An Experimental Studies on A Solar Still Using Ground Heat and Without Using Any Energy Storage Medium

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Abstract— This paper deals with the experiments conducted on a conventional single slope solar still by using earth heat and is modified without energy storage medium. An attempt has been made to utilize the maximum amount of solar energy and to reduce the heat loss from the sides and bottom of the still. The conventional still is modified without any energy storage medium which is provided in the basin for different depths of saline water. The earth heat functions as energy storage medium and also as an insulation layer to reduce the bottom and side loss coefficients. The earth heat is used for absorbing the excess heat energy from solar radiation during the noon hours. Due to this, the heat accumulated in the space between the water and glass surface is reduced and hence the temperature difference between the water and glass surfaces increases. The depth (quantity) of the saline water in the basin will influence the performance of the still and some of the parameters like basin temperature, water temperature, glass temperature, earth heat temperature and still productivity. This study deals with the effect of aforesaid parameters on the performance of the still. To show the effectiveness of the modification, its performance is compared with the conventional still by using earth heat under the same climatic condition. It is found that the still yield is increased by 17% with almost no cost for this modification

Key words: Single basin still, saline water temperature, glass temperature, earth heat temperature, hourly yield

I. INTRODUCTION

Solar desalination is a process of separation of pure water from saline or sea water by using solar energy. The use of solar still is a cheap method of providing clean water. The solar assisted desalination system can be classified as: (i) passive (conventional) solar still and (ii) active (modified) solar still. The simple or conventional solar still consists of a black-painted copper or steel basin to receive solar radiation in which saline or sea water is kept. The basin is placed in a trapezoidal wooden box, which is covered by a glass cover at an angle of 23° to the horizontal to retain the solar thermal energy inside the still due to green house effect. That solar thermal energy is utilized to heat the saline or sea water. The basin is fully covered by earth surface. The Earth has a certain depth of existence to receive the heat and it can reflect back the same amount of heat during night hours to the basin, it is working under the principle of semi infinite heat transfer mode.

Due to the existence of phase equilibrium between the saline water surface and air space, the air just over the water surface will be saturated with water vapour corresponding to the water temperature. With the solar radiation incident on the saline water, its surface temperature increases which causes the increase of saturated pressure of water vapour near the water surface corresponding to the water temperature. At that time the partial pressure of water vapour near the glass surface will be less as the temperature of the inner surface of the glass cover is lower than that of the water surface. The temperature difference between the water and inner glass surface causes the difference in partial pressures of water vapour which causes the transfer of water vapour from the basin water surface to glass surface and the condensation on the inner surface of the glass.

The rate of evaporation of water vapour from the water surface depends on the rate of condensation of water vapour in the glass cover. Even in the areas of higher solar intensity, the annual performance of the still per square meter of aperture is limited to an average of about 2.5–3.0 L day-1. Interest in the conventional solar still has been due to its simple design, construction and low operating and maintenance cost, mainly in remote areas with no electricity supply. However, its low productivity simulates and motivates the researchers to develop novel methods to enhance the still productivity. Numerous attempts have been made by many researchers to increase the rate of evaporation of water and utilize the maximum solar energy that strikes on the still to enhance the system efficiency which utilizes a minimum amount of still surface.

II. REVIEW WORK CARRIEDOUT

Tiwari et al. [1, 2] had presented a review about the works on passive and active solar stills. It was recommended by them that only passive solar stills can be economical to provide potable water in which they had compared the still productivity of a passive still for two different occasions and also compared the still productivity with an active solar still. In the months of January and June, they achieved still productivity of 1.26 and 1.6 Lm-2 day, respectively, which shows that the still productivity varies with the climatic condition. In the active solar still which was coupled with flat plate collector they achieved the enhanced still productivity of 1.45 and 2.6 Lm-2 day during the months of January and June, respectively.

Safwat Nafey et al. [3] presented a paper on the parameters affecting the solar still output. In this paper, they had dealt with the effect of the following factors like solar intensity, ambient temperature, wind velocity, glass cover angle and depth of saline water on the performance of still.

Abdul - Enein et al. [4] had discussed the still productivity for different parameters like depth of saline water, insulation thickness and various cover angles. As per their findings the still productivity was approximately 2.5 kgm-2 day at 40mm depth, 3.5 kgm-2 day at 50mm depth and 2.8 kgm-2 day at 80mm depth for maximum solar intensity of 1016Wm-2 in the month of July.

Mousa et al. [5] compared the still productivity of conventional still with double-glass cover cooling arrangement. In that study conventional still productivity was 1.4 kgm-2 day in the month of March and 3 kgm-2 day in June. They had 34% of increase in still productivity.

Khalifa et al. [6] presented a paper by modifying the conventional still with preheating of saline water and utilizing external and internal condensers for vapour condensation as well as for preheating.

Rahim et al. [7] proposed an approach for a conventional still to store excess energy during day time that can be used for continuation of evaporation at night. In this work the authors had divided the basin water into evaporating and heat storing zone. They had found that the heat storing capacity of water during day time is about 35% of the total amount of solar energy entering the still.

In this study, experiments have been conducted with same climatic conditions for different quantities (depth) of saline water. Also mathematical modelling is developed to show the variations of parameters like water temperature, glass temperature, earth heat temperature and hourly yield and validate them with the experimental values.

III. MODIFICATIONS IN A PASSIVE SOLAR STILL

The productivity of the solar still increases as the saturation pressure of water vapour increases, which is determined by the temperature of the water. Also the productivity increases for high temperature difference between the water surface and the glass cover. To increase the rate of production of still the following points are to be considered. All the modifications are made to achieve the following conditions:

Increasing the saline water temperature. This will be achieved by reducing the heat loss from the water through the sides and bottom of the still and heat loss from surface of water by convection and radiation to the glass cover through the air–vapour space.

Reducing the glass cover temperature. As the water vapour condenses on the glass cover, the latent heat of condensation heats the glass cover hence the inner glass cover temperature increases. To reduce the temperature of the glass cover, it should be cooled either by saline water or by blowing air over the outer surface of the glass cover.

At noon the solar intensity will be higher. At that time, as the temperature of the inner surface of the glass cover increases, the rate of condensation decreases. So, the rate of evaporation of water vapour will be more than the rate of condensation on the glass cover that causes the increase in temperature of the air–vapour space between the water surface and glass cover.

Therefore, to improve the rate of production of pure water in a conventional solar still, modifications are being made to increase the temperature of saline water in the basin, to reduce the temperature of the glass cover, to reduce the heat losses and utilize the maximum energy available for the evaporation of water from the basin. For the last three decades many researchers have been making many modifications to achieve the above-said parameters.

In the conventional still, heat is accumulated inside the solar still due to the liberation of latent heat of condensation which reduces the incoming solar energy through the glass cover and air–vapour space and also reduces the evaporation of water. That heat is wasted to the atmosphere through the glass cover. If the heat of condensation and radiation heat from the water surface which are accumulated in the air–vapour space is utilized properly, then the productivity of the still will increase.

IV. PROPOSED MODIFICATIONS

In this study, the conventional still is modified to reduce the heat accumulation in the air–vapour space and to store the excess solar energy during sunshine hours for the continuation of the evaporation process at night. For this, energy storage medium can be used to store the excess solar energy. The following points are to be considered for the selection of without any energy storage medium for effective performance of the still.

– Heat capacity of the without using storage medium should be high so that the temperature rise will be more which will increase the temperature of the saline water.
– The earth heat should not reduce the temperature of the saline water in the evaporating zone which will reduce the temperature gradient between water and glass surface.
– Earth heat should have low thermal conductivity to reduce heat loss through the bottom of the still.

In this study, the earth heat is used to continue the evaporation of saline water during evening and night. As the thermal conductivity of the earth is low, it will act as an insulator to reduce the heat loss through sides and bottom of the still. When the depth of the saline water increases, the bottom loss coefficient decreases which will reduce the heat loss from the still.

V. EXPERIMENTAL SET-UP

The schematic diagram of single-basin single slope solar still is designed as shown in Figure 1, which is modified by removing insulation medium in the basin. The conventional solar still consists of the following components: (a) basin; (b) glass cover; (c) aluminium channel to collect condensate. The still has a rectangular basin having an area of 0.75m * 0.50m made by bending a GI plate of 2mm thickness and assembled by soldering. The inner surfaces of the basin facing the sun are painted black for maximum absorption of solar radiation.

The bottom and side walls of the basin are covered with earth surface. The still cover is made of 0.003m thick ordinary glass and kept at an inclined position at an angle of 23° with respect to the horizontal. An aluminum channel is attached to the lower end of the glass cover to collect the condensed water (yield) which slides from the inner surface of the glass cover and that condensed water is taken outside using a funnel arrangement and collected in a measured jar. Holes are made in the sides of the still frame for feeding raw saline water, and a tap is provided to drain the saline water.

Calibrated Ni Cr–Ni thermocouples, connected to a multichannel temperature recorder are inserted through the holes provided in the sides of the still and fixed at different points to measure the temperatures of different parts of the still like basin, water, earth heat, inner surfaces of the glass and ambient temperature. To keep the whole system vapour tight, silicon rubber is used as a sealant because it remains elastic for quite a long time.

The global solar radiation on a horizontal surface is measured using a solar intensity meter. This instrument is digital type, can measure in the range 1–100mWcm-2 solar intensity with an accuracy of 2mWcm-2. A plastic beaker of 1 L capacity is used to measure the hourly yield. The still is placed along the east-west direction and inclined glass cover surface is facing south to intercept maximum solar radiation.

In this conventional single-basin single slope passive solar still, experiments have been carried out to find the effect of water depth or quantity of saline water in the still productivity and to find the optimum depth (quantity) of saline water at which the still yield will be maximum.

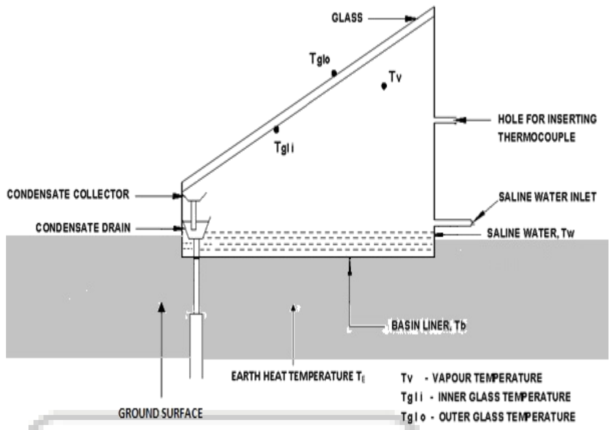

Fig. 1: Sectional view of the solar still

VI. RESULTS AND DISCUSSION

In the conventional still using earth heat, experiments are conducted for different depths of saline water (different quantity) per m2 area of the basin to get the optimum quantity of saline water. To evaluate the performance of the modified solar still, experiments have been conducted in the same solar still under the same climatic conditions for different depths of of saline water.

Experiments are conducted by covering a wide range of parameters such as temperature of water, temperature of glass cover, hourly yield, earth heat temperature, difference between water and glass cover. At this particular condition, experiments were conducted for a number of days so that analysis and comparison could be done fairly under the same climatic condition and to get concurrent results.

The effect of depth (quantity) of saline water in the conventional still by using earth heat have been analyzed

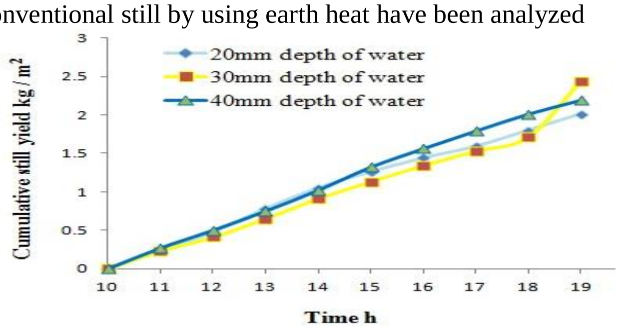

Fig. 2: Variation of still output for different depths of saline water in the modified still using earth heat without any energy storage medium

Figure 2 shows the variation of still yield with time. It is found that for a certain lower depth (20 mm) of saline water, the yield per day is low and increases with depth and again starts decreasing beyond certain depth of saline water. It is predicted that for a particular depth of water (30 mm), yield per day is maximum. It is obvious that the still output is optimized at 30mm depth of saline water.

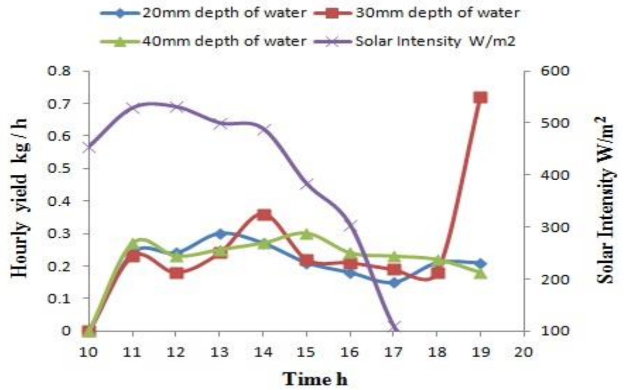

Fig. 3: Hourly yields for different depths of saline water and for the same climatic condition in the modified Still using earth heat

In Figure 3, variation of hourly yield with the time for different thickness of saline water is given. It is predicted that for 30 mm depth of saline water, hourly yield is very high as 0.36 kg at 13.00 pm and it is around 0.5 kg during the period of 11.30 hours to 12.30 hours. Again during the evening, 13.00 hours to 15.30 hours the hourly yield attains the value of 0.6 kg. Compared with this, for other thickness of saline water, hourly yield is quietly low. Again it is noted that after 17.00 hours there is a steep increase in still yield till 19.00hours.

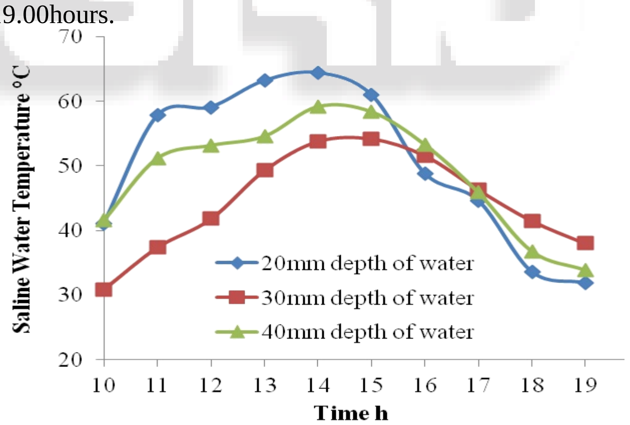

Fig. 4: Saline water temperatures for different depths of saline water and for the same climatic condition in the modified still using earth heat without Energy storage medium

From Figure 4, it is understood that for 30mm depth of saline water, temperature of the saline water attained higher value and remained higher for longer period whereas for 40mm depth the temperature of saline water was not as high as that of 30mm depth of saline water. It is understood that the temperature difference between the saline water surface and inner surface of glass cover is higher for 20mm depth of saline water than for 30mm depth. Even though the still experienced a higher temperature difference for 20mm depth of saline water, it led to greater heat loss from the still and was not utilized for evaporation.

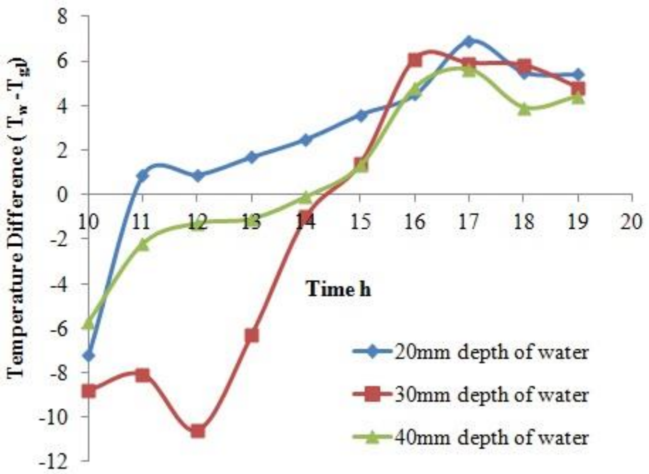

Fig. 5: Temperature differences for different depths of saline water and glass cover for the same climatic condition in the modified still using earth heat

From Figure 5, for 20 mm depth of saline water temperature difference is high from 11.30 to 13.00 hours but hourly still hourly yield is not so high. The high temperature difference leads to increase of radiation loss. Whereas for 40 mm depth of saline water even though temperature difference is not so high during the peak hours hourly still hourly yield is high.

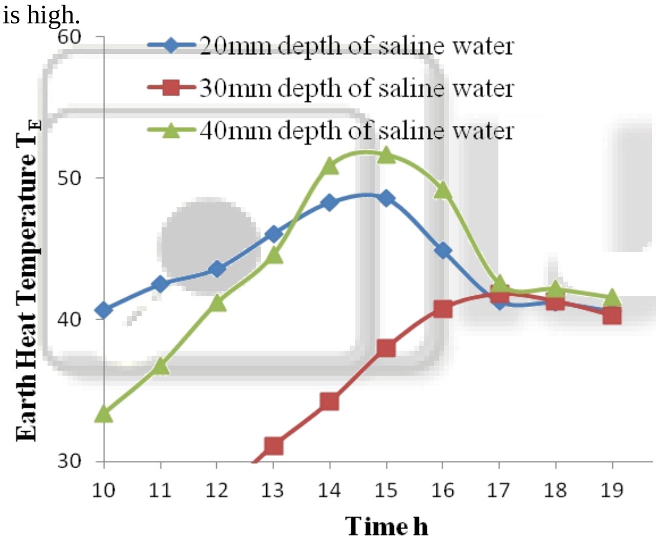

Fig. 6: Earth heat temperatures for different depths of saline water and for the same climatic condition in the modified still using earth heat without Energy storage medium

From Figure 6, compares the earth heat temperature for different thickness of saline water in the modified still. For 20 mm thick of saline water attains very high temperature of about 48.6° C at 15.00 hours. Hence for 40 mm thick layer of saline water temperature is about 51.7°C. Whereas for 30mm depth of saline water is about 41.8°C hence utilization of earth heat in this depth minimizes the convective losses and stores the heat energy.

From Figures 1 to 6, parameters like cumulative still yield, hourly yield, water temperature, ground heat temperature and temperature differences between the saline water and the glass cover are compared for different thickness of saline water used in the modified solar still. From the above discussion, it is understood that the modified still with 30 mm thickness of saline water gives the maximum daily hourly yield of 2.43 kg/m2day.

VII. Conclusions

It is clearly understood that the available earth heat and their effects were analyzed in different manners. This study mainly deals with the effect of parameters on the performance of the still and to optimize the performance. It is found that this kind of still can be implemented in commercial basis for a small family which needs potable drinking quantity of around 15 L day_1. From the analyses of data collected over the span of 1 year the following conclusions can be drawn:

- The system has the advantages of using the earth heat to enhance the still yield and its efficiency.
- Saline water temperature in the still without gravel is raised to about 64.4°C which appreciably reduces the heat losses from the still compared without gravel solar still water temperature of about 59.7°C.
- Still yield per day without the gravel increased by about 17%.
- Maximum efficiency of the still without gravel is found to be 42% which is 8% higher than the conventional still using earth heat efficiency.
- Still yield is 2.43 kg m-2 day-1.

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