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Experimental study on modified single slope single basin active solar still

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HIGHLIGHTS

- A new solar still with secondary cover is proposed.
- This model proves better distillate than a conventional design.
- Shading on secondary cover enhances yield.
- Wet cotton cloth on secondary cover also accelerates production.
- Secondary cover material has impact on production rate.

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ABSTRACT

In this present study an attempt has been made to enhance the productivity of a basin type single slope active solar still with improved condensation technique. A new design having additional condensing cover has been proposed and study of its performance was carried out throughout the year. Due to extra condensing surface, higher yield was observed as compared to conventional single slope still. It was experimentally found that water depth, shading on condensing surface and material of extra condensing surface have significant roles in the distillate output of the proposed new design. The yield of the proposed solar still was found to be 3.015 kg/m^2/day on a particular day in April '12 which was about 25% more than that of a conventional solar still running in parallel under the same climatic conditions. This paper also aimed at finding an optimum design condition of a new model for better productivity. Additional increment in yield up to 14.5% was also observed with further modifications in the design.

1. Introduction

Water is very essential for sustainability of mankind. We do need this precious water in applications such as drinking, cooking, washing, irrigation, etc. Potable water scarcity has been a common situation around the globe especially in developing countries. Unfortunately we are continuously losing fresh water reserves mainly due to industrialization. So, it is not only necessary to preserve fresh water but also to develop an eco-friendly technology to get the distilled water from saline/contaminated water. Among various water treatment technologies, 'solar distillation' is one which is based on renewable energy, easy to operate and low cost technology to produce distilled water by using solar energy and it can be a solution to problems of shortage of drinking water especially in rural areas.

Solar distillation technique has the advantage of being eco-friendly, zero fuel cost and low maintenance cost. But on the other hand, it has the disadvantage of occupying a large space and being a slow process leading to less distillate output per unit of time. For the last many decades, efforts are continuously being made to make this technology more efficient, economical and faster. Delyannis [1] extensively reviewed different desalination processes using renewable energy resources. According to him, the first reported solar distillation plant was fabricated by a Swedish engineer, Carlos Wilson in Las Salinas, Chile in 1872 for supplying fresh water to a nitrate mining community. That plant produced potable water for about 40 years until the mines were exhausted. Velmurugana & Srithar [2] also reviewed various researches done on improvement of productivity of solar stills.

Distillation through a solar still depends upon various design parameters (e.g. shape of still, size of still, its orientation, tilt angle of condensing cover, etc.), climatic parameters (e.g., ambient temperature, amount of solar radiation, wind velocity, etc.) and operational parameters (e.g. water depth, heat absorbing material, cooling of condensing cover, etc.). Many researchers worked on these parameters and proposed number of designs and theories. Zurigat & Abu-Arabi [3] modeled a regenerative desalination unit consisting of two basins with provision

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for cooling water to flow in and out. This arrangement had the advantage of increasing the temperature difference between water and glass cover in the first effect and utilized the latent heat of water vapor condensing on the glass of the first effect to produce more fresh water in the second effect. Dwivedi & Tiwari [4] analyzed the performance of a still by evaluating internal heat transfer coefficients of single and double slope passive solar stills in summer as well as winter climatic conditions for different water depths (0.01, 0.02 and 0.03 m) by various thermal models. Dwivedi & Tiwari [5] also compared two stills on the basis of life cycle cost.

Salah et al. [6] used different types of absorbing materials to examine their effect on the yields of solar stills. Also Akash et al. [7] studied the effect of using different absorbing materials in a single basin double slope solar still to enhance the productivity. A black rubber mat and black ink were reported to increase the yield by 38% and 45% respectively. Boubekri & Chaker [8] proposed internal and external reflectors on a single slope solar still to increase the rate of received solar radiation and found increase in overall productivity by 72.8% in the winter. Tiris et al. [9] integrated a flat plate collector with the solar still to increase the temperature of the basin water. Also Badran & Al-Tahaineh [10] made some experimental investigations to study the effect of coupling a flat plate collector on the productivity. It was found that with the collector the productivity was increased by 36%. Boukar & Harmim [11] compared passive and active solar stills.

Kumar & Bai [12] applied water cooling system on the side walls to achieve more condensation and found efficiency to be 30%. Khalifa [13] investigated the cover tilt angle as the most crucial parameter which affects the performance of a still. He found a relationship between latitude and cover tilt angle for various seasons. Badran [14] experimentally studied different operational parameters of a single slope solar still. The still productivity increased up to 51% when combined enhancers such as asphalt basin liner and sprinkler were applied to the still.

Tiwari & Tiwari [15] made an attempt to analyze the effect of water depth on evaporative mass transfer coefficient on a passive single slope distillation system in summer climatic conditions. El-Nashar [16] analyzed that performance of a solar desalination plant is influenced by the ability of the glazing system to transmit solar radiation to the collector absorption surface. Cleaning the surface with jets of compressed air improves its productivity. Al-Hussaini & Smith [17] studied the effect of applying vacuum inside the solar still. A solar still's productivity was found to increase by 100% with the vacuum. Khalifa et al. [18] made an arrangement of condensers to enhance the productivity of the solar still.

In the present work, experiments have been conducted to analyze the performance of a modified basin type solar still, consisting of a secondary condensing cover. The performance of the modified still has been compared, by perfectly synchronized experiments, with that of the conventional basin type single slope solar still of identical dimensions and material. Effects of shading the secondary cover of a modified still with wooden frame, covering it with wet cotton cloth and replacing it with aluminium have also been analyzed.

2. Principle and system description

The principle behind the working of a basin type solar sill is water evaporation and condensation. Impure water fed into the still and solar radiation entering the still through a transparent top cover are entrapped within the still and raises the temperature of the water. At its corresponding vapor pressure, water from the surface evaporates and leaves all contaminants and microbes behind in the basin and sticks to the inner side of the top cover. This is called internal heat transfer. Due to the temperature difference between the cover and atmosphere, these vapors release heat and condense and purified water tickles down along the inclined cover and collects through a channel. This is called external heat transfer. This type of still is the passive type. In an active solar still, extra thermal energy is fed into the basin by external mode for faster evaporation.

2.1. The modified solar still (Model-1)

Larger condensing area leads to higher faster heat transfer from the still causing higher distillate output. Adopting this principle, an active solar still with secondary condensing surface was designed, fabricated and installed at KIET, Ghaziabad, India (latitude 28° 40′ N, longitude 77° 26′ E). The still was so designed that without compromising the dimensions of the basin area containing water as well as the dimensions of condensing cover, additional condensing surface was incorporated. With the secondary condensing cover, the area available for condensation of vapor was increased by 57%. Schematic diagrams of a cross-sectional view of the proposed new design and conventional still are shown in Fig. 1. The body of the solar still was made up of fiber reinforced plastic (FRP) with 4 mm thickness. The basin body was enclosed

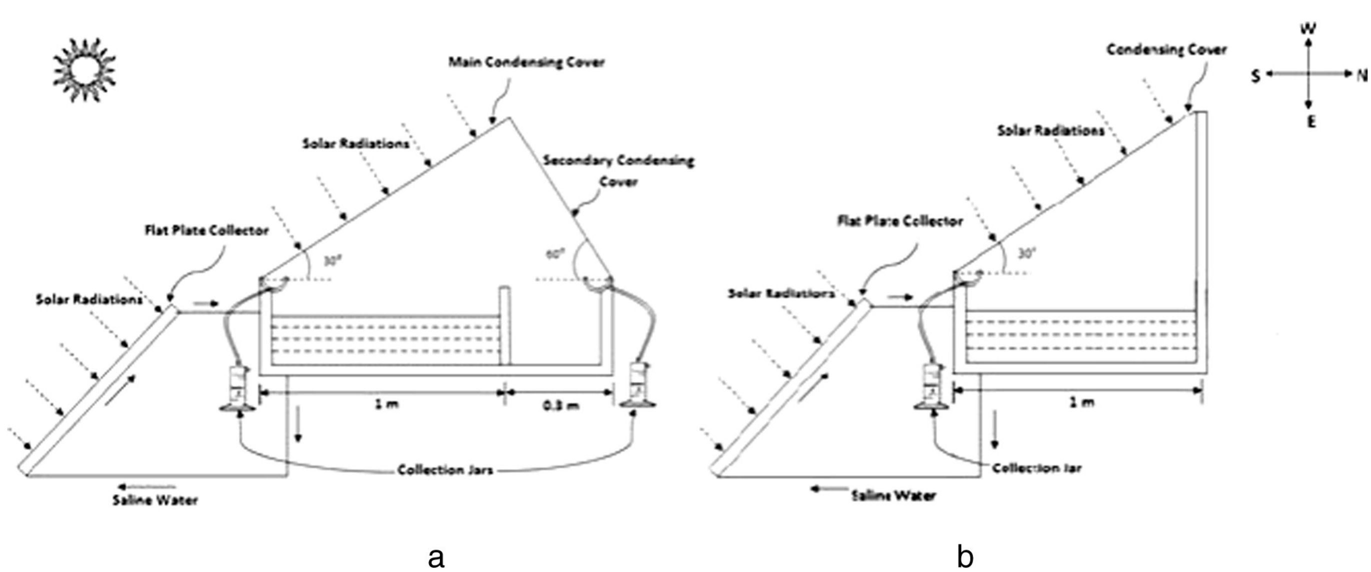

Fig. 1. Schematic diagram of (a) proposed solar still and (b) conventional solar still.