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EXPERIMENTAL INVESTIGATION OF THE ENHANCEMENT PARAMETERS ON THE PERFORMANCE OF SINGLE-SLOPE SOLAR STILL

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Abstract- Pure water production is considered as an utmost necessity, especially in the arid and remote areas. One of the most important processes in this production is the distillation using an alternative source as a power supply. Recently, solar distillation systems were widely studied, mainly because of its low cost and ease of use. In the present study, the effect of air velocity and presence of wire screen mesh on a conventional single slop solar still performance were investigated experimentally. It is found that the solar still productivity can be improved by 22.8% with increasing of air velocity up to 4 m/s. Adding a wire screen mesh with increasing of air velocity, up to 2.5 m/s, resulted in an increase of the solar still productivity up to 36.6%.
Keywords: Solar still, Single slope, Still performance, screen mesh liner

1. INTRODUCTION

The rapid and incredible change in the climate nature and the serious and continuous need to the fresh water in many arid and remote areas on the planet led to conduct various methods to produce fresh water by different means by researchers [1]. The most common method for fresh water production is desalination of sea water by implementing direct solar energy, since it costs much less than the other methods, namely; vapor compression, thin film distillation, multi-effect evaporation, multi-stage flash distillation, electro dialysis, and reverse osmosis. However, the use of solar energy still has some challenges for instance the productivity is low for Solar Still even though the solar energy is available and can be implemented with low cost and maintenance [2]. The studies have shown that using of solar distillation can be considered reliable when the water demand is not large and when the method is implemented in optimal weather conditions [3].

The solar stills (basin-type) are the most common systems that are used in solar distillation processes. However, the operation of solar still is restricted to three shortcomings. Firstly, in the evaporation–condensation processes, the latent heat of condensation is not reusable. Secondly, limited condensation process and finally, small evaporation surface. It has been proven that maximum productivity of a basin-type solar still is about 2-3 L/m2 day [4].

Many studies proved that the solar radiation intensity has a direct effect on the productivity of the still, also there is confirm relation between the brine level in the still basin and the productivity of it. This relation shows that increases the brine level led to decreasing the still productivity and vice versa [5].

Recently, researchers presented various studies comprised many parameters that affect the operation of the single-slope solar still (basin type) to enhance its performance and increasing the productivity. Tenthani et al. [6] studied the effect of solar still internal surfaces color on its performance. To avoid water vapour condensation on the internal walls, black color is usually used to paint them. Using white color has enhanced the still productivity by 7.14%.

The effect of incorporating an external passive condenser to a solar still is investigated experimentally by Ahmed [7] during summer, autumn and winter for 24 hour. The author constructed three identical stills; the first considered as a reference, the second still connected with a passive condenser through a pipe at the upper part of its back, while the third still connected with a passive condenser through pipes from the lower and upper parts of its back. Results obtained from the second still showed that there are 15.1, 15.08 and 16.6% increase in the still productivity through summer, autumn and winter respectively, when compared with results of the first still. Whereas results obtained using the third still showed an increase of 30.54, 33.6 and 35.8% in productivity through summer, autumn and winter respectively, with respect to the results of the first still. Also, he found that the average overnight still productivity represents 10.8, 13 and 19.7% of the total daily productivity for summer, autumn and winter respectively.

Excitement effect on improving the still performance is carried out by Kumar et al. [8]. They used agitation to enhance the solar still productivity. The agitation effect, which represented by a shaft coupled with a constant angular velocity dc motor, breaks the water surface boundary layer and enhanced the distilled yield of the still. Their results demonstrated that the still productivity increased by 21.67% as compared with the productivity of the conventional solar still.

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A new model of solar still presented by Franceschetti and Gonella [9] to produce potable water at low temperature using solar radiation. This still simulated to be used in tropical areas and for small isolated communities where conventional energy or electric network connections sources are unavailable. Performance of the still based on some main points, such as suction pipes, heat exchange between entering water and vapor, and continuous cycle operation. It is found that simulation results with a good approximation of the distillation yield under different climates may reaches up to 5.8 liters per square meter per day. A theoretical and experimental investigation for the solar still productivity enhancement using a floating perforated black plate is presented by Nafey et al. [10]. Experimental results showed that the still productivity increased by 15% (at 3 cm brine depth) and 40% (at 6 cm brine depth) when an aluminum perforated plate is used. These results agreed well with results obtained from mathematical model developed by the researchers. Enhancement of solar still performance studied theoretically and experimentally by Nijmeh et al. [11]. They directed their work to enhance water absorptivity of solar radiation using different absorbing materials, like charcoal, dissolved salts and violet dye. Still efficiency is improved by 26% when potassium permanganate (dissolved salt) is added. While, the best enhancement they obtained was 29% when violet dye is used. A numerical study presented by El-Sebaii [12], stated that both brine-glass cover temperature difference and distillation yield increases up to a certain value at higher wind speed.
Tarawneh [13] studied the effect of cooling glass cover on the solar still performance for different water depth (0.5, 2, 3 and 4 cm) in the still basin. His experiments showed that there is an increase of 17-23% in the still distilled yield, and the highest still productivity corresponding to the lower water depth.
Badran [5] presented an experimental study of the effect of using sprinkler and asphalt basin liner on the still performance. His study proved that the still productivity reached 51% when such combined enhancement is used.
The aim the present work is to investigate the effect of using different operational techniques on the single slop basin-type solar still performance for the climate of Iraq-Najaf. The operational techniques have been used were cooling glass cover and basin wire screen mesh liner, which assumed to improve the solar still productivity, especially there are few studies included the effect of cooling glass cover on the productivity of still.

2. XPERIMENTAL SETUP

The experimental components used in this work are single slope solar still, feeding tank and air supplying unit. To carry the above instrumentations, a frame was built.
A single slop solar still, Fig. 1, has been fabricated using large variety of materials. The materials have been chosen depending on three points. The first is knowledge of the conditions dominant for various parts of the still, the next one is cost considerations and the last one is ease of assembling it in construction [5]. The solar still's technical specifications are shown in Table 1.

2.1. Basin Liner and The distillate channel

The main part of the solar still is the basin liner. This part absorbs the irradiation that is transmitted through the glass cover. The basin liner has a high absorbance to solar radiation and resistance to hot raw water (saline) and to accidental pricking. In this work, the base of the still is divided into two parts; the first one is the basin liner, which is made of aluminum sheet with 1mm thickness and of 100 ×100 cm with maximum height of 6 cm. The basin liner painted with thermal black paint to increase its solar radiation absorptivity.

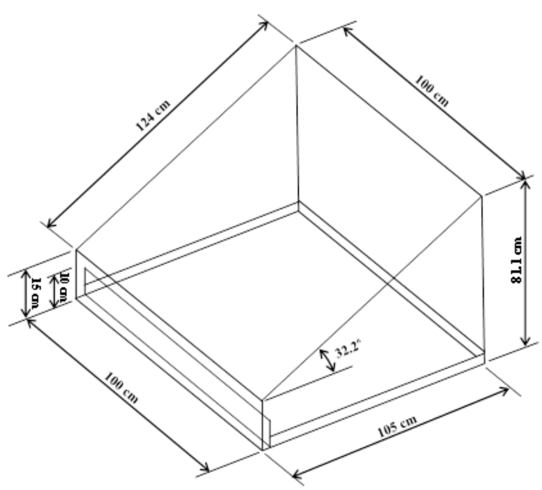

Figure 1. Isometric view of the experimental setup.

The other part is the distillate channel, which is used to accumulate the condensed water droplets on the inner surface of glass cover at the lower edge and deliver it to storage. It is made of 4 mm thick glass sheet with 100 × 5 cm, inserted vertically between the frontal edge of the basin liner and the lower side of the still. The base of the channel is sloped to direct the distilled water towards the storage.

Table 1. The solar still technical specifications

Specification	Dimensions
Basin area, m2	1
Glass area, m2	1.24
Glass thickness, m	0.004
Number of glass	1
Minimum still height, m	0.15
Maximum still height, m	0.811
Slope of glass	32.2o

2.2. Glass cover

The solar still cover is typically constructed from transmissive material, allowing the solar radiation to reach the basin liner. Thus, window glass of 4 mm thickness and average transmissivity of 0.88 is used here, and fixed with an angle of 32.2o. Furthermore, rubber sheet, silicon and clamps are used to fix the glass cover on the solar still frame to ensure efficient operation for the still.

2.3. Insulating Material and Side Components

The bottom and sides of the solar still are insulated to reduce the heat losses. The insulating material, in this work, is a glass wool with thickness and thermal conductivity of 5 cm and 0.038 W/m.°C, respectively. The side walls of the still are made of plywood of 14 mm thickness.

2.4. Air supplying unit:

An axial fan, as shown in Fig. 2, is used to supply different velocities of air up to 6 m/s. It is oriented directly to the surface of the solar still (glass cover) to increase the heat exchange on the outer glass cover, hence, increase the condensation process on the inner surface of the glass cover.

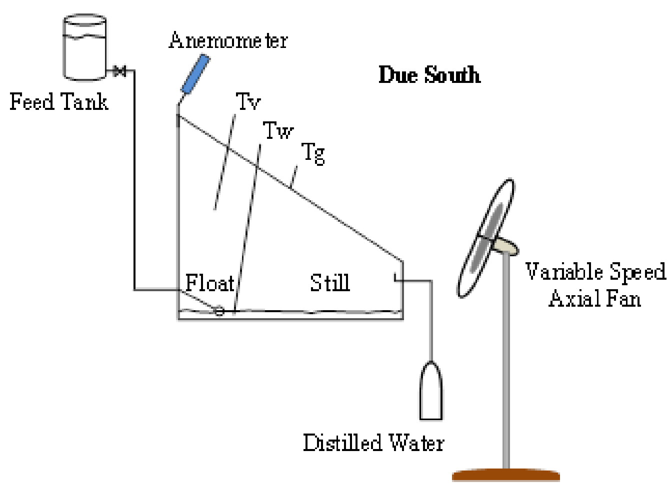

Figure 2. The solar still overall schematic diagram.

2.5. Screen mesh liner

A wire screen mesh of 99 cm × 99 cm with a wire diameter of 0.3 cm and aperture of 3 cm is utilized in the present work. The screen is painted with thermal black paint to increases the sun light absorption and placed in the basin of the solar still. The geometrical shape of the screen increases the surface area for the evaporation process.

2.6. Measuring instruments

2.6.1. Wind speed

The wind speed, in this experimental work, is measured using a digital anemometer type AM-4826 with range of (0.4-30 m/s) and accuracy of ±(0.2%+1d).

2.6.2. Temperature

Temperature is measured at specified locations inside and outside the still, this is achieved using T-type thermocouples ranging between -150 oC ~ 400 oC with basic accuracy of ±0.2% of reading. The temperature measuring system consists of 7 thermocouples each with 0.8 mm probe. They are distributed as shown in Fig. 2. All thermocouples are connected to Multi-channel Temperature Meter type (AT4564) with 64 channels.

2.6..3. Solar radiation

Solar radiation, in the present work, is obtained by Davis weather station, which is installed at 10 m above the ground in the Engineering Technical College building in Najaf / Iraq (44o E, 31o N), [14]. This station measures the solar radiation in (W/m2) with range from 0 to 1800 W/m2 and accuracy of ±0.3%.

The single slope basin-type solar still operation depends basically on the incident solar radiation. It passes through the transparent glass cover to reach the basin liner and heat it, which in turn heats the brine above it. The brine will evaporate, then it will condense on the inner surface of the sloped glass cover and run down the cover to the distilled channel. Finally, distilled yield goes along the channel to be collected in a vessel or tank.

All experiments of this work were carried out in May 2017 at the roof of the communication department building in the Engineering Technical College, Najaf. The brine depth of (1.5 cm) is used in the still basin during these experiments with salinity of 2200 to 2250 ppm.

3. RESULTS AND DISCUSSION

The effects of wind speed for different basin liner construction (i.e. black paint, wire screen mesh) on the solar still productivity are presented in this section. Variables like inner glass temperature (Tg), ambient temperature (Tair), water temperature (Tw), vapor temperature (Tv), solar radiation (I), wind speed (Vair), and productivity were measured hourly. Figs. 3-6 show the variation of solar still temperature with respect to sunlight hours. It can be seen that, with the increase of air velocity the temperature of water always exceeds the vapor temperature earlier. The glass temperature is always less than the two other temperatures, while the ambient temperature is the least. The maximum water temperature found to be achieved at about 14:00.

Fig. 7 shows the behavior of the solar radiation throughout a sunny day. The solar radiation uniformly increases to reach its maximum at the mid-day, followed by a uniform decrease to hit its minimum after sunset. Same trend has been found for all experiments with all air velocity. The still productivity along the day is shown in Fig. 8. For all velocities, the productivity increases with the time progress until it reaches its maximum between 13:00 to 14:00 corresponding to the higher solar intensity.

Fig. 9 shows the effect of air velocity on the daily cumulative still productivity for the conducted experiments. It can be seen from the figure that as the air velocity increases, the still productivity increases. This result is in agreement with that reported by Badran [5] and El-Sebaii [15]. Also, it is demonstrated that the still productivity increased by 22.8% on increasing the air velocity from 0.9 m/s to 4 m/s. The main reason of this increase is the enhancement in the condensation process on the inner surface of the glass cover due to the increase in temperature difference between water and glass cover.

The effect of using screen mesh liner on the still productivity for two air velocities are shown in Figs. 10-11. The figures stated that when the wire screen mesh fitted to the basin liner the productivity increased by 20.7% and 20.9% for air velocity of 0.9 m/s and 2.5 m/s, respectively. This enhancement in productivity is due to the increase of the black surfaces (i.e. increase of the evaporation areas) that in contact with water in the basin which led to risen the absorptivity within the basin, which in turn increases the evaporation process.

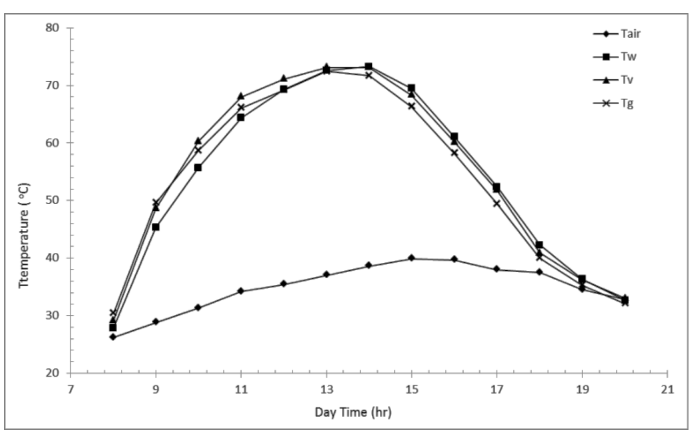

Figure 3. Hourly variation of the solar still temperatures for air velocity of 0.9 m/s.

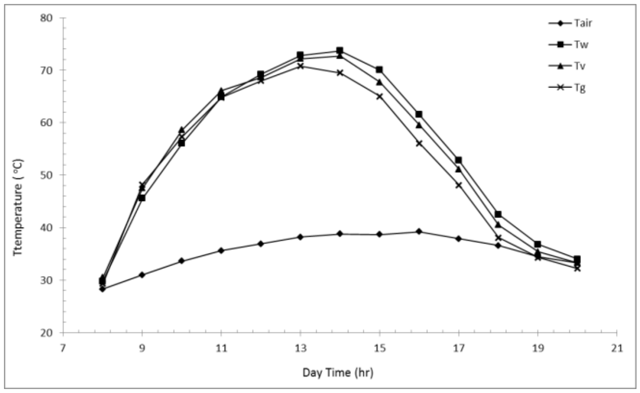

Figure 4. Hourly variation of the solar still temperatures for air velocity of 1.6 m/s.

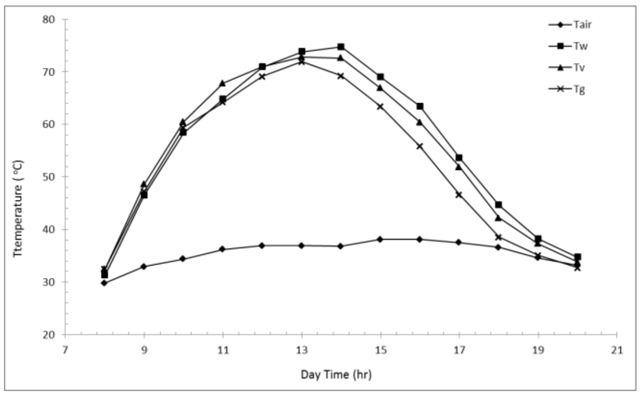

Figure 5. Hourly variation of the solar still temperatures for air velocity of 2.5 m/s.

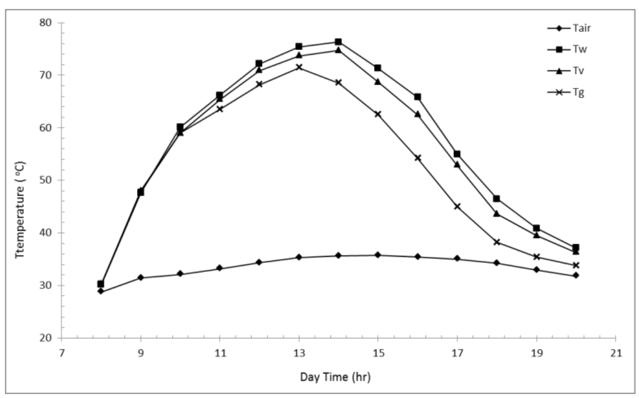

Figure 6. Hourly variation of the solar still temperatures for air velocity of 4 m/s.

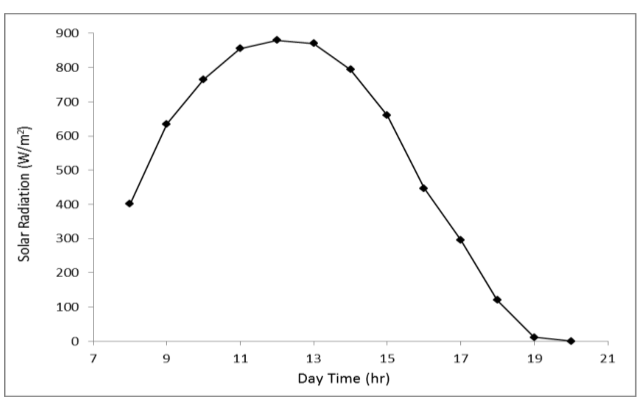

Figure 7. Hourly variation of the solar intensity for air velocity of 0.9 m/s.

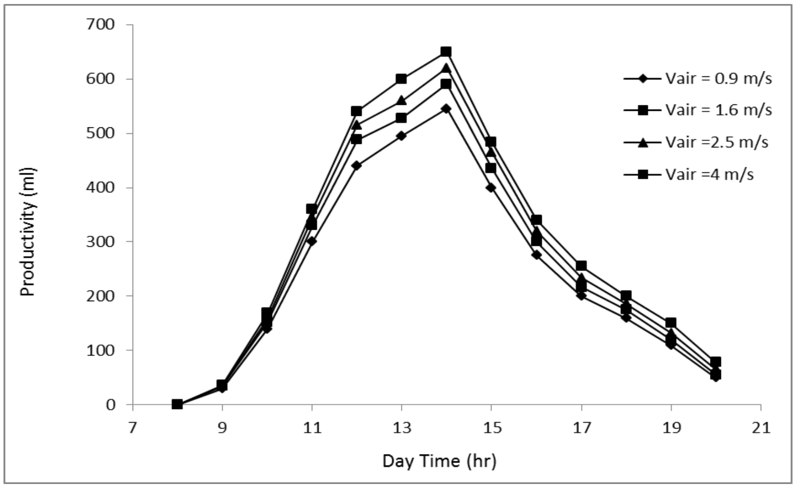

Figure 8. Hourly variation of the solar still productivity for different air velocity.

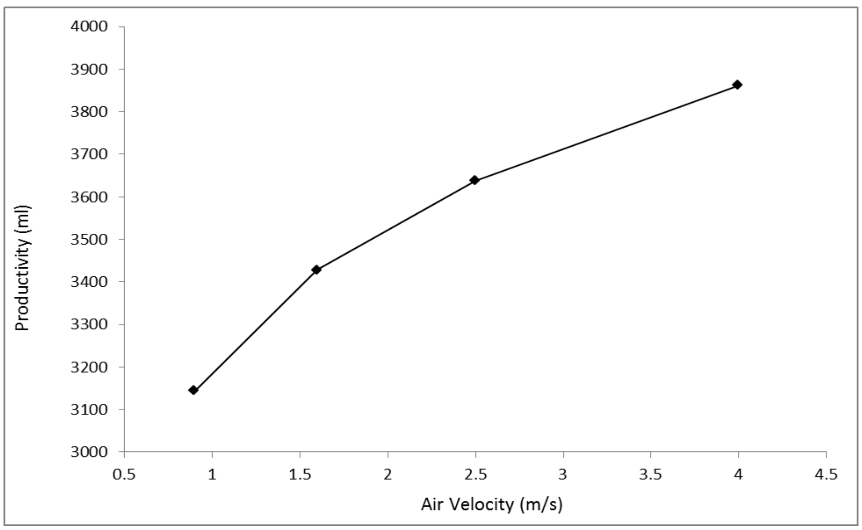

Figure 9. Variation of the still productivity with air velocity.

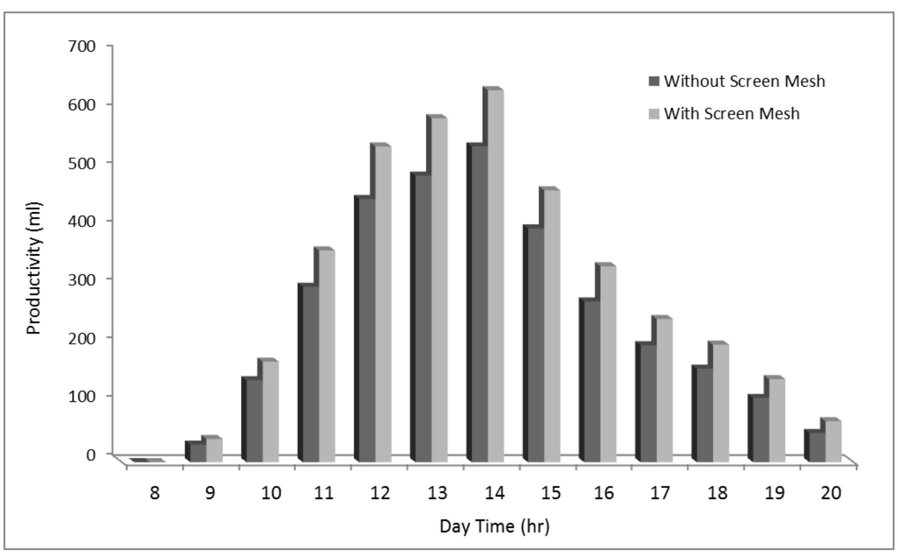

Figure 10. Hourly variation of the still productivity for air velocity of 0.9 m/s with and without present of the screen mesh

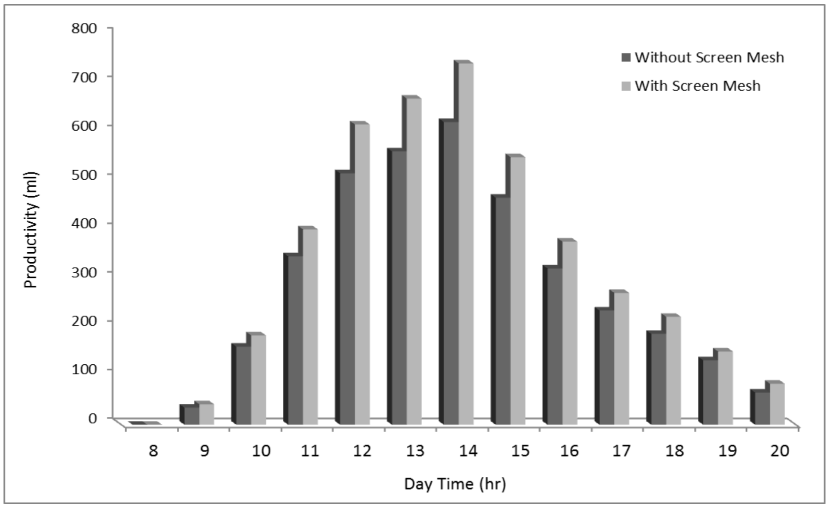

Figure 11. Hourly variation of the still productivity for air velocity of 2.5 m/s with and without present of the screen mesh

4. CONCLUSIONS

An experimental investigation has been carried out to predict a single slope solar still productivity using different operational parameters. It is clear from the present work that the solar still productivity enhanced when the air velocity increased. This enhancement is reached up 22.8% when the air velocity increased from 0.9 to 4 m/s. The presence of wire screen mesh, on the other hand, achieved an additional enhancement reached up to 20.9% for air velocity of 2.5 m/s when it used in the basin of the still.

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