Kandasamy et al. International Journal of Energy and Environmental Engineering 2013, 4:4
http://www.journal-ijeee.com/content/4/1/4

International Journal of Energy and Environmental Engineering
a SpringerOpen Journal

ORIGINAL RESEARCH Open Access

Performance correlation for single-basin double-slope solar still

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Abstract

In this study, an attempt has been made to develop a new correlation for the productivity of a single-basin double-slope solar still using experimental results obtained for different brine depths (0.01, 0.02, 0.03, 0.04, 0.05, and 0.06 m) in the basin in Coimbatore, Tamilnadu, India. The proposed correlation has been validated with the experimental results for one of the typical days in Coimbatore, Tamilnadu, India. A concluding correlation has been developed by including the results mentioned in the literature regarding double-slope solar still alone and the proposed correlation. The concluding correlation is compared with the correlation developed by the researcher based on the results in the literature regarding both single- and double-slope solar stills. The results indicate that the correlation coefficient R^2 is slightly higher as compared with that of previous results obtained for both single- and double-slope single-basin solar stills.

Keywords: Distillation, Single-basin solar still, Brine water depths, Correlation

Background

Water is very much essential for human beings. Supplying drinkable water is one of the major problems in developing countries. A solar still is a simple device which is used in converting brackish/saline water into potable/drinkable water. Many researchers have found the productivity for different brine depths in the basin of a single-slope single-basin solar still [1-15].

Further attempts have been made by researchers to investigate the effect of water depth in double-slope single-basin solar still. A digital simulation method has been done for the productivity of a complicated still by Cooper [16], and the influence of more common variables such as water depth, wind velocity, still insulation, double glass cover, cover slope, and daily variability on the productivity has been investigated. Results of the simulation indicate that water depth and thermal insulation have little effect on the productivity at shallow water depth and that a double glass cover and high cover slopes are not justifiable. Garg and Mann [17] have investigated the effect of climatic, operational, and design parameters for single- and double-slope solar stills under the Indian arid zone regions and to find the effect of all possible variables on the performance of the single-effect solar still. Akash et al. [18] have studied the basin-type solar still under local climatic conditions and concluded that lower water depth and salinity of the brine produced higher distillate yields for the double-slope passive solar still. The effect of wind speed on daily productivity of some active and passive solar stills using computer simulation for different solar still designs has been studied by El-Sebaii [19]. It has been shown that for the active and multi-effective passive stills, daily productivity increases with the increase of wind velocity up to a typical velocity; beyond that, the productivity becomes insignificant for single-effect passive stills. Al-Hinani et al. [20] have studied the effect of climatic, design, and operational parameters such as solar intensity, wind velocity, ambient temperature, glass cover slope angle, feedwater temperature water depth on the basin, and basin material on the distillate output of the basin-type solar still. They found that the 23° cover tilt angle, 0.1-m insulation thickness, and asphalt coating of solar still of the shallow water basin are the optimum parameters for producing higher yields. Al-Hayeka and Badran [21] have found the productivity of freshwater of two different designs of stills, which are asymmetric greenhouse with mirror and symmetric greenhouse solar stills, under

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the climatic conditions of Jordan. It was inferred that the distilled water output of the asymmetric greenhouse type was 20% higher than that of the symmetric greenhouse type. Mowla and Karimi [22] have simulated a mathematical model for a solar still; the rate of production of freshwater has been calculated, and experiments have been carried out in Shiraz. It has been found that the experimental and calculated results are in good agreement. The effect of water depth on the transient performance of a double-basin solar still has been investigated by Tiwari and Tiwari [23].

Siddiqui and Bajpai [24] have made an attempt to develop a correlation between the thickness of dust collected and the difference in efficiencies for all seasons in Lucknow, India. The equation derived is very good for the measurement of correlation with experimental results for all the months. Pragya et al. [25] have made an attempt to investigate the advantages of a two-layer solar panel for the enhancement of solar energy absorption. Results have shown an increase of 70% in the output. Hitesh and Shah [26] have aimed to evaluate the effect of various energy-absorbing plates in solar still to increase the daily distillate yield. It has been concluded that the utilization of aluminium floating plate has a significant impact on the productivity of the still.

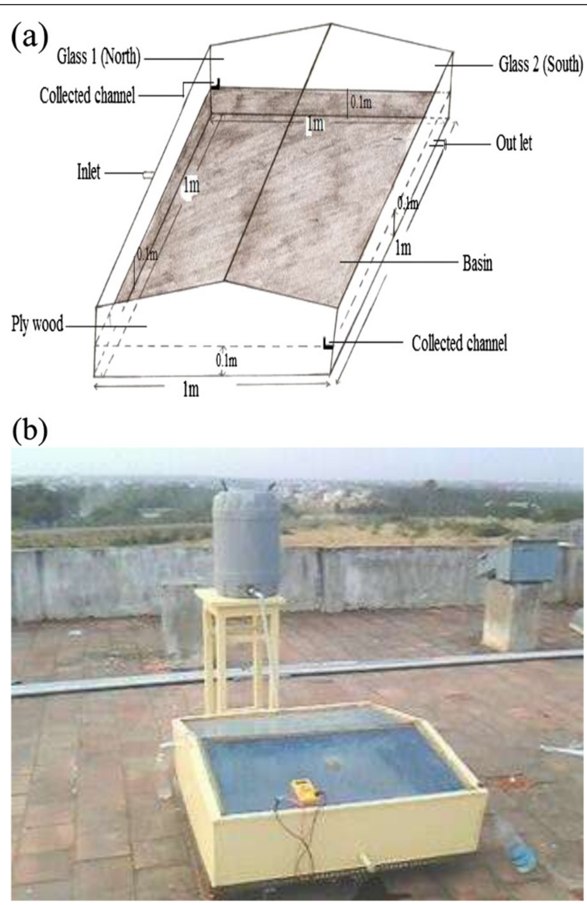

Figure 1 Schematic diagram of double-slope single-basin solar still (a) and photograph of experimental still (b).

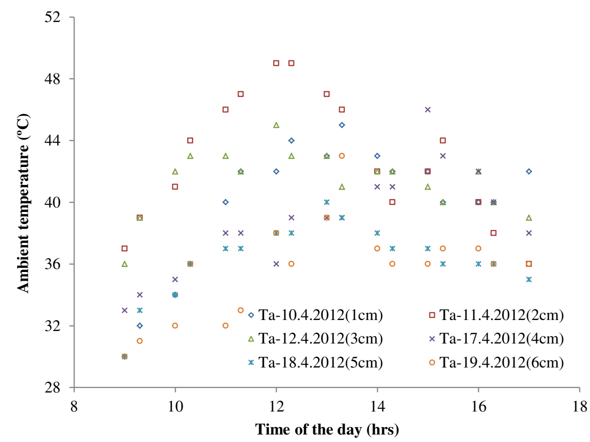

Figure 2 Variation of ambient temperature for experimental days with different brine depths.

The main objective of this work is to propose a correlation to find the productivity of the still based on the experimental results for different brine depth in the basin of the double-slope solar still. Experimental studies were carried out to validate the developed correlation. The correlation has been compared with the correlation developed by Khalifa and Hamood [27].

The decrease in productivity depends on the design parameter, location, and range of depth of brine water in the basin. Moreover, the existing models lack the inclusion of factors influencing the working of the still. These inconveniences paved the way for the present investigation to propose a correlation for a double-slope single-basin solar still alone.

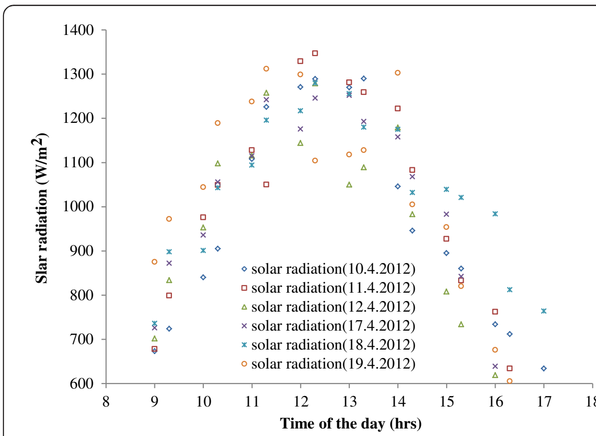

Figure 3 Variation of intensity of solar radiation for experimental days with different brine depths.

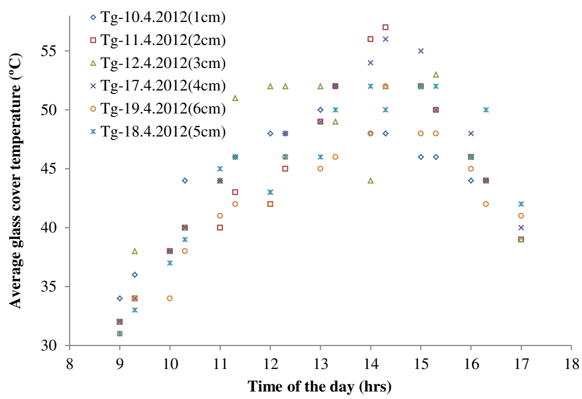

Figure 4 Variation of average glass cover temperature for experimental days with different brine depths.

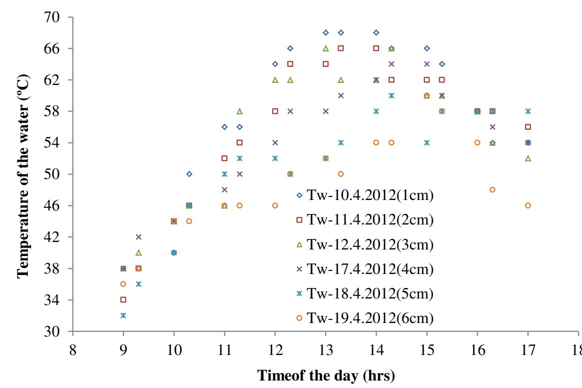

Figure 6 Variation of water temperature for the experimental days with different brine depths.

Methods

Experimental setup and observations

A schematic diagram of the double-slope single-basin solar still is shown in Figure 1a, and a photograph of the experimental setup of double-slope single-basin solar still with an inclination angle of the condensing glass cover (11°) is shown in Figure 1b. The experiments were conducted for many days with different brine depths in the basin from January to May 2012. Among the observations of experimental days, typical days have been selected for the proposed correlation based on the output and average solar radiation. Hence, in the month of April 2012, experimental observations for six different brine depths, namely 0.01, 0.02, 0.03, 0.04, 0.05, and 0.06 m, as the output and average solar radiation are high.

The experimental still is made of galvanized iron sheet with a basin area of 1 m^2. A glass cover with a 0.004-m thickness was used as condensing surface with an inclination angle of 11°, which is equal to the latitude of the location (latitude = 11°N). The bottom surface of the still basin is painted black to absorb a large amount of solar radiation. The yield of the solar still is collected using a graduated measuring jar. The solar still was oriented in the north–south direction to receive solar radiation throughout the working hours of the day. Experiments were conducted from 9 a.m. to 5 p.m. from the month of January to May 2012. Solar radiation, ambient temperature, distillate output, and basin, water, and cover glass temperatures have been measured for an interval of 30 min. The intensity of solar radiation is measured using a solar radiation monitor, and a digital thermometer is used to measure ambient temperature. Calibrated iron-constantan thermocouples are used to measure the basin, water, and glass cover temperatures.

Results and discussion

The variation of ambient temperature and solar radiation for experimental days are shown in Figures 2 and 3. From Figure 2, it is clear that for all experimental days, the

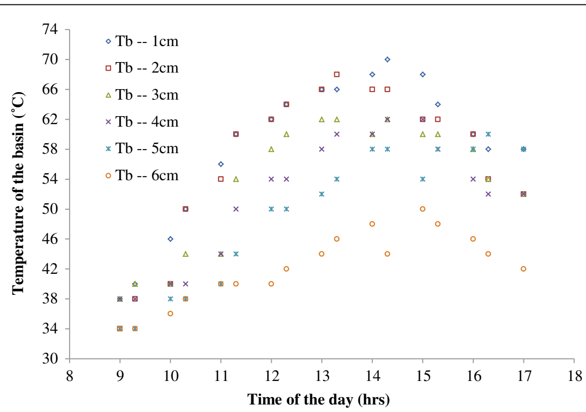

Figure 5 Variation of basin temperature for experimental days with different brine depths.

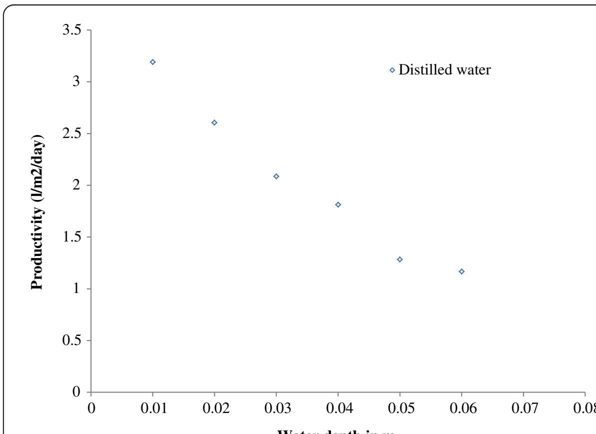

Figure 7 Variation of distilled water output between 9 a.m. to 5 p.m. for different brine depths.

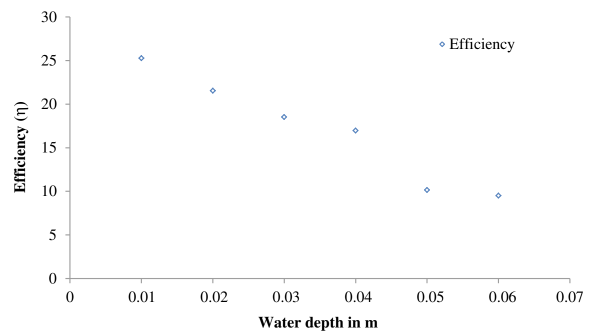

Figure 8 Variation of average efficiency for different depths.

ambient temperature is higher than 30°C from the morning hours. The maximum ambient temperature recorded was 49°C in one of the hours of the experimental day, and days are seen to be clear sunny days. The variation of solar radiation in Figure 3 shows that the intensity gradually increases from morning, reaches a maximum value at 1 p.m., and gradually decreases in the evening hours. The maximum intensity of solar radiation in one of the hours in experimental days is found to be 1,347 W/m^2.

The experiments were performed on a single-basin double-slope solar still for different brine depths of 0.01, 0.02, 0.03, 0.04, 0.05, and 0.06 m on 10 to 12 and 17 to 19 April 2012. Figure 4 shows the variation of the still's average glass cover temperature for different brine depths maintained in the basin. The average glass cover temperature gradually increases until 1 p.m. and decreases gradually during the evening hours. For the brine depth of 0.02 m, the maximum temperature of the glass cover is found to be 57°C due to the large convection and radiation heat transfer from water to the glass cover.

The variation of water and basin temperatures of the proposed still for different brine depths has been depicted

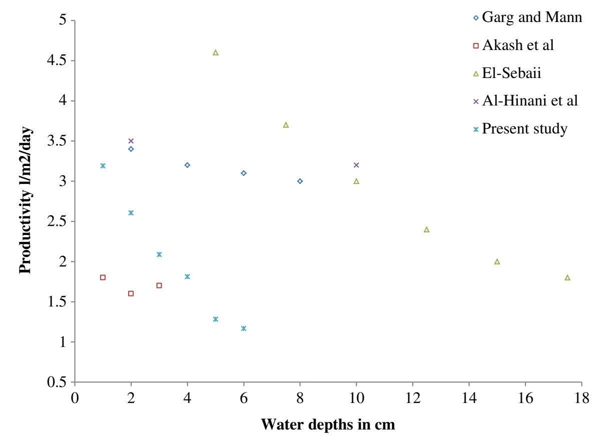

Figure 10 The scattered correlation of the literature for double-slope single-basin solar still.

in Figures 5 and 6. From Figures 5 and 6, it is observed that the water and basin temperatures for the brine depth of 0.01 m reached a maximum of 68°C and 70°C, respectively. Since the thermal capacity of the water in the basin is low when compared with the other brine depths, water and basin temperatures reached a maximum. Moreover, the temperature between the glass cover and water is high in order to produce more distillate yields as expected.

The amount of distillate yield from 9 a.m. to 5 p.m. has been measured for the considered brine depths and is presented in Figure 7. It is clear from the figure that for the least water depth, the distillate yield decreases every 30 min. Thus, for the water depth of 0.01 m, the distillate yield for the proposed still for every 30 min is higher than the other brine depths considered for the experiment. This is in accordance with previous results obtained by the researchers [1-15].

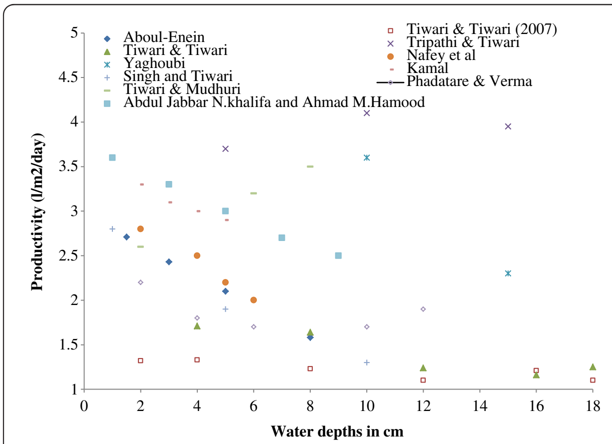

Figure 9 The scattered correlation of the literature for single-slope single-basin solar still.

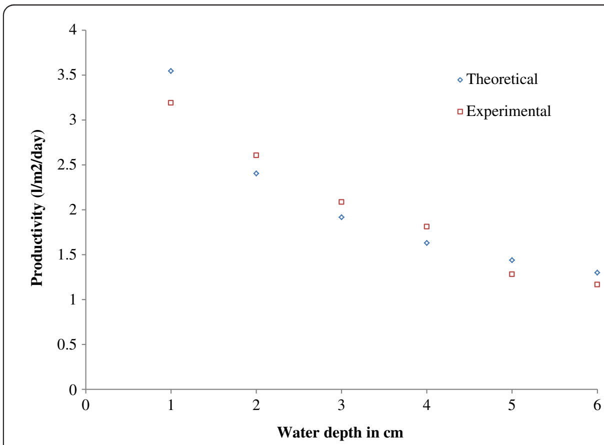

Figure 11 Variation of experimental and theoretical productivity for different depths.

For the 0.01-m brine depth, a maximum of 350 ml for a 30-min interval from 1 p.m. to 1:30 p.m. has been obtained.

Figure 8 shows the variation of average efficiency of the still for brine depths considered in the study. It is observed that the average efficiency of 25% has been obtained for 0.01 m of brine depth.

The result confirmed that the performance of the still is better for the least water depth, and it also inferred that when the brine depth increases, the efficiency decreases.

Developed correlation

Regression lines were drawn, and R^2 value had been found for the data collected from the literature regarding single- and double-slope basin-type solar stills separately by means of a least square method. A concluding correlation has been developed for single-basin double-slope solar still with literature data and correlation developed from the present investigation. A power regression in the form $y = C(d)^n$ was chosen so that no output is found at zero depth, where the productivity is in liters per square meter per day and the brine depth is in centimeters.

Figures 9 and 10 shows the correlations developed using the result of data from literature for single-slope solar still and double-slope solar still separately. The correlations for single-slope solar still and concluding correlation for double-slope solar still are as follows:

$$y = 2.833d^{-0.20}, R^2 = 0.829, \quad (1)$$

and

$$y = 5.885d^{-0.292}, R^2 = 0.869, \quad (2)$$

where R^2 is the correlation coefficient.

Performance of the correlation

A concluding correlation has been proposed with the experimental results of the present study and literature data for double-slope single-basin solar still. The concluding correlation developed has been compared with the concluding correlation developed by Khalifa and Hamood [27]. Also, a correlation has been developed for single-slope single-basin solar still separately from the data available in the literature. It has been found that for single-slope single-basin solar still alone, it has the regression coefficient of 0.829 which is higher than the correlation developed by Khalifa and Hamood [27] including both single- and double-slope basin-type solar stills.

The concluding correlation proposed which includes the present investigation and data in the literature for double-slope single-basin solar still has the regression coefficient of 0.869, which is higher than the correlation for the single-slope single-basin solar still. The concluding correlation has been validated for one of the typical days with different brine depths and is depicted in Figure 11. From the figure, it is observed that the theoretical results are in close agreement with the experimental observations with least error.

Conclusions

The correlations are developed separately for single-slope single-basin solar still using data from the literature, and the concluding correlation includes data from the literature and the present study. Results have shown that the R^2 value of 0.829 obtained for the single-slope single-basin solar still and the R^2 value of 0.869 for the concluding correlation are higher than previous correlations developed by Khalifa and Hamood [27]. Hence, it is confirmed that correlation should be done separately for single- and double-slope single-basin solar stills instead of combining the data of both single- and double-slope single-basin solar stills. The regression coefficient of the concluding correlation approaches to unity, and the correlation may be a perfect positive correlation with least error.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SK developed the correlation for the proposed system. MV did the literature review regarding the correlation for solar still. SS compared the developed correlation with the existing correlation and finalized the correlation for single-basin double-slope solar still. JB went through the text of the paper and critically checked the correlation for correctness. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank the University Grand Commission (UGC), The Government of India, New Delhi, for the award of Rajiv Gandhi National Research Fellowship for SC/ST.

Received: 3 July 2012 Accepted: 13 December 2012
Published: 16 January 2013

References

1. Tiwari, GN, Madhuri: Effect of water depth on daily yield of the still. Desalination **61**, 67–75 (1987)
2. Kamal, WA: A theoretical and experimental study of the basin type solar still under the Arabian Gulf climatic conditions. Solar and Wind Technology **5**, 147–157 (1988)
3. Farid, M, Hamad, F: Performance of single-basin solar still. Renew. Energy **3**, 75–83 (1993)
4. Yaghoubi, MA, Sabzevari, A: Calculation of the hourly output of a solar still for various cities in Iran. Renew. Energy **7**, 427–435 (1996)
5. Toure, S, Meukam, P: A numerical model and experimental investigation for a solar still in climatic conditions in Abidjan (Cote D'ivoire). Renew. Energy **11**, 319–330 (1997)
6. Aboul-Enein, S, Eli-Sebaii, AA, El-Bialy, E: Investigation of a single-basin solar still with deep basins. Renew. Energy **14**, 299–305 (1998)
7. Nafey, AS, Abdelkader, M, Abdelmotalip, A, Mabrouk, AA: Parameters affecting solar still productivity. Energ. Convers. Manage. **41**, 1797–1809 (2000)
8. Nafey, AS, Abdelkader, M, Abdelmotalip, A, Mabrouk, AA: Enhancement of solar still productivity using floating perforated black plate. Energ. Convers. Manage. **43**, 937–946 (2002)
9. Singh, HN, Tiwari, GN: Monthly performance of passive and active solar still for different Indian climatic conditions. Desalination **168**, 145–150 (2004)

10. Tripathi, R, Tiwari, GN: Effect of water depth on internal heat and mass transfer for active solar distillation. Desalination **173**, 187–200 (2005)
11. Abu-Arabi, M, Zurigat, Y: Year round comparative performance study of solar desalination units. Desalination **172**, 137–143 (2005)
12. Tripathi, R, Tiwari, GN: Thermal modeling of passive and active solar stills for different depths of water by using the concept of solar fraction. Solar Energy **80**, 956–967 (2006)
13. Phadatare, MK, Verma, SK: Influence of water depth on internal heat and mass transfer in a plastic solar still. Desalination **217**, 267–275 (2007)
14. Tiwari, AK, Tiwari, GN: Thermal modeling based on solar fraction and experimental study of the annual and seasonal performance of a single slope passive solar still: the effect of water depths. Desalination **207**, 184–204 (2007)
15. Badran, OO: Experimental study of the enhancement parameters on a single slope solar still productivity. Desalination **209**, 136–143 (2007)
16. Cooper, PI: Digital simulation of transient solar still process. Solar Energy **12**, 313–331 (1969)
17. Garg, HP, Mann, HS: Effect of climatic, operational and design parameters on the year round performance of single slope and double slope solar still under Indian arid zone conditions. Solar Energy **18**, 159–164 (1976)
18. Akash, BA, Mohsen, MN, Nayfeh, W: Experimental study of the basin type solar still under local climatic conditions. Energ. Convers. Manage. **41**, 883–890 (2000)
19. El-Sebaii, AA: Effect of wind speed on active and passive solar stills. Desalination **45**, 1187–1204 (2004)
20. Al-Hinani, H, Al-Nassri, MS, Jubran, BA: Effect of climatic, design and operational parameters on the yield of a simple solar still. Energ. Convers. Manage. **43**, 1639–1650 (2002)
21. Al-Hayeka, I, Badran, OO: The effect of using different designs of solar stills on water distillation. Desalination **169**, 121–127 (2004)
22. Mowla, D, Karimi, G: Mathematical modeling of solar stills in Iran. Solar Energy **55**, 389–393 (1995)
23. Tiwari, AK, Tiwari, GN: Effect of water depths on heat and mass transfer in a passive solar still: in summer climatic condition. Desalination **195**, 78–94 (2006)
24. Siddiqui, R, Bajpai, U: Correlation between thickness of dust collected on photovoltaic module and difference in efficiencies in composite climate. Int. J. Energ. Res. Environ. Eng. **3**(26), 1–7 (2012)
25. Pragya, S, Tirumalachetty, H: Enhancement of energy generation from two layer solar panel. Int. J. Energ. Res. Environ. Eng. **3**(12), 1–9 (2012)
26. Hitesh, P, Shah, PK: Investigation on solar stills having floating plates. Int. J. Energ. Res. Environ. Eng. **3**(8), 1–5 (2012)
27. Khalifa, AJN, Hamood, AM: On the verification of the effect of water depth on the performance of basin type solar stills. Solar Energy **83**, 1312–1321 (2009)

doi:10.1186/2251-6832-4-4
Cite this article as: Kandasamy *et al.*: **Performance correlation for single-basin double-slope solar still.** *International Journal of Energy and Environmental Engineering* 2013 **4**:4.