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Study on performance of floating solar still using pumice stone as photothermal material

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Abstract

In this article, the rate of freshwater production in the floating solar still using the pumice stone is investigated. In this device, the use of a one-way valve has given this device the ability to direct lake or pool water into its basin in a controlled manner. By placing a type of photothermeral material (pumice stone) in the basin of the solar still, the efficiency of the device and the amount of freshwater production increase compared to the simple device. All experiments were performed in Semnan, Iran. The temperature, productivity, and exergy efficiency of this device without the use of pumice stone and modified with pumice stone were compared. Finally, a cost analysis was performed to check the economic status of the device. The results showed that the daily production rate of the floating solar still modified with pumice stone in autumn and spring was 113 and 219 cm^3, respectively, and for the conventional floating solar still was 82 and 189 cm^3, respectively. The costs of producing each liter of freshwater for a floating solar still modified with pumice stone and the conventional floating solar still for the autumn were 0.0847 and 0.104 $\$/m^2$, respectively, and in the spring, this cost for the floating solar still modified with pumice stone is 0.043 $\$/m^2$.

Keywords: Floating solar still, Thermal storage, Pumice stone, Performance, Cost analysis.

1. Introduction

Water desalination methods are inspired by rain mechanisms. The seas and oceans receive the solar radiation and their water vaporizes. The water vapor above the atmosphere is condensed due to the cold and the wind, pouring into the ground as rain drops, creating a flow of freshwater [1]. One of water desalination methods is use of solar stills. Shanmogham et al. [2] performed the experiments on a solar still with various materials such as rock, pebbles, and iron waste. Calcium rocks were observed to act as the best photothermal material in solar still due to their high specific heat (910 J/kg.K). Nafey et al. [3] used rubber and sand in the solar still to increase the water production. The results showed that the production rate of the device was improved by using thicker rubber and larger of sand particles. Abdallah et al. [4] used various absorbent materials, including transparent metal sponges with and without coating and black and white volcanic rocks, to improve the performance of solar still. The results showed that the freshwater production improved by 28, 43, and 60% by using metal sponges with and without coating and black stones, respectively.

The absence of solar radiation throughout the day and night is one of the important weaknesses in the use of solar systems. For this reason, the continued work of solar systems during the absence of the sun stops and this reduces their efficiency. In order to solve this problem, it is necessary to provide the heat needed for these devices in the absence of sunlight (at dusk or night). Solar energy cannot be directly stored and must be stored first in other forms of energy, such as electrical, chemical, or thermal. Applying energy storage methods in the form of heat is an appropriate solution. As a result, the efficiency of these devices can be increased by proper combination of heat storage methods with solar systems. Thermal energy storage is very popular due to the creation of easy storage methods and many applications. In this article, the pumice stone as the photothermal material is used to increase the rate of freshwater production in the floating solar still.

2. Experimental procedure

The floating solar still is made using 4 mm and 3 mm thick Plexiglas sheet (See Fig. 1). Plexiglas sheets with 4 mm thickness is used as the cover and the 3 mm thick Plexiglas is used as the body of solar still. The slope of the glass cover is considered 35 degrees according to the geographical coordinates of the tested area. The basin is built with sides of 0.5 m × 0.5 m. The height of this basin is 6 cm and on the bottom of this structure, there is a three-quarter-inch one-way valve to control the water entering and storing from the surface of the lake. This experiment was conducted in two periods of autumn and spring. The pumice stone, as the photothermal material, is placed in the basin of the solar still. All experiments were carried out in Semnan city and in autumn on 1401/09/06 and 1401/09/07 and in spring on 1402/02/10, 1402/02/11, and 1402/02/12.

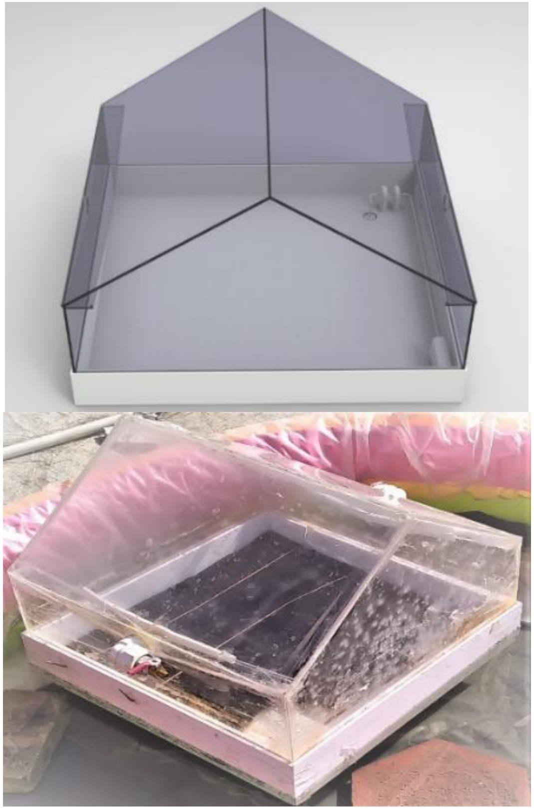

Figure 1. A view of the floating solar still

3. Results and discussion

3.1. Results of pumice stone (Autumn season)

Figure 2 shows the hourly production rates for the modified floating solar still with pumice stone and conventional solar still without pumice stone. Hourly production rate is increased by placing the pumice stone in the floating solar still due to creating a greater temperature difference between the water surface and glass cover and the greater radiation absorbed by the pumice stone. According to this figure, the highest production rate of the floating solar still occurs at 12 am, and after this hour, the efficiency decreases due to the decrease in the intensity of the solar radiation.

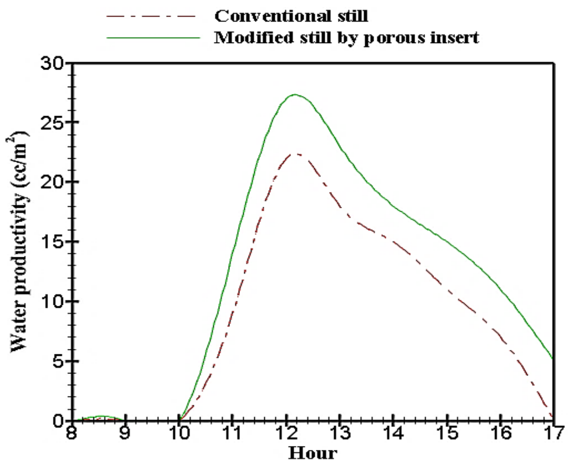

Figure 2. Hourly production rate for modified floating solar still with pumice stone and conventional solar still without pumice stone

Figure 3 shows the hourly efficiency for the modified floating solar still with the pumice stone and the conventional solar still without the pumice stone. From this figure, it can be observed that by placing the pumice stone in the solar still, the efficiency increases. In the conventional solar still without the pumice stone, at 12 am, the efficiency of the solar still is maximized. From 12 am to 5 pm, due to the drop in water temperature due to the decrease in radiation intensity and the decrease in ambient temperature, the rapid efficiency decrease is observed.

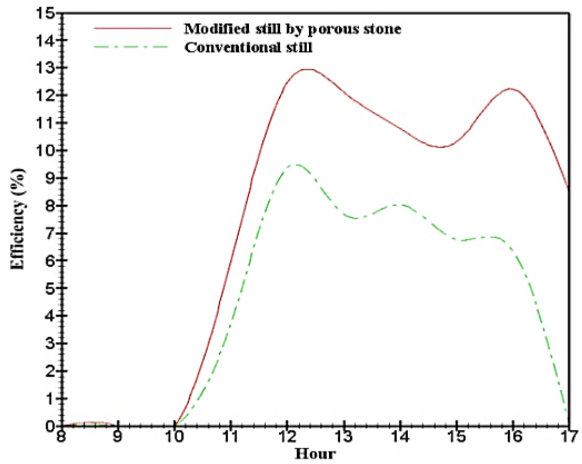

Figure 3. Hourly efficiency for modified floating solar still with pumice stone and conventional solar still without pumice stone

3.2. Results of pumice stone and pebbles (Spring season)

Figure 4 shows the hourly production rates for the modified floating solar stills with the pumice stone and pebbles. It is clear from the figure that hourly production rate increases by placing the pumice stone and pebbles in a floating solar still. In addition, the modified floating solar still with the pumice stone produces more freshwater as compared with the modified floating solar still with the pebbles.

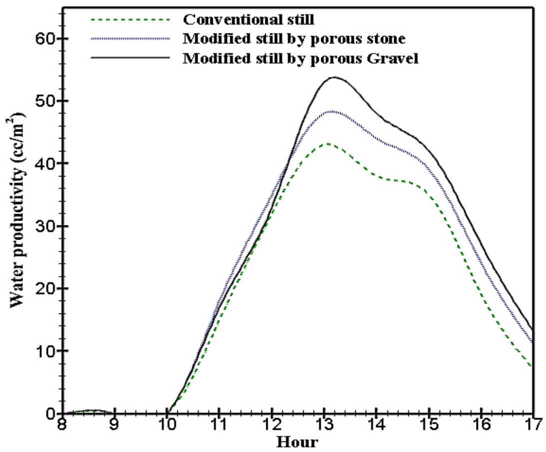

Figure 4. Hourly production rate for modified floating solar stills with pumice stone and pebbles and conventional solar still without pumice stone and pebbles

Figure 5 shows the hourly efficiency for the modified floating solar stills with the pumice stone and pebbles and conventional solar still without pumice stone and pebbles. From this figure, it can be observed that by placing the pumice stone and pebbles in a floating solar still, the hourly efficiency increases. In conventional solar still without pumice stone and pebbles, at 3 pm, the efficiency of the solar still is maximized. The efficiency is decreased from 1 pm to 5 pm due to the drop in water temperature and decrease in radiation intensity and ambient temperature.

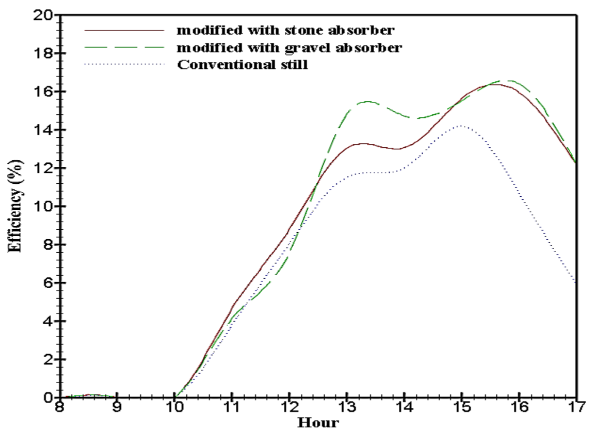

Figure 5. Hourly efficiency for modified floating solar stills with pumice stone and pebbles and conventional solar still without pumice stone and pebbles

4. Conclusions

In this study, the performance of a modified floating solar still with pumice stone and pebbles was investigated, experimentally. The main results of this research are summarized here:

- Floating solar still using pumice stone can keep water temperature balanced for greater efficiency and prevent rapid reduction of water temperature in the absence of the sun due to storing solar thermal energy.
- Daily production rates of modified floating solar still with pumice stone in autumn and spring seasons are 113 and 219 cm^3, respectively. Daily production rates for conventional floating solar still in autumn and spring seasons are 82 and 189 cm^3, respectively. Therefore, productivity in autumn and spring increases by about 37.80% and 15.90%, respectively by using pumice stone in solar still.
- Daily production rate of modified floating solar still with pebbles is 233 cm^3. Therefore, production rate increases by about 23.30% in spring by using pebbles.

5. References

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