

Experimental Investigation of the Effects of Preheating on Still Productivity

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Abstract – Single basin solar still (SBSS) has low productivity in this experimental research, some techniques have been employed to solve this problem, these techniques consist of using a flat plate collector. The main aim of this research was to make efficient use of the flat plate collector (FPC) to increase solar still productivity, and it works as a hybrid device. The model solar water heater for the flat plate collector (FPC) was coupled with a solar still, and the tests were repeated in 3 to 5 winter days, and the results were measured in the same way for each day. The results revealed that the productivity of the still increased 87 % when coupled with one, and decreased 20 % and 50 % when coupled with two and three flat plate collectors in southern Algeria, respectively.

Keywords: Solar energy, solar desalination, solar still, flat plate collector, productivity.

Received: 03/05/2020 – Accepted: 19/06/2020

I. Introduction

Solar energy is one of the renewable energies; it is used in several fields, especially in solar distillation. Algeria has great energy potential in solar energy and it is favorable for solar distillation and heating of water. A study shows that any variation in solar radiation has an influence on the conventional solar still [1,2]. Several researches have been made in the south-eastern region of Algeria with the aim of treating polluted groundwater to transform it into pure portable water; researchers have conceived a small pilot distillation station in this area. Their studies aim at improving the efficiency of a small solar distillation station under real insulation for underground geothermal desalination of water in the arid regions, and also to generate drinking water in arid regions. The small station had more than 15 l/m² of daily capacity [3-5]. In the same direction, a simpler study shows step by step the conventional solar still construction which can produce between 4 to 6 l/m² per day [6]. The transformation of affected groundwater into pure water is the subject of several research projects around the world [7-9]. The main objective of any

researcher in the field of solar distillation is to improve the performance of a solar still using several simple, complex, economical, environmental techniques. Among the techniques used, it is to take the glass cover (the condenser) as a factor of improvement; either by varying the angle of the cover (10, 15, 20, 30, 35 and 45 °) relative to the horizontal to determine the best angles which give the best performance of the still [10], either study the heat flow which passes from the interior of the still to the exterior via the cover [11], or to investigate the temperature gradient between the water and the cover [12] or to see the effect of double glazing on the performance of the solar still [13]. The use of a commercial refractor has improved the performance of solar stills and this has been proven experimentally [14, 15]. In solar distillers, the energy storage technique was used to increase productivity so that copper, stainless steel, mica, aluminum, sand and a black metallic plate of Zinc were dipped into the water basin and increased the productivity of pure water between 19 and 45 % [16, 21]. The preheating by an external solar device such as solar collectors is a relatively complex process used in active

solar distillation [22, 26].

The aim of the present paper is to conduct an experimental study under the climatic conditions of south-east Algeria for the solar still in active mode. To improve productivity, various operational techniques have proposed.

II. Experimental investigations

II.1. solar still coupled with flat-plate collector

Figure 1 shows the schematic diagram of a flat plate collector coupled to a single slope solar still. In Figure 1 and 2 we see four identical stills that were made from different local materials in order to reduce cost and make construction easier. Solar stills coupled with 3 different number of FPCs, namely single collector, two collectors and three collectors, collector inclination of 30° is fixed for all experiments. There were four phases in the experiment: witness still, still with one FPC, still with two FPCs connected in series and still with 3 FPCs connected in series. For all of the four experiments, the following parameters are measured on 12 h basis: The parameters, outer glass temperature, inner glass temperature, vapour temperature, water temperature, ambient temperature, incident radiation on glass cover and collector/collectors, inlet and outlet temperatures of collector/collectors and distillate output

$$\eta_D = \frac{\sum m_{FW} L}{A_g \sum I(t)} \times 100 \quad (1)$$

For the active solar still,

$$\eta_D = \frac{\sum m_{FW} L}{A_g \sum I(t) + A_c \sum I_c(t)} \times 100 \quad (2)$$

Where m_{FW} is yield, L is latent heat, A_g and A_c are areas of glass cover and collector and $I(t)$ and $I_c(t)$ are incident radiations on still and collector.

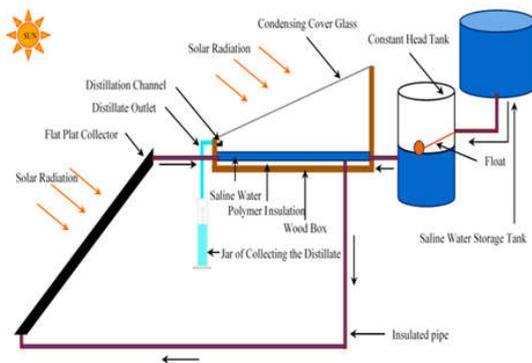
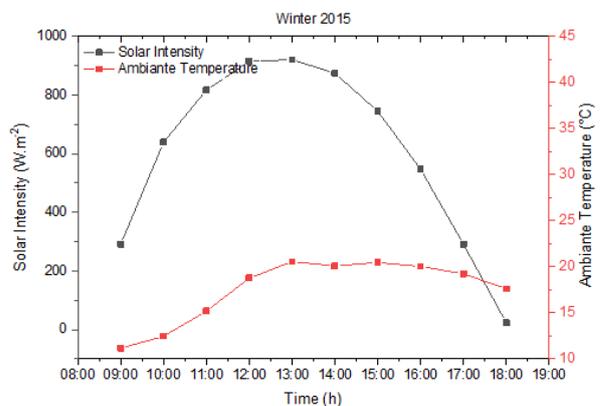


Figure .1. Line diagram of an active solar still coupled with flat-plate collector

III. Result and discussions

III.1. Solar intensity, ambient temperature and wind speed

We report in this study the comparative performance of a single basin active solar still with 30 condensing cover inclination with one FPC and two different numbers of FPCs connected in series and a single slope. The tilt angle and three different collector inclinations were fixed at 30° for the solar still (experimental result shows 30° was optimal inclination angle in winter at Ouargla's city). Figure 3 shows the ambient temperature, wind speed and the varying intensity of solar for January the 18th and this day as is shown in the figure has the maximum irradiance (910 W.m⁻²) at 13:00 h, maximum wind speed (7.5 m.s⁻¹) at 10:00h and maximum ambient temperature (20 °C) at 13:00h. Figure 3 also shows that the minimum irradiance (245 W.m⁻²) at 09:00 h and 17:00 h, and minimum wind speed (2 m.s⁻¹) at 09:00 h, 17:00h and 18:00h, and minimum ambient temperature (11 °C) at 09:00 h. These results show beyond reasonable doubt that Ouargla has an attractive solar energy.



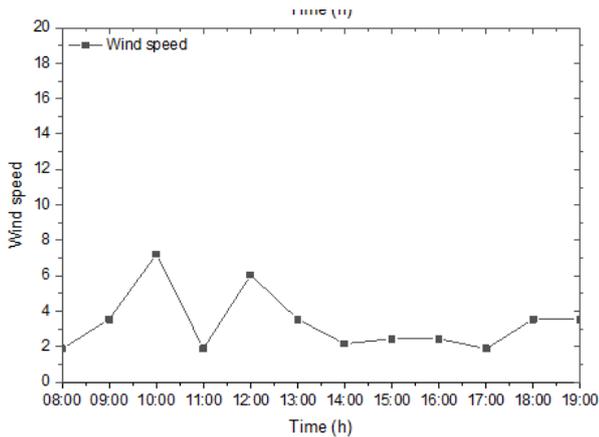


Figure 3. Solar intensity, ambient temperature and wind speed vs local time (18/01/2015)

III.2. Hourly variation of productivity

Figure 4 shows that high productivity is achieved for the still coupled with 1FPCs in comparison to others to the 12h period. The distillation efficiency and the daily productivity are for the still coupled with three different FPC arrangements are shown in figure 6. The still with 1 FPC and 2 FPCs in series obtain respectively a maximum yield of 6.669 kg and 2.87 kg. The still with 3 FPC however has a productivity of 1.75 kg and 0.606 kg for witness solar still. It becomes obvious that the still with single FPC gives more yield than FPCs connected in series. The cause of this is that the still with one FPC has an increased area for solar radiation; maintain low temperature of condensing cover for more time (less than 60°C).

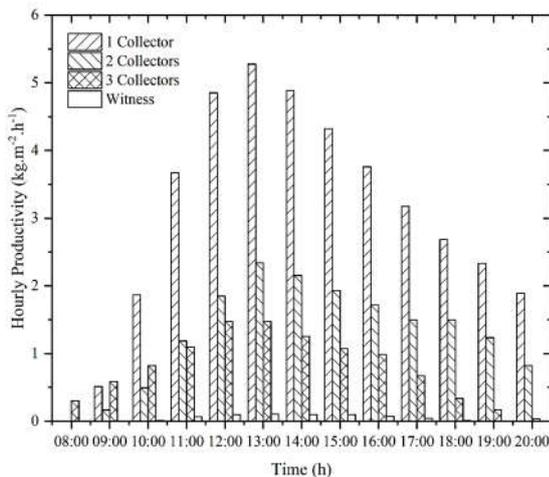


Figure 4. Hourly variation of productivity

III.2. Average daily production for different configurations

Compared to the one with witness, the still with 1 FPC has a greater daily productivity by 1000%. In comparison to the one with a witness, the still with 3 FPCs in series has 300% less efficiency. The yield and still efficiency will increase with the increase in ΔT which is a tendency that we can observe for the still with one FPC as well as for the still with 2 FPCs in series. However, the efficiency has decreased compared to other two cases, as the increase in area off sets the advantage of increase in yield for the still with 3 FPCs in series.

Nevertheless, the productivity is found to decrease for the still with 3 FPCs in series due to the increase in collector area and the distillation efficiency is optimum for the witness still compared to other arrangements as shown in Figure 5.

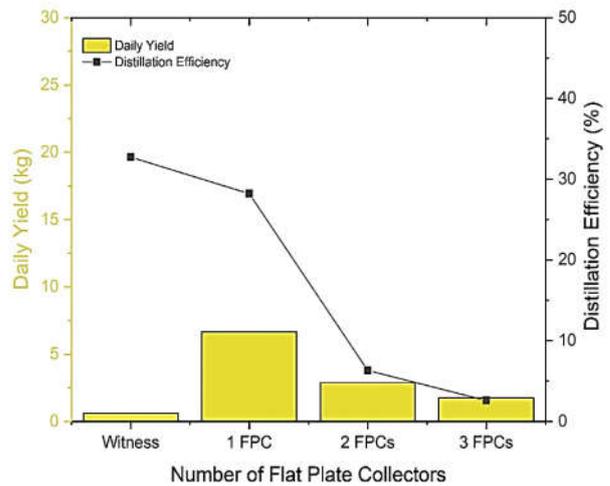


Figure 5. The average daily production for different configurations

III.3. Hourly variation of temperatures

Figure 6 shows the hourly water and condensing cover inside temperatures for still coupled with different numbers of FPCs in series. Because of more added area with 3 FPCs for solar radiation, maximum temperatures are obtained for the still with 3 FPCs connected in series when compared with witness, 2 FPCs and 1 FPC. There is significant increase for the still with 2 FPCs to 3 FPCs when there is water and condensing cover inside temperature because the local solar irradiation was very high during experimentation.

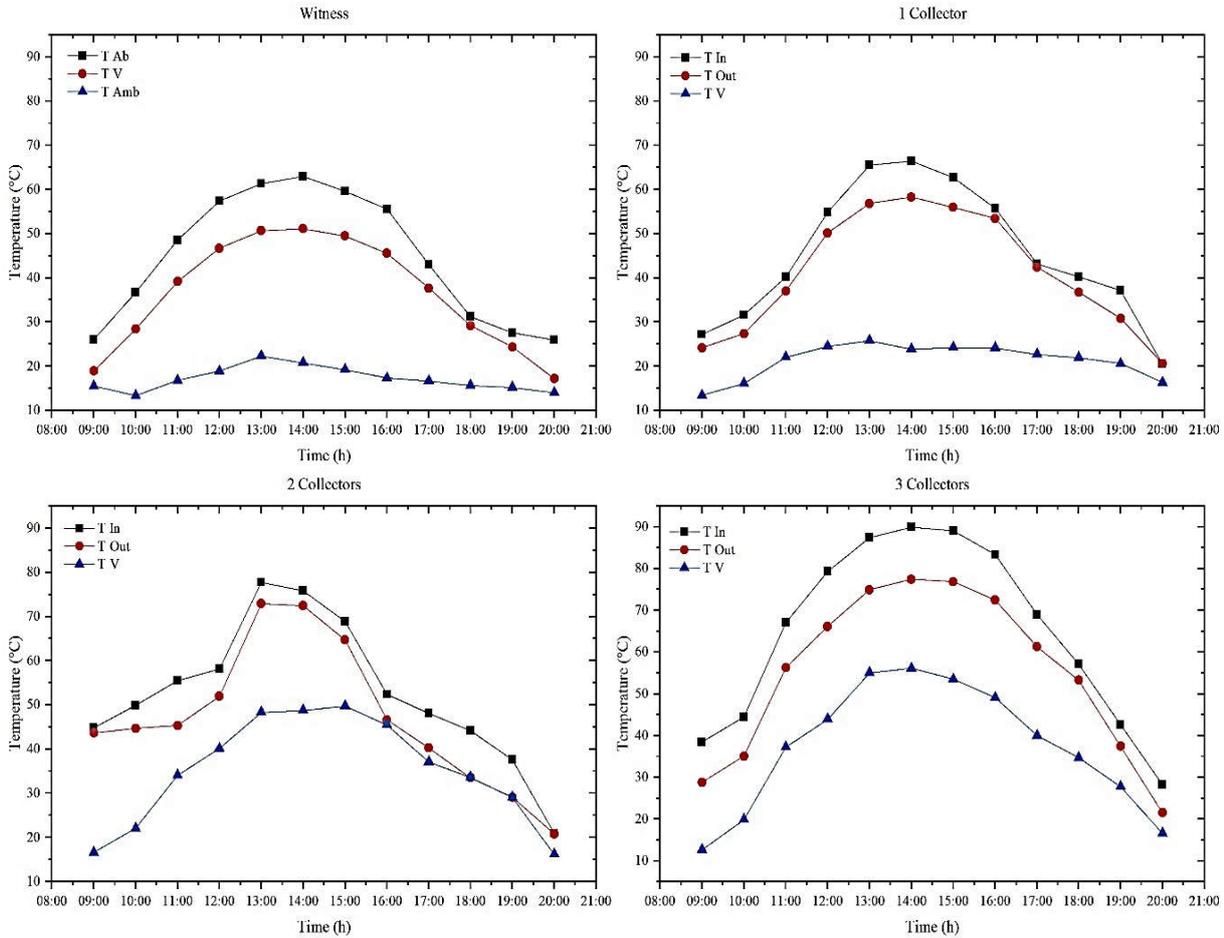


Figure .6. Hourly variation of temperatures

IV. Conclusion

- 1 and 2 FPCs connected in series obtain more productivity compared to that with one FPC. Consequently, to enhance the distillate yield the one FPC is found to be more suitable. The partial pressure difference between water temperature and condensing cover temperature is found to be high, which directly influences the yield.
- The still with 2 FPC and 3 FPCs connected in series have distillation efficiencies of 6% and 3% respectively. The still with single FPC obtains a distillate efficiency of 17% and consequently the witness solar stills with produces the optimum (20%).
- The still with single FPC obtains a maximum yield of 6.669 kg whereas the yield is 2.87 kg for the still with 2 FPCs in series and 1.75 kg for 3 FPCs respectively.
- For the still with 2 and 3 FPCs in series has an average daily yield is 380% and 73% less

Respectively when compared to still with single FPC. For the still with 2 and 3 FPCs in series respectively,

- when compared to that with single FPC the distillate efficiencies are 183% less and 466% less
- To witness an increase in productivity it is not necessary to increase the number of collectors and to obtain the highest productivity there are several factors that must be studied. The study will be useful for designing efficient active solar distillation systems for the winter climatic conditions with 31.95°N, 5.4°E.

Acknowledgment

For providing the experimental facilities, we are very thankful to Dr. TEKHA Mohammed member in the LENREZA's Lab teacher in the department of Materials Science, Kasdi Merbah Ouargla University. Algeria.

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