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Enhanced productivity of double-slope solar still using local rocks

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Abstract

At present, Oman faces a serious problem on water shortage due to lack of freshwater sources and low underground water levels. Conversely, Oman has a high level of solar radiation and various types of rocks. Three different types of local rocks have been used in this study, namely, basalt rocks, concrete bricks and crashed rocks, to enhance the productivity of water by increasing the time of output from the double-slope solar still. Results revealed a remarkable increase in the productivity of the basin with concrete bricks by 42%, which was more than that of the productivity of the basin without concrete at 7 pm. Moreover, the productivity of the basin with igneous rocks was improved by 111%, which was more than that of a clear basin at 7 pm. The maximum water temperature of the basin with concrete bricks and the clear basin was 73.2 ℃ and 75.2 ℃ at 1 pm, respectively. In addition, the maximum water temperature of the basin with igneous rocks and the clear basin was 71.6 ℃ at 3 pm and 77.3 ℃ at 2 pm, respectively.

Keywords: water distillation, double slope solar still, single slope solar.

1. Introduction

Water deficiency is a serious issue in most populations worldwide, especially in the Middle East and most of African countries, because of the dwindling water resources due to climate change and improper allocation of existing resources. In the future, conflicts regarding the control of water resources may arise, which may result in the modification of maps of several countries. Therefore, allocating water resources properly, making societies aware of the extent of this problem, finding innovative sources of water and applying sensible policies to resolve conflicts related to this problem are ways to solve it. Therefore, distillation of brackish water, seawater and non-potable water by using solar energy is one of the most important methods at present in providing safe drinking water and for agricultural purposes.

Water scarcity is the main problem in Oman and the Middle East. Osama [1] reviewed this serious matter and provided essential information about the existing water resources and water balance in Oman in the past, with a future projection up to 2030. Scarcity and depletion, seawater intrusion and anthropogenic pollution are the main groundwater issues, although 94% of the total water consumption of Oman is groundwater. The water quantity plan and management in Oman has been investigated by Talal et al. [2] by using geographical information system techniques. The results showed a significant spatial difference among Omani provinces in terms of water quantity stress and its determinants. Al-Awadhi et al.'s study contributes to solving the water scarcity problem in Oman. The obtained results can be vital guides toward addressing the matters concerning the effects of environmental issues on the water resource management in this country. In 2016, Rachael reported comprehensive details on groundwater use and

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policies in Oman, which is an International Water Management Institute project publication. The proposed groundwater policies must be implemented to protect the natural resources for the common good of the present and future populations, as well as the environment and economic development in Oman [3].

Solar distillation or seawater desalination are important methods used in covering the deficit in drinking water. Hichem et al. investigated the performance of a cooling tower used in a solar distiller [4]. Al-Garni et al. studied the effects of glass slope and water depth on the productivity of a double-slope solar still. The results showed that the maximum productivity was at an angle of 35° and increased with the decrease of water depth during the winter or summer season [5]. A number of methods regarding solar distillation techniques have been developed in the past decades to increase the productivity of the designed techniques [6, 7, 8]. In 2000, the Government of Oman assessed water availability and adopted a national water resource master plan for 2001–2020 [9]. Desalinated water contributes to the water supplies of Oman.

The goal of this study is to investigate the effect of using rocks and other abundant materials on the productivity of double-slope solar still.

2. Experimental Setup

2.1. Fabrication of solar still

Two identical single-basin double-slope solar stills were fabricated and used. One still was used as a reference unit and the other one as test unit. The main reason for using two identical units is to arouse the change in the meteorological parameters, namely, solar radiation, ambient temperature and wind velocity, during the test day. The inner basin was 1500 mm × 1000 mm × 100 mm, which was made from a 1.5-mm-thick galvanised steel and painted black to increase the amount of energy absorbed and thus improve the quantity of water productivity. A 12.5-mm-wide channel was welded on the basin walls, which was inclined at 1.5° to gather distilled water from the cover, as shown in Figure 1. A rubber washer was used to prevent any leaks between the cover and basin. The bottom and walls of the solar still were insulated by a 50-mm polystyrene sheet and then covered by a 15-mm-thick plywood to reduce heat losses from the basin to the surroundings. Figs. 1 and 2 show a cross-section of the double-slope solar still and a photograph of the rig, respectively. The top cover was made from 6-mm-thick clear glass with a tilt angle of 35°, as recommended in [5].

The three types of rocks used in the test are as follows.

- Igneous rock (basalt rock), as shown in Fig. 3-a.
- Concrete brick (100 mm × 200 mm × 100 mm), as shown in Fig. 3-b.
- Crashed rock (basalt rock average size [(10–14) mm × (30–35) mm × (16–19) mm], as shown in Fig.3-c.

Figs. 4 and 5 illustrate the double-slope solar still with igneous and crashed rocks, respectively.

2.2. Instruments

A digital portable thermometer was used to measure the temperature of the water basin through a small hole made in the opposite direction of the input water to prevent any influence from the input water to the fabricated water, as shown in Fig. 2. The output water (water productivity) from each double-slope solar still was collected by using a plastic container from two output pipes and then weighed by using a RADWAG digital balance-type WLC 10/A2, with readability of [d] = 0.1 g. The water level inside the basin was controlled by using a float valve at a depth of 2 cm, as recommended by [10].

The double-slope solar stills were installed and tested on the roof of the Faculty of Engineering building of the University of Buraimi in Oman.

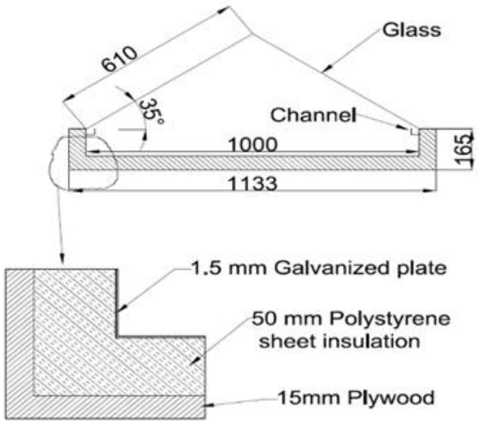

Fig. 1. Cross-section of the double-slope solar still.

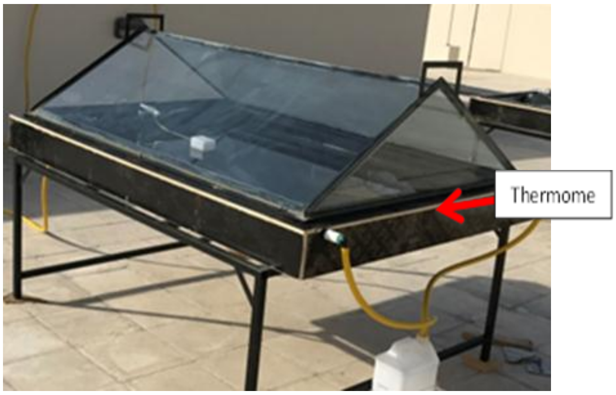

Fig. 2. Photograph of the double-slope solar still

(a) Basalt rock (b) Concrete brick (c) Basalt crashed rock

Fig. 3. Three different types of local rocks

Fig. 4. Double-slope solar still with igneous rocks.

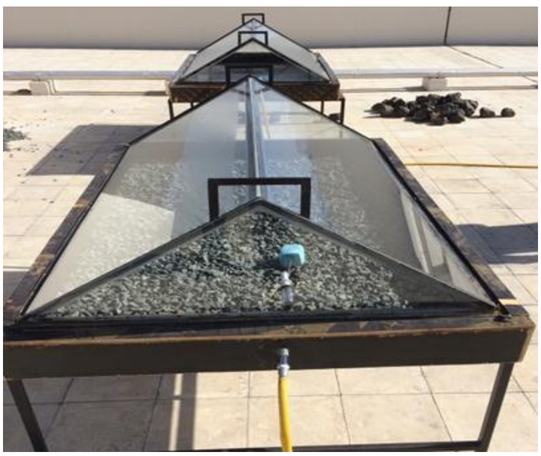

Fig. 5. Double-slope solar still with crashed rocks.

3. Results and Discussion

3.1. Water productivity

Fig. 6 shows the comparison of the water productivity between the two cases, one with concrete bricks and the other without concrete bricks, in which the productivity of the clear basin was 48% higher than that of the concrete brick basin, which was 10 am. Furthermore, this percentage decreased gradually, reaching 2.4% at 3 pm. At 3.20 pm, the productivity of concrete brick basin increased from 0% to 42% at 7 pm compared with that of the clear basin. The reason for this change is the decrease in the intensity of the solar radiation on both solar stills due to the change in position of the sun, which caused a reduction in temperature of water in both basins. However, the concrete bricks rejected the heat advancing to the water and surroundings, which resulted in a better water than that of the clear basin. The highest water productivity of the concrete brick and rock basins was 42% and 111%, respectively, as shown in Fig. 7. The maximum productivity of the clear basin was 49.8% at 11 am, which was higher than that of the rock basin. This result indicated that the amount of water collected from the clear basin doubled the amount of water collected form the rock basin at 11 am. This percentage gradually decreased until reaching 0% at 3.20 pm. Furthermore, the productivity of the rock basin slowly increased from 0% to 10.9% at 4 pm, 32.6% at 5 pm, 61% at 6 pm and 111% at 7 pm in comparison with that of the clear basin. Table 1 shows the variation between the concrete brick basin and rock basin from 3.2 pm to 7 pm. Generally, the water productivity of the basalt rock basin was better than that of the concrete brick basin, especially after 4 pm only. This result agrees with that of [10] when coal was used to improve the productivity of the single-basin double-slope passive solar still.

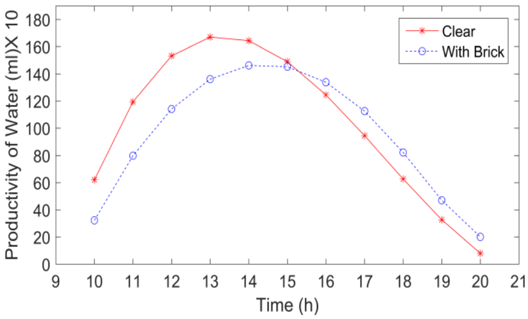

Fig. 6. Comparison between water productivity of double-slope still with and without concrete bricks during the day.

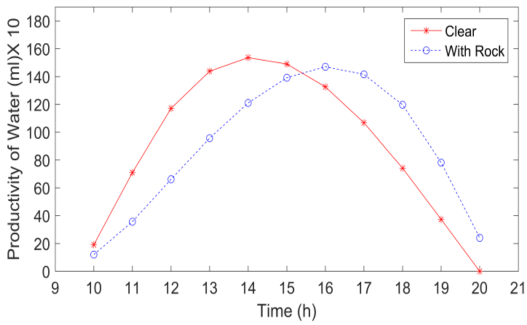

Fig. 7. Comparison between water productivity of double-slope still with and without basalt rocks during the day.

Table 1. Percentage of productivity of the two cases: Concrete brick and basalt rock basins in comparison with the clear basin after 4 pm

Time (h)	Percentage of concrete brick basin productivity with respect to the clear basin (%)	Percentage of basalt rock basin productivity with respect to the clear basin (%)
16	7.5	10.9
17	19	32.6
18	32	61
19	44	111

Fig. 8 illustrates the variation of the water productivity of crashed rock and clear basins during the day. The productivity of the clear basin was constantly better than that of the crashed rock basin. Hence, no heat gain and storage were observed in the crashed rocks due to the small area of the crashed rocks facing the solar radiation in comparison with the rocks used in the previous test. In addition, almost the entire crashed rocks semi-submerged in the water due to the reduced amount of solar radiation absorbed.

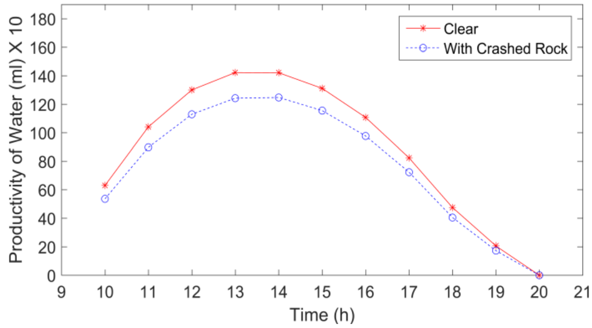

Fig. 8. Comparison between water productivity of double-slope still with and without crashed rocks during the day.

3.2. Water temperature

The water temperature of the basin double-slope still is the second parameter measured in this test. Fig. 9 shows the variation of the water temperature difference between the double-slope stills with and without concrete bricks during the day. The maximum difference was 12.1 ℃ at 10 am and decreased to 2 ℃ at 1 pm when the maximum temperature of the clear basin reached 75.2 ℃. At 5 pm, the difference reached zero. The water temperature of the concrete brick basin increased more than that of without concrete brick basin by 2.6 ℃ at 6 pm and 5.2 ℃ at 7 pm. This increase in temperature resulted from the heat dissipated from the concrete bricks. Fig. 10 shows a similar water temperature behaviour among the basins with and without basalt rocks. The difference was 12.1 ℃ at 10 am, although a significant variance was observed among them. The variance decreased from 2 pm to 6.5 ℃, when the water temperature of the clear basin reached 77.3 ℃, and then reached zero at 4.30 pm. By contrast, the water temperature curve of the basin with rocks rose above that of the basin without rocks from 1.8 ℃ at 5 pm and 4.5 ℃ at 6 pm to 6.8 ℃ at 7 pm. This comparison indicates an advantage in using basalt rocks than concrete bricks. However, no increase in water temperature was observed when crashed rocks were used in the double-slope solar still, as shown in Fig. 11.

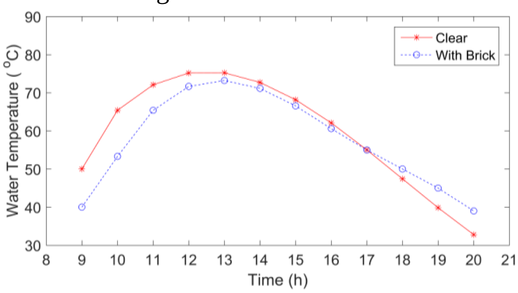

Fig. 9. Comparison between water temperature of double-slope still with and without concrete bricks during the day.

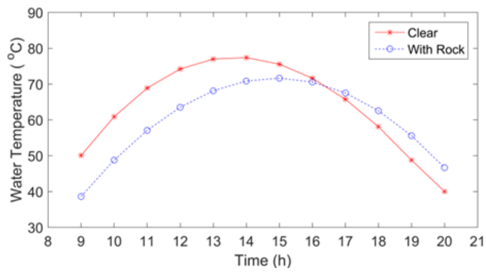

Fig. 10. Comparison between water temperature of double-slope still with and without basalt rocks during the day.

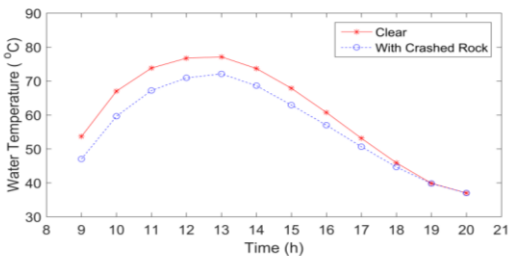

Fig. 11. Comparison between water temperature of double-slope still with and without crashed rocks and during the day.

4. Conclusions

Tests were conducted on a double-slope distillation system using three types of local rocks, namely, concrete bricks, basalt rocks and crashed rocks. The tests were performed at Al Buraimi in Oman in May 2017. The results are as follows. The water productivity of the basin with concrete bricks increased by 42% than that of the clear basin. The hottest water temperature of the clear and concrete brick basins was 75.2 ℃ and 73.2 ℃, respectively. In addition, the water output of the basin with basalt rocks increased more than 100% than that of the clear basin. Moreover, an insignificant productivity of the basin with crashed rocks was observed in comparison with that of the clear basin.

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