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Parameters affecting the performance of a low cost solar still

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HIGHLIGHTS

- The triangular solar still is designed using cheap & durable materials.
- The initial water depth has an inverse relationship with the production.
- The water productivity is nearly proportional to the solar radiation.
- The water quality parameters are within the accepted ranges of drinking water.

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ABSTRACT

This study aims at developing a low cost technique to be used in rural and coastal areas for converting saline water into potable water using solar energy. A triangular solar still (TrSS) was, therefore, designed and developed with cheap, lightweight, local and available materials. A number of field experiments were carried out to evaluate the effects of solar radiation intensity, ambient air temperature and the initial water depth on the daily water production of the TrSS. A time lag of about and hour between the hourly peaks of solar radiation and water production is observed. Finally, a few essential relationships were attained, e.g. between the daily production and the initial water depth, between the daily production and daily solar radiation, and between the daily production and the average ambient temperature. The effect of the initial water depth in the basin on the daily water productivity was evaluated by varying the water depths (1.5, 2.5 and 5 cm) with the climatic condition of Malaysia and an inverse proportional relationship was revealed between them. However, the daily water productivity is nearly proportional to the daily solar radiation. In addition, some important water quality parameters were tested in the laboratory to evaluate the distillate quality and were then compared with the drinking water standards.

1. Introduction

In underdeveloped and developing countries, many remote and coastal areas do not have enough resources of electric power for producing potable water using any conventional desalination techniques; namely multi-stage flash, reverse osmosis and vapor compression. The initial installment cost, and the operation and maintenance cost of these techniques are very high and are far beyond the fiscal recourses solvency in most local areas. In addition, a water pipe line distribution system is not available in these regions, and the road network and transportation system are insufficient to carry a large amount of potable water regularly from desalination plant area to the consumers [1]. From the above reasons, solar distillation is most suitable and required in these regions.

Many researchers have investigated on solar stills of different designs, e.g. simple-type [2,3], single basin [4,5], double basin [6], tubular [7–11], triangular [12], pyramid [13] and hemispherical solar stills [14–16]. The performance of solar still has been improved using a hybrid photovoltaic/thermal (PV/T) system [17], an evacuated tubular collector integrated still [18], a concentrator with a phase change material [19], air flow integrated tubular still [20], asymmetrical still with different insulations [21] and a sun tracking photovoltaic system [22]. Besides, solar still was also used to refine and treat wastewater [23]. A complicated system is, however, generally costly and may require regular monitoring with skilled personnel, which makes the complicated system unsuitable in remote and coastal areas [24].

In general, there are two sorts of factors that influence the productivity of a solar still: climate and operating conditions. The climate condition mainly includes solar intensity, wind velocity, and ambient temperature, while operating condition mainly includes the cover angle, the material coated on the basin, the

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Nomenclature

d_w	initial water depth in the trough/basin (cm)	T_w	temperature of water (°C)
EC	electrical conductivity (μS/cm)	T_{ha}	temperature of humid air (°C)
P_h	hourly production rate (ml/h or kg/m^2 h)	T_t	temperature of trough (°C)
P_d	total daily water production (kg/m^2 d)	T_a	temperature of ambient air (°C)
RH_{ha}	relative humidity of the humid air (%)	TrSS	triangular solar still
R_s	solar radiation or daily radiation flux (mV or W/m^2 d)	WHO	World Health Organization
TDS	total dissolved solids (ppm)		

water depth, the temperature difference between the water and cover, and the insulation [25].

Nafey et al. [26] investigated on the main parameters affecting solar still performance under the weather conditions of the Suez Gulf area by using four single-sloped solar still units. The developed equation relates the dependent and independent variables which control the daily productivity and could be used to predict the daily productivity with a reasonable confidence level. The effect of the solar radiation on productivity has been investigated in many publications [26–28]. It is found that the solar radiation is the most affecting parameter on the still productivity [29]. The fresh water productivity of the still is generally proportional to daily solar radiation. However, the measured ambient temperature is lower than other temperatures [30]. The production rate depends on water, glass and atmospheric temperatures, water–glass temperature difference and glass-atmospheric temperature difference [31,32]. Tsilingiris [33] observed errors in temperature measurement and implications on performance.

Dev et al. [34] studied on the inverted absorber solar still (IASS) with various water depths and total dissolved solids (TDS) in Oman. It is observed that for the climatic condition of Oman, the optimum water depth for the IASS was 0.03 m, above which the addition of reflector under the basin does not affect its performance much more in comparison to that of the simple solar still for sea water. Tarawneh [35] studied on the effect of water depth on the productivity of a solar still in Jordan. Different depths of brackish water (0.5, 2, 3 and 4 cm) with the TDS of 5000 ppm were tested under the same climatic condition. The obtained results showed that the decreased water depth has a significant effect on the increased water productivity, while the performance characteristics showed that the water productivity was closely related to the incident solar radiation intensity. The similar results were also obtained for a basin type solar still in Turkey [36] and Jordan [37].

The present study aims at developing an eco-friendly technology, triangular solar still (TrSS), at lower cost to convert saline water into potable water using solar energy in rural and coastal areas. Furthermore, this study aims to improve the performance and to increase its productivity. It is, therefore, required to evaluate a few important parameters affecting the daily water productivity. The effects of some design and operational parameters (e.g. solar radiation intensity, ambient air temperature and the initial water depth) on the performance of the TrSS were investigated. Additionally, some important parameters (e.g. pH and salinity) were tested in the laboratory to evaluate the product water quality.

2. TrSS and its water production principle

Fig. 1(a) and (b) shows the schematic diagram and the photograph of experimental set-up of the TrSS, respectively. The TrSS is comprised of a frame, a triangular cover and a rectangular trough inside the cover. The frame, cover and trough are made of PVC pipe, polythene film and Perspex, respectively. The frame can restrain the deformation of a polythene film used as a triangular cover.

Table 1
Fabrication cost of a triangular solar still.

Items	Quantity	Unit cost	Cost (RM)
Polythene for cover (0.15 mm thickness)	1.66 m^2	RM1.44/m^2	2.39
PVC pipe for frame (15 mm diameter)	9 m	RM10.80/m	97.20
Perspex for trough (3 mm thickness)	0.376 m^2	RM15.625/m^2	5.87
Nylon rope	50 m	RM11.90/roll	5.95
Transparent scotch tape	2 m	RM1.99/roll	0.67
Total			112.10

Note: PVC = polyvinyl chloride; US$ 1 ≈ RM 3.2.

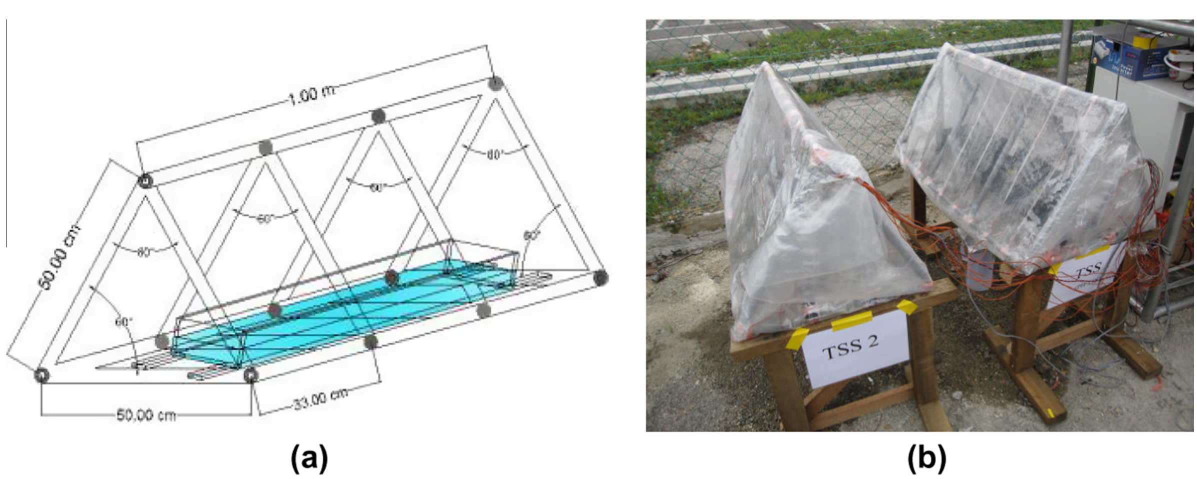

Fig. 1. Triangular solar still, (a) schematic diagram and (b) photograph of experimental set-up.

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