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ORIGINAL ARTICLE

Study on stepped type basin in a solar still

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Abstract In this work a stepped solar still is used to enhance the productivity of the solar still. The concept of integrating the stepped solar still along with inclined flat plate collector is introduced in this research work. In this stepped type solar still, a conventional basin of area 1 m^2, was placed at the bottom. Another absorber plate, stepped type was fixed on the top of the conventional basin. It consists of subsequent trays and inclined flat plate collectors. This ensures an additional exposure area which augments the evaporation rate. Experiments were conducted with various depths in the conventional basin. A conventional still was fabricated and run parallel with the experimental set up for comparison. Sensible heat storage mediums such as rocks, pebbles were added to the top basin of stepped trays and bottom conventional basins to increase the temperature of water in the still. Wicks were placed on the inclined flat plate collector to augment the evaporation rate due to capillarity. A higher evaporation rate is obtained in the packing material with wicks and pebbles in tray combinations. Theoretical analysis was performed and it agrees with experimental values. Efficiency of the system was also compared with conventional solar still.

1. Introduction

Water is the one of the resources that is potentially useful to all living beings. Often water sources are brackish containing harmful bacteria and therefore cannot be used for drinking. Distillation is the one of the processes that can be used for water purification. Desalination refers to the process of removing salt and other minerals from water. Water is desalinated in order to convert salt water to fresh water which is suitable for human consumption or irrigation. Most of the research in desalination was focused on developing cost effective ways of providing fresh water for human use.

Various research works are being carried out to improve the performance of the still. The basin area of the still, free surface area of water, inlet temperature of water, wind velocity, solar radiation, depth are some of the factors that affect the productivity of the solar still. Experimental investigations have been done by Moustafa et al. (1979) on stepped solar still and wick type evaporator still and the efficiency of the still improved by reducing the radiation losses from the basin. A simple expression was derived by Gandhidasan (1983) to calculate

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Nomenclature

English letters

A	area, m^2
C_p	specific heat, J/kg K
$I(t)$	solar flux on an inclined collector, W/m^2
p	partial pressure, Pa
Q	heat transfer rate, W
T	Temperature, °C
dt	time interval, s
h_{fg}	enthalpy of evaporation at T_w, J/kg
m	mass, kg
m_c	condensate, kg/m^2
U	side heat loss coefficient from basin to ambient, W/m^2 K
V	wind velocity, m/s

Greeks

ε	emissivity
α	absorptivity
ρ	density, kg/m^3
β	Collector surface inclination, °
σ	Stefan–Boltzmann constant, W/m^2 K^4

Subscripts

a	ambient
b	basin
c	convective
e	evaporative
g	glass
r	radiative
w	water
p	pebble
loss	side loss

the amount of water evaporated from the tilted solar still. The energy balance equations in terms of various heat transfer coefficients of the solar were discussed by Tiwari (2002). Double glass cover was used and studied by Zurigat and Abu-Arabi (2004). Modeling of the system along with performance analysis was also compared. Aybar et al. (2005) tested the absorber plate with black cloth, wick materials and the experimental results showed an increase in the fresh water generation rate by two to three times more than the conventional system. Abdel-Rehim and Lasheen (2007) used the oil heat exchanger to preheat the saline water inside the solar still and got 18% increase in productivity. Suleiman (2007) studied the effect of water depth on productivity and their experimental results showed that a higher productivity of 6.7 L/day was obtained for a low water depth. Velmurugan and Srithar (2007) used sponge cubes in the still and acquired 57.8% more yield than the conventional still. Dimri et al. (2008) have done theoretical and experimental analyses of a solar still with a flat plate collector with various condensing materials. Velmurugan et al. (2009a) worked with an industrial effluent in a fin type single solar still and a stepped solar still separately. The maximum output was found in the fin type solar still. Also Velmurugan et al. (2009b) used solar integrated along with solar still to enhance productivity. Many materials such as sponges, fins, wick and pebbles are added in the still and maximum 78% productivity was found for fin, sponge combinations.

A new design of a stepped solar desalination system with a flashing chamber was experimentally investigated by El-Zahaby et al. (2010). Effect of a spray system for sea water was investigated experimentally at different velocities. Kalidasa Murugavel et al. (2010) fabricated a still and tested it with different sensible heat storage materials like quartzite rock, red brick pieces, cement concrete pieces, washed stones and iron scraps. It was found that a inch quartzite rock is the effective sensible heat storage medium among the other materials.

Dev et al. (2011) fabricated an inverted absorber solar still and the experimentation was carried out for different water depths and total dissolved solids. Results were compared with the conventional single slope solar still. Kalidasa Murugavel and Srithar (2011) used different wick materials like light cotton cloth, sponge, coir mate, waste cotton pieces in a double slope solar still. Higher yield was obtained by using light black cotton cloth. Omara et al. (2013) made a comparison study between a modified stepped solar still with and without reflector and compared it with a conventional solar still. It was shown that about 20% of daily efficiency has been improved in the modified still.

The objective of this work is to increase the evaporation rate by means of providing a stepped tray type basin along with a conventional basin. It was shown in previous research works by the corresponding author, K. Srithar, that evaporation rate was substantially increased by means of placing the stepped solar still. In this work, in addition to stepped trays, subsequent inclined flat plate collectors are introduced. This will ensure more evaporation due to the lower depth in stepped trays and more exposure area by means of capillary action in the wicks placed on the flat plate collectors. Three small stepped trays sandwiched among three inclined flat plate collectors. Each set of trays has four small segments with a total area of 240 cm^2. There are three inclined flat plate collectors with an area of 60×70 cm^2, each was sandwiched among the trays. The saline water from storage tank got collected in the first tray. The excess water glided over the inclined flat plate collector and reached the second tray and so on. Finally, the pre heated saline water entered the conventional basin. As soon as a constant depth was reached in the conventional basin the supply was stopped. This procedure was repeated for every one hour. Little effect of evaporation from the conventional basin was experienced whereas high evaporation rates were observed from stepped type basin. In order to improve the area of exposure packing materials which consist of coconut coir, wooden chips, sand and coal were used in the inclined flat plate. To improve the capillary effect and thereby exposure area, sponges of various sizes were placed on the stepped trays and conventional basins. Sensible heat storage materials like rocks and pebbles were also used in stepped tray basin and conventional basin to increase the temperature of the saline water.