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ENHANCING THE YIELD OF A NOVEL SOLAR DESALINATION SYSTEM

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Abstract
Potable water shortage is being increased day by day due to rapid growth of population, industrialization and excessive use of pesticides and fertilizers. Desalination using solar energy could a better solution to this global problem. Solar stills are used to produce potable water particularly in remote arid areas. Distillate output through solar still is affected by the many climatic as well as design parameters; one of them is temperature of condensing cover. Lowering its temperature causes higher condensation rate due to larger difference between water surface temperature and cover temperature. Experiments have been conducted on a self-designed novel solar still. A conventional single slope single basin solar still is modified by incorporating auxiliary condensing surface. This additional condensing surface when covered with wet cotton cloth, condensation on inner surface of this cover was accelerated. Average 16.5 % higher yield was achieved during February month.

Key words: Solar desalination, Novel still, cotton cloth, Condensing Cover

1. Introduction

Water and energy are two inseparable elements, which are very vital for human civilization [1]. The growth of any country directly indirectly dependents upon availability of clean and safe potable water. World is faced by the multifaced challenges of fast growing populations, accelerated depleting limited water reserves and a drying up of freshwater resources due to changing rain patterns and elevating temperatures from climate change [2]. Around 97.1% of the water in the world is as ocean, approximately 2% is caped as ice in polar regions and less than 1% is available for the need of the human life, vegetation and animals [3]. With growth of industrial and agricultural sector, water scarcity has become a key problem in most of the countries [4]. The World Health Organization (WHO) prescribes a Total Dissolved Solids (TDS) limit in the water of maximum 1000 PPM for safe drinking [5].
Distillation and desalination are the appropriate methods for supplying safe water. Numerous sources of energy can be used for distillation of water such as vestige fuels, renewable and non-renewable sources and electrical energy [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 output 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 conventional 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 atmosphere and cover, these vapors release their heat too atmosphere and get condense. Resulting desalinated water tickles down along the cover and collected in a jar through the 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 auxiliary condensing cover (Fig.1) was designed, fabricated and installed at KIET, Ghaziabad, India (Latitude 28° 40' N) [13, 14]. Modified still was so designed that without altering the dimensions of its basin area containing water as well as main condensing cover, an auxiliary condensing surface was incorporated. The body of the 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 auxiliary condensing cover (1x 0.67 m^2) was 60° and facing north direction. Both the condensing covers were 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 0.5 m high iron stand. Collection of yield from both the covers of still was carried into separate channels and taken out through flexible and insulated pipes into two different measuring jars.

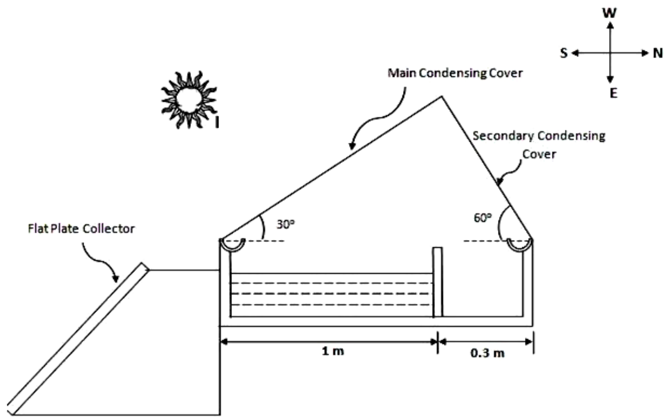

Fig 1. Schematic diagram of the experimental set-up

To provide additional heat energy, still was coupled with a natural convective flat plate collector (FPC). The body of the FPC was made up of GI sheet mounted with ten parallel tubes of aluminum with 8 mm ID and 1 mm thickness each. The inclination of FPC was also made 30° from horizontal, facing towards south. The base of collector was insulated with glass wool sheet of around 20 mm thickness.
Solarimeter (0–1000 W/m2, ±3% error) was implemented to measure the solar radiation intensity. An Anemometer (0.4–30 m/s, ±2%) was implemented to measure wind velocity. Thermocouples (0–100 °C, ±1% error) were used to measure temperatures at different identified critical 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 measurement.

3. Methodology adopted

The yield (distillate production) is directly proportional to the temperature difference between condensing cover inner surface and water surface. So the north facing condensing cover was cooled by covering it through wet cotton cloth. This cotton cloth was kept wet all the time by sprinkling water on it at an interval of two hours. Experiments were conducted in the month of February, a winter season in the northern India. Auxiliary 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 auxiliary cover is bare (b) still when auxiliary cover is enclosed 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 3rd day while minimum of 8.9 ºC and maximum 25.7 ºC were recorded on 4th day. Fig 4 indicates the temperature of water in the still on the two consecutive days. On the 3rd day, when the auxiliary cover is not enclosed with wet cotton cloth, solar radiations are also coming in to basin through this cover also. But on the 4th day, the auxiliary cover was covered 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).

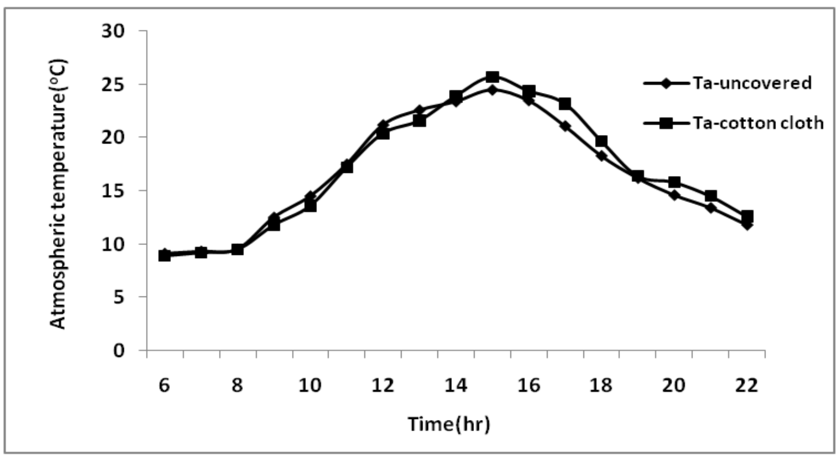

Fig 3. Variation of atmospheric temperature on the two consecutive days

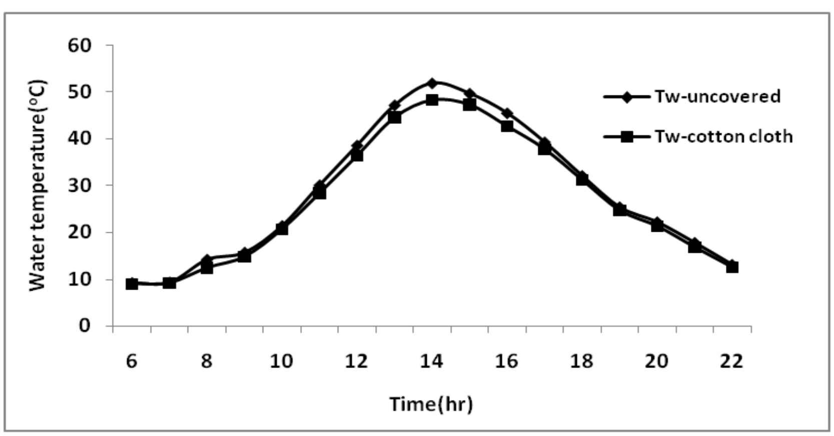

Fig 4. Variation of water temperature in the still on the two consecutive days

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 auxiliary cover was not covered due to a higher energy available and a little higher water temperature (as discussed earlier). Relatively 6.45 % lower yield was attained when the auxiliary cover was covered.

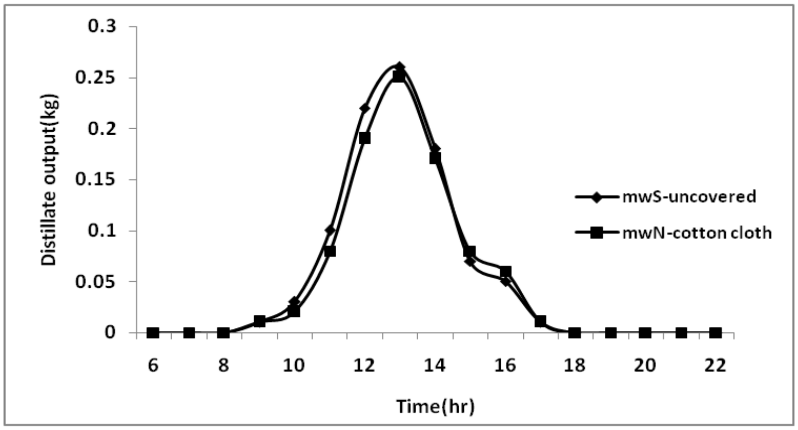

Fig 5. Variation of distillate output through south facing cover on the two consecutive days

Fig 6 shows the distillate output through north facing auxiliary 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, auxiliary cover's temperature lowered down.

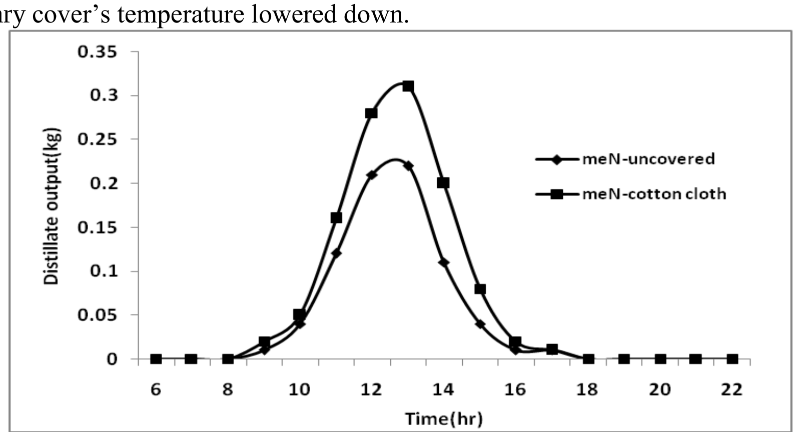

Fig 6. Variation of distillate output through north facing cover on the two consecutive days

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

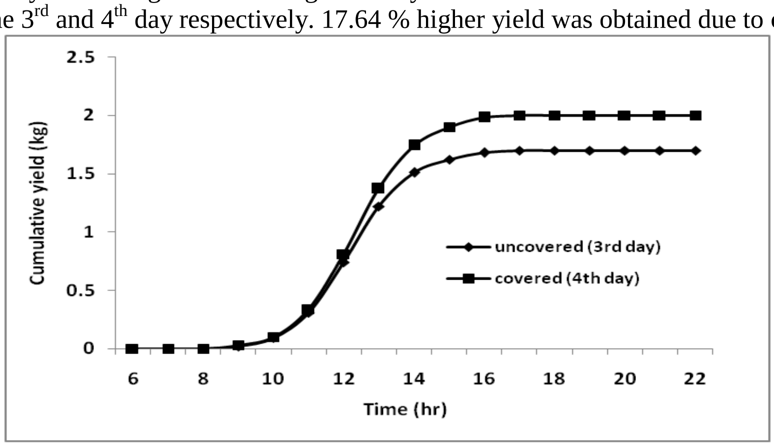

Fig 7. Cumulative distillate output through both the covers on the two consecutive days

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