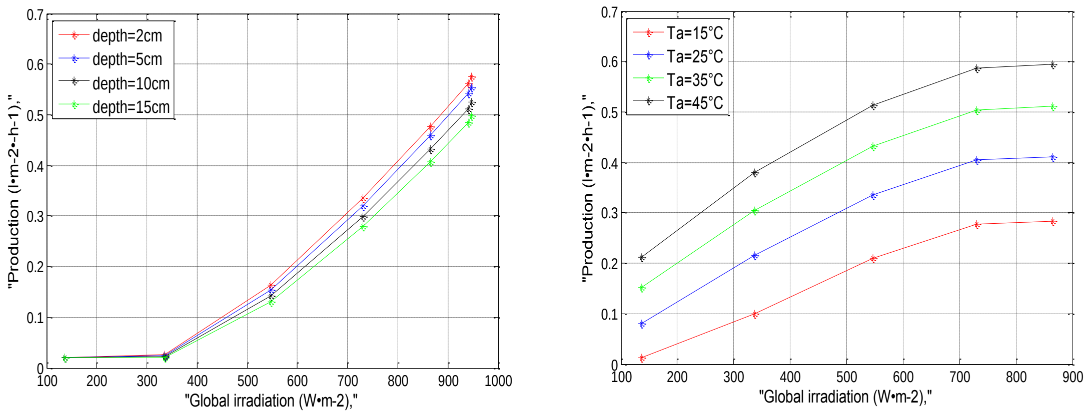

Fig. 2. (a) the influence of the water thickness on the amount of the distillated water; (b) the effect of the ambient temperature on production.

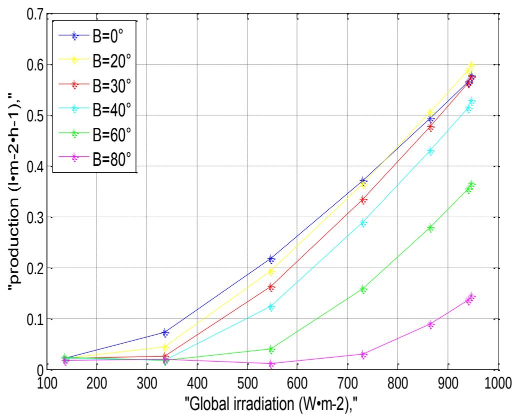

Fig. 3 the influence of the inclination on the distillated water.

The instantaneous thermal curvature of each solar still component shown in "Fig .4.(a)," is similar to that obtained by "Bilal and all."[6]. In this way, the increase on water temperature may reach a value of 63°C, even for experimental work carried by Badran, and Tahaineh [5], the obtained results are similar to those issued from the non-heating system. In this way, the temperature change at each solar-still component with a preheating system "Fig. 4.(b)," has the same form that in the case of a non-preheating system, excepting that they are much higher. This increase show that the preheating temperature leads to a preheating of the internal side of the insulator, of the brain, of the water and the internal side of glass respectively "Fig. 5,". Some experimental works led to the same results [2,5].

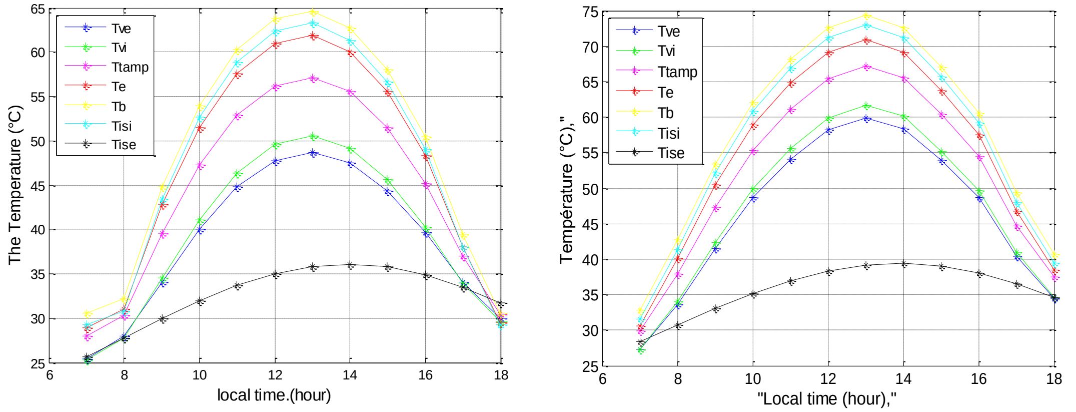

Fig. 4. (a) the non-preheating solar still variation of different elements temperatures; (b) the preheating solar still variation of different elements temperatures

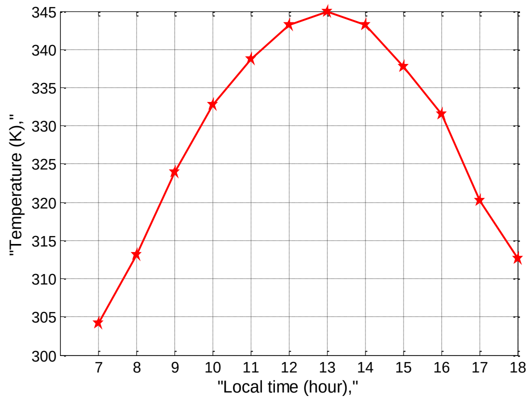

Fig. 5 the balance temporary temperature variation.

The production of distilled water increases with the global irradiation. However, likely applied for higher power and for both systems, the production is more important for higher received radiation "Fig. 6. (a),". Hence, coupling with a solar collector involves an additional surface in order to collect more solar radiation to heat water to be distilled, in order improve the evaporation process and getting, consequently, a better production for a preheating system than the no one, these results agree with results obtained by “Haddad and all.” [4], as well as with those obtained by Badran and Tahaineh [5].

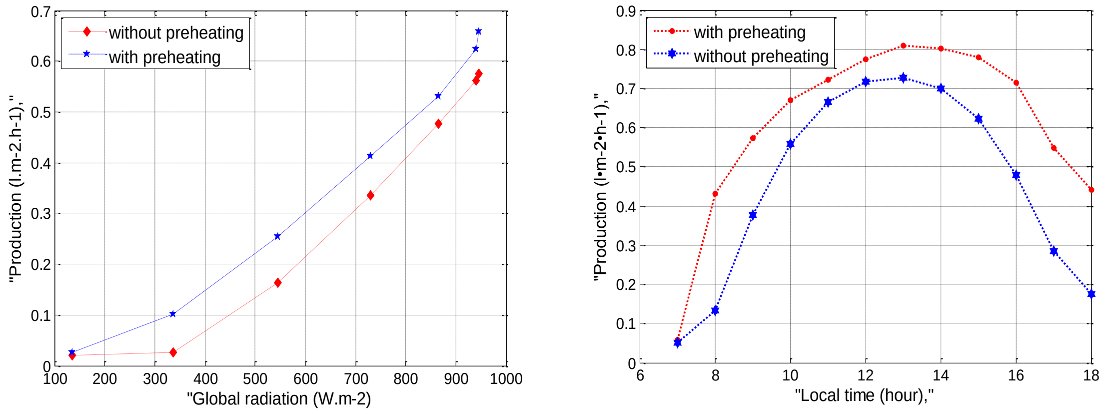

Fig. 6. (a) the variation of production in the global irradiations function for a non and preheating solar still; (b) the temporary variation of the production for a non and preheating solar still.

Taking into consideration the ambient temperature, the first hours of the day (before 8^h), where the system should reach its performance temperature; there appears a difference on the production between the solar still and the coupled system, with respectively a production 3,46 $l/m^2.h$, for the non-preheating solar still and 5,52 $l/m^2.h$ for the preheating one " Fig.6. (b),".

This can be explained that preheating water in the collector leads to increase the difference between the water temperatures of the internal glass of the distiller, which has a direct effect on the evaporation rate. As a result there is an improvement of the solar still production of about 37%.

These results show are in a good agreement with those experienced and obtained by Badran and Tahaineh [5], where the improvement of the production reached a rate of 36% when using the preheating system.

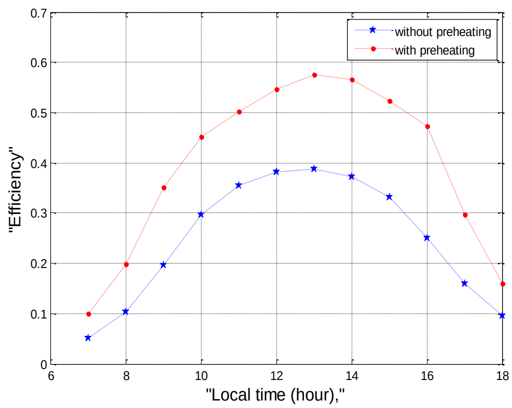

Fig. 7. the variation of the still solar global efficiency with non and preheating.

The temporal change of the global efficiency is similar to that of the global radiation "Fig 7,". At the first, the global efficiency increases and reaches its maximum value at 13^h00, then a decrease of the value is observed at the end of the day. In this way, the global efficiency of the non-heating system is about 37%, whereas, that of preheating reaches a value 56%.

These results agree with the experimental obtained by “Haddad and all.” [1], where they observed that the global efficiency of the solar still with preheating system is largely higher. Than that usual from a non-preheating one.

5. Conclusion:

The solar irradiation remains on the production of distilled water, where the increase on the ambient temperature leads to increase the water production distilled. Our study shows that an increase on the water depth has opposite effect and leads to consequently to a decrease of distilled water production. Moreover, the use of a preheating saline water (increase of the temperature difference between the evaporation surface and the condensation surface), allows improving the production of about 37%.

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