Enhancing the productivity of modified solar still by cooling the secondary condensing cover

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Abstract

Potable water scarcity is increasing day by day due to rapid industrialization and excessive use of pesticides and fertilizers. Desalination using solar energy is a better solution as waste water management. Solar stills are used to produce potable water particularly in remote arid areas. Distillate output through solar still is affected by the temperature of its condensing cover. Lowering its temperature can cause higher condensation rate due to larger difference between water temperature and cover temperature. Experiments have been conducted on a new design of solar still. Single slope single basin solar still is modified by incorporating additional condensing surface. This additional condensing surface when cooled with wet cotton cloth, condensation on inner surface of this cover was accelerated. Average 21.8 % higher yield was achieved during February month.

Key words
Desalination, Modified still, Productivity, Condensing Cover

1. Introduction

Energy and water are two non-separable items, which are the vital elements for human civilization [1]. The growth of any country is sustainable when its population is supplied with clean and safe drinking water. world is faced by the twin challenges of growing populations, depleting limited water reserves and a drying up of freshwater sources due to changing precipitation patterns and increased temperatures from climate change [2]. Around 97% of the water in the world is in the ocean, approximately 2% is stored as ice in polar region and only 1% is fresh water available for the need of the plants, animals and human life [3]. With population growth and development of industry and agriculture, water shortage has become a major problem in most of the countries [4]. The World Health Organization prescribes a Total Dissolved Solids (TDS) limit in water of 1000 parts per million for safe drinking [5].

Distillation is one of the appropriate methods for supplying safe water. Many sources of energy can be used for distillation of water such as fossil fuels, renewable and non-renewable sources and electricity [6]. Desalination systems require energy for the separation of salt and water. Solar desalination systems are systems that utilize the solar energy (radiation coming from sun) for the separation of water, salt and bacteria. Classification of solar desalination varies depending on way of energy supply and techniques. The most common type of solar desalination system is the solar still [7].

Many investigations are being carried out throughout the world since long to enhance the productivity of the solar still. Yield output of a still is dependent upon its design features and climatic conditions. Eltawil and Omara [8] increased the productivity of a single slope solar still by using a flat plate solar collector, perforated tubes, spraying unit, solar air collector and external condenser. Salah et al. [9] used different types of absorbing materials to enhance the yields of solar stills. Boubekri & Chaker [10] proposed internal and external reflectors on single slope solar still to increase the rate of solar radiation falling on the cover and found increase in overall productivity by 72.8% in the winter. Kumar & Bai [11] applied water cooling system for side walls to enhance condensation and found efficiency to be 30%. Khalifa [12] investigated cover tilt angle as most crucial parameter affecting the performance of still. He proposed relationship between latitude and cover tilt angle for various seasons.

Working of basin type solar sill is based upon natural hydrological cycle and green house effect. Solar still is a closed basin with transparent cover. Brackish (salty and contaminated) water is fed into the still and the solar radiations entering into still through transparent top cover is entrapped within still and raises the temperature of water contained in it due to green house effect. At its corresponding vapor pressure, water from surface evaporates and leaves all contaminants and microbes behind in the basin. These vapors stick to inner side of condensing cover.

This process is called as internal heat transfer. Due to temperature difference between cover and atmosphere, these vapors release their heat too atmosphere and get condense. Resulting purified water tickles down along the inclined cover and collected in a jar through a channel. This process is called external heat transfer. This type of still is of passive type. In active type solar still, water if preheated in a flat plate collector for faster evaporation.

2. System description

A modified active solar still with secondary condensing surface (Fig.1) was designed, fabricated and installed in Ghaziabad, India (Latitude 28° 40' N) [13]. Modified still was so designed that keeping the dimensions of basin area containing water as well as condensing cover area same, an additional condensing surface was incorporated. The body of the solar still was made up of fiber reinforced plastic (FRP) with 4 mm thickness. The base dimensions of basin were 1.3 x1 m^2 and water was stored in 1x1 m^2 area only. The inclination of the main condensing cover (1x1.16 m^2) was 30° with horizontal (facing south direction) which is approximately equal to the latitude of Ghaziabad. The inclination of the secondary condensing cover (1x 0.67 m^2) was 60° and facing north direction. Both the condensing covers were made up of plane glass of 4 mm thickness. The inner bottom and the side inner surfaces of the solar still were painted black just to increase the absorption of solar radiation. Solar still was mounted on an iron stand, 0.5 m high. Collection of yield from both the covers of still was carried into separate channels provided at lower sides of covers and taken out through flexible pipes into two different measuring jars.

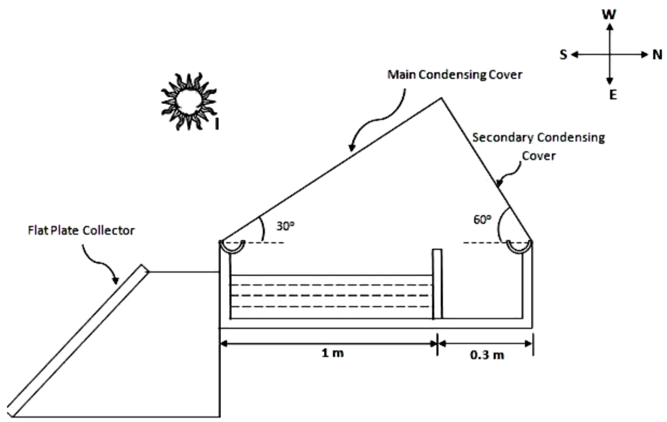

Fig 1. Schematic diagram of the experimental set-up

To provide additional heat energy, still was coupled with a flat plate collector (natural convection mode). The body of the collector was made up of GI sheet having ten parallel tubes of aluminum with 8 mm internal diameter and 1 mm thickness each. The inclination of flat plate collector was also 30° from horizontal, facing towards south. The base of collector was insulated with glass wool sheet of 20 mm thickness.

Solarimeter (0–1000 W/m2, ±3% error) was used to measure solar radiation intensity, Anemometer (0.4–30 m/s, ±2%) was used to measure wind velocity, Thermocouples (0–100 °C, ±1% error) were used to measure temperatures at different points in the still, Thermometer (0–100 °C, ±0.5% error) was used to measure atmospheric temperature and Measuring jars (0–2000 ml, ±2% error) were used to measure yield volume. Proper uncertainty analysis was done to compensate the errors in the measurement.

3. Methodology adopted

The yield (distillate production) is directly proportional to the temperature difference between water and condensing cover. So north facing condensing cover was cooled by covering it through wet cotton cloth. This cloth was kept wet by sprinkling water on it at every two hours. Experiments were conducted in the month of February, a winter season in the northern India. Secondary condensing cover was kept uncovered (fig 2.a) on odd days of the month (1st, 3rd, 5th etc.) and covered with wet cotton cloth (fig 2.b) on the even days (2nd, 4th, 6th etc.). Observations of 28 days were recorded. Here the comparative observations for two consecutive days (3rd and 4th days) are shown as sample.

(a) (b)

Fig 2. (a) Still when secondary cover is bare (b) Still when secondary cover is covered with wet cotton cloth

4. Results and discussion

Fig 3 shows the atmospheric temperature during the whole day starting at 6:00 in the morning till the 10:00 in the night. Minimum temperature of 9.1 ºC and maximum 24.5 ºC were recorded on the 3rd day while minimum of 8.9 ºC and maximum 25.7 ºC were recorded on the 4th day. Fig 4 indicates the temperature of water in the still on the two consecutive days. On the 3rd day, when the secondary cover is not covered with wet cotton cloth, solar radiations were also coming in to basin through this cover. But on the 4th day, the secondary cover was cooled with wet cotton cloth, so the solar radiations were not coming into the still through this cover. Total radiations entering into still are higher on 3rd day, that's why a little higher temperature of water was achieved on the same day (max 51.9 ºC) in comparison with next day (max 48.3 ºC).

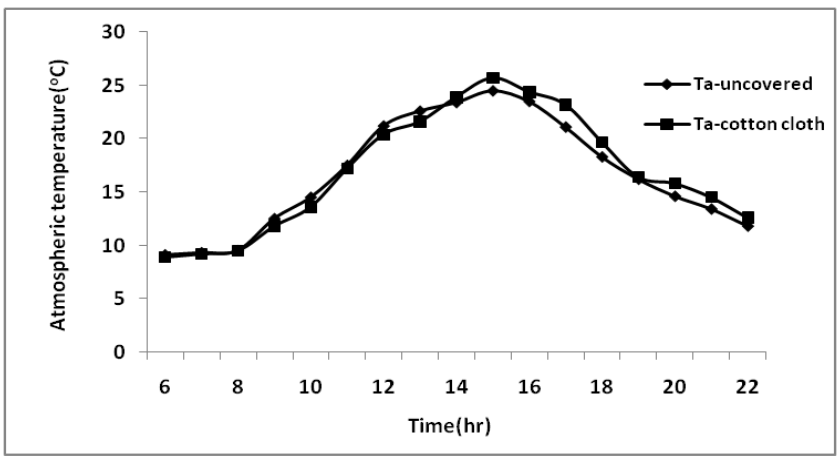

Fig 3. Variation of atmospheric temperature on the two consecutive days

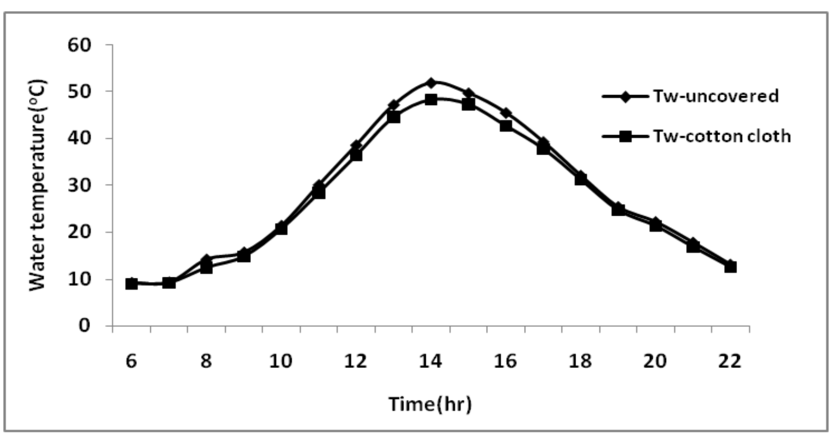

Fig 4. Variation of water temperature in the still on the two consecutive days

Fig 5 shows the distillate output through south facing cover on the two consecutive days. Total 930 ml yield was obtained on the 3rd day while 870 ml yield was produced on the 4th day. A little higher yield was achieved when secondary cover was not covered due to a higher energy available and a little higher water temperature (as discussed earlier). Relatively 6.45 % lower yield through south facing cover was observed when the secondary cover was covered.

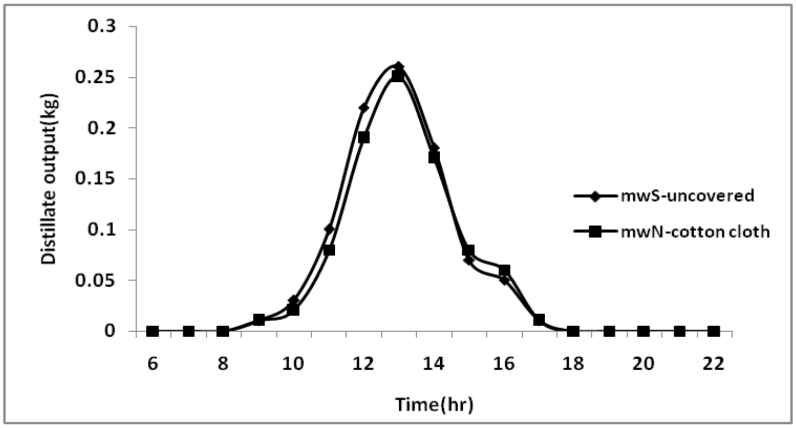

Fig 5. Variation of distillate output through south facing cover on the two consecutive days

Fig 6 shows the distillate output through north facing secondary cover on the two consecutive days. There is a big difference in the yield output on the two days. In the mid day, difference in the yield is quite noticeable. Total 770 ml yield was obtained on the 3rd day while 1130 ml yield was produced on the 4th day. It is noticeable that 46.7% higher yield was achieved when this cover was covered with wet cotton cloth. This is due to higher temperature difference between water and condensing cover. Water in the cotton cloth extracted latent heat of evaporation from its surroundings as well as from condensing cover. Due to this reason, secondary cover's temperature lowered down.

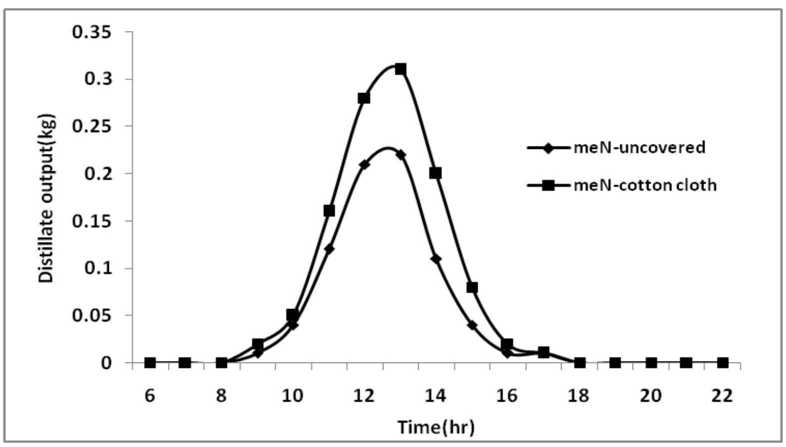

Fig 6. Variation of distillate output through north facing cover on the two consecutive days

Fig 7 shows the cumulative yield through south facing secondary cover on the two consecutive days. Distillate output was 1700 ml and 2000 ml on the 3rd and the 4th day respectively. Overall 17.64 % higher yield was obtained due to cooling with wet cotton cloth.

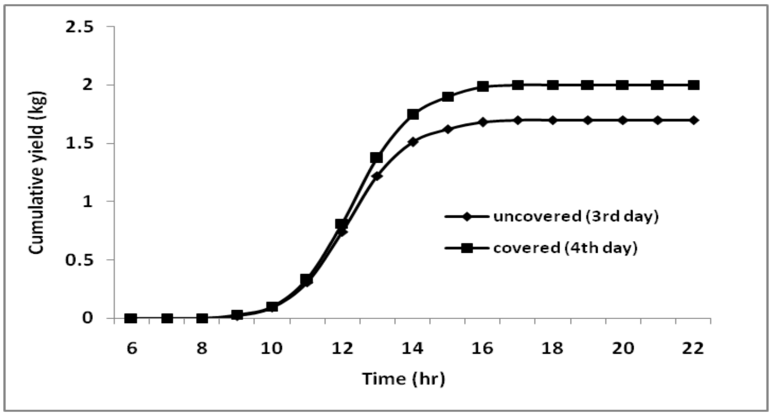

Fig 7. Cumulative distillate output through both the covers on the two consecutive days

Fig 8 shows the comparative yield output of the two stills in the month of the February. Monthly average of the still when not covered with the cloth was 1833.33 ml whereas yield increased to 2233.33 ml when secondary cover was cooled with wet cotton cloth. Average 21.8 % higher yield was observed with covering. Day 7th, 8th, 9th and 10th were not clear sky days, so the observations of these days are not considered.

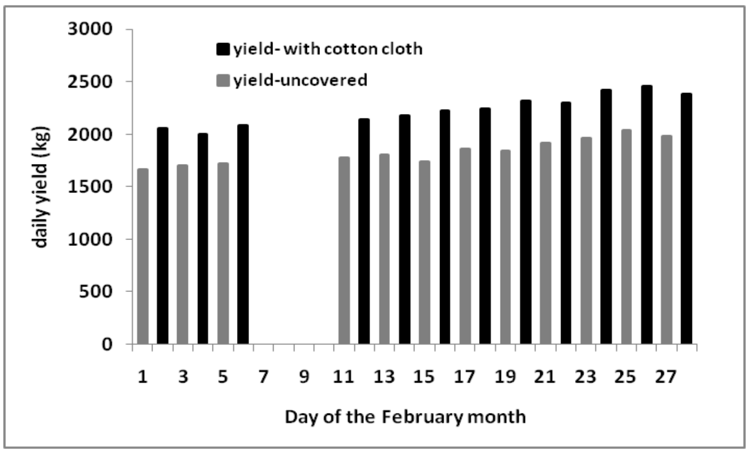

Fig 8. Variation of distillate output during the complete month of February

5. Conclusions

Cooling of secondary condensing cover with wet cotton cloth improves the productivity of the modified still. Though the amount of solar energy entering into the still is reduced due to covering of secondary cover, overall yield output of the device is enhanced. Continuous sprinkle of water may enhance the yield of the still.

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