



Investigation the performance of a single slope double basin solar still under Iraqi conditions

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Abstract

Water scarcity is one of the issues facing Iraq and the world, so finding green ways to desalinate water without harming the environment is one of an important factors. One of these methods is the use of solar energy in water desalination. The traditional solar distillation is one of the successful methods in water desalination, but the productivity of the traditional distillation is somewhat low per square meter, so the productivity of the traditional distillation must be improved. For that reason, a double basin solar still may improve the fresh water output by utilizing the condensation latent heat to heat the water in the upper basin instead of losing it to the atmosphere, as in the case of the conventional solar still. The present work aims to examine the solar still with a double basin for three water depths in the lower basin, 10, 20, and 30 mm, on freshwater productivity and daily efficiency. The still basin area is 400 mm × 1000 mm, with six sub-basins constructed above the first glass cover, each 1 L in volume. The experiments were performed in April 2025 under the climatic conditions of Baghdad, Iraq (Latitude: 33.315° N, Longitude: 44.366° E). The results revealed that the productivity of the double-basin solar still is inversely proportional to the water depth of the lower basin. The maximum water temperature is about 74.5 °C for the lower basin and 71.5 °C for the upper basin at 10 mm water depth. The maximum daily productivity is 6788 ml/m² at 10 mm water depth. The overall daily efficiency was 72, 70.1, and 62.44 % for 10 mm, 20 mm, and 30 mm water depth. The double basin solar still enhances the distilled water daily for 10 mm water depth by 2.84 % at 20 mm water depth and 14.32% at 30 mm water depth.



Keywords: Solar desalination; Double basin; Solar still; Productivity; Solar energy.

Nomenclature

English letters		Greek symbols	
CSS	Conventional solar still	τ	Transmissivity
SSDBSS	Single slope double basin solar still	α	Absorptivity
DSDBSS	Double slope double basin solar still	η	Efficiency
CFD	Computational fluid dynamics	Subscripts	
P	Productivity	lb	Lower basin
I	Global solar radiation on a horizontal surface	ub	Upper basin
L	Latent heat of evaporation	h	Hourly
T	Temperature	d	Daily
A	Basin area	w	Water

1. Introduction

Providing high-quality water is becoming important, and solving this issue is difficult in many regions. Drinking water is rare in arid areas with high amounts of thermal solar radiation and high temperatures. The continuation of housing in these regions depends on the capability to produce sufficient amounts of fresh water.

In 2022, 2.2 billion people lacked access to safe drinking water. This included 1.5 billion people with access to clean water within 30 minutes, 292 million with access to clean water further than 30 minutes away, 296 million using unprotected water sources, and 115 million using water from rivers, lakes, dams, or ponds [1]. The WHO recommends an acceptable range of salt in water (500 to 1000) ppm. The amount of salt reduction is evident by considering that the water accessible on Earth has a salt concentration reaching 10,000 ppm. In comparison, the salt concentration of the sea water ranges (35000 - 45000) ppm. The objective of the desalination system is to minimize the salt concentration in water with a TDS of less than 500. Desalination systems need much energy to separate salt and minerals from the seawater. There are many arid regions in the world facing drinkable water issues, and having renewable energy sources



available for use, mainly solar radiation, which can be used to operate desalination processes. These processes are called solar desalination systems. Hence, solar desalination is the way to meet the water demand. The low efficiency of most conventional solar stills is due to inadequate dissipation of the latent heat of the vapor condensation at the glass cover surface. In the double basin solar, the latent heat of vaporization rejected by the glass cover surface of the lower basin is used to heat the upper basin's water rather than release it to the ambient. Therefore, it increases the evaporation and condensation rates in the solar still [2].

Many theoretical and experimental studies have been performed by researchers on solar distillation systems order to improve the efficiency and productivity. Kabeel et al. (2018) [3] investigated the effect of using graphite on the performance of the solar still. The productivity was approximately 4.41 L/day.m² and 7.73 L/day.m² for the conventional solar still and solar still with graphite, respectively. Jani and Modi (2019) [4] evaluated the performance of a single basin dual-slope solar still type equipped with circular and square hollow fins for various water and they found the maximum productivity was 1491.7 and 967.2 L/m².day when using the circular-finned and square-finned solar still, respectively, at 1 cm water depth. Kabeel et al. (2019) [5] improved the productivity of the solar still experimentally by using hybrid storage materials, graphite nanoparticles and paraffin wax as a mixture. The highest improvement in potable water productivity was 94.5% at 3.5 kg of hybrid storage materials compared to that without hybrid materials. Badran et al. (2023) [6] enhanced the productivity of a multi-slope solar still equipped with a photo voltaic (PV) array system. The results revealed that the productivity of the solar still equipped with PV array increased more than three times to reach of 9.39 to 0.9 L/m².day compared to the conventional solar still (CSS). Alaian et al. (2016) [7] investigated experimentally the performance of a solar still equipped with pin-finned wick material. The results showed an enhanced solar still productivity of up to 23%. Modi et al. (2018) [8] investigated the performance of the single-slope double-basin solar still (SSDBSS) experimentally by varying the water level in the lower basin. The daily yields were 2024, 1944, 1892, and 1792 ml/m² for the water depths of (1, 2, 3, and 4) cm, respectively, in the lower basin. Modi et al. (2019) [9] investigated the performance of SSDBSS with and without using nanoparticles. The maximum increase in productivity was 17.6% obtained for the 0.01% concentration weight of Al₂O₃ in the lower basin. Modi et al. (2022) [10] investigated experimentally the effectiveness of SSDBSS



using wick and hollow fins at different water depths in the lower basin. . The results reveal that at 10 mm water depth in the lower basin, the total maximum productivity was about 4.2, 3.9, and 4.1 L/m² from SSDBSS with wick fins, hollow fins, and without fins, respectively. Nadgire et al. (2020) [11] investigated experimentally and analyzed the performance of SSDBSS using computational fluid dynamics (CFD). The results show that the experimental productivity is 3.2 L/m², while it is 3.74 L/m² in CFD simulation. El-Sebaey et al. (2022) [12] investigated experimentally and mathematically for two models of single-basin and double-basin solar stills by varying the water level in CSS and the lower basin of SSDBSS. The results revealed that the total productivity for the CSS and SSDBSS at 20 mm water depth was 1.785 and 2.855 L/m².day, the total productivity is reduced by 15.41 and 14.36% as the equivalent water depth is increased from 20 to 30 mm for the CSS and SSDBSS, respectively. The maximum deviation for the developed model to predict the performance of CSS and SSDBSS was $\pm 6.6\%$. Rajaseenivasan et al. (2013) [13] investigated experimentally and theoretically the effect of varying the water depth in both lower and upper basins on the productivity of the double-slope double-basin solar still (DSDBSS). For the same conditions the DSDBSS productivity is higher than the double-slope single basin solar still by 85%. The deviation between experimental and theoretical was within 10%. Panchal (2015) [14] Improved the productivity of SSDBSS with vacuum tubes. The results showed the productivity increased to 65% with black granite gravel and vacuum tubes, while it increased to 56% with vacuum tubes only for SSDBSS. Raj Kamal et al. (2021) [15] investigated the effect of using external heater in the bottom basin on a CSS and SSDBSS with continuous water circulation. The results of distilled water from SSDBSS and CSS were observed as 5.78 and 2.74 L/m².day, respectively while, the productivity from SSDBSS with electric heater was 6.72 L/m².day. Modi and Modi (2019) [16] Investigated the effect of utilizing a small pile of various wick materials on productivity from SSDBSS. The results revealed the productivity when using a black cotton cloth and jute cloth of 0.771 L/m² and 0.91 L/m², respectively, for 10 mm water depth in the lower basin, while the productivity of 0.8287 L/m² and 0.6823 L/m², respectively, for 20 mm water depth in the lower basin.

By reviewing previous literature in the world and Iraq, it was found that the study of double-basin stills is scarce in Iraq and has not been given attention, and since the scarcity of potable water is one of the problems facing Iraq at present, therefore an experimental study on the double basin solar still is

conducted under Baghdad, Iraq, (33.315° N, 44.366° E), weather conditions. The objective was to evaluate the effect of varying water depths (10 mm, 20mm, and 30mm) on the thermal performance and productivity of the system.

2. Experimental work

2.1 Experimental setup

The double basin solar still under study contains two brine basins. The first is constructed from 1.5 mm-thick galvanized steel, measuring 400 mm wide, 1000 mm long, and 60 mm high. The tank serves as the base for a glasshouse consisting of two right-angled trapezoidal sides. The smaller side is 80 mm high, while the larger side is 267 mm high, creating a 25° inclination angle to the horizontal. The front face of the glasshouse measures 80 mm wide and 1000 mm long. The still contains two glass covers of 4 mm thickness [17][18]. The lower covers the lower tank of the still. Above the lower cover, six sub-basins are constructed from 4 mm-thick clear glass. Each tank has a triangular cross-section, with a base of 67 mm and a height of 31 mm. The tank is 1000 mm long, the same length as the still. The capacity of each tank is approximately 1 liter, as shown in Figure 1a.

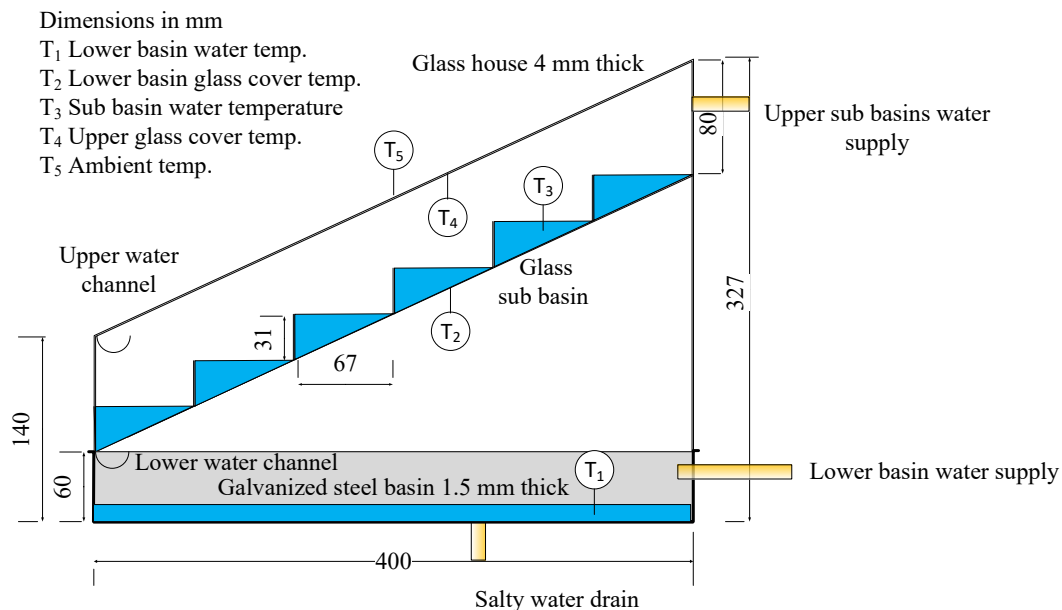


Fig. 1a: Schematic diagram of the SSDBSS

The galvanized steel basin is insulated by XPS foam 50 mm thick, with a 30 kg/m³ density, on all four sides and the bottom. A plywood block of 18 mm covers the foam in thickness to reduce the heat loss and protect the foam from mechanical damage [19].

Nine holes were drilled in the SSDBSS, two of them to supply salty water for upper and lower basins, another two used to collect the condensate water to the containers from upper and lower basins, one hole at the bottom of the lower basin to drain the salty water, while the brain in the upper sub-basins is pump through the supply hole, and the last 4 holes used to pass through the thermocouple wires. Figure 1b shows a Photograph of the single slope double basin still.

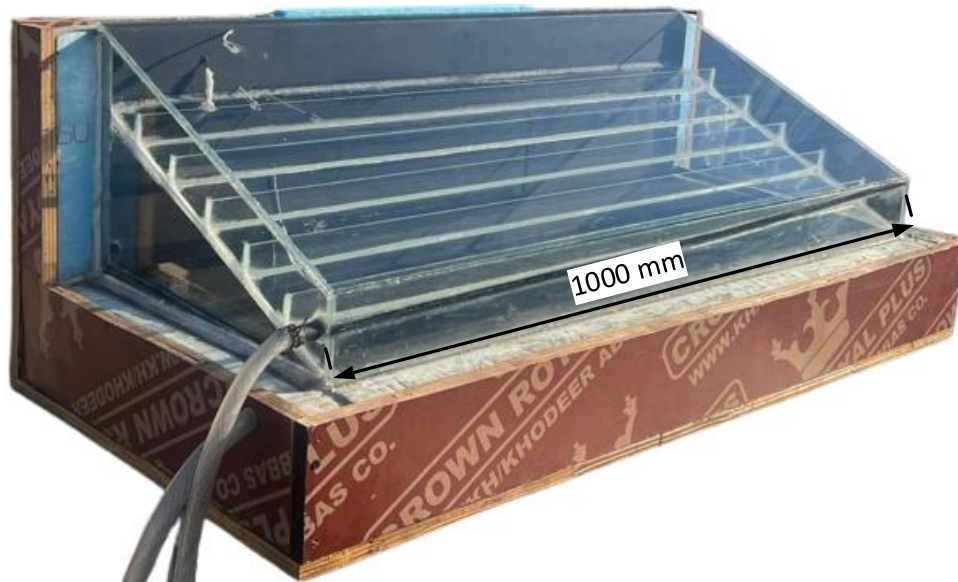


Fig. 1b: Photograph of the SSDBSS

The hourly productivity can be calculated as follows:

$$P_h = P_{ub} + P_{lb} \quad (1)$$

The daily productivity is given by:

$$P_d = \sum 24h P_h \quad (2)$$

The hourly thermal efficiency can be calculated as follows:

$$\eta_h = \frac{P_h \times L}{I(t) \tau \cdot \alpha \cdot A \cdot 3600} \quad (3)$$

Where the numerical value of transmittance – absorptance product is about 0.9 [٢٠]

The overall thermal efficiency can be calculated as follows [21]:

$$\eta_d = \frac{P_d \cdot L}{\sum I(t) \cdot \tau \cdot \alpha \cdot A \times 3600} \quad (4)$$

The latent heat of evaporation either extracted from the steam table at a given temperature or using the equation below [٢2]

$$L = 2.4935 \times 10^6 (1 - 9.4779 \times 10^{-4} T_w + 1.3132 \times 10^{-7} T_w^2 - 4.7974 \times 10^{-9} T_w^3) \quad (5)$$

2.2 Measuring Instruments

Five K-type thermocouples are installed at different locations in the SSDBSS to measure the lower water, lower glass, upper water, upper glass and ambient temperatures T_1 , T_2 , T_3 , T_4 , and T_5 as shown in Fig. 1. The uncertainty of the experiment is illustrated in Table 1.

Table (1): the measuring parameters during the experiments and the measuring devices

Sr. No	Measuring Parameter	Measuring Instrument	Specifications		Standard uncertainty
			Range	Accuracy	
1	Collection of distilled water	Measuring jar	0-100 mL	±1 mL	0.577 mL
			0-250 mL	±2.5 mL	1.155 mL
2	Ambient temperature, glass cover surface and water temperatures in the two basins	Type K Thermocouple	-270 to 1260 °C	±2.2°C	1.1°C

2.3 Test procedure

The SSDBSS was examined under Baghdad, Iraq (33.315° N, 44.366° E) weather conditions. In this work, the effect of using three different water depths of 10 mm, 20 mm, and 30 mm in the lower basin

and a fixed volume of water of 6.2 litres in the upper sub-basins on the freshwater productivity, hourly and daily efficiency of the SSDBSS. The experiments were conducted on three sunny days: 18, 19, and 20 April 2025. The experiment steps can be expressed as follows:

1. Fill the two basins of the SSDBSS with water, and batch feed at 25° C based on the water depths for the lower basin of 10 mm, 20 mm, and 30 mm, and 6.2 L for the upper basin.
2. Turn on the data logger to record the temperature hourly for 24-hour.
3. The distilled water is measured each hour from 8:00 to 18:00, and the time from 18:00 to 8:00 is recorded at the beginning of the next day.
4. Remove the brine water from the lower basin by using a drain valve at the bottom of the lower basin, while in the upper basin the water is removed by a pump.

3 Results and discussion

The experimentations were performed for three clear sunny days: 18th, 19th, and 20th of April 2025 for 30, 10, and 20 mm water depths in the lower basin, respectively in Baghdad, Iraq (33.3152° N, 44.3661° E). Metronome 8 software is used to extract the weather data of Baghdad, Iraq, for April 20 2025, as illustrated in Fig. 2.

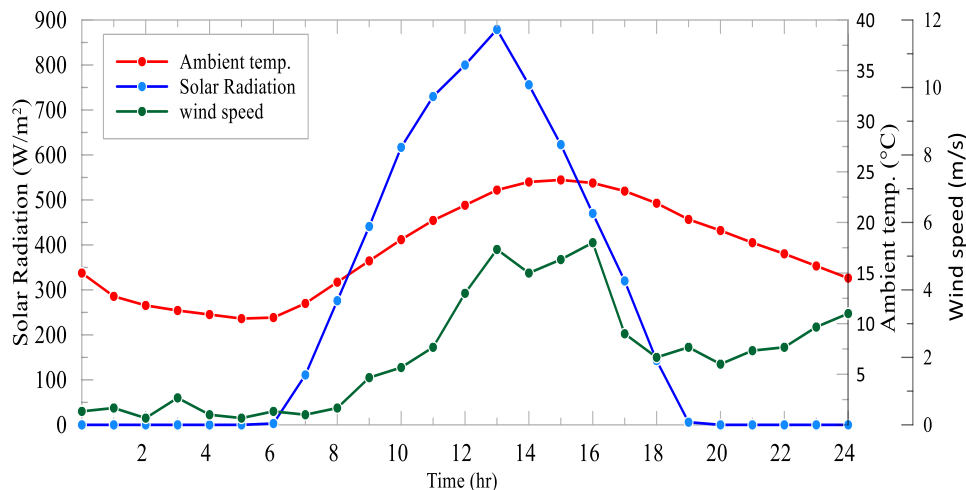


Fig. 2: Weather data at Baghdad, Iraq on April 20, 2025.

The variation of the still components' temperature is shown in Figure 3. The maximum temperature is for the lower basin temperature, because the inside is painted black, which helps absorb the most

significant amount of solar radiation. The cover of the lower basin contains hot water above due to gaining the latent heat of condensation of the steam generated from the lower basin; all of these factors lead to an increase in the temperature of the water in the lower basin to the highest temperature recorded throughout the day. The second highest temperature is the lower basin glass cover, followed by the upper basin water temperature, and finally the lowest temperature of the still is the upper glass cover due to losing the latent heat of condensation of the vapour generated at the upper basin to the ambient by convection.

Figure 4 demonstrates the effect of water depth on the upper and lower basin water temperatures. The figure shows that the maximum upper and lower basin temperatures for the first half of the day are for the minimum water depth of 10 mm, due to the lower thermal mass of the water for both basins. In the second half of the day, the 10 mm depth lost heat to the outside, causing its temperature to drop significantly, leading the 20 and 30 mm water depths to have a higher temperature. The maximum water temperature occurs at solar noon, it is about 74.5 °C and 71.5 °C for the lower and upper basins at 10 mm water depth.

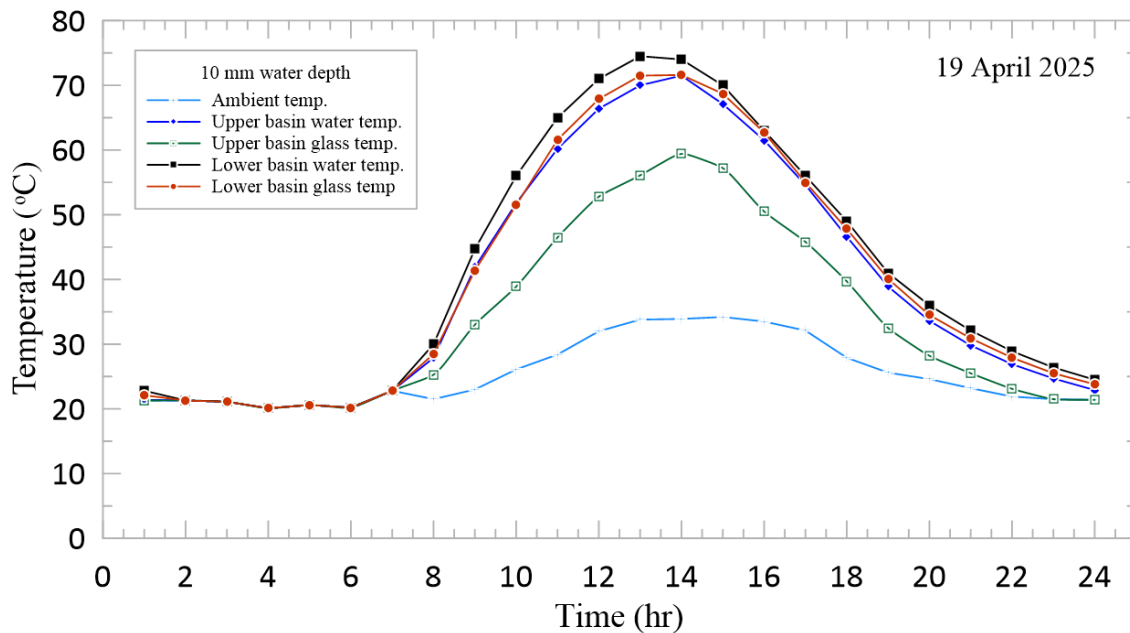


Fig. 3: The temperature distribution in the SSDBSS with time for 10 mm water depth.

Figure 5 illustrates the variation of freshwater productivity for the lower and upper basins when the water depth is 10 mm. The figure shows that the upper basin gives higher productivity as compared to the lower basin productivity, due to two reasons, the first is the thermal mass of the water in the upper sub-basins is lower than that for the water at the lower basin; the second is that cover of the upper basin has a low temperature as mentioned in Figure 3, so the generation of vapour in the upper still is more than that generated in the lower also the condensation of vapour on the upper cover is more than that on the lower cover.

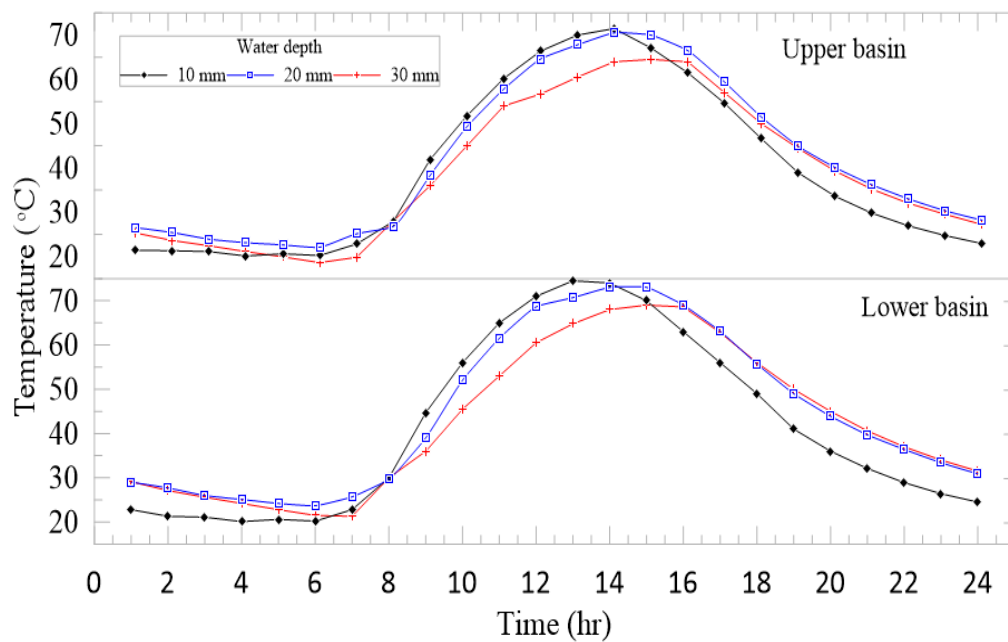


Fig. 4: The effect of water depth on the lower and upper water basin temperature.

The hourly distilled water from the upper and lower basins is illustrated in Figure 6 for three water depths. As expected, the productivity of the SSDBSS is inversely proportional to the depth of the water in the lower basin. The maximum hourly productivity is at 15:00, and it was 850 and 275 ml/m² for the upper and lower basins when the water depth is 10 mm. For 20 mm depth, it was 725 and 225 ml/m² for the upper and lower basin, while it was a record for the upper and lower basin when the water depth is 30 mm, 600 and 162 ml/m².

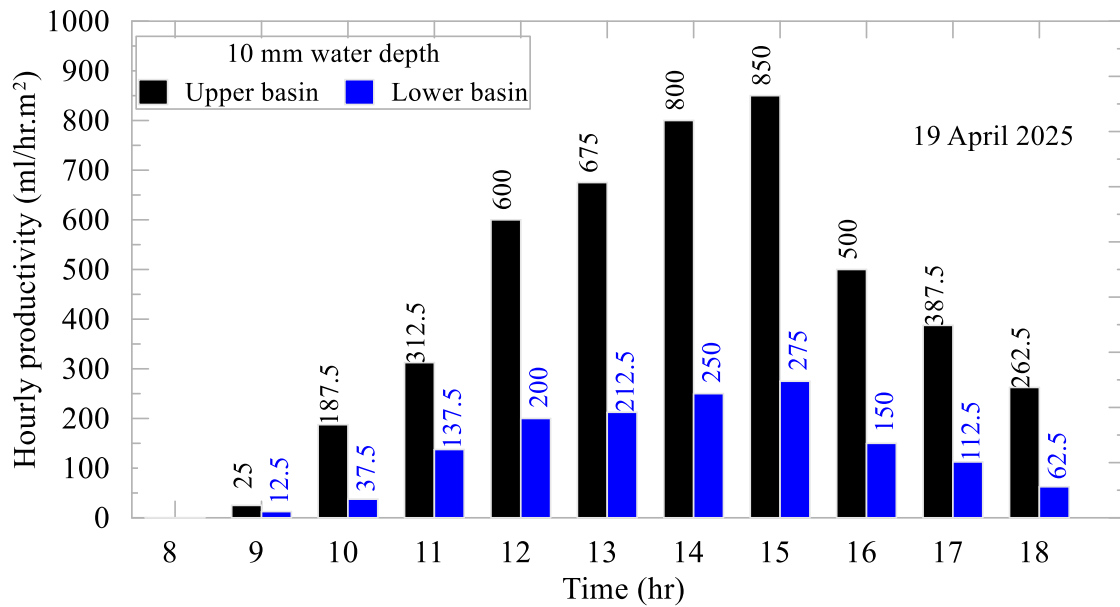


Fig. 5: The variation of lower and upper basin hourly freshwater productivity with time.

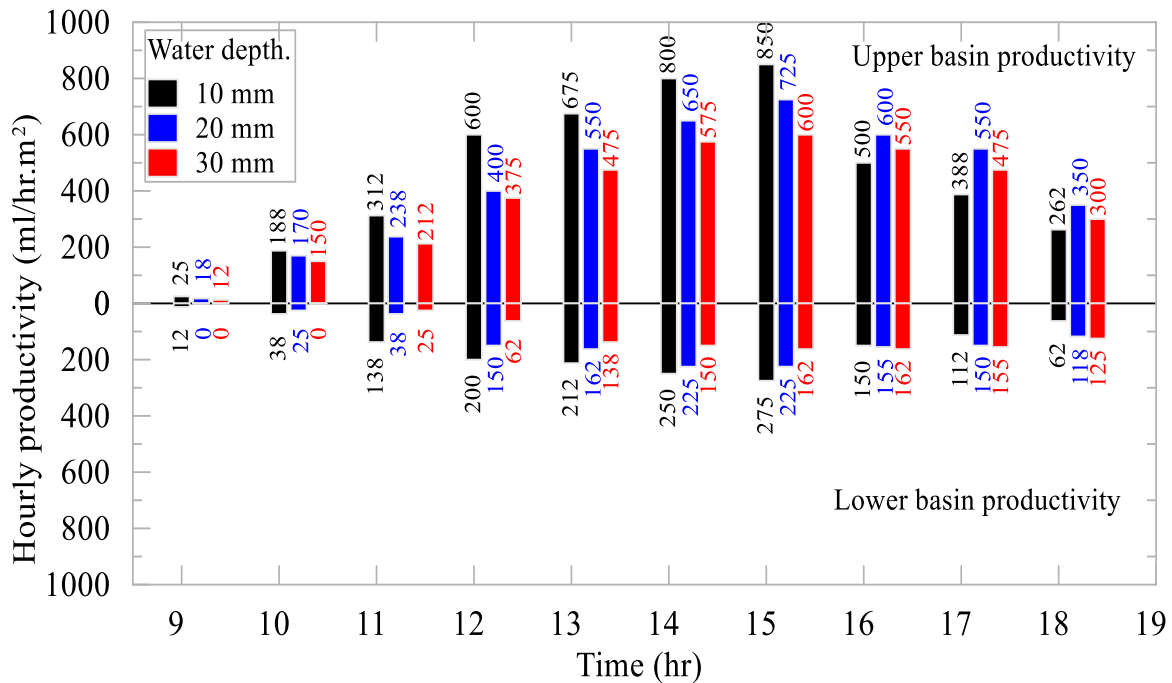


Fig.6: The effect of water depth on the lower and upper basin productivity at different water depth

Figure 7 shows the effect of water depth on the accumulated productivity; it can be seen from the figure that the maximum water productivity of about 6.788 l/m².day is for the 10 mm water depth,

followed by $6.6 \text{ l/m}^2.\text{day}$ for 20 mm depth and $5.938 \text{ l/m}^2.\text{day}$ for 30 mm depth. It can be shown from the figure that the difference between 10 and 20 mm water depth is insignificant.

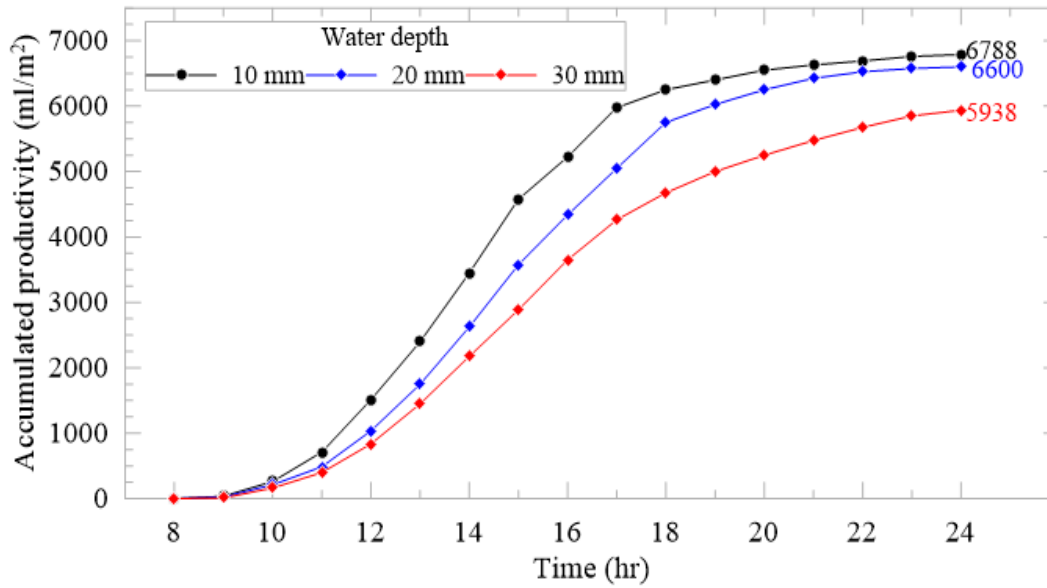


Fig.7: Freshwater accumulation productivity at various water depths.

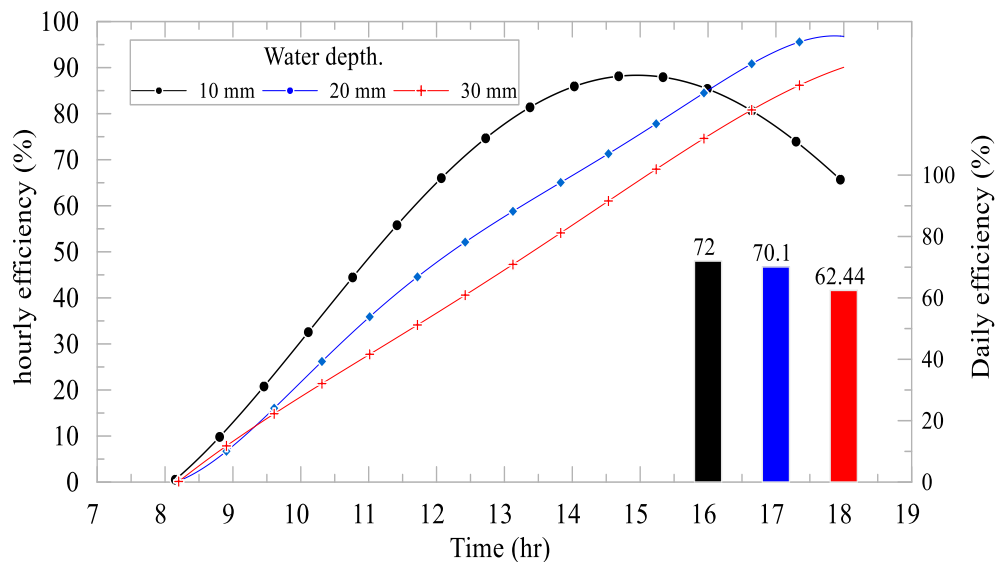


Figure (8): The hourly and daily efficiencies for the SSDBSS at various water depths.

The variation of hourly efficiency of the solar still at different water depths is illustrated in Figure 8; the figure shows that the 10 mm water depth still gives higher hourly efficiency from 8:00 to 16:00, after



that the efficiency decreases below the efficiency for 20 mm and 30 mm. The figure shows that the hourly efficiency of the distiller at depths of 20 and 30 mm continues to increase after sunset. This is due to the increase in the thermal mass of the water at greater depths, which leads to an illusory increase in efficiency. The daily efficiency is 72, 70.1 and 62.44 % for 10, 20, and 30 mm water depths in the lower basin, respectively.

4 Conclusion:

From studying the effect of the water depth in the lower basin of the double-basin solar still on the productivity and efficiency of the still, the following can be concluded:

1. The productivity is inversely proportional to the water depth of the lower basin, which means the distilled output water at 10 mm water depth is greater compared to 20 mm and 30 mm water depths.
2. The maximum water temperature is 74.5 °C for the lower basin and 71.5 for the upper basin at 10 mm water depth.
3. The maximum hourly and daily productivity was 1125 ml/m² and 6787.5 ml/m², respectively, for 10 mm water depth.
4. The overall daily efficiencies were 72 % for 10 mm water depths, 70.1 % for 20 mm water depths, and 62.44 % for 30 mm water depths.
5. The SSDBSS enhances the distilled water daily for 10 mm water depth by 2.84 % at 20 mm water depth and 14.32% at 30 mm water depth.

5 Future works

Future investigations will aim to enhance the performance of the double-basin solar still by increasing the effective evaporation surface area in the lower basin through the incorporation of wick materials. These materials are anticipated to facilitate uniform water distribution via capillary action, leading to improved evaporation efficiency and a corresponding increase in freshwater yield.

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