EXPERIMENTAL INVESTIGATION OF SOLAR STILL OPERATED WITH PARAFFIN WAX, PELTIER MODULE AND PARABOLIC TROUGH COLLECTOR FOR DESALINATION OF BRACKISH WATER

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Abstract: The fast depletion of non-renewable sources of energy has increased the use of solar energy. Solar Energy is free, unending and eco-friendly. This research paper focuses on the study of performing and analyzing a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable and depends only on non-conventional solar energy. Direct and indirect methods are used for desalinating brackish water to clean water. Solar desalination process by using phase changing material utilizes a minimum amount of energy to produce portable water and this process is completely eco-friendly and it also utilizes minimum area for installation. Solar parabolic trough collector heats water for solar still and thermoelectric system increases condensation at top of the glass. This modified system increases the production rate of pure water. The condensed water on the inner glass is collected in a separate channel every 60 minutes and measured. For each modification, hourly output is recorded and compared with conventional still. This system is suited for water desalination in remote areas and rural places which have low availability and limited demand.

Index Terms **- Solar energy, Solar still, Peltier cell, Thermoelectric cooling, Phase change material, Paraffin wax, Parabolic trough collector**

I. Introduction

In a modern era, water requirement is increasing continuously because of industrial development, village development, intensified agriculture, and improvement in the standard of living and an increase in the world population. Need of water for humans is 1 or 2 litres per day. The minimum requirement for water for a person in developing countries is 20 litres per day. The scarcity of water occurs in underdeveloped areas or villages. To solve this problem, some new drinking water sources are being discovered, and new water distillation techniques are being developed. Distillation is one of many processes that can be used for water purification. Solar energy is clean, easily available, inexhaustible, and non-conventional energy. The energy input in form of heat and solar radiation is the source of energy. When solar energy is used for this purpose, it is known as Solar Water Distillation. Solar Distillation is an attractive process to produce portable water using free of cost solar energy [Hrushikesh Kulkarni, Chinmay Kute (2015)]. Solar distillation is an attractive alternative because of its non-complicated technology as well as no requirement of highly skilled labour for maintenance work and low energy consumption [S.S. Thipse (2014)].

II. Literature Survey

1) Meganathan. V, Sriman Saii. P. V, et al., have carried out experiment of Water Desalination in Solar Still using Phase Change Material (Paraffin Wax). The total water collected without paraffin wax was 1830 [ml] and with paraffin wax the water collected was 1910 [ml].
2) Kantesh.D.C, has carried out experiment of Water Desalination in Solar Still using Phase Change Material (Paraffin Wax). The total water collected without paraffin wax was 750 [ml] and with paraffin wax the water collected was 810 [ml]
3) Patil Digvijay Tanaji, et al., have carried out experiment of Parabolic Trough Collector based Solar Water Heating System using Forced Circulation. They found out that using Aluminium surface the temperature was around 103°C and using glass surface with forced circulation they found out the temperature of glass surface was around 125°C.
4) S. Nanda Kumar, et al., have carried out experiment of Water Desalination in Conventional Solar Still. They compared the water temperature inside solar still of white coloured surface and black coloured surface. They found out that at 1:00 pm, the water temperature inside white solar still was 53°C and water temperature inside black solar still was 76°C.

III. Methodology

The main objective of this method is to get portable water from brackish water using solar energy. Following modified methods and tools are included for improving production rate of clean water and effectiveness of evaporation and condensation.

- ***Parabolic Trough Solar Collector***

Solar parabolic reflector is connected to a conventional still with a connecting pipe. Parabolic reflectors increase the temperature of water up to 65-68 ºC which recirculate to the still for increased evaporation rate of water [V.K Jebasingh G, M Joselin Herbert (2015)].

- ***Thermoelectric Cooling and Heating***

Thermoelectric cooling is a way to remove heat energy from a medium, device or component by applying a voltage of constant polarity to a junction between two dissimilar electrical semiconductor or conductor materials [Rakesh B, K Anuj Sayan(2016)]. Thermoelectric cooling system works on Peltier principle. Peltier module cell is used for cooling glass surface to improve condensation effect of evaporated water [Mahesh P Gotte, P R Walke (2019)]. Another Peltier cell is used for heating paraffin wax as PCM material.

- ***Phase change material (PCM)***

A phase change material releases and absorbs heat energy to maintain a regulated temperature. When a phase change material is in the solid phase, it absorbs heat as the temperature increases. The temperature of the phase change material increases till its melting point is reached. After the external temperature decreases, the phase change material starts to release the energy which is absorbed from it. During the phase change process, the changed material would absorb a large amount of heat with no change in temperature. Phase change materials are very suitable in heat absorption or release of energy by changing phase [Meganathan V, Sriman Saii (2019)].

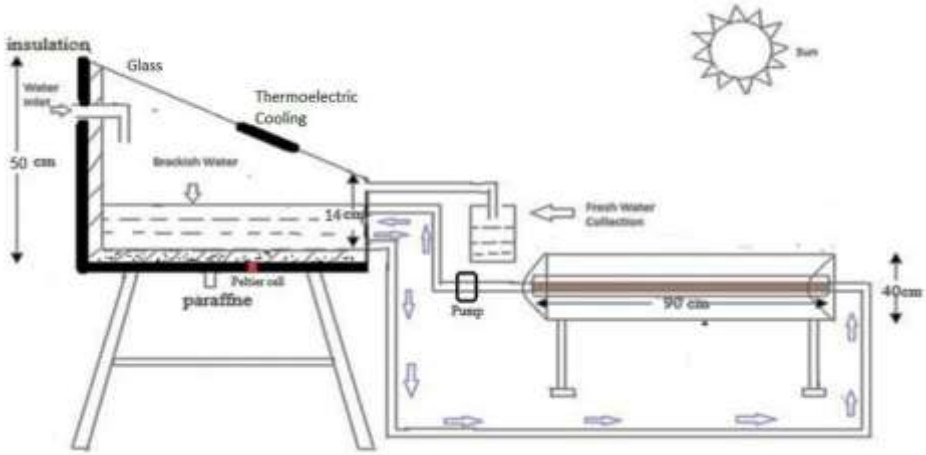


Fig 1. Schematic diagram of solar desalination experimental setup.

IV. Experimental work of Solar desalination system

- **Experimental work Setup components**

Table 1. Components of the modified solar desalination system

Sr. No	Name of Components	Specification or Dimension of Component and Description	Diagram / Figure
1.	**Solar Still**	• Material: Mild Steel • Dimension: 600 x 500 x 500 [mm] • Front Step Height: 14 [mm] • It stores brackish water and converts it into freshwater	
2	**Transparent Glass**	● Thickness - 6[mm]. ● Transmitivity-89%. ● Density-2500 [kg/m^{3}] ● The angle of Tilting: 30º ● Allows sunlight through it and the water vapor is condensed on it.	

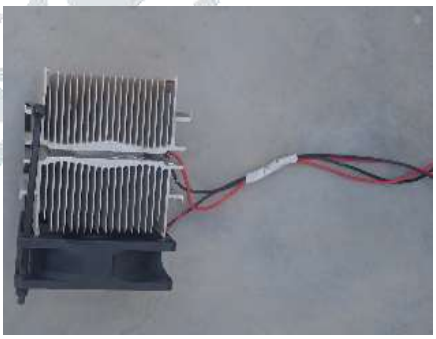
3.	**Solar parabolic trough collector**	• Material: Reflecting glass. • Length: 900 [mm] • Radius of Curvature: 75 [mm] • It increases the temperature of the water before it reaches the solar still.	
4.	**Evacuated tube with U shaped copper pipe:**	• It increases temperature of inlet water. • Evacuated tubes are known for their fast-heating properties.	 
5.	**Phase Change Material**	• Melting point- 37 [℃] • Colour - white. • Density- 900 [kg/m3]. • Boiling Point – 322 [℃]. • It can absorb the heat in the daytime and liberate that heat during night time. The main purpose of using PCM is to increase the yield of fresh water. Paraffin wax in the form of a slab is used.	
6.	**Thermoelectric heating and cooling Unit**	• Voltage: 12 [Volt] • Current: 6 [Amp] • Material: aluminum and semiconductor • Material: Aluminum sink and Peltier module • It removes the heat and decreases the temperature of the system. It is located at the top of the glass.	
7.	**Solar Panel**	• Voltage: 17.11 [Volt] • Power: 25 [Watt] • Solar panel supply power for operating water pump, Peltier module.	
8	**Water Pump**	• Material: Plastic • Voltage: 12 [Volt] • Current: 4 [Amp] • Used for water circulation.	

Fig 2. Experimental setup used for practical experiment work.

- **Experiment work procedure**

The fabrication of the system was completed in the last week of February, 2021. Assembled it on a rooftop of a high building where sunlight was sufficient to experiment.

- We performed the experiment for 5 consecutive days from 8th April to 12th April, 2021 with different setups and with 10 liters of water in every setup.
- On 8th April, 2021, experimented using convectional still which had only solar still and no other attachments were added. We measured water collected every hour from 8 am to 6 pm and at the end of the day we measured the amount of water collected.
- On the 9th April, 2021, experimented with adding paraffin wax to the bottom of convectional still which was being heated by a Peltier cell placed below it, as a result, there was more heating in water, the water temperature increased as compared to conventional still and hence evaporation rate was increased. Similarly, at the end of the day, we measured the amount of water collected.
- On the 10th April, 2021, carried out an experiment adding 4 Peltier cells on glass in which the cooling side of Peltier was attached to the glass surface and they were getting power from a solar panel. This was done to increase the condensation rate. We measured the glass temperature throughout the day every 60 minutes. At the end of the day, we measured the amount of water collected.
- On the 11th April, 2021, experimented adding a parabolic reflector on the surface of which glass was there to reflect and concentrate the sunlight at a point. Along with that, an evacuated tube containing U shaped copper tube was placed at that point. This was done to increase the temperature of inlet water. The temperature inside the evacuated tube was measured every hour and we also circulated the water for 10 minutes every hour inside U shaped copper tube which was placed inside the evacuated tube. And at the end of the day, we measured the amount of water collected.
- On 12th April, 2021, performed experiment integrating all the previous 4 systems. And the experiment was carried out similarly.

In this experimental model PCM placed above insulating material. The PCM gets heated and melts when its temperature reaches its melting point, and when the melting process is complete its temperature continues to rise based on the intensity of solar radiation and length of the day. In this process, the energy is stored in the PCM which is released back after declining atmospheric temp. The maximum energy released from it is observed by brackish water and some energy will be lost based on the insulation in the system. Due to this, the water evaporates and is adhered to a glass slab, then the condensed vapor flow down gradually. As the brine concentration in the system increases, it must be discharged out of the system. The cycle repeats from morning to evening. The vapor from the glass slab is collected in the collector through pipes and are portable. By reducing the temperature of the glass through the Peltier cell, the temperature of the water which is stick to the glass reduces the boiling point of the water also reduces. So, the output of the freshwater will increase.

V. Result and Discussion

Experimental analysis has been made to study the effective temperature of water and glass concerning time and analysis of pure water productivity.

Tables 2 and 3 show experiment work data with daytime and comparison of the designed system.

Table 2 Experimental Data for distillation systems

Time	Conventional Still			Modified Still with Wax		Modified Still with Thermoelectric			Modified still with parabolic trough collector	
	Water collected	Water Temp (°C)	Glass Temp (°C)	Water collected	Water Temp (°C)	Water collected	Water Temp (°C)	Glass Temp (°C)	Water collected	Water Temp (°C)
08:00 AM	0 [ml]	26	21	0 [ml]	26	0 [ml]	27	21	0 [ml]	25
09:00 AM	0 [ml]	27	23	0 [ml]	27	5 [ml]	28	22	9 [ml]	27
10:00 AM	5 [ml]	28	24	7 [ml]	28	8 [ml]	28	23	11 [ml]	30
11:00 AM	12 [ml]	32	29	14 [ml]	34	12 [ml]	35	28	19 [ml]	37
12:00 PM	17 [ml]	39	37	20 [ml]	41	19 [ml]	40	35	24 [ml]	44
01:00 PM	19 [ml]	46	39	24 [ml]	47	25 [ml]	46	40	29 [ml]	50
02:00 PM	24 [ml]	52	41	26 [ml]	53	31 [ml]	51	42	38 [ml]	54
03:00 PM	29 [ml]	53	46	33 [ml]	57	38 [ml]	52	43	46 [ml]	68
04:00 PM	17 [ml]	52	45	25 [ml]	54	35 [ml]	52	43	35 [ml]	63
05:00 PM	8 [ml]	50	39	17 [ml]	49	29 [ml]	48	40	28 [ml]	60
06:00 PM	0[ml]	42	36	13 [ml]	46	16 [ml]	40	36	22 [ml]	56
Total	**131 [ml]**			**179 [ml]**		**218 [ml]**			**256 [ml]**	

Table 3. Comparison of Conventional still and Modified still with all designed attachments

Time	**Conventional Still**			**Modified Still with all designed attachment**		
	Water collected	**Water Temp (°C)**	**Glass Temp (°C)**	**Water collected**	**Water Temp (°C)**	**Glass Temp (°C)**
8:00 AM	0 [ml]	26	21	0 [ml]	28	21
9:00 AM	0 [ml]	27	23	14 [ml]	30	21
10:00 AM	5 [ml]	28	24	26 [ml]	32	22
11:00 AM	12 [ml]	32	29	32 [ml]	39	28
12:00 PM	17 [ml]	39	37	43 [ml]	49	34
1:00 PM	19 [ml]	46	39	49 [ml]	58	41
2:00 PM	24 [ml]	52	41	55 [ml]	67	42
3:00 PM	29 [ml]	53	46	57 [ml]	73	42
4:00 PM	17 [ml]	52	45	43 [ml]	66	42
5:00 PM	8 [ml]	50	39	36 [ml]	61	39
6:00 PM	0 [ml]	42	36	27 [ml]	56	35
Total	**131 [ml]**			**382 [ml]**		

- On 8th April, 2021, we carried out experiment and at the end of the day we got around 131[ml] of water.
- On 9th April, 2021, we carried out experiment adding paraffin wax to the bottom of convectional still which was being heated by a Peltier cell placed below it, and at the end of the day we got around 179 [ml] of water which was greater than previous system.
- On 10th April, 2021, we carried out experiment adding 4 Peltier cells on glass in which cooling side of Peltier was attached to glass surface and they were getting power from solar panel. At the end of the day, we got around 218 [ml] of water which was greater than previous two systems.
- On 11th April, 2021, we carried out experiment adding a parabolic reflector on the surface of which glass was there to reflect and concentrate the sunlight at a point. Along with that a evacuated tube containing U shaped copper tube was placed at that point. As a result, the temperature inside the evacuated tube was around 95-100 °C and at the end of the day we got around 256 [ml] of water which was greater than previous 3 systems.
- On 12th April, 2021, we carried out experiment integrating all the previous 4 system together. As a result, we got around 382 [ml] of water at the end of the day which was much greater than all the previous systems. Hence, we got around 3 times more water as compared to conventional still, which was aim of our project to increase production and efficiency of convectional solar desalination system.
- In each system the water initially used was having TDS reading of around 700 and finally in every system we were getting TDS readings ranging between 100-130 which is nearer to that of mineral water.

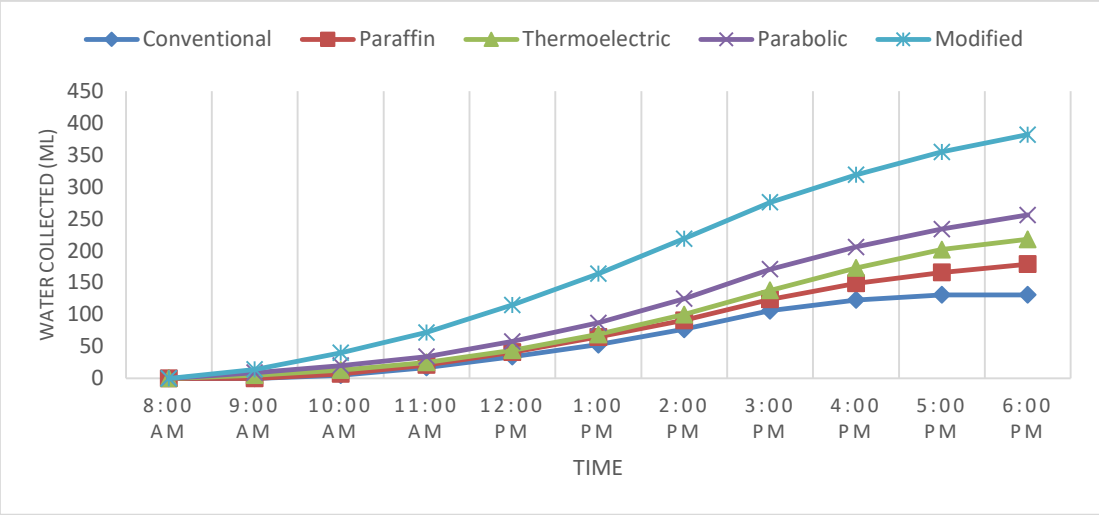


Fig. 3 Graph for Water collected (ml) Vs Time

Table 3 depicts the total water collected for different systems which is a plot of all readings in Table 2. The dark blue line shows a total of 131 [ml] water collected by the convectional system. The red line shows a total of 179 [ml] water collected by modified still with paraffin wax. The green line shows a total of 218 [ml] water collected by modified still with the thermoelectric system. The purple line shows a total of 256 [ml] water collected by modified still with parabolic reflector and the light blue line shows a total of 382 [ml] water collected by Modified still (All together). Therefore, in every modification, we were able to achieve higher efficiency and production as compared to conventional still.

As shown in Fig.4 glass temperature of the modified solar still system is lower than a conventional still system. In Fig.3 different modified parameters are shown like conventional still, modified still with wax, modified still with thermoelectric cooling, modified still with parabolic collector, and modified still with all integrated parameters. As shown in Fig.5, temperature of water is highest for the modified solar still system. Productivity of pure water is higher for modified still system compared to conventional still system.

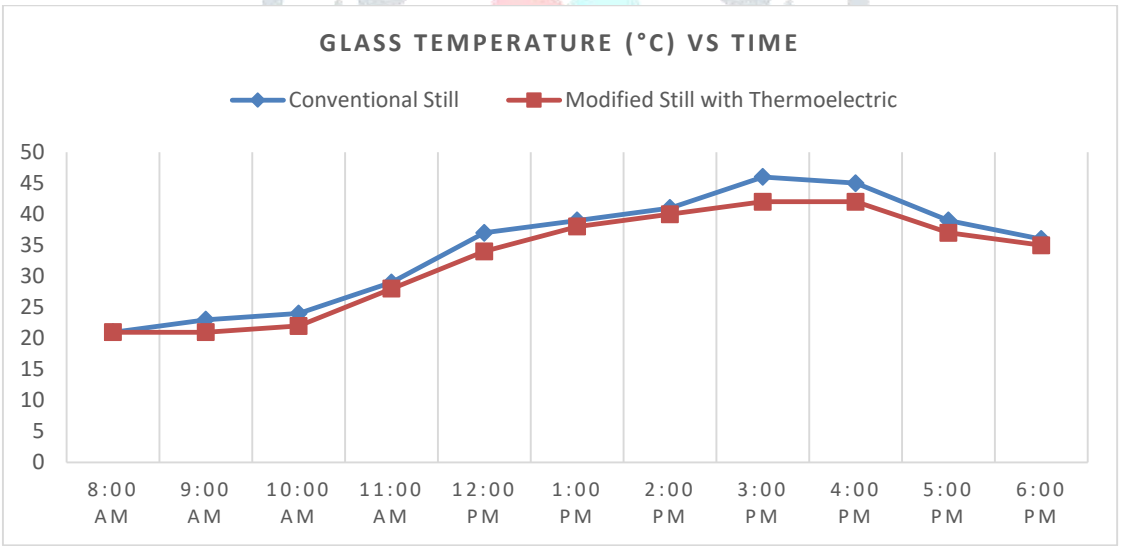


Fig.4 Graph for Glass temperature Vs Time

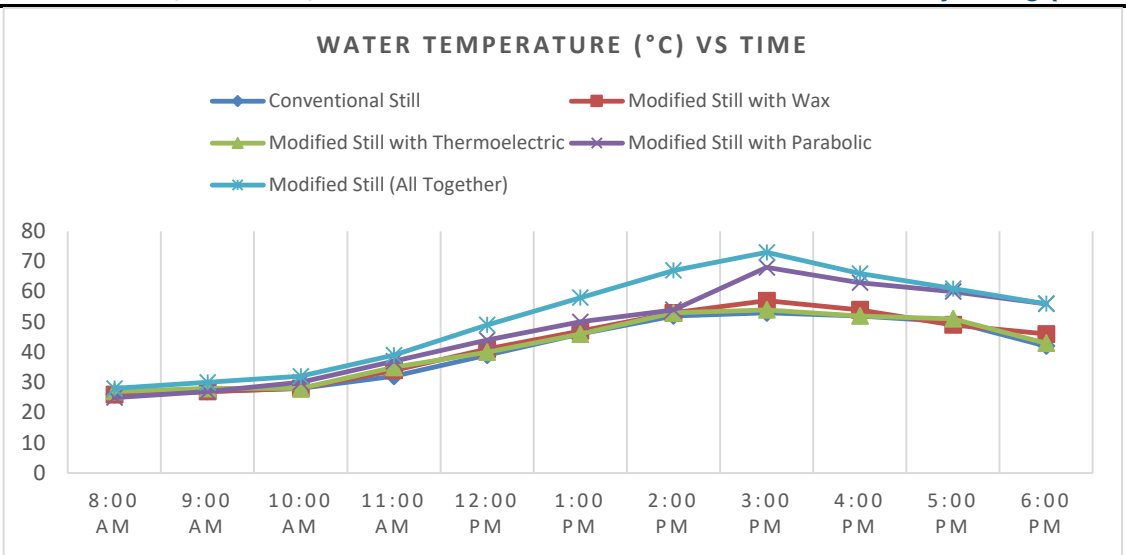


Fig.5 Graph for water temperature Vs Time

- **TDS Reading**

The initial TDS reading was around 700 and the final reading we were getting was in the range of 100-130 which is almost nearer to mineral water shown in Fig.6.

Fig. 6. Distilled Water TDS value

VI. Conclusion

The Solar still equipped with Paraffin Wax, Thermoelectric Cooling System and Parabolic Trough Collector is designed and fabricated to improve the daily yield and efficiency of the still. From the test carried out, the following conclusions are:

- The conventional solar still and modified solar still experimental results show that there is temperature increase in modified solar still as compared to the conventional solar still.
- The conventional solar still and modified solar still experimental results show that the distillation rate is higher in modified solar still as compared to the conventional solar still.
- From 8 AM to 6 PM, distilled water collected from the conventional solar still is 131 [ml], while 382 [ml] distilled water is collected in total for modified solar still which is almost 3 times of the water collected in conventional solar still.
- Modified solar still efficiency is better as compared to conventional solar still.

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