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Improvement techniques of solar still efficiency: A review

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ABSTRACT

A technique used to convert brackish or saline water into potable water is called as solar desalination. The demand of consumable water keeps on increasing due to high population density and automation. Solar energy is used for the conversion phenomenon and the device used for desalination is known as a solar still. Active and passive solar stills are the major types of solar stills. Without the utilization of high grade energy (electrical energy), freshwater is derived from the passive solar still. The yield from the solar still (active or passive solar still) depends upon meteorological, and design and operational parameters. By the mercy of nature, meteorological parameters cannot be controlled by human beings. Many researchers framed mathematical expressions, conducted experiments and validated the outcome from the various types of solar stills by varying the design and operating parameters. The methodologies used in the past years to improve the performance of the active and passive solar stills were reviewed in this paper.

Contents

Abbreviations: PCM, Phase Change Materials; ECM, Energy Storage Material; DEAHP, Double Effect Absorption Heat Pump; MED, Multi-Effect Distillation; LTC, Low Temperature solar Collectors; COP, Coefficient of Performance; PR, Performance Ratio; AHP, Absorption Heat Pump; MSF, Multi-Stage Flash; GOR, Gain Output Rate; TES, Thermal Energy Storage; MSTC, Massive Solar–Thermal Collector; DHS, Domestic Hot Water; SH, Space Heating; LT-MED, Low Temperature Multi-Effect Distillation; TVC-MED, Thermal Vapour Compression Multi-Effect Distillation; CSP, Concentrating Solar Power; IPDP, Integrated Power and Desalination Plants; TSS, Tubular Solar Still; IASS, Inverted Absorber Solar Still; TDS, Total Dissolved Solid; ETC, Evacuated Tubular Collector

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1. Introduction

There is an important need for pure drinking water in many developing countries. Often water sources are brackish (contain dissolved salts) and/or contain harmful bacteria and therefore cannot be directly used for drinking purpose. In addition, there are many coastal locations where seawater is abundant but potable water is not available. Solar desalination is a solar technology with a very long history and installations were built over 2000 years ago, although to produce salt rather than drinking water. The various factors affecting the productivity of solar stills [1–3] are solar intensity, wind velocity, ambient temperature, water–glass temperature difference, free surface area of water, absorber plate area, temperature of inlet water, glass angle and depth of water. The solar intensity, wind velocity and ambient temperature cannot be controlled as they are meteorological parameters. Whereas the remaining parameters, such as free surface area of water, absorber plate area, temperature of inlet water, glass angle and depth of water can be varied to enhance the productivity of the solar stills. By considering the various factors affecting the productivity of the solar still, various modifications are being made to enhance the productivity of the solar still.

Bassam A/K Abu-Hijleh et al. [4] proposed a modified technique to enhance the desalination production by placing sponge cubes over the water surface. The sponge cubes increased the surface area over which the evaporation of water took place and increased the still yield by 18%. Velmurugan et al. [5] increased the exposure area of the water surface using sponges (450 sponges of size $20 \times 35 \times 35$ mm^3) and fins (5 numbers with a size of $900 \times 35 \times 1$ mm^3) in a single basin solar still; the study found that the productivity increases from 1.88 to 2.8 kg/m^2/day. Hiroshi Tanaka et al. [6] theoretically studied the effect of both internal and external reflectors on the amount of solar radiation absorbed by a basin liner as well as on the distillated yield of a single slope basin type still. The inclination of both the still and reflector is advisable, and the productivity is 21% higher than the conventional solar still throughout the year. Kaushal et al. [7] carried out an extensive review on solar stills and highlighted that the solar still efficiency increases by 20% when 1.3 mm cooling film thickness is introduced on a glass cover having a thickness of 5 mm. The annual yield significantly depends on water depth and inclination of condensing cover. In a tilted wick solar still, the daily productivity of the still with reflector increases by 9% as compared to simple solar still. Shukla et al. [8] used jute cloth for increasing the evaporation rate. One end of the jute cloth was dipped into the water reservoir while the surface of the jute cloth was spread over the basin exposed to sunrays. A mathematical model was developed to find the heat transfer coefficients and validated with the experimental values. Rahim [9] proposed an approach in a conventional still to store excess energy during daytime that can be used for continuation of evaporation at night. In the approach, the basin water was divided into evaporating and heat storing zones. The heat storing capacity of the water during daytime was about 35% of the total amount of solar energy entering the still. Hassan et al. [10] conducted an experiment in a stepped solar still with the use of phase change energy storage mixture and also a passive internal condenser in addition to the glass plate condensation. The mixture was an emulsion of paraffin wax, paraffin oil and water in a specific ratio to which aluminum turnings were added to assist in heat transfer by conduction. The design used the latent heat of fusion of the mixture for obtaining continued desalination even after sunset. Results indicated that the use of the energy storage material led to a larger improvement in still yield of 5.2 kg/m^2/day. Kalidasa Murugavel et al. [11] conducted experiments on a double slope simulation type solar still with a thin layer of water in the basin. For maintaining the thin layer of water in the basin, the water was spread throughout the basin by some kind of wick or porous materials. Experimental results of still yield by using wick materials, light cotton cloth, light jute cloth and sponge sheets of small thickness and porous materials like washed natural rock of small sizes were compared. The result showed that the still with a black light cotton cloth as spread material was found to be more productive. El-Sebaii et al. [12] studied the performance of a single slope still with Phase Change Materials (PCM) as a storage medium and found that after sunset, the PCM acts as a heat source for the basin water until the early morning of the next day. The result showed that there was a decrease in the output at daytime but an increase in productivity at nighttime. The double production of pure water on a summer day with a daily efficiency of 84.3% was achieved by the PCM incorporated solar still. Voropoulos et al. [13] coupled a conventional solar still with a solar collector field along with a hot water storage tank and conducted experiments. The result showed that the output of a conventional solar still is significantly increased if it is coupled with a solar collector field and a hot water storage tank. Draw-off of hot water volume equal to 1/4, 1 /2 or 1 tank volume reduces distilled water output by 36%, 57% or 75%, respectively and energy output during the distillation is about 1900, 3300 and 5200 MJ. Tiwari et al. [14] attempted to find out the effect of water depth on the evaporative mass transfer coefficient for a passive single-slope desalination system in summer climatic conditions. They conducted an experiment on a south facing, single slope, solar still of 30° inclination of condensing cover, for 24 h on five different days for five different water depths from 0.04 m to 0.18 m. The study leads to the conclusion that the convective and evaporative heat transfer coefficients are important for varying water depths to optimize the same for the highest yield. The fluctuations in the value of convective heat transfer coefficient from water to condensing cover, as observed for lower water depth, reduce with the increase in water depth. Janarthanan et al. [15] derived an expression for flowing water, glass, tilted-wick water surface and floating-wick water surface temperature and efficiency of the floating cum tilted-wick type solar still. The result showed that glass cover temperature decreases significantly due to the water flowing over the glass cover which causes fast evaporation during peak sunny hours. The effect of water flowing over the glass cover has a fascinating role on the performance of the still. An attempt was made by Dimri et al. [16] to evaluate inner and outer glass temperature and its effects on productivity. The effect showed that higher yield was observed for an active solar distillation system as compared to the passive mode due to higher operating temperature differences between water and inner glass cover. The yield decreases with increase in glass cover thickness and the