DOR: 20.1001.1.24234931.1401.9.1.9.0

Original Article Volume 9, Issue 1, Spring & Summer, p. p. 29-31

Received: 05/24/21 **Journal of Renewable and New Energy**

Accepted: 07/12/21 **jrenew.ir**

Experimental Investigation of the Effect of Using Sand on the Performance of Solar Still

Mohammad Reza Assari[1*], Ehsan Esfandeh[2], Reza Baharvand[2]

1-Associate Professor,Department of Mechanical Engineering, Jundi-Shapur University of Technology, Dezful, Iran
2- Msc,Department of Mechanical Engineering, Jundi-Shapur University of Technology, Dezful, Iran
* P.O.B. 64615-334 Dezful, Iran, assari@jsu.ac.ir

Received: 24 May 2021 Accepted: 12 July 2021

Abstract

Nowadays, population growth, pollution, climate change, depletion of groundwater resources, and excessive water consumption are the main reasons for the freshwater shortage. One of the methods for producing water is solar energy, which is performed on devices called solar still. This study examines the effect of using different masses of sand on the production of double slope single basin solar still with a basin surface of 0.27 m^2 at a constant water depth of 1.5 cm on sunny winter days was investigated. The sand acts as heat storage, and when the solar radiation is low, the heat stored in it returns to the still. The findings show that production in solar still without sand and solar still with a mass of 1 kg of sand is identical, also. Increasing sand mass from 1 to 2 kilograms decreases the amount of still production also. On the other hand, the energy and exergy efficiency system has also lessened with increasing sand mass. As a result, putting 1 kilogram of sand in this solar still is optimal, and growing it negatively affects the system performance on sunny days.

Keywords: Solar Still, Sand, Energy, Exergy

1. INTRODUCTION

Fresh water, like clean air, is a necessity for human life. Nowadays, the crisis facing human society is the lack of fresh water due to the growth in population, pollution, and climate changes. It is significant to get fresh water with low-tech and cheap technology. Solar still is one of the best methods to change salty water or non-drinking water to fresh water. Solar stills offer particular advantages like easy construction, minimum exploitation skills, maintenance, and better environmental compatibility [1].

The principles and operation of all solar stills are similar and follow the basic rules of evaporation and distillation. The solar radiation heats the saline water by passing through the glass surface of the still. When the water inside the still evaporates, salt, germs, and other water-soluble particles remain in the basin and the water vapor free of these substances moves upward. The slope of the glass directs the distilled water droplets that are on the glass to the water outlet duct. Solar still is divided into active and passive categories. In the passive solar still, the saline water entering the still does not receive any heat from the heat source, and it enters directly into the system, such as basin, stepped, spherical, tubular, pyramidal, and inactive solar still. A heat source such as a solar collector, solar pond, heater, etc., heats the saline water entering the still. Then it enters the system [2].

We used different methods to increase the efficiency and productivity of solar still, one of which is the use of energy storage such as phase change materials (PCM), energy storage materials like sand, sponge, etc.

Sonawane [3] used PCM in single slope basin solar still. The system area is 1 square meter, and the conclusion was that the use of PCM in solar still increases the amount of freshwater production to 65% compared to solar still without PCM.

Dumka et al. [4] evaluated a single slope basin solar still by placing 100 cotton bags filled with sand. They carried out experiments on basin water masses of 30 and 40 kilograms. The conclusion was that sand in the solar still increases the production rate for the 30 and 40 kilograms basin water mass to 28.56% and 30.99%, respectively.

Abu-Hijleh and Rababa'h [5] studied the effect of a sponge cube on the performance of a single slope basin solar still. Sponge cubes with dimensions of 6 cm. They found that using a sponge improved production still by up to 273%.

The purpose of this study is to examine the effect of different masses of sand on the performance of a double slope basin solar still on sunny winter days. It also analyzes the energy and exergy efficiency of the system.

2. EXPERIMENT SETUP

Figure 1 shows a schematic of the solar still used in this study. The type of solar still is a double slope basin, which includes the basin, the distillation duct, the glass cover, and the PVC insulation cover. The length and width of the basin are 800 and 347 mm, respectively. So the basin area is equal to 0.27 m^2. The still is made of galvanized sheet with a thickness of 0.6 mm with black color. Water distillation ducts are made of stainless steel and glass cover with a thickness of 4 mm and an angle of 45 degrees are installed.

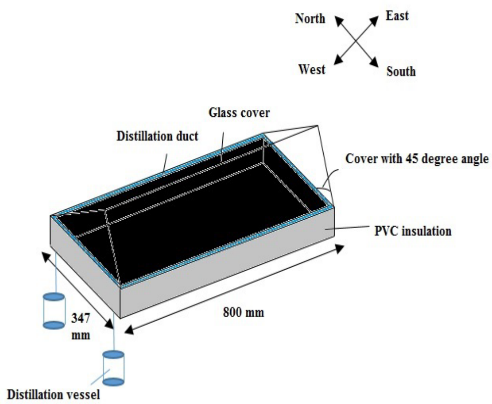

Figure 1. Schematic of a Double Slope Solar Still in the Present Study

3. How to Perform the Experiment

The experiments were performed at the Dezful Jundishapur University of Technology, located in southwestern Iran, with a longitude of 48.36 degrees and a latitude of 32.42 degrees for three consecutive days in winter. Water depth of 1.5 cm was constant, and on the first, second, and third days of the experiment, we used still without sand (simple), still with a mass of sand, 1 kilogram and 2 kilograms, respectively.

3.1. Energy and Exergy Analysis of Solar Still

3.1.1. Energy

The following equation [6] defines the energy efficiency:

$$\eta_{th} = \frac{\sum m_{ew} \times L}{\sum I(t) \times A \times 3600} \quad (1)$$

3.1.2. Exergy

Exergy efficiency in solar still is defined as follows [7]:

$$\eta_{ex} = \frac{\dot{E}_{x,evap}}{\dot{E}_{x,sun}} \quad (2)$$

$\dot{E}_{x,evap}$ Is the exergy output from the solar still and $\dot{E}_{x,sun}$ is the exergy input from the solar still. Therefore the output exergy is calculated from the following equation [7]:

$$\dot{E}_{x,evap} = \frac{\dot{m}_{ew}L}{3600}\left[1 - \left(\frac{T_a+273}{T_w+273}\right)\right] \quad (3)$$

Input exergy is also obtained as follows [7]:

$$\dot{E}_{x,sun} = A_b I_t \left[1 - \frac{4}{3}\left(\frac{T_a + 273}{T_s}\right) + \frac{1}{3}\left(\frac{T_a + 273}{T_s}\right)^4\right] \quad (4)$$

Energy efficiency is higher than exergy in all experiment modes, and as the production of still decreases with increasing the amount of sand from 1 to 2 kilograms, both energy and exergy efficiency decreases.

4. The Accuracy of Equipment Used in the Experiment

The connection of thermal sensors was to a data logger with an accuracy of 0.015 ± 0.01%. The TES132 device measured the solar radiation with an accuracy of $1W/m^2$. We used a container with an accuracy of 1 mm to measure the amount of water produced.

5. Results and Discussion

5.1. The Investigation of Horizontal Solar Radiation

One of the influential parameters in solar still is solar radiation, so that reducing or increasing it has a considerable impact on the amount of still production. Solar radiation in all tests is almost the same; therefore, the sand mass is a parameter that affects the amount of production.

5.2. Investigating the Amount of Solar Still Water Production

In the solar still, the final product is the amount of freshwater production. As shown in Figure 2, at the basin surface area of 0.27 m2, the amount of production in still without sand and still with one kilogram of sand was the same. By increasing the amount of sand to 2 kilograms, the amount of still production decreases.

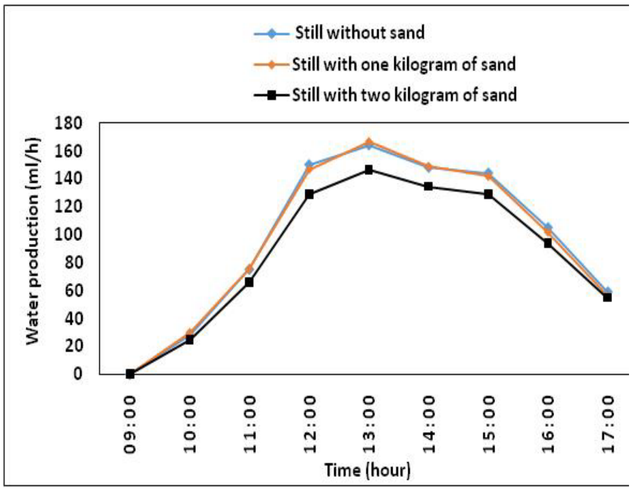

Figure 2. Hourly Production in Solar Still

5.3. Investigating the Temperature of Solar Still

The maximum basin water temperatures for still without sand, still with 1 kilogram of sand, and still with 2 kilograms of sand are 54, 55, and 58.5 ° C, respectively. Since the still is kept in the south direction during the experiment; therefore, the southern glass has a higher temperature than the northern glass.

6. Conclusions

- The daily production of still without sand, still with one kilogram of sand, and still with two kilograms of sand are, respectively, 868, 869, and 780 ml per day (3124, 3128, and 2808 ml per square meter per day).
- Energy efficiency for still without sand and still with one kilogram of sand is 42.2% and for still with two kilograms of sand is 38.0%.
- Exergy efficiency for still without sand and still with one kilogram of sand is 2.7% and for still with two kilograms of sand is 2.4%.

7. Nomenclature

η_{th} *Energy efficiency*
m_{ew} *Water production (ml/h)*
L *Latent heat of vaporization (J/kg)*
$I(t)$ *Solar radiation (W/m^2)*
A *Basin surface area (m^2)*
η_{ex} *exergy efficiency*
$\dot{E}_{x,evap}$ *exergy output from solar still (W)*
$\dot{E}_{x,sun}$ *exergy input to solar still (W)*
T_a *Ambient temperature (℃)*
T_W *Water temperature (℃)*
T_S *Temperature of the sun (K)*

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