

Design and Performance Evaluation of Inverted Pyramid Type Solar Distillation Unit

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Abstract— Drinking water is still a big problem in most arid and remote area. There is almost no water left on earth that is safe to drink without purification after 20-25 years from today. This is seemingly bold statement, but it is unfortunately true. Only 1% of earth water is in a fresh, liquid state and nearly all polluted by both diseases and toxic chemicals. For this reason purification of water supplies is very important. The research work was under taken to design and performance evolution of inverted pyramid type solar distillation unit at Department of Renewable Energy Sources, CAET, Talsande, Kolhapur. In this study, Inverted Pyramid type solar still was designed and fabricated, and performance evaluation was carried. The distilled output was 350 ml. the maximum thermal efficiency was 32.2 %.

Key words: Purification of water, Solar still

I. INTRODUCTION

Water is the most abundant & important substance in nature. About 70% of the planet is covered in water, yet all that, only around 2% is fresh water and of that 2%, about 1.6% is polar ice caps and glaciers, 0.4% is drinkable water from underground wells or rivers and streams and nearly all of this is polluted by both diseases. Around 1.5 to 2 million children are die and 35 to 40 million people are affected by water borne dices (Palak patel et al). A toxic chemical for this reason purification of water is important. The need for safe, clean drinking water is increasing rapidly. The availability of clean portable water is a major problem faced

by the humanity in last few decades all over the world. It is estimated that out of 1, 62, 000 of 5, 75, 000 Indian villages alone face the problem of brackish or contaminated water (Srinivas et al., 2010). The increasing pollution will magnify the problem of water scarcity. This scenario is not sustainable for the future of mankind. There is need of major development in the solar distillation as solution to this problem. Therefore, research and development of solar still is one of the ways to provide a sustainable source of potable water in Indian context.

II. MATERIAL AND METHOD

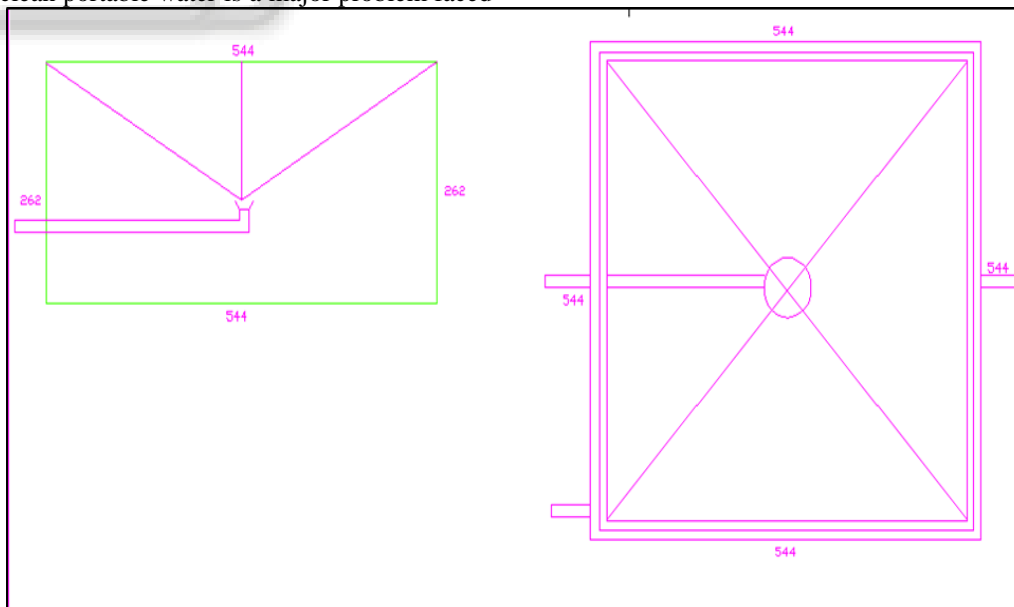
A. Experimental Location

The experiment was conducted in Pad. Dr. D. Y. Patil collage of Agricultural Engineering and Technology, Talsande. In summer temperature is about 22-40°C and in winter ranges from 12-30°C. Daily average temperature is 23-30°C.

B. Inverted Pyramid Type Solar Distillation Unit

It consist of deep, bracken basin of impure water covered with a four side sloping transparent roof solar radiation that passes through the transparent roof heats the water in blackened basin. Thus evaporating water which gets condensed on the cooler under side of the glass and gets collected as distillate attached to the glass.

C. Design of Solar Distillation Unit



1. Front view

2. Top view

Fig. 1: View of Pyramid type Solar Distillation Unit

The base of the solar still is made of G.I. (0.60 mm thick) box of dimension (1.64 x 1.64 x 25 cm). This box is embedded into another box of wood shown in figure 1. Here square box of 50cm x 50cm, Height H= 25 cm. This also

contains same box of thermocol inside it between the G.I box and wooden box. The thermocol is having 10 cm thickness. The collector is fixed at the center such that the water slipping on the surface of the glass will fall in this

collector under the effect of gravity. Four angle of glass having same size joined in inverted pyramid shape. Peak point of the pyramid is 15cm deep from the top edge of basin. Aluminum angle bolted with basin where top side of the glass is stick and fixed so that glass can rest on it. This completes the construction of the model. The holes for the inlet of water, outlet of brackish water and outlet of pure water is made as per the convenience. We have made the outlet of brackish water at right bottom of the model (seeing from front of the model), outlet of the pure water from the center of basin and inlet at the right wall above the outlet.

D. Components of Solar Still

1) Still Basin

It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material have high absorptivity or very less reflectivity and very less transmittivity. These are the criteria's for selecting the basin materials. We have used blackened galvanised iron sheet having size 1.64x 1.64 x 25 cm Box of G I.

2) Side Walls

It generally provides rigidity to the still. But technically it provides thermal resistance to the heat transfer that takes place from the system to the surrounding. So it must be made from the material that is having low value of thermal conductivity and should be rigid enough to sustain its own weight and the weight of the top cover. The thickness of the side wall was 12 mm and thickness of insulation used i.e. thermocol was 10 mm.

3) Top Cover

The passage from where irradiation occurs on the surface of the basin is top cover. Also it is the surface where condensed water gets collect.

4) Collector

The condensate that is formed slides over the inclined top cover and falls from peak point, this point which fetches out the pure water is called collector. The materials used were plastic funnel of 6cm diameter.

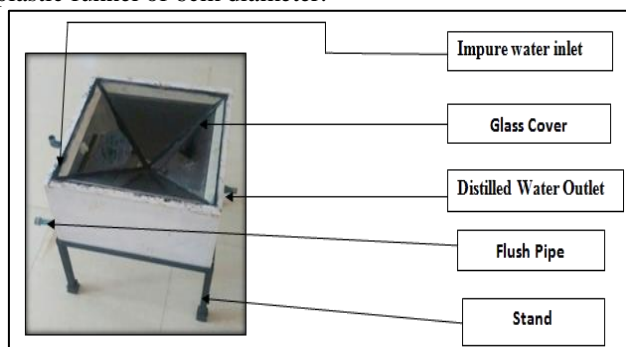


Fig. 2: Components of Basin type solar distillation unit

Sr. No.	Materials	Qty	Cost
1	Wood	1x450	450/-
2	Thermocol	3x10	30/-
3	G.I.	1x600	600/-
4	Glass	1x200	200/-
5	Funnel	1x15	15/-
6	Tap & Coupling	3x30	90/-
7	Fabrication	2000	2000/-
8	Stationary	300	300/-
Total			3685/-

Table 1: Cost of manufacturing solar distillation unit

E. Chemical Analysis

Chemical analysis of impure and pure (distilled) water which were used for the study was carried out for pH, electrical conductivity (EC), TDS (Mg²⁺, Ca²⁺, ions etc.)

F. Distillation Efficiency

$$\eta = \frac{Q \times 2.3}{G \times A}$$

Where,

Q = Daily output, lit/day

G = Global radiation, MJ/m²

A = Area of basin, m²

G. Cost economics of Solar Still

For the success of any new technology, it was essential to know whether the technology was economically viable or not. Therefore, an attempt was made for estimation of economic study of the Basin Type of Solar Distillation Unit.

H. Payback Period

The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment. It shows the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflows.

$$\text{Payback Period} = \frac{\text{Capital investment}}{(\text{profit} + \text{Depreciation})}$$

III. RESULTS AND DISCUSSION

A. Performance Evaluation

Inverted Pyramid Type Solar Distillation Unit was evaluated for winter season with load test.

Sr. No	Time, hr	Temperature °c			Wind Velocity (Km/hr)	Solar Radiation (W/m ²)
		Ambient	Inlet	Outlet		
1	10:00	29.4	31.9	29.3	1.7	390
2	10:30	31.1	37.7	33.6	0.8	480
3	11:00	32.2	35.5	43.8	0.9	574
4	11:30	34.6	42.6	44.5	4.0	641
5	12:00	33.9	44.8	53.1	5.3	643
6	12:30	34.6	47.8	56.2	2.9	662
7	1:00	37.2	48.5	59.2	2.1	623
8	1:30	34.2	48.8	60.5	2.5	583
9	2:00	34.9	49.5	57.5	4.5	515
10	2:30	35.3	48.3	52.8	1.5	371
11	3:00	34.5	47.1	47.4	4.2	282
12	3:30	31.0	45.1	41.4	1.6	190
13	4:00	32.8	41.2	38.9	1.5	67

Table 2: Measurement of temperature profile (15th Dec 2015) for depth 1 cm

B. Observations

- 1) Amount of impure water poured initially = 2.5 litre
- 2) Amount of pure water obtained at the end of the exp. = 0.350 litre

It was observed from Fig. 4.1 shows that as temperature increase with increases in time and vice versa. It was also observed that the maximum ambient temperature obtained at 1:00 p.m. i.e 37.2°C with inlet Temp. of 48.5°C.

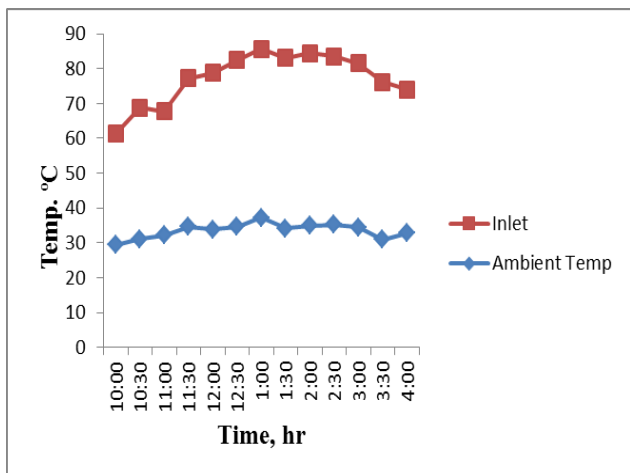


Fig. 3: Variation in Ambient temp., Inlet Temp. VS Time

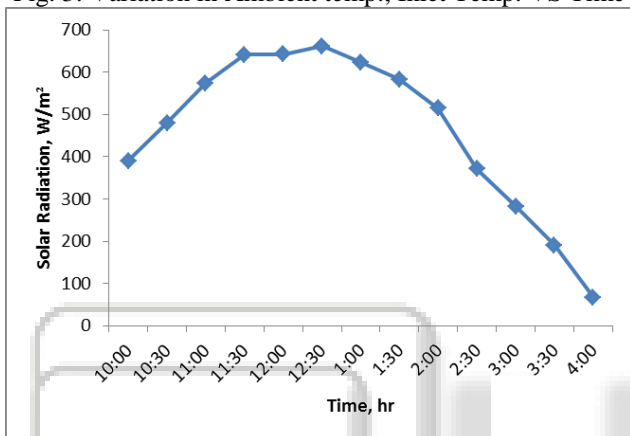


Fig. 2: Variation in Solar Radiation VS Time

Fig.2 shows that maximum solar radiation obtained at 12.30 p.m. i.e. 662W/m² and minimum solar radiation i.e. 67 W/m² obtained at 4 p.m.

Fig.3 shows that maximum Wind velocity obtained at 12.00 p.m. i.e. 5.3 Km/hr and minimum i.e. 0.8 Km/hr obtained at 10.30 a.m.

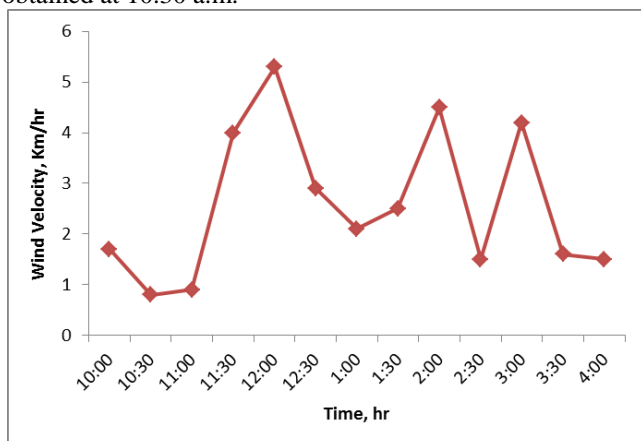


Fig. 3: Variation in Wind velocity VS Time

C. Distillation Efficiency

Efficiency of Inverted Pyramid type solar distillation unit was observed as 38.75%.

$$\eta = \frac{Q \times 2.3}{G \times A}$$

$$\eta = \frac{0.350 \times 2.3}{10 \times 0.25}$$

$$\eta = 32\%$$

D. Chemical Analysis of Water

Sr. No.	Chemical Property	Drain Water	Distilled water	Std. Result IS:10500(1991)
1	p ^H	8.5	7.5	6.5 to 8.5
2	TDS (mg/lit)	364 ppm	30 ppm	Less than 500

Table 3: Chemical analysis of impure and pure water samples

Chemical analysis of impure and distilled water which were used for study was carried out for pH, TDS depicted in Table 4.2 as can be observed from the table, chemical analysis of distilled and impure water had a reduction in the pH, and TDS etc. in the pure water.

E. Economic Analysis

The economic study of Inverted Pyramid type solar distillation unit was calculated on the basis of simple techno economic analysis It was observed from the calculation the cost of the system is recovered within 3 months only, that is the payback period of the unit was only 0.3years.

Payback Period = Capital investment / (profit + Depreciation)

$$= \frac{3685}{2500 + 368.15}$$

$$= \frac{3685}{2868.15}$$

Payback Period = 1.28 months

IV. CONCLUSION

- 1) From the graph we can conclude that the maximum ambient temperature obtained at 1:00 p.m. i.e 37.2°C with inlet Temp. of 48.5°C.
- 2) From the graph we can conclude that maximum solar radiation obtained at 12.30 p.m. i.e. 662W/m² and minimum solar radiation i.e. 67 W/m² obtained at 4 p.m.
- 3) Maximum Wind velocity obtained at 12.00 p.m. i.e. 5.3 Km/hr and minimum i.e. 0.8 Km/hr obtained at 10.30 a.m.
- 4) The efficiency of the still has been calculated as 32.2% and the distillate output collected as 0.350 L/day.
- 5) The payback period for double slope solar distillation unit were observed to be 1.28 months.

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