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Enhancing yield of double slope solar distillers through experimental studies

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Abstract

Water resources are still considered as a big challenge that need to be tackled especially in a country like Oman with available sea water and sun energy. The idea of utilizing solar energy in the distillation of sea water will lead to a success in helping the economy of Oman and at the same time, assisting the rural people in getting water that can be used in irrigation and drinking purpose with lowest cost. The sultanate of Oman over the year receives a high degree of solar radiation and in an average of 9.49 hours per day of sunshine with 18.7l MJ/m^2 per day of solar radiation. The sultanate of Oman has a coastline of about 1700 km with a population of more than 5 million. Many villages nearer to coastal area of Oman are occupied by rural people who need to have pure and fresh water. Desalination through solar still is one of the desalination techniques, which is quite suited in coastal areas for the purification of sea water using solar energy. In this study, sea water was distilled using double slope solar still and wadi stone and aluminium reflector were used to enhance the yield of the solar stills.

Keywords: Double slope solar distiller; Aluminum reflector; Omani wadi stone; Yield

1. Introduction

The shortage of rainfall and the increase of population create water scarcity in many countries. In addition, the economic development and global warming also make a worldwide imbalance between supply and demand of fresh water. To meet out the demand of fresh water, most of seashore countries utilize various desalination techniques such as multi-effect evaporation, multi-stage flash distillation, thin film distillation, reverse osmosis and electro dialysis. The desalination techniques are energy intensive and costly towards operation and maintenance. Most of the existing desalination plants use fossil fuels as sources of energy. The use of conventional energy sources (hydrocarbon fuels) to drive these techniques has a negative impact on the environment [1- 3].

Solar distillation is a most attractive, environment friendly and simple technique compared to other desalination techniques. It is well suited at the locations where solar energy is abundant. When saline or brackish or contaminated water is kept in a closed container under the open sky, it gets evaporated. The solar energy is used to accelerate the process of evaporation in the solar still [4-5]. The function of a solar still is to capture the evaporated water vapour by condensing it on a cool surface. Solar stills are classified broadly into two categories namely passive and active solar stills. Passive solar stills require solar energy for evaporation of saline water whereas active solar stills require an additional thermal energy by external mode for faster evaporation [6- 8]. The passive solar still is the most economical solar still to provide drinking water for domestic applications at decentralized level. This is due to the fact that it is simple in design and fabrication, easy to handle, long life and low production cost [9-12]. Passive solar stills are available in the different configurations like basin type solar still, wick type solar still, tubular solar still, spherical solar still, parabolic solar still, fibre reinforced plastic solar still, vertical solar still, cascade solar still, staircase solar still, etc. Out of them, basin type solar stills are widely used for domestic purposes in the arid and semi-arid areas due to their

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economic advantages like low investment cost, low maintenance cost and low production cost [13-15]. Numerous factors affect the productivity of a solar still. The design factors such as absorbing material, absorbing area, condensing cover material, cover slope, cooling of cover, water depth, insulation material, insulation thickness, geographical position of the still, sun tracking system, etc and the climatic factors such as solar intensity, ambient temperature, wind velocity, etc affect the productivity of the solar still [16-18]. Generally, the production of fresh water by solar still is quite low. However, it can be improved with the proper control of most significant factors like absorbing material, water depth, condensing cover material, etc [19-20]. The objective of this study is to enhance the yield of solar still with Omani wadi stone and aluminium reflector.

2. Experimental Setup

The basin of 1m x 1m in size is made with galvanized iron sheet. In order to gain more heat energy, the surrounds of basin are painted black. The sides of basin are insulated with black lacquered wood, which prevents heat from escaping. The basin's bottom is covered with aluminum foil of 2 mm thick and top is covered with fiber glass of 5 mm thick. The glass is sealed in such a way that no pressure or vapor may escape. The storage can be set to 25 cm from the basin's base to assure the guarantee that gravity forces the water into the basin. The storage can be chosen to provide seawater without having to remove the glass and maintain the gasket in place. A total of 50 liters of sea water may be kept in the tank. The fresh water can be gathered in plastic can of 10 liters' capacity and is properly sealed. The solar distiller's frame is composed of mild steel to sustain the weight without failing. The entire set is detachable, with four powerful wheels linked to the apparatus's legs.

Table 1 Specifications

Part No.	Geometrical Parameter	Size/Quantity
1	Length of basin	1 m
2	Width of basin	1 m
3	Area of basin	1 m^2
4	Depth of basin	20 cm
5	Thickness of glass	5 mm
6	Slope inclination	23^0
7	Stone bed height	25 mm
8	Stone volume	0.025 m^3
9	Aluminum foil	1m x 1m

Normally, Omani wadi absorbs heat quickly during day time and releases it during night time. Due to the block body nature, it can be considered as heat storage medium in this study. 20 kg of Omani wadi stones of 5 mm size are taken to conduct experiments.

Figure 1 Schematic

The basin of solar still was filled with fresh seawater of 50 liters. When the still was placed under the sun radiation, the incident solar radiation was transmitted through the glass cover. The seawater was thus heated and gave off water vapour. The water vapour was raised upwards and left the salt and other contaminates in the basin. The water vapour condensed on the glass cover and the condensate (fresh water) was collected in a storage container. The fresh water yield was measured using a measuring jar with an accuracy of 10 ml. The schematic of experimental setup used in this study is shown in Figure 2.

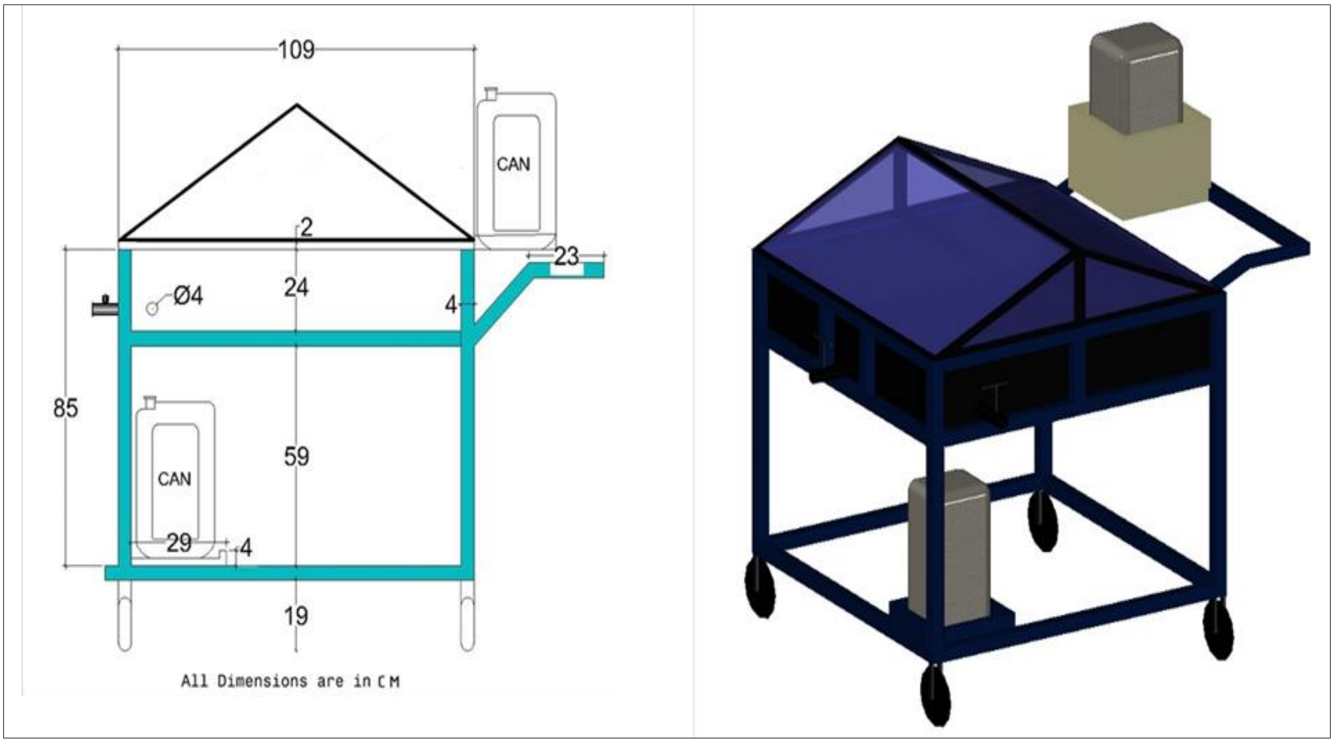

Figure 2 Schematic of double slope solar distiller

3. Results and Discussion

The experiments were conducted in Al-Seeb, Muscat, Oman (Elevation: 32.76^0, longitude: 58° 9' 59.4468'' E, altitude: 23° 37' 37.8012'' N). The experiment was started on April 24th 2024 and completed on April 7th 2024.The experiment was started on first day 6.00 AM and completed on next day 6.00 AM. The solar still was placed with the tilted glass facing the sun (facing south) for all the experiments conducted. The solar intensity was recorded for one-hour interval. The yield was measured in regular basis from the current day 6.00 AM to next day 6.00 AM. Every day, the salts and other contaminants left in the seawater were flushed out and basin was filled with 50 liters of fresh seawater before starting the next experiment. The following four experimental conditions, each experimental condition with 3 consecutive days were considered in this study.

- Without aluminum reflector & without Omani wadi stone
- With aluminum reflector & without Omani wadi stone
- Without aluminum reflector & with 20 kg Omani wadi stone
- With aluminum reflector & with 20 kg Omani wadi stone

Table 2 Experiment results

Experiment Condition	Day tested	Yield (liter)			Average Yield (liter/day)
		Day	Night	Total	
Without aluminum reflector & without stone	24/4/2024	1.65	0.85	2.5	2.04
	25/4/2024	1	0.6	1.6	
	26/4/2024	1.11	0.9	2.01	
With aluminum reflector & without stone	27/4/2024	0.8	1.2	2	2.36
	28/4/2024	1.3	1.4	2.7	
	29/4/2024	1.2	1.2	2.4	
Without aluminum reflector & with stone	30/4/2024	1.5	1.7	3.2	2.62
	1/5/2024	0.9	1.1	2	
	2/5/2024	1.6	1.05	2.65	
With aluminum reflector & with stone	3/5/2024	1.5	1.4	2.9	2.87
	4/5/2024	1.6	1.2	2.8	
	5/5/2024	1.6	1.3	2.9	

From the Table, the following points were noticed.

The effect of placing aluminum foil around the walls of the basin increased the utilization of heat to evaporate the water, thus the yield is increased by

$$\text{Yield} = (2.36 - 2.04) / (2.04) = 15.69\%$$

The effect of stone on the yield of solar distiller is

$$\text{Yield} = (2.62 - 2.04) / (2.04) = 28.43\%$$

The effect of both (aluminum reflector and stone) on the yield of solar distiller is

$$\text{Yield} = (2.87 - 2.04) / 2.04 = 40.69\%$$

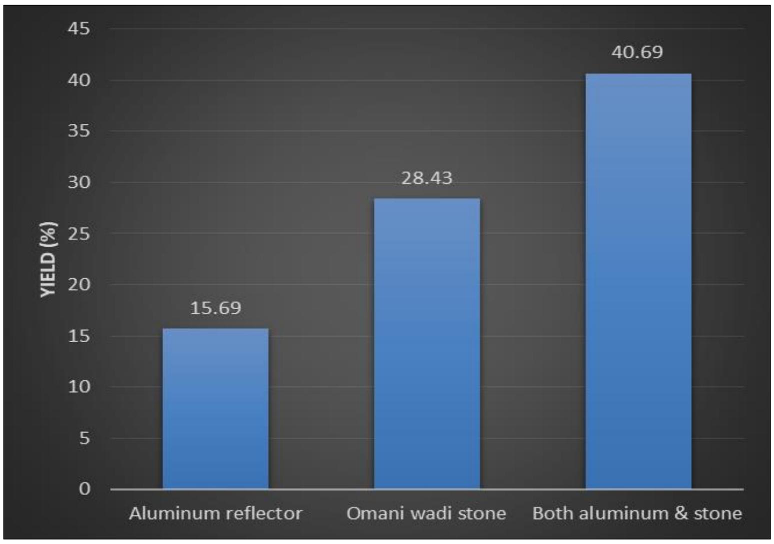

Figure 3 Yield of solar distiller

From the Figure3, it is evident that the yield of double slope solar distiller is increased by 15.69% with the use of aluminum reflector and increased by 28.43% with the use of Omani stones, and increased by 40.69% with the use of both aluminum reflector and stone. The stone helped to increase the yield, as the stone stores the heat by the daytime and release it when the sun is set. Also, aluminum reflector helped to increase the yield significantly in this study.

The fresh water samples were tested for analyzing their quality. From the test results given in the Table3, it was observed that the fresh water obtained from the solar still were found with good quality in comparison with Omani standard for un-bottled drinking water. It is evident from this analysis that the distilled fresh water is suitable for human consumption.

Table 3 Water quality analysis

Analysis Item	Unit	Omani standard	Distilled water
pH		6.5-8.5	6.75
Chloride	mg/1	<250	3.91
Flouride	mg/1	0.6-0.8	0.74
Nitrate	mg/1	<50	0
Sodium	mg/1	<200	3.79
Sulphate	mg/1	<250	4.43
Sulphide	mg/1	<0.05	0
Total hardness	mg/1	<200	19.65
TDS	mg/1	120-600	140
Calcium	mg/1	<30	4.35
Potassium	mg/1	<30	1.39
Magnesium	mg/1	<30	2.10
Sodium	mg/1	<200	3.79
Lead	mg/1	<0.01	0.001
Copper	mg/1	<2	Nil
Iron	mg/1	<l	Nil

4. Conclusion

Water is an important requirement and there is extremely demand on it for all human beings. Solar distillation can be a perfect choice for countries and people who don't have the enough sources and supplies of water. In this study, four experimental conditions, each experimental condition with 3 consecutive days were considered and experiments were conducted for each experimental condition. From the experiment results, the average yield was noted to be 2.04, 2.36, 2.62 and 2.87 liters respectively and also noted that the yield of double slope solar distiller was increased by 15.69% with the use of aluminum reflector and increased by 28.43% with the use of Omani stones, and increased by 40.69% with the use of both aluminum reflector and stone. From the experiment results, it is evident that the yield of double slope solar distiller is enhanced significantly with the use of aluminum reflector and Omani wadi stone.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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