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Investigation of charcoal, coco peat and black sponge as absorber materials on the performance enhancement of low cost solar still

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ABSTRACT

Basin type solar still productivity is lower compared to the conventional desalination systems. Improving the design and use of porous basin material will increase the productivity of the still. In this work, experiments were conducted on modified stills to compare the performance with conventional still. Four stills S1, S2, S3 and S4 were tested simultaneously under similar environmental conditions. S1, S2 and S3 are modified stills and S4 is the conventional still. Two stills used a mixture of coco peat and charcoal (S1) and black sponge (S2) as absorber material. Still S3 and S4 have black painted basin with no absorber material. Experiments were conducted by taking different quantities of water in the range of 5–10 kg in the basin. Still S1 produced 10.85% more distillate over S3 due to material and 25.33% more over S4 due to material and design. Maximum distillate output of 4.80 L/m^2-d was obtained for S1 with 5 kg of water in the basin whereas S4 produced 3.83 L/m^2-d at an average solar radiation intensity of 687 W/m^2 (24.73 MJ/m^2-d). The estimated cost of 1 L of distilled water was found to be 1.39 INR (0.02 USD). High distillate, simple construction and low water production cost make the still S1 more practical and economical solution for developing countries.

Keywords: Black sponge; Charcoal; Coco peat; Double glass wall; Low cost; Solar desalination

1. Introduction

Distilled water has many applications right from the lead acid battery, automotive cooling systems, canning the foods, chemical and biological laboratories. In majority of the cases, electrical distillation method is used which is fast and easy, with a disadvantage of larger carbon footprint. In India, 1 kWh of electrical energy produced is equivalent to an emission of 1 kg of CO_2 [1] at the source, for coal based power plants. Including the losses of distribution and end appliance, the carbon emission reaches to 1.58 kg of CO_2 [2–4]. India, being a tropical country has more than 300 days of good sunshine in most of the parts. More than 90% of the places have annual average global horizontal radiation (GHI) in the range of 4.5–6.0 kWh/m^2-d [5]. So, use of solar energy could eliminate the carbon emissions due to the electricity consumption for production of distilled water. Solar still is a very proven technology and out of which basin type of solar still is good option among the various designs. Basin type of solar still has one disadvantage that of low distillate output per unit area.

Efficiency of solar still depends on the design parameters, environmental parameters and operational parameters. Environmental parameters such as solar radiation intensity, ambient temperature, wind velocity, dust and cloud cover affect the performance of the still. The environmental parameters are site dependent and hence can't be changed. Operational parameters like depth of water in the basin, surface cooling of condensing cover, salinity of water, operating still under vacuum, inlet water temperature, forced convection inside still are critical in

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the improvement of efficiency of the still. Depth of water level in the basin is one of the most significant factor that affects the output of solar still. Phadatare et al. [6] varied the basin water depth from 20 to 120 mm. They have obtained maximum output of 2.1 L/m^2-d for water basin depth of 20 mm. Their results concluded that with increase in depth of water, still productivity decreases. Tiwari et al. [7] conducted the experiments with five water depth varying from 40 to 180 mm. They found that the water depth has significant effect on the heat transfer coefficients. They obtained a significant nocturnal distillate output in case of higher water depth due to the storage effect and low ambient temperature during night. Feilizadeh et al. [8] investigated the effect of water depth and water surface to cover distance on productivity of the still separately. They also investigated the effect of water depth on productivity of still with the same water to surface cover distance. They found that reducing water surface to cover distance increases the distillate output up to 26%. The difference between the basin water temperature and condensing cover temperature has significant effect on distillate output. Lower the cover temperature, higher will be the distillate output. Surface cooling with water is one of the method to achieve the cover cooling. Suneesh et al. [9] used surface cooling technique using cotton gauze. They obtained 4.30L/m^2-d of distilled water with surface cooling using cotton gauze whereas without cotton gauze it was 3.30 L/m^2-d. Taamneh et al. [10] used forced convection in solar still using fan and obtained 25% improvement in distillate output over free convection still.

Design parameters include size and shape of still, type of still, material used for fabrication, basin material, heat storage material, use of external condenser, external and internal reflectors, inclination of condensing cover, thickness and material of condensing cover. Abdallah et al. [11]studied the effect of different basin materials on the productivity of the still. They found that gain in overnight production for coated metallic wiry sponges, uncoated metallic wiry sponges and black volcanic rocks of 28%, 43% and 60% respectively over a conventional still with no absorbing basin material (basin painted black). Abu-Hijleh et al. [12] conducted experiments with different size sponge cubes. They obtained an improvement in productivity over an identical still without cubes was in the range of 18% to 273%. Kalidasa Murugavel et al. [13] investigated different basin materials with minimum water mass. They concluded that light black cotton cloth was the effective wick material among light cotton cloth, sponge sheet, coir mate and waste cotton pieces. Heat storage materials store heat when it's available in excess and release it when it's available in less quantity. Use of heat storage material to improve distillate output of solar still during non-sunshine hours using latent heat storage material [14,15] and sensible heat storage materials [16–20] were investigated. To improve the efficiency of solar still, various design modifications like hemispherical still [21], conical still [22] triangular pyramid still [23], pyramid still with concave wick [24] were investigated. El-Sebaii et al. [25] used fins integrated with the basin liner of still to enhance heat transfer from basin to water. Deniz [26] investigated solar still coupled with vacuum tube collector to improve the productivity. Srivastava et al. [27] used low thermal inertia floating porous absorber to increase the productivity of still. Karimi Estahbanati et al. [28] used internal reflector in single slope solar still and found 34% increase in yearly productivity. Jones et al. [29] investigated performance of solar still with three different cover materials (glass, Plexiglas and plastic wrap).

The modified stills (S1, S2 and S3) are innovative than conventional still (S4) with respect to the wall design and absorber materials used. Modified stills used double glass walls with inner glass wall painted as black to avoid shade effect in case of conventional still. The air gap between the walls act as an insulator and reduce heat loss to the atmosphere. High porous mixture of coco peat and charcoal is used as an absorber material in S1. Use of natural absorber material with higher porosity and absorptivity may improve the productivity of the still.

The objectives of the present work are to: (a) enhance the productivity of basin type of still using cheap, environmental friendly basin materials (b) modify the design over conventional still (c) compare the yields of the present work with the reported values (d) compare the economics of different designs.

2. Materials and method

2.1 Experimental set up and procedure

In this work four geometrically identical basin type of solar stills (S1, S2, S3 and S4) were designed and fabricated. Three of them (S1, S2 and S3) are modified stills and S4 is the conventional type. Fig. 1. shows the schematic diagram of modified stills and conventional still. The solar still is divided into two parts 1. Tray and 2. Cover. The tray was fabricated using stainless steel sheet (1 mm thick) having about 0.5 m^2 (900 mm × 580 mm × 50 mm) basin area. The walls of cover have height of 40 mm and 260 mm for low and high side respectively to get an inclination of 14°. The inclination angle was approximately equal to (latitude +3°) which receives solar radiation normal to it for most period of the year. The cover of modified stills were fabricated with 4 mm thick window glass having double glass arrangement at the walls (excluding the front wall) with 30 mm air gap. The inner surface of the inner walls were painted with black paint to absorb more heat while outer surface of inner walls and both the surfaces of outer walls were kept transparent. The cover of conventional still was having same dimensions and its walls were fabricated using 12 mm plywood board and painted black from inside. Three modified stills differ from each other on the basis of basin material used. The material used for S1 was a mixture of charcoal and coco peat of 20 mm thick, S2 was black sponge material of 20 mm thick (Fig. 2.) and S3 basin was similar to the conventional still S4 with black painted basin and has no filler material. Expanded polystyrene of 20 mm thickness was used as an insulation. S4 was insulated at side walls, tray sides and bottom, while S1, S2 and S3 had been provided with insulation only on the tray sides and bottom. Silicone gel was used to stick glasses and glass putty was used between basin tray and cover to arrest water vapour leakage from solar still to the surroundings.

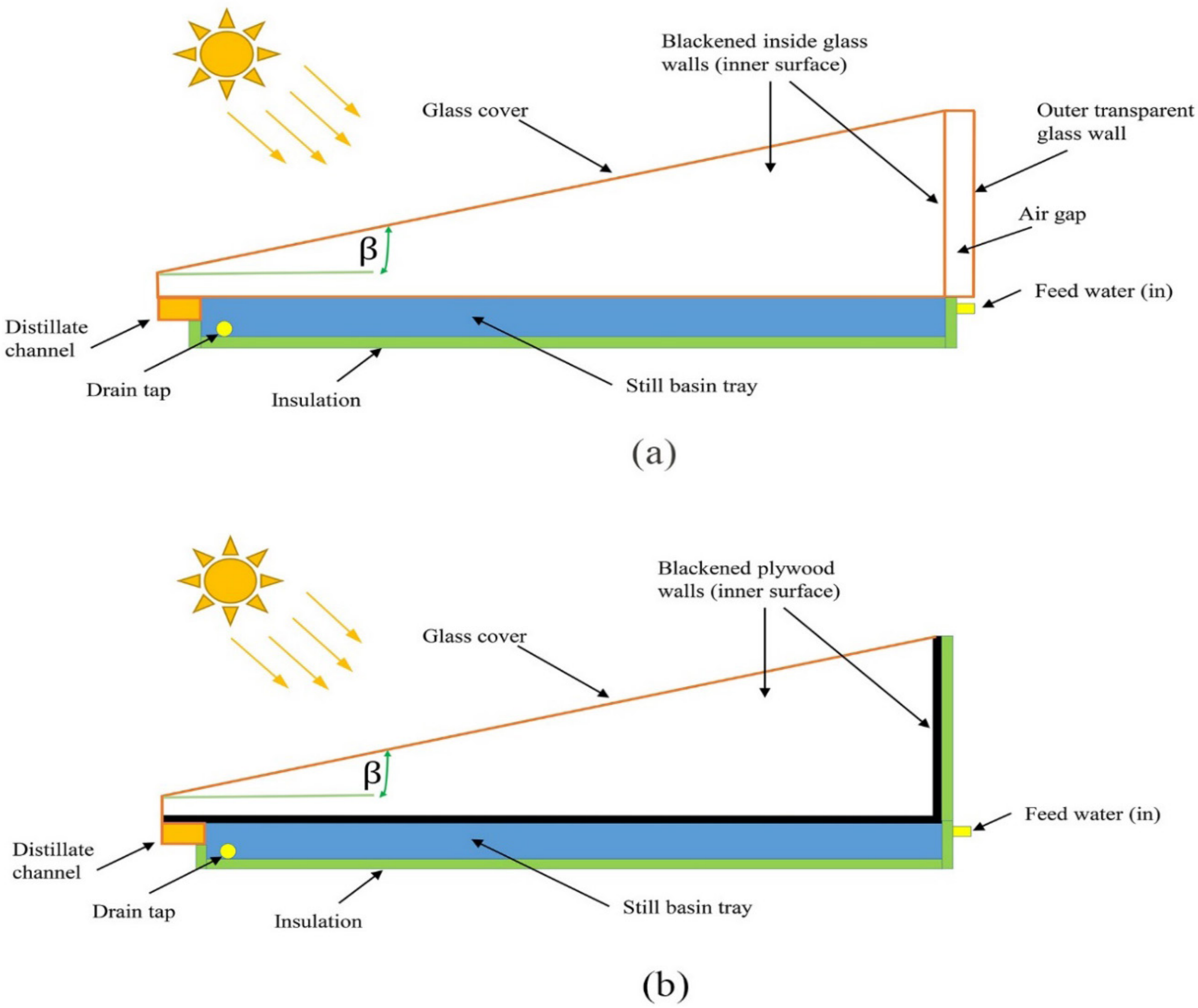

Fig. 1. Schematic diagram of a) modified still b) conventional still.

Fig. 2. Various basin materials (a) coco peat (b) charcoal powder (c) black sponge.

Experiments were carried at Solar Energy Lab, Department of Energy & Environment (DEE), NIT Trichy, Trichy (10.7589°N, 78.8132°E) during the months of March and April 2016 from 8.00 h to 18.00 h. All the four stills were kept side by side with their condensing covers facing due south and tested under similar atmospheric conditions to find out the exact improvement in their performance. Fig. 3 shows the photograph of the experimental setup. All the four stills were individually tested for 5 kg, 7.5 kg and 10 kg of tap water (approximately 10 mm, 15 mm and 20 mm basin depth respectively) in the basin. The solar radiation intensity, basin water temperature, inner and outer glass cover temperatures and ambient temperature were recorded for every 10 s with the help of data logger. Distillate output was measured every hour using the measuring jar and recorded manually. Table 1 shows the accuracy and range of different instruments used for experimentation.

2.2. Electrical distillation

Experiments were conducted to find out electrical power consumption to produce one litre of distilled water by resistance heater type electrical single distillation unit. An electrical single distillation unit (Riviera make) of 1.5 kW rating was used. The experimental set up is as shown in Fig. 4. Tap water was provided to the distillation unit with overflow arrangement to ensure the required level of water maintained in the equipment. Cooling water was provided to the glass condenser to condense water vapours formed because of boiling of water in the still. The power consumption was measured using Fluke 434 series II energy analyser. The distilled water output was measured using 500 ml measuring cylinder. Cooling water flow rate was measured using 500 ml measuring cylinder and a stop watch. The details of the experiment outcomes are given in Table 3.

2.3. Analysis of water quality

Samples of water obtained from solar still were tested for TDS, conductivity (Hach sension 5) and pH (DURALAB) at Bioenergy Lab, DEE, NIT Trichy. Samples of water obtained from single distillation unit, double distillation unit, split air conditioner, tap water and reverse osmosis plant were also tested for the purpose of comparison (Table 4).

2.4. Efficiency of solar still

Efficiency of the basin type solar still (η) was calculated using the following equation:

$$\eta = \frac{(m \times L)/3600}{A \times I \times H} \tag{1}$$

where m is the quantity of distillate in kg, L is latent heat of evaporation of water in kJ/kg, A is the basin area in m^2, I is the average solar radiation intensity in W/m^2 and H is the time interval in hour. Instantaneous efficiency was calculated with an hourly distillate output and average solar radiation intensity for that time period. Overall efficiency was calculated with overall distillate output including nocturnal output and average solar radiation intensity for the time period from 8.00 h to 18.00 h (10 h).

Table 1
Details of instrumentation

S. No	Instruments	Accuracy	Range
1	Kipp & Zonen Pyranomter	± 1 W/m^2	0–4000 W/m^2
2	Thermocouple	±1°C	0–100°C
3	Measuring jar	± 5 ml	0–500 ml
4	Data Logger Yokogava GX20	±1°C	0 to 100°C
		±0.06 mV	–20 to 20 mV

Fig. 3. Photograph of the experimental set up.

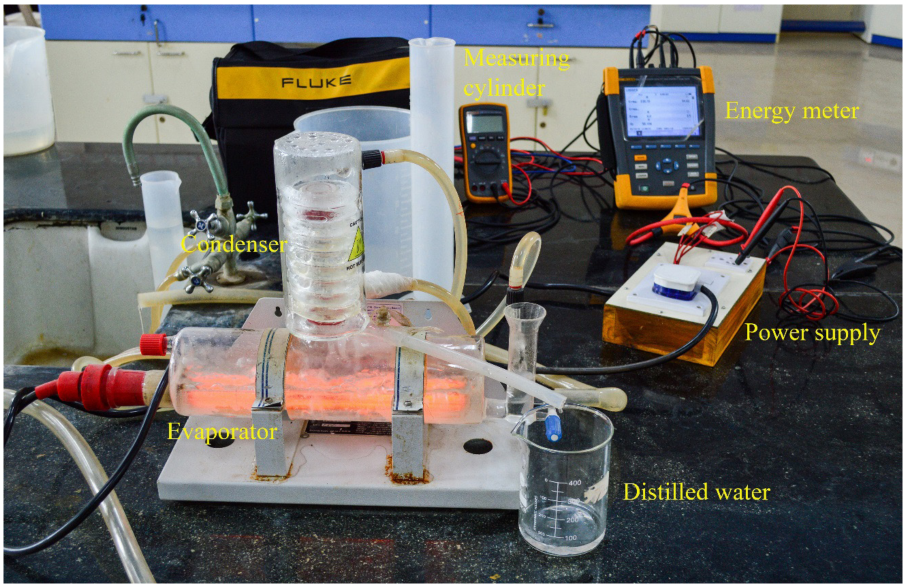

Fig. 4. Experimental set up for electrical single distillation.

Table 2
Cost breakdown of the solar stills (in Indian Rupees)

S. No	Component of still	S1	S2	S3	S4
1	Stainless steel basin tray (0.5 m^2)	2000	2000	2000	2000
2	Glass cover (4 mm)	250	250	250	250
3	Glass walls double/ single (4 mm)	400	400	400	–
4	Plywood wall (12 mm)	–	–	–	350
5	Expanded polystyrene insulation (20 mm)	100	100	100	100
6	Coco peat & charcoal	50	–	–	–
7	Black sponge	–	150	–	–
7	Black paint (250 mL)	60	60	60	60
8	Silicone sealant tube (260 ml)	120	120	120	120
9	Glass putty (0.5 kg)	20	20	20	20
10	Labour (1 man day)	400	400	400	400
	Total cost in INR (US$)	3400 (50)	3500 (51)	3350 (49)	3300 (48)

Note: 1 US$ = 68.28 INR (February 2016) (costs are based on Trichy market rates)

Table 3
Experimental parameters of electrical single distillation

Method of distillation	Electrical single distillation
Temperature of feed water and distilled water (°C)	28.10, 54.60
Temperature of cooling water in and out (°C)	28.10,43.50
Electrical power required for distilled water (kWh/L)	0.97
Temperature of overflow water (°C)	56.60
Flow rate of overflow water (L/h)	3.00
Cooling water required in (L/ h)	72.00

3. Results and discussion

Fig. 5. shows the hourly variation of solar radiation intensity and the ambient temperature for an almost clear day of the month of April 2016. It could be seen, that solar intensity reaches a maximum around 12.00 h whereas the maximum ambient temperature was reached around 15.00 h.

The cumulative distillate output of solar still including nocturnal output is shown in Fig. 6. Maximum distillate output of 4.80 L/m^2-d was obtained from still S1 with 5 kg of water in the basin whereas it was 3.83 L/m^2-d for conventional still S4. Still S3 produced 13.05% more distillate over S4 due to the design modifications whereas still S1 produced 10.85% more distillate over S3 with the use of coco peat and charcoal mixture as basin material. Hence S1 produced 25.33% more distillate over S4.

Table 4
Water quality comparison of solar still with other options

Quality parameters	Solar still	Single distilled water	Double distilled water	Split air conditioner condensate	Tap water	Reverse osmosis (drinking water) plant
TDS (mg/l)	10.58	3.20	0.80	16.50	670	81.50
Conductivity (μS/cm)	15.37	5.40	1.35	27.40	953	135.80
pH (at 25°C)	6.25	6.36	5.88	6.53	8.96	8.65

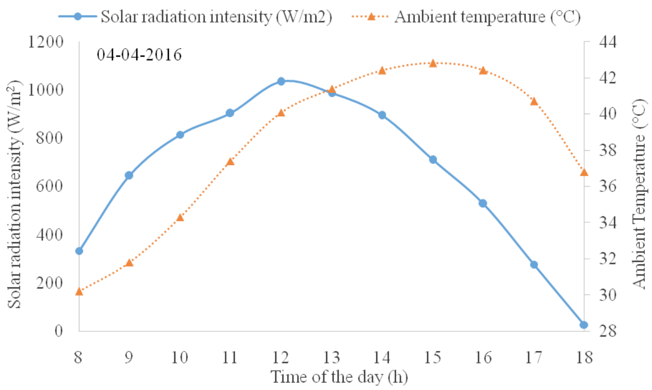

Fig. 5. Variation of solar radiation intensity and the ambient temperature.

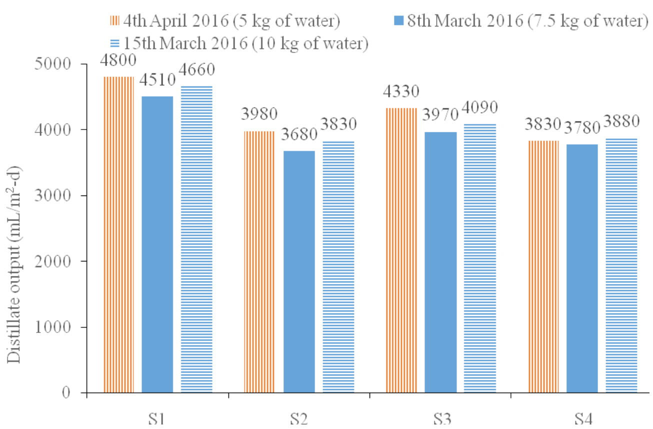

Fig. 6. Solar still productivity variation with 5 kg, 7.5 kg and 10 kg of water in the basin.

Average solar radiation intensity (over a period of 10 h between 8.00 h to 18.00 h) was 687 W/m^2 (24.73 MJ/m^2-d) on 04-04-2016 (5 kg of water in the basin), whereas it was 633W/m^2 (22.79 MJ/m^2-d)on 08-03-2016 (7.5 kg of water) and 656 W/m^2 (23.62 MJ/m^2-d) on 15-03-2016. When 5 kg of water was used in the basin, the average radiation intensity was 8.53% and 4.73% higher than 7.5 kg and 10 kg of water in the basin respectively. Table 5 shows the distilled water output with 5 kg of water in the basin compared to 7.5 kg and 10 kg of water in the basin. Effect of variation of solar radiation intensity on distillate output was higher in modified stills S1, S2 and S3 compared to the conventional still S4. Also distillate output variation was more in S3 indicating the influence of modified design of still was more compared to the different basin materials.

Table 5
Distillate output with 5 kg water compared to 7.5 kg and 10 kg water in the basin

Solar stills	Distilled water output with 5 kg water in the basin	
	Compared to 7.5 kg water in the basin	Compared to 10 kg water in the basin
S1	+6.43%	+3.00%
S2	+8.15%	+3.92%
S3	+9.07%	+5.87%
S4	+1.32%	-1.31%

Fig. 7. shows the variation of distillate output for solar stills with the time. All the four stills were having almost same output by 9.00 h. At 11.00 h, still S4 had maximum output while output for S1 and S3 were slightly lower. After 12.00 h output for S1 remained higher than other stills throughout the day. Distillate output for S4 fallen after 13.00 h whereas it increased for S2. Distillate output of S1 and S3 almost remained same up to 12.00 h after that output of S1 remained higher throughout the day.

3.1. Effect of absorber materials and modified design on the driving force

Variation of difference between basin and inner glass temperatures ($T_B - T_I$) of the stills with the time at 5 kg, 7.5 kg and 10 kg of water in the basin is shown in Figs. 8a, 8b and 8c respectively. Difference between basin and inner glass temperatures is a driving force for getting distillate output. Higher the basin water temperature compared to inner glass temperature, higher is the distillate output. In Fig. 8a, $T_B - T_I$ for all the four stills S1, S2, S3 and S4 is neg-

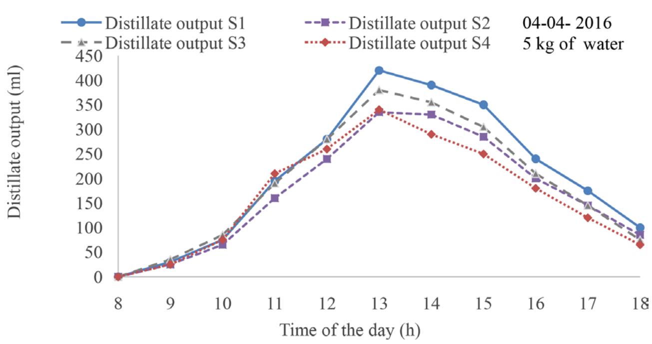

Fig. 7. Variation of distillate output of solar stills with the time.

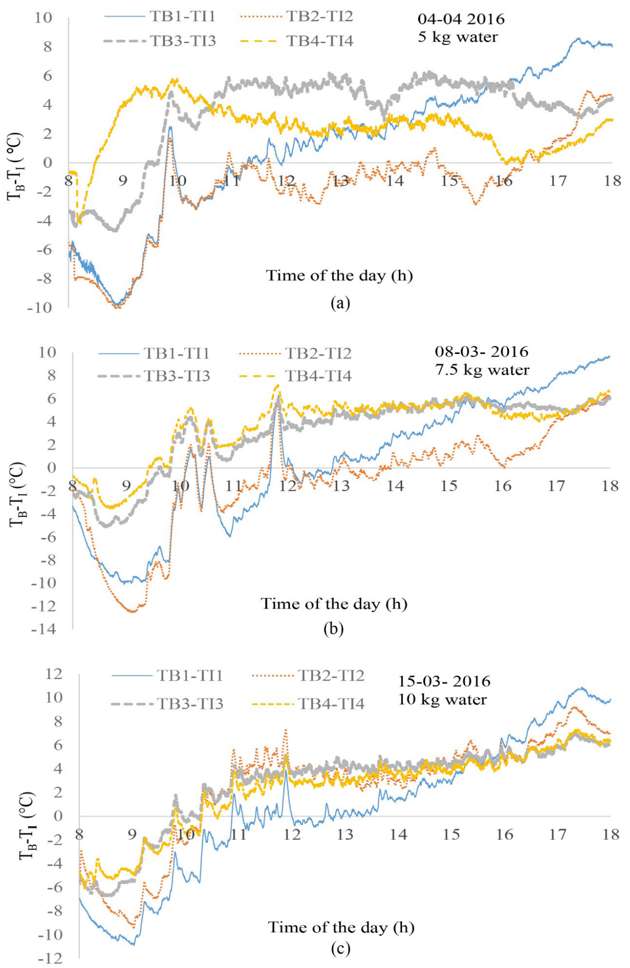

Fig. 8. Variation of difference between basin and inner glass temperatures of stills with the time at (a) 5 kg (b) 7.5 kg and (c) 10 kg of water.

ative in early hours due to thermal mass of water in the basin and lower solar radiation intensity. The side walls of modified stills which were black painted, absorb more radiation compared to the basin because radiation falls almost normal to the walls. The temperature of condensing cover glass increases rapidly for S1, S2 and S3, whereas it is not so for S4, due to the walls are made up of plywood. The higher negative value of $T_B – T_I$ for S1 and S2 compared to S3 is because water is more conductive and transparent in nature than the materials used in S1 and S2. Hence solar radiation directly goes to black painted basin surface in S3, heats total water mass and thus increases T_{B3} rapidly compared to T_{B1} and T_{B2}. For S4, $T_B – T_I$ becomes positive by around 8.30 h onwards and it remains positive for almost throughout the day. It takes little more time for S3 compared to S4, it becomes positive by around 9.30 h due to glass walls and it remains positive throughout the day. $T_B – T_I$ remains negative for S1 and S2 till 11.00 h with one sharp rise and fall due to reduction in solar intensity due to intermittent clouds. After around 11.30 h, $T_B – T_I$ keep on rising for S1 for the day whereas it keep on fluctuating for S2. The reason behind this is the material property of black plastic sponge which do not possess enough capillary action to keep its surface wet. The thickness of the black sponge is 20 mm and the depth of water level is approximately 10 mm for 5 kg water in the basin. The higher productivity of S1 compared to S2, S3 and S4 is due to the increasing positive temperature difference, $T_B – T_I$ with the time.

Fig. 8b shows similar trends as shown in Fig. 8a. The amount of water in the basin was increased to 7.5 kg which attains positive value of $T_B – T_I$, for S3 and S4 little after 9.30 h. Due to the increased thermal mass positive value of $T_B – T_I$, for S1 was attained by 13.00 h and for S2 by 14.00 h with few rise and falls due to the variation in solar radiation intensity.

Fig. 8c shows the variation of $T_B – T_I$ with the time for 10 kg of water in the basin. Due to the increased thermal mass, positive value of $T_B – T_I$, for S2, S3 and S4 attained little after 10.00 h, whereas for S1 it was after 13.30 h. The depth of 10 kg water in the basin was approximately 20 mm in height which was equal to the height of the black sponge used. This helps faster heating of water in S2 which resulted in positive value of $T_B – T_I$ and highest output for S2 obtained with 10 kg of water compared to 5 kg and 7.5 kg water in the basin.

3.2. Effect of water depth on productivity

The variation of productivity of S1 with the time at 5 kg, 7.5 kg and 10 kg of water in the basin has been shown in Fig. 9a. Up to 9.00 h productivity remains almost same for all the three quantity of water. After 9.00 h distillate output for 5 kg water in basin was higher compared to that with 7.5 kg and 10 kg water in the basin because of lower thermal mass. After 15.00 h distillate output decreases for 5 kg water in the basin and it increases for 10 kg water in the basin due to higher stored thermal energy. Productivity of S1 with 7.5 kg water in the basin remains in between that of for 5 kg and 10 kg water in the basin except a fall at 11.00 h and 14.00 h due to the lower solar radiation intensity during that period.

The variation of productivity of S2 with the time at 5 kg, 7.5 kg and 10 kg of water in the basin has been shown in Fig. 9b. Up to 10.00 h, the productivity remains almost same for all the three quantity of water. After 10.00 h distillate output for 5 kg water in basin was higher compared to that with 7.5 kg and 10 kg water in the basin because of lower thermal mass. After 13.00 h, distillate output decreases for 5 kg water in the basin and it increases due to higher stored thermal energy for 10 kg water in the basin. Productivity of S2 with 7.5 kg water in the basin remains in between that of for 5 kg and 10 kg water in the basin except a fall at 11.00 h and 14.00 h due to lower solar radiation intensity during that period.

The variation of productivity of S3 with the time at 5 kg, 7.5 kg and 10 kg of water in the basin has been shown in Fig. 9c. Because of lower thermal mass, productivity of S3 with 5 kg water remained higher than that of with 7.5 kg and 10 kg water in the basin from 8.00 h up to 14.00 h. After 14.00 h, the distillate output decreases for 5 kg water in the basin and it increases due to higher stored thermal energy for 10 kg water in the basin. Productivity of S3 with 7.5 kg water in the basin remains in between that of for 5 kg and 10 kg water in the basin except fall at 11.00 h and 14.00 h due to lower solar radiation intensity during that period.

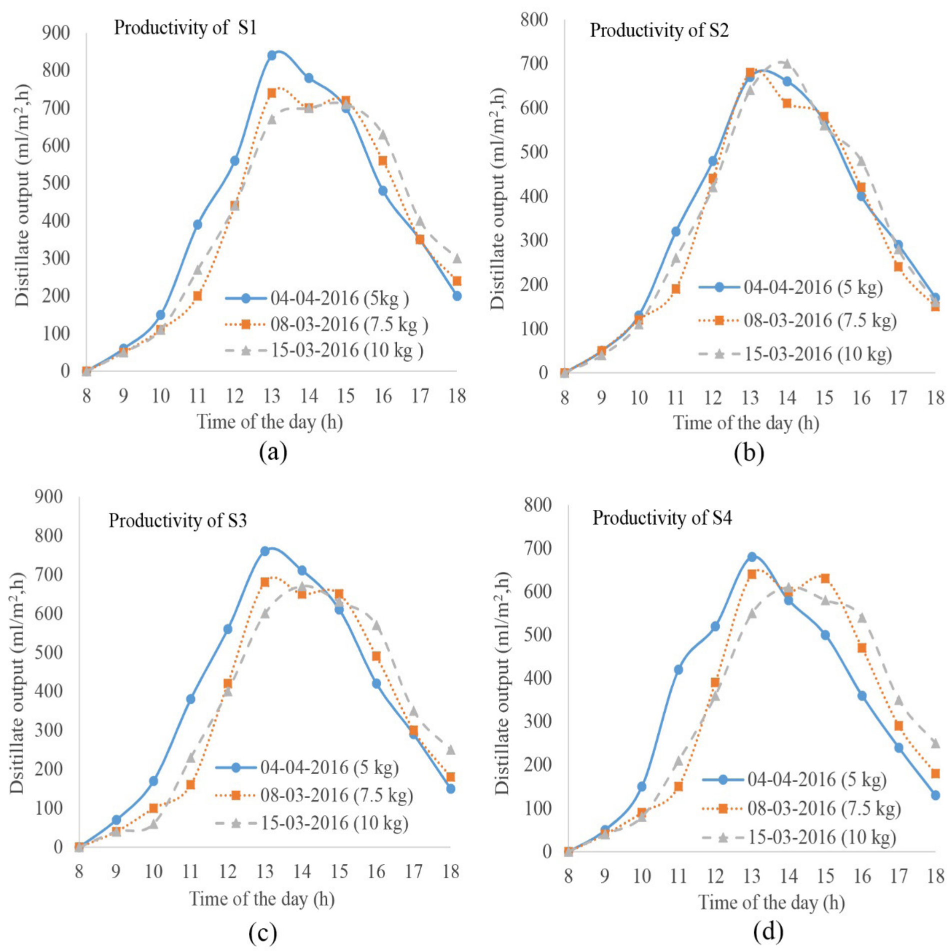

Fig. 9. Productivity variation of still (a) S1 (b) S2 (c) S3 and (d) S4 with respect to time at 5 kg, 7.5 kg and 10 kg of water in the basin.

The variation of productivity of S4 with the time at 5 kg, 7.5 kg and 10 kg of water in the basin has been shown in Fig. 9d. Up to 9.00 h productivity remains almost same for all the three quantity of water. After 9.00 h distillate output for 5 kg water in basin was higher compared to that with 7.5 kg and 10 kg water in the basin up to 13.00 h because of lower thermal mass. After 13.00 h distillate output decreases for 5 kg water in the basin and it increases for 10 kg water in the basin due to higher stored thermal energy. Productivity of S4 with 7.5 kg water in the basin remains in between that of for 5 kg and 10 kg water in the basin except a fall at 11.00 h and 14.00 h due to lower solar radiation intensity during that period.

3.3. Effect of design modifications and absorber material on the productivity

Modified stills S1, S2 and S3 differ in design from conventional still S4 in the construction of wall. Double glass wall with inner wall painted black absorbs solar radiation during early and late hours. Conventional still S4 has opaque wall which reduced the amount of solar radiation due to wall shadow. The productivity of the still is directly proportional to the solar radiation and hence modified stills S1 and S3 produced more distillate than S4. S1 used mixture of coco peat and charcoal whereas S2 used black plastic sponge. S1 produced more distillate than S2 due to the hydrophilic nature of coco peat. Still S1 performed better than S3 due to highly porous organic basin material whereas S3 had no basin material.

4. Performance and cost. analysis of solar stills

Comparison of the present work with the other basin type stills on their distillate output, total cost of the still and overall efficiency is presented in Table 6. The distillate output varies from place to place due to different environmental conditions, however, the overall efficiency value could be used to compare the performance of different stills [34]. Present work has the higher productivity than most of the other stills and lowest cost amongst all. The efficiency of the present still is also highest compared to the other basin type models, the reason being the response of the absorber material and design was very good with reference to the environmental conditions, i.e.

- Coco peat and charcoal mixture has higher absorptivity for solar radiation, good porosity to supply water to

Table 6
Comparison of productivity, total cost and overall efficiency of various basin type solar stills

S. No	Description	Location	Maximum distillate output	Total cost	Overall efficiency
1	"V" type still with cotton gauze cooling [9]	India	4.30 L/ m^2-d	200 USD	NA
2	Variation of distillate output of the still based on specific height [30]	India	4.186 L/ m^2-d	9000 INR (136 USD)	39.59%
3	Single slope plastic still [6]	India	2.10 L/ m^2-d	NA	34.00%
4	Single slope solar still [28]	Iran	4.25 kg/m^2-d	NA	NA
5	Integrated solar still with sandy reservoir [16]	Iran	3.00 L/m^2-d	NA	NA
6	Triangular pyramid still [23]	India	4.30 kg/m^2-d	NA	NA
7	External condenser and agitation used in single basin solar still [31]	India	2.667 kg/ m^2-d	27,400 INR/m^2	30.57%
8	Fin type solar still [32]	India	2.91 L/m^2-d	NA	NA
9	Modified solar still with water sprinkler [33]	India	3.541 L/m^2-d	NA	NA
10	Circular and square fins in the basin of solar still [4]	India	4.55 kg/m^2-d	154.17 USD	NA
11	Pyramid shaped solar still [10]	Jordan	2.616 L/ m^2-d	NA	NA
12	Solar still with concave wick surface [24]	Egypt	4.10 L/ m^2-d	145.5 USD	30.00%
13	Different types of wick materials in double slope type basin still [13]	India	2.05 kg/ m^2-d	NA	NA
14.	Double slope single basin still with different energy storage materials [17]	India	2.095 L/ m^2-d	NA	NA
15	Conical solar still [22]	Egypt	3.38 L/ m^2-d	NA	NA
16	Tilted still with basin and wick [34]	India	4.33 L/m^2-d	20,054 INR (299 USD)	43.10%
17	Single sloped basin still with porous fins [35]	India	7.50 kg/m^2-d	NA	NA
18	Single basin solar still with fins [25]	Egypt	5.065 kg/m^2-d	2764 LE (387 USD)	NA
19	Double walled basin type solar still with coco peat and charcoal mixture as basin material [Present work]	India	4.80 L/m^2-d	6800 INR (100 USD)	46.15%

NA: Not available

the surface by capillary action and also storage of solar energy during high irradiance.

- Double glazed walls used with air insulation at all the sides.
- The exterior surface of the outer wall of the still was transparent and interior surface of the inner wall was coated black.

The total fixed cost of the modified and conventional stills are given in Table 2. The minimum average daily productivity is considered as 3.50 L/m^2-d from experimental data. Assume the still operates for 330 days in the year, for Indian climatic conditions. Then the cost of 1 L of distilled water from the still S1 was estimated as 1.39 INR (0.02 USD).

5. Conclusion

Design, fabrication and testing of modified and conventional stills with different basin materials were performed for desalination of water. Modified still S1 and conventional still S4 produced maximum distillate of 4.8 L/m^2-d and 3.83 L/m^2-d, respectively at cumulative solar radiation of 24.73 MJ/m^2-d. Still S1 produced 20.60%, 10.85% and 25.33% more distillate than S2, S3 and S4. High porosity of coco peat and absorptivity of charcoal (S1) resulted in higher evaporation rate leading to the increased productivity. Black sponge (S2) is not recommended to be used as basin material since it gives lower output than the conventional still. Modified still S1 could be justified as a sustainable design since the material is eco-friendly and cost effective.

6. Nomenclature

A — Basin area (m^2)
H — Time interval (hour)
I — Average solar radiation intensity (W/m^2)
L — Latent heat of evaporation of water (kJ/kg)
m — Quantity of distillate (kg)
S1, S2, S3 and S4 — Solar still 1, 2, 3 and 4 respectively

Subscripts

B — Basin
I — Inner glass surface
O — Outer glass surface

Greek symbol

η — Efficiency of basin type solar still (%)
β — Inclination angle (degrees)

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