J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol 11 (12):901 - 907, 2020

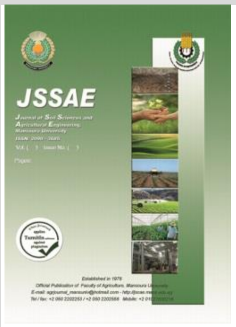
Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Improving The Performance Of Stepped-Type Solar Still Using External Booster Mirrors

Abd Allah, W. E. *; M. K. Abd El-Wahab ; Muna M. Abu-Hashem and Hanan M. El-Shal

Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt



ABSTRACT

In an attempt to improve its performance and productivity, a simple low cost modification of stepped-type solar still (SSS) was presented by installing external booster mirrors fixed at its top and bottom edges. The SSS's step width was 4cm and depth of 2cm and black-painted aluminized absorber within area of 0.46 m2. Thus, two SSSs units (conventional without mirrors and modified with same fabricated specifications but with booster mirrors) were investigated at Faculty of Agriculture, Zagazig University, Zagazig, Sharkia Governorate, Egypt in order to assess and compare their performance represented of productivity, indicated temperatures, some thermo-physical properties and daily efficiency under three different water salinity levels of 15000, 35000 and 45000 ppm under solar radiation flux range of 270-1143 and 267-998 W/m2 in case of modified and conventional SSS, respectively, and ambient temperature range of 31.2 to 37.6 oC. The obtained results revealed that, the indicating maximum temperatures gained by modified SSS comparing to the conventional one increased by 14.3, 11.5, 8.6 and 2.5% for glass, water, absorber and vapor, respectively. The daily yielded productively for the modified SSS were 9.91, 7.87 and 6.97 l/m2.d with increase of 84.2, 60.9 and 55.6 % compared to the productivity of the conventional SSS at the previous water salinity levels, respectively. Furthermore, the annual cost of one liter distillate (in EGP; 1 $ = 15.7 EGP) for both conventional and modified SSSs was estimated as (1.33 and 0.88), (1.46 and 1.107) and (1.6 and 1.25) at the same previously mentioned salinity levels, respectively.

Keywords: Stepped solar still; Booster mirrors; Thermo-physical properties; Daily efficiency; Cost

INTRODUCTION

Supplying freshwater for peoples live at remote regions and islands is essential in order to provide the necessary quantities of safe drinkable water. Due to its easy construction with low maintenance requirement and free energy and environmental operation, many researches had been focused on solar stills. Therefore researchers always seek to improve its productivity because of the limited production where for simple conventional still is only 2–5 l/m^2/day as reported by (Velmurugan and Srithar, 2011). This makes solar stills have disadvantage of low production compared to their costs (Omara *et al*., 2014).

Keeping in view the success of operating solar stills is mainly depends on solar insolation. In this context, Egypt located in Sunbelt area and has 9-11 hours of sunshine daily with ray few cloudy days with annual direct normal solar radiation 2000-2300 kWh/m^2 (NREA, 2011). In order to reduce construction costs with keeping enough quantities of evaporating energy, mirror reflectors can be used for this purpose. Omara *et al*. (2017) reported that, either external or internal reflectors are cheap modification to increase directly the incident solar radiation onto the still basin as well as the distillate efficiency of the still. Another factor inversely affecting the performance of operating solar stills is the depth of water. Thus, stepped solar still could present solution of this problem through keeping minimum depth leading to increase the distillate water productivity (Omara *et al*., 2014).

Reviewing literatures focusing on solar still performance with external booster top and bottom mirror reflectors, Tanaka and Nakatake (2006) presented a geometrical method to estimate the reflected solar radiation by both internal and external reflectors on the basin still. the distillate water productivity increased by 48%. Tanaka and Nakatake (2009) conducted numerical study on an inclined wick solar still with a forwards top mirror on the upper edge of the still (15° from vertical). Their results revealed that the productivity increased by 27% over that with a vertical reflector with the same length of still. Additionally, Tanaka (2009) reported that at 30°N latitude, the reflector effect is around 15% over of productivity obtained comparing to the traditional wick still without top reflector. Srivastava and Agrawal (2013) studied conventional still with twin reflector booster mirrors with increment of 79% over without reflectors. El-Sebaii (2000) obtained increase of 19% (in summer) and 30% (in winter) by using external mirror reflectors with double slope single basin solar still (at Tanta, Egypt 31° N). Omara *et al.* (2013) investigated the productivity of a stepped solar still combined with internal reflectors 5mm-depth and 120mm-width and obtained higher productivity of 75% more than the basin solar still. El-Samadony *et al.* (2015) experimentally studied the performance of stepped solar still integrated with external top/bottom reflectors compared to basin solar still. The results indicated that the glass and water temperatures were higher than that of the

[*] Corresponding author.
E-mail address: dr.wesam15@yahoo.com
DOI: 10.21608/jssae.2020.174211

basin still by about 8 and 15 ºC, respectively, within increase in daily productivity about 92% moreover.

Regarding to the importance of estimation of thermo-physical properties to describe evaporative properties of the water that express to productivity and efficiency of any solar still, in the present study a simple modification by installing external booster mirrors at top and bottom edges of a stepped-type solar still to investigate improving its performance comparing to the conventional one is proposed.

MATERIALS AND METHODS

Experimental work was carried out during 2020 at Faculty of Agriculture, Zagazig University, Zagazig, Sharkia, Egypt (Latitude 30.5º – Longitude 31.5º). Two stepped solar stills (SSS) were investigated to assess their productivity and thermo-physical properties under the same climate conditions: first was the conventional one, the second was modified using external top and bottom booster mirror reflectors as shown in Fig. (1 and 2). The top mirror is inclined by angle 15º to vertical plane, and the bottom is inclined by angle 50º to horizontal plane. These values is installed to be the optimum top and bottom external reflectors as reported by (Tanaka, 2010; 2015).

Both conventional and modified SSSs mainly consisted of stepped basin within step width of 4cm and depth of 2cm, wooden box and 3mm-thickness glass cover. The stepped basin was made of black-painted aluminum. The wooden box was inclined 30º with horizontal plane. The basin was insulated by glass wool from the bottom and all sides in order to minimize heat losses from SSS to surroundings. Two 20 liters-plastic tank was used to feed each SSS with the saline water through plastic hoses provided with controlling valves. The modified SSS was provided with bottom and top booster mirror reflectors with the same surface area of still considering of adjusting tilt angles for both reflectors. Table (1) shows the specifications of the conventional and modified SSSs.

1- Conventional SSS without mirrors **2- Modified SSS with booster mirrors** **3-Inlet of saline water** **4- Outlet of distillate water**
5-Thermocouples **6-Bottom booster mirror** **7-Top booster mirror**

Fig. 1. Photo of conventional and modified SSS.

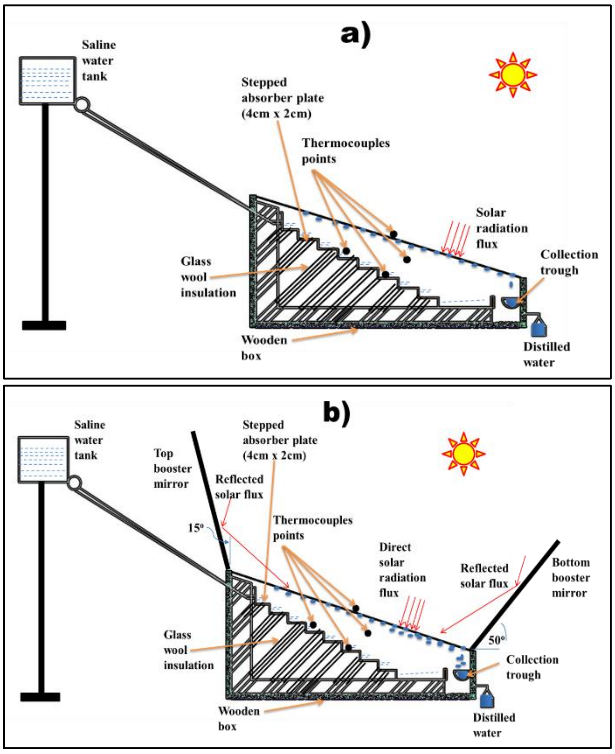


Fig. 2. Schematic drawing of a) conventional SSS, and b) modified SSS.

Table 1. the spesifications of experimental SSSs.

Parameter	Specification of SSSs
Stepped basin material	Aluminum
Surface absorber area, m^2	0.4606
Basin thickness, mm	1.5
Wooden box dimensions, cm	75*55
Wooden box thickness, cm	2.5
Insulation thickness, cm	2.5 (Glass wool)
Cover material	Glass (3 mm of thickness)

Preparing the saline water:

The feeding saline water was prepared by adding 15, 35 and 45 g of salt to one liter of purified water considering the completely continuous agitation for obtaining the salinity levels of 15000, 35000 and 45000 ppm (mg/l=1ppm), respectively, as a representation and simulation of brackish and saline water.

The experimental procedure:

The main experiments were conducted from hour 8:30 to 17:30 in order to assess the hourly/daily productivity of distillate water obtained using both conventional and modified SSSs under the same weather conditions to evaluate the performance effect of external booster mirror reflectors on enhancing SSS thermal performance. All readings and measurements of solar radiation and temperatures and were recorded every 30 minute time intervals. The thermo-physical properties considering the productivity of both conventional and modified SSSs was investigated using three different salinity levels of water 15000, 35000 and 45000 ppm as a simulation of brackish water and seawater. The output distillate water is collected by a measuring jar which is placed at the outlet of the SSS.

Measurements and determinations:

Solar radiation flux

The solar radiation flux (SRF) for both conventional and modified SSSs during operating insolation hours (8:30 to 17:30) was measured using a solar power meter (Model of TES-132, TENMARS, Taiwan), with measuring range of 0-2000 W/m^2, resolution of 0.1 W/m^2 and accuracy of ± 10 W/m^2.

Temperatures

Calibrated type-K thermocouples (measuring range of -100 to 1300°C and accuracy of ±0.1% rdg + 0.7°C) connected to a digital data logging thermometer (TENSMARS TM747-DU,Taiwan) were used to measure the temperatures (°C) at different points inside the SSS. The temperature of ambient (T_{am}), glass cover (T_g), absorber (T_{abs}), water (T_w) and vapor (T_v) were measured every 30 min.

Hourly productivity

The hourly SSS productivity per on square meter (l/m^2.h) was calculated as follow:

$$\text{Hourly productivity} = \frac{\text{hourly collected distillate water } (ml)}{\text{absorber area } (m^2) * 1000}, \quad l/m^2h$$

Cumulative productivity

The daily cumulative SSS productivity per one square meter (l/m^2.d) was estimated by adding the obtained hourly productivity to the previous hour yield for the whole consecutive hours throughout day from hour 8:30 to 17:30.

Thermo-Physical properties

Thermo-Physical properties were determined using the measured temperatures (T_{am}, T_g, T_{abs} and T_w) for evaporative and condensate surfaces by the following relations according to (Arunkumar et al., 2010; Brooker et al., 1982; Toyama et al., 1983):

The thermal conductivity (K) is given by:

$$K = 0.0244 + (0.7673 \times 10^{-4})T_{av}, \quad W/m.K$$

The water dynamic viscosity (μ) is given by:

$$\mu = (1.718 \times 10^{-5}) + (4.620 \times 10^{-8})T_{av}, \quad Pa.s$$

The water density (ρ) is given by:

$$\rho = \frac{353.44}{(273.35 + T_{av})}, \quad kg/m^3$$

Where,

***T_{av}* is the arithmetic mean temperature of evaporative and condensate surfaces that can be expressed by:**

$$T_{av} = \frac{T_w + T_g}{2}$$

The saturation vapor pressure (p) is given by:

$$p = 6893.03 \exp\left(54.63 - \frac{12301}{(1.8\,T_v + 491.69)} - 5.17 \ln(1.8\,T_v + 491.69)\right), Pa$$

The latent heat of water (h) is given by:

$$h = -0.00061432\,T_w^{\,3} + 0.0058927\,T_w^{\,2} - 2.36418\,T_w + 2500.79, \quad kJ/kg$$

Daily SSS efficiency

The daily thermal efficiency of both conventional and modified SSSs is determined as follow:

$$\eta_d = \frac{\sum_1^n \dot{m}_w \times h}{\sum_1^n A \times SRF\,(t)}$$

Where,

($\sum \dot{m}_w$) is the summation of the hourly productivity of distillate water, multiplied by the latent heat (*h*); hence, the result is divided by the average daily solar radiation flux (*SRF*) over the whole absorber surface area ($\sum A$) of the SSS, (*n*) is the number of effective operating hours.

RESULTS AND DISCUSSION

The obtained results were discussed under the following items:

Hourly solar radiation flux (SRF) and ambient temperature (T_{am}):

The mean values of variation of hourly SRF and T_{am} for both conventional and modified SSSs obtained during the experimental days is shown in Fig. (3). In general, it can be noticed that the hourly SRF, for both conventional and modified SSSs, increased in the morning period until reaching the maximum values around noon period, then it begun to decrease progressively until reaching the minimum values at the end of day hours. With an overview, it can be explained the increasing of incident SRF for modified SSS compared to conventional one as a result of increasing reflected SRF due to the effect of external booster mirrors in addition to the natural incident SRF on modified SSS receiver. Of course, it may be expressed to the same trends for all following indicators of SSS performance. The maximum hourly SRF for both conventional and modified SSSs (in average for experimental days) was recorded 1143 and 998 W/m^2, respectively, while the minimum values were 270 and 267 W/m^2, respectively. Generally, the averaged SRF for modified SSS increased by 13% more than the conventional one. But regarding to ambient temperatures, it had the same trend due to the experiments were carried out in the same time for both SSSs. From the obtained results, it can be observed that the average values of ambient temperatures thought the experimental days ranged from 31.2 to 37.6 °C.

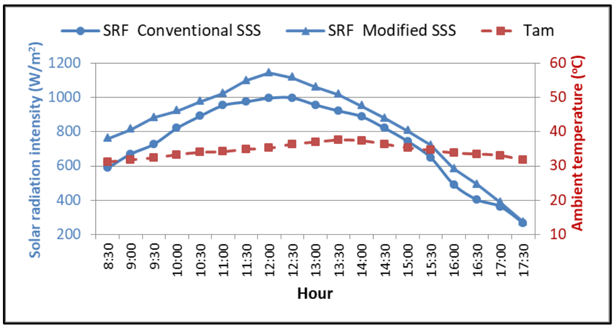


Fig. 3. Variations (in average) of hourly solar radiation flux and ambient temperature conditions during the experimental days.

Distribution of hourly indicating temperatures (T_g, T_w, T_{abs}, and T_v):

The mean values of variations of hourly different indicating temperatures: glass temperature (T_g, shown in Fig. 4,a), water temperature (T_w, shown in Fig. 4,b), absorber temperature (T_{abs}, shown in Fig. 4,c) and inner vapor temperature (T_v, shown in Fig. 4,d) for both conventional and modified SSS obtained during the experimental days is shown in Fig. (4). On general overview, the trend of all hourly measured temperatures (T_g, T_w, T_{abs} and T_v) of both conventional and modified SSS reached its peak values at noon period as well as SRI distribution during the day. The obtained results showed that all indicating temperatures for the modified SSS higher than for the conventional SSS, where the maximum values of: T_g increased from 55.9 to 63.9 ºC (with increase of 14.3%); T_w increased from 98.4 to 109.7 ºC (with increase of 11.5%); T_{abs} increased from 98.7 to 107.2 ºC (with increase of 8.6%); T_v increased from 81.2 to 83.2 ºC (with increase of 2.5%). While these values in average were estimated as: T_g increased from 45.3 to 54.9 ºC (with increase of 21.2%); T_w increased from 73.2 to 83.3 ºC (with increase of 13.8%); T_{abs} increased from 72.7 to 78.8 ºC (with increase of 8.4%); T_v increased from 62.8 to 65.9 ºC (with increase of 4.9%). Therefore, and from the obtained results, using booster mirrors with SSS led to clear improvement for all indicating temperatures thus later properties and productivity would be improved.

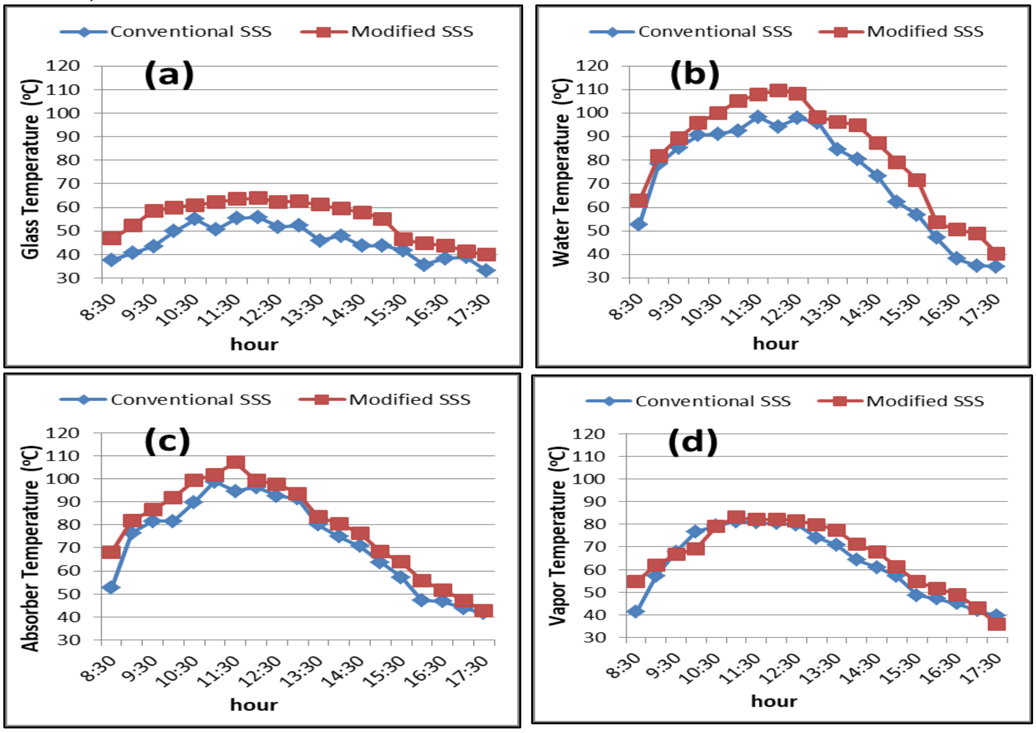


Fig. 4. Variations of average hourly temperatures of: (a) glass, (b) water, (c) absorber and (d) vapor, for both conventional and modified SSSs.

Distribution of hourly indicating thermo-physical properties (K, μ, ρ, p and h):

The mean values of variations of hourly different thermo-physical properties: thermal conductivity (K, shown in Fig. 5,a), water dynamic viscosity (μ, shown in Fig. 5,b), water density (ρ, shown in Fig. 5,c)), saturation pressure (p, shown in Fig. 5,c) and latent heat of evaporation (h, shown in Fig. 5,e) for both conventional and modified SSS obtained during the experimental days is shown in Fig. (5).

As a general overview, the trend of thermo-physical properties of K, μ and p of both conventional and modified SSS reached its peak values at noon period as well as SRI distribution during the day meanwhile thermo-physical properties of ρ and h tends upside down SRI trends. This is because of SRI directly proportional to thermal conductivity, water dynamic viscosity and saturation pressure but inversely proportional to water density and latent heat due to high temperatures as a result of trapping solar radiation and its conversion to heat energy. Furthermore, the external top and bottom booster mirrors reflectors concentrate the incident SRI over the SSS area hence thermo-physical properties for the modified SSS should be better than the conventional one.

The obtained results revealed that, the water thermal conductivity was ranged from (0.02714 to 0.0230 W/m.K) and (2.906E-02 to 3.06E-02 W/m.K) for conventional and modified SSS, respectively, with increase in average of 0.26% for the modified SSS. The water dynamic viscosity was ranged from (1.9E-05 to 2.05E-05 Pa.s) and (1.9E-05 to 2.09E-05 Pa.s) for conventional and modified SSS, respectively, with increase in average of 0.50% for the modified SSS. The saturation pressure was ranged from (5391.4 to 37193.5 Pa) and (5818.8 to 45784.8 Pa) for conventional and modified SSS, respectively, with increase in average of 7.8% for the modified SSS. In contrast, the water density was ranged from (1.0213 to 1.144 kg/m^3) and (0.99937 to 1.139 kg/m^3) for conventional and modified SSS, respectively, with decrease in average of 0.28% for the modified SSS. Additionally, the water latent heat was ranged from (1767.2 to 2380.7 kJ/kg) and (1691.2 to 2364.1 kJ/kg) for conventional and modified SSS, respectively, with decrease in average of 0.537% for the modified SSS.

Hourly and cumulative productivity:

Depending on the same earlier behavior of SRF distribution from hour 8:30 to 17:30 within similar conditions of average values of 784, 759 and 770 W/m^2 for conventional SSS and 886, 843 and 862 W/m^2 for modified SSS, Fig. (6) showed the obtained results of hourly and daily cumulative productivity for both conventional and modified SSSs at different salinity levels of 15000, 35000 and 45000 ppm, respectively. General overview, it can be observed that, distillate water productivity inversely increased with reducing the salinity under nearly conditions of SRF. This is logical because higher concentrations of salinity required more evaporative energy to overcome the bond energy. From the obtained results, the distillate water productively attained its maximum values at noon period and its rates remained high at the afternoon time. The highest obtained values of hourly productivity of modified SSS compared to the conventional one increased from 0.65024 to 1.04058, 0.62858 to 0.96830 and 0.62446 to 0.93498 l/m^2.h with increase of 60, 54 and 49.7 % at water salinity levels of 15000, 35000 and 45000 ppm, respectively, while the recorded cumulative productively at the end of day increased from 5.38 to 9.91, 4.89 to 7.87and 4.48 to 6.97 l/m^2.d with increase of 84.2, 60.9 and 55.6 % for the same salinity levels, respectively. It is clear that, in general, the hourly and cumulative productivity of distillate water reduced inversely whenever the water salinity increased. This is may be due to the increase of water mass resulted by increasing water salinity led to high thermal heat capacity then a reduction in evaporating rate may occur as reported by (Tawfik, 2012).

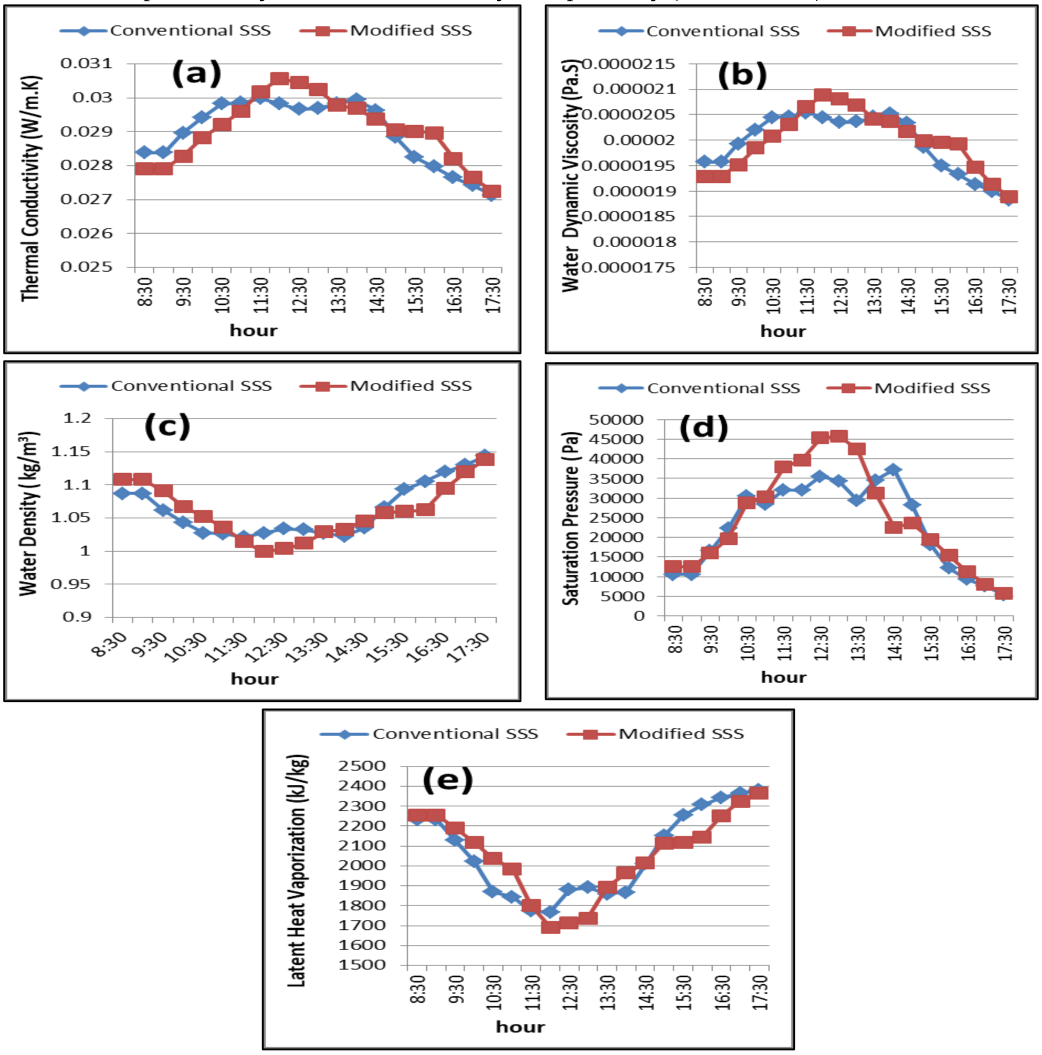


Fig. 5. Variations of average hourly thermo-physical properties of: (a) thermal conductivity, (b) water dynamic viscosity, (c) water density, (d) saturation pressure and (e) latent heat of evaporation, for both conventional and modified SSSs.

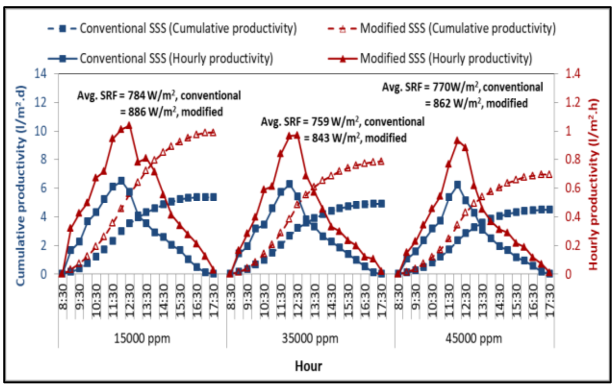


Fig. 6. Variations of hourly and cumulative distillate water productivity for both conventional and modified SSSs at different salinity levels.

Daily SSS efficiency

Determination of daily thermal efficiency of both conventional and modified SSSs at different salinity levels of 15000, 35000 and 45000 ppm have been illustrated as shown in Fig. (7). In general, the daily efficiency decreased by increase of water salinity due to the distillate water productivity negatively affected by increase of salinity level. The modified SSS was higher efficiency more than conventional SSS at any water salinity. The daily efficiency of modified SSS was found to be 64.2, 52.3and 45.7% at salinity of 15000, 35000 and 45000ppm, respectively, while for conventional SSS, it was about 39.6, 37.0 and 33.4% at the same salinity levels, respectively.

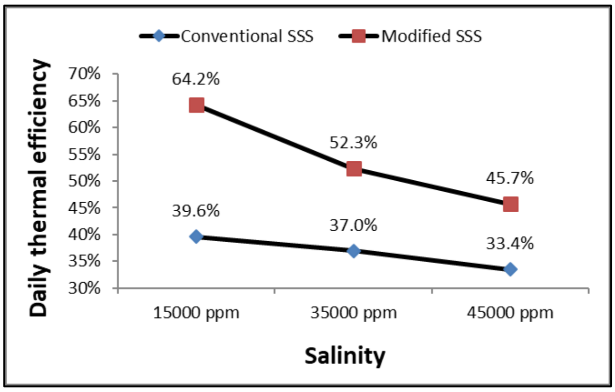


Fig. 7. Daily thermal efficiency of both conventional and modified SSSs at different salinity levels.

Cost estimation

The cost estimation of the solar distillation is necessary, thus fabricating of solar stills using simple and cheap materials should be preferred. In this study a very simple modification using external booster mirrors with SSS was investigated to can increase the productivity of distillate fresh water compared to the conventional SSS. Since, cost of solar still depends on distillate water productivity that depends on solar radiation fluxes, so, the cost of one liter of distillate for modified SSS is estimated compared to the conventional one.

The total fixed cost for both conventional and modified SSSs including prices of materials and fabrication was about $TFC_{conventional}$=1700EGP and $TFC_{modified}$=2100EGP. The variable cost is assumed 30%TFC per year according to (Kabeel, 2009). Then total cost considering still life time of 10years is obtained by TC=1.3TFC×10, so, $TC_{conventional}$= 1.3×860×10=11180EGP and $TC_{modified}$=1.3×1050×10=13650EGP. Then, the cumulative daily productivity multiplied by 340 is taken assuming that the solar still operates 340 days/year, where the sun rise along the year in Egypt according to (Omara *et al*., 2014). Fig. (8) showed the estimated annual cost of one liter distillate (in EGP; 1 $ = 15.7 EGP)for both conventional and modified SSSs as (1.33 and 0.88), (1.46 and 1.107) and (1.6 and 1.25) at different salinity levels of 15000, 35000 and 45000ppm, respectively.

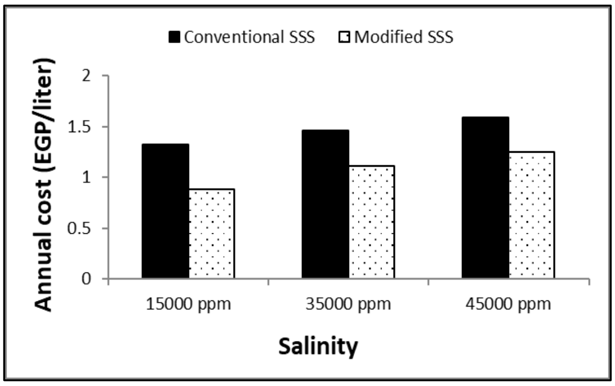


Fig. 8. Annual cost of one liter distillate for both conventional and modified SSSs at different salinity levels.

CONCLUSION

In this study, a modified stepped solar still using external top and bottom booster mirrors as reflectors was investigated in order to assess its productivity and thermo-physical properties compared to the conventional one. The obtained experimental results revealed that, performance of the modified still was better than the conventional one. In a comparison of modified still results compared to the conventional still:

- The maximum and average T_g increased with 14.3 and 21.2%, respectively.
- The maximum and average T_w increased with 11.5 and 13.8%, respectively.
- The maximum and average T_{abs} increased with 8.6 and 8.4%, respectively.
- The maximum and average T_v increased with 2.5 and 4.9%, respectively.
- The daily productivity increased with 84.2, 60.9 and 55.6 % at 15000, 35000 and 45000 ppm of salinity levels, respectively.

Additionally, some thermo-physical properties of modified still were estimated:

- The thermal conductivity ranged from 2.906E-02 to 3.06E-02 W/m.K
- The water dynamic viscosity ranged from 1.9E-05 to 2.09E-05 Pa.s
- The saturation pressure ranged from 5818.8 to 45784.8 Pa
- The water density ranged from 0.99937 to 1.139 kg/m^3
- The latent heat of evaporation ranged from 1691.2 to 2364.1 kJ/kg.
- The daily thermal efficiency of modified SSS was found to be 64.2, 52.3and 45.7% at salinity of 15000, 35000 and 45000ppm, respectively.

Furthermore, the annual cost of one liter distillate (in EGP; 1 $ = 15.7 EGP) for both conventional and modified SSSs was estimated as (1.33 and 0.88), (1.46 and 1.107) and (1.6 and 1.25) at different salinity levels of 15000, 35000 and 45000ppm, respectively.

REFERENCES

Arunkumar, T; Jayaprakash, R; Prakash, A; Suneesh, P; Karthik, M; and Kumar, S. (2010). Study of thermo physical properties and an improvement in production of distillate yield in pyramid solar still with boosting mirror. *Indian Journal of Science and Technology*. 3(8), 879-884.

Brooker, D.B; Bakker-Arkema, F.W; and Hall, C.W. (1982). Drying cereal grains.

El-Samadony, Y; Abdullah, A; and Omara, Z. (2015). Experimental study of stepped solar still integrated with reflectors and external condenser. *Experimental heat transfer*. 28(4), 392-404.

El-Sebaii, A. (2000). Effect of wind speed on some designs of solar stills. *Energy Conversion and Management*. 41(6), 523-538.

Kabeel, A. (2009). Performance of solar still with a concave wick evaporation surface. *Energy*. 34(10), 1504-1509.

Omara, Z; Kabeel, A; and Abdullah, A. (2017). A review of solar still performance with reflectors. *Renewable and Sustainable Energy Reviews.* 68, 638-649.

Omara, Z; Kabeel, A; and Younes, M. (2014). Enhancing the stepped solar still performance using internal and external reflectors. *Energy conversion and management.* 78, 876-881.

Omara, Z; Kabeel, A.E; and Younes, M. (2013). Enhancing the stepped solar still performance using internal reflectors. *Desalination*. 314, 67-72.

Srivastava, P.K; and Agrawal, S. (2013). Experimental and theoretical analysis of single sloped basin type solar still consisting of multiple low thermal inertia floating porous absorbers. *Desalination.* 311, 198-205.

Tanaka, H. (2009). Tilted wick solar still with external flat plate reflector: optimum inclination of still and reflector. *Desalination.* 249(1), 411-415.

Tanaka, H. (2010). Monthly optimum inclination of glass cover and external reflector of a basin type solar still with internal and external reflector. *Solar Energy*. 84(11), 1959-1966.

Tanaka, H. (2015). Tilted Wick Solar Still with Flat Plate Bottom Reflector: Numerical Analysis for a Case with a Gap Between Them. *Journal of Fundamentals of Renewable Energy and Applications.* 5(4), 1000175.

Tanaka, H; and Nakatake, Y. (2006). Theoretical analysis of a basin type solar still with internal and external reflectors. *Desalination.* 197(1-3), 205-216.

Tanaka, H; and Nakatake, Y. (2009). Increase in distillate productivity by inclining the flat plate external reflector of a tilted-wick solar still in winter. *Solar Energy*. 83(6), 785-789.

Tawfik, M. (2012). Improving the performance of a pyramid-shaped solar still. *Misr Journal of Agricultural Engineering.* 29(4), 1239-1254.

Toyama, S; Aragaki, T; Murase, K; and Tsumura, K. (1983). Simulation of a multieffect solar distillator. *Desalination.* 45(1-3), 101-108.

Velmurugan, V; and Srithar, K. (2011). Performance analysis of solar stills based on various factors affecting the productivity—a review. *Renewable and sustainable energy reviews.* 15(2), 1294-1304.

تحسين أداء المقطر الشمسي المتدرج باستخدام المرايا العاكسة الخارجية

وسام السيد عبد الله، محمد عبد الوهاب، منى محمد أبو هاشم و حنان محمد الشال

قسم الهندسة الزراعية ، كلية الزراعة، جامعة الزقازيق، مصر

يعد توفير المياة العذبة للسكان الذين يعيشون في المناطق والجزر النائية أمراً ضرورياً لإمدادهم بالكميات اللازمة من المياة الصالحة للشرب، لذا ُتستخدم المقطرات الشمسية لهذا الغرض. في محاولة لتحسين الإنتاجية الفيزيقية الحرارية وإنتاجية المقطر الشمسي المتدرج (السلالم المتدرجة-SSS) كهدف رئيسي لهذا البحث، تم تثبيت مرايا عاكسة خارجية في الحافة العلوية بزاوية ١٥ مْ مع الرأسي والسفلية ٥٠ مْ مع الأفقي لمقطر شمسي متدرج تم تصنيعه بمواصفات ٤ سم عرض التدرج وعمق ٢ سم ولوح امتصاص من الألمونيوم بمساحة سطحية ٠,٤٦ م٢، و تم طلاؤه باللون الأسود. تم استخدام وحدتين من المقطرات الشمسية المتدرجة (احداهما تقليدية بدون تثبيت مرايا والأخري بنفس مواصفات التصنيع ولكن تثبيت المرايا العاكسة العلوية والسفلية). وتم تقييم أدائهما المتمثل في كمية الإنتاجية ودرجات الحرارة وبعض الخصائص الفيزيقية الحرارية وذلك باستخدام ثلاثة مستويات مختلفة من ملوحة المياه هي ١٥٠٠٠ ، ٣٥٠٠٠ و ٤٥٠٠٠ جزء في المليون كمحاكاة للماء قليل الملوحة والماء المالح تحت نطاق من تدفقات الإشعاع الشمسي من ٢٦٧ إلى ٩٩٨ و ٢٧٠ الى ١١٤٣ وات/م٢ للمقطر التقليدي والمعدل علي الترتيب (التدفق المتزايد للاشعاع الشمسي بالنسبة للمقطر المعدل يرجع الي إجمالي الاشعاع الشمسي المنعكس علي السطح المستقبل مضافاً اليه الاشعاع الشمسي الساقط مباشرة كما فى التقليدي) ، ومدي درجات حرارة للوسط المحيط من ٣١,٢ إلى ٣٧,٦ درجة مئوية. أجريت التجارب في كلية الزراعة جامعة الزقازيق،محافظة الشرقية، مصر (خط العرض ٣٠,٥ درجة - خط الطول ٣١,٥ درجة). أوضحت النتائج المتحصل عليها -زيادة درجات الحرارة القصوى باستخدام المقطر الشمسي المتدرج المعدل باستخدام المرايا العاكسة مقارنة بالآخر التقليدي بنسبة ١٤,٣ و ١١,٥ و ٨,٦ و ٢,٥٪ للزجاج والماء واللوح الماص والبخار على الترتيب. - بلغ نصيب المتر المربع من الإنتاجية اليومية للمقطر المعدل ٩,٩١ ، ٧,٨٧ و ٦,٩٧ لتر/م٢ بزيادة بلغت ٨٤,٢ و ٦٠,٩ و ٥٥,٦٪ مقارنة بإنتاجية المتر المربع للمقطر التقليدي عند مستويات ملوحة المياه المذكورة عاليه، على الترتيب. - علاوة على ذلك ، تم تقدير الخصائص الفيزيقية الحرارية لكل من المقطرات التقليدية والمعدلة بناء علي القيم المتوسطة المتحصل عليها من درجات الحرارة لجميع مستويات الملوحة. وكانت بالنسبة للمقطر المعدل: مدي الموصلية الحرارية من ٢,٩٠٦ ×١٠-٢ إلى ٣,٦ ×١٠-٢ وات/م.كلفن، مدي اللزوجة الديناميكية للماء من ١,٩ ×١٠-٥ إلى ٢,٠٩ ×١٠-٥ باسكال.ثانية ، مدي ضغط التشبع من ٥٨١٨,٨ إلى ٤٥٧٨٤,٨ باسكال ، مدي كثافة الماء من ٠,٩٩٩٣٧ إلى ١,١٣٩ كجم/م٣ ، مدي الحرارة الكامنة للتبخير من 1691.2 إلى2364.1 كيلوجول/كجم، و الكفاءة اليومية قدرت بـ ٦٤,٢، ٥٢,٣ و ٤٥,٧% لمستويات الملوحة المذكورة عاليه، علي الترتيب.- أيضا تم تقدير تكلفة انتاج اللتر الواحد من الماء المقطر (بالجنيه المصري) حيث بلغت (١,٦٠ و ١,٢٥) ، (١,٤٦ و ١,١٠٧) و (١,٣٣ و ٠,٨٨) باستخدام كلا المقطرات التقليدي والمعدل علي الترتيب، عند مستويات الملوحة الثلاثة السابق ذكرها عاليه. - في النهاية ، يمكن التوصية باستخدام المقطر الشمسي المعدل باستخدام المرايا العاكسة العلوية والسفلية نظرًا لنتائجها المحسنة للإنتاجية والخصائص الفيزيقية الحرارية مقارنةً بالمقطر المتدرج التقليدي البسيط بدون مرايا عاكسة.