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Annual Performance analysis of Double basin solar still with Evacuated tubes

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***Abstract**:*
Solar still is an unpretentious technique to transformation accessible salty or saline water into drinking water by usage of Sun rays. It is not famous like reverse osmosis (RO) system due to its low potable water production. Henceforth, the foremost intention of the current investigation is to assess year around analysis of double basin solar still with Evacuated tubes. From the year around performance investigation, it has been evaluated that, the, distillate water production of still is around 12 liter per day, and energy payback time and cost or potable water per day is around 117 days and 0.51 Rs.

***Keywords** Solar still, distillate output, solar energy*

1. Introduction

Water is one of the most important aspect of the world today. Without water, the existence of the human being and other living organism is not possible. Also, the pure water quantity is very limited. Solar still is a simple stratagem to transform saline water into drinkable water.

Glass is the unsurpassed substantial to protection (Duffie et al. [1] since it has advanced transmission and lower reflectivity. Also, glass is impervious to updraft radiation. Lower angle of latitude place and higher latitude place the solar still angle remains different. (Fath et al. [2]. Mahesana is situated in Gujarat district and it has a decent consecration of sun radiations. Hence, numerous number of researchers have done in Mahesana district on solar still [3-24]. (Panchal (2010, 2011, 2016a, 2016b), Panchal et al. (2010), Panchal, Doshi et al. (2011), Panchal, Patel et al. (2011), Panchal and Shah (2011a, 2011b, 2012a, 2012b, 2013a, 2013b, 2013c, 2013d, 2014a, 2014b, 2014c, 2014d), Panchal, Thakar, and Thakkar (2014), Panchal and Patel (2016), Panchal and Mohan (2017) and Panchal and Sanjay (2017)).

The key goal of this current investigation is to inspect the concert of double basin solar still with vacuum tubes yearly and associated its distillate output with other investigators work

2. Experimental set up

Fig.1 Experimental set up of double basin solar still with evacuated tubes

Fig. 1 demonstrates current research work on solar still. The general dimensions of the top basin used is 1000 mm *1000 mm *500 mm, and the upper basin is 1006 mm *1000 mm *500 mm. The lower basin is black covered to upsurge energy preoccupation. Two opening glass of 4 cm breadth providing in the present investigational set up. The lower glass cover is fixed at 8 mm above the basin bottom and upper cover was fixed at 10 cm above lower cover. An insulation of 5 cm in thickness was provided on all sides to reduce heat losses. Here polyurethane foam (PUF) with a thermal conductivity of 0.025 W/m2 K was used in the present experiment. The evaporated water in the lower basin and the upper basin was condensed by plane glass about 4 mm in thickness. The condensed water of the lower and upper basins was collected by measuring jar A silicone rubber sealant was provided to hold the toughened glass in contact with the still surfaces. A total of 4 holes was made on the lower and upper basins for the location of thermocouples. Here, 14 vacuum tubes were coupled with a hole about 6 cm in diameter in the lower side of the top basin.

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3. Result and Discussion

3.1 Hourly differences of solar concentration against time

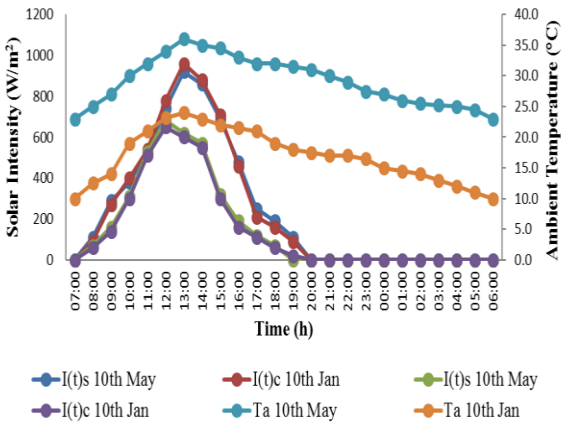

Fig.2. Hourly variations of solar intensity versus time during summer and winter conditions

Fig.2 shows that the hourly differences of sun energy concentration and ambient temperature on 10th May and 10th January. 2013. It illustrates that, sun rays pending it spreads its supreme worth at mid-day, then it reductions over. This arc is experiential in both trial days. The uppermost logged worth of sun rays was 980 and 960 W/m^2 and 600 and 620 W/m^2 for vacuum tubes and solar still during trial days. The supreme ambient temperature is originating about 36 °C and 24 °C through 10th May and 10th January, 2013.

3.2 Lower and upper basin water temperature differences

Fig. 3 demonstrates the difference of water temperatures of lower and upper basin throughout trial days. Climate condition always affects the temperature gained by passive solar still during summer and winter experimental day, hence summer and winter experimental day, maximum temperature achieved at 15:00 pm and 14:00 pm. It is also experiential that, the lower basin water temperature remnants high through the day during summer and winter experimental day, due to augmentation of vacuum tubes. During winter experimental day, temperature is found more than 60 °C during 14:00 pm. Generally, water temperature of passive solar still remains lower during winter, but here lower basin removes excess heat to the upper basin, hence water temperature remains higher during peak hours. It is a main benefit found in this arrangement of passive solar still.

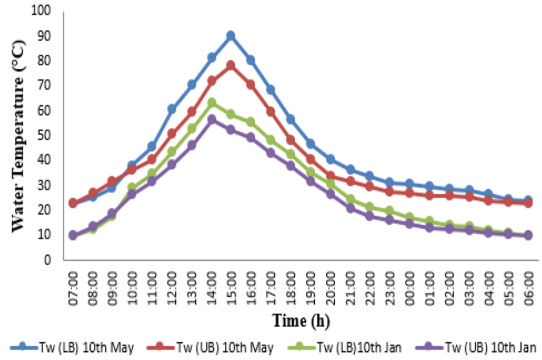

Fig.3 Difference of water temperature inside lower and upper basin in Double basin solar still with evacuated tubes

3.3 Average hourly differences of water temperature in solar still

Average water temperature is very important in present investigations. Hence, individual justifications required for lower basin water temperature and upper basin water temperature. Most crucial basin of present passive solar still is "lower basin", due to augmentation it with vacuum tubes. Fig. 4 represents average water temperature of inside lower basin during July – 2012 to June - 2013. It is clearly found that, water temperature remains lower during early morning then it increases up to mid day hours then reduces slowly during off-sunshine hours for all experimental days. Higher and lower average water temperature is found during experimental days of May and January 2013 due to difference between the higher and lower solar intensity and ambient temperature. Average water temperature of monsoon experimental days is lies between the summer experimental and winter experimental days. It is also found that, after sunshine hours, water temperature inside lower basin is not changed drastically but slowly compared with lower basin due to its volumetric heat capacity.

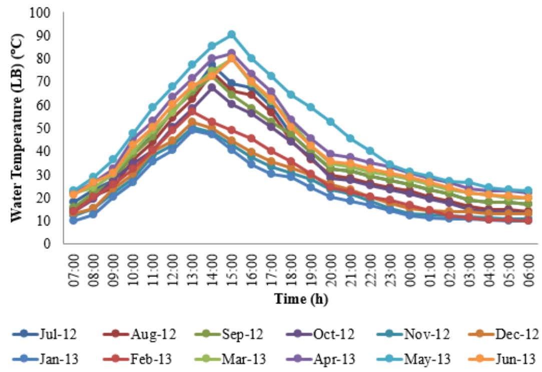

Fig. 4 Average hourly differences of lower basin water temperature

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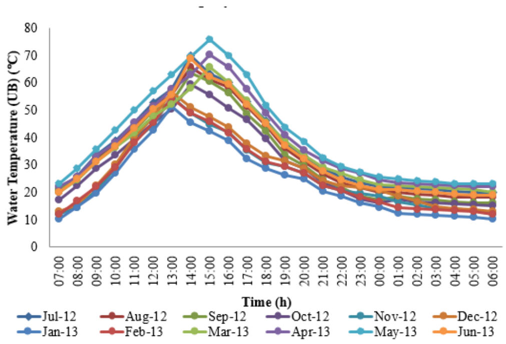

Fig. 5 Average hourly differences of upper basin water temperature

Fig.5 represents average temperature variations of upper basin during summer and winter experimental days. Upper basin received solar radiation from top and excess heat from lower basin, hence its average water temperature during summer and winter experimental days remain higher. Due to higher water temperature inside top basin, performance of upper basin is also higher compared with ordinary passive solar still due to higher water temperature inside it. Higher upper basin average water temperatures found during May 2013 and lower during January, 2013. Remaining average experimental days water temperatures found between above two months.

3.4 Hourly variations of distillate output of lower and upper basin during summer and winter climate conditions

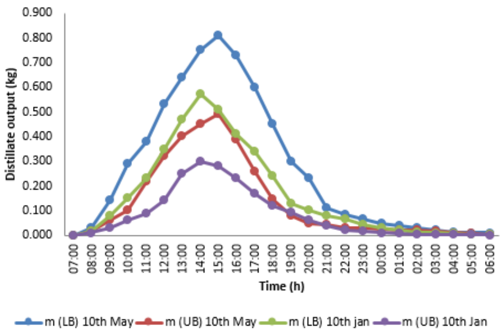

Fig. 6 Hourly difference distillate output for lower and upper basin during trial days

Fig. 6 signifies the hourly difference of distillate output during trial days. It is found that, higher water and lower glass cover temperature difference found higher distillate output inside passive solar still. In normal passive solar still, distillate output increased from morning to midday due to better availability of sunrays and then decrease due to unavailability of sunrays. But in this still, after sunshine hours, due to the higher heat capacity of water, lower basin acts as a heat reservoir and maintains higher water temperature for distillate output and also release the latent heat of condensation to upper basin for producing distillate output. Hence, not only lower basin, but also an upper basin produces the distillate output after sunshine hours. During summer experimental day, maximum water temperature gained between 15:00 pm and 14:00 pm and winter experimental day gained between 14:00- 15:00 pm due to the climate condition effect on distillate output. Lowest ambient temperature and climate condition gained peak distillate output early and summer gained during after midday (15:00 pm to 16:00 pm). It is also demonstrated that, after sunshine hours (after 17:00 pm) distillate output is decreased drastically in passive solar still due to absence of solar radiation. But, here same condition is found during winter climate condition, but not in summer. In winter climate conditions, it is demonstrated that, after 17:00 pm there is a marginal gap between the output of lower basin and upper basin, but there is a big gap between the output of lower and upper basin in summer climate condition.

3.5 Hourly Differences of Average Distillate Output for Lower Basin

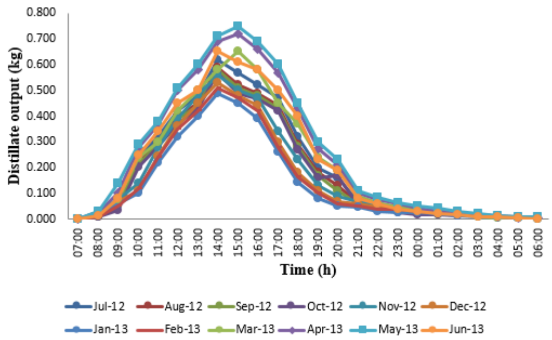

Fig. 6 Hourly differences of average distillate output of lower basin

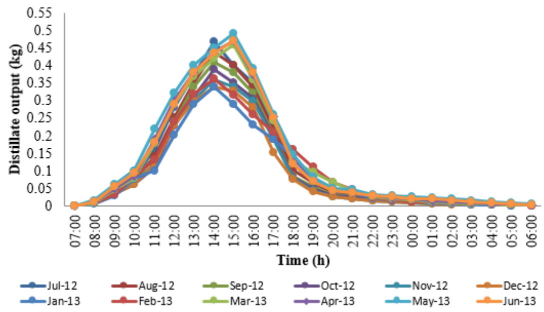

Fig. 7 Hourly differences of average distillate output of upper basin

To understand the general presentation the average distillate output of lower and upper basin production an important role. Figs. 6 and 7 represent hourly differences of distillate output of lower and upper basin during year-round analysis during July 2012 to June 2013. It obviously demonstrations alike

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curve tendencies for increase and decrease in distillate output for both basins. It is also revealed that, average supreme distillate output increased during the month of May, 2013 and lower during the month of January, 2013 for lower and upper basin

3.6 Judgement of normal distillate output of lower and upper basin

Table 1 represents the average daily and monthly distillate output of present investigations. It is revealed that, there are over-all 292 sunshine days in entire year during July-2012 to June 2013. It is also on behalf of that, average daily distillate output of lower basin is found 5.23 kg and upper basin is 2.89 kg. Hence, total average daily distillate output of solar still is 8.13 kg.

Table 1: Average Daily and Monthly Distillate Output

Month of Year	No of clear sky days	Average daily distillate output of Lower basin (kg)	Average daily distillate output of Upper basin (kg)	Average Monthly distillate output of Lower basin (kg)	Average Monthly distillate output of Lower basin (kg)	Average daily distillate output of DBSWVT (kg)
Jul-12	25	5.4	2.7	135	14.58	8.1
Aug-12	23	5.1	2.95	117.3	15.045	8.05
Sep-12	22	4.9	2.9	107.8	14.21	7.8
Oct-12	20	4.80	2.87	96	13.776	7.67
Nov-12	22	4.71	2.8	103.62	13.188	7.51
Dec-12	23	4.6	2.5	105.8	11.5	7.1
Jan-13	17	4.4	2.1	74.8	9.24	6.5
Feb-13	20	4.8	2.6	96	12.48	7.4
Mar-13	31	5.9	3.1	182.9	18.29	9
Apr-13	30	6.1	3.32	183	20.252	9.42
May-13	31	6.3	3.62	195.3	22.806	9.92
June-13	28	5.8	3.32	162.4	19.256	9.12
Average	292	5.23	2.89	129.99	15.38	8.13

3.7 Economic analysis of present investigations

Table 2: Fabrication cost of present Investigations

Details of component	Quantity	@ Materials	INR
Mild still Plate	36 kg	R_{MS} = Rs. 78/kg	2808
Evacuated Glass Tubes	14	R_{EGT} = Rs. 200/pic.	2800
Silicon Seal	14	R_{ss}= Rs. 50/pic.	700
EGT Cap	14	R_{cap}= Rs. 50/pic.	700
Glass cover(Glass thickness 5mm)	1.043 m²	R_{glass} = Rs. 190/m²	198
Glass Tray(Glass thickness 5mm)	1.5 m²	R_{glass} = Rs. 190/m²	285
Thermocouple wire (K- Type)	30 m	$R_{k\text{-}type}$ = Rs. 35/m	1050
Sealant	4 m	R_{selant}= Rs. 25/m	100
Fiber reinforced plastic	2.3 m²	R_{FRP} = Rs. 180/m²	414
Stand	1	-	200
Manufacturing cost	-		1300
Total			10555

Before supply any new passive solar still in market, its economic analysis plays important role. Hence, Table 2 represents the capital fabrication cost. It is shown that, total capital cost is found 10555 INR. Table 3 characterizes annual cost of potable water produced by solar still and it is found 0.51/kg INR and Table 4 represents the payback period of solar still is 117 days.

Table 3 : Annual cost of water produced in present investigations

Particular	Cost INR
Principal cost (P)	10555
Salvage Value (S) (10% of principle value)	1055.5
Life of still (n)	20
Interest rate (i)	10%
Capital Recovery Factor (CRF)=	0.106079
Sinking Fund Factor (SFF)=	0.006079
Annual First Cost = (CRF*P)	1119.666
Annual Salvage Value (SFF*P)	64.16647
Annual Maintenance Cost (Rs. 0.15* Annual Cost)	167.95
Annual Cost /m² = Annual first cost + Annual maintenance cost- Annual salvage value	1223.45
Annual Distillate output of solar still	2374.69
Annual cost of distillate output per kg = Annual First Cost/Annual Yield	0.5152

Table 4 : Energy payback time of solar still

Fabrication cost	10555
Operating cost	Rs 5/day
Maintenance cost	Rs 5/day
cost of feed water	Rs 1/day
Cost of distilled water	Rs 12/kg
Annual distillate output of present solar still	8.13 kg/day
Cost of water produced /day	97.56 INR
Subsidized cost given by government sectors is taken as 4%,	
Net Profit = cost of water produced - operating cost-Maintenance cost- cost of feed water	480 INR
Payback period = (Investment - Subsidized cost)/(Net Profit)	117 Days

3.8 Comparison of present investigations with others work

Table 5 : Comparison of present solar still with other researchers work

Sr. No.	Name of Researcher	Type of attachment with passive solar still	Increase in distillate output (%)
1	Dev and Tiwari, (2012)	Evacuated tube collector coupled with passive solar still	32%
2	Sampathkumar Karuppusamy (2012)	Evacuated tube collector with granite gravel	59.78%
3	Xiong. *et al*. (2013)	Multi-effect passive solar still integrated with evacuated tubes and corrugated sheet	90%
4	Z. M. Omara et al. (2013)	Evacuated tubes with wick materials	108%
5	Present work	Double basin solar still with vacuum tubes	225%

Generally conventional passive solar still received 2.5 kg average distillate output. Hence, Table 5 represents comparison of present work with others.

4. Conclusion

Following points are obtained:

- Present investigations found impressive distillate output during daytime and night time.
- Present solar still has fabrication cost around 10555 INR.
- It can be obtained about 0.5152 Rs/kg of water from present solar still.
- It can be obtained energy payback time around 117 days.
- Present solar still increased distillate output of water around 225% compared with conventional passive solar still.

5. Acknowledgements

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