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Parameters influencing the productivity of solar stills – A review

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ABSTRACT

In this paper, a review is made on the various parameters influencing the productivity of the solar stills. The researches on the factors improving productivity such as area of absorption, minimum depth of water, water–glass cover temperature difference, inlet water temperature, heat storage, phase change materials, vacuum technology and other methods such as using reflectors, condensers, multi effect distillation, etc. are discussed here. The review showed that the productivity increases when the area of the absorption is increased. The basin water depth is the main parameter that affects the productivity of the still. The increase of the water–glass cover temperature difference ($T_w - T_g$) also plays a vital role in increasing the productivity. Preheating the feed water to the still basin shows a considerable improvement in the productivity. The studies showed that solar stills with heat storage medium and phase change materials can produce distillate during off-shine hours (nocturnal distillation) and thereby, enhance the productivity. Maintaining vacuum conditions and the use of reflectors and condensers improves the performance of the solar stills. Various modifications in the solar stills such as weir type stills, multi effect distillation, thermoelectric cooling, inclined type stills, etc. enhanced the productivity of the solar stills.

Contents

Abbreviations: MPLC, micro programming logic circuit; ETC, Evacuated Tube Collector; UCZ, upper convective zone; NCZ, non-convective zone; LCZ, lower convective zone; FPC, flat plate collector; SSP, shallow solar pond; PCM, phase change material; LHTESS, latent heat thermal energy storage system; CR, conversion ratio; PTSS, portable thermoelectric solar still; TSS, tubular solar still; PV, photo voltaic; DC, direct current; TDS, total dissolved solvent; SGHT, symmetric green house type; ASGHT, asymmetric green house type

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1. Introduction

Solar desalination is the process of converting the impure brackish water into potable drinking water using solar energy. The solar desalination methods have been used by the man kind for thousands of years. Infact, solar stills were the first method which was used on a small scale to convert impure saline water to potable water. In the year 1872 in Las Salines, Chile, Caros Wison, a Swedish engineer supplied fresh water to workers at a salt peter and silver mine by the process of solar desalination. It operated for around 40 years and produced an average of 22.7 m^3 of distillate per day using the effluent from the mine as feed water.

The main drawback of the solar desalination using solar stills is its low productivity. Normally, a solar still can yield 2.5–5 l/m^2/day of distillate. Several researches have been done to increase the productivity of the solar stills. Murugavel et al. [1] conducted experiments in basin type double slope solar still using different wick materials. The layer of water with wick material in the basin will increase the evaporation area and increase the productivity. Phadatare et al. [2] studied the effect of water depth on the internal heat and mass transfer in a single basin single slope plastic solar still. The results proved that with the increase in the water depth, the productivity of the solar still decreases.Velmurugan et al. [3] made an attempt to enhance the productivity of the solar stills by connecting a mini solar pond and a single basin solar still in series. Velmurugan et al. [4] conducted experiments in a stepped solar still by maintaining minimum depth of water. Theoretical and experimental analysis was made for fin type, sponge type and combination of fin and sponge type stepped solar still.

When the fin and sponge type stepped still was used, the productivity increased by 80% than the ordinary single basin solar still. Abdulrahman et al. [5] performed tests in four basin type solar stills. Three stills had a glass cover of thickness 3 mm, 5 mm, 6 mm, while the fourth was plastic. The still with the thinnest glass cover had shown the highest production rates, up by 15.5%. Valsaraj [6] conducted experiments in a single slope basin solar still after introducing a floating perforated and folded aluminium sheet on the water surface. Due to the modifications made the productivity of the single slope basin solar still is improved. Elango et al. [7] conducted experiments with nanofluids of aluminium oxide (Al_2O_3), zinc oxide (ZnO) and tin oxide (SnO_2). The productivity of stills with nanofluids of Al_2O_3, ZnO and SnO was 29.95%, 12.67% and 18.63% higher than the still with water. Rahmani et al. [8] used a natural circulation loop to improve the productivity of the basin type solar still. The productivity of the still with natural circulation loop was 3.72 kg/m^2 and the maximum efficiency was 45.5%. Sathyamurthy et al. [9] conducted experiments on a triangular pyramid solar still. The effect of water depth and wind speed on the productivity of the still has been discussed. The results show that increasing the wind speed from 1.5 to 3 m/s, increases the productivity from 8% to 15.5%.

In this work, the researches on productivity of the solar stills are reviewed. The parameters such as area of absorption, minimum water depth, water–glass temperature difference, hot inlet water temperature, heat storage, phase change materials, vacuum technology and other types such as using reflectors, weir-type stills, etc. are focussed.

2. Area of absorption

The rate of evaporation of water in the solar still is proportional to the surface area of absorption of water [10]. The productivity increases with the increase in the exposure area of the water. This can be done by using jute cloth, wick, sponges, etc in the still basin. Sakthivel et al. [11] conducted experiments in a single slope solar still with jute cloth placed in a vertical position in the middle and attached to the sides of the wall on one side as shown in Fig. 1. Jute is a long, soft, shiny vegetable fibre that can be spun into coarse, strong threads. Jute cloth is one of the easily available natural fibres in India which can absorb water. It is 100% biodegradable and thus environment-friendly.

The bottom edge of the jute cloth is dipped into the basin saline water. The presence of jute cloth increases the evaporation surface and also it can attain very high temperature since it has very low heat capacity. The effective area of the basin is 1 m $\times$ 0.5 m. The thickness of the still is 0.003 m. The glass cover was kept at an optimum angle of 25° with the horizontal. For lesser angles of inclination the condensing vapour may fall into the saline water. The condensed water flows down through the aluminium channel attached to the lower end of the glass cover. The condensate is collected and measured using a measurement jar. A hole is provided at the side of the still to feed the saline water and a tap is provided to drain the saline water. The thermocouples are provided at different points to measure the temperatures of the basin, water, jute cloth, air–vapour mixture, inner and outer surface of the glass cover and ambient temperature. Silicon rubber is used as a sealant to prevent any vapour leakages. The intensity of solar radiation is measured using solarimeter in the range of 1–100 mW/cm^2. The capacity of the measuring jar used is 2 l to measure the hourly yield. The still is placed along the east–west direction and the glass cover faces south to intercept maximum intensity of solar radiation. Experiments were conducted in the conventional still and still with jute cloth simultaneously with different quantities of water from January to August 2006.

With 30 kg of saline water, the still yield with jute cloth was 4 kg/m^2 which are about 20% more than the conventional still yield. The maximum efficiency of the still with jute cloth was found as 52% whereas the efficiency of the conventional still was 44%. The efficiency of a solar still is defined as the amount of energy utilised in vaporising water in the still over the amount of incident solar energy on the still. The use of jute cloth in the still increased the area of absorption. Also any other cloth materials such as cotton can also be used in the still and comparative studies can be made.