ENHANCED SOLAR DESALINATION UNITS

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ABSTRACT:
The present article is an experimental study for enhancing the productivity of a solar still. Basin-type solar stills with basin area of one meter square are used in the study. Two means are used for enhancing its productivity: Integrating the solar still to a solar water heater (SWH) to pre- heat the feed water to the still and using some metals as energy storage media. Experiments on the still integrated to a SWH were run on three consecutive days 7, 8, 9/5/2017. The maximum outlet water temperature from the SWH was recorded for 9/5/2017 and it was 70.2 ^{O}C at a time when the inlet water temperature was 36^{O}C and solar intensity was 720 W/m^2. Thus an increase in inlet water temperature of 92.7% was recorded at solar noon as a result of using the SWH. 2470 ml of distillate could be collected by 6 pm on 9/5/2017, which corresponds to a 69.19 % increase in still productivity compared to a reference still. A maximum hourly productivity of 400 and 900 m*l* on 9/5/2017 were recorded for maximum water basin temperatures of 57.7 and 59.8°C for stills without and with SWH, respectively. Experiments on enhancing still productivity using metals as energy storage materials are run on three days (11/5, 12/5, 12/6/2017), which had maximum solar intensity at solar noon of 655, 690 and 710 W/m^2, respectively. Studying the effect of addition of copper filings (CF) showed that an increase of 36.2% in still productivity is noticed when adding one kg of CF to the still. This corresponds to 48.1% and 55.4% when using 2 and 3 kg of CF, respectively. On the other hand, iron is used in two forms as an energy storage material; as iron filings (IF) and as iron swarf (IS). Examination of the results of this test indicated that a 23.9% increase in productivity of still using IF is achieved more than containing IS. Comparing copper with iron, it is noticed that the productivity of the CF still is 34.1% higher than that of the IF still. Thus, the significance of the materials used as energy storage media could be arranged as follows: CF > IS > IF.

Keywords: desalination, solar water heater (SWH), productivity, iron filings (IF), iron swarf (IS), copper filings (CF).

1- INTRODUCTION

Approximately 76% of the global population has access to potable water, with only 46% of people in Africa are able to access potable water. Thus, the availability of drinking water is reducing day by day; whereas the requirement of drinking water is increasing rapidly. For this reason there is a great need for some cheap, innovative and sustainable means for water desalination [1, 2]. Desalination is by definition a process of removing minerals and salts from saline water to produce freshwater, that can be used for human use or irrigation. It is applied to seawater and brackish water with different performances criteria especially in remote areas [3].

Desalination processes consume significant amounts of energy, and many countries in the world, particularly those suffering from severe water shortages, cannot afford the energy required for desalination [4]. Various technologies are being used for desalination of saline water such as multi- stage flash process, multiple effect, vapor compression, reverse osmosis, ion exchange and electrodialysis [5].

Since the industrial revolution, fossil energy has been explored and deployed in great amounts, which has resulted in depletion of such resources. For this reason, new sources of energy and renewable energy are being developed. Although, progress and development has occurred in most parts of the world, there are areas, still remote and undeveloped where even the basic requirement of electric power is either scarce or totally absent till date [6]

Distillation is a natural phenomenon. Solar energy heats water source, evaporates it and it condenses by clouds to come back to the earth as rainfall. Solar stills are simulating this natural process in a small scale. Solar energy can directly or indirectly be used for desalination. Direct solar stills use the solar energy to produce distillate directly in the solar collector and do not need other expensive and unsustainable energy sources such as fossil fuel [7].

There are different designs of solar desalination units. The systems involved in solar distillation operate under two modes: passive and active. Passive solar stills are generally divided into basin and inclined types, the most common passive solar still is the basin-type solar still. A single basin solar still is a very simple device used for converting available brackish or waste water into potable water [8]. To enhance the productivity of the single basin solar still, so many research works are being carried out:, e.g., using a multi wick solar still with electrical blower or a flat plate collector was integrated with a single basin solar still leading to a maximum increase in productivity of potable water of 52% [9]. When a still is coupled with a solar collector to enhance the evaporation and condensation rates in the double effect solar stills, the temperature of basin water could be increased by supplying additional thermal energy from some external source. In the case of a double- basin solar still (DBSS), the additional thermal energy is mostly supplied to the lower basin of the still since it receives less solar radiation than the upper basin, due to the decrease in the amount of solar radiation transmitted through the upper basin of the DBSS.

A solar still coupled to a heat exchanger is a very useful system for a distillation process. The heat gain via the heat exchanger is an additional amount of thermal energy to the still and thus, leads to an enhancement of performance of the system. An overall increase in the system efficiency of 20–25% was obtained when the inlet temperature of the heat exchanger fluid equals 40^{O}C [10].

The efficiency of solar energy utilization and the performance of the basin type solar still could be enhanced by modifying its design, even with keeping the basin area unchanged. Studies showed that a higher ratio of area of condensation to area of evaporation leads to a higher productivity, if not contradicted by another factor such as shading. Basin temperature has a positive effect on productivity. Besides, the productivity is affected directly and positively with the intensity of solar radiation [11].

The performance of a solar still could also be enhanced by adding an energy storage material, either chemical or metallic material, in the basin of the still. Some of the materials tested are: paraffin wax, copper slag, aluminum slag, iron slag, cast iron slag and copper chips. Solar energy is stored in these materials, and the energy is then recovered with a water stream at different flow rates. Results indicated that iron slag has the highest storage capacity followed by cast iron slag then aluminum slag and copper chips and copper slag. It is also noted that the addition of paraffin wax to the solid metallic material greatly improves its storage capacity and duration [12].

The present work is an experimental study for enhancing the productivity of a solar still. This is achieved by two means: first by integrating the solar still to a solar water heater for raising the feed water temperature and the second is by adding energy storage materials in the still basin to increase the amount of solar radiation absorbed and to store solar energy. A comparison is made between the two methods used.

2- EXPERIMENTAL WORK:

2.1. Experimental Setup:

The experimental work is performed in the Solar Energy Lab., Faculty of Engineering, Minia University. A basin- type solar still unit consists of squared water basin with area of 1 m^2 and a glass cover inclined with an angle 30.75 to the horizontal. The basin is fitted with two openings for feeding the still with saline water and for receiving the distillate (desalinated water). One more opening is fitted for washing the still free of the remaining salts.

The solar water heater is used to heat the inlet water to the still. The solar water heater includes an enclosure 100cm × 50 cm, containing the metallic absorber plate which absorbs the heat of the sun, glass cover over the enclosure that allows the sun's rays to pass through to the absorber (while reducing heat loss by convection from the top) and back and sides thermal insulation to reduce heat loss by conduction. Metallic tubes, through which water passes, are connected to the surface of the absorber plate to transfer the heat from the absorber plate and transfer it to the object.

2.2. Procedure:

Experiments are run on several days through May and August, 2017, from 9 am to 6 pm. Water with salt concentration of 35,000 ppm is used and the water depth in the basin was kept at 5 cm. The experiments are divided into two sets: one for studying the effect of integrating the solar still with a solar water heater and the other for studying the effect of addition of an energy storage material to enhance still productivity.

2.3. Parameters Studied:

2.3.1. Solar still integrated with solar water heater (SWH):

Experiments are run on two stills: one is integrated with SWH and the other without SWH and is used as a reference. Salt water is prepared by dissolving 35 gm of raw sodium chloride per liter (to give a concentration of 35,000 ppm). About 16 liters of saline water is prepared and is contained in two tanks (each having about 8 liters). One tank is used to feed the still without SWH while the other is used to feed the SWH (for the object of preheating it before being fed to the second still). The water in the solar basin is evaporated and it is condensed on the inclined cover glass; forming a thin film which flows to the lower edge of the cover and then to the output tube where it is collected and measured periodically every one hour ($m\ell/h/m^2$). Other measurements made are: ambient temperature, water temperature to SWH, water temperature from SWH, basin water temperature, and solar intensity, SI, (W/m^2).

2.3.2. Solar still with metals as energy storage materials:

Two metals are used as energy storage materials: iron (as iron filings (IF) and iron swarf (IS)) and copper filings (CF). For studying the effect of addition of CF, experiments are run on two stills on three days; one still with 1kg of copper filings (CF) and the other without CF. In the second day the amount of CF is increased to 2 kg and in the third day it is increased to 3 kg. Each day the two stills; with and without CF, are fed with saline water and operated and the distilled water is collected from each and is measured. The water in the solar basin is evaporated and it is condensed on the lower side of the glass cover and it is collected and measured periodically every one hour. Other measurements recorded are: ambient temperature, basin water temperature, and solar intensity, SI.

2.3.3. Comparing the effect of IF and IS on still productivity:

Experiments are run on two stills: one with 3kg of iron filings (IF) and the other with 3kg of iron swarf (IS). Saline water is prepared and fed to two stills one having the (IF) and the other having the (IS). The two stills are subjected to solar radiation and the productivity of each is measured periodically every one hour, together with other measurements as given before.

2.3.4. Comparison between the effect of IF and CF on still productivity:

The experiments described before are repeated on two stills; one having 3 kg of IF and the other having 3 kg of CF and the same measurements are taken and recorded as before.

2.4. Instrumentation:

The instruments used are: Analytical balance (model Chans Crop. Pin Brook, NJ, with a capacity of 200g and a readability of 0.001g), solar meter (Model HANNI, SOLAR 130) and digital thermometer which reads in the range -10 to 110 ℃.

3. RESULTS AND DISCUSSION:

3.1 Enhancing the Still Productivity Using a Solar Water Heater (SWH):

The results are obtained for three days (7, 8, 9/5/2017) and the recorded values for solar intensity (SI) are presented in figure 1.

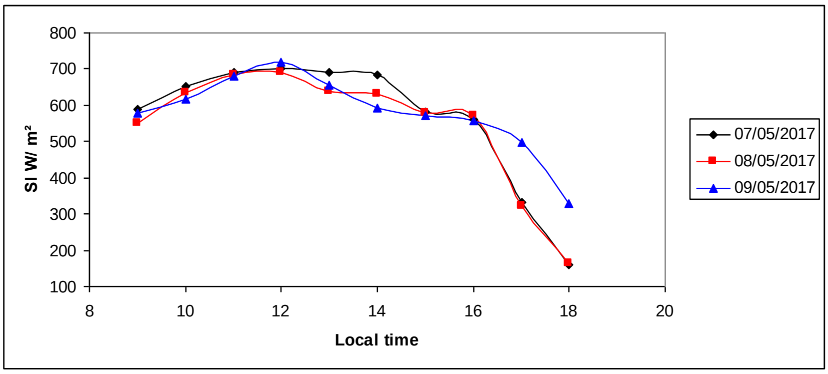

Fig. 1: Variation of SI with local time for three days (7/5, 8/5, 9/5/2017)

The maximum SI values were obtained at noon, 12 pm, and it were 702, 690 and 720 W/m^2 for (7, 8, 9/5/ 2017), respectively.

3.1.1 Evaluation of the performance of solar water heater (SWH):

Effect of variation of solar intensity on outlet water temperature from SWH Sample results are shown in Fig. 2 for 8/5/2017.

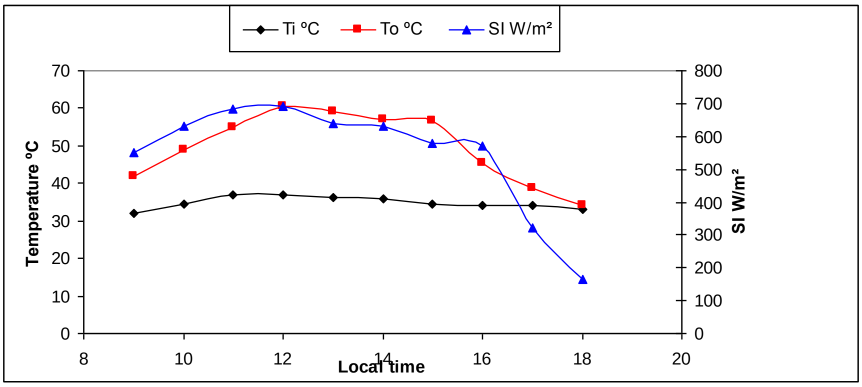

Fig. 2: Variation of SI, inlet and outlet water temperature to and from SWH with local time in (8/5/2017)

It is noticed that the maximum temperature is at solar noon, 12 pm. Water temperature from the SWH is 60.4°C and the temperature, Ti, to SWH is 37°C. To is greater than Ti at noon time by 63.2%. This is to be compared with 92.7% on 7/5/2017, which corresponds to a SI of 702 W/m^2 at solar noon. The change of SI and outlet water temperature with local time for 7/5/2017 is shown in Fig. 3.

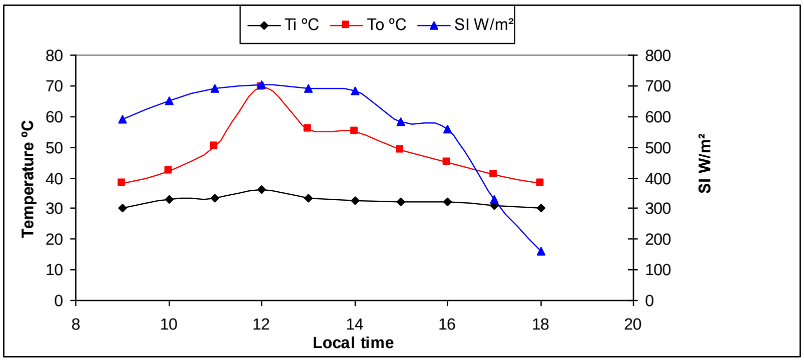

Fig. 3: Variation of SI, Ti and To from SWH with local time on 7/5/2017

Examination of Fig. 3 clarifies that the maximum outlet water temperature from the SWH is obtained at maximum value of SI, which is satisfied at solar noon.

3.1.2 Effect of integrating a SWH to the still on its performance:

3.1.2.1 Change of hourly productivity of still with time:

Experiments are run on a solar still and its productivity is recorded periodically. Experimental results are repeated for three days with different values of SI. The recorded values are presented in Fig. 4.

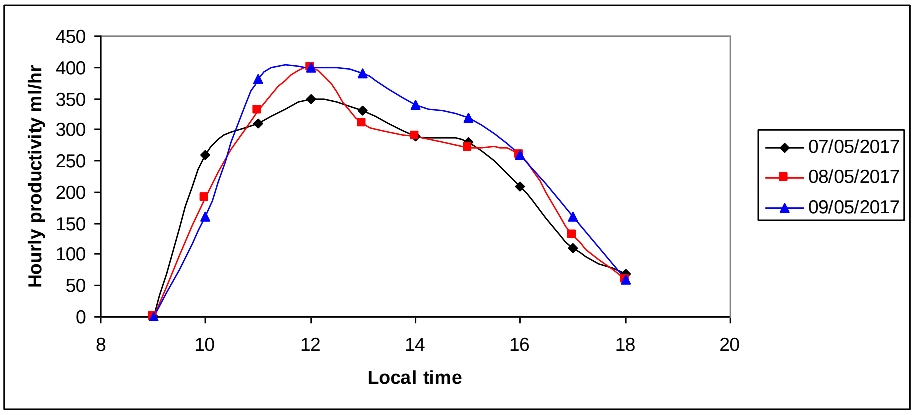

Fig. 4: Variation of productivity with local time for still without SWH (in 7/5, 8/5, 9/5/2017)

2470 m*l* of water could be collected by 6 pm in 9/5/2017. This corresponds to 2240 and 2210 m*l* in 8/5/2017 and 7/5/2017, respectively. It is worthy to note that this amount of distillate corresponds to a maximum SI of 720 w/m^2 in 9/5/2017 at solar noon and a total SI of 5801 W/m^2 along the experiment hours, which are both higher than its corresponding values in 8/5/2017 and 7/5/2017. Although the total SI on 7/5 was higher than on 8/5 (5644 W/m^2 for 7/5 compared to 5459 W/m^2 for 8/5), the still on 8/5 gave higher productivity (2240 m*l* in 8/5 compared to 2210 m*l* in 7/5). This is because the average inlet water temperature on 7/5 was higher than on 8/5 (32.33°C on 7/5 compared to 31.42 °C on 8/5). Thus, it could be concluded that the productivity of the still is enhanced by increasing inlet water temperature. The percentage increase in still productivity in 8/5 over 7/5 is 1.36%.

3.1.2.2 Effect of SWH on still productivity:

This test was performed using two solar stills simultaneously; one is connected to a SWH and the other is not and the productivity of the stills is recorded periodically. The experimental results are presented graphically in Fig. 5 for the still connected to SWH for three different days. This figure shows higher productivity for the solar still in 9/5 than in 8/5 and 7/5/2017.

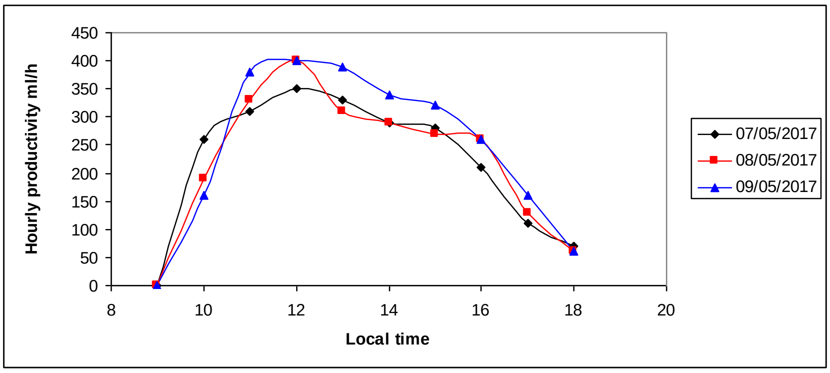

Fig. 5: Variation of productivity with local time for still with SWH (in 7/5, 8/5, 9/5/2017)

Figs. 6 –8 are plots for the hourly productivity of stills with and without SWH versus local time. Values of SI are also given in these figures since it is directly related to the local time.

The percentage increase in still productivity due to the presence of SWH at solar noon is: 68.57, 35 and 47.5% for the three days in 7/5, 8/5 and 9/5, respectively. It is clear that the order of magnitude of percentage increase comes in the same order of average SI at solar noon for the three days: 68.57%, 35%, 47.5% increase in productivity for average SI of 661.5, 639 and 649 W/m^2, respectively. When these values for percentage increase in still productivity are compared with the values recorded at the end of experiments, it becomes clear

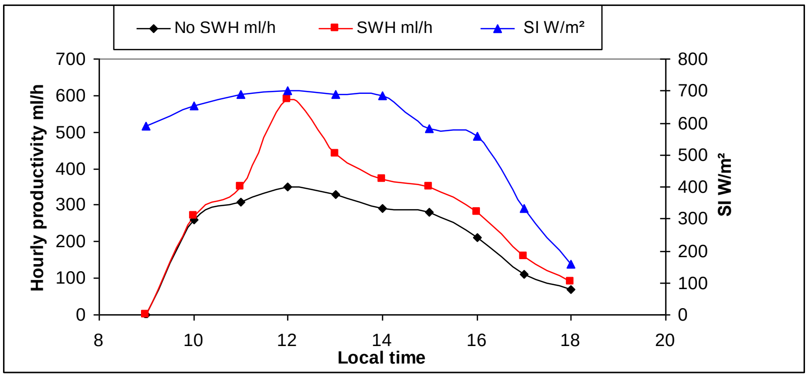

Fig. 6: Variation of hourly productivity with local time in 7/5/2017

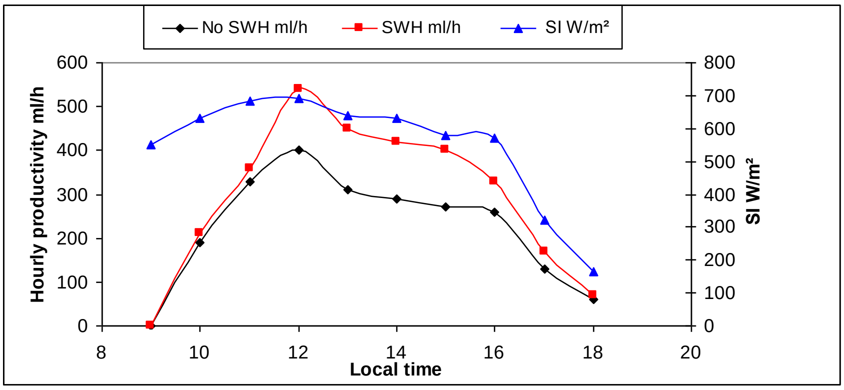

Fig. 7: Effect of variation of SI on hourly productivity in 8/5/2017

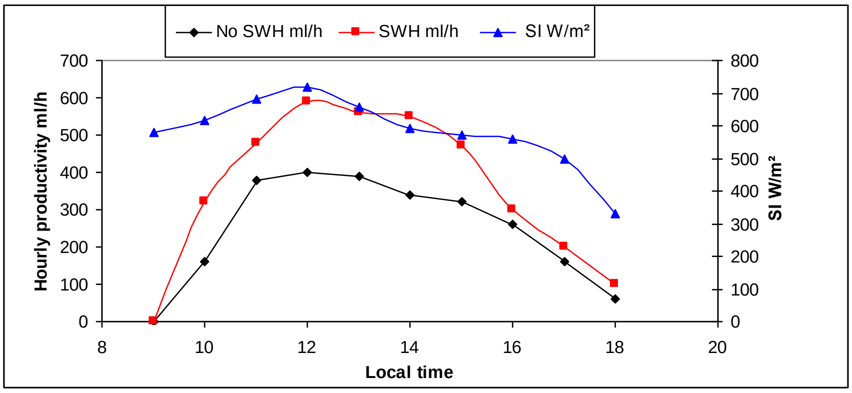

Fig. 8: Effect of variation of SI on hourly productivity in 9/5/2017

that SWH has a pronounced effect at higher SI, which is almost satisfied at solar noon. This agrees with the results of Nagarajan P.K., et al., 2017 [13]. They found that the yield from solar still increased with the increase in solar intensity during summer and decrease with wind velocity in winter. It also comes in accordance with the results of E. Kabeel, et al., 2012 [3]. They found that preheating the feed water of the stepped still had a slight effect on enhancing its productivity.

3.1.2.3. Effect of variation of SI on hourly productivity*:*

Figs. 9 - 11 are plotted for hourly productivity of the stills versus SI, both in presence and absence of SWH for the three days of experimentation.

An increase of 31.22% in the still productivity is accomplished as a result of the presence of the SWH. These data are on 7/5/2017. The corresponding percentages on 8/5 and 9/5 are 31.69% and 69.195, respectively. Thus, a much higher percentage increase (69.19 %) in still productivity is noticed in 9/5 which is characterized by the highest average solar intensity among the three days of experimentation. A percentage increase of 1.7% was noticed in the

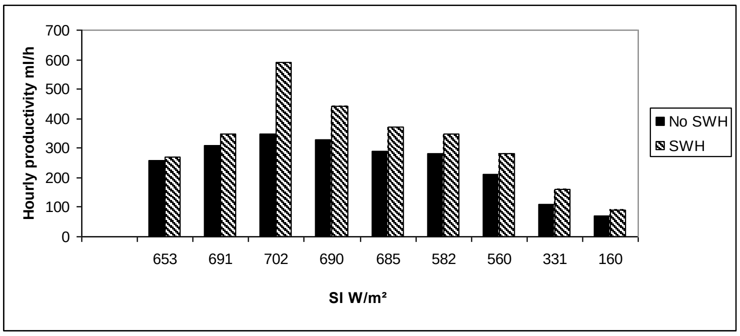

Fig. 9: Variation of hourly productivity with SI for still with and without SWH in 7/5/2017

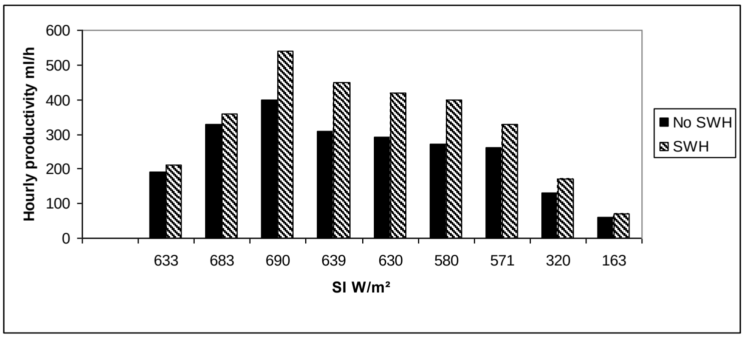

Fig. 10: Variation of hourly productivity with SI for still with and without SWH in 8/5/2017

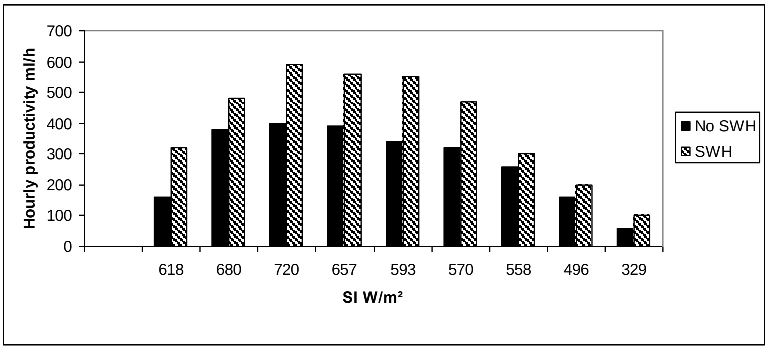

Fig. 11: Variation of hourly productivity with SI for still with and without SWH in 9/5/2017

still productivity in 8/5 over that of 7/5. This is to be compared to 1.36% when no SWH is used. This increase is also attributed to higher inlet water temperature in 8/5 than in 7/5. These results agree with the results of S.A. El-Agouz, et al., 2014 [14] and Aghareed M. Tayeb [12] who concluded that the inlet hot water temperature and flow rate had an important effect on productivity.

3.1.2.4 Effect of basin temperature on still productivity:

The basin temperature is recorded and plotted versus still productivity for the two units with and without SWH in 9/5/2017. The results are plotted as seen in Figs.12 and 13.

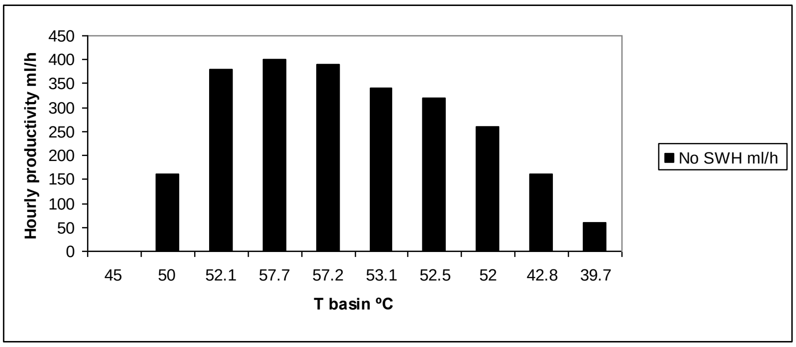

Fig. 12: Effect of variation of basin temperature on productivity of still without SWH in 9/5/2017

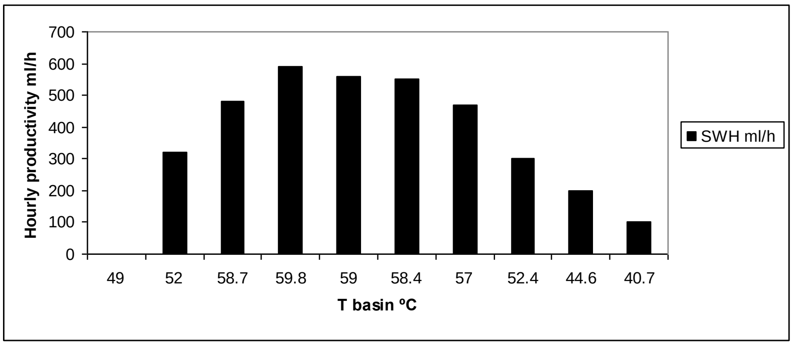

Fig. 13: Effect of variation of basin temperature on productivity of still with SWH in 9/5/2017

It is clear from these two figures that still productivity increases with increasing the water basin temperature. A maximum hourly productivity of 400 and 900 m*l* was recorded for maximum water basin temperatures of 57.7 and 59.8°C for stills without and with SWH, respectively.

3.2. Enhancing still productivity using metals as energy storage materials:

3.2.1 Use of copper filings (CF):

Experiments are run on three days (11/5, 12/5, 12/6/2017) with different values for SI. The variation of SI along these days is shown in Fig.14. Day 12/6 had the highest average SI among the three days and the highest value at solar noon (average of 480.3, 510.9, 520.4 W/m^2 and values at solar noon 655, 690,710 W/m^2 in 11/5, 12/5, 12/6, respectively).

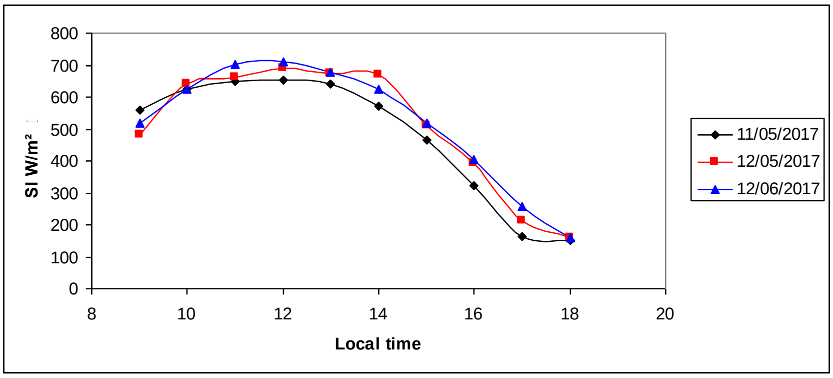

Fig. 14: Variation of SI with local time for three days (11/5, 12/5, 12/6 2017)

3.2.1.1 Effect of weight of copper filings (CF) on still productivity:

Different weights of copper filings (CF); 1, 2, 3 kg are added to one still and its productivity is compared with a reference still. The results on 11/5; when using 1 kg of CF, are shown in Figure 15. Figures 16 and 17 present the productivity of still in 12/5, 12/6/2017.

When using 1 kg of copper filings: Fig. 15 shows that the still with CF gave higher productivity than the other without CF (2520 m*l* when using 1 kg of CF compared to 1850 m*l* when no CF is used). Thus, a 36.2 % increase in productivity is realized when using 1 kg of CF.

Figure 16 shows the results of experiments run in 12/5/2017 using 2 kg of CF. It is clear that the still with CF has higher productivity along the day when compared with the still without CF (2770 m*l* when using CF compared to 1870 m*l* for the still without CF). Thus, an increase of 48.1% in still productivity is realized when using 2 kg of CF.

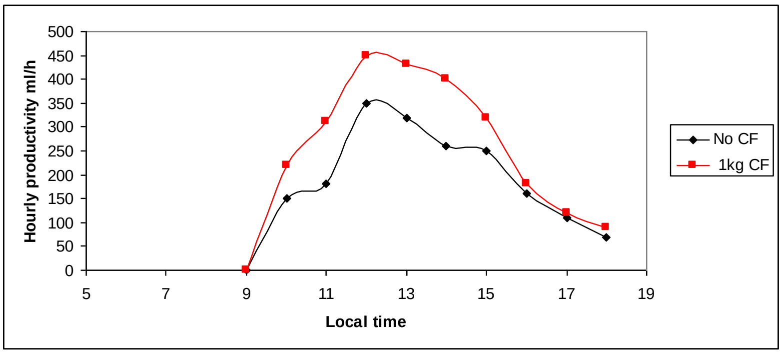

Fig. 15: Variation of productivity with local time for stills with and without 1 kg of CF in 11/5/2017

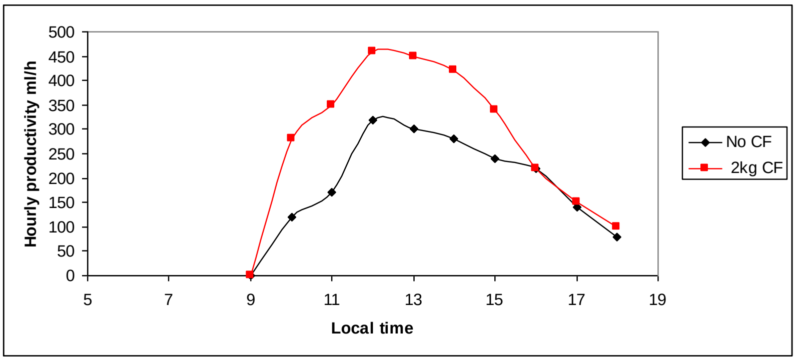

Fig. 16: Variation of productivity with local time for stills with and without 2 kg of CF in 12/5/2017

Fig. 17 is similar to Fig .16 but with the addition of 3 kg of CF. The same trend is shown as in Fig.16, i.e., an increase in still productivity due to the addition of CF. A 55.4% increase in still productivity is attained as a result of addition of 3 kg of CF. The results of this test show the same trend as those of Aghareed M. Tayeb, 1996 [12] who made a study using some metallic industrial wastes as energy storage materials. In her study she found that the energy that could be stored from these materials is as follows: 319, 272.5, 123.8, 225.5 and 294.3 joules (in the period from 2 pm o sunset) for iron slag, copper chips, cast iron slag, copper slag and aluminum slag, respectively. Abdallah, et al., 2009 [15] used some metallic materials in solar stills and they found that the overall average gain in the collected distilled water; taking into consideration the overnight water collections, were 28%, 43% and 60% higher than the reference still for coated and uncoated metallic wiry sponges and black rocks, respectively.

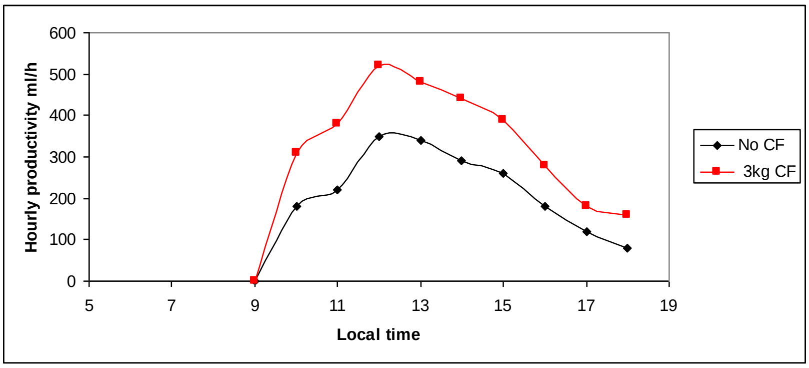

Fig. 17: Variation of productivity with local time for stills with and without 3 kg of CF in 12/6/2017

3.2.1.2 Effect of SI on still productivity:

Figs.18 - 20 are plots for the variation of still productivity versus SI with and without the addition of CF. Examination of these figures clarifies that hourly still productivity is proportional to SI.

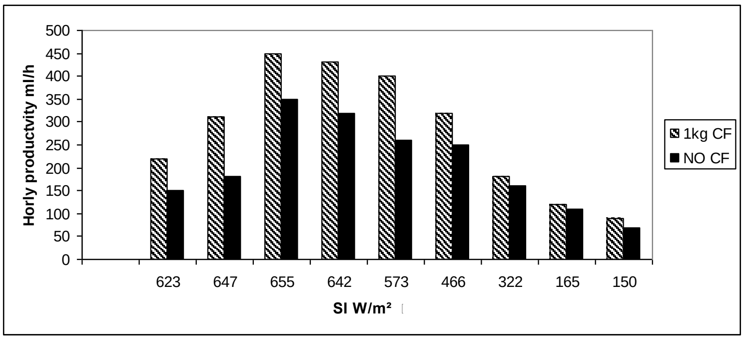

Fig. 18: Variation of hourly productivity with SI for stills with and without 1 kg of CF in 11/5/2017

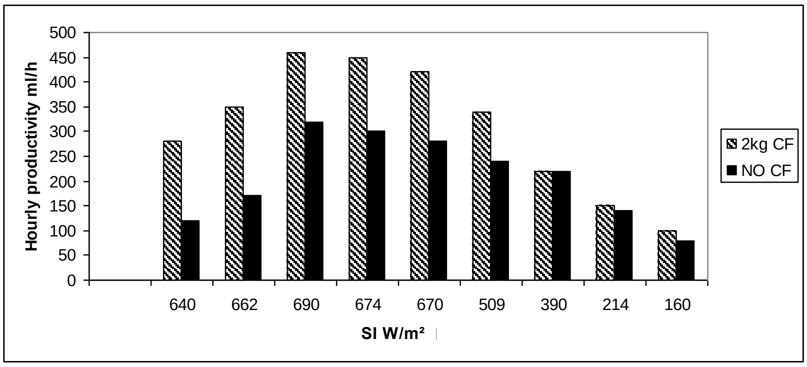

Fig. 19: Variation of hourly productivity with SI for stills with and without 2 kg of CF in 12/5/2017

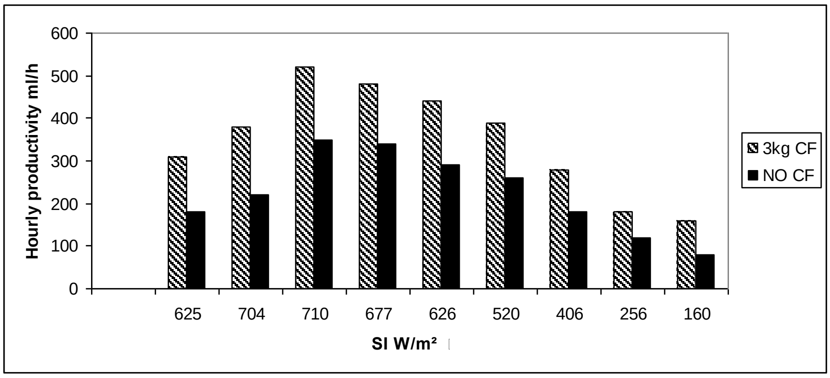

Fig. 20: Variation of hourly productivity with SI for stills with and without 3 kg of CF in 12/6/2017

3.2.1.3. Change of still productivity with local time:

Figs. 21 - 23 show the change of hourly productivity and SI with time for stills containing 1, 2 or 3 kg of CF compared to stills without CF.

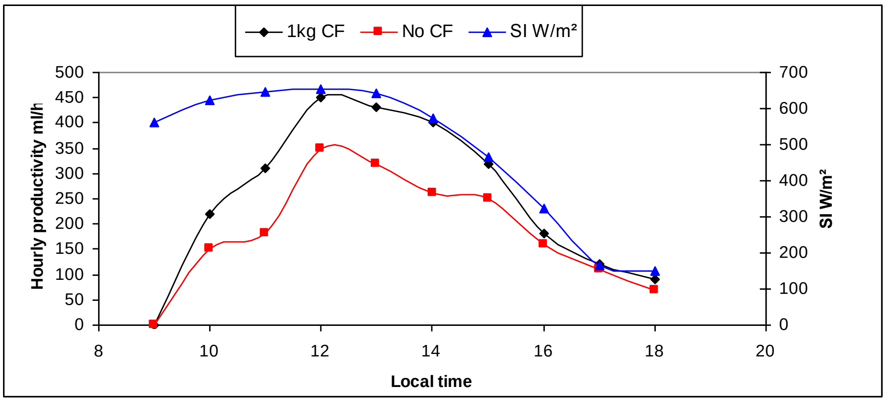

Fig. 21: Variation of hourly productivity and SI with local time for stills with and without 1 kg of CF in 11/5/2017

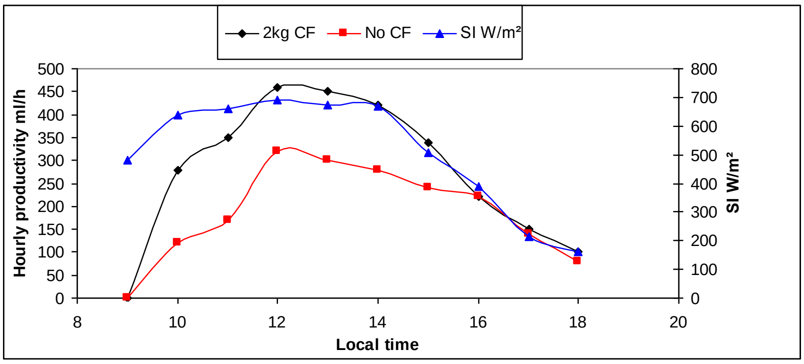

Fig. 22: Variation of Hourly productivity and SI with local time for stills with and without 2 kg of CF in 12/5/2017

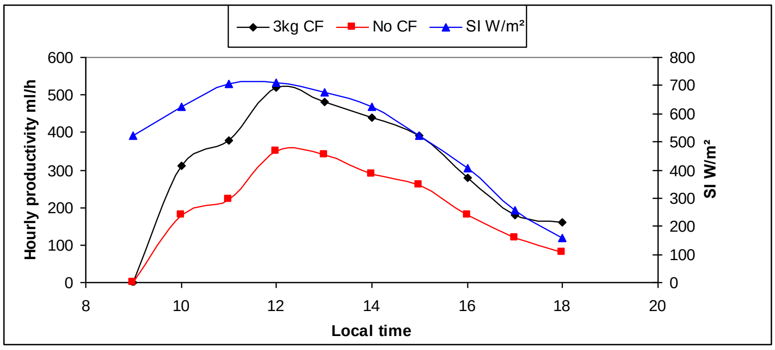

Fig. 23: Variation of hourly still productivity and SI with local time for stills with and without 3 kg of CF in 12/6/2017

Figs. 21, 22 and 23 show that an increase of 15.33%, 19.39% and 21.7% in still productivity was accomplished when using 1, 2 or 3 kg of CF, respectively**.**

3.2.1.3 Variation of hourly productivity with basin temperature:

The results of this test are given in Figs. 24 and 25.

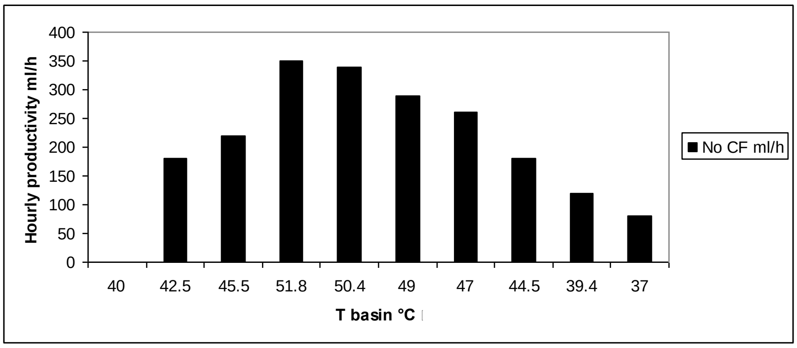

Fig. 24: Effect of variation of basin temperature on productivity of still without CF in 12/6/2017

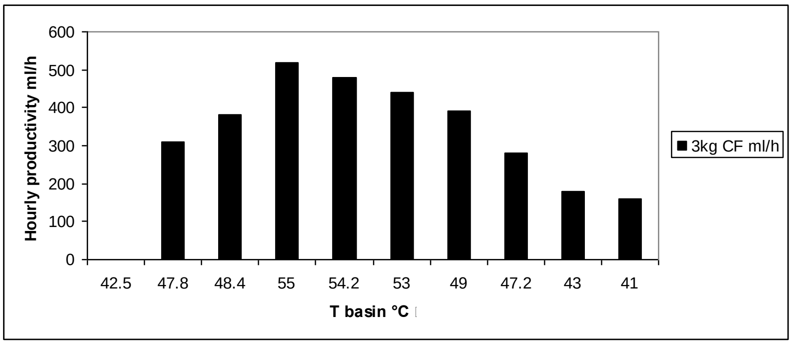

Fig. 25: Effect of variation of basin temperature on hourly productivity for still with 3 Kg of CF in 12/6/2017

Figures 3.24 and 3.25 show that the still productivity is proportional to the basin temperature. This seems to be logical since a higher still temperature means more evaporation and hence higher productivity.

3.2.2. Use of iron as an energy storage material:

Iron is used as an energy storage material on 7/8/2017. The change of SI with local time for this day is shown in Fig. 26. The maximum SI for this day was recorded at 12pm and it was 644 W/m^2. The average SI for that day was 475.9 W/m^2.

Iron is used in two forms: as iron filings (still A) and as iron swarf (still B); 3 kg in each still. Stills A and B are operated simultaneously and the productivity of both is recorded periodically.

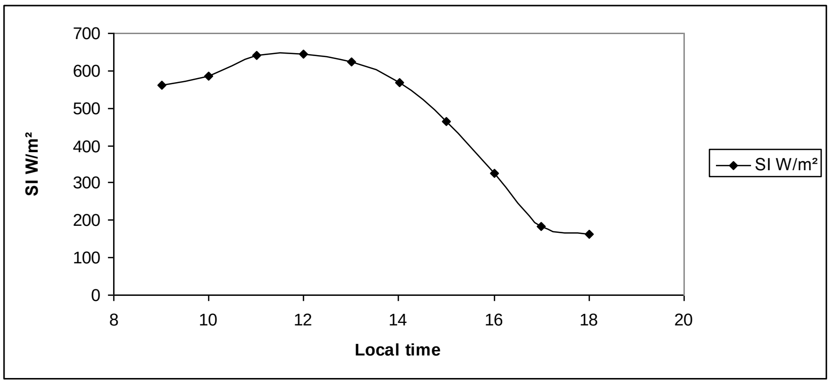

Fig. 26: Variation of SI with local time in 7/8/2017

3.2.2.1 Comparison between iron filings (IF) and iron swarf (IS):

. The results of this test are plotted as in Fig. 27.

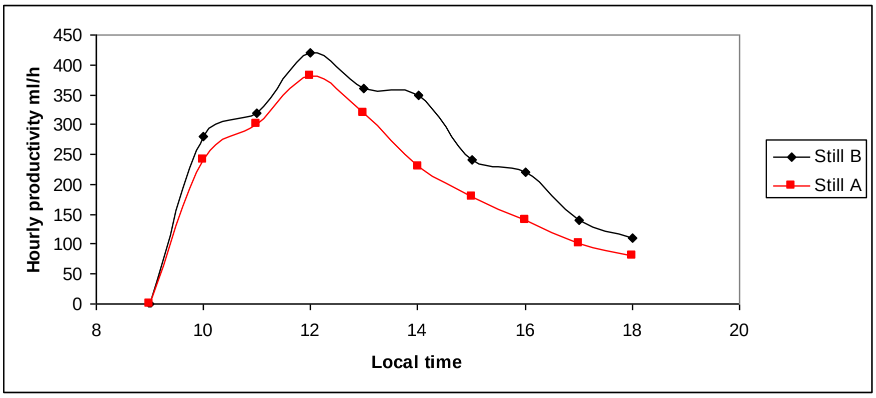

Fig. 27: Variation of productivity with local time for stills with IF and IS in 7/8/2017

A 23.9% increase in productivity of still B was noticed over that of still A. This is because IF has small particle size and it is more compact, thus it was almost immersed in water of the still. On the other side, IS is fluffy and part of it appeared from the surface of water in the still thus participated in absorbing a portion of the solar radiation. Similar results were satisfied by Pankaj K. Srivastava, et al., 2013 [6]. They found that the extended part of the fins received most of the solar radiation with minimum shading and satisfied more increase in still productivity. The results also show the same trend as the results obtained by A.E. Kabeel, et al., 2011 [16]. In their work they found that the daily production of still could be greatly enhanced using sponge cubes. When the fin and sponge type stepped solar still was used, the average daily water production was found to be 80% higher than ordinary single basin solar still.

Fig. 28 is a plot for hourly productivity of stills A and B versus SI. The figure shows the same trend as before, i.e., increase of productivity with the increase of SI.

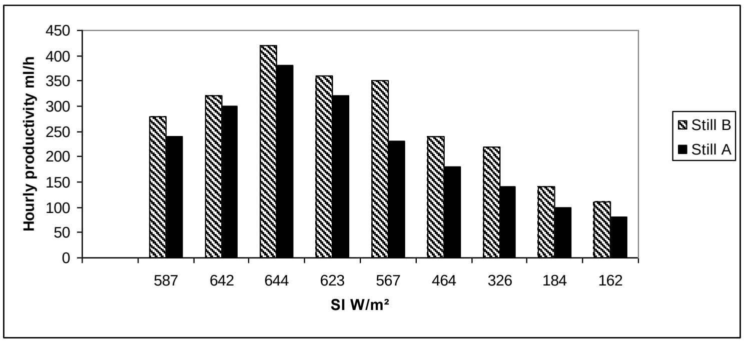

Fig. 3.28: Variation of hourly productivity with SI for stills A and B

Figs. 29 and 30 are plots of hourly productivity of stills A and B versus basin temperature.

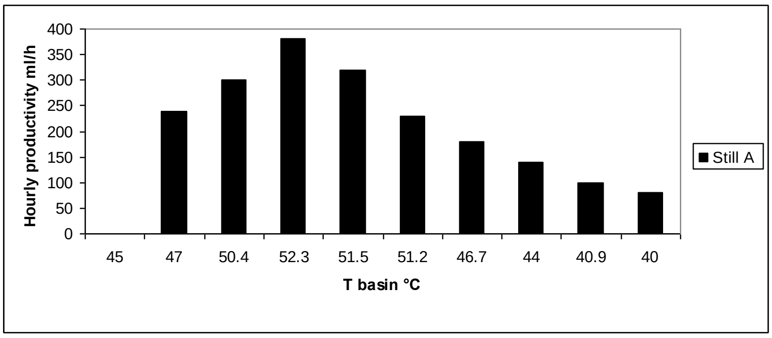

Fig. 29: Effect of variation of basin temperature on hourly productivity of still A

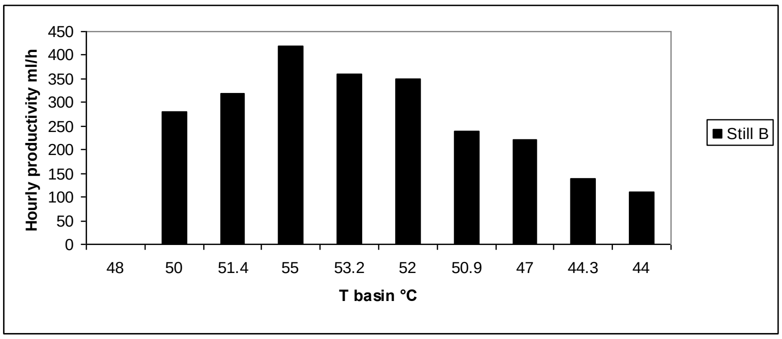

Fig. 30: Effect of variation of basin temperature on hourly productivity of still B

These figures show the same trend as before, i.e., an increase in productivity as a result of increase of basin temperature. The maximum basin temperature for the still with IF was 52.3°C corresponding to 55°C for the still with IS under the same SI at solar noon. This is equal to 5.16% increase in basin B temperature. This agrees with the work of A.S. Abdullah, 2013 [1]. He found that fresh water productivity was increased as a result of increasing water temperature. The productivity of the stepped still increased by integrating aluminum filling as simple solar energy storage system beneath the absorber plate (53% higher than the productivity of the conventional still).

3.2.2.2 Comparison between IF and CF:

This test was run in 1/8/2017 when the values of SI was as shown in Fig. 31.

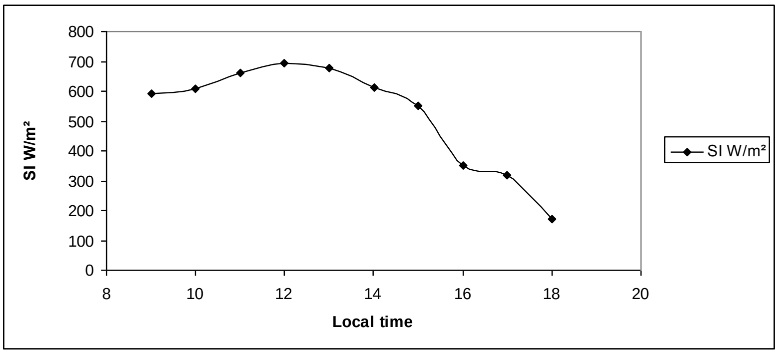

Fig. 31: Variation of SI with local time in 1/8/2017

The maximum SI recorded for this day was 692 W/m^2 at 12 pm. The average SI of this day was 523.3 W/m^2.

For the object of comparing the performance of (IF) and (CF) as energy storage materials, two experimental runs were performed on two desalination units; one having 3 kg of IF and the other having 3 kg of CF. The results of this test are plotted as given in Fig. 32.

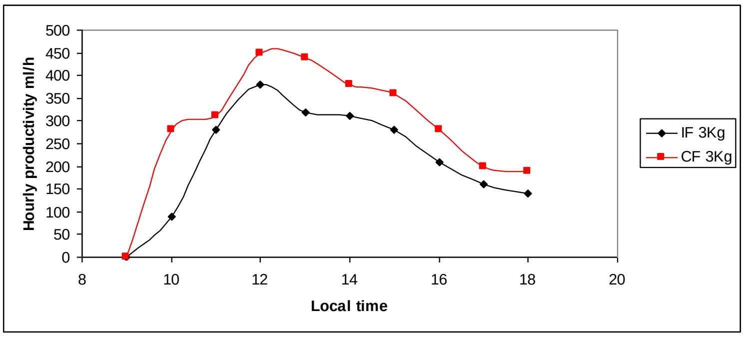

Fig. 32: Variation of hourly productivity with local time for still with CF and still with IF

Examination of Fig. 32 shows that (CF) results in higher productivity than (IF). The daily productivity (from 9 am to 6 pm) of the still having CF was 2890 m*l* and the corresponding value for the still having IF was 2170 m*l*. Thus, 33.2% increase in daily productivity was achieved when using CF over that when using IF. Fig. 33 shows the variation of stills productivity having IF and CF with SI. The figure shows higher productivity with higher SI, with relatively higher values for CF.

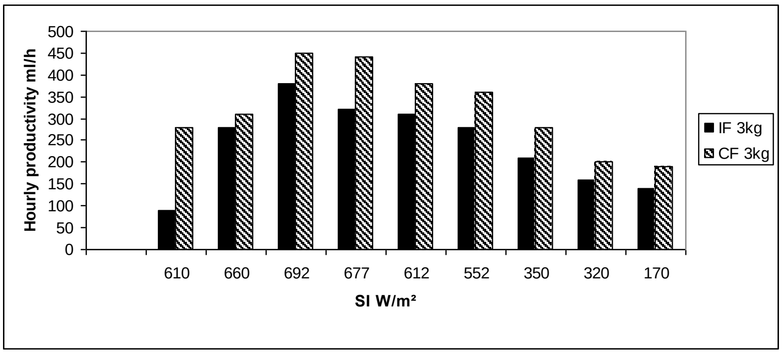

Fig. 33: Variation of hourly productivity with SI for still with IF and still with CF

3.2.2.3 Variation of hourly productivity with basin temperature:

Results of this test are plotted as in Figs. 34 and 35 for IF and CF, respectively.

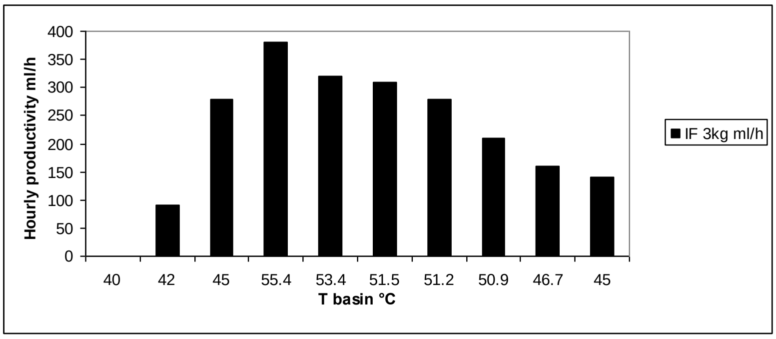

Fig. 34: Effect of variation of basin temperature on hourly productivity of still with IF

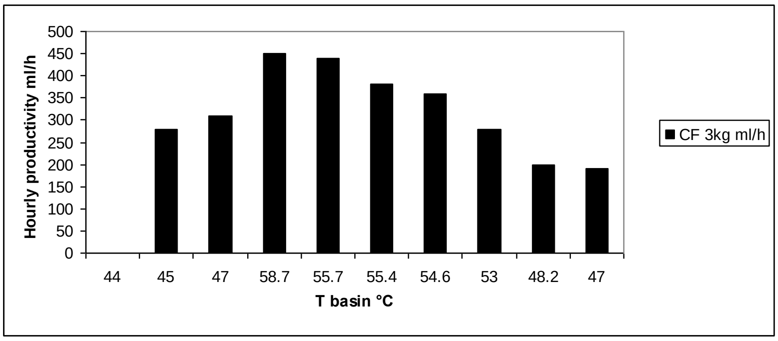

Fig. 35: Effect of variation of basin temperature on hourly productivity of still with CF

When using IF a maximum of 55.4°C was reached for basin temperature at solar noon and this condition resulted in a maximum hourly productivity of 380 m*l*. When using CF a maximum water basin temperature of 58.7°C was reached at solar noon. AT noon time, 12 pm, the still with CF was 5.95% higher in its basin temperature than that with IF and its maximum hourly productivity was 450 m*l*.

3.2.3. Comparison between stills with different metals and with SWH:

Experiments on copper and iron are made on different days so, comparison between both as energy storage media will not be fair. For that object the daily productivity in each case is divided by the integrated amount of solar energy obtained through the working hours of experiments. In this case the productivity per unit solar energy is obtained and a comparison could then be obtained. The data from the present test and the previous ones are summarized in table 1.

Table 1: Comparison between the productivity of stills as ml/unit SI

Date / Readings	1/8/2017			7/8/2017			9/5/2017		
		Daily prod.	Prod./ unit SI		Daily Prod.	Prod./ unit SI		Daily prod.	Prod./ unit SI
Integrated solar energy, w/m^2	5233			4759			5801		
Productivity when using IF		2170	**0.41**		1970	**0.41**			
Productivity when using CF		2890	**0.55**			**0.51**			
Productivity when using IS					2440	**0.51**			
Still integrated to SWH								3570	**0.43**

Thus, the significance of the materials used as energy storage media could be arranged as follows: CF > IS > IF, with the still integrated to a SWH just a little better than that with IF (0.43m*l*/W/m^2 for the still with SWH compared to 0.41m*l*/W/m^2 for the still with IF)

Conclusion:

The following conclusions could be made from the present work:

- The productivity of the still is enhanced by increasing inlet water temperature. An increase of 31.22%, 31.69% and 69.195% for 7/5, 8/5 and 9/5/2017, respectively was accomplished in still productivity as a result of integrating the solar still to a SWH. Different percentages were obtained for different solar intensities for these three days.
- The effect of integrating a SWH becomes pronounced at higher SI, e,g, at solar noon.
- The order of magnitude of percentage increase in still productivity comes in the same order of average SI at solar noon; 68.57%, 35% and 47.5% increase in productivity for average SI of 661.5, 639 and 649 W/m^2, respectively.
- The effect of the various metals and various shapes of a metal on productivity is in the order : CF > IS > IF, with the still integrated to a SWH just a little better than that with IF.

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ملخص البحث

اظهرت النتائج ان انتاجيه المياه العذبه لكل وحده الطاقه الشمسيه زادت بزياده درجه حراره المياه المغذيه لها .وقد تم تحقيق زياده انتاجيه المياه العذبه بنسبه ٣١.٢٢% و٣١.٦٩% و ٦٩.١٥٩% لأيام ٥/٧ و ٥/٨ و ٢٠١٧/٥/٩ على التوالى نتيجه لتوصيل سخان المياه بالطاقه الشمسيه . نسب مختلفه تم الحصول عليها لشده الطاقه الشمسيه لهذه الايام الثلاثه. توصيل سخان المياه بالطاقه الشمسيه اظهر تأثير قوى نتيجه لزياده الشده الشمسيه فى وقت الظهر .نسبه زياده انتاجيه وحدات الطاقه الشمسيه نتيجه لزياده متوسط الشده الشمسيه كان ٦٨.٥٧% و ٣٥% و ٤٧.٥% للانتاجيه لمتوسط ٦٦١.٥ و ٦٣٩ و ٦٤٩ وحده طاقه / م^2 على التوالى .

تأثير المعادن المختلفه باشكالها المختلفه على الانتاجيه كالتالى براده النحاس > رايش الحديد > براده الحديد .انتاجيه وحده الطاقه المتصله بسخان المياه بالطاقه الشمسيه افضل قليلا فى الاداء من وحده الطاقه التى تحتوى على براده الحديد .