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Various methods applied to solar still for enhancement of distillate output

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ABSTRACT

Solar still is not so much attractive in a market due to its lower productivity. Researchers from all around the world have tried to improve distillate output of solar still, but still, no one has tried solar still to put as a commercial product. Hence, there is a lot of scope of research work on the solar still. In this present review paper, various research works done by researchers have shown, and three primary methods like use of fin, energy storage materials and multi-basin solar still have discussed. All of above methods are crucial for improvement in distillate output of solar still. Fin enhances the surface area of water inside the basin for even distribution of water for increment in distillate production. Energy storage materials have pore holes to store the hot water and excess energy during sunshine hours and release during off-sunshine hours for the increase in distillate production. Multi-basin solar still uses the latent heat of condensation from lower basin to increase a temperature of the top or middle basin for increment in distillate production. Hence combination all of above method in the solar still, then the solar still can be used as a commercial product for potable water in household and industry.

1. Introduction

Most of the world in today's time suffers from an acute shortage of fresh potable water for drinking. The production of clean water has been one of the most difficult issues in recent time. The need of the hour is to provide a large chunk of the population with fresh water and also that can be economical as well as efficient especially in those areas which have remained remote in the fast growing world today. The use of non-conventional energy for the production of fresh water leads to the research of the only device available which consumes solar energy is the Solar Still.

The solar still have been serving the purpose for a very long time through the history. The Arab alchemists used this technology to produce fresh water way back in 1551. At that time, it produced 23,000 l of clean water per day given the area of distillation plant was 47,000 m^2 which reduce to a calculation of 4.9 kg/m^2 of the still surface in the whole day. The still used for this purpose was of single sloped type [1]. The commercialization of solar still has also been done earlier to provide people with fresh water [2]. The efficiency of the solar still puts a shackle on the full-fledged commercialization of it and increased efficiency shall also be contributing to the production of fresh water on a massive scale.

Many types of solar still have been developed which have different designs variations and properties. They are active solar still, passive solar still, flat plate type solar still, concentrated type solar still, wick type solar still, box type solar still single stage solar still and multi-stage solar still. Other miscellaneous types of solar still that have been developed are the solar still with continuous water flow and the weir type solar still, the plastic solar water purifiers and the hybrid solar stills [3]. However, it was observed that in a given day and for per meter square of the basin type solar still, the maximum output was 5.3 l in summer days and 0.9 l during winter season [4].

Solar still is a very simple device used to convert available brackish or saline water into drinkable water by use of solar energy. Many researchers from the all around the world have worked on solar still for improvement in distillate output. Kalidasa et al. [5] reviewed various parameters of solar still like water depth, orientation, glass cover thickness, etc. Kaushal and Varun [6] discussed various designs, and its effect on distillate output has studied. A.E. Kabeel, S.A. El-Agouz [7] discussed various parameters like size of still, insulation thickness, cooling of the glass cover, etc. and their effect on distillate output. Peter Wassouf et al. [8] discussed various lower cost designs of solar still and tested in climate conditions of England and found that lower cost models of solar still are the best solution for fresh water requirement of the small family. Velmurugan and Sridhar [9] discussed various numerical and experimental studies of single basin solar still and its effect on distillate output. Inclined type solar still is a good solution to increase evaporative heat transfer coefficient. Kalidasa Murugavel et al.

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[10] studied various designs of inclined type solar still with conventional solar still based on distillate output. V. Manikandan et al. [11] studied different wick materials used in single basin solar still and their effect on distillate output with and without wick materials. Gang Xiao et al. [12] studied the various surface heating effect of water on different designs of conventional and multi-basin solar still. The distillate output of solar still always depends on evaporation and condensation. Various factors of affecting on evaporation and condensation in the solar still have extensively studied by Muthu Manohar et al. [13] by using different designs of single and multi-basin solar still. Ali. F. Muftah et al. [14] studied various new models of solar still like the pyramid, triangular basin and many others with conventional solar still concerning distillate output and energy payback time. Prakash and Velmurugan [15] reviewed various research work of solar still on multi-basin like an effect of water depth, sponge materials, additives, etc. and compared with the conventional passive solar still. Vishwanath Kumar et al. [16] studied various heat and mass transfer models of different designs of solar still of single and multi-basin. They also showed the effect of heat and mass transfer on distillate output. El-Sebaii and E.El-Bialy [17] reviewed some advanced designs of single basin solar still coupled with evacuated tubes, flat plate collector, heat exchanger, etc. They showed the effect of such attachments on distillate output compared with conventional solar still. Yadav and Sudhakar [18] reviewed the various traditional design of solar still for the home to supply potable water. They studied the quality of fresh water by use of different brackish and saline water. Kabel et al. [19] reviewed various designs of inclined solar still and effect of the various parameters like water depth, a thickness of wick, wick materials, etc. on distillate output. Elango et al. [20] reviewed heat and mass transfer relation of various solar still coupled with humidifier, dehumidifier and heat exchangers. Durikeshwan and Murugavel [21] studied various designs of solar still like solar still with the inbuilt condenser, evaporator, cooling coil and found that the distillate output of any solar still depends on those parameters. Mohammed Shadi et al. [22] reviewed various parameters of sea water like pH, TDS and many other parameters on health and how they diminished by the use of the different designs of solar still. Sharshir et al. [25] reviewed different models of humidification and dehumidification coupled with solar water heater and solar still. They also explained how solar still can be used for the industrial application by use of humidification and dehumidification techniques. Mojtaba Edalatpour et al. [24] studied heat and mass transfer model and numerical simulation techniques for the latest designs of solar still. Sharshir et al. [25] reviewed exergy and energy analysis of various types of solar still like the passive solar still, active solar still, solar still coupled with various attachments like heat exchanger, heat pipes. Omara et al. [26] reviewed the use of reflector materials, orientation and size on distillate output of various designs of solar still. Panchal and Patel [27] discussed different thermal energy storage materials and its effect on the conventional design of solar still and augmented with evacuated tubes, flat plate collector, heat exchanger, etc. Kabeel et al. [28] reviewed various models of solar still based on energy exchange mechanism by use of energy balance equations. Ravishankar Sathyamurthi [29] discussed different current active models of solar still and comparison with them based on energy payback time and distillate output. Hitesh [30] reviewed different phase change materials and its effect on energy storage materials and distillate production. Rajaseenivasan et al. [31] discussed various designs of the multi-basin solar still regarding percentage increment in distillate output.

There have been many attempts to innovate the factors like the feed water rate, the water gap, the absorber material and the type of collector used with the solar still. K.S·Reddy et al. [46] experimented and found that for maximum effects, the mass flow rate was 7.20 kg per hour and the gap was found to be 0.05 m based on which the yield of distillate improved up to 16.64 kg/m^2-day. He has used single basin solar still with a basin area of 0.58 square meters [32]. In a similar attempt to improve the efficiency, a fan and an immersion rod were used as external attachments in a single slope solar still. The fan was placed to cool the outer glass cover of the solar still and while considering the wind speeds at 7 and 9 m/s, the increment in the productivity was observed to be of 5.2 and 10.3% respectively. The use of water heater of 500 W capacity increased the productivity by 250% when the glass angle was 35 °C to the horizontal and water depth was 1 cm [33]. Sellami et al. [34] have conducted series of experiments on a single slope solar still by changing the base materials such as jute cloth or black granite gravels. They obtained productivity of more than 5 l/m^2, and the experiment also suggested that the latent heat storage was far better than the sensible heat storage [34]. In one of the experiments for the base materials, it was found that the mixture of alluvial sand and the Portland cement in equal masses increased the productivity up to 39.7% when 300 g of the mixture was used. However, when the mixture was increased to 400 g, the productivity yielded only an increment of 33.08% [35]. Similarly, an attempt was made to attach fins to the base to increase the productivity by increasing the net convective heat transfer coefficient. It has found that aluminum fins had a productivity increment more than compared to stainless steel fins of spherical and helical types. Also, the combination these kinds of fins increased distillate output of 92% compared with conventional solar still [36].

A multistage solar still with the evacuated tube was also considered for the experiment and was found that the productivity was 14.2 kg/m^2-day which was about three times of a maximum productivity of the conventional basin solar still. The evacuated tube was placed inside the still to increase the evaporation rate of the water. The increment in productivity was also observed when the solar still was modified to multi-effect, and an added vacuum tube was inserted which resulted in the highest water productivity of 40.6 kg/day while the area of the absorber considered for the experimental purpose was 1.08 m^2 [37].

This paper presents an altogether different approach to enhance the productivity for the enhancement of up to 100 l/day by making the suitable modifications and transforming the still into an active multi-stage solar still. The basin surface is to be coated with suitable absorbing material so as to increase the temperature of the still. On the other hand, fins are to be used to increase the net convective heat transfer coefficient and to maximize the production of the fresh water. The evacuated tube is also to be placed inside the still so as to increase the evaporation process. The aim and future scope are to improve the economic aspect of the still so as to make it readily available to the masses at much less cost and optimized effect.

2. Augmentations provided in solar still

For increment in distillate output from the solar still several developments like the attachment of fin, energy absorbing materials, and multi basins are discussed:

2.1. Fin

The still solar technology has been serving the humanity for a very extended period of time. There have been many modifications since decades to improve the productivity of the same. One of the significant improvements which have been done is the use of fins at the base of the still. Integration of fins in the basin plate of the solar still increases the basin exposure area and thus leads to the higher heat transfer rate and higher evaporation rate. Hence, distillate output of conventional solar still is enhanced.

In a series of comparative experiments done before, V. Velumurugan et al. [38] observed that when the wick was used in a single basin solar still, the productivity increased up to 29.6% as compared to the use of sponges which increased the productivity by 15.3%. In the same still, when fins were used, the increment observed was 45.5%. The experiment also suggested that the use of fins decreased the preheating time