

Effect of Different Absorbing Materials on The Performance of Basin Solar Still Under Libyan Climate Conditions

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المخلص: تطرح هذه الدراسة العملية استخدام عدة أنواع من السطح الماص للمقطر الشمسي الحوضي لتحسين الإنتاجية من خلال تحسين الامتصاصية. هذه المواد هي المطاط الأسود والصلب والألومنيوم بالطلاء الأسود وبدون الطلاء. تم تصنيع عدد اثنين من المقطرات الشمسية الحوضية المتطابقة باستخدام المواد المتوفرة محليا. تم مقارنة النتائج للمقطرين من حيث الإنتاجية. وتبين من النتائج أن المطاط الأسود أعطى أكبر إنتاجية للمياه النقية يليه الصلب المطلي بالأسود. متوسط التحسين في إنتاجية المياه النقية لمدة ثلاثة أيام كان حوالي 50% عند مقارنة المطاط الأسود مع الألومنيوم المطلي بالأسود ونحو 43% عند مقارنة المطاط الأسود مع الصلب المطلي بالأسود.

Abstract: This experimental study deals with a single-basin solar still using various absorbing materials with and without black painting. Different types of absorbing materials with and without black painting were used to enhance the solar still productivity through improvement in absorptivity. These materials are steel and aluminum with and without black painting and rubber. Two identical solar stills were manufactured using locally available materials. All the results were compared together to reach the best absorbing materials with and without painting that can be used for solar still. It was found that the rubber absorber has the highest water collection during daytime, followed by the black painted steel absorber, then by black painted aluminum absorber and steel without painting absorber. The average enhancement in the daily productivity was about 50% for the rubber absorber compared with the black painted aluminum absorber and about 43% for the rubber absorber compared with the black painted steel absorber.

Keywords: Solar still, Thermal performance, Painting, Absorbing materials, Water collection, Libyan climate

1. INTRODUCTION

The solar still is in a completely airtight envelope formed by wooden frame and a transparent cover at top. The black basin absorbs the maximum part of the transmitted radiation through the cover. Consequently, water contained in the basin heated up and evaporates in the saturated condition inside the still. Water vapor rises up until it is exposed to the cooler inner surface of the cover. Therefore, it condenses as pure water, slides down along the cover bottom surface due to gravity and is collected using drainage. Even people at rural areas using local available materials can easily perform the construction of this type of still. Single slope solar stills are one of the solar devices which can be used for fresh water production. The main drawback of a traditional solar still is the low amount of distilled water produced per unit area which makes the single-basin solar still unacceptable in some instances. Therefore, there is great scope to improve the efficiency of such type of solar stills.

Abdallah et al. [1] presented the effect of using different absorbing materials in order to enhance the solar still yield through improvement in the thermal conductivity. These materials are coated and uncoated porous media. The results showed that the uncoated sponge has the highest water collection during daytime, followed by the black rocks and then coated metallic wiry sponges. On the other hand, the overall average gain in the collected distilled water taking into the consideration the overnight

water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively. Murugavel and Srithar [2] presented performance study on basin type double slope solar still with different wick materials and minimum mass of water. Stills with aluminum rectangular fin arranged in different configurations and covered with different wicks were also tested. The results showed that, the still with light black cotton cloth is the effective wick material. The still with rectangular aluminum fin covered with cotton cloth and arranged in lengthwise direction was more effective. Nafey et al. [3] studied theoretically and experimentally the effect of using the floating perforated black plate at different brine depths under the same operating conditions. They found that using the floating perforated black aluminum plate in the solar still increases solar still productivity by 15% (at brine depth of 3 cm) and 40% (at brine depth of 6 cm). Tiris et al. [4] examined the effects of using various different black-painted absorber materials on the thermal performance of a solar desalination unit. In addition, Akash et al. [5] studied the effect of using different absorbing materials like black rubber mat, black dye and black ink to enhance the productivity of water. They found that the use of absorbing black rubber mat increased the daily water productivity by 38% and black ink increased it by 45%. Black dye was the best absorbing material used in terms of water productivity and enhancement by about 60%. Recently, Abu-Hijleh and

Rababah [6] evaluated experimentally the performance of a solar still with different sizes of black coal and black steel cubes placed in the basin. They showed that the increase in distillate production of the still ranged from 18% to 27.3% compared to an identical still without sponge cubes under the same conditions. Some researchers used the solid material for energy storages in solar distillation Nafey, M. Abdelkader [7] and Naim and AbdelKawi [8]. They examined the use of black gravel and charcoal bed of particles within a single slope solar still as a storage medium. They found that the charcoal particles and the black gravel have improved the productivity. Valsaraj [9] conducted an experimental study of single basin still with absorber aluminum sheet floating over the water surface. The results indicated that, the floating absorber sheet improves the output of the still compared to an ordinary conventional still. Sakthivel and Shanmugasundaram [10] studied the effect of black granite gravel as a storage medium and found that, the still yield was increased by 17%-20%. Rahim [11] developed a conventional still to store excess energy during daytime, which increase evaporation at night. They found that the heat storing capacity of water during daytime is about 35% of the total amount of solar energy entering the still. A single slope single basin solar still with baffle suspended absorber (SBSSBA) to decrease the preheating time of the basin water of solar still was designed and fabricated using locally available materials by El-Sebaii [12]. Comparisons

of the performance of the SBSSBA and the conventional unit, the single slope single basin solar still (SBSS), were carried out. It was found that the daily productivity of the SBSSBA was about 20% higher than that of the conventional still (SBSS). The main objective of the present study is to determine the effect of using different absorbing materials in order to enhance the solar still yield through improvement in the thermal conductivity. These materials are Aluminum no black painting (absorber 1), Aluminum black painted (absorber 2), Steel no black painting (absorber 3), Steel black painted (absorber 4) and rubber (absorber 5). All the results were compared together to reach the best operating technique that can be used for solar still augmentation in the production of drinking water for arid regions in the Libyan desert.

2. EXPERIMENTAL SETUP

Two units of a single slope solar still were designed and constructed to investigate the different design and operating parameters under the same weather conditions. The unit consists of a metallic box ($1 \times 1 \text{ m}^2$) having four sides made of steel sheet (2 mm thick). Two of these sides are of rectangular shape, while the other two sides are trapezoidal as shown in Figure 1. Three holes were made in each unit; two of them are in the base for the drainage and distilled output and the third in the backside for feeding. The sides of each box were painted with white color from the inside in order to reflect the solar radiation to the water surface. The base of each unit was painted with black color to

increase the solar absorption. The effective basin area of each still was kept at 1000 mm x 1000 mm (1 m²) and it is made of different absorbing materials sheet of 1.0 mm thickness. Condensing cover was made of plane thermal glass with (108×147×6) mm³, fixed to the top of the vertical wall of the stills using rubber gasket on bottom sides. The outside walls and the base of unit were insulated with wool insulation of 30 mm thick (thermal conductivity 0.04 W/m K). A collection trough was used for each still box to collect the condensed water. This trough was fixed to the lower rectangular side of the still box. The condensing surface in still unit is the plastic sheet 3 mm thick cover only. The glass cover of still box was adjusted on the edge of the rectangular sides. Silicon rubber sealant was used to prevent leakage from any gap between the glass covers and the still box. Plastic tubes were used to discharge the distilled water from unit to the bottles. The still units were adjusted at the glass angle of 12.5° and oriented to the south with its face. The distilled water is measured hourly through the daytime. Solar radiation intensity, wind velocity and ambient temperature were measured simultaneously by a digital pyrometer, an anemometer and thermometer indicators. The hourly variations of all the above mentioned parameters were used to evaluate average values of each for further numerical computations. The data selected for discussion were based on similar solar intensity pattern for getting concurrent results.

The measuring devices used in the system were as follows: Six thermocouples (type-k) coupled to a digital thermometer with a range from 0 to 99.9°C with ±1°C accuracy were used to measure the temperatures of the various components of the still system. The solar intensity was measured with the help of a calibrated pyranometer of least count 20W/m². It is generally measured as the total solar radiation. A 30mm steel rule fixed to wall was used to measure water level inside the basin with least count ±0.5 mm. The distillate output was recorded with the help of a measuring cylindrical jar with least count 1ml. The ambient air velocity was measured with an electronic digital anemometer of model Lutron AM-4201. It had the least count of 0.1 m/s with 2% accuracy on the full-scale range of 0.2 to 40.0 m/s.

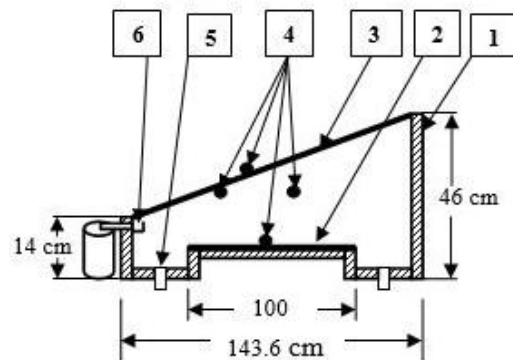


Figure (1). Single slope solar still design
Metallic box and wool insulation (1),
Base plate (Absorber) (2), Glass cover
(3), Different thermocouples (4), Holes
(5), Plastic tubes and bottles (6)

3. RESULTS AND DISCUSSION

The experiment was conducted at the Faculty of Engineering, Sabrta during the

period from 20-5-2012 to 16-6-2012. The conductivity of the used brackish water was measured to be $3530 \mu\text{s}/\text{cm}^3$ and its salinity was $3260 \text{ mg}/\text{l}$ at $27.8 \text{ }^\circ\text{C}$ and 1.5 cm depth of water in the basin. The results obtained are discussed below. Figure 2 compares the hourly productivity and absorber temperature variation of the stills 1 and 2. The variation patterns of absorber temperature and hourly productivity of the stills 1 and 2 are closely matching.

The percentage increase in daily productivity (gain %) was calculated and the calculation was based on the following relation:

$$\text{Gain \%} = 100 \times (\text{P}_n - \text{P}_m) / \text{P}_m$$

Where n is the higher productivity still and m is the lower productivity still for any two solar stills compared. The results of the calculation are presented in Table 1.

Figure 3 shows the effect of water depth for absorbers 4 and 5. The Figure shows that hourly productivity decreased with increased depth of the water.

The absorber 1 (Aluminum no black painting) and absorber 2 (Aluminum black painting) temperatures, glass temperatures and hourly productivity versus daytime for solar still are shown in Figure 4. The absorber surface temperature was around 40°C in early mornings and reaching up to 63°C as a maximum temperature at mid noon. Therefore, at mid noon period, the thermal losses of the solar still were minimal, and the thermal performance increased proportionally. This is attributed

to the increase of the surrounding ambient temperature of the still and higher solar radiation. The enhancement in the daily productivity was about 43.5% for absorber 2 compared with absorber 1 as shown in Table 1.

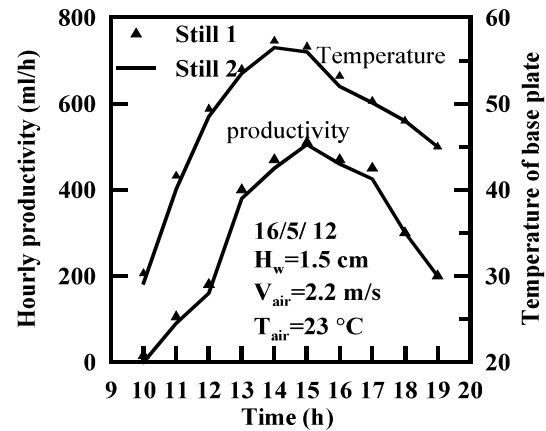


Figure (2). Comparison of hourly productivity and absorber temperature of the two stills 1 and 2.

Figure 5 presents the absorber and glass temperatures and hourly productivity for solar still with absorber 3 (Steel no black painting) and absorber 4 (Steel black painted). The absorber surface temperature was around 35°C in early mornings and reaching up to 62°C as a maximum temperature at mid noon. The enhancement in the daily productivity was about 46.3% for absorber 4 compared with absorber 3 as shown in Table 1.

Figure 6 shows the absorber temperature, glass temperatures and hourly productivity versus daytime for the two solar stills with absorber 4 (Steel black painted) and absorber 2 (Aluminum black painted). The absorber surface temperature was around 65 and 58°C and the glass temperatures was around

45 and 41°C as a maximum temperature for absorbers 4 and 2.

Table (1). Productivity and gain of absorbing materials at different days

Absorbers	Date	\dot{m}_{ap} , ml/m ² day	Gain, %
Absorber 2	20/5/12	3660	43.5
Absorber 1		2550	
Absorber 4	23/5/12	3700	46.3
Absorber 3		2530	
Absorber 4	5/6/12	3610	18.4
Absorber 2		3050	
Absorber 2	7/6/12	3660	43.5
Absorber 3		2550	
Absorber 5	27/5/12	5210	27.7
		4080	
and Absorber 2	28/5/12	4240	33
		3190	
	14/6/12	5890	89.4
		3110	
Absorber 5	30/5/12	4675	33.5
		3500	
and Absorber 4	31/5/12	5770	23.8
		4660	
	16/6/12	6240	73.3
		3600	

The enhancement in the daily productivity was about 18.4% for absorber 4 compared with absorber 2 as shown in Table 1. This is due to higher absorber temperature for steel (65 °C) than that for aluminum (58 °C).

Figure 7 presents the absorber temperature, glass temperatures and hourly productivity versus daytime for the two solar stills with absorber 5 (Rubber) and absorber 2 (Aluminum black painted) at different days. It can be seen that the highest absorber surface temperature and hourly productivity were recorded when using absorber 5 at different days. The enhancement in the daily

productivity was about 27.7, 33 and 89.4% for absorber 5 compared with absorber 2 at 27-28/5 and 14/6/2012 respectively as shown in Table 1.

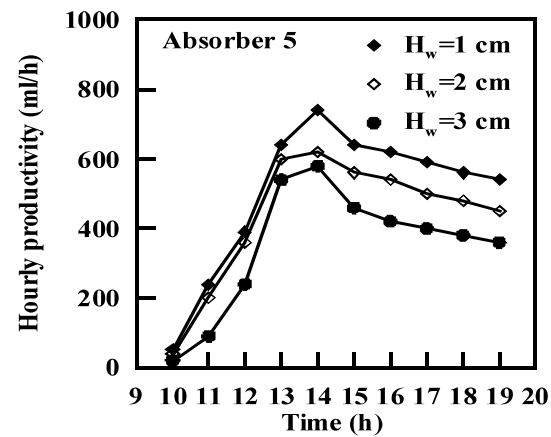
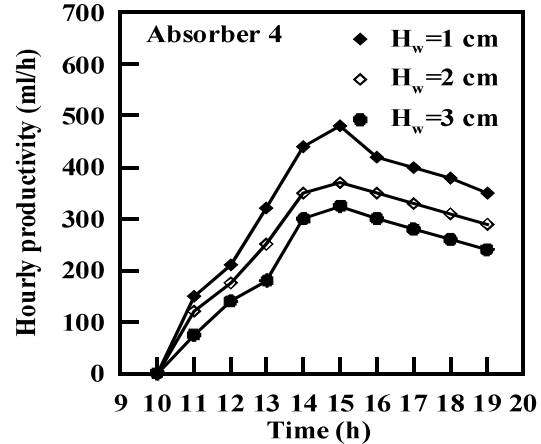


Figure (3). Hourly productivity for the absorbers 4 and 5 at different water depths.

Figure 8 shows the variation of the absorber temperature, glass temperatures and hourly productivity versus daytime for the two solar stills with absorber 5 (Rubber) & absorber 4 (Steel black painted) at different days. It can be seen that the highest absorber surface temperature and hourly productivity were recorded when using absorber 5 at all different days. The enhancement in the daily productivity was about 33.5, 23.8 and 73.3 % for absorber 5 compared with absorber 4 at

30-31/5 and 16/6/2012 respectively as shown in Table 1.

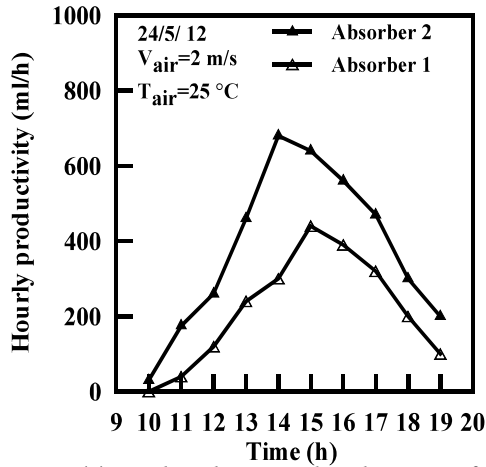
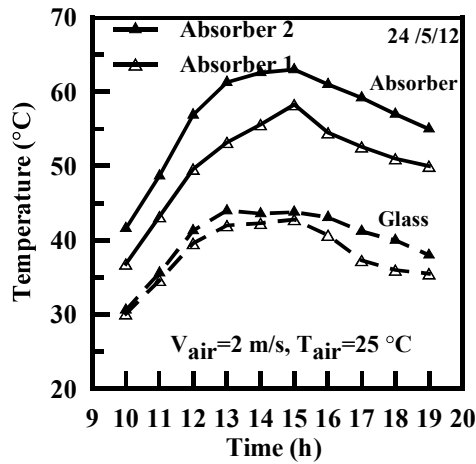


Figure (4). Absorber and glass surface temperatures and hourly productivity for the two solar stills with absorbers 1 and 2.

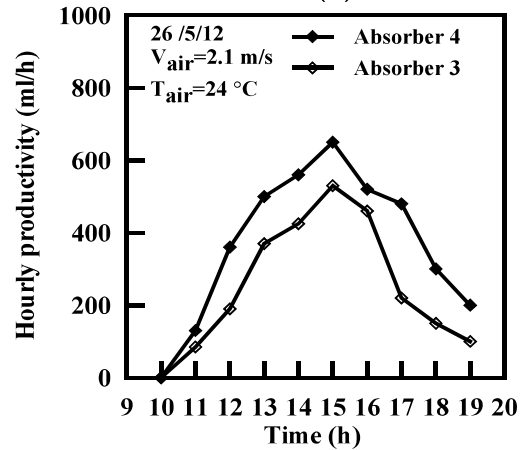
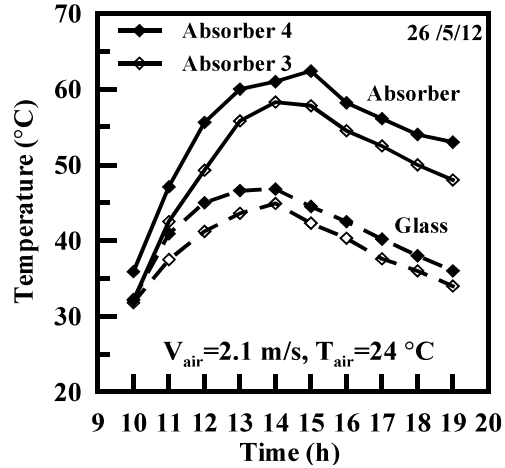


Figure (5). Absorber surface temperature and hourly productivity for the two solar stills with absorbers 3 and 4.

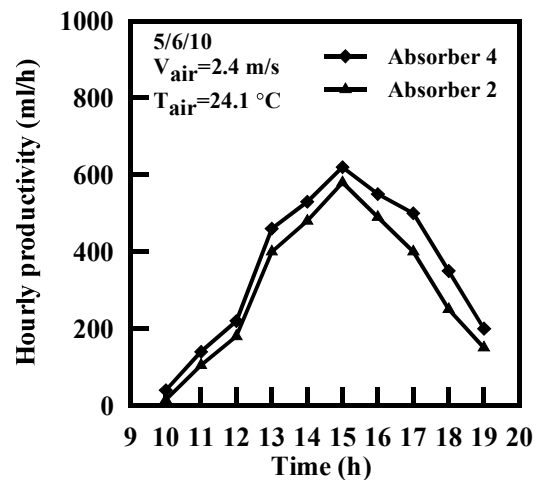
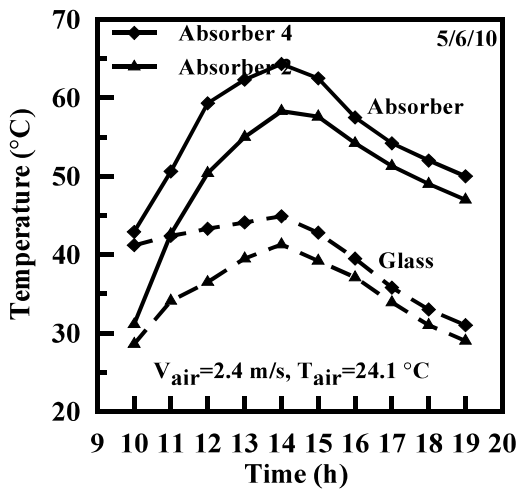


Figure (6). Absorber surface temperature and hourly productivity for the two solar stills with absorbers 4 & 2

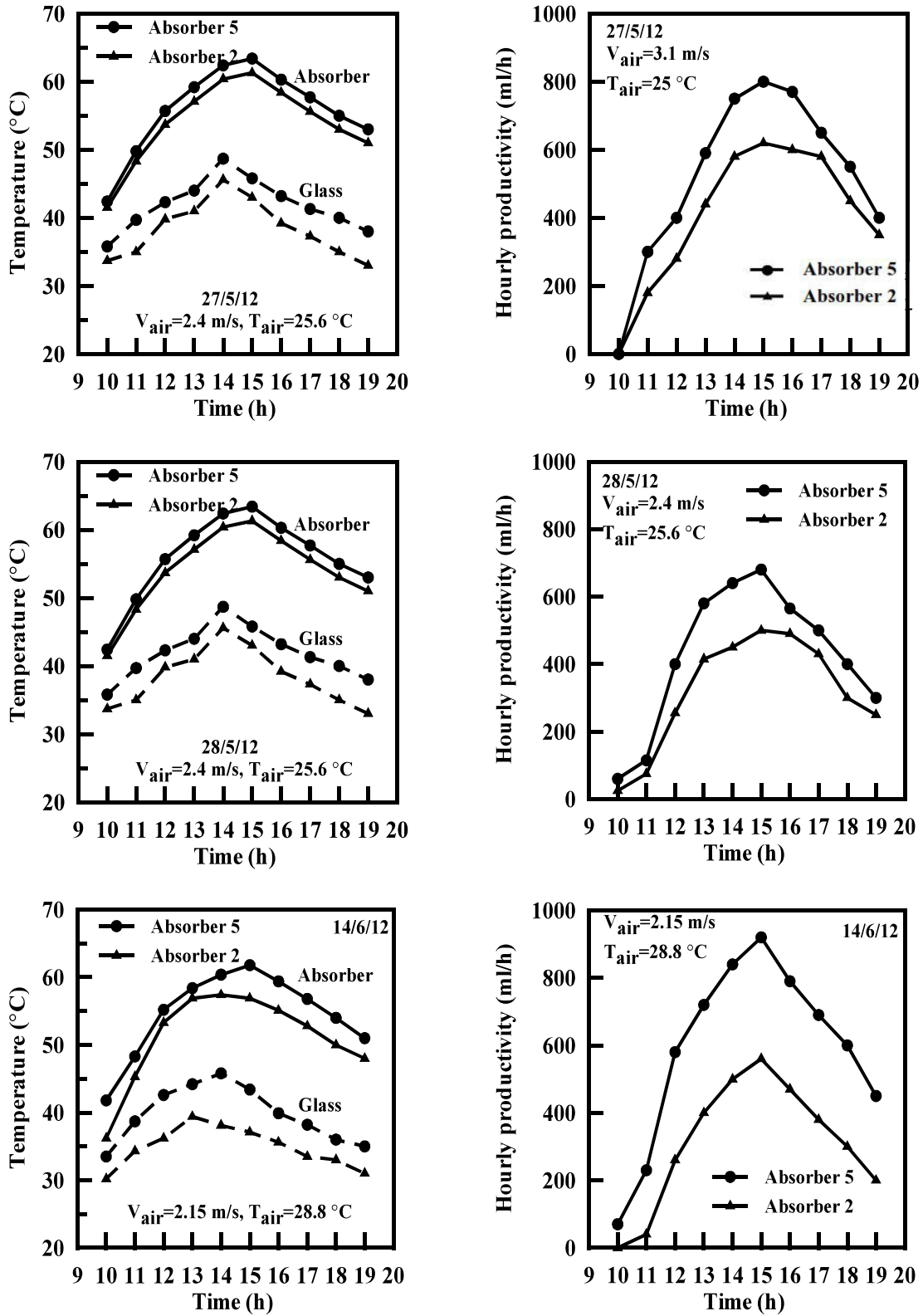


Figure (7). Absorber surface temperature and hourly productivity for the two solar stills with absorbers 2 and 5 at different days

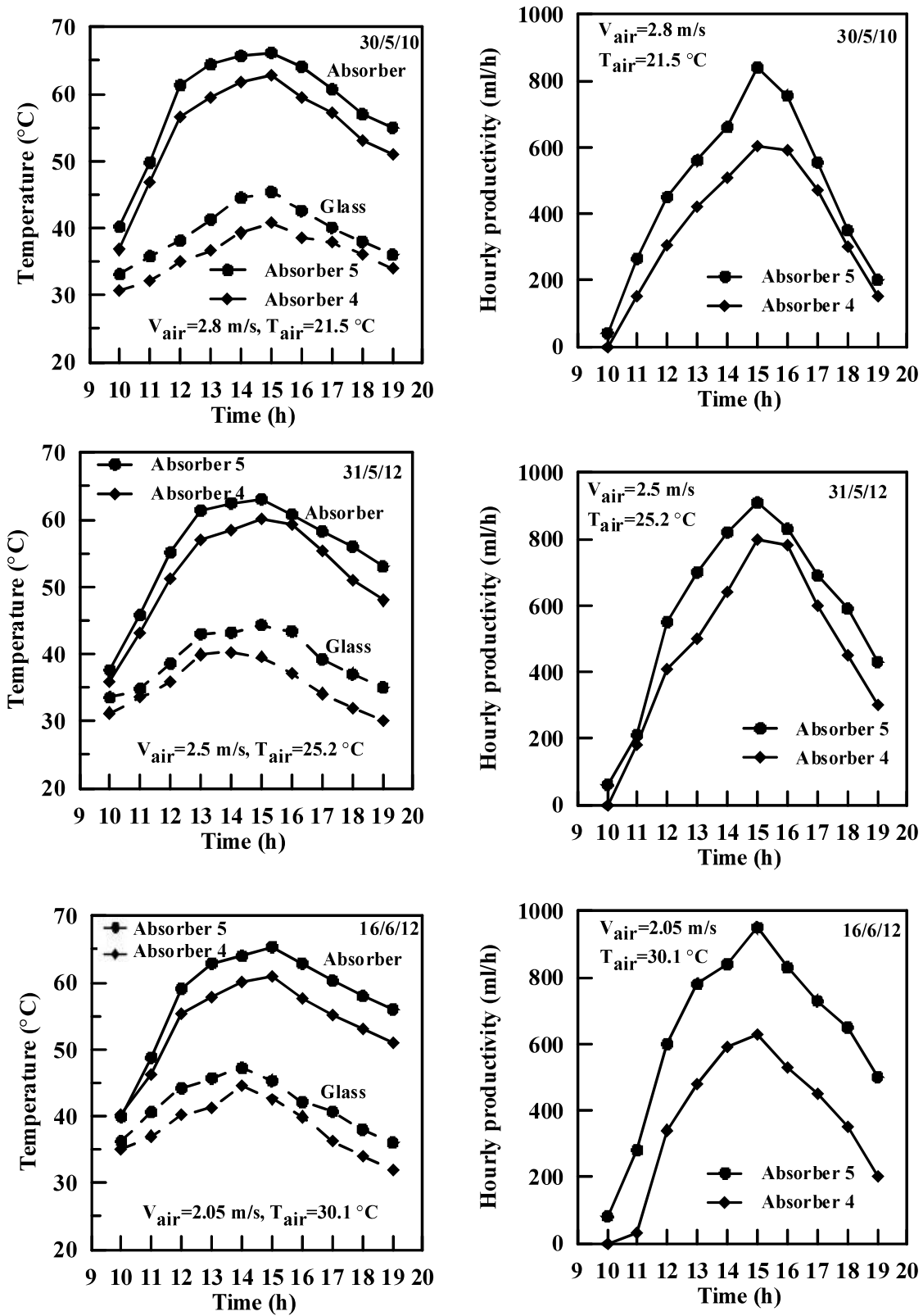


Figure (8). Absorber and glass temperatures and hourly productivity for the two solar stills with absorbers 4 and 5 at different days

4. CONCLUSIONS

An experimental work has been conducted to predict the productivity of a single slope solar still using different painting and absorbing materials. Based on the obtained results, the following conclusions can be drawn:

- The depth of the water over the absorber has a considerable influence on the productivity of the still.
- The absorber 5 (Rubber) has the highest water collection during daytime, followed by the absorber 4 (Steel black painted).
- The lower thermal conductivity of the absorber material increases the productivity of the solar still.
- The black painting of the absorber has clear influence on the increase of solar still productivity.
- The average enhancement for the three days tested in the daily productivity was about 50% for absorber 5 (Rubber) compared with the absorber 2 (Aluminum black painted) while, about 43 % for absorber 5 (Rubber) compared with absorber 4 (Steel black painted).

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