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Performance Enhancement of a Solar Water Distillation System Using External Reflector and Auxiliary Heating



Abstract: - Solar water distillation is a simple, cheap, and sustainable technique for freshwater production; however, its low productivity and limited operation during nighttime remain major challenges. This research investigated experimentally the performance enhancement of a solar water distillation system through the use of an external reflector and auxiliary heating elements. Initially, daytime experiments were conducted to evaluate the effect of an external reflector on volume of freshwater collection. The results show that the use of the external reflector with the solar still produced 110 ml more distilled water collected in 11 hours of observation compared to not using it. To further enhance evaporation during nighttime and enable continuous operation, external heating elements were integrated at the bottom of the solar basin, therefore a 24-hour observation was carried out. The total collected volume of distilled water increased significantly to 2504 ml with the help of the heating elements which is powered by 32 Ah battery through solar PV. This result demonstrates that the combined use of an external reflector and heating elements effectively enhances freshwater productivity and enables continuous day–night water distillation, making the system more viable for practical and remote applications.

Keywords: Solar water distillation, Solar still, External reflector, Auxiliary heating elements, Day–night distillation, Renewable desalination.

Introduction

Water distillation is very useful to purify the water in rural and coastal areas where electrical energy is not available to do so. In the fourth century, a process was discovered to make drinkable water, like evaporation and condensation. Arabian people are the first known to use this process in sixteen centuries. The references for this acknowledgement type are only regarded as the theoretical stage. No one considered the practical use of solar water distillation at that time. In 1872, the first solar still was discovered in Las Salinas by Charles Wilsan. This solar still consists of a water basin that occupies 4450 square meters, which is made of blackened plywood and covered by a glass that is placed at an inclination. The inclination of glass depends on the latitude of that place where the solar still is placed. This is the first time this type of system has been used in a mining operation for animals approx. The water made by this process is 19680 liters per day. After this distillation process is widely used in rural areas that are far from the main city or where electricity is not easily available, this type of project will be essential [1]. A large part of this society does not have drinkable water, which is a major issue in rural areas and where electricity is not easily available. So to avoid this type of problem, water management is necessary, which is why this project is gaining popularity day by day in the coastal and rural areas. This distillation is the most sustainable and most economical distillation in this time. The requirement of this process is increased because of the free solar energy [2]. The circumstance of water is not as good as any other before; the generation had to face the problem of drinkable water. We cannot expect to live comfortably on Earth without access to drinkable water. Water from natural sources might have several kinds of impurities. There is a large impurity dissolved in seas and ocean water, which is very harmful to the human body as well as animals [3]. There are many places where water does not exist in a consumable structure because of pollution, substantial metal substances, and saltiness. So as to make water consumable, it must be blessed to dispose of life forms, equipped for causing a wide range of infections, and contain minerals and natural substances that could cause hurt. Consumable water ought to be lackluster and be free from scent, evident turbidity, and taste. Throughout the years, significant increments in populace development, substantial mechanical use, and poor water management by the executives have caused shortages of water far and wide. The flow away and flow environmental modification among diminished rain seasons are relied upon to intensify circumstances, convincing humanity to search for possible wellsprings of water.

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A Research was done by A. Mehta et al. [4] in which it was observed that the water is more distilled in between 11:30 am to 1:45pm and after that the temperature starts decreasing. The TDS level achieved by this was 81 PPM. Similarly, research was done by P. Kalita et al [5] in IIT Guwahati. This research reviewed recent development in solar distillation system in which the evaporation process depends on the various parameter such as the intensity of solar radiation, size of solar basin transmission capacity of glass, temperature of water inside the basin, the angle of glass which is covered the basin and depth of water. S.L.Jadhav et al. [6] fabricated four solar still of different capacities and analyzed rate of distilled water production. The highest purification was recorded between 11:30 am to 12:30 noons. The TSS, TDS, TS, sulfates, and chloride were reduced to zero after the solar distillation in the entire four still. A. bhattacharya [7] performed research on solar water distillation in rural household and upgraded the solar water distillation system to improve performance and increase the evaporation rate of water inside the basin. The fabrication of solar still is such as which is evaporate more water at low temperature. A theoretical analysis of water distillation using solar still was performed by D.W. Medugu and L.G. Ndatuwong [8]. They experimented on distillation performance of the solar still system having distillation efficiency of 99.67% as compared to the theoretical analysis. R. K. Jain et al. [9] estimated the most effective geometrical and location of solar distill, which increased volume of the distilled water by increasing the evaporation rate and also fabrication should be strong enough to bear the external effect of temperature. Md. M. Uddin and A. I. Sifat [10] investigated the optimization of different parameters of the distillation process and fabricated a solar still focusing the cost and effectiveness toward solar water purification. A review was done on this type of distillation by R. Gugulothu et al. [11], who used thermal energy storage to increase their output and efficiency of solar power. They experiment combination of sun tracking system coupled with PCM, dyes sponges and Nano material. A. Ahsan et al. [12] evaluated designs of seven types of solar stills (sphere-shaped, pyramidal, and semi-circular, twice over basin, concentric couples) which are used in the process of distillation. The maximum efficiency was observed in tubular solar still due to concentrator effect. M. Afrand et al. [13] introduced external reflector to the basin to reflect the solar radiation to the glass which is covered. The glass should be inclined at define angle which is the latitude of that place where solar water distillation is installed. Further M. Afrand et al. [14] presented a system having inclined glass cover at 25 degrees which depends on latitude of that position and measured the temperature of glass cover, seawater interface and moist air using numerical method. The experiment was performed by R. Singh et al. [15] on passive type of solar water distillation which might be single basin and double basin.

1. Methodology

The distilled water works on the same principle as rain. The seawater evaporates, then condenses, and then returns to earth as rain. In solar water distillation, the same process is working. First, water evaporates in the basin, after that condenses on the inner surface of glass, and then is collected through a pipe in the collection tank. Both the rainwater and the distilled water are safe, and their pH value, total dissolved solids (TDS), and conductivity are also the same. A glass is covered on the solar stills, which allow transmitting the solar radiation into the inner water. The inner surface of the solar basin is blackened by black silicon to increase the solar radiation absorption. When water starts to vaporize, then moisture in the air is trapped between the solar base and surface of glass, which is the infrared region (long-wave radiation) [16]. The long wave radiation inside the cover is not transmitted through glass, which is why it reflects into the still. In this way the greenhouse effect is obtained. After that condensation, only salt and microbes are left behind on the basin, and condensed water is collected through a pipe in the collection tank. There are no moving parts in the solar distillation system, so no maintenance is required. This process is continuously working until sunset and beyond that if water remains hot. Daily one-time water should be added, and daily one-time water should overflow through overflow port [17].

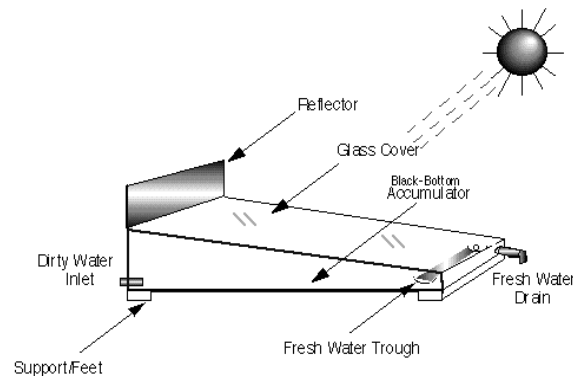


Figure 1: Working of solar still [16]

2. Design and fabrication of Solar water distillation with reflector

The basic operation of the distillation process is to evaporate the water in the wood box and condense water. Standard plywood is used in this process to provide strength and store the contaminated water. The surface is capable of bearing the external and internal damages. In this research, the dimensions of the solar basin's base are 790 mm by 610 mm. The area can increase or decrease depending on the amount of distilled water required. The area increases with more water and decreases with less. The front height of the wood box is 16 cm, and the back height of the distillation box is 42 cm. All the specifications and dimensions are described in Table 1.

Glass is inclined at a 30-degree angle from the base of solar water distillation, which depends on the latitude of that place where the solar water distillation system is placed to work which is shown in figure 2. The inner surface of the solar basin is whitewashed with black silicon, which absorbs solar radiation due to the high absorption capacity of the colour black.

When the solar radiation is incident on the glass, then water vaporizes and condenses on the inner surface of the water. Water from the inner side of the glass is collected in a tank with the help of a collecting pipe.

The various parts and materials used in designing of the solar still is given below:

- Transparent cover
- Black liner
- Basin tray
- Sealant
- Insulation
- Condensate channel
- External reflector

Table 1: Specifications of fabricated Solar distillation system

Specifications	Dimension
Basin area	4819 cm square
Top glass area	4712 cm square
Glass thickness	5 mm
Height(front)	16 cm
Height(back)	42 cm
Thickness of plywood	1.5 cm
Slope of the glass	30 degree



Figure 2: Solar water distillation with using reflector

3. Results and Discussion

The observation has been completed on the solar water distillation system in month of April. Contaminated water is packed in basin and with the help of evaporation and condensation process distill water is collected through outlet pipes in the tank.

The observation and measured values are recorded in different hours throughout the days. Volume of water collected with and without the help of reflector which is shown in Table 2.

It is observed that with the help of reflector plate volume of water collected through solar water distillation system is more than that of solar water distillation system without reflector plate which is also shown in Figure 3.

Table 2: Volume of water obtained without and with using reflector

Observation Time	Volume of water obtained without using reflector(ml)	Volume of water obtained with reflector(ml)
9:00-10:00	70	82
10:00-11:00	90	106
11:00-12:00	100	120
12:00-13:00	120	150
13:00-14:00	95	110
14:00-15:00	130	160
15:00-16:00	80	95
16:00-20:00	420	470
Total Duaration (in hours) = 11 hours	1105	1215

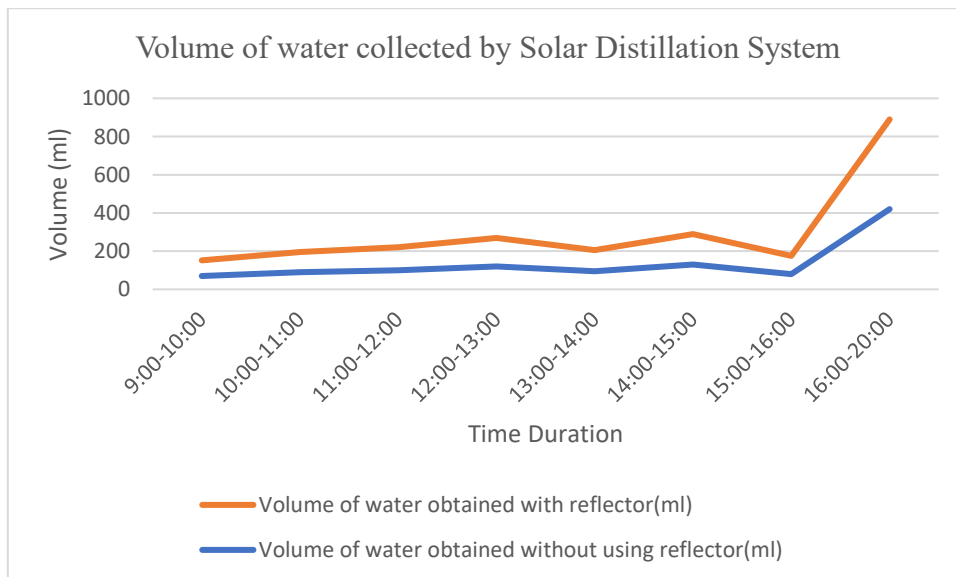


Figure 3: Comparison of volume of water collected by Solar Distillation System with and without reflector

Further, to increase the evaporation rate of contaminated water, heating elements are used at the bottom surface of basin of solar still which is powered by 32 Ah battery through solar PV which is shown in figure 4. Variation of electrical parameters of Solar PV and battery with time duration are shown in Table 3.

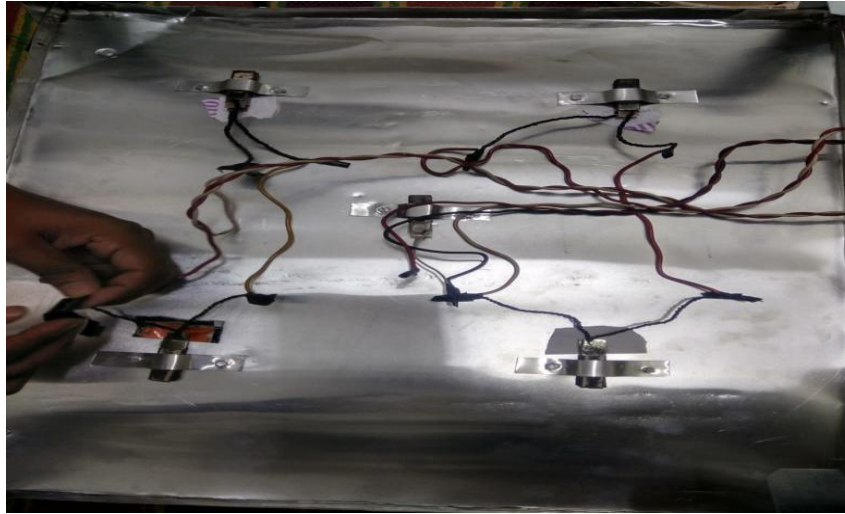


Figure 4: Heating Element at the bottom surface of basin

Table 3: Variation of electrical parameters of Solar still with Heating element powered by Solar PV throughout day

S. No.	Time duration	Open circuit voltage across solar panel terminal (volt)	Battery connected with heating element	
			Voltage across battery terminal (volt)	Current delivered to the load (amp)
1	7:00-8:00	8.9	8.2	4.55
2	8:00-9:00	10	8.8	4.88
3	9:00-10:00	12.3	9.4	5.22
4	10:00-11:00	14.3	11.2	6.22
5	11:00-12:00	16	12.4	6.88
6	12:00-13:00	17	12.6	7
7	13:00-14:00	18	13	7.22
8	14:00-15:00	18	12.9	7.16
9	15:00-16:00	16	12.4	6.88
10	16:00-17:00	12.4	12.2	6.77
11	17:00-19:00	10	8.1	4.5

Further, solar water distillation system with heating elements is put under observation for 24 hours which is shown in figure 5.

During day time, water is distilled by both direct solar radiation and heating element through battery. Hence volume of distilled water collected is further increased which is depended on power supply by battery. All the

observations related to volume of water collection with heating elements throughout the day is mentioned in Table 4.



Figure 5: Solar Water distillation with Heating element powered by Solar PV

Table 4: Volume of Water obtained with heating elements integrated with Solar Still

Sr. No.	Time Duration	Volume of water obtained with heater (ml)
1	7:00-8:00	225
2	8:00-9:00	150
3	9:00-10:00	105
4	10:00-11:00	110
5	11:00-12:00	125
6	12:00-13:00	140
7	13:00-14:00	110
8	14:00-15:00	140
9	15:00-16:00	102
10	16:00-20:00 (4 hours)	425
11	20:00-24:00 (4 hours)	355
12	24:00-7:00 (4 hours)	272
Total Duaration (in hours)= 24 hours		2504

Heater is more efficient in night because condensation rate is increased during night. We can obtain distilled water during night time only with the help of battery. Battery stores the charges with the help of 100-watt solar PV during the day time. This energy stored in the battery is used in the night to evaporate the water by heating elements. So here it is very important to analyze performance of the battery during the time when there is no solar radiation. For this we used fully charged battery connected with heating elements. We started this analysis from 7pm and observed volume of water collected in pot in each hour. Variation between terminal voltage and current delivered of 12v, 32Ah battery and the volume of collected distilled water is mentioned in Table 5.

In this case, it is observed that total volume of water collected by Solar still with heating elements during night is 977 ml. The variation of battery voltage and current with respect to time is shown in the figure 6.

Table 5: Distilled water obtained during night with the help of Heating elements

S. No.	Time Duration (night)	Battery		Volume of distilled water collected (ml)
		Voltage (Volt)	Current (Amp)	
1	19:00-20:00	12.9	6.66	135
2	20:00-21:00	11.6	6.44	140
3	21:00-22:00	10.3	5.72	142
4	22:00-23:00	9.1	5.05	118
5	23:00-24:00	8.1	4.5	132
6	24:00- 6:00	8	0.6	310

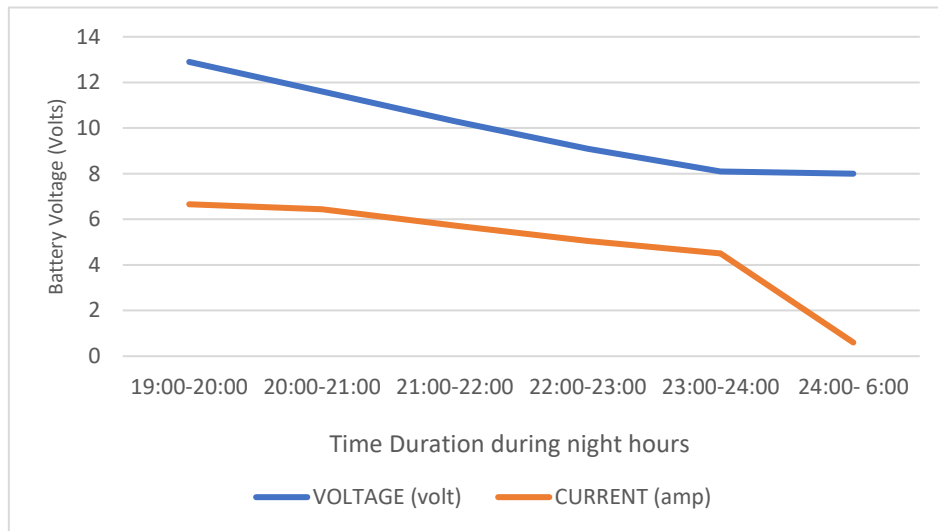


Figure 6: Variation of Battery voltage and current

4. Conclusion

The results of this research found that in solar water distillation system, for 11 hours of observation during daytime, the volume of water obtained without an external reflector is 1105 ml, and the water obtained with an external reflector is 1215 ml. The use of the external reflector results in 110 ml more distilled water collected in 11 hours of observation compared to not using it.

Further to increase the evaporation rate at night, external heating elements are placed in the solar basin to evaporate the water. For this purpose, an observation of 24 hours throughout the day is performed. With the help of heating elements integrated with the solar still, the volume of collected distilled water is 2504 ml, which is far more than that of solar water distillation without heating elements. The main advantage of heating elements is that the distilled water is continuously obtained throughout day and night.

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