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Glass basin solar still with integrated preheated water supply – Theoretical and experimental investigation

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HIGHLIGHTS

- A glass basin solar still with integrated preheated supply is investigated.
- Effect of water depth variation in preheater section is analyzed.
- Energy storing materials are used in the hollow glass fins.
- Presence of energy storing material augments the distillate output of system.

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ABSTRACT

Theoretical and experimental investigation is performed in a glass basin solar still. The glass basin solar still is separated into two sections as preheater (lower) and evaporator (upper) by a glass plate. The preheater section contains five rectangular hollow glasses as fins which enhance the heat transfer rate. Also provisions are made to place the energy storing materials (charcoal, sand and metal scrap) in the hollow space of glass fins. The evaporator section contains the saline water to evaporate. The saline water enters in the one end of preheater section and flow around the fins and gets heated. The water that fills the preheater section completely then enters into the evaporator section through a hole at another end. System performance is analyzed by varying the preheater section water depth (2, 4, 6 and 8 cm) with the help of glass pieces. The effect of energy storing materials in fins also investigated. The result shows that the increase in water depth in preheater section reduces the day time productivity but considerably enhances the nocturnal productivity of the glass basin solar still. The presence of charcoal in fins augments the total distillate output of the system up to 3.61 kg/day.

1. Introduction

The various techniques in a single basin passive solar still is reviewed and reported that the capacity of the system is augmented by reducing the basin water depth, placing of the internal and external mirror, providing energy storing and wick materials, integration with the external collectors, solar pond and condenser [1]. The different factors that affect the potential of the basin type solar still is reviewed and concluded that the system ability is affected by metrological, operational, and design parameters [2]. The performance improvement techniques in the multi basin solar still is studied and concluded that the multi effect solar still is better than the single basin solar still [3].

A single slope solar still with asphalt as energy storing material in the basin is tested and resulted in 29% higher distillate than the conventional solar still [4]. The quartzite rock, red brick pieces, cement concrete pieces, washed stones and iron scraps are used in the basin of a single basin solar still and found that the presence of material enhances the distillate output of solar still [5]. A vapor adsorption solar still with activated carbon – methanol is tested and found that it considerably reduces the bottom heat loss and increases the water temperature in basin [6]. A double basin solar still is investigated with the different wick and energy storing materials in the lower basin and concluded that the jute cloth and mild steel pieces has the higher impact on productivity of the solar still [7–9]. A single basin solar still integrated with an evacuated tube solar collector in the natural circulation mode is analyzed and resulted in the higher distillate of the system [10]. A solar still with an integrated flat plate collector arrangement enhances the distillate by 60% higher distillate than the conventional solar still [11]. A solar still integrated with the pin finned wicks in basin is tested and found that the higher evaporation rate and efficiency than the conventional solar still [12]. Corrugated and vertical fins are used in the basin of solar still and it shows that the output is enhanced by 21% and 40% higher than the conventional solar still for vertical and corrugated finned still respectively [13]. The distillate output of the solar

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Nomenclature

A	area, m^2
C	specific heat, J/kg·K
d	difference
h	heat transfer coefficient, $W/m^2 \cdot K$
H	height, m
I	solar radiation, W/m^2
l	length, m
m	mass, kg
P	partial pressure, Pa
Q	heat transfer, W
T	temperature, °C
t	time, s
U	overall heat transfer coefficient, $W/m^2 \cdot K$
V	wind velocity, m/s

Subscript

atm	atmosphere
b	basin
c	convection
e	evaporation
eff	effective
f	feed water
gc	glass cover
in	input
mg	middle glass
r	radiation
sh	shadow
we	water in evaporator
wp	water in preheater

Greek letters

α	absorpitivity
τ	transmitivity
ρ	reflectivity
ε	emissivity
σ	Stefan Boltzmann constant

still is considerably augmented by using the rectangular fins in the basin [14]. A solar still with vertical fins in the basin is examined and found that the system competence increases with the number of fins [15]. Integration of the circular and square fins in basin of a single basin solar still is considerably enhanced the distillate output and reduces the cost of distilled water [16]. A triple basin solar desalination system capability is augmented by means of providing fins and energy storing material in the solar still [17].

The literature shows that the potential of the solar still can be augmented by increasing the basin water temperature and by means of integrating it with some external collector. Also the presence of energy storing material increases the heat capacity of basin and the fins enhances the heat transfer rate between the basin and water. This work made an attempt to integrate the preheating and evaporating process in the solar still itself. The basin is divided into two sections and the bottom section is known as water preheater section and the upper section is called as evaporation section. Also the lower section contains the hollow fins in order to improve the heat capacity of the basin. The whole basin setup is made of glass, to ensure entered solar radiation transmit up to the basin of preheating section. Saline water enters at the bottom, gets heated and the preheated saline water is evaporated at evaporator section. Experiments are conducted to study the effect of varying the water mass in preheater section. The mass of water in the preheater section is varied by placing the glass pieces in the basin. Different energy storing materials like charcoal, river sand and metal scraps are used in the fins to augment the heat capacity of basin. A mathematical model also developed for the proposed glass basin solar still and validated with the experimental results. The performance of the glass basin solar still is compared with a conventional single basin solar still.

2. Mathematical modeling

The energy balance analysis is applied to the modified solar still in order to theoretically evaluate the performance of the system. The basin plate, water in preheater, middle glass, water in evaporator, and top glass cover are considered for this analysis. The energy flow in the glass basin solar still is represented in the Fig. 1.

2.1. Basin plate

Energy received by basin = Energy transferred to the basin to water in preheater + Energy loss to the atmosphere + Energy stored in the

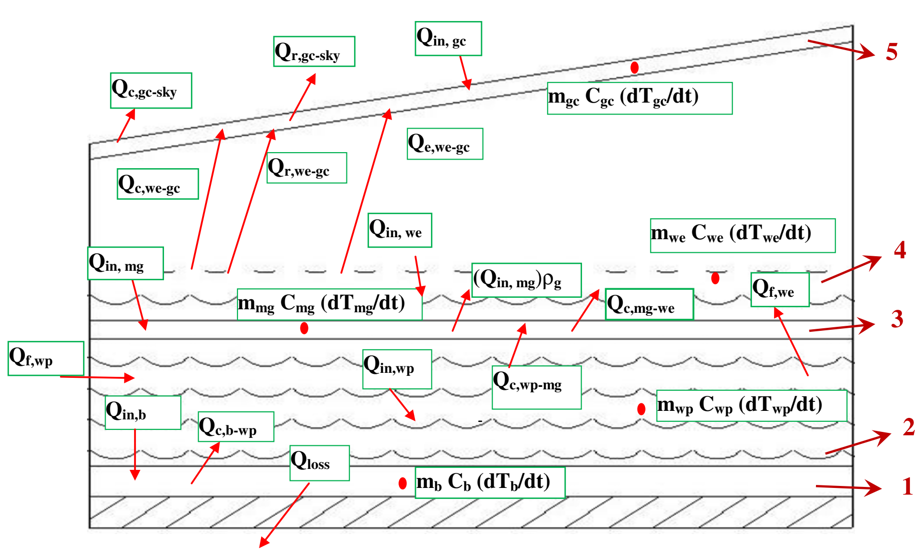

Fig. 1. Energy flow diagram of glass basin solar still. 1. Basin, 2. Water in preheater, 3. Middle glass cover, 4. Water in evaporator, 5. Glass cover.