Effect of Cone Shape Condenser Plate Tilt Angle on Solar Still Productivity

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Abstract. The demand for fresh water continues to increase and it is crucial for sustaining life. One approach to meet this demand is through desalination of sea water. Solar desalination is a low cost technique to produce fresh water with a simple working process. The still’s design parameters such as the cover angle and material can impact the yield. This research aspires to examine the influence of cone condenser plate tilt angle on the solar still throughput. Results showed that the utmost amount of fresh water produced is from the still with the tilt angle of 50 degrees.

1. Introduction

Clean drinking water is vital to daily life. Oceans can provide a limitless source of water but could not be consumed due to its high salinity [1]. Solar desalination can be employed to convert sea water to fresh water by making use of the thermal energy from the sun’s radiation.

A solar still is easy to construct, inexpensive and requires little upkeep [2]. The amount of fresh water generated by a solar still is the measuring factor of its performance. Currently, numerous solar still layouts have been conceived and tested. The design of the solar still will determine its efficacy as it is reliant on items such as the insulation material, tilt angle, condenser plate material and absorption expanse [3,4].

Evaporation and condensation are still the basic course of a solar still system. Water in the solar still is heated directly by the sun’s radiation passing through the transparent cover. Evaporation will cause the water vapour to arise to which it then condenses on the inner surface of the transparent cover [5].

Weather conditions are also an important factor in the evaporation process. The evaporation rate increases when the weather is sunny as the solar radiation intensifies with the additional sunlight [6]. Plastic is easier to construct into cone shape condenser plate as compared to glass although the latter is better suited for long term usage [7]. Basin materials such as stainless steel and aluminium as well as sawdust and styrofoam insulators have been studied for their solar still efficiency potential by Burbano [8]. He concluded that under the same internal heat and temperatures, the sawdust and aluminium combination displayed the greatest effectiveness.

There are two groups of solar stills, passive and active. For passive still, the only source of energy it receives to heat up the water in the basin is wholly from the sun. Active still on the other hand is provided with extra thermal energy on top of the direct solar energy it receives to heat up the water [9].
For this study, passive stills of varying cone condenser plate tilt angles were assembled employing local materials. The trials were performed to examine the influences of the tilt angle on the solar still productivity under the Malaysian environment.

2. Methodology
0.5 mm thick aluminium sheet is formed into the solar still evaporator basin and coated all over with black paint to further enhance the absorption of radiation [10]. The diameter of the basin is 280 mm and 20 mm in height (figure 1). One litre of salt water at 35,000 ppm is contained in the basin at a height of 16 mm. The condenser plate is made of 0.35 mm thick Polyvinylchloride (PVC). Polystyrene of 35 mm thickness is placed around and underneath the basin as an insulator and the still is then mounted on a plywood stand. Condensation of the evaporated water from the basin will occur on the cone condenser plate’s inner surface to which it will then flow into the gutter and accumulated in the bottle below.

Figure 1. Solar still construction.

Subsequently, three stills with different cone tilt angles were constructed and tested (figure 2).

Figure 2. Solar stills of 30°, 40°, and 50° condenser plate tilt angle.
The trials were carried out in Shah Alam, Malaysia (3.0733° N) for a 12-hour duration (7 AM to 7 PM) with the stills yield quantified every 2 hours. A SENSION 7 Benchtop Conductivity Meter was utilized to ascertain salinity values while solar irradiance was measured using a KIMO SL200 Solarimeter. A Sunleaves Hygro-Thermometer measures the relative humidity and ambient temperature while Type K thermocouples (chromel-alumel) fastened to specific points on the still documented the temperatures.

3. Results and Discussions
From 7 am, the ambient irradiance begins to climb until it peaks at 1 pm and then gradually descending after that. The basins water temperatures and also the ambient temperature follow the same trend as the ambient irradiance and this also coincide with Prakash et al [4]. It was noted that the water temperatures in all the basins were greater than the ambient temperature. Arunkumar et al [11] stated that this was caused by the absorption of the solar energy by the water in the basins, hence the increase in temperatures. Solar still B recorded the greatest water temperature that is 62.5 °C at 3 pm.

![Figure 3. Ambient temperature and water temperatures in the evaporator basins.](image)
The stills evaporator basins water temperatures and the ambient temperature are displayed in figure 3. The amount of condensed water accumulated in the three solar stills for the twelve-hour period is displayed in figure 4.

![Figure 4. Amount of condensed water in the solar stills for the twelve-hour period.](image)

The extent of solar transmissibility across the condenser plates matches the water condensation rate in each still and is corroborated by Jadhav [12]. Highest condensation rate was observed in still C with the steepest condenser plate tilt angle of 50 degrees whereas still A at 30 degrees tilt angle displayed the lowest condensation rate. This may be attributable to the fact that a steeper tilt angle will allow a faster flow of the condensed water into the gutter as compared to a smaller tilt angle where some condensation may fall back into the evaporator basin [13].

The total throughput for solar stills A, B and C is presented in table 1. While still C yielded the highest amount of 107.0 ml, still A displayed the lowest which is 7.5 ml. Still C has the greatest condensation/evaporation ratio as the steepest angle of 50 degrees allows the condensate to quickly flow into the gutter rather than dropping back into the basin as concurred by Ceccarelli [14].

| Solar Still | Evaporation (ml) | Condensation (ml) | Condensation/Evaporation (%) |
|-------------|------------------|-------------------|-----------------------------|
| A           | 250              | 7.5               | 3.0                         |
| B           | 280              | 56.2              | 20.1                        |
| C           | 320              | 107.0             | 33.4                        |

Table 2 presents the solar stills water salinity. The condensed water produced by all stills are less than 1,000 ppm and therefore can be safely consumed [15].
Table 2. Solar stills water salinity.

| Solar Still | Evaporator Basin | Condensed Water |
|-------------|------------------|-----------------|
|             | Before (ppm)     | After (ppm)     |
| A           | 35000            | 41100           | 400             |
| B           | 35000            | 50000           | 400             |
| C           | 35000            | 45000           | 500             |

4. Conclusions
The efficiency of passive solar stills with cone condenser plates at varying tilt angles were empirically researched under Malaysian settings. The steepest condenser plate tilt angle of 50 degrees produced the most amount of fresh water at 107.0 ml compared to the still with the gentlest slope of 30 degrees (7.5 ml). A higher water temperature in the basin can definitely increase the evaporation rate. The condensed water from the stills are safe for drinking as the salinity is less than 1,000 ppm. As such, this research has ascertained that a 50 degree cone condenser plate tilt angle solar still will be able to generate the maximum quantity of fresh water.

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