MODIFIED STEPPED SOLAR STILL WITH ENHANCED EVAPORATION TECHNIQUES

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ABSTRACT

A comprehensive study was carried out to improve the thermal performance of the stepped solar still. The modification was done in the stepped solar still, which increased the evaporative surface area and decreased the saline water depth to minimum. Besides, a paraffin wax mixed with aluminum oxide nanomaterial was fixed under the steps of the distiller. The performance of the stepped solar still was investigated under different operating parameters in the outdoor conditions of Kafrelsheikh in Egypt. The experimental results revealed that the stepped solar still with the modification performed superior as compared to the conventional solar still. In addition, the cost of one liter of distilled water obtained from the modified stepped still was lower than that obtained from the traditional basin still.

Keywords: Stepped solar still; Solar distillation; Nanoparticle; Aluminum oxide

1 INTRODUCTION

Numerous investigations have been carried out to enhance the freshwater productivity of the solar still. The basin area of the still, free surface area of the water, depth of the water in the still and inlet water temperature are considered as the main factors affecting the productivity of the solar still. To increase the basin area, fins and corrugated absorbers [1-4] and wick materials [5-10], stepped absorber [11-15] were used. The evaporation rate of brine water in the still can be better when using a phase change material or a thermal storing material [16]. The influence of using carbon nanotubes-water nanofluid on the distilled water productivity of a modified vacuum solar still was studied by Gnanadason et al. [17]. Omara et al. [18] studied the effects of using the aluminum oxide nanoparticles on the performance of a corrugated wick solar still. The results revealed that using the aluminum oxide nanoparticles improved the freshwater productivity. Besides, the wick material obtained an increase in the output yield.

The main aim of this study is to improve the thermal performance of the stepped solar still. The modification was done in the stepped solar still, which increased the evaporative surface area and decreased the saline water depth to minimum. Besides, a paraffin wax mixed with aluminum oxide nanomaterial was fixed under the steps of the distiller.

2 EXPERIMENTAL SET-UP

Two solar stills were designed and fabricated to study and compare the performance of the solar desalination systems.

Figure 1 shows a cross-sectional view of solar stills. The first one is a conventional still and the second is a modified stepped still. The conventional still (a single basin) has a basin area of 0.5 m^2 (50

cm×100 cm). The modified still has the same specification and dimensions of conventional still except that the still base is not flat but has a stepped form with the dimensions shown in the figure. The stills are made of 1.5 mm thick galvanized sheet painted by black spray to absorb the solar rays as much as possible. A wooden box (3 cm thickness) is used as a container for the solar distillers. The uniform space between the wooden box and the outer surface of the still is filled by 5 cm of glass wool as insulator to decrease the heat losses from the bottom and sides as much as possible. A tilted trough is fixed at the lower edge of the glass to accumulate the distilled water through a plastic pipe into an external calibrated bottle.The experiments were conducted on the outdoor environment of Kafrelsheikh University, Kafrelsheikh (31.1107° N and 30.9388° E), Egypt. The brackish water was kept at 0.5 cm height inside the solar stills. The collected distillate was accumulated every 24 hours.

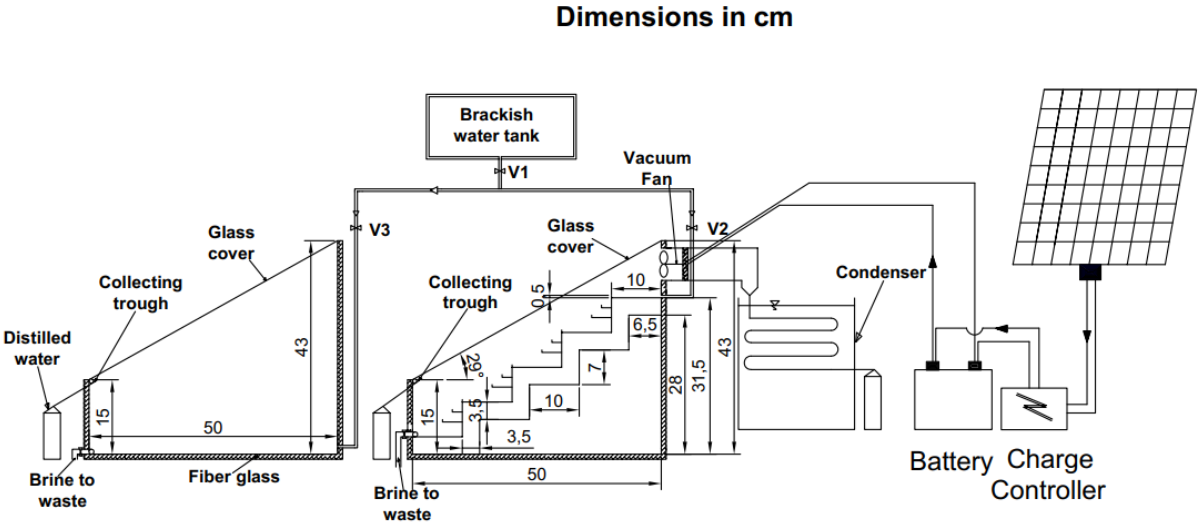

Figure 1. Schematic diagram of the experimental test-rig.

3 RESULTS AND DISCUSSION

It is revealed from the results that the basin water temperature of modified still is higher than that of conventional still. These differences in water temperature are because the combination of the reasons of increase in water temperature which is caused because of the aluminum oxide nanoparticles, stepped basin liner, and paraffin wax material. Also, it can be observed that the freshwater productivity for modified still is greater than that of conventional type at all times. In addition, the results demonstrated that the distillate production of modified solar still (stepped distiller with paraffin wax mixed with aluminum oxide nanoparticles) reached about 85% higher than that of conventional solar still.

Figure 2 shows a comparison between the productivity of the conventional solar still and modified distiller at different measuring days. It is seen from the figure that the productivity of the modified still is greater than that of the conventional one. Regarding the cost evaluation analyses, the cost of one liter from the conventional still = 0.049 $. While, the cost of one liter from the stepped still = 0.040 $.

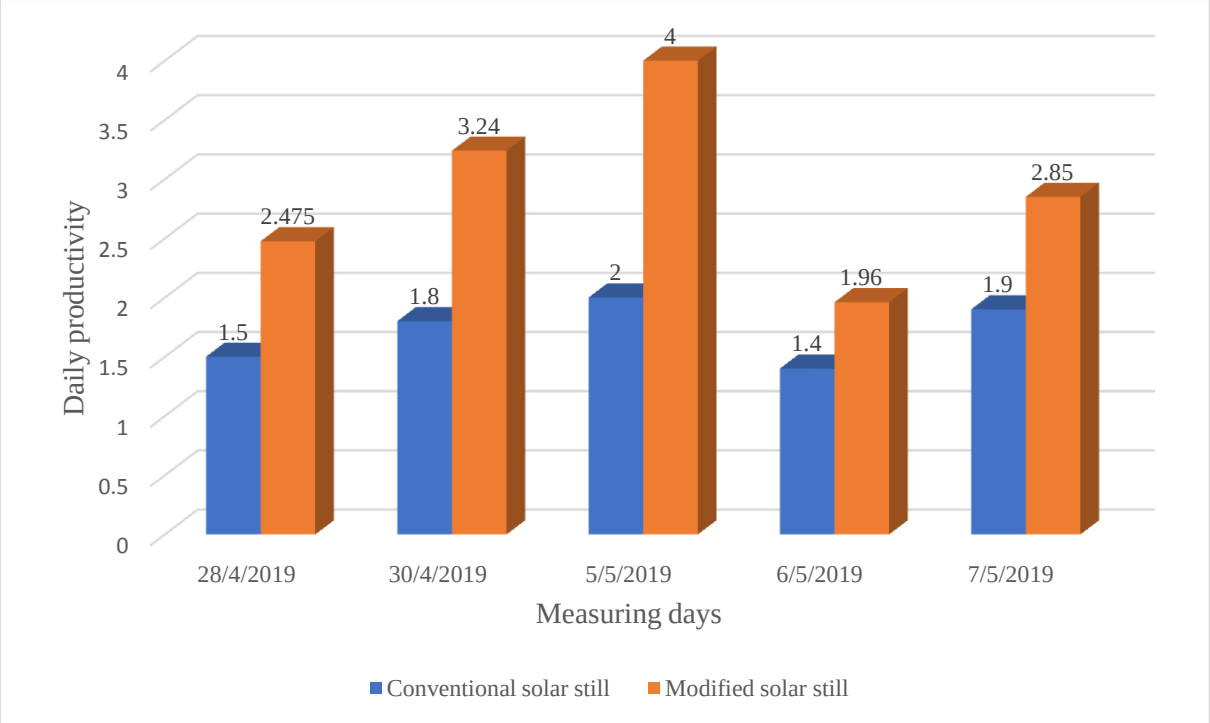

Figure 2. Comparison between the productivity of the conventional solar still and modified distiller at different measuring days.

4 CONCLUSIONS

A comprehensive study was carried out to improve the thermal performance of the stepped solar still. The experimental results revealed that the stepped solar still with the modification performed superior as compared to the conventional solar still. In addition, the cost of one liter of distilled water obtained from the modified stepped still was lower than that obtained from the traditional basin still. The results demonstrated that the distillate production of modified solar still (stepped distiller with paraffin wax mixed with aluminum oxide nanoparticles) reached about 85% higher than that of conventional solar still. The cost of one liter from the conventional and stepped stills = 0.049 and 0.040 $, respectively.

REFERENCES

Alaian, W.M., E.A. Elnegiry, and A.M. Hamed, *Experimental investigation on the performance of solar still augmented with pin-finned wick.* Desalination, 2016. **379**: p. 10-15.

Ahmed, H.M. *The effects of various types and layouts of wick materials on the thermal performance of conventional solar stills*. in *Smart Energy Grid Engineering (SEGE), 2016 IEEE*. 2016. IEEE.

El-Agouz, S., *Experimental investigation of stepped solar still with continuous water circulation.* Energy Conversion and Management, 2014. **86**: p. 186-193.

Haddad, Z., A. Chaker, and A. Rahmani, *Improving the basin type solar still performances using a vertical rotating wick.* Desalination, 2017. **418**: p. 71-78.

Kabeel, A., Z. Omara, and M. Younes, *Techniques used to improve the performance of the stepped solar still—A review.* Renewable and Sustainable Energy Reviews, 2015. **46**: p. 178-188.

Kabeel, A., et al., *Theoretical and experimental parametric study of modified stepped solar still.* Desalination, 2012. **289**: p. 12-20.

Koilraj, G.M., et al., *Effect of nanofluids in a modified vacuum single basin solar still.* International Journal of Scientific & Engineering Research, 2012. **3**(1): p. 1-7.

Omara, Z., M.H. Hamed, and A. Kabeel, *Performance of finned and corrugated absorbers solar stills under Egyptian conditions.* Desalination, 2011. **277**(1-3): p. 281-287.

Suneesh, P., et al., *Augmentation of distillate yield in "V"-type inclined wick solar still with cotton gauze cooling under regenerative effect.* Cogent Engineering, 2016. **3**(1): p. 1202476.

Omara, Z., et al., *Experimental investigation of corrugated absorber solar still with wick and reflectors.* Desalination, 2016. **381**: p. 111-116.

Omara, Z., M.A. Eltawil, and E.A. ElNashar, *A new hybrid desalination system using wicks/solar still and evacuated solar water heater.* Desalination, 2013. **325**: p. 56-64.

Omara, Z., A. Kabeel, and M. Younes, *Enhancing the stepped solar still performance using internal reflectors.* Desalination, 2013. **314**: p. 67-72.

Omara, Z., A. Kabeel, and F. Essa, *Effect of using nanofluids and providing vacuum on the yield of corrugated wick solar still.* Energy Conversion and Management, 2015. **103**: p. 965-972.

Pal, P., et al., *Performance analysis of modified basin type double slope multi–wick solar still.* Desalination, 2017. **422**: p. 68-82.

Rajaseenivasan, T. and K. Srithar, *Performance investigation on solar still with circular and square fins in basin with CO_2 mitigation and economic analysis.* Desalination, 2016. **380**: p. 66-74.

Sharshir, S.W., et al., *The effects of flake graphite nanoparticles, phase change material, and film cooling on the solar still performance.* Applied Energy, 2017. **191**: p. 358-366.

Velmurugan, V., et al., *Integrated performance of stepped and single basin solar stills with mini solar pond.* Desalination, 2009. **249**(3): p. 902-909.

Velmurugan, V., et al., *Single basin solar still with fin for enhancing productivity.* Energy Conversion and Management, 2008. **49**(10): p. 2602-2608.