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Experimental performance investigation of tilted solar still with basin and wick for distillate quality and enviro-economic aspects

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HIGHLIGHTS

- Enhanced distillate yield by incorporating partitioned basin in tilted solar still
- Year round performance analysis of tilted solar still with basin and wick
- Economic feasibility and environmental benefits of tilted solar stills

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ABSTRACT

Tilted wick type and stepped solar stills are well known for their increased distillate yield compared to basin type stills. In this study experiments were conducted on tilted solar still with basin and tilted solar still with wick to assess their performance, distillate quality, environmental benefits and economic feasibility. Distillate quality of both the tested units was superior. Annual average distillate yield of tilted solar still with basin was nearly 19.76% higher than that of the unit with wick. Maximum distillate yield of 4.99 L/d and 4.54 L/d was noticed for tilted solar still with basin and wick, respectively during April. Yearly average thermal and exergy efficiency was around 41.06% and 3.06% for the unit with basin and 33.83% and 2.88% for the unit with wick. Energy payback time of the unit with basin was around 2.80 yrs and it can prevent 17.65 tons of CO_2 emission during 20 yrs of life time. Distillate production cost was around 0.026 USD/L (Rs. 1.74/L) and 0.046 USD/L (Rs. 3.08/L) for an interest rate of 5% and 12%, respectively. Tilted solar still with basin has superior performance compared to that of unit with wick and can produce 21.76 L of distillate/USD invested on it.

1. Introduction

Availability of clean drinking water is one of the keys for socio-economic betterment of any nation. In current scenario, most of the regions of the globe are heavily affected by water scarcity and water pollution leading to improper supply of clean drinking water for mankind. The unavailability of clean drinking water can be tackled by distillation of saline and polluted water which are available in plenty [1]. Conventional distillation technologies are powered by fossil fuels which again add up environmental pollution [2]. Treatment of saline and polluted water at near zero carbon emission and zero fuel cost can be achieved by utilizing solar thermal energy for distillation and is highly suitable for remote, arid and rural regions where abundant solar radiation is available throughout the year [3]. Utilization of solar energy for conventional desalination units can be made viable by developing novel and low cost solar thermal technologies [4]. Solar still (4700.0 m^2) which has the capability to generate 23.0 kL of potable water/day was installed and operated nearly for 40 yrs in Northern Chile [5]. Solar still has proved to be capable of removing 96.0% of fluoride content from polluted feed water [6]. Usage of solar still by public can be made applicable by enhancing its distillate productivity and by lowering the production cost per litre of distillate [7].

1.1. Basin type solar stills

The productivity of conventional deep basin solar still is around 2.0 to 3.0 kg/m^2-d [8,9] which is the minimum requirement of drinking water for an adult person as recommended by the World Health Organization (WHO) [10,11]. Distillate yield of solar stills has been enhanced by modifying the design [12,13] and by preheating the feed water using waste heat [14] and solar collectors [15–17]. Finned single basin solar still was found to produce 19.0% higher distillate yield than basin type still [18]. Yield enhancement in the range of 9.0 to 19.0% has been

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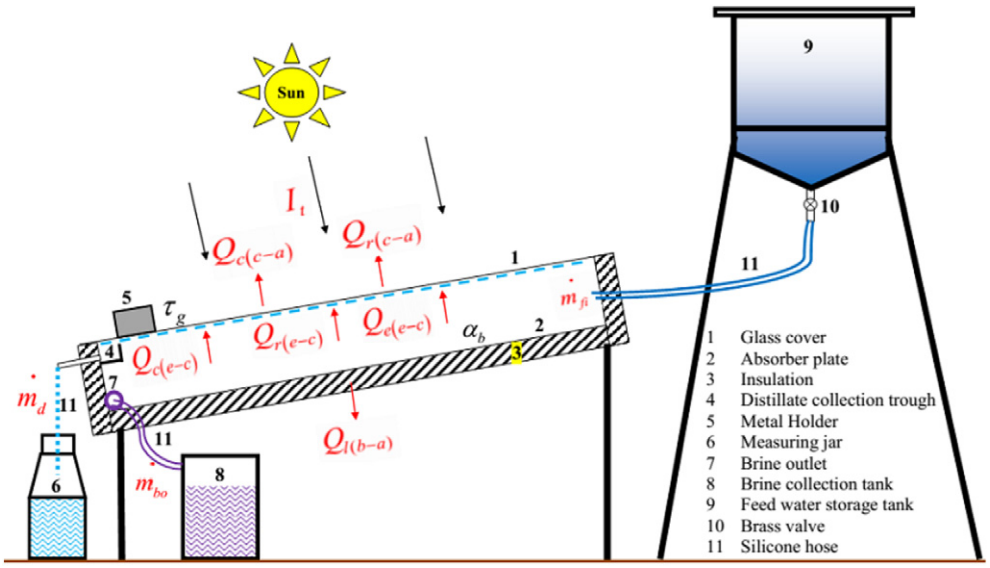

Fig. 1. Schematic representation of tilted solar still.

achieved by incorporating separate passive condenser with basin solar still [19]. Nearly, 72.0% enhancement in yield has been achieved by incorporating forced condensing system in basin type still [20]. Continuous disturbance of water mass and addition of active condenser unit to conventional basin type still has enhanced its yield by 39.49% [21]. Sprinkling of water over the glass cover has increased the yield of basin type still by 20.0% [22]. Distillate yield of basin type still with finned condenser and operating under low pressure of 5000.0 Pa was found to produce nearly 16.2% yield higher than conventional still [23]. Addition of black dye [24] and incorporation of activated carbon-methanol based vapor adsorption basin has increased the yield by 60.0% and 75.0%, respectively [25]. Addition of nanoparticles to feed water [26] and incorporation of phase change material with basin liner [27] has also been tried to enhance the distillate yield of conventional solar still. Nearly, 26.0% enhancement in yield was noticed from parabolic dish concentrator coupled hemispherical basin type still with PCM (phase change material) compared to the unit without PCM [28]. Yield enhancement in the range of 33.7% was noticed by incorporating metal scarp as heat storage medium in basin solar still [29]. Injection of hot air to the water mass of basin type still with PCM was found to be capable of producing nearly 109.0% higher yield than conventional solar still [30]. Apart from simple basin solar stills hemispherical solar still [31], triangular or double slope solar still [32,33] and tubular solar still [34,35] has been tested for their feasibility of drinking water supply. Integrating solar collectors and storage systems with basin type stills can enhance its productivity by 194.0% with a penalty of initial cost being three times higher than conventional still [36].

1.2. Solar stills with wick

Distillate yield was found to increase by 90.0% by adopting corrugated basin lined with wick as evaporating surface in basin type still [37]. Incorporating wicks with inclined still was found to increase its yield by nearly thrice compared to the unit with bare absorber plate [38]. Single slope wick solar still with blackened jute wick was capable of producing distillate yield of nearly 2.5 L/m^2-d on cold sunny day [39]. Incorporation of blackened conical shaped cotton wick in floating conical solar still was capable of producing nearly 2.0 to 4.0 L/m^2-d of distillate [40]. Hot brine leaving the wick type solar still was further allowed to evaporate in a basin type still kept under shade there by nearly 43.0% enhancement in total yield was obtained [41]. Single and double slope wick solar stills are highly efficient in winter rather than summer due to reduced heat losses in winter because of lower operating temperature [42]. The efficiency of wick-type solar still was around 53.0% during sunny day when charcoal cloth was used as wick for evaporating surface however, the major drawback of this wick is its high price compared to other wicks [43]. Effect of different wick materials like light jute cloth, coir mate pieces, sponge sheet, waste cotton cloth and light black cotton on distillate yield enhancement of double slope still has been studied by Murugavel and Srithar [44]. Water coral fleece in combination with stepped absorber plate in inclined still was found to increase the distillate yield nearly by 71.2% [45]. Partial shading of glass cover of inclined wick solar still was found to enhance its yield by 3.0% [46]. Incorporating vertical and inclined flat plate reflectors with tilted wick solar still was found to increase its yield by 21.0% and 27.0%, respectively [47,48]. V-trough concentrators have been coupled with wick type solar still to enhance the yield by 3.6% and 77.3% during summer and winter, respectively [49]. Wick type solar still integrated with evacuated solar water heater produces 114.0% of distillate higher than basin type still [50]. Humid air-vapor mixture released from wick

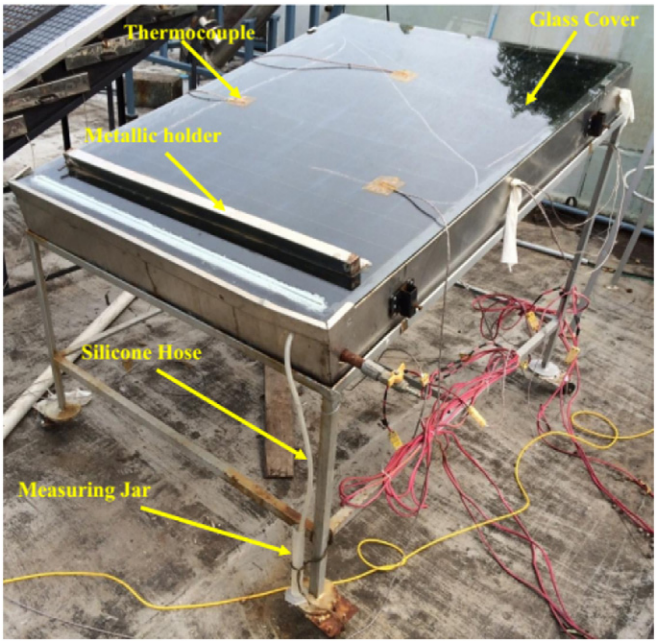

Fig. 2. Tilted solar still.