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Thermal Behaviour of a Novel Vertical Solar Still under Desert Climatic Conditions

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Abstract: A design of a novel vertical solar still prototype provided with two basins has been constructed and has been experimented under desert climatic conditions of Adrar, Algeria. The intention of construction of experimental prototype is to be able, to evaluate different design approaches and so the initial apparatus is very easy to dismantle and modifying, it is constructed from locally available material, it main parts are upper and lower basin, the upper basin is designed in way that, brackish water is divided in three trays stairs. The two basins are connected in front by a vertical solar flat collector and in rear by an isolated metallic wall. Vertical sides of the still are covered by two vertical glazing. Brackish water trickles from the upper basin to the lower on back of the absorber plate of flat collector by mean of a cotton cloth. This paper present design, thermal behaviour of vertical still tested under local desert climatic conditions. Out door tests were conducted at different days under different conditions for all sky conditions. The solar still has been tested on the platform test field of the renewable energy research unity, of Adrar, Algeria. Experimental tests conducted from April to May 2006 on solar still show that, the daily productivity reaches 8.06l/m^2.day for due south orientation with a total solar radiation intensity of 25.31MJ/m^2. East orientation before noon and afternoon west orientation daily productivity of solar still reaches 8.64 l/m^2.day with a total solar radiation intensity of 27.98MJ/m^2.

Key words: Desert of Algeria · Solar energy · Solar distillation · Vertical still

INTRODUCTION

Natural fresh water resources are being depleted rapidly, as a result of population growth and socio-economical development. The increasing demand for water puts enormous strain on the underground aquifer, which results in lowering water levels and increasing salt content. The south of Algeria is blessed of the highest levels of solar radiation in the world. The introduction of solar stills in rural and arid zones of Algeria, promise to enhance the people quality of life and to improve health standards. An extensive review of various types of solar stills was done by [1]; this review was updated by [2]. Nebbia was investigated a research on vertical solar still [3], the still had a vertical structure with four trays. Coffey was experimented and developed a vertical solar still [4]; this vertical solar still had a dark vertical micro porous evaporator which is housed in a transparent tube. [5] reported that very little information on vertical solar stills has been published in literature. [6] presented transient analysis of multi-effect vertical solar still having a flat plate collector as generator of heat. [7] are developed a rugged deign of a high efficiency multi-stage solar still. Authors have constructed, experimented and investigated direct and indirect vertical solar stills [8-10]. This work deals with an investigation on the thermal behaviour of a novel vertical still tested under desert climatic conditions of Adrar, Algeria.

MATERIALS AND METHODS

Prototype Description: A schematic diagram of new proposed vertical solar still is shown in the Figure 1; the still body is viewed in cross section as a trapezoid. Upper basin (1) is divided into three stairs trays; basin supplied by brackish water from head reservoir (2), basin is coved by an inclined glass cover (3), first tray (4) is filled with thin water film, last tray is provided with an overflow (5), from this brackish water is then trickles by a PVC tube distributor (6) provided with holes. In the front of solar still a flat plate (10) solar collector generate heat from solar radiation that strikes glass cover (12) and transmitted and absorbed by blackened Aluminium plate (11). A Cotton cloth (7) sealed in back of Aluminium plate.

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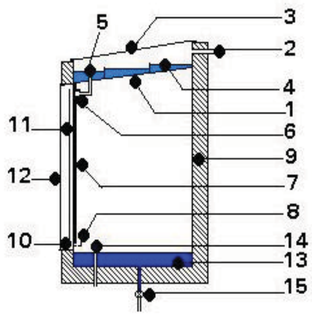

Fig. 1: schematic diagram of solar still

Fig. 2: upper basin under construction

Fig. 3: lower basin under construction

Brackish water trickles down cotton cloth to lower basin (13), this basin is provided also by an overflow(14),in two vertical sides lower basin is cover by two verticals glass cover and back by an isolated metallic wall (9).

Brackish water that trickles down cotton cloth is collected in rectangular gutter (8), saline water outlet is evacuated from tub (15).

Figure 2. shows the photograph of the upper basin under construction, that has a light sloped plane of 6.95° to the horizontal, upper basin is made from black iron,

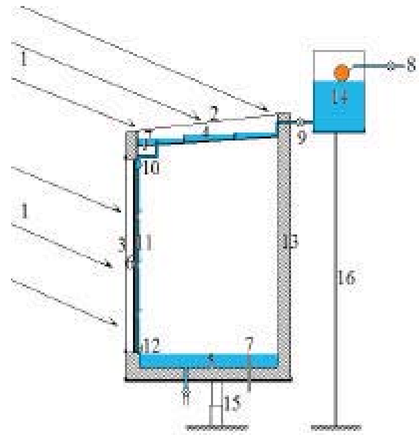

Fig. 4: A schematic diagram of different components of solar still

with an effective area of 0.219 m^2, height vary from 0.055 to 0.09 m, it's length 0.488 m and it's width 0.45 m, upper basin is covered by 0.275 m^2 sloped glazing cover sheet.

Figure 3. shows the photograph of the lower basin under construction, two parallel and vertical sides were covered each by glass covers. The base of trapezoid made by galvanised steel form the lower basin with surface area of 0.249 m^2, it's height 0.09 m., it's width.0.49m and it's length 0.51 m,. The solar still function as direct and indirect solar still, the great height is 0.98m and the small height of the trapezoid was 0.93 m, the stand base had surface area of 0.51x051 m^2.

The compact body of the solar still prototype had a vertical flat plate collector that generates heat form solar radiation; the casing is covered with 0.004 m glass cover thickness. The vertical solar still turn around a vertical axis.

Operating Principle and Experimental Set Up: Figure 4 shows a schematic diagram of different component of solar still. Each morning, upper and lower basins are flashed from salty water and are filled with raw water from a constant head tank that feed the upper basin. Collecting through is provided at the lower edge of the inner surfaces of the inclined glass cover where we collect distilled water. From upper basin tickles down water on back of absorbing plate, through cotton cloth to the lower basin, collecting through were provided at the lower edges of the inner surfaces of the vertical glass cover. Solar radiation, after passing inclined, two vertical glass cover. Water vapour then condenses on glazing covers and flows down the cover into collecting troughs. Distilled water is collected from inclined and two vertical faces.

Fig. 5: Experimental set up of novel solar still

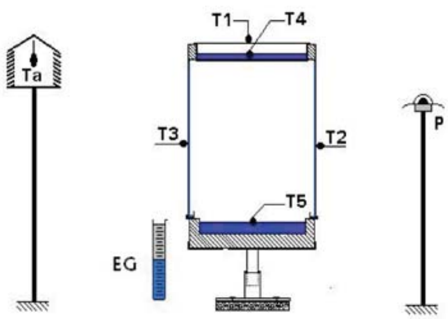

Fig. 6: Experimental instrument

Figure 5 shows the experimental set up of the novel vertical solar still unit. Tests has been carried out on the prototype from April to May 2006, on the testing field of the platform of Renewable Energy Research Unity in desert environment of Adrar, Algeria, it's latitude is 27° 53' N, it's longitude is 0° 17' W and it's elevation from sea level is 364 m.

Figure 6 shows location of different experimental instruments. The total solar radiation on the horizontal plane is measured with a Kipp and Zonen pyranometer (p) CM11 of class 2. Temperatures are measured by thermocouples of K type. Ambient temperature Ta is measured under a shelter by K type thermocouple. The distilled water is measured each hour by a graduated test tube(EG) of 1000 ml.

Temperatures of brackish water T4,in upper basin Tw,ub and T5 of lower basin, Tw, lb. Temperatures T1, T2 and T3 respectively of inclined, east and west glass covers, Tgi, Tge and Tgo, were recorded continuously over 24 hours each five minutes. Raw data are registered on Fluke data logger and then handled on a PC for treatment and analysis.

RESULTS AND DISCUSSION

Local well water is supplied to vertical solar still by pump from an elevated raw water storage tank. Tests on the solar still for collection of distilled water are conducted from 8 to 16 hours all day tests.

During two days of April, April 3rd and April 15th, solar still is oriented toward due south; Figure 7 shows the variation of daily ambient temperature variation versus time for 3 and 15 April. Averages daily values of ambient temperatures respectively for 3 and 15 April are 33.31 and 31.64 °C. Figure 8 shows the variation of daily total solar radiation on horizontal plane for days of 3 and 15 April. 3 April is sunny day and 4 April is cloudy day, this is appeared on the solar radiation curve profile on figure 8. Maximum values of total radiation are respectively for 3 and 15 April 981.82 and 738.79 W/m^2. During 3 and 15 April solar energy radiation intensity are respectively 25.31 and 20.09 MJ/m^2. Solar still is tested from 8 to 16 hours, the distillate output is measured each end of interval hour.

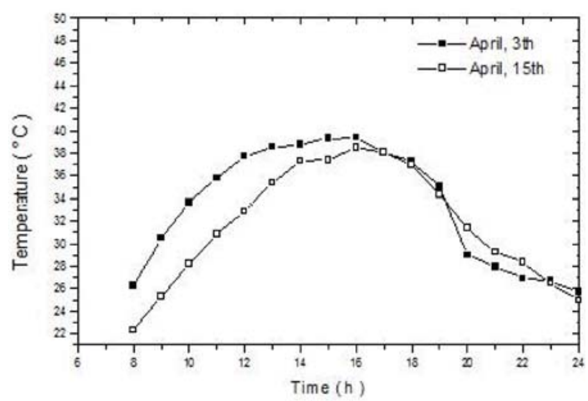

Fig. 7: Ambient temperature versus time

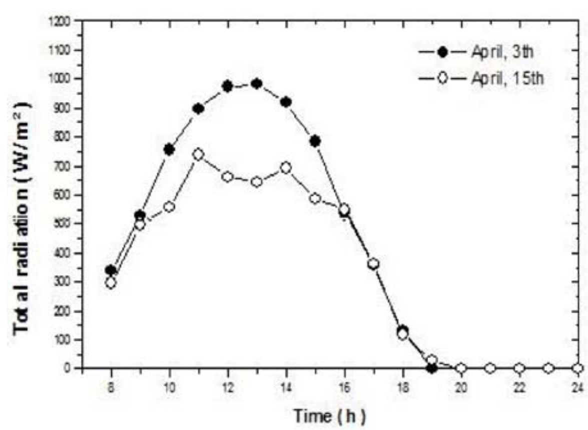

Fig. 8: Total solar radiation versus time.

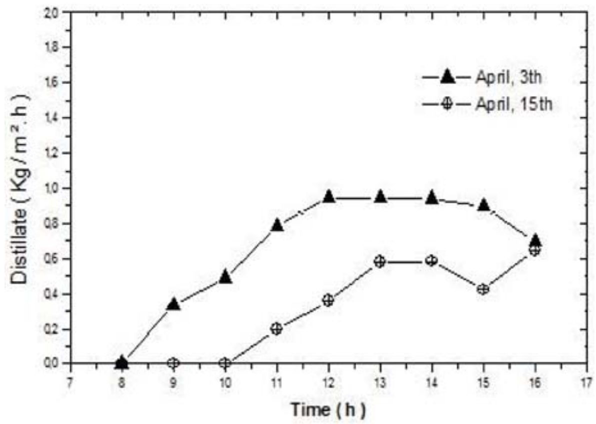

Fig. 9: Distillate production versus time

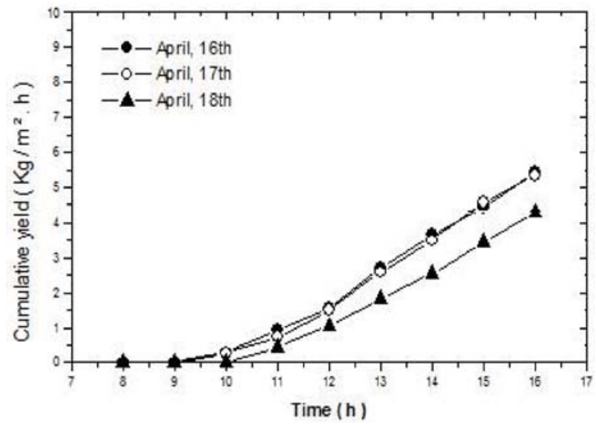

Fig. 10: Cumulate yield of Distillate versus time

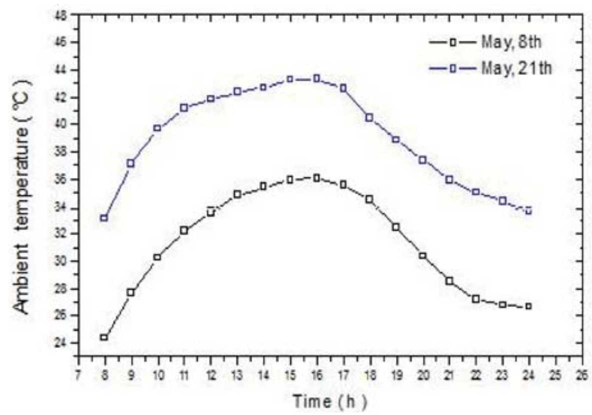

Fig. 11: Ambient temperature versus time

Figure 9. shows the variation of the hourly yield production of solar still over a sunny and cloudy day of April. From figure 9, we show that during the sunny day, the productivity start early than that of cloudy days, daily productivity from distilled water for 3 April are respectively for inclined glass cover of upper basin, east and west vertical glass cover of lower basin 4.84, 1.78 and 1.44 l/m^2.day. daily productivity from distilled water for 15 April are respectively for inclined cover glass of upper basin, east and west vertical cover glass of lower basin 2.33, 1.24 and 1.09 l/m^2.day. From experimental tests, vertical solar still produce more distilled water for the inclined cover glass for the upper basin over sunny day of by 51.86% than inclined cover glass for the cloudy day of April. The daily productivity from distilled water for sunny day of April, 3rd and cloudy April 15 April are respectively 8.06 and 4.66 l/m^2.day.

Effect of Adding Dye on Th Productivity of Solar Still: To enhance solar still productivity, blue colour dye is added to the brackish water of the upper basin during April 16 and 17 an April 18 day, upper basin is tested without dye. Figure 10 shows the cumulative yield of distillate water versus time. Production of distillate start for 16 and 17 April with blue dye added to the upper basin for 10 hour. For 18 April, distillate production starts at 11 hour because of wind storm. daily productivity from distilled water for 16 April are respectively for inclined cover glass of upper basin, east and west vertical cover glass of lower basin 4.88, 1.45 and 1.41 l/m^2.day. Daily productivity from distilled water for 17 April are respectively for inclined cover glass of upper basin, east and west vertical cover glass of lower basin 4.43, 1.35 and 1.52 l/m^2.day.

Daily productivity from distilled water for 18 April are respectively for inclined cover glass of upper basin, east and west vertical cover glass of lower basin 3.61, 1.37 and 1.19 l/m^2.day. Daily productivity from distilled water respectively for 16 and 17 April for the vertical solar still are respectively 7.74 and 7.3 l/m^2 for additive dye. 18 April where solar still is tested without adding any dye to upper basin, daily productivity was 6.17 l/m^2.day. Solar still productivity was enhanced for 20.28% by adding dye to the upper basin.

Orientation of solar still: In order to achieve high yield of distilled water the still orientation should be the direction at which the highest average incident solar radiation is obtained. During 8 May solar still was oriented toward due south and 21 May solar still was oriented toward east from 8 to 13 hours local time and toward west from 13 to sunset.

Figure 11 shows the variation of ambient temperature during days of 8 and 21May. Daily averages ambient temperatures of 8 and 21 May are respectively 31.3 and

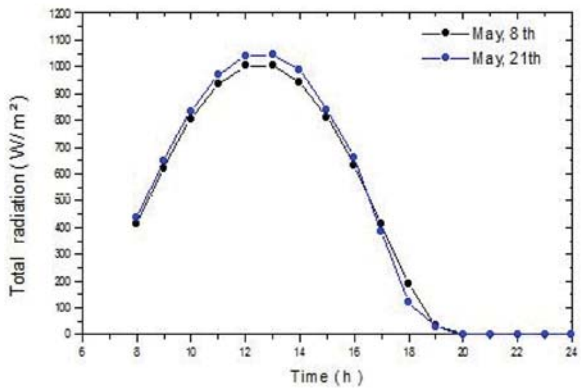

Fig. 12: Total solar radiation versus time

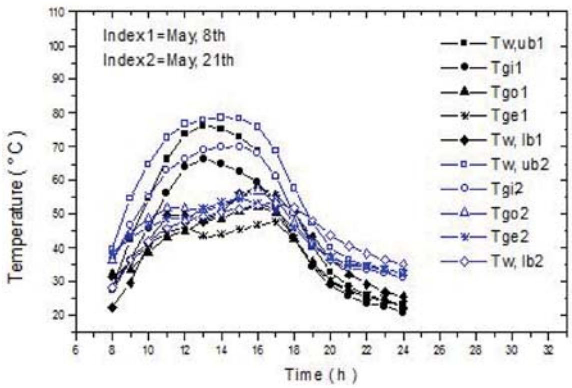

Fig. 13: variation of different temperatures of solar still versus time

38.98°C. Figure 12 shows the total solar radiation for days of 8 and 21 May, maximum values are respectively 1004.47 and 1043.29 W/m^2. Daily solar energy radiation that reaches the horizontal plane during 8 and 21 May are respectively 27.34 and 27.98 MJ/m^2. Energy collected to produce distilled water is at least the same. Double orientation of solar still improve still yield.

Figure 13. shows the variation of different temperatures water temperature in the upper basin Tw, ub, cover inclined glass temperature Tgi, cover vertical west glass, Tgo, cover vertical east glass and lower basin water temperature for days of 8 and 21May. Maximum value of brackish water of upper basin registered in 8 May is 76.23°C when solar still is oriented toward due south, it occurs at 13 hours at the end hour of orientation of solar still towards east orientation. For day of 21 May maximum value registered is 78.74 °C it occurs in the first hour of orientation of solar still toward west orientation in the afternoon.

Maximum value of brackish water of lower basin registered in 8 May is 57.93°C, it occurs 16 hours afternoon, when solar still is oriented toward due south.

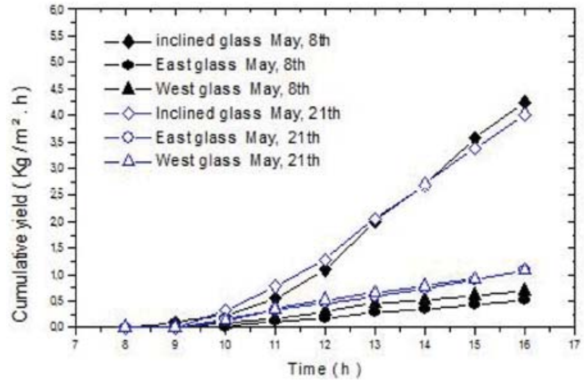

Fig. 14: Cumulate yield of Distillate versus time

For day of 21 May maximum value registered is 53.46 °C it occur at 17 hours in the afternoon when solar still is oriented toward the west.

Figure 14 shows the cumulative yield for different condensing surface of the vertical solar still: inclined glass cover, east and west vertical glass cover during days of 8 and 21 May. Between 9 and 16 hours cumulative yield of the inclined glass cover, east vertical glass cover and west vertical glass cover are respectively 4.245, 0.5225 and 0.6957 l/m^2.day for 8 May when solar still was oriented toward due south. For the day of 21 May, between 10 and 16 hour, cumulative yield of the inclined cover glass, east vertical cover glass and west vertical cover glass are respectively 4.016, 1.086 and 1.085 l/m^2.day.

Cumulative yields for east and west vertical cover glass are greater than of the cumulative yields for east and west vertical cover glass when solar was oriented towards due south, orientation of solar still towards east and west improve solar still productivity. For orientation due south the daily productivity of the vertical solar still 7.42 l/m^2.day and daily productivity for east and west orientation are 8.64 l/m^2.day. From experimental tests lower basin acts as an accumulator of heat for the afternoon. During experimental tests we found difficulty to maintain the same level in the solar still reservoir and in the distribution of brackish water in the trays of the upper basin was not uniform.

CONCLUSIONS

The simple operation of the novel vertical solar still provide with upper and lower basin which requires no technique parts is acceptable and appropriate to the social structures in the desert regions of Algeria for producing distilled water. The flexibility of the prototype creates optimal adaptation to a variety of local conditions.

The design of the upper basin increase solar still productivity. During daylight the productivity of upper basin decreases with an increase of water depth and the reverse is of overnight for lower basin due to increased in heat capacity of water. Under weather conditions of desert at Adrar, Algeria, vertical sides of this new vertical still produced daily more distilled water than inclined side of the upper basin.

Adding dye to upper basin improve daily productivity of solar still by 20.28%. The apparatus is sensible to solar radiation cloudy day decease daily productivity of solar still by 51.86%. Daily productivity of solar still reaches 8.06l/m^2.day for single orientation with a total solar radiation on horizontal plane of 25.31MJ/m^2, for double orientation it reaches 8.64 l/m^2.day with a total solar radiation on horizontal plane of 27.98MJ/m^2. Lower basin acts after sunset as accumulator for latent heat accumulated in heat capacity of brackish water.

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