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Productivity-Improving of a Single Gradient Solar Still

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Abstract: This research paper concentrates on improving the performance of solar distilled with the single gradient in the province of DhiQar-Iraq. Two solar distillations have been designed with the same dimensions and with an area of (1250 cm²). The effect of the condensation cover on the two distillations' productivity by using a glassy and a plastic covers has been studied. From the laboratory experiments, the distillation with the glass cover had a good productivity compared with the other one. After this step, the researcher tried to increase and improve the distillation productivity by adding the coal powder to the distillation base after mixing the powder with the black dye and compares it with a distillation painted with the black dye only. Adding the coal powder to the black dye increased the distillation efficiency approximately with a percentage of (8.2%). The highest efficiency of the solar distillation with the glassy cover and the base dyed with the black dye was (57.2%), while the highest efficiency of the solar distillation with the glassy cover and the base dyed with the black dye that mixed with the coal powder was (65.4%).

Keywords: Solar still, productivity-improving, distillation, black dye, coal powder.

I. Introduction

The supply of drinking water is one of the major problems in developing countries. Clean Water is a basic human necessity, and without water the life will be impossible [1]. Water is the imperative source of life and it is overridden to live next to oxygen. Pure water is the most important substance for nourishing human life, and it's a key to life. Water shortage problem in all over the world, Where 40% of the world's population suffer from scarcity of fresh water [2, 3]. Although 75 percent of the earth is covered with water, 97 % of Earth's water is too salty for us to use. 3% of Earth's water is fresh water, only one-third is accessible at the lakes and rivers [4, 5]. Solar desalination is one of the cheapest methods for this problem. Solar still is widely used in the solar desalination [6]. Solar distillation is one of the available methods for water distillation, and sunlight is one of several forms of heat energy that can be used to power that process. Sunlight has the advantages of zero fuel cost, but it requires more space (for collection) and generally more equipment [7]. Solar distillation has been used to produce low yield. In remote areas this method used to get a safe and pure supplies of water. For households without access to potable water, a simple solar still can easily produce the drinking and cooking water. Also, distilled water can be used in industry, such as water jackets, batteries, and chemical solutions [2, 8].

Sun is the main source of energy in the universe. We can take advantage from this energy source, directly or indirectly, by turning the solar energy into another type of energy (electrical, mechanical, chemical, thermal) [9]. The solar distillation is one of the methods that used to take advantage of direct solar energy for the purpose of distilling water. "Solar distillation" device, which is used in this process, is similar in its process with evaporation of naturally occurring water that evaporates from the surface of the earth due to the high temperature, and then condense to form clouds and then falls as drops as water dripped [10].

The solar radiation is a form of thermal energy that used in the distillation process. Also, this method is one of the oldest techniques which used for this purpose. The distillation with a pool is one of the most important kinds of the desalination system [11, 12]. The first solar distillation station has been established by Swedish engineer in 1972. The productivity of it was 4.255 l / m² [4] and it built on an area of 4450 m². Since 1950, the practical researches begin focused on improving the techniques to get the fresh water from salt water using solar energy using the solar distillation technique. There were many kinds of the distillation method. The scientific researches are going toward designing and studying new types of the distillation. The traditional solar distillation is the simplest types, it usually consists of a black color base with a glass cover declined with a specific depending on the geographic location. The water steam will condense on the internal surface of it and then the water accumulated within channels. The water produced by this technique is ranging from (1- 4) l / m² with a thermal efficiency up to approximately 50% depending on several factors, including distilled basin properties and the weather condition such as, air temperature and the amount of solar radiation... etc. [13].

II. Experimental procedures

Two solar distillations were designed with the same dimensions; each one consists of a base of aluminum with a thickness of 0.1 cm, a length of 50 cm, a width of 25 cm, and a height of 5 cm, the figure 1 shows the two

distiller. This base was put in a box of wood as a thermal insulator to insulate the still from the outer condition effects. The wooden box dimensions are 51 cm in length, 26 cm in width and the height of the front and back sides are 8 cm and 15 cm, respectively. To have a maximum solar radiation we chose a dip angle of the cover of condensation about 15° . To feed the solar distilled with salt water, one hole, with dimensions of 51 cm and 1 cm, was made in one of the wooden box sides. A plastic tube was used along the front side of the distilled. This plastic tube has a trench to insert the condensation cover which has a thickness of 0.4 cm and a length of 51 cm. Finally, the distilled water will enter through this hole and drain out to the water accumulation bottle. The plastic tube is opened from one side and is closed from the other side.

The two water distilled experiment was done in two steps, the first one was to test the effect of the condensation cover on the two distilled performance and knowing the better one. Both of the distilled were dyed with the black dye to increase the solar energy absorption (the black color has the highest solar radiation absorption), finally increase the productivity. After that, a glass and a plastic condensation covers (have the same dimensions with a length of 51 mm, width of 28 mm, and a thickness of 4 mm) were used to cover the first and the second distilled ailed respectively. The differences in the distilled ailed productivity had been studied. In the second step and after knowing that the distiller with the glass cover is the better one, the plastic cover of the second distiller was replaced with a glass cover after removing the black dye and using a black dye mixed with the black coal powder. The last model was studied and compared with the glass cover distilled that dyed with the black dye only. The performance of these two distilled had been studied for many days. The distilled internal temperature was measured using the mercurial thermometer. A plastic tube was used to transfer the water to the measurement's bottle which used to measure the pure (distilled) water quantity which produced by each distilled, this plastic bottle that used to that purpose has a capacity of 5 l. Figure (1) shows the two distiller.

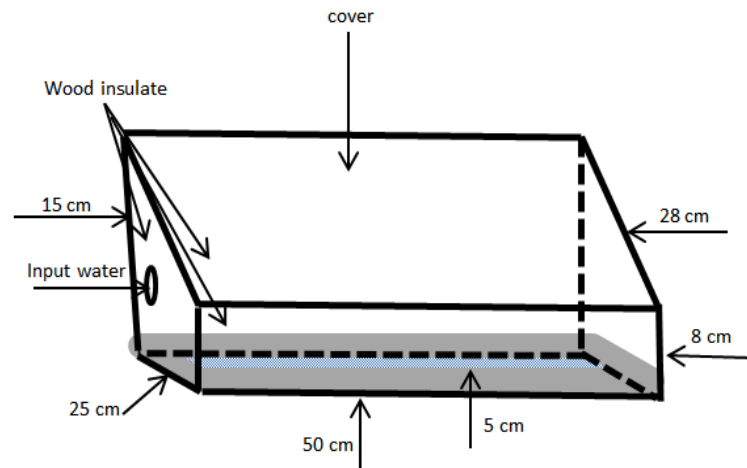


Fig. 1: Schematic diagram of a single slope solar still.

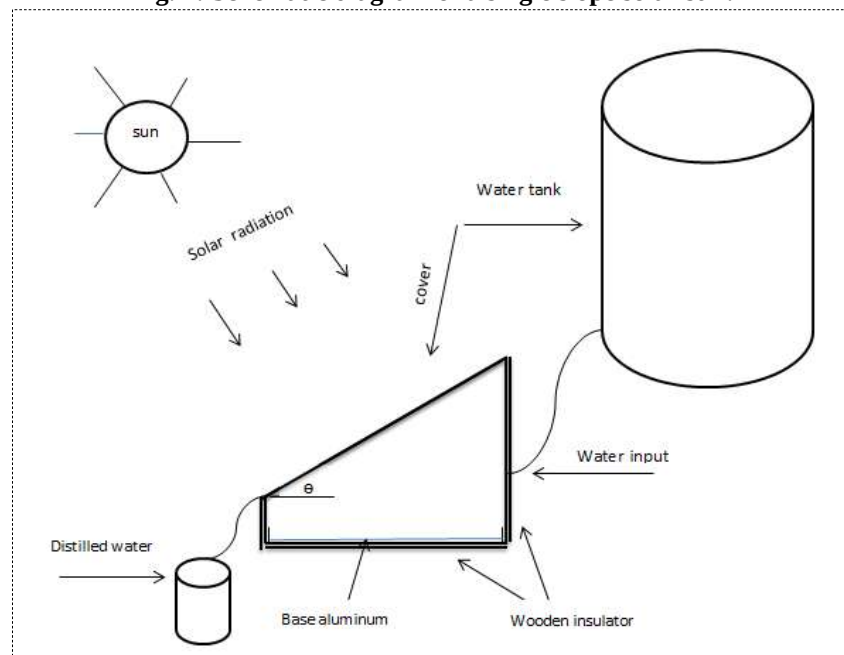


Fig. 2: Schematic diagram of the experimental setup.

III. Experimental Results and Discussion

A. Comparison between the performance of a distiller with glass cover and another with plastic cover

An experiment was done to examine the performance of the two solar distillers for several days of May, the two distillers were prepared to work after fixing them and making sure that there are no presence of any problem in their design. The two distillers were put on concrete blocks to the south to be exposed to solar radiation for long possible time, then they resolved by the settlement balance to ensure that the distribution of water in the interior basin of the distiller is at equilibrium after that, an amount of salty water was put in the distillers basin for 3 cm height at early morning, then the two distillers began working at 8 a.m. till 6 p.m. the practical result are shown in the following forms for the days of experiment:

Fig. 3a daily production of the two solar stills through some days of May 2014, fig. 3b Values of solar radiation to the days of the test, fig. 3c daily production to the two solar stills with solar radiation to the test days. These Figures show that there are that clear increasing in the production of the distiller with glass cover for the days 15-18/5/2014 and that depends on the quantity of solar radiation, which was in increasing in these days, and we notice that there was a slightly increasing in the production on the day 19/5/2014, because there were clouds in that day, which led to a decreasing in the quantity of the solar radiation, and a decreasing in the distillers production. It was clear an increasing in the production for the day 25/5/2014 because of the increasing in the solar radiation for this day. But which was clear with respect to the solar distiller that has a plastic cover in the same Figures 1,2 and 3 is totally different from that presented in the distiller which has a glass cover, in which show a clear decreasing in the production of this distiller for all days, and this decreasing is due to the nature of the plastic cover that effects so much by the increasing of the temperature which increase inside the solar distiller, and the weather conditions around it, where gets a concavity occurs in this plastic cover at the middle between the black and the front wall of the distiller, also the water spots that condensed on this cover fall in this distiller and only few drops get out to the channel that used to drain the condensed water outside the distiller. This concavity increases daily in the plastic cover, which lead to the decreasing in the distills production gradually as it clear in the mentioned figures.

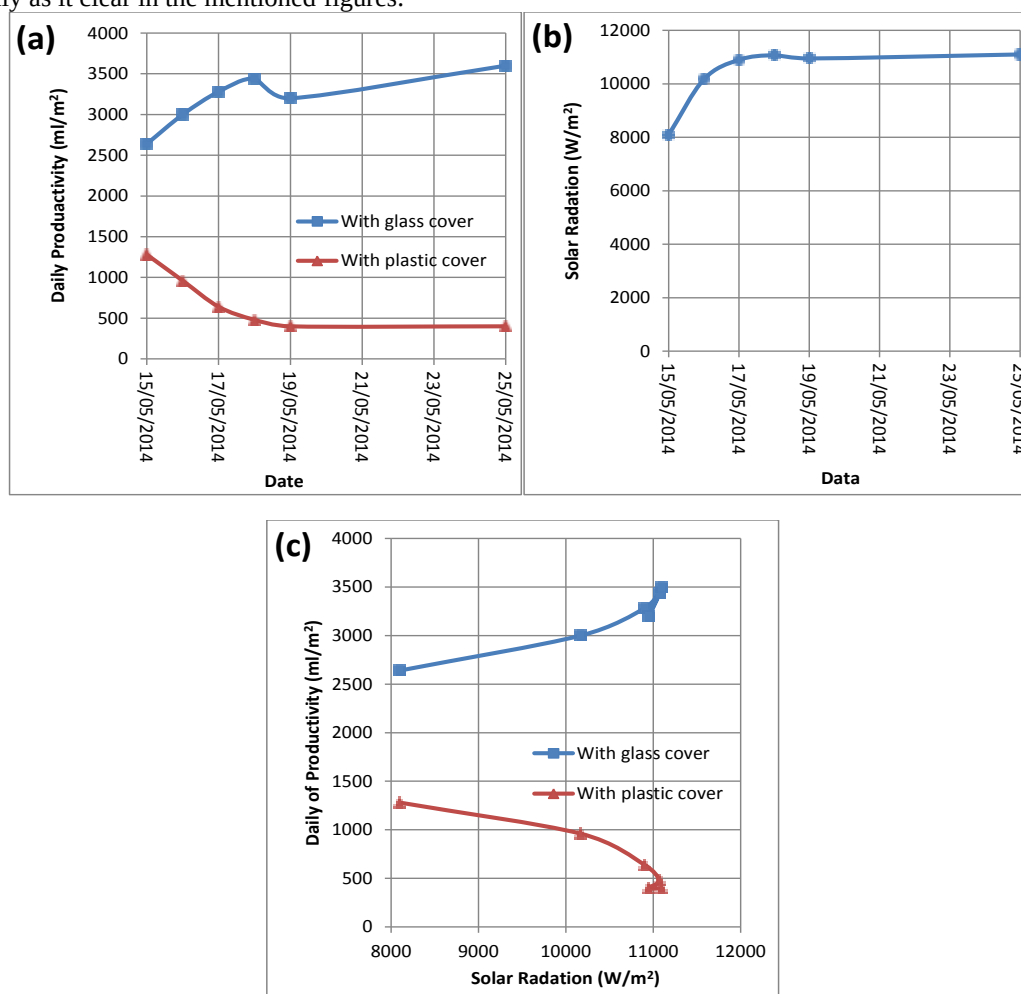


Fig. 3:(a) Daily production of the two solar stills through test days. (b) Solar radiation to the days of the test. (c) Daily production to the two solar stills with solar radiation to the test days.

B. Comparison between the performance of a distiller with black dye and that with black dye from coal powder

An experiment done between the two distillers for several days of May and June after preparing them like the preparation of the two distillers in part A.

Fig. 4a daily production of the two solar stills through some days of May June 2014, fig. 4b Values of solar radiation to the days of the test, fig.4c daily production to the two solar stills with solar radiation to the test days. Figures 4a, b and c show that the performance of the solar distiller with a black dye base which mixed with coal powder is more than that of the solar distiller with black dye base for all the days of the experiment. Also, shows a difference between the performance of the two solar distillers, in which the performance for the days 30-31/5/2014, was more than that for the other days, and this difference is due to the increasing in the quantity of solar radiation in the first two days, and its decreasing in the other days. And what is clear also, is the large decreasing in the performance of the two distillers on the two days 4-3/5/2014, and this is because the weather was totally cloudy on 4/6/2014 and almost totally cloudy on 5/6/2014, then the performance of the two distillers increased again on 6/6/2014, due to the increasing of the solar radiation in this day. The cause of the performance the solar distiller of black dyes base mixed with coal powder is because of the mixing of the coal powder with the black dye lead to a roughness in the absorption surface (distiller base), and this lead to reduce the reflection that happened for the radiation in the smooth surface, in addition to that adding coal powder lead to increase the thickness of the absorbtion layer (distiller base), and thus an increase in the amount of the absorbed solar radiation, and increase in the productivity of this distiller.

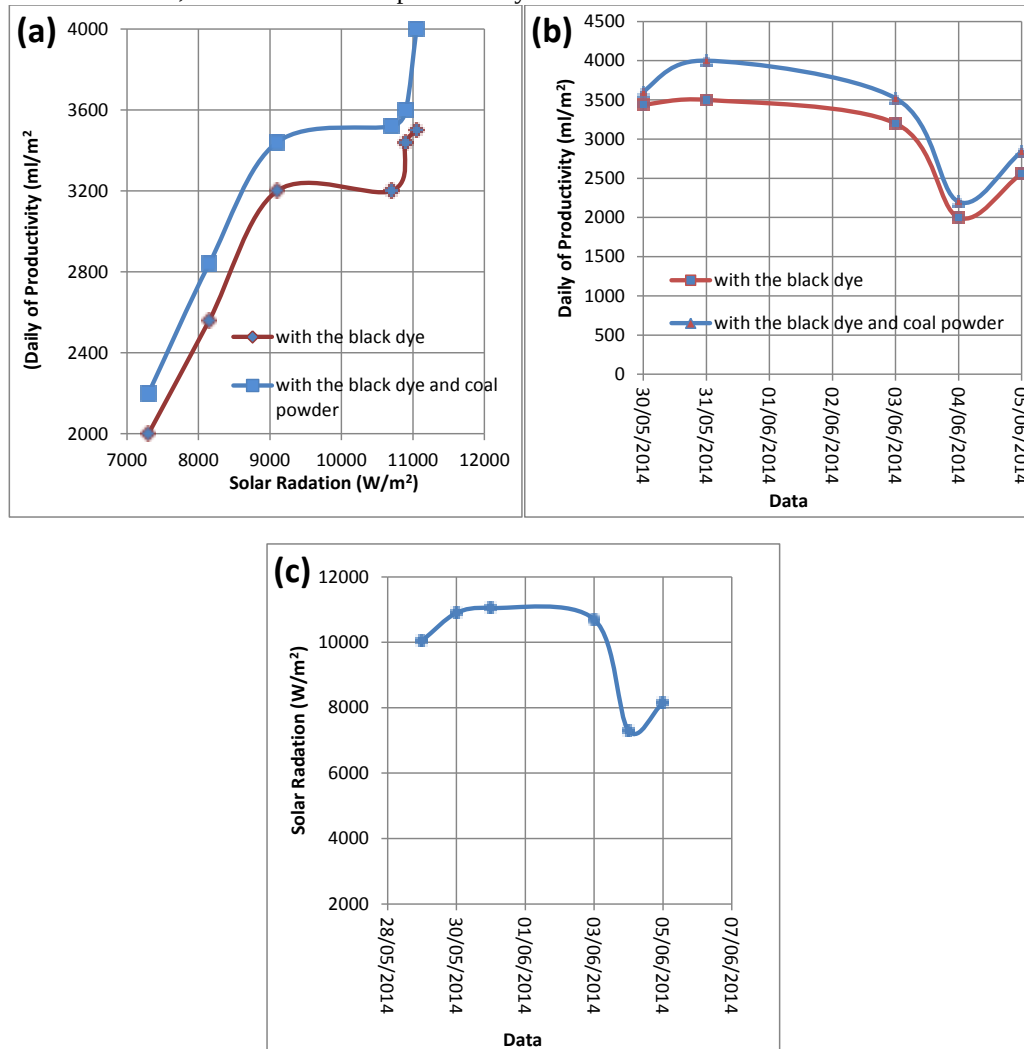


Fig. 4: (a) Daily production of the two solar stills through some days of May June 2014. (b) Solar radiation to the days test. (c) Daily production to the two solar stills with solar radiation to the test days.

Solar still efficiency of basin-type stills is commonly expressed by Eq. (1):

$$E_{bsn} = (P L / I A_b) \times 100\% \quad (1)$$

The still	Production (ml/m ² /day)	Solar radiation (w/m ²)	%Thermal efficiency
The distilled solar glass cover and base black dyewith coal powder	4000	11050	65.4
The distilled solar glass cover and base black dye	3500	11050	57.2
Solar distilled a plastic cover and the base of black dye	1280	8100	28.5

Based on the results obtained from the experimental work, the following can be concluded: (1) The maximum distillate productivity of the proposed still is 4 l/m². (2) The greatest efficiency solar the distilled the distilled solar glass cover and base bleached dyed black with charcoal powder where was 65.4%. (3) Add coal powder to dye used in the coating of the solar distilled working to increase the efficiency of this distilled.

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