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Different parameters affecting the rate of evaporation and condensation on passive solar still – A review

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ABSTRACT

Scarcity for water exists in many countries even though three-fourth of the earth is covered by water. The reasons for scarcity of water are worldwide rapid growth of industry and immeasurable population. Solar still is the only efficient solution for water problem in hot climatic conditional areas where scarcity of water and electricity occurs. Solar still is a very simple solar device that is used for converting the available brackish water into potable water. Investigation shows that the productivity of basin type solar still is limited. Various literature reported several experimental and numerical investigations on basin type of solar still. An extensive review on different parameters affecting the rate of evaporation and condensation on passive solar still has been carried out in this paper.

Contents

1. Introduction

Water is essential for all life forms on earth – human, plants and animals. Water is one of the most abundant resources on earth, covering three-fourths of the planet's surface. About 97% of the earth's water is present as saltwater in oceans and the remaining 3% as fresh water in the form of ice, ground water, lakes, and rivers. Less than 1% fresh water is within human reach. Nature itself provides most of the required fresh water, through hydrological cycle.

The enormous population and rapid growth of industry lead a worldwide imbalance between supply and demand of fresh water. Most desalination plants such as reverse osmosis, membrane

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Nomenclature

Q	heat transfer energy (W)
h	heat transfer coefficient (W/m^2 K)
A	area (m^2)
p	partial pressure of water vapor (N/m^2)
M	molecular weight (g/mol)
c	specific heat capacity (J/kg K)
T	temperature (°C)
v	mean wind velocity (mph)

Subscripts

b	basin
g	glass
w	water
c	convection
e	evaporation
a	air
T	total
p_a	saturated vapor pressure at room temperature
fg	change during evaporation
$g.c$	glass cover

distillation, multistage and multiple effect distillation use fossil fuel as a source of energy. The above-mentioned treatment processes are available to supply clean potable water to rural and urban peoples. However, for the people living in remote areas, no device is available at inexpensive cost to supply drinking water. Solar distillation is a most attractive and simple technique among other treatment processes.

In 1872, Swedish engineer C. Wilson designed the first conventional solar still for supplying fresh water to nitrate mining community in Northern Chile. The operation of solar still is similar to natural hydrological cycle that includes two processes, namely evaporation and condensation. A black painted basin contains brackish water or waste water and a transparent cover is enclosed in a completely air tight area. Transparent cover passes incident solar irradiance and it is absorbed by the basin plate. Consequently basin water gets heated up and evaporates in the saturated conditions inside the still killing all pathogenic bacteria. Water vapors rises towards the cooler inner surface of the cover, where they condense to pure water. Due to gravity condensed water run down along the cover bottom surface, getting collected in a collecting tray. The still is easy to fabricate and do not require maintenance and skilled labors.

There are two types of solar stills namely active solar still and passive solar still. In active solar still additional collectors or condensers are used to enhance the productivity. In passive solar still simple modifications within basin are used to enhance the productivity.

The progress in improving the effectiveness of the single basin passive solar still has been reviewed by Kalidasa Murugavel et al. [1]. Velmurugan et al. [2] reviewed the performance analysis of solar stills based on various factors affecting the productivity. Kabeel et al. [3] reviewed the research and developments on solar still. Kaushal et al. [4] reviewed the different types of solar still. Sampathkumar et al. [5] reviewed the active solar distillation in detailed. Xiao et al. [6] reviewed the solar stills for brine desalination. However, the still productivity mainly depends on evaporation and condensation rate. Hence, the main objective of this review is on different parameters affecting the rate of evaporation and condensation on passive solar still.

2. Factors affecting the yield of solar still

The performance of solar still is generally expressed as the quantity of water produced by basin area in a day. The quantity of water produced by solar still varies with solar radiation available, atmosphere humidity, ambient temperature, sky conditions and wind speed, and cannot be controlled by humans as they are meteorological parameters. The design parameters such as orientation of the still, area of absorber plate, inclination of glass cover, slopes of the cover, insulation materials, depth of water, inlet temperature of water and the temperature difference between the glass cover and the basin water affect the production rate.

3. Evaporation rate

The evaporative heat transfer from the basin water to the glass cover is given by Malik et al. [7]

$$Q_{e,b.w-g.c} = h_{e,b.w-g.c} A_b (p_{b.w} - p_{g.c}) \quad (1)$$

where the evaporative heat transfer coefficient from the basin water to the glass cover is given by Malik et al. [7]

$$h_{e,b.w-g.c} = \frac{M_w h_{fg} p_T}{M_a c_{pa} (p_T - p_{b.w})(p_T - p_{g.c})} h_{c,b.w-g.c} \quad (2)$$

The convective heat transfer from basin water to glass cover is given by Dunkle [8]

$$h_{c,b.w-g.c} = 0.884 \left[(T_{b.w} - T_{g.c}) + \frac{(p_{b.w} - p_{g.c})(T_{b.w} + 273.15)}{268,900 - p_{b.w}} \right]^{2/3} \quad (3)$$

From Eq. (1) it is clear that evaporative heat transfer from basin water to the glass cover depends on the absorber plate (basin) area (A_b) and the difference between partial pressure of basin water temperature ($p_{b.w}$) and partial pressures of glass cover temperature (p_{gc}). Evaporation rate of still depends on basin water, glass cover and atmospheric temperature difference.

Evaporation rate of basin water is increased by adding dyes to water. Absorber area is increased by placing some kind of wick materials and absorber materials on the basin. Water temperature is increased by hot water flowing in the basin and surface heating techniques.

Evaporation rate of solar still plays an important role in productivity. Evaporation rate mainly depends on the solar radiation availability. The following factors affect the evaporation rate of solar still:

- basin construction materials;
- depth of water;
- absorption rate of basin water;
- absorption rate of still basin;
- volumetric heat capacity of the basin;
- inlet temperature of water; and
- temperature of top surface water.