PERFORMANCE EVALUATION OF TWO DEFFERENT ACTIVE SOLAR STILLS

Mona F.M. Atia[1*], M.M.A. El-Sharabasy[2] and M.A. Tawfik[1]

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

2. Agric. Eng. Dept., Fac. Agric., Damietta Univ., Egypt

ABSTRACT: The main goal of this work is evaluating the performance of two solar desalination systems under active mode using an integrated solar flat plate collector (FPC). The first one included a glass covered pyramid solar still (PSS) combined with FPC, whilst the second is consists of a greenhouse solar still (GSS) with the same area of brine basin and provided with transparent acrylic cover and connected to another similar FPC. The two systems were fully powered by solar energy using photo voltaic (PV) system. The pre-experiment was performed to evaluate the thermal performance of FPC to determine the optimum hot water flow rate to be used in the main experiment. The main experiment aims to investigate the performance of the two active solar stills under different brine depths and salinity levels. The effect of using basin auxiliary materials including black wick clothes (BWC) and black rubber mat (BRM) on the performance of solar stills was studied with taking into consideration the performance indicators. The obtained results revealed that, the water flow rate of 0.30 l/min achieved the highest values of maximum and average thermal efficiency for the solar FPC. Furthermore, there was no remarkable difference in the hourly productivity and accumulated yield for active PSS and GSS under the best operating condition of brine depth 1cm, salinity level 10000 ppm using BWC and water flow rate 0.30 l/min. Nevertheless, the instantaneous efficiency of active PSS was higher than active GSS, particularly at noon. The cost of distilled water unit is approximately equal for both stills. In conclusion, the two designs of stills proved a good performance with advantages of lightweight, durability and formability for the transparent acrylic cover of GSS over the fragile glass cover of PSS.

Key words: Active mode, pyramid solar still, greenhouse solar still, auxiliary materials, desalination cost.

INTRODUCTION

Water is the most plentiful resource on earth, covering 75% of the earth's surface. Many countries is suffering from huge shortage of fresh water, particularly in arid and semi-arid region all over the world. The explanation for this problem apparent contradiction is, of course, that 97.5% of the earth's water is salt water within the oceans, seas and other surface water sources is only 2.5% potable water in lakes, rivers and under the ground. The potable water is important, not for human only but also for animals and plants, hence solving this problem must involve better ways of desalination **(Shatat and Riffat, 2014).** Thus, there is an urgent need to great efforts to find out new sources of water to reduce the lack of water all over the world **(Colombo et al., 1999)**. One of the sustainable solutions to face the potable water shortage is the solar distillation by using solar still because this type uses sustainable and renewable energy source to convert the brackish, saline and impure water to potable water. Regarding solar desalination, the solar still basin filled with saline water and covered with transparent glazing cover that makes the temperature of saline water in the basin rises to be evaporated and rises up and condense onto the inner surface of the cover. The distilled

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*Corresponding author: Tel. : +201284311139

E-mail address: monayaliza.monayaliza@yahoo.com

water slide down to the collecting channel, where the distillated water is pure and hygienic **(Al-Hayek and Badran, 2004)**. Nevertheless, the major disadvantage of solar still is the low productivity compared with other desalination system **(Nafey *et al.*, 2002)**. In the same context, the maximum efficiency of solar still is low that around 50% **(Kaushal, 2010)**. The solar still performance need to be enhanced by improving the factors affecting the solar stills. The factors affecting the solar still distilled output water is the solar radiation intensity, ambient temperature, wind speed, temperature difference between glass–water, surface area of saline water , brine depth, titled angle of cover, cover material, cover thickness, areas of absorber plate and condensation **(Nafey *et al.*, 2000; Samee *et al.*, 2007)**. The environmental factors can't be controlled but other factors can be changed to enhance the output of the solar still. The productivity of the solar still can be increased by several modifications such as; integrating flat plate collector, adding energy storing materials **(Velmurugan and Srithar, 2011)**. **Bekheit *et al.* (2001)** observed that the daily yield per still area in the basin solar still mainly depends on the evaporative area and condensing surfaces. Due to the large condensation area, the pyramid solar still is more effective and economical comparing with conventional single slope single basin solar still **(Nayi and Modi, 2018)**. On one hand, solar transparent insulation materials (TIM) with selective cover plates completely transparent to infrared (IR) radiations and have lower heat loss coefficients **(Kaushika and Sumathy, 2003)**. Also, using TIM gives additional gains of solar heat **(Kisilewicz, 2007)**. On the other hand, the auxiliary materials in the basin enhanced the solar still productivity and efficiency, so the stills with aluminum fins covered with cotton cloths are more effective than coir mate and sponge **(Murugavel and Srithar, 2011)**. In the same context, the materials like black rubber, wicked evaporation surfaces **(Nafey *et al.*, 2001; Kabeel, 2009)** and *.. etc.*, are used in basin solar stills which not only increase the basin solar radiation absorption but also increases the heat capacity of the basin due to their properties **(Sakthivel and Shanmugasundaram (2008)**. **Badran *et al.* (2005)** tested two solar stills: solar still coupled with and without collector. They found that production of the first is more than the second.

In light of above, the aim of this study is evaluating the performance of two active stills represent in the greenhouse solar still (GSS) and pyramid solar still (PSS) which fully operated by PV system under different operating conditions represented in salinity level, brine depth and heat absorbing auxiliary materials.

MATERIALS AND METHODS

The present investigation was carried out at Minya Al-Qamh district, Sharkia Governorate, Egypt (Latitude $30^{o}35^{/}$N, Longitude $31^{o}31^{/}$E) during summer months throughout period from July 2017 to August 2017.
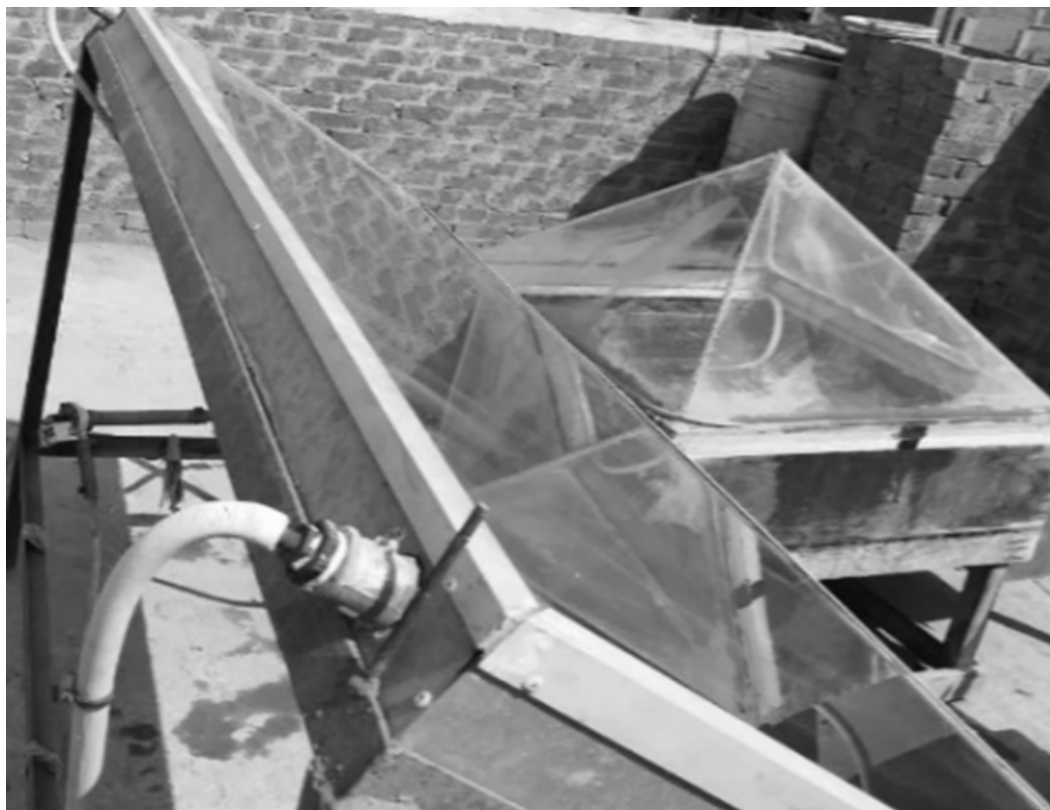
Materials

The solar distillation system

Two active mode desalination systems were constructed and assembled which, one system has GSS and the other has PSS. Each of active solar still was connected to a solar flat plate collector (FPC). The two solar desalination systems were powered by photovoltaic (PV) system. The components of desalination system can be described as follows:

The solar stills

In this work, two different designs of solar still were used. The GSS and PSS were provided with acrylic and glass covers, respectively as seen in Figs. 1 and 2. Each solar still mainly consists of a brine basin, wooden box and transparent cover. The brine basin was made of galvanized iron provided with anti-rust material and black matt paint. The wooden box fixed on four pillars with height of 40 cm above the ground and contains the brine basin. The basin insulated from the bottom and the sides by glass wool layer and sawdust in order to minimize the heat losses from the sides and bottom of the solar still to surroundings. The basin was provided with heat exchanger which was comprised of 5/16 inch (0.793 cm) copper serpentine to make the active mode solar still operation is possible. A plastic tank with 20 l in volume was used to feed each still with the brine by the syphonic process through plastic hose provided with controlling valve. Table 1 shows the specifications of the GSS and PSS.

Fig. 1. Pictorial view of the greenhouse solar still (GSS)

Fig. 2. Pictorial view of the pyramid solar still (PSS)

Table 1. The specifications of the GSS and PSS

Part	Specification of solar still	
	GSS	**PSS**
Basin material	Galvanized iron	Galvanized iron
Area of the basin, m^2	0.56	0.56
Basin depth, mm	100	100
Basin thickness , mm	3	3
Wooden box thickness, cm	2	2
Wooden box dimensions, mm	710×1120	890×890
Wooden box depth, mm	270	270
Total insulation thickness, mm:	150	150
- **Glass wool, mm**	50	50
- **Saw dust, mm**	100	100
Cover material	Acrylic	Glass
Cover thickness, mm	3	3
Cover area, m^2	1.05	0.623

The solar flat plate collector (FPC)

Two similar FPCs were connected to each still for active mode operation. The flat plate solar collector was designed as rectangular section shape, where the absorber plate welded to the black copper pipes and welded to aluminum frame with glass cover. The absorber plate with black paint and side walls made of galvanized iron sheet. The FPC was south facing with 30□ tilted angle on horizontal. It was put on iron holder above the ground with a distance of 80 cm. The absorber of FPC was insulated from heat losing with glass wool. The technical description of the solar FPC is shown in Table 2. The tape water is heated by FPC and delivered to the solar still through a copper serpentine wherein, the circulating of water was continued in close loop between the solar still and FPC. The serpentine was soldered to the basin bottom (from outside) as a heat exchanger to heat up the saline water by the hot water. The hot water circulation was done by a centrifugal pump with 70W.

PV system

Two solar panels (Polycrystalline) with total power 350 W (200 W+ 150 W) connected in serial connection were used as a source of power for operating the centrifugal pump to circulate the hot water during the active mode operation for solar stills. A 300 W inverter was used with input and output voltages of 12 VDC and 220 VAC, respectively.

The auxiliary materials

Black wick clothes (BWC) and black rubber mat (BRM) were used as auxiliary materials for absorbing more heat in brine basin.

Methods

The pre-experiment

The pre-experiment was carried out without loads to obtain the optimum flow rate of the hot water through the solar collector. The solar collector filled with tape water at morning so, the fresh water temperature in the solar collector increased to transfer the useful heat gained to

Table 2. Technical description of the FPC

Feature	Value
Glass-cover thickness, mm	5
Glass-cover emissivity	0.84
Tilt angle, degree	30
Length of copper pipe, cm	1.85
Pipe radius , mm (inch)	4.762 (3/16)
Pipe wall thickness, mm	1
Absorber thickness (Aluminum),mm	3
Absorber dimension (L ×W), m	1.90 × 0.70
Absorber emissivity	0.40
Header pipe diameter , mm (inch)	19.05 (3/4)
Insulation layer thickness (Rockwool), mm	50

the solar still through the heat exchanger (the copper serpentine) beneath the brine basin. Three water flow rates of 0.30, 0.45 and 0.55 l/min without loads were used to determine the flow rate that achieves the highest heat gained and thermal efficiency; hence it can be used in the main experiment.

Preparing the brine

To prepare the brine, 10 and 35 g of fine salt was added to liter of water for obtaining the salinity levels of 10000 and 35000 ppm (mg/l= 1ppm), respectively. The continuous agitation to the point of total melting solution is very important before pouring the brine into the feeding tank to start the experiment.

The main experiment

The main experiment was carried out during the period from 8.00 am to 4.00 pm in each of experimental day. The experiment intended to evaluate two types of active solar stills represented in GSS and PSS under the following operating parameters:

1. Three different brine depths of 1, 3 and 5 cm.

2. Two levels of salinity concentration 10000 and 35000 ppm intended to simulate the brackish water and seawater, respectively.

3. Two auxiliary materials of BWC and BRM used in brine basin comparing to the basin without auxiliary materials.

Measuring and Determinations

Weather conditions

Solar radiation intensity (W/m^2) was measured and recorded every 10 min using solar power meter, resolution 0.1 W/m^2, with measuring range of 0-2000 W/m^2, and accuracy $\pm$ 10 W/m^2.

Temperatures

The temperature of the ambient (T_{am}), outer cover (T_{co}), the inner cover (T_{ci}), the space between the brine and the inner cover (T_s), brine (T_{br}), bottom of basin (T_b), the inlet and outlet water (T_{fi}, T_{fo}) from the FPC were measured every 10 min by using K-type thermocouple sensors which can be inserted to digital thermometer (Model Omron E5C4, Japan) with resolution of 0.1°C.

Useful heat gained

It represents the heat stored in the hot water due to flowing through the solar FPC which can be estimated by the following relation given by **Kargarsharifabad et al. (2014)**:

$$Q_C - MC_p (T_{out} - T_{in}) \dots\dots\dots (1)$$

Where:

Q_c = the useful heat gained (W).

M= mass flow rate (kg/sec.).

C_p = specific heat of hot water (J/kg □C).

T_{out} = hot water outlet temperature (□C).

T_{in} = water inlet temperature (□C).

The thermal efficiency of FPC (η_{th})

The thermal efficiency of the solar FPC is the useful heat gained divided to the available incident energy from the sun onto the FPC surface, as the following equation given by **Kalogirou (2013)**:

$$\eta_{th} = \frac{Q_c}{G \times A_c} \times 100 \quad ....(2)$$

Where:

η_{th} = thermal efficiency,(%)

G = the intensity of solar radiation (W/m^2)

A_c = collector surface area (m^2)

The instantaneous efficiency of the solar stills (ηi)

The productivity of the solar still was calculated by weighting the collected distilled water from the receiving bottles every hour and then the total productivity can be evaluated. The instantaneous efficiency is an indicator to the amount of the useful solar energy gained by the solar still basin. By using the relation that given by **Duffie and Beckman (1991)**, the instantaneous efficiency (ηi) can be determine hourly as follows:

$$\eta i = \frac{m_D \times h_{fg}}{A_g \times G} \times 100\% \quad ....(3)$$

Where:

m_D = production rate of the solar still (kg/hr.)

h_{fg} = water latent heat of evaporation (2260 kJ/kg)

G = solar radiation flux (kJ/m^2.hr.)

Ag = cover collecting area (m^2)

Cost analysis

The cost analysis was carried out for the desalination systems of GSS and PSS on basis of life time the desalination system taken as 10

years (1\$=17EGP–year of 2017) using equations given by **Fath *et al.* (2003)** as follows:

$$C_{RF} = \frac{i(1+i)^n}{(1+i)^n - 1} \quad ....(4)$$

C_{RF} =capital recovery factor

i= is the interest per year, which is assumed as 12%.

n= is the number of life years, which is assumed as 10 years in this analysis.

$$FAC = P \ (CRF) .... (5)$$

FAC=fixed annual cost, (EGP).

P=capital cost of desalination system, (EGP).

$$S_{FF} = \frac{i}{(1+i)^n - 1} \quad ....(6)$$

S_{FF} = sinking fund factor.

$$ASV = 0.2P \ (SFF) ....(7)$$

ASV = annual salvage value

$$AMC = 0.15 \ FAC .... (8)$$

AMC= annual maintenance operational cost, (EGP/y).

$$AC = FAC + AMC - ASV ...... (9)$$

$$C_{PL} = \frac{AC}{M} ....(10)$$

C_{PL} =cost of distilled water per liter, (EGP/L).

AC= annual cost, (EGP/y).

M=annual productivity, (L/y).

RESULTS AND DISCUSSION

Distribution of Hourly Total Solar Radiation

Fig. 3 show that the solar radiation intensity (SRD) increased in the morning until it reached the maximum value around noon period, then it started to decrease gradually to reach the minimum value at the end of experiment of day. As well, the same trend was observed in the hourly productivity and instantaneous efficiency. It was obvious that from the experimental day of July 20 has the maximum hourly SRD with value 1010 W/m^2 and the average of SRD was 801.11 W/m^2. Fig. 3 depicts that the temperature of ambient (T_{amb}), outer cover (T_{co}), inner cover
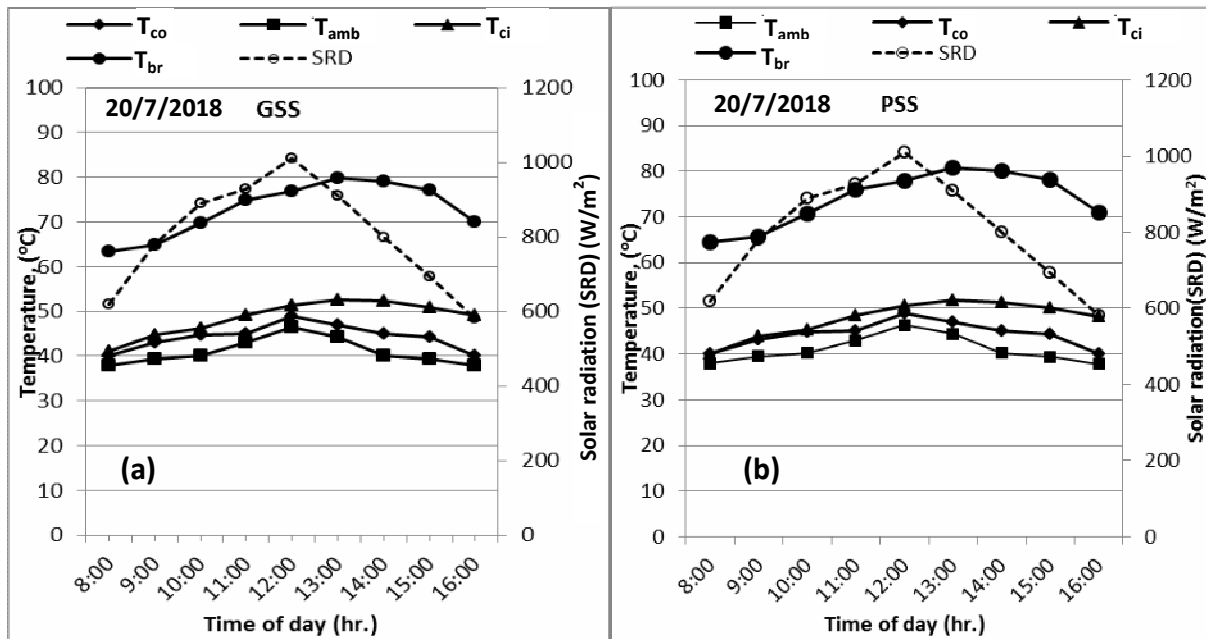
Fig. 3. Variation of ambient (T_{amb}), Cover (T_{co}, T_{ci}), brine (T_{br}) and solar radiation intensity (SRD) during the maximum radiation day for : a) GSS, b) PSS

(T_{ci}) and the brine (T_{br}) were measured during the maximum hourly irradiation energy day. It is obvious that the maximum values of T_{am}, T_{co}, T_{ci}, and T_{br} were 46.4, 49.0, 52.7 and 79.7 °C, respectively for GSS and 44.4, 47.0, 51.8 and 80.7°C, respectively for PSS. It was noticed that a clear gap in temperature values between the glass cover temperature (T_g) and brine temperature. This can be attributed to the fact of the cover has lower thermal heat capacity compared with the brine. So, using the solar still at noon period can be more effective than the morning hours.

Effect of Flow Rate on the Thermal Performance of the Solar FPC

No doubt that the flow rate of water through the FPC and the incident SRD on its surface area affecting strongly the useful heat gained and the thermal efficiency of FPC. Thus, it is necessary to find out the optimum flow rate of water that achieves the highest useful heat gained and consequently the thermal efficiency. In this work, the practical experiments were performed throughout 4 consecutive days for each flow rate of water wherein, the average hourly values of

the 4 days for SRD, useful heat gained and FPC thermal efficiency were recorded. Fig. 4 show that there is an inversely relationship between the useful heat gained and the water flow rate. Accordingly, the increase in water flow rate led to decrease the useful heat gained, and consequently the thermal efficiency of FPC, as seen in Fig. 5. So, the highest value of the useful heat gained was achieved at the lowest value of water flow rate all over the eight operating hours. The results showed that, the flow rate of 0.30 l/min gave the highest values of maximum and average thermal efficiency for the solar FPC of 62.3 and 58.40%, respectively.

The obtained results revealed that the increase of water flow rate from 0.30 to 0.55 l/min was companied with a remarkable decrease in the daily average values of useful heat gained from 613.11 to 533.4 W and the collector average daily thermal efficiency from 58.4 to 47.2% under daily average values of SRD in the range of 835.9-919.4 W/m² during the experiment period. It is obvious that the water flow rate of 0.30 l/min gave the highest value for each of useful heat gained and collector thermal efficiency.
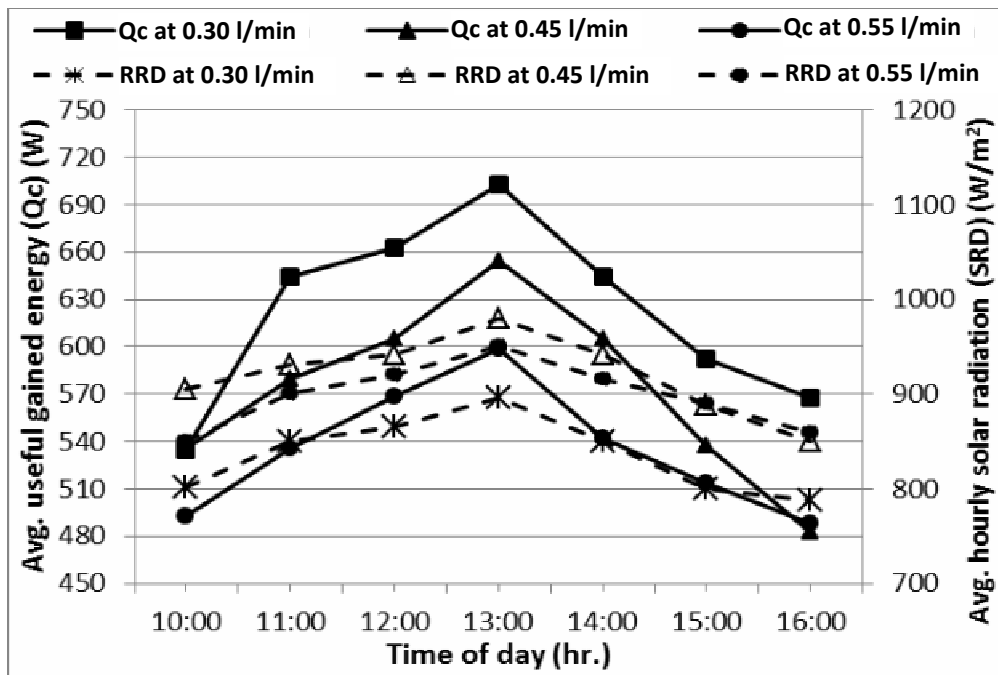
Fig. 4. Effect of water flow rate and SRD on the average hourly values of useful heat gained of FPC during the experiment period
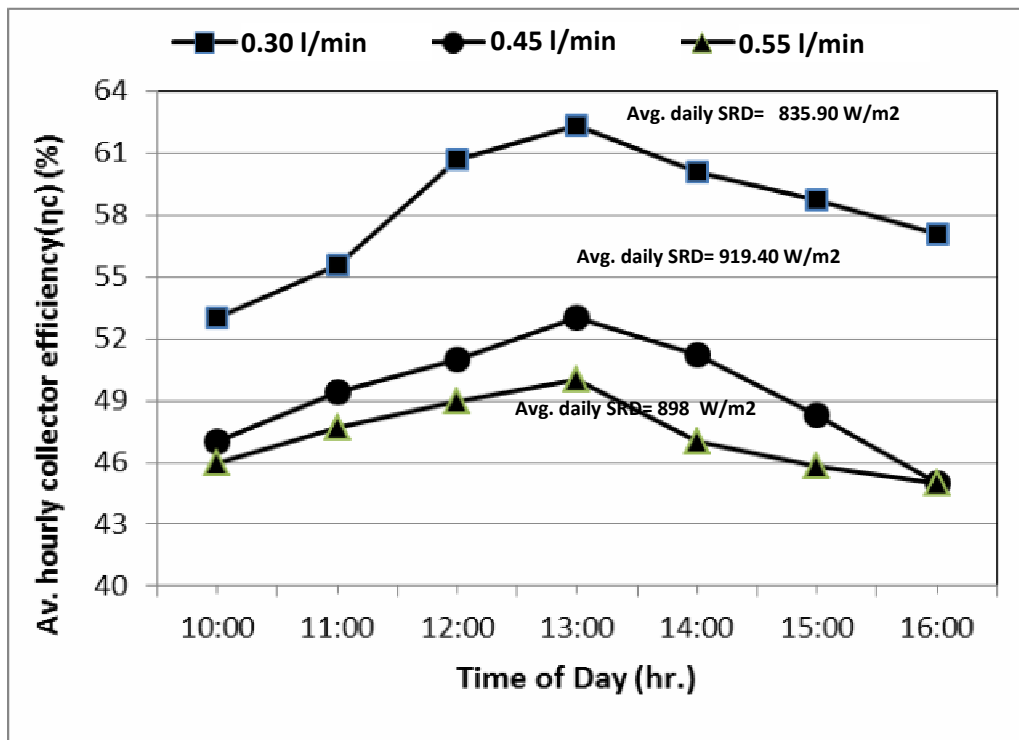

Fig.5. Effect of water flow rate on the average hourly thermal efficiency of FPC during the experiment period

Effect of Brine Depth, Water Salinity and the Auxiliary Black Materials in Basin on the Hourly Productivity of GSS and PSS Under Active Mode

According to the pre-experiment results, the performance evaluation of GSS and PSS were performed through the main experiment under active mode using the optimum water flow rate of 0.30 l/min. The performance of GSS and PSS were evaluated using BWC and BRM in the basin as well as without any auxiliary materials under different brine depths and salinity levels regarding the hourly productivity, as displayed in Figs. 6 and 7. It is clear that, the hourly productivity has the same trend of SRD that rises from the lowest value at morning to reach the maximum value at noon period for all treatments of this work. The obtained results of GSS showed that, the maximum value of hourly productivity were 0.830, 0.980 and 0.920 l/m^2.hr., for without auxiliary materials, BWC and BRM, respectively at brine depth 1 cm, salinity level 10000 ppm. Concerning PSS, the maximum value of hourly productivity was 0.850, 0.990 and 0.970 L/m^2.hr., for each of without auxiliary materials, BWC and BRM, respectively at the same brine depth and salinity level. The results revealed that, the highest average daily productivity of 0.595 and 0.565 l/m^2.hr., were recorded for PSS and GSS, respectively due to using BWC under brine depth 1 cm and salinity level 10000 ppm. The increment in average daily productivity for PSS was 5.03% only over GSS under the optimum brine depth, salinity level and water flow rate of 0.30 l/min. The effect of the different brine depths, salinity levels and auxiliary materials on the accumulated yield of PSS and GSS was depicted in Figs. 7 and 8. The obtained results showed that the maximum value of the accumulated yield for GSS and PSS was recorded by using BWC in the basin at 1 cm brine depth and salinity level of 10000 ppm. It was found that, the increase of salinity level from 10000 to 35000 ppm at brine depth of 1cm led to reduce the accumulated yield of all treatments of this investigation. This is because the increase of water salinity level leads to the high thermal capacity of the brine resulting in an increase in the brine heat capacity. The highest accumulated yield of PSS was 3.54, 5.36 and

3.96 l/m^2 for each of without auxiliary materials, BWC and BRM, respectively. Regarding the GSS, the highest accumulated yield was 3.49, 5.09 and 3.51 l/m^2 for each of without auxiliary materials, BWC and BRM, respectively. There was no remarkable difference between the highest accumulated yield for PSS (5.36 l/m^2) and GSS (5.09 l/m^2) under the best operating conditions of brine depth 1 cm, salinity level 10000 ppm using BWC and water flow rate 0.30 l/min. In conclusion, the two types of active solar still proved good performance; especially there is no need to tracking sun for both designs with advantage of the small condensing area for PSS. Nevertheless, the GSS has cover's advantages of lightweight, durability and formability comparing to the glass cover of PSS.

Effect of Brine Depth, Water Salinity and Auxiliary Materials on the Solar Still Instantaneous Efficiency

It is well known that the solar still instantaneous efficiency mainly depends on the hourly productivity, SRD intensity and the cover collecting area (condensation area). As the previous discussion, there is considerable positive influence of using auxiliary materials in brine basin on the hourly productivity of solar still. This is due to the capability of these materials to absorb more heat and help in increase the distilled water yield, subsequently the instantaneous efficiency of solar stills may enhance.

As seen in Figs. 8 and 9, it is apparent that the solar still instantaneous efficiency decreased as the brine depth and salinity level increased from 1 to 5cm and 10000 to 35000 ppm, respectively under all treatments of this study. This observation can be explained as the increasing of the brine depth and salinity would lead to increase the heat capacity and lowering the brine temperature and consequently the evaporation rate.

The obtained results showed that the maximum instantaneous efficiency of PSS at noon was 50.73%, 62.37% and 61.11% for without auxiliary materials, BWC and with BRM, respectively at the brine depth of 1cm using water salinity of 10000 ppm and water flow rate of 0.30 l/min. On the other hand, the highest instantaneous efficiency of GSS was 33.95%, 42.31% and 32.40% for without auxiliary
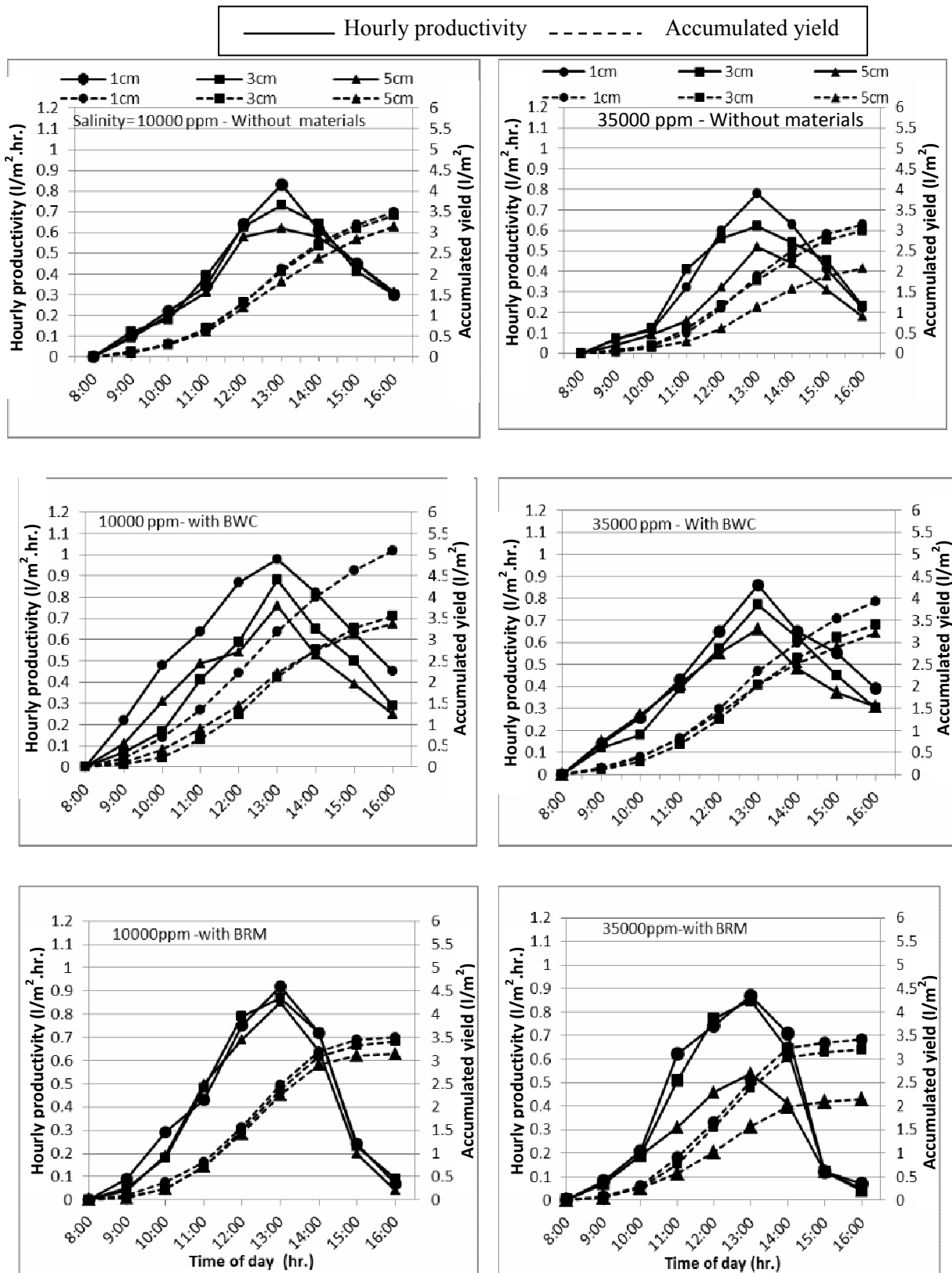
Fig. 6.   Effect of brine depth, salinity level and auxiliary materials on hourly productivity and accumulated yield of the active GSS at water flow rate 0.30 l/min.
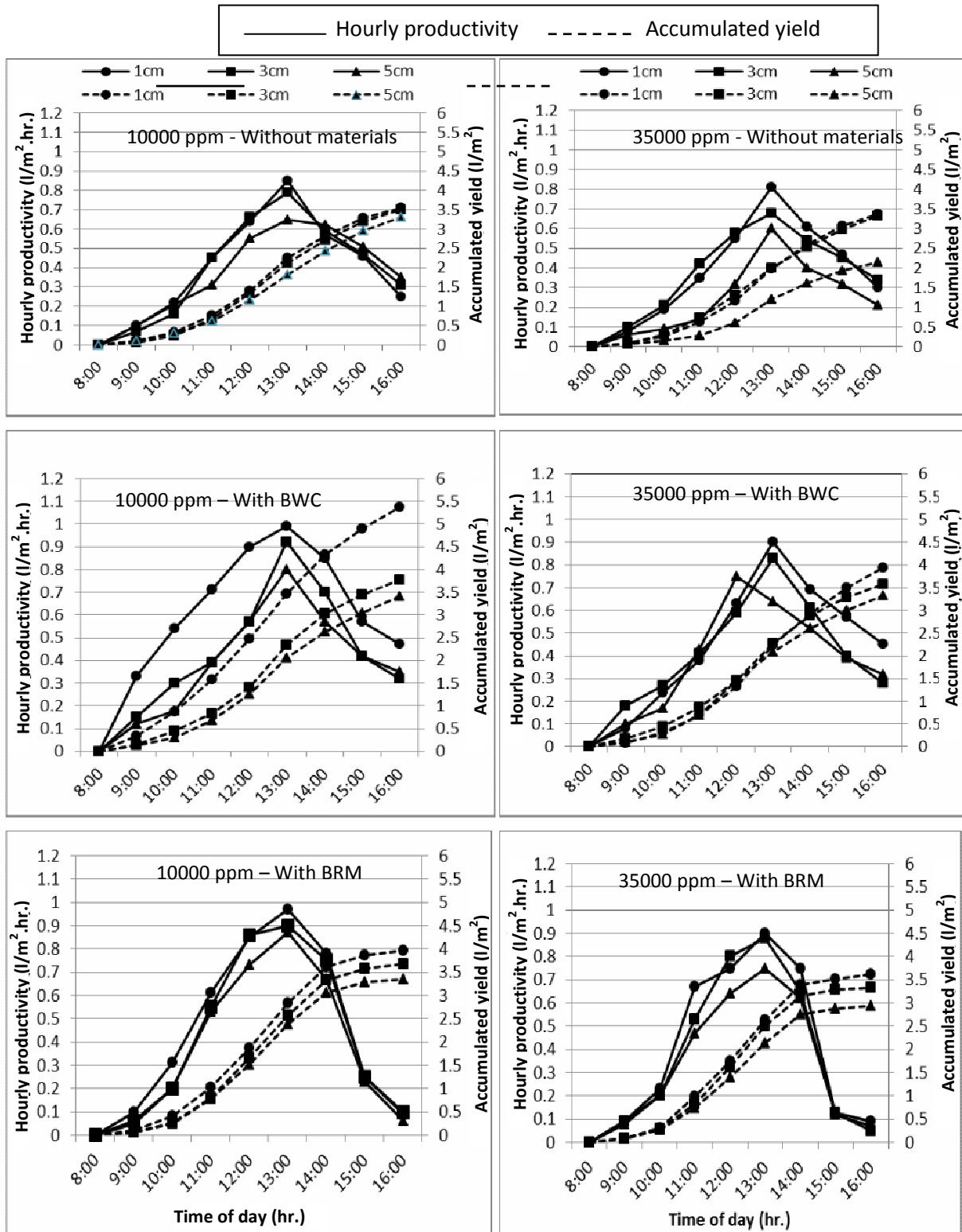
Fig. 7. Effect of brine depth, salinity level and auxiliary materials on hourly productivity and accumulated yield of the active PSS at flow rate 0.30 l/min.
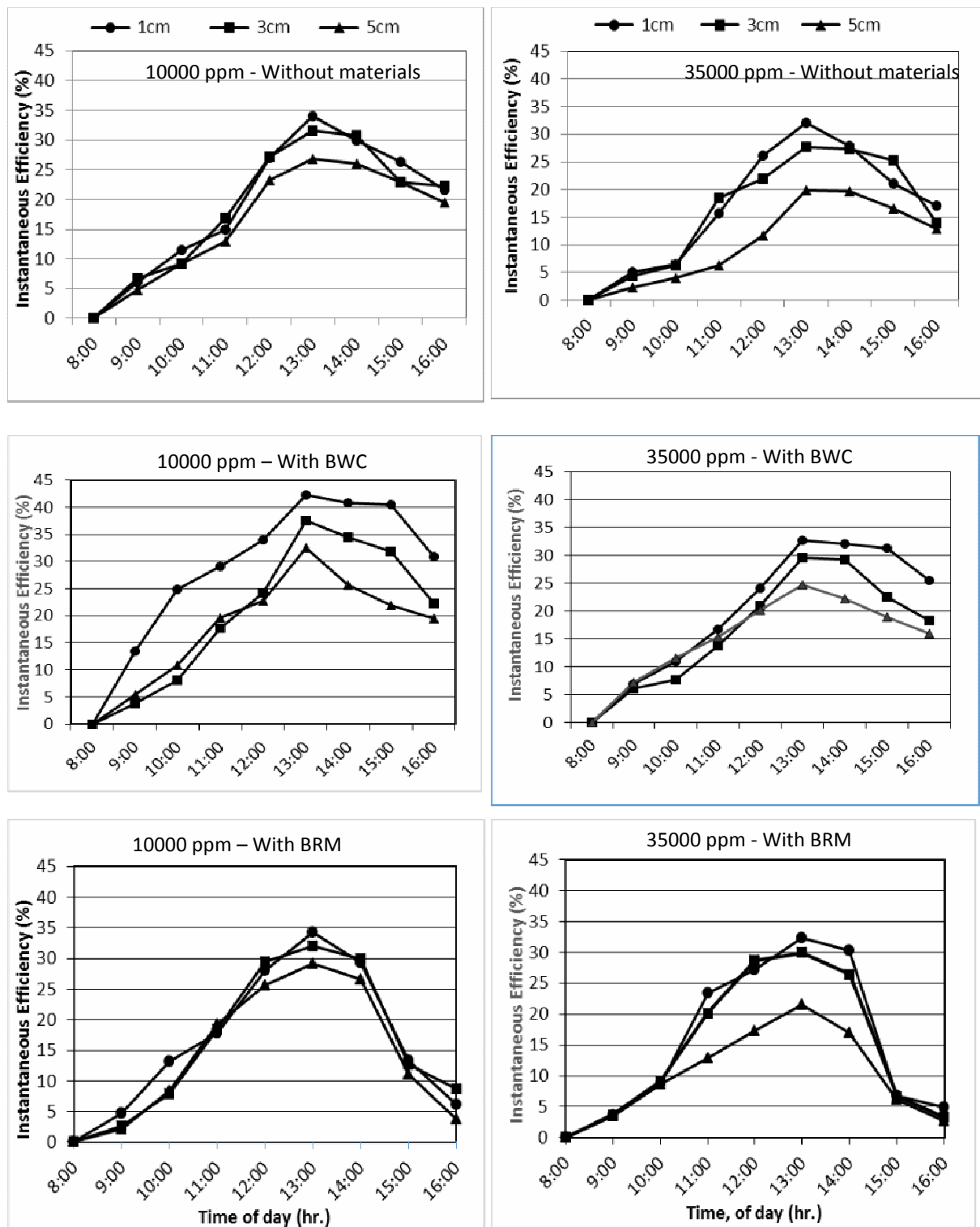
Fig. 8. Effect of brine depth, salinity level and auxiliary materials on the instantaneous efficiency of the active GSS at water flow rate 0.30 l/min.
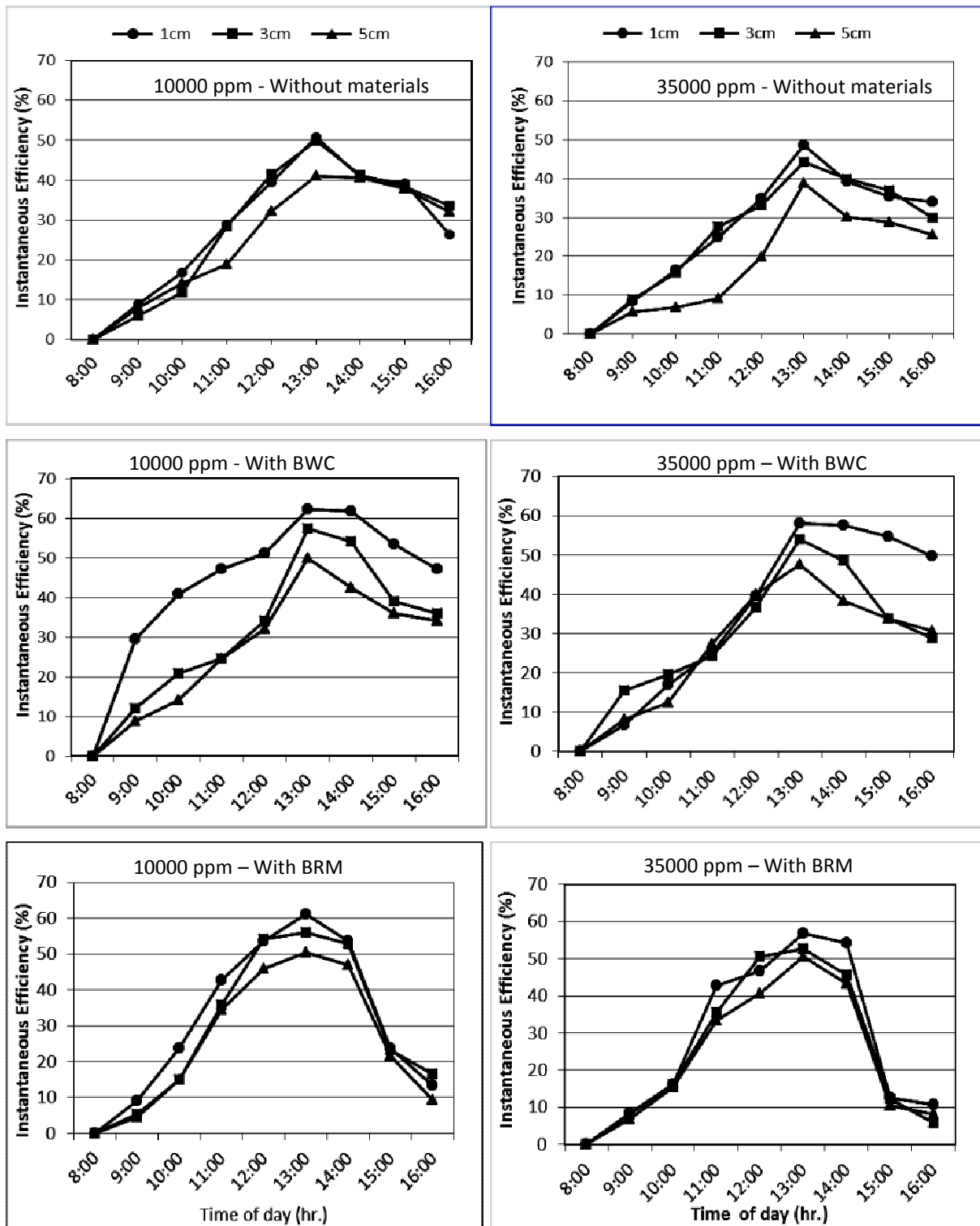
Fig. 9. Effect of brine depth, salinity level and auxiliary materials on the instantaneous efficiency of the active PSS at water flow rate 0.30 l/min.

materials, BWC and BRM respectively at same operating conditions.

It was noticed that using BWC led to conserve the heat within the brine basin during the afternoon period until the end of experimental day (at 4:00pm), comparing to either BRM or without auxiliary materials. It was proved by the obtained data wherein, the instantaneous efficiency declined from the highest 62.37% at noon to 48% for PSS and from 42.31% to 31% for GSS at brine depth 1 cm and salinity of 10000 ppm. In light of above, there is a remarkable increment in the instantaneous efficiency of PSS by 32.16% over GSS at noon using brine depth 1 cm, salinity level 10000 ppm and BWC. Since the difference in hourly productivity for both stills is very tiny, this increment can be referred to the small condensation area of PSS comparing to the GSS. It can be concluded that, the best thermal performance for the solar stills are at brine depth 1cm, salinity level 10000 ppm using BWC, wherein the highest instantaneous efficiency was achieved for the active PSS and GSS.

Effect of Solar Still Design, Brine Depth and Auxiliary Materials on Cost of the Distilled Water Unit at the Optimum Salinity Level

Fig. 10 shows that, the cost of distilled water unit for the two active desalination systems. The cost analysis revealed that, the cost of distilled water unit was increased by increasing the brine depth from 1 to 5cm and salinity level from 10000 to 35000 ppm.

According the calculations, cost of the distilled water unit for PSS desalination system were 0.99, 0.65, 0.88 LE/L for without auxiliary materials , BWC and BRM, respectively at brine depth 1 cm, salinity level 10000 ppm and water flow rate of 0.30 l/min. Whilst, the lowest cost of using GSS desalination system was 1, 0.69 and 0.99 LE/L for without auxiliary materials, BWC and BRM, respectively at the same operating conditions. It can be observed that, remarkable reduction in the cost of distilled water unit by using BWC at brine depth 1cm and salinity 10000 ppm comparing to other depths. Nevertheless, there is no big gap between the cost of desalination for BRM and no auxiliary materials treatments.

As seen in Fig.10, the lowest cost of distilled water unit for PSS (0.65 EGP/l or~0.04 USD/l) and GSS (0.69 EGP/l or~0.04 USD/l) are approximately similar in case of using BWC at brine depth 1cm and salinity 10000 ppm. In summary, the desalination systems contained the two different solar still designs; greenhouse and pyramid have potential economic aspect indeed.

Conclusion

In this work, the thermal performance of two solar desalination systems were evaluated including two different designs of greenhouse solar still (GSS) with acrylic cover and pyramid solar still (PSS) with glass cover which are coupled with solar flat plate collector (FPC) for active mode operation. The active mode was fully powered by PV system. Additionally, the effect of using auxiliary materials represented in the black wicked clothes (BWC) and black rubber mat (BRM) in brine basin was investigated comparing to the treatment of without any material. The results of pre-experiment revealed that, the highest useful gained energy and thermal efficiency were 62.3 and 58.40%, respectively for FPC at flow rate of 0.30 l/min. Regarding the results of main experiment, the highest hourly productivity and accumulated yield for PSS were 0.990 $l/m^2.hr.$, and 5.36 l/m^2, respectively, whilst for GSS were 0.980 $l/m^2.hr.$, and 5.09 l/m^2, respectively under the best operating conditions of brine depth 1 cm, salinity level 10000 ppm using BWC and water flow rate 0.30 l/min. Thence, there is no remarkable difference between productivity of both design. Moreover, the maximum instantaneous efficiency of active PSS and active GSS were 62.37 and 42.31%, respectively with an increment of about 32.16%. From the economic point of view, the lowest cost of distilled water unit for PSS (0.65 EGP/l or ~ 0.04 USD/l) and GSS (0.69 EGP/l or~0.04 USD/l) are approximately similar under same operating conditions represented in brine depth 1 cm, salinity level 10000 ppm, water flow rate 0.30 l/min and using BWC. In conclusion, the two designs of solar still proved good performance with advantages of lightweight, durability and formability for the acrylic cover of GSS over the fragile glass cover of PSS.
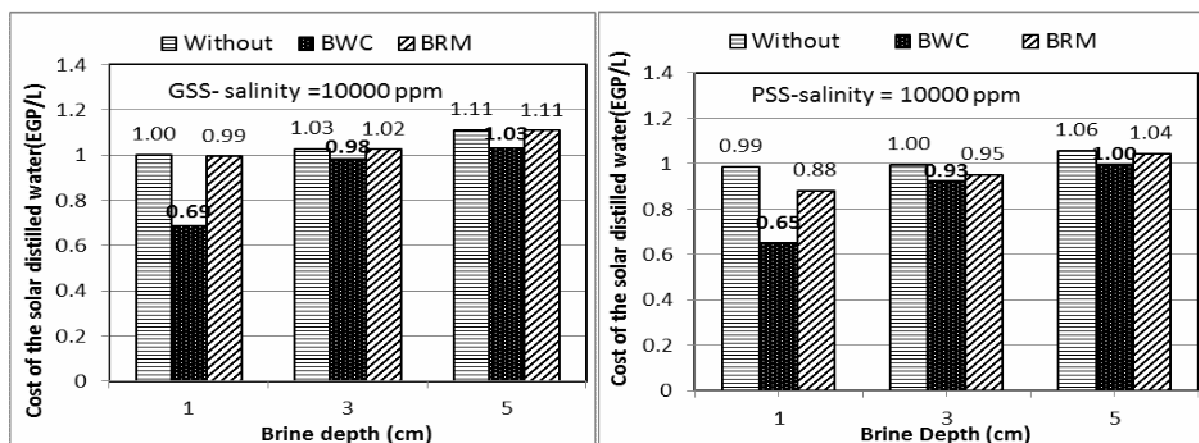
Fig. 10. The costs of the distilled water unit at the optimum salinity level for GSS and PSS

REFERENCES

Al-Hayek, I. and O.O. Badran (2004). The effect of using different designs of solar stills on water distillation. Desalination, 169 : 121 - 127.

Badran, A.A., A.A. Al-Hallaq, I.A.E. Salman and M.Z. Odat (2005). A solar still augmented with a flat plate collector. Desalination, 172: 227-234.

Bekheit, M., A.E. Kabeel, E.A. El-Negiry and A.M. Hamed (2001).Theoretical and experimental investigation of roof-type solar still augmented with corrugated wick of cloth layer. In: 12th Int. Mechanical Power Eng. Conf., Mansoura, Egypt, 73–85.

Colombo, D., M. De Gerloni and M. Reali (1999). An energy-efficient submarine desalination plant. Desalination, 6 (2-3): 122-171.

Duffie, J.A. and W.A. Beckman (1991). Solar Engineering of Thermal Processes. John Wiley and Sons, New York.

Fath, H.E., M. El-Samanody, K. Fahmy and A. Hassabou (2003). Thermal economic analysis and comparison between pyramid shaped and single slope solar still configurations. Desalination, 159: 69-79.

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

Kalogirou, S.A. (2013). Solar Energy Engineering: Processes and Systems. 2nd Ed. Amsterdam: Acad. Press, Elsevier Sci., ISBN: 978-0-12-397270-5.

Kargarsharifabad, H., M. Behshad-Shafii, M. Taeibi-Rahni and M. Abbaspour (2014). Exergy analysis of a flat plate solar collector in combination with heat pipe. Int. J. Environ. Res., 8 (1): 39-48.

Kaushal, A. (2010). Solar stills: A review. Renew. Sustain Energy Rev., 14 (1):446-453.

Kaushika, N.D. and K. Sumathy (2003). Solar transparent insulation materials: a review. Renew. Sustain. Energy Rev., 7(4):317-351.

Kisilewicz, T. (2007): Computer simulation in solar architecture design. Architec. Eng. and Design Manag., 3(2): 106-123

Murugavel, K.K. and K. Srithar (2011). Performance study on basin type double slope solar still with different wick materials and minimum mass of water, Renew. Energy, 36 (2): 612–620.

Nafey, A.S., M. Abdelkader, A. Abdelmotalip and A.A. Mabrouk (2000). Parameters affecting solar still productivity. Energy Convers. and Manag., 42: 1797–1809.

Nafey, A.S., M. Abdelkader, A. Abdelmotalip and A.A. Mabrouk (2001). Solar still productivity enhancement. Energy Convs. Manag., 42:1401–1408.

Nafey, A.S., M. Abdelkader, A. Abdelmotalip and A. A. Mabrouk (2002). Enhancement of solar still productivity using floating perforated black plate. Energy Convers. Manag., 43 (7): 937-946.

Nayi, K.H. and K.V. Modi (2018). Pyramid solar still: A comprehensive review. Renew. Sustain. Energy Rev., 81:136–148

Sakthivel, M. and S. Shanmugasundaram (2008). Effect of energy storage medium (black granite gravel) on the performance of a solar still. Energy Res., 32:68-82.

Samee, M.A., U. K. Mirza, T. Majeed and N. Ahmad (2007). Design and performance of a simple single basin solar still. Renew. Sustain. Energy Rev., 11(3): 543-549.

Shatat, M. and S.B. Riffat (2014). Water desalination technologies utilizing conventional and renewable energy sources. Int. J. of Low-Carbon Technol., 9:1748-1317.

Velmurugan, V. and K. Srithar (2011). Performance analysis of solar stills based on various factors affecting the productivity. Renew. Sustain. Energy Rev., 15 (2): 1294-1304.

تقيــــــيم أداء نـــوعيــــــن مـــن المقطـــــــرات الشمـــــسيــــــة الفعــــالــــة

منى فوزي محمد عطيه¹ ـ محب محمد انيس الشرباصي ² ـ محمد على توفيق¹

١ـ قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢ـ قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

الهدف الرئيسي لهذه الدراسة هو تقييم أداء نظامين لتحلية المياة الفعالة تكاملي مع المجمع الشمسي المسطح. النظام الأول يشمل المقطر الشمسي الهرمي مزود بغطاء زجاجي ومتصل بمجمع شمسي، بينما النظام الثانى يتكون من المقطر الشمسي ذو الصوبه المزود بغطاء أكريلك شفاف ومتصل أيضاً بمجمع شمسي آخر مماثل بحيث أن مساحة حوض المحلول الملحي متساوية في كلا المقطرين، علماً بأن كلا نظامي التحلية يتم تشغيلهما بالكامل بإستخدام الألواح الكهروضوئية الشمسية، أجريت تجربة مبدئية لتقييم أداء المجمع الشمسي المسطح لتحديد أفضل معدل لسريان الماء الساخن خلال المجمع ليتم إستخدامه في التجربة الأساسية، أما التجربة الأساسية كانت تهدف إلى تقييم أداء المقطرين تحت النظام الفعال بإستخدام أعماق مختلفة للمحلول الملحي ودرجة الملوحة، كذلك تم دراسة تأثير إستخدام الأقمشة السوداء والحصيرة المطاطية السوداء داخل حوض المياه المالحة على آداء المقطرين الشمسيين مع الأخذ في الأعتبار جميع مؤشرات الأداء، فقد أوضحت النتائج المتحصل عليها ان معدل تدفق الماء ٠,٣٠ لتر/ دقيقة خلال المجمع قد حقق أعلى قيم لكل من الحرارة المكتسبة و الكفاءة الحرارية للمجمع الشمسي، بالإضافة إلي ذلك فإنه لا يوجد فرق واضح في قيم أقصي إنتاجية في الساعة والأنتاجية اليومية لكل من المقطر الشمسي الهرمي و ذو الصوبه الفعالين تحت أفضل ظروف تشغيل و التي تتمثل في عمق ١ سم للمياه المالحة ومستوى ملوحة ١٠٠٠٠ جزء في المليون مع إستخدام الأقمشه السوداء عند معدل تدفق للماء الساخن ٠,٣٠ لتر/دقيقة، ومع ذلك فإن إستخدام المقطر الشمسي الهرمى الفعال قد حقق كفاءة لحظية أعلي من المقطر الشمسي ذو الصوبه الفعال بشكل عام وخاصة عند الظهيرة تحت ظروف التشغيل المذكورة، أيضاً فإن تكلفة وحدة الإنتاج من الماء المقطر لكل من المقطرين كانت تقريباً متساوية، وفي النهاية فإن كل من المقطرين قد أظهرا أداءً جيداً و فعالاً مع مميزات الوزن الخفيف والمتانة وسهولة التشكيل لغطاء الأكريلك الشفاف بالمقطر الشمسي ذو الصوبة مقارنة بالغطاء الزجاجي القابل للكسر والخاص بالمقطر الشمسي الهرمي.