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Design and Development of Double Slope Type Solar Distillation Unit

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Abstract

Water is fundamental to human life on earth for survival and good health. Access to safe water is a major challenge in many communities in developing countries. As world population and social-economic growth, societies are challenged to provide fresh water to meet those needs for all of their people. Growing demands of freshwater resources are creating an urgent need to develop self sustained system to meet the demand of fresh water. Among the available purification technologies, solar distillation process proves to be a suitable solution for resolving this existing crisis. The sun's energy heat increases the rate of evaporation. As the water evaporates, water vapor rises and condenses on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The purpose of this research is to design a water distillation system that can purify water from nearly any source. The designed model produces 1.6 litres of pure water from 12 litres of dirty water during eight hours. The TDS in the pure water is 30 ppm. The efficiency is 22.33 % at water depth of 0.02 m.

Keywords: Solar distillation, TDS, pure water, efficiency.

Introduction

Water is the most abundant and 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 and35 to 40 million people are affected by water borne dices[1]. A toxic chemical for this reason purification of water is important and solution to these problems is solar desalination.

Solar distillation is very old technology. It is simple treatment of water purification. The basic principles of solar distillation are yet effective, the sun heat evaporates the water and the vapour condenses on inner surface of the cover. The condensate runs into trough from which it can be collected in storage containers. The solar still is Non-conventional, cheap, simple, easy to construct and is of low Thermal capacity. The two main categories of basin stills are single and double sloped. The double sloped basin still has two sloped pieces of glass rather than one. The main parts of still are basin, frame, glass cover and support structure. Solar distillation has advantage of cost saving over other types of distillation such as reverse osmosis[2].

Access to safe water is a major challenge in many communities in developing countries. As world population and social-economic growth, societies are challenged to provide fresh water to meet those needs for all their people Growing demands of fresh water resources are creating an urgent need to develop self sustained system to meet the demand of fresh water. Among the available purification technologies, solar desalination process proves to be a suitable solution for resolving this existing crisis.

Material and Methods

Experimental Location: Talsande has diverse climate. It is exceptionally hot and dry during summer with temperature reaching as high as 40^{o}C. Talsande receives about 1140 mm rainfall during monsoon, which is followed by pleasant temperature in winter. Talsande is situated at Latitude: 16 51' 46.2672" N and Longitude: 74 14' 19.77" E and Altitude of 605 m above sea level.

There are a number of parameters which affect the performance of a solar still. These were measured: Climatic Parameter: Solar Radiation, Ambient Temperature, Wind Speed, Humidity, Design Parameters, Operational Parameters, Water Depth: Water depth will be measured by measuring scale, Preheating of Water: Preheating of water will be measured by Thermometer, Input Water supply arrangement.

Components of solar still: Cover plate: The passage from where irradiation occurs on the surface of basin is top cover. Also it is the surface where condensate collects.

The glass used having thickness of 3.5mm and size is 800×410 mm.

Insolation: The insolation used in between the basin and the plywood to reduce the heat loss due to conduction. The material used was thermocol and thickness of insulating material was 6 mm.

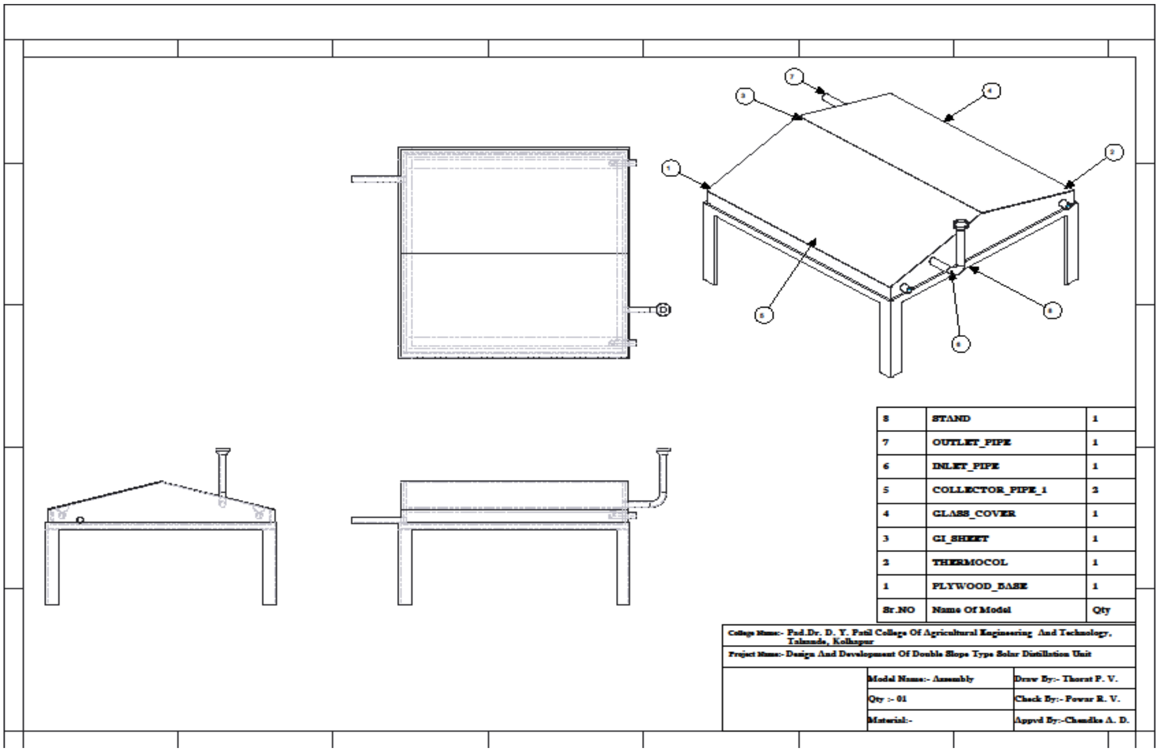

Figure-1
Constructional detail of Double Slope type Solar Distillation Unit

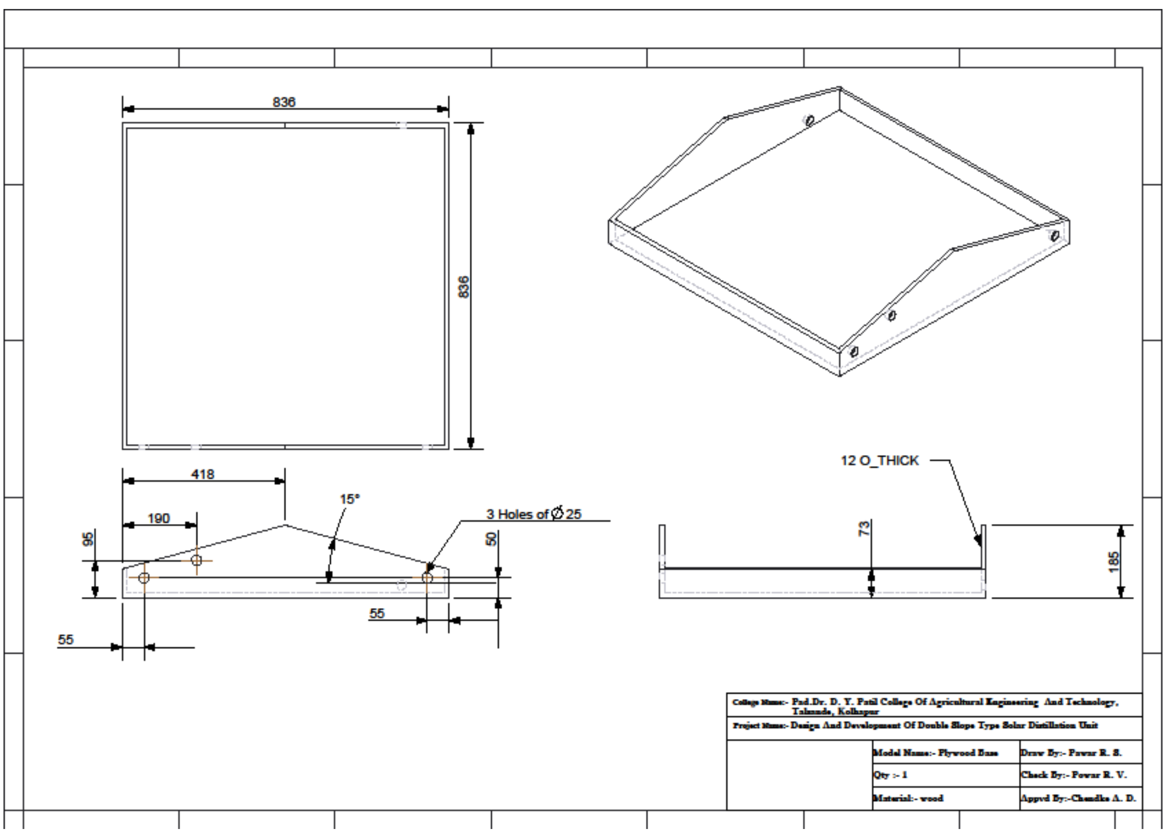

Figure-2
Design of basin of solar still

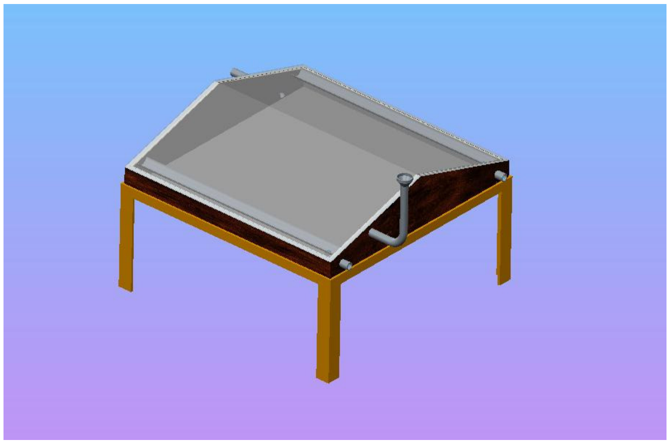

Figure-3
Proposed model of solar distillation system

Basin: Basin is the part of the system in which the water to be distilled was kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that, the material have high absorptivity and very less transmissivity. The material used for basin was galvanized iron and it was black painted to increase it's absorptivity. The area of the basin was 800×800×55 mm. The thermal conductivity of this material is $300 W/m^0 C$.

Collector: The condensate i.e. formed on the glass surface slides over the glass plate and falls in the passage. This passage which fetches out the pure water is called channel or collector. The material used for the channel was P.V.C.
Water inlet: The inlet pipe provided to supply water into water basin. Its diameter was 25 mm.

Water outlet: It was provided for removal of solid particles which were remains in the basin after evaporation. Its diameter was 25mm.

Determination of efficiency of Solar Still:

$$E= (Q\times2.3)/ (G\times A) \quad (1)$$

Where: Q= Daily output of distilled water (lit/day), E= Overall efficiency, G=Daily global solar irradiation (MJ/m^2), (1 kW-h = 3.60×10^6J), A= Area of basin still (m^2).

Chemical analysis: Chemical analysis of impure and distilled water which were used for the study was carried out for pH, TDS etc[3].

Economic evaluation of solar still: It was essential to check whether the technology was economically viable or not. Therefore, an attempt will be made for estimation of economic study of the double slope type solar distillation unit.

Pay-back 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.

Pay-back period = $Capital\ investment/(Annual\ profit + Depreciation)$

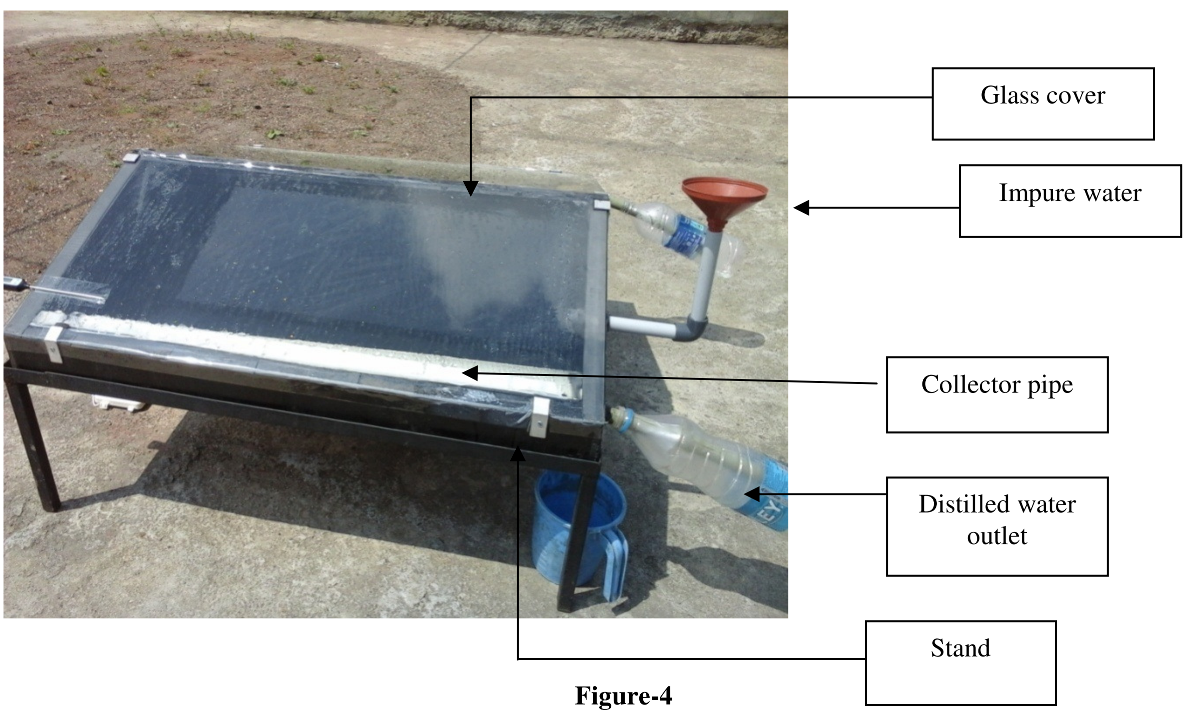

Figure-4
Double Slope type Solar Distillation Unit

Results and Discussion

Meteorological Conditions: The amount of sunshine hours was around 11.5 which was an average of the daily sunshine hours during the duration of data collection. The daily average insolation was about 20.81×10^6 Jm^{-2}. The ambient temperature during the project duration ranged from 19°C to 34°C with the highest temperatures always observed around 11:00-13:00 hrs.

Figure-5 represents the temperature variation in the solar still during eight hours. The maximum temperature in the system is of 63^0C obtained at 01:00 P.M.

Figure-6 represents the solar radiation variation in the solar still during eight hours. The maximum solar radiation in the system was 786 W/m^2 obtained at 12 P.M.

Table-1
Readings at 2 cm depth

Sr No.	Time (hr)	T_w (◦C)	T_{atm} (◦C)	T_g (◦C)	Humidity (%)	Solar radiation (W/m^2)	Wind velocity m/s)	Distillate (lit.)
1	09:00	32.5	25.2	28.5	62	54	3.2	
2	10:00	40.8	32.5	35.1	59	149	11.3	
3	11:00	48.5	33.6	42.8	56	281	3.2	
4	12:00	57.2	35.0	48.4	51	786	6.4	
5	01:00	60.4	35.8	50.2	46	717	1.6	1.6
6	02:00	60.3	35.3	50.0	45	547	1.6	
7	03:00	56.5	32.2	42.6	48	91	9.7	
8	04:00	49.7	31.1	33.5	50	42	8	
9	05:00	45.3	25.9	31.9	53	16	1.6	

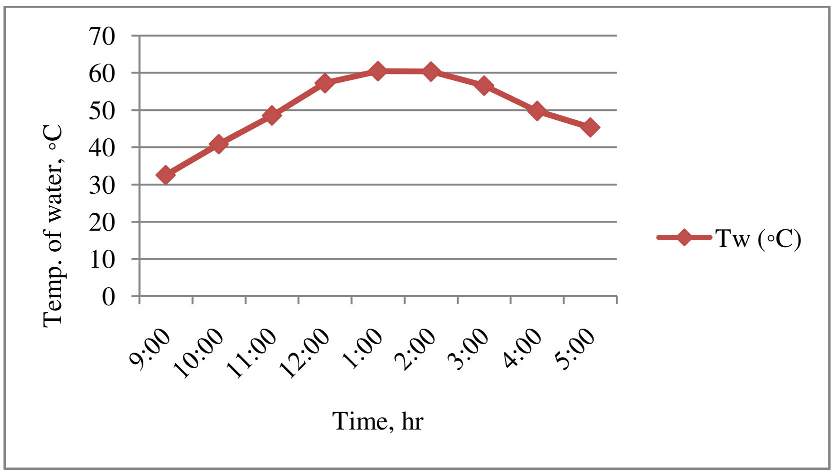

Figure-5
Temp. Vs Time

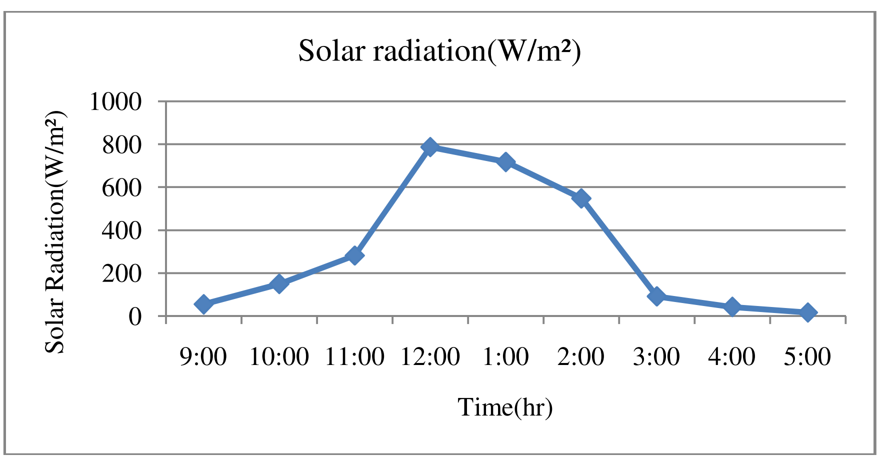

Figure-6
Solar Radiation Vs Time

Figure-7 represents the temperature variation in the solar still during eight hours. Maximum glass temperature i.e. 50^0C occurs at 1.00 p.m.

Observations taken: Time taken for drop to come to channel = 1 hour, Time taken for drop to come out of channel = 0.5 hour, Amount of brackish water poured initially = 12 litre, Amount of pure water obtained at the end of the exp. = 1.6 litre, Temperature of the condensate = 29 ^{0}C

TDS of purified water = 30 ppm.

Chemical analysis of impure and distilled water which were used for study was carried out for pH, TDS depicted in table-4,5 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.

Table-2
Chemical analysis of impure and pure water samples

Sr. No.	Chemical Property	Drain Water	Distilled water
1	p^H	8.5	7.5
2	TDS	364 ppm	30 ppm

Cost Chart: Determination of efficiency of Solar Still: E= (Q x 2.3) / (G x A), E= (1.6 x 2.3) / (25.74 x 0.64), E = 0.2233 = 22.33 %, Efficiency of distillation unit was observed as 22.33%, Economic evaluation of solar still

Table-3
Represents the cost of manufacturing of solar distillation unit

Sr. No.	Materials	Qty	Cost
1	Plywood	1	520/-
2	Thermocol	2	60/-
3	G.I. sheet	1	930/-
4	Glass	2	300/-
5	P.V.C. Channel	2	70/-
6	Stand	1	400/-
7	Tap pipes and elbow	3	60/-
8	Fabrication	-	1000/-
9	Stationary	-	200/-
Total			**3540/-**

Cost estimation: The economic study of double slope solar distillation unit was calculated on the basis of simple techno economic analysis shown in the Table 4.7. This indicates that solar base distillation system is operated 250 days (except only in rainy days) in western region of Maharashtra in a year and produces 400 litre distilled water. Comparing electric operated distillation system, it consumes 260 electric units (1.042 × 250) to produce 400 litre distilled water in India, people have to pay Rs. 6.5 per electric unit (KWh) in the domestic sector. The total cost to operate electric base distillation unit to produce 400 L distilled water is Rs.1693.25. (Rs. 6.5 × 260.5). Hence, we could save Rs.1693.25 per year by utilizing this solar distillation system for obtaining distilled water and hence could save electricity in huge[3].

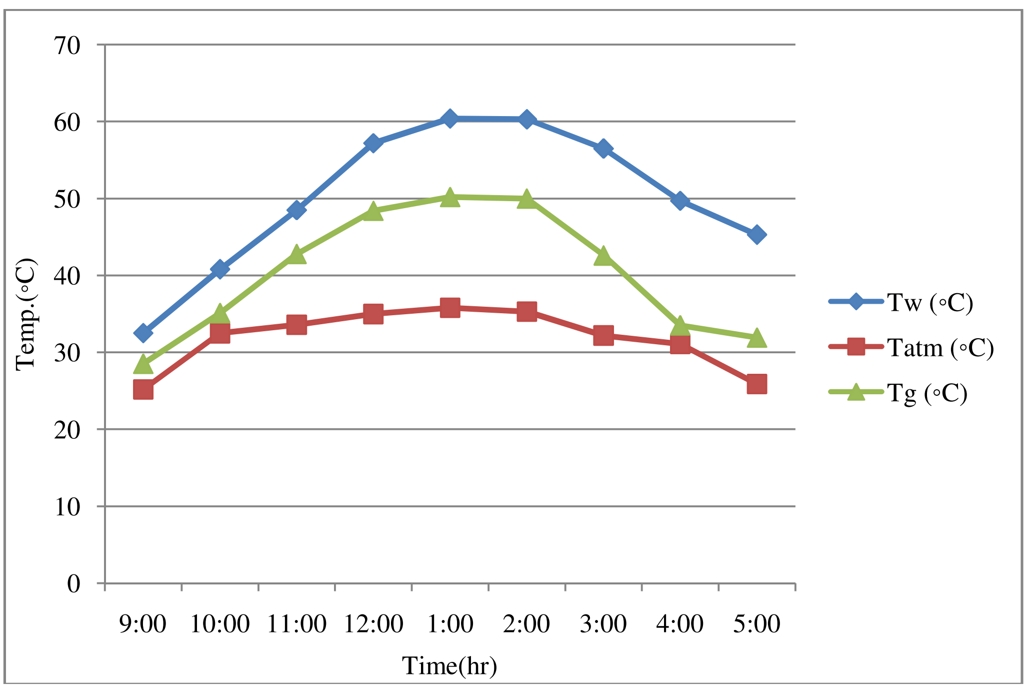

Figure-7
Temp. Vs Time

Table-4
Energy measures for techno economics of distillation systems

Energy measures	**Solar system**	**Electric system**
Energy required to evaporate 1.6 L water		
E = m × Cp × Δt + m × λ	1.042 kWh	1.042 kWh
m = Mass of water (1.6,kg)		
Cp = Specific heat of water (1 Kcal/kg/°C)		
Δt =Average temperature difference of water (52°C)		
λ = Latent heat of vaporization (540 Kcal/kg)		
Energy required for 400 L distilled water in 250 days in a year (kWh)	260.5	260.5
Electricity tariff to produced 400 L distilled water in Rs.6.5		1693.25/-
Revenue generated from 400 L distilled water at Rs.20	8000/-	8000/-
Net profit from system in Rs.	8000/-	6306.75/-

Pay-back 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.

Pay-back period $= Capital\ investment/(Annual\ profit + Depreciation)$.

=3540/ (4460+354)
=0.73

The payback period for double slope solar distillation unit were observed to be 7 months.

Conclusion

From the graph, we can conclude that the increase in temperature and hence the evaporation is maximum in the period of 12:00 am to 02:00 pm. The brackish water we have supplied was 12 litres and at the end of the experiment we got 1.6 litre distilled water. The TDS level of purified water obtained is 30 PPM. So the water obtained is potable. The efficiency of the still has been calculated as 22.33% and the distillate output collected as 1.6 L/day. The payback period for double slope solar distillation unit were observed to be 7 months.

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