Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.968897

56 (2015) 2584–2592
December

Taylor & Francis
Taylor & Francis Group

The effect of cover tilt angle of a double slope solar still on the productivity in summer and winter seasons

Trad Abderachid*, Kaabi Abdenacer

Laboratory of Environmental Engineering, University of Constantine 3, Algeria, Tel. +213 0 776 08 22 42; Fax: +213 0 32567372; email: rachidtrade@yahoo.com (T. Abderachid), Tel. +213 0 772 95 51 49; Fax: +213 0 32567372; email: kaabiabdenacer@yahoo.co.uk (K. Abdenacer)

Received 10 December 2013; Accepted 28 May 2014

ABSTRACT

Algeria is interested in using solar still in order to produce distilled water from brackish water, since the climate is characterized by a high solar radiation during almost all the season. In this study, a computer program is set up in order to simulate the effect of the cover tilt angle on the performance of a double slope solar still under climatic conditions of the area of Constantine (northeast of Algeria), using meteorological data recorded during the last decade (2002–2012). 1 August 2005 and 28 February 2010 are selected as successively the hottest days for, respectively, summer and winter seasons. The obtained results show that 10° and 45° represent the optimum angles of inclination allowing to receive a maximum solar radiation for this type of solar still during the considered seasons, by increasing the evaporation–condensation phenomenon. However, in the summer season, a tilt of 10° gives a higher daily productivity compared to that of 45° with an increase of the productivity of about 24.45%. In contrast, in the winter season, a tilt of 45° gives higher daily productivity compared to that of 10° with an increase of the productivity of about 34.28%. Therefore, the tilt angle is an important factor to be considered for a solar still design. A water (brine) depth of 0.02 m gives higher daily productivity at optimum angles of the still.

Keywords: Solar still; Tilt angle; Performance

1. Introduction

Consumption of fresh water is increasing all over the world, mainly due to the population rapid growth as well as the industrial increasing need of water. Solar energy can be considered as a mean to overcome this problem as it is freely available in areas of the world where the water need is very pronounced. Solar distillation is used to distill brackish and/or saline water through solar energy [1]. Desalination of brackish or seawater represents one of the means to resolve the water deficiency. Simple solar still is mainly used due to its simple design, its construction, and its low operation and maintenance costs. However, its low productivity leads to develop other methods to increase efficiency. One of the key parameters that bring attention is the cover tilt angle. Different cover tilt angles were used in

*Corresponding author.

Presented at the 4th Maghreb Conference on Desalination and Water Treatment (CMTDE 2013) 15–18 December 2013, Hammamet, Tunisia

different investigations. Singh and Tiwari [2] developed, among other factors, analytical expressions for water and glass cover temperatures and yield as functions of cover inclinations. Other studies make in evidence the detailed effect of the cover tilt angle on the productivity [3–5]. Many experimental and numerical investigations have been developed on different designs of solar stills [6–9] in order to reach an optimum design by examining the effect of operational parameters or by changing parameters such as the glass cover inclination, on the solar still performance [10,11]. Among parameters affecting the solar still performance, we find, mainly, the intensity of solar radiation, the sunshine duration, and the type of the solar still [12] as well as the geographic difference and the weather conditions. Since the received solar radiation is considered as an important factor related to the cover slope of the still, it is then necessary to study the effect of the inclination angle on the performance of the distillation system. Moreover, as the inclination angle and the direction of the cover inclination depend on the latitude [10,11], in terms of the glass cover inclination, this can be lead to optimize the solar still yield area as well [11]. In relation with the inclination term, water depth is considered among one of the important parameters affecting significantly the solar still productivity [13]. At this stage and through the literature review, we can notice that there are no studies using simulation in order to look for the effect of the inclination angle on the production of freshwater from conventional solar still, under climatic conditions of Constantine (northeast of Algeria). The aim of this present work was then to compare the effect of the cover tilt angle of a double slope solar still on the productivity in both summer and winter seasons and looking for the optimum design parameters, under the considered climatic conditions. The simulation days correspond to 1 August 2005 (in the summer case) and 28 February 2010 (in the winter case), where the maximum temperature and the average wind speed are, respectively, 44 and 25℃, and 6.11 and 2.22 m/s. Constantine is located at the eastern part of Algeria, with a latitude of 36˚ 22´ to the north, a longitude of 6˚ 37´ to the east, and a mean elevation of 800 m from the sea level. The effects of the tilt angles of 10˚ and 45˚ and different water depths on the productivity are also analyzed.

2. Description of the system

Fig. 1 represent the studied symmetrical solar still with a double slope; this solar still is set up under climatic conditions of Constantine (northeast of Algeria). A simulation is developed to compare numerically the effect of the cover tilt angle on the performance of a double slope solar still in both summer and winter hottest days. This type of solar still represents a single basin, with a single effect, covered by two faces having a sloping glass covers of 3 mm in thickness and symmetrical at the center of the basin (Fig. 1). The vertical height of the solar still sides is of 0.15 m for both smaller and larger inclination angles of the condensing cover (10˚ and 45˚, respectively). The performance of the solar still is very simple, where the transparent glass cover allows the solar radiation to pass to the water (brine) and heats it. The evaporated water condenses at the inner side of the glass cover and flows down the cover till the outlet side, where it is collected. The solar still is made of aluminum, because of its relatively low cost, its good resistance to corrosion at its low and medium temperatures, and its low weight. The basin is covered by a wooden box and insulated with expanded polystyrene (100 mm thick), in order to minimize heat losses from the bottom to the environment. In addition, the solar still base is normally blackened at the inner side to enable the maximum absorption of solar radiation.

2.1. Experimental setup and procedure

The experiment is supposed to be carried out in the area of Constantine (northeast of Algeria) with a latitude of 36˚ 22´ to the north, a longitude of 6˚ 37´ to the east, during both hottest days, in the summer season (1 August 2005) and the winter season (28 February 2010). The considered solar still is directed to the south in order to receive the maximum possible solar radiation, and all the experiments are to be started at 6.00 am local and to be finished at 7.00 pm.

The fixed aim was that the effect of a small and a large angle of the cover tilt on the solar still productivity is already studied and compared. The unit of solar still consists of an aluminum material considered as cheap local made. Its basis has an effective area of 1 m. Thermally treated glass covers have 3 mm in thickness; build up with different tilt angles. The glass surfaces cover the top part of the solar still with symmetrical slopes of 10˚ and 45˚ to the horizontal and on both sides. These tilted glass covers served as a solar energy transmitter as well as a condensing surface for the vapor generated in the basin. Silicon rubber is used to seal the glass covers and the basis since silicon has a good bonding between the glass and different materials.

2.2. Instrumentation

During operations, measurements of solar intensities, ambient temperature, and temperatures of different elements of the solar still are carried out regularly

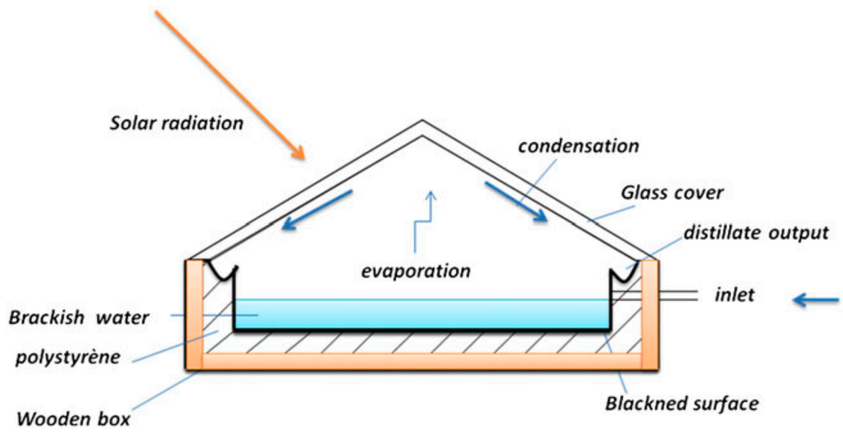

Fig. 1. Symmetrical solar still with a double slope.

at each hour and the yield is collected in a channel attached to the lower end of the glass cover, then is taken outside using a water tap and then measured directly by a measuring instrument.

A solar meter is used as an instrument to measure the instantaneous intensity of solar radiation, and a digital thermometer is used to measure ambient temperature.

Thermocouples are connected to a multipoint recorder in order to measure temperatures at different parts of the solar still, for example, basin liner, basin water, enclosure vapor, and the inner and outer sides of the glass cover.

2.3. Distillate measurements

Hourly measurements are carried out for, respectively, the ambient temperature, the glass cover temperature, and the water temperature during the two hottest days. These measurements are made after the sunset as well for a full description of the solar still performance.

A measuring tank is used to collect the condensate, once every one hour from the start of the operation (usually at 6.00 am) to the selected end of the test (19.00 pm). The hourly measured condensate was accumulated in a larger measuring tank, and the total collected during the day is compared to the summed-up hourly values.

3. Thermal analysis of the solar still

The following assumptions are taken into consideration, when setting up the energy balance equations, for different components of the double slope solar still, and this system is governed by different heat and mass transfer modes as well.

- The system is considered in full-steady conditions.
- The solar distillate runway is considered as a vapor leakage proof.
- The heat capacities of the glass covers as well as absorbing and insulating materials are neglected.
- Temperature dependent on heat transfer coefficients should be considered.
- Each component of the system, bottom/size, and the sides are considered perfectly insulated.
- Solar radiation absorbed by the walls is negligible.
- Changed design of the solar still is relied to the change in the tilt angle in both summer and winter seasons.
- The area of the solar still is 1 m^2, with the inner basis having a length = 1 m and a width = 1 m.

3.1. Symmetrical (double slope) type of solar still

In this type of solar still, time dependent on solar energy is transmitted to the water and the absorber bottom through the transparent covers, and the temperature of these elements changes as a result of the absorbed energy fractions, the heat losses, and the thermal properties. The energy balance equation per unit of the glass cover area through which there are heat exchanges with, respectively, water and the environment can be written as follows:

$$m_g Cp_g \frac{\partial t_g}{\partial t} = I_g(t)A_g + \left(q_{c,w-g} + q_{ev,w-g} + q_{r,w-g}\right) - \left(q_{r-sky}\right) - \left(q_{c-a}\right) \quad (1)$$

The global heat transfer is composed of internal and external heat transfers. The internal heat transfer quantities between water and the glass cover (convective case) and the radiation and the evaporation processes are, respectively, expressed as follows:

$$q_{r,w-g} = h_{r,w-g} = \left(T_w - T_g\right) \tag{2}$$

$$q_{c,w-g} = h_{c,w-g}\left(T_w - T_g\right) \tag{3}$$

$$q_{ev,w-g} = h_{ev,w-g}\left(T_w - T_g\right) \tag{4}$$

The total internal heat transfer coefficient (h_1) is:

$$h_1 = q_{c,w-g} + q_{ev,w-g} + q_{r,w-g} \tag{5}$$

The coefficient of the radiative heat transfer ($h_{r,w-g}$), is given by Duffie and Beckman [14]:

$$h_{r,w-g} = \varepsilon_{\text{eff}} \cdot \sigma\left(T_w^2 + T_g^2\right)\left(T_w + T_g\right) \tag{6}$$

where ε_{eff} is the emissivity and can be computed as follows:

$$\varepsilon_{\text{eff}} = \left(\frac{1}{\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_g} - 1}\right)^{-1} \tag{7}$$

Since the process of evaporation–condensation, issued from the heat and mass transfer, is taking place in the same time, Dunkle's equation concerning the convective and the evaporative fractions is then used [15]:

$$h_{c,w-g} = 0.884 \times \left[(T_w - T_g) + \frac{P_w - P_g}{268.9 \times 10^3 - P_w} T_w\right]^{1/3} \tag{8}$$

$$h_{ev,w-g} = 16.276 \times 10^{-3} \times h_{c,w-g} \times \frac{P_w - P_g}{T_w - T_g} \tag{9}$$

P_w and P_g are the vapor pressures corresponding, respectively, to water and glass temperatures and are obtained from the following relations:

$$P_w = e^{(25.317 - 5{,}144/T_W)} \tag{10}$$

$$P_g = e^{(25.317 - 5{,}144/T_g)} \tag{11}$$

The hourly yield per unit area depends on water and glass temperatures and is given by:

$$m_{ew} = \frac{h_{ev\left(T_w - T_g\right)}}{Lv} \times 3{,}600 \tag{12}$$

The total daily yield can be obtained through the following relation:

$$M_{ew} = \sum m_{ew} \tag{13}$$

The external heat transfer from the cover to the atmosphere is composed of two modes of heat transfer: radiative and convective.

$$q_{r,g-\text{sky}} = h_{r,g-\text{sky}}\left(T_g - T_{\text{sky}}\right) \tag{14}$$

$$q_{c,g-a} = h_{c,g-a}\left(T_g - T_a\right) \tag{15}$$

The coefficient of the radiative heat transfer, $h_{r,\text{ge-sky}}$, between the cover and the sky is given by Duffie Beckmann [14]:

$$h_{r,g-\text{sky}} = \varepsilon_g \sigma\left(T^2{}_g + T^2{}_{\text{sky}}\right)\left(T_g + T_{\text{sky}}\right) \tag{16}$$

where the sky temperature T_{sky} is [16]:

$$q_{\text{sky}} = 0.0552 \times T_a{}^{1.5} \tag{17}$$

The coefficient of the convective heat transfer $h_{c,g-a}$ is a function of the wind speed and is computed as follows [17]:

$$h_{c,g-a} = 2.8 + 3.0 \times V \tag{18}$$

The total external heat transfer (h_2) is then:

$$h_2 = q_{r,g-\text{sky}} + q_{c,g-a} \tag{19}$$

For the water mass, the corresponding energy exchange, per unit area, taking place between the basin liner and the cover is:

$$\begin{aligned} m_w C p_w \frac{\partial t_w}{\partial t} = I_w(t) A_w + \left(q_{c,b-w}\right) \\ - \left(q_{c,w-g} + q_{ev,w-g} + q_{r,w-g}\right) \end{aligned} \tag{20}$$

The equation of the energy balance, in the case of the basin liner, per unit area is:

$$m_b Cp_b \frac{\partial t_b}{\partial t} = I_b(t)A_b - \left(q_{c,b-w}\right) - \left(q_{cd,b-\mathrm{in}}\right) \tag{21}$$

The heat exchanged by convection between the water and the absorber is:

$$q_{c,b-w} = h_{c,b-w}(T_b - T_w) \tag{22}$$

where the coefficient of heat transfer $h_{c,b-w}$ is given as:

$$h_{c,b-w} = \frac{CK}{L}\left[(Gr.\,\mathrm{Pr})\right]^{1/4} \tag{23}$$

The heat loss by conduction from the basin liner to the insulation is:

$$q_{cd,b-\mathrm{in}} = h_{cd,b-\mathrm{in}}(T_b - T_{\mathrm{in}}) \tag{24}$$

where

$$h_{cd,b-\mathrm{in}} = \frac{K_b}{L_b} \tag{25}$$

The equation of the energy balance for the basin insulation per unit area is:

$$m_{\mathrm{in}} C_{\mathrm{in}} \frac{\mathrm{d}T_{\mathrm{in}}}{\mathrm{d}t} = \left(q_{cd,b-\mathrm{in}}\right) - \left(q_{\mathrm{loss}}\right) \tag{26}$$

The heat lost from the insulation to the environment can be written as:

$$q_{\mathrm{loss}} = U_{\mathrm{in}}(T_{\mathrm{in}} - T_a) \tag{27}$$

The global coefficient of heat transfer U_{in} is computed from the Fourier's equation of conduction:

$$U_{\mathrm{in}} = \left(\frac{L_{\mathrm{in}}}{K_{\mathrm{in}}} + \frac{1}{h_{\mathrm{in}}}\right)^{-1} \tag{28}$$

The fraction of the total incident solar radiations *I(t)* that can be reached and absorbed by each element related to the balance equations, considered in the solar still, depend on the optical properties of the materials such as the transmittance, the absorptance, and the reflectance [18].

4. Results and discussion

The above nonlinear system related to differential equations can be resolved numerically using MATLAB software (version 7.0), by applying the Gauss–Seidel implicit iterative method [19], and at a time step of one hour. A computer program is used in order to look for the effect of smaller and larger inclination angles and an operating water depth in both winter and summer seasons on the performance of a symmetrical solar still with a double slope. This is carried out under climatic conditions of Constantine, recorded on, respectively, 1 August 2005 and 28 February 2010. These are considered as the two typical hottest days recorded during the last decade (2002–2012).

Figs. 2 and 3 indicate the change of solar radiation, absorbed by different elements of solar still at inclination angles of 10° and 45° and ambient temperatures with time.

The daily change of solar radiation for the considered solar still shows the same pattern of change for different inclination angles, where the solar radiation increases till it reaches its maximum value and then comes its decrease to its minimum value. It can be observed through the Fig. 2 that the considered solar still receives the maximum solar radiation at 12.00 h (971.14 W/m^2 and 877.77 W/m^2 corresponding to the inclination angles of 45° and 10°, respectively). In the opposite, Fig. 3 shows that the same solar still receives the maximum solar radiation at the same time (886.36 w/m^2 and 748.93 W/m^2 corresponding to the inclination angles of 45° and 10°, respectively).

Fig. 4 shows a comparison in change of solar radiation received by the solar still with double slope at the considered summer and winter seasons, where they have similar trend and reach their maximum values of, respectively, 971.14 W/m^2 and 886.36 W/m^2 at 12.00 h corresponding optimum inclination angles of the covers of, respectively, 10° and 45°. It is known

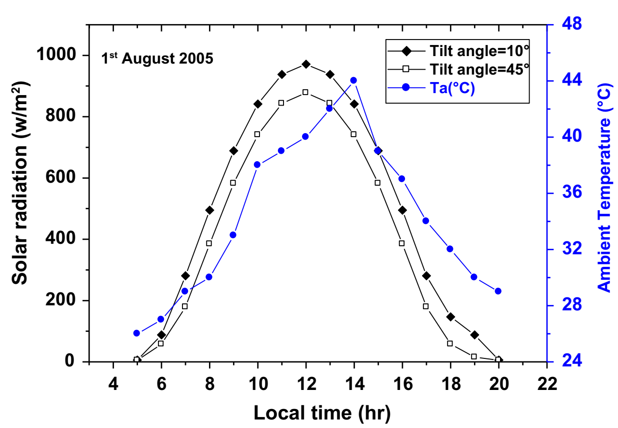

Fig. 2. Change of solar radiation, at different inclination angles and different ambient temperatures with time (summer season).

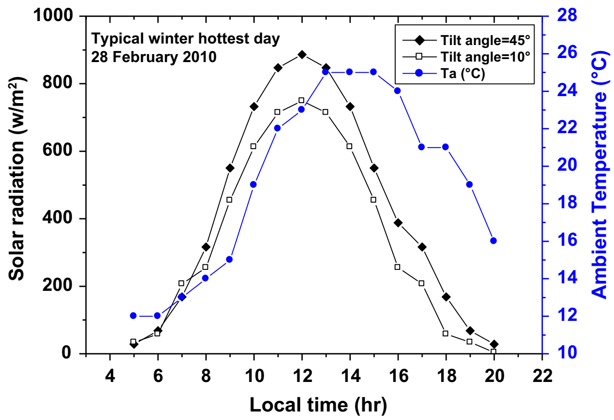

Fig. 3. Change of solar radiation at different inclination angles and different ambient temperature with time (winter season).

that for lower angles of sun rays incidence, the transmittance is higher and the reflectance is lower, resulting in an increase of the radiation amount available for the basin water to be heated. Besides, as the glass cover angle is smaller, the distance between the cover and the basin water (still height) is at the minimum; then, the solar radiation reaches rapidly the basin water as well as a maximum volume air with vapor is purged into the condenser area [13]. In addition, the glass cover has a higher solar transmittance for different angles of solar incidence. The distribution of ambient temperature in the considered summer and winter seasons is shown in Figs. 2 and 3. From these figures, one can observe that there is a suitable distribution of this temperature for both hottest days, particularly at 1 August 2005, where the highest value of the ambient temperature (44℃) is recorded at around 13.00 h, corresponding to a maximum solar radiation. However for ambient air during the winter hottest day (28 February 2010), the maximum value (25℃) is reached during the period 13.00–15.00 h.

The effect of the basin water depth on the daily productivity of a symmetrical solar still with a double slope for lower inclination angle (10˚) in summer day and larger one (45˚) in winter day is shown in Fig. 5.

We can notice from the above figure that as the water depth decreases, the daily solar still production increases, but the maximum values of this production are obtained at 0.02 m of water depth for both hottest days, this indicates that the productivity for a symmetrical solar still with a double slope increases by 88.27% in the summer day and by 78.94% in the winter day. In general, the increase in the solar still production is due to the fact that as the depth decreases during the daylight, the water will have a lower heat capacity, resulting in a higher temperature in the basin and, thus, higher evaporation rate, especially in the summer hottest day as the received solar radiation is higher. Solar radiation is the most important parameter which affecting the productivity as it provides the energy required for water evaporation, and with the same solar irradiance, the evaporation rate increases with the reduced mass of water on the absorber plate [20]. It is well known that the water depth is inversely proportional to the productivity of the solar still [6,20,21] and a water depth of 0.02 m was found to be the optimum depth [3,20].

The time change with the cover and water temperatures and with the production rate, at the hottest days in both summer and winter seasons, for the considered solar still system is shown in Figs. 6 and 7. It seems that there is a dependency of the hourly production on the evaporation–condensation process for this system.

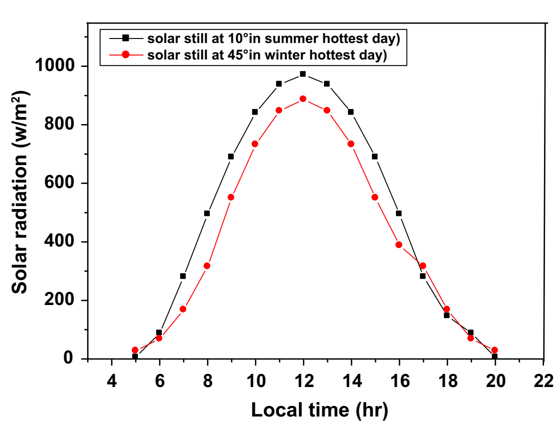

Fig. 4. Change of solar radiation with time at optimum angles (summer and winter cases).

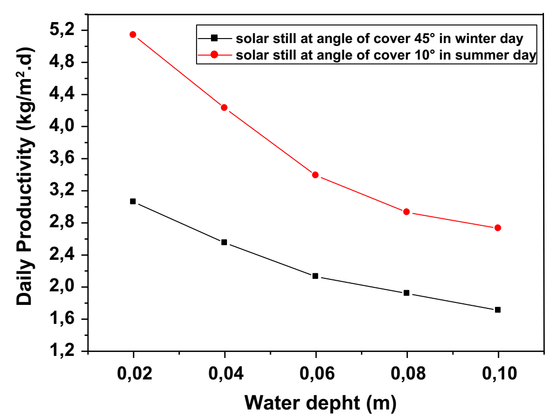

Fig. 5. Effect of water depth on the daily productivity of a symmetrical solar still with a double slope in summer and winter hottest days.

Many investigators have reported, in their studies, that there is an increase in water production and in the temperatures of solar still components from which the increase in solar radiation and in the solar still production correlates very well with the temperature distributions of the considered solar still [12,22]. Through the considered figures, it is noticed that the production rate increases as the temperature difference between water and that of the cover increases, and this increase is related to the increase in solar radiation with time. The temperature difference between the glass and the basin water increases as well, leading to an increase on the natural circulation of air mass inside the still. This increases also both convective and evaporative heat transfers between the basin water and the cover.

Similar agreement is observed for the production rate in the case of a double slope solar still as shown in Fig. 8. The production rate begins very slowly due to the warming of the stills and the low solar energy during the morning hours. The peak production rate is obtained at around 15:00 h for both hottest days (summer and winter seasons); after this time, production begins to decrease slowly with the decrease in the solar radiation intensity until the sunset, corresponding two days. It is also noticed that the maximum production rate is obtained in the case of the summer hottest day compared to the winter one because of the maximum concentration of solar radiation.

It becomes more clear, through the Fig. 9, that the daily production of water issued from the solar still, for the considered hottest days, at smaller and greater inclination angles is found more important for the solar still at the cover tilt angle of 10˚ than that at the cover tilt angle of 45˚, in summer hottest day and with an increase in the production of about 24.45%. In contrast, in winter season, the largest angle (45˚) gives higher daily production compared to the smallest one (10˚) with an increase in the production of about 34.28%. However, when comparing the two seasons, it is noticed that the daily production of a solar still with a double slope process at an angle of 10˚ in summer hottest day is found higher than that obtained in the winter hottest day at an angle of 45˚, where we can notice an increase of 67.97%. This result can be explained by the fact that the declination angle "δ" has a positive value in the summer, in relation with the change of solar radiation during the same day, leading to the decrease in the reflectivity radiation of the cover as the cover angle decreases [22].

Moreover, many experimental and theoretical studies found that the cover tilt angle should be smaller in

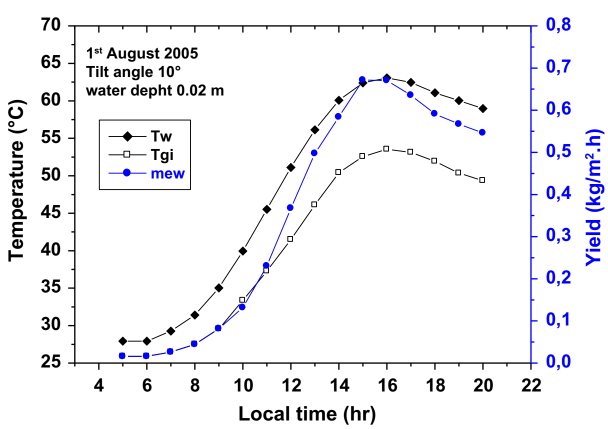

Fig. 6. Time change with the inner cover and the water temperatures and with the production rate, case of a symmetrical solar at summer hottest day.

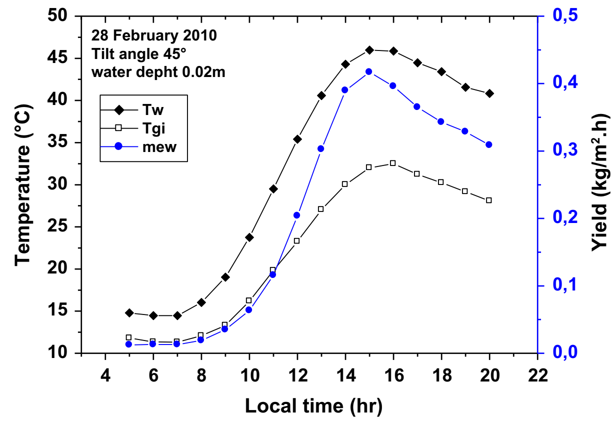

Fig. 7. Time change with the inner cover and the water temperatures and with the production rate, case of a symmetrical solar still at winter hottest day.

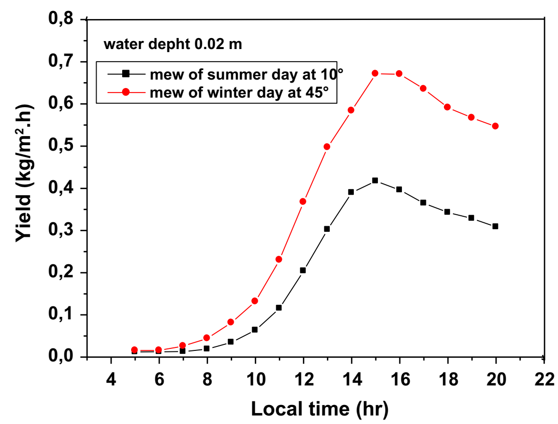

Fig. 8. Comparison between the production rates of a symmetrical solar still, for summer and winter hottest days.

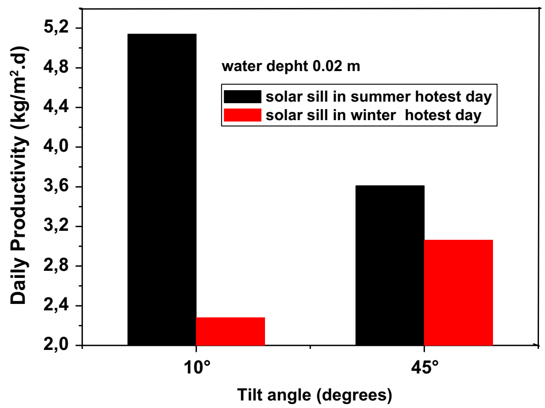

Fig. 9. Effect of the tilt angle on the daily production of a symmetrical solar still with a double slope, in summer and winter hottest days.

the summer [4,8]. Kamal [23] and Singh and Tiwari [10] found that a cover tilt angle of 10˚ represents the optimum angle in the summer season for both the double and the single slope solar stills. Garg and Mann [24] have investigated on the single and double slope solar stills and found also that a glass angle of 10˚ represents the optimum angle, and they concluded that the angle of the cover tilt should be larger in the winter and smaller in the summer.

5. Conclusion

A computer program is set up, in order to study and compare, numerically, the effect of both smaller and larger inclination angles on the performance of a symmetrical solar still with a double slope, under the climatic conditions related to the area of Constantine (northeast of Algeria). 1 August of 2005 and 28 February 2010 are selected for realizing this study as it is considered as the hottest two days during the last decade (2002–2012) in winter and summer season, respectively.

Through the obtained results, it noticed that the relation between the cover tilt angle and the simple solar still production can be established where the optimum tilt angles should be taken into consideration. The relation between these parameters may be summarized as follows:

- The cover tilt angle should be larger in the winter season and smaller in the summer season.
- Angles of 10˚ and 45˚ should be taken as the optimum inclination angles to allow receiving a maximum solar radiation during the summer and the winter hottest days.
- The increase in the water depth leads to the decrease in the solar still production, and a depth of 0.02 m is considered as the optimum height that gives the maximum production at the considered inclination angles and for both seasons.
- For a maximum production, the cover tilt angle should be smaller in the summer season and larger in the winter season.
- The daily production, in summer hottest day, of the considered system and at a cover tilt angle of 10˚ is found higher than that of a system with a cover tilt angle of 45˚ in winter hottest day, where the increase is about 67.97%.

Finally, we conclude from the obtained results that the inclination angle of the solar still cover represents an important parameter that can improve the performance of the solar still. This type of solar still, planted with two sloped covers during two different seasons, is among the most simple and least expensive systems, made of local materials and with the availability of sufficient sunlight.

Nomenclature

A	—	area (m^2)
C	—	specific heat, J/kg℃
Gr	—	grashof number, dimensionless
I	—	fraction of an absorbed solar radiation, W/m^2
h_1	—	total internal heat transfer coefficient, W/m^2℃
h_2	—	total external heat transfer, W/m^2℃
K	—	thermal conductivity, W/m℃
L	—	thickness, m
m	—	mass, kg
mew	—	production rate, kg/m^2.h
P	—	partial pressure, N/m^2
Pr	—	prandtl number, dimensionless
q	—	heat flux, W/m^2
t	—	time, s
dt	—	small time interval, s
T	—	temperature,℃
U	—	overall heat transfer coefficient, W/m^2℃
V	—	wind velocity, m/s

Greek letters

β	—	inclination angle (˚)
σ	—	constant of Stefan–Boltzmann, W/m^2℃^{4}
ε	—	emissivity, dimensionless
δ	—	declination angle (˚)

Subscripts

a	—	ambient
b	—	basin liner
c	—	convection
cd	—	conduction

eff — effective
ev — evaporation
g — glass
i — internal
in — insulation
r — radiation
w — water

References

[1] S. Hikmet Aybar, Hossein Assefi, A review and comparison of solar distillation: Direct and indirect type systems, Desalin. Water Treat. 19 (2010) 321–331.
[2] H.N. Singh, G.N. Tiwari, Monthly performance of passive and active solar stills for different Indian climatic conditions, Desalination 168 (2004) 145–150.
[3] W.A. Kamal, A theoretical and experimental study of the basin-type solar still under the arabian gulf climatic conditions, Solar Wind Technol. 5 (1988) 147–157.
[4] S. Aboul-Enein, A.A. El-Sebaii, E. El-Bialy, Investigation of a single-basin solar still with deep basins, Renewable Energy 14 (1998) 299–305.
[5] H. Aybar, H. Assefi, Simulation of a solar still to investigate water depth and glass angle, Desalin. Water Treat. 7 (2009) 35–40.
[6] H. Al-Hinai, M.S. Al-Nassri, B.A. Jubran, Effect of climatic design and operational parameters on the yield of a simple solar still, Energy Convers. Manage. 43 (2002) 1639–1650.
[7] B.A. Akash, M. Mohsen, Waleed Nayfeh, Experimental study of the basin type solar still under local climate conditions, Energy Convers. Manage. 41 (2000) 883–890.
[8] A.J.N. Khalifa, On the effect of cover tilt angle of the simple solar still on its productivity in different seasons and latitudes, Energy Convers. Manage. 52 (2011) 431–436.
[9] R. Balan, J. Chandrasekaran, S. Shanmugan, B. Janarthanan, Review on passive solar distillation, Desalin. Water Treat. 28 (2011) 217–238.
[10] A.K. Singh, G.N. Tiwari, P.B. Sharma, E. Khan, Optimization of orientation for higher yield of solar still for a given location, Energy Convers. Manage. 36 (1995) 175–181.
[11] G.N. Tiwari, J.M. Thomas, E. Khan, Optimisation of glass cover inclination for maximum yield in a solar still, Heat Recovery Syst. CHP 14 (1994) 447–455.
[12] I. Al-Hayeka, O. Badran, The effect of using different designs of solar stills on water distillation, Desalination, 169 (2004) 121–127.
[13] M.R. Rajamanickam, A. Ragupathy, Influence of water depth on internal heat and mass transfer in a double slope solar still, Energy Procedia 14 (2012) 1701–1708.
[14] J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Processes, second ed., John Wiley & Sons Inc, New York, NY, 1991, p. 919.
[15] R.V. Dunkle, Solar water distillation: The roof type solar still and multi effect diffusion still, International developments in heat transfer, Proceedings of International Heat transfer Conference, University of Colorado 5 (1961) 895–902.
[16] V.B. Sharma, S.C. Mullick, Estimation of heat-transfer coefficients, the upward heat flow, and evaporation in a solar still, ASME, J. Sol. Energy Eng. 113 (1991) 36–41.
[17] J.H. Watmuff, W.W.S. Charters, D. Proctor, Solar and wind induced external coefficients solar collectors, Int. Heliotech. J. 2 (1977) 56.
[18] E. Rubio, J.L. Fernández, M.A. Porta-Gándara, Modeling thermal asymmetries in double slope solar stills, Renewable Energy 29 (2004) 895–906.
[19] R.L. Burden, J.D. Faires, Numerical Analysis, third ed., PWS Publishers, Boston, MA, 1985.
[20] R. Tripathi, G.N. Tiwari, Effect of water depth on internal heat and mass transfer for active solar distillation, Desalination 173 (2005) 187–200.
[21] R. Tripathi, G.N. Tiwari, Thermal modeling of passive and active solar stills for different depths of water by using the concept of solar fraction, Sol. Energy 80 (2006) 956–967.
[22] H. Al-Hinai, M.S. Al-Nassri, B.A. Jubran, Parametric investigation of a double-effect solar still in comparison with a single-effect solar still, Desalination 150 (2002) 75–83.
[23] W.A. Kamal, A theoretical and experimental study of the basin-type solar still under the Arabian Gulf climatic conditions, Solar Wind Technol. 5 (1988) 147–157.
[24] H.P. Garg, H.S. Mann, Effect of climatic operational and design parameters on the year round performance of single slope and double slope solar still under Indian arid zone conditions, Sol. Energy 18 (1976) 159–163.