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Roof top Cemented Solar Still

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ABSTRACT

This paper presents the solar still to cater the need of distilled water in an academic institution, school's laboratories, workshops and domestic purpose. This distilled water could convert into potable water with mixing some ions to meet the drinking water demand in rural areas also. Presently solar stills are available in glass and fibre material with squashed sealing which was difficult to care and moving. As easily movable cover over the basin of solar still had several advantages over available solar still, apart from economical advantages, therefore an attempt has been made to construct solar still above the terrace with taking advantages of slab of building for basin of 1m² area for its evaluation. Thermal efficiency of developed solar still was found as 31%. The yield of distilled water in developed solar still was varied from 1725-2381ml/m²-day whereas in already developed still produced average distilled water as 1800ml/m²-day from winter and summer season. The physicochemical analysis was made to examine the effect of distillation on tap water. A drastic reduction in the TDS, Chlorides, Calcium hardness and Magnesium hardness, dissolved silica was observed through solar distillation

KEYWORDS Solar Energy, Solar Still, Distilled water, Low cost

INTRODUCTION

Solar still structure was designed and constructed at Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology (CAET), Dediapada. This still was constructed at college terrace building using cemented base with fixing of cut section of 50mm diameter PVC pipe to make the frame as shown in Plate-1(a). The size of collector 1m x 1m was prepared with arranging 80 bricks as shown in Plate-1(b). This still painted with dull black colour as it absorbs maximum energy and in which water was impounded with 1inch height. The 4mm toughen glass frame as dome for distillation unit was kept properly over the collection channel which is fixed in concrete base structure so that it became leak proof shown in Plate-1(c). The distilled water-collecting channel made from cut section of 50mm PVC pipe surrounding the basin. The collecting channels were fabricated so as to catch the condensed droplets of water inside the solar still. The material used for the fabrication of this unit is presented in Table-2. The water present in basin got evaporated due to higher temperature inside the heating chamber.Water vapour inside the heating chamber got condensed in the form of small droplets of water due to lower temperature on inner side of glass. Condensed droplets of evaporated water were collected through the front channels. Surrounding condensed water was collected through surrounding channel from all sides at bottom. The cost required to construct the cement base solar still on top of the floor estimated ₹ 6,830/-

METHODOLOGY

During theoretical design calculations for solar still (Plate-1), peak winter season was considered. In winter season, December month was selected for finding the solar declination angle (δ), Slope of collector (β), intensity of insolation on horizontal and vertical surface (Brenidorfer *et. al.* 1985) and value of Cos θ is shown in Table-1. The device to be situated at latitude of 21°38′ 0″N (Kiran and Mudliar, 2012). Minimum insolation on horizontal plane during winter, for 10th of December is 426w/m² for Dediapada. (Anna M. and S. Rangrajan, 1980). The newly solar still unit was evaluated for load and no load test and compared with available solar still in market (single slope).

Plate-1. Low cost solar still

TABLE 1
DETAILS OF DESIGN CALCULATIONS FOR SOLAR STILL

S. N.	Particulars	Symbol	Design parameter of solar still
1	Solar declination angle	δ	$\delta = 23.45 \sin [0.9863(284 + n)]$ $\delta = -23.38$

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2	Slope of collector	β	β = (Φ - δ) β = 45°
3	Solar radiation in December on horizontal surface	W/m^2	426
4	Value of Cos θ	Cos θ	0.98
5	Value of Cosθ_h	Cosθ_h	0.72
6	Intensity of insolation on horizontal	I_c	$I_c = I_h \times \cos\theta$ $I_c = 417$
7	Intensity of insolation on sloping surface	I_s	$I_s = I_h \times \cos\theta / \cos\theta_h$ $I_s = 555W/m^2$
8	Cosine of θ_h	θ_h	$\theta_h = 43°.9'$

NO LOAD TEST
The low cost solar still with area of 1m x 1m was evaluated in winter and summer for no load test. The maximum average temperature was observed in winter during no load test was 69.5°C at 14 hrs and the same time solar intensity was 603w/m², ambient temperature was 30.1°C, and outside relative humidity was 29.0%. The trend obtained in no load test during performance testing. It is revealed from Figure 1 that the temperature inside the still increased with solar intensity in morning hours up to 14 hrs and then started declining as day progressed.

TABLE 2
MATERIAL USED FOR FABRICATION OF SOLAR STILL

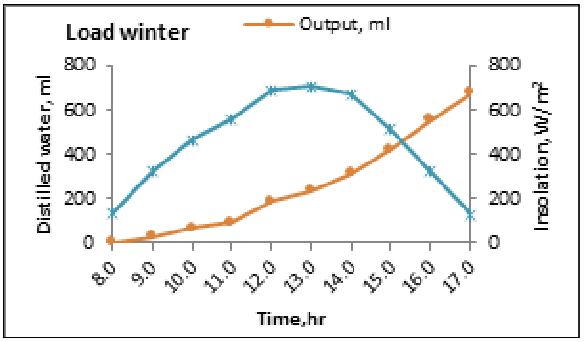
S. N.	Item	Specification	Quantity required	Rate of item (₹)	Total Cost (₹)
1	PVC pipe	50 mm diameter	2 m	70/m	140/-
2	Black paint	standard	500 gm	240/kg	120/-
3	Bricks	standard	80	6/no.	480/-
4	Cement	53 grade	1.5 bag	300/bag	450/-
5	Sand	Fine	30 kg	8/kg	240/-
6	Labor charge	-	1 days	300/day	300/-
7	Glass frame	1 m x 1 m frame with 4mm thick glass	1 piece	4900/each	4900/-
8	Miscellaneous	-	-	-	200/-
TOTAL					6830/-

Solar still was also evaluated in summer for no load along with solar energy, ambient temperature, inside and outside humidity. In summer, maximum inside temperature reached in solar still was 74.6°C where as ambient temperature, solar radiation and outside relative humidity were found as 33.5°C, 574w/m² and 37.7% respectively.

LOAD TEST
Solar still was tested with impounding water with 1 inch depth in basin in winter. The hourly cumulative distilled water obtained was observed with solar intensity, ambient temperature, relative humidity and wind speed in winter shown in Figure 2.

The maximum average temperature was observed at 13 hrs, when solar intensity was 708w/m², ambient temperature was 28.6°C at 14 hrs and ambient Rh was 30.5% as shown in Figure 2 It was observed that inside temperature increased as the solar intensity increased and humidity decreases. It was observed that maximum distillation rate obtained at 16 hrs which was highest as 133ml. Average overnight distillation observed in solar still unit was 1050ml which was due to higher condensation rate at night. The maximum cumulative distillation obtained in winter season was 1725ml.

FIGURE 1
PERFORMANCE OF SOLAR STILL DURING LOAD TEST IN WINTER



The performance of solar still during summer, maximum temperature obtained at 14 hrs was 66.4°C, when solar intensity was 734w/m² at 13 hrs and ambient temperature was 34.9°C, ambient Rh was 33.3% and inside Rh was 53.1% as shown in Figure 2 Trend observed in load test during performance. It was observed that inside temperature increased as the solar intensity increased and hence rate of heat utilization for heating the water was more in noon time and accordingly evaporation was observed more after noon hours. The rate of condensation was increased afternoon time as solar intensity decreased. Cumulative distilled water obtained from solar still in summer month was 2381ml including day and night condensation. It was observed that maximum distillation rate obtained in evening hours. Highest distillation rate was observed as 186ml at 17 hrs. Average overnight distillation observed in solar still unit was 1300ml which was higher than day time distillation rate and may be due to the day heat absorbed by cemented structure which release in the night also.

EFFICIENCY OF SOLAR STILL
Efficiency of solar still was calculated with following equation $= mewd \times \lambda / A_b \times (I)_t \times 3600$

Where, mewd = daily output, kg/m^2day

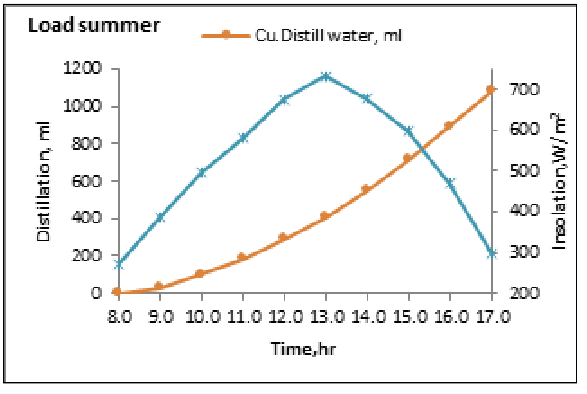
λ = Latent of heat water, kJ/kg

A_b = basin area

I = Solar insolation w/m^2

Efficiency of developed solar still was found as 31%.

FIGURE 2
PERFORMANCE OF SOLAR STILL DURING LOAD TEST IN SUMMER



TOTAL DISSOLVED SOLID AND pH
The results of pH and total dissolved solid measurement of distilled water and normal water were 7.0, 7.8 and 0ppm, 350ppm respectively. The distilled water can be used for various purposes considering its low dissolved solid and normal pH.

COST ECONOMICS

The total cost that of the investment spread over the entire useful life of the plant, including initial cost, operation cost, maintenance and interest are taken in consideration for payback period. Considering the average distilled water obtained from developed solar still as 2 liters for 300 days a year and 600 liters of distilled water may produced. By considering the market value of distilled water ₹ 15/lit and total income generated while producing 600 liters of distilled water is tabulated in Table-3.

TABLE 3
DETAILS ABOUT COST ANALYSIS OF SOLAR STILL

Sr. No.	Particulars	Amount (₹)
1.	Total Revenue	9000.00
2.	Cost of Device	6830.00
3.	Cost of Energy	Nil
4.	Cost of Labour, Operation and Maintenance for trouble free working (After every 2 year)	300.00

The cost of unit is recovered within 10 months only, i.e. the payback period of the unit was only 10 month and after that period the unit will produce net profit. Payback period is minimum it may due to the lower cost of unit. Benefit cost ratio and net present worth were observed as 1.9 and ₹52,414/- respectively.

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CONCLUSION

Average distilled water obtained is 2053ml/m^2-day from developed solar still constructed on top of building. Concentration of pH and TDS in solar distilled water was found to be 7.0 and 0 respectively. Thermal efficiency of developed solar still was found as 31%.

REFERENCES

[1] Lashkaripour G.R. and Zivadar M. (2005) Desalination of brackish water in Zahedan city in Iran, Desalination Vol.177:1–5.
[2] Velmurugan. V. and Srithar K. (2011) Performance analysis of solar still based on various factor affecting the productivity-A review, renewable and sustainable energy review 15:129–130
[3] B. Bouchekima (2003) A small solar desalination plant for the production of drinkable water in remote arid areas of southern Algeria, Desalination, Vol. 159:197 –204.
[4] Joseph J., Saravanan R., Renganarayanan S. (2005) Studies on a single-stage solar desalination system for domestic applications, Desalination, Vol.173:77 – 82.
[5] Tarawneh K. (2007) Effect of Water Depth on the Performance Evaluation of Solar Still, Jordan Journal of Mechanical and Industrial Engineering, Volume 1(1):23 – 29.
[6] Sengar,S.H, Mohod A.G., Khandetod Y.P., Modak S.P., Gupta D.K. (2011) Design and Development of wick type solar distillation system, Journal of Soil science and Environmental Management, Vol 2(7):125 – 133.
[7] Arunkumar, T. and Vinothkumar K. , Ahsan A, Jayaprakash R., Sanjay K. (2012) Experimental Study on Various Solar Still Designs, International Scholarly Research Network, ISRN Renewable Energy, , Article ID 569381, 10.
[8] Pandey A. K., Dinesh K, Sharma R., Sharma U., Vijh R. K., Ahlawat S.P.S. (2005) Population Structure and Genetic Bottleneck Analysis of Ankleshwar Poultry Breed by Microsatellite Markers. Genetic analysis of ankleshwar poultry, 19.
[9] Anna M. and Rangarajan S. (1980) Solar Radiation over India, Allied Publisher Privet Ltd., New Delhi : 404.
[10] Brenidorfer B. Kennedy L, Bateman C O (1995) "Solar dryer; their role in post harvest processing, Commonwealth Secretariat Marlborough house", London, Swly 5hx.
[11] Ali A.F. Al-Hamadani, Shukla S. K. and Dwivedi A. (2012) Experimental Performance Analysis of a Solar Distillation System with PCM Storage, International Journal of Research in Engineering and Technology (IJRET) Vol. 1(6):43-78.
[12] Dara, S. S. (1999) A text book on experimental and calculation in engineering chemistry, S. Chand publication, New Delhi, pp 5 – 13.
[13] Kothari, S. and Sengar S. H. (2007) Performance evaluation of solar stills. Bioved, 18(1, 2):35 – 37.
[14] Ashish K., Prashant A. and Mohd. A. Z. (2014) Distillate water quality analysis and economics study of a passive solar still. Recent Research in Science and Technology, 6(1):128 – 130.