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Construction of a Portable Solar Distillation Still

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Abstract—*Solar distillation is one of the important methods of utilizing solar energy for the supply of potable water to small communities where natural supply of fresh water is inadequate or of poor quality. Solar distillation is the use of solar energy to evaporate water and collect its condensate within the same closed system. Unlike other forms of water purification, it can turn salt or brackish water into fresh drinking water.*

The structure that houses the process is known as a solar still. Although the size, dimensions, materials, and configuration of the still may vary, all stills rely on the simple procedure wherein an influent solution enters the system and the clean condensate is collected at the other end. Solar distillation differs from other forms of desalination that are more energy-intensive methods, such as reverse osmosis, or simply boiling water due to its use of free energy. Solar stills are mainly categorized as either passive or active stills.

In the present project a portable passive solar still was constructed and experiments carried out to purify borewell water of nearby area. It was noted that the constructed portable still would be able to purify approximately 5litres of saline water in an 8 hour period, if used in areas with high sunlight (approximately 25^{o}C). The production capacity of the solar still was noted to be 30% of the evaporated water which is collected as condensate. Total dissolved solid of the condensed purified water was observed to be reduced to 15% of the influent value.

Keywords*: solar distillation, solar still, borewell water, saline water, potable water.*

1. INTRODUCTION

The population being as large as it is, a major portion still suffers from water scarcity. Even more so, the part of population that does receive water, 1.2 billion of them are exposed to diseases because of inadequate sanitation [1]. Many developments in technologies like Reverse Osmosis, and other advancements have helped solve the problem to a huge extent [2]. However, the poor and the needy still suffer greatly from lack of sanitary water.

The fundamental aspects of a solar still have gone unchanged since ancient times, the simplicity of the design is one of the solar still's chief benefits [3]. However, there are many variations on the theme of the typical single slope/basin still and these can fall into one of two categories, active or passive. These labels classify the still by the method [4] it uses to acquire the energy to drive the evaporation of the water. Passive solar stills are, of course, more conventional and have been the only ones discussed up to this point. Active stills, however, can obtain "waste" heat from a myriad of sources. These distillers use additional heat sources to promote existing thermal processes [5].

2. LITERATURE REVIEW

One of the very first initiatives to use solar energy for water desalination was suggested by Aristotle [6]. However, the first modern sun-powered desalination plant was built in Las Salinas, Chile in 1872 [7]. It is considered to be the first industrial installation for harnessing solar energy. The Las Salinas plant was envisioned to purify the nearby saltpeter mining effluent to supply the miners and their families freshwater. The plant was constructed of wood and timber framework covered with one sheet of glass. It consisted of 64 bays having a total surface area of 4450 m^2 and a total land surface area of 7896 m^2. It produced 22.70 m^3 of fresh water per day. The plant was in operation for about 40 years until the mines were closed down.

Interest in solar distillation [8] wavered for some time, until historical events prompted further research and development. World War II was a great catalyst for the Massachusetts Institute of Technology to develop appropriate solar stills for use in more remote areas of the world during emergencies. This trend ended near the early 70's with the advent of more lucrative desalination techniques like the aforementioned reverse osmosis or multi-stage flash, a technique that involves a series of stages where evaporation relies on lowering the pressure of each stage to lower the boiling or "flashing" point of the water. Today, renewed enthusiasm for solar distillation comes from individuals, communities, and organizations seeking an appropriate technology that is cheap, simple, and conceivable in rural settings.

3. PRINCIPLE OF OPERATION

The basic principles of solar water distillation are simple yet effective, as distillation replicates the way nature makes rain. The solar energy provides heat for evaporation. As the water evaporates, water vapor rises and subsequently condenses on the glass surface provided for collection of the pure condensate [9]. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end product is pure distilled water. A solar still mimics the natural process of water cycle and help us attaining clean water through our very own condensation or moisture trap. Figure 1 shows the basic structure of a solar still.

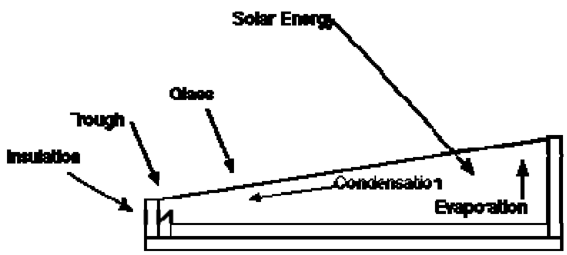

Figure 1: Basic structure of a solar still

4. CONSTRUCTION OF SOLAR DISTILLATION STILL

The construction of the working model in the present project consists of a wooden trapezoid whose walls and base are made of waterproof plywood. The plywood was covered with black silicone lining so as to avoid direct contact between wood and water. Also, black color of silicone allows maximum absorption of heat than any other color [10]. Figure 2 shows the solar still constructed for the present project.

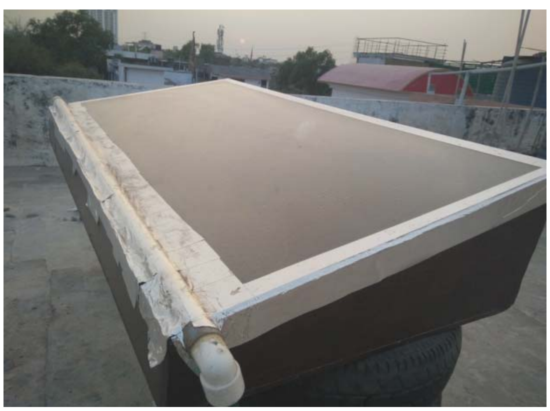

Figure 2: Constructed Solar Still

Cover is made of glass plane of 4 mm thickness so as to allow the pure sunlight to pass through the top of the apparatus and increase the efficiency of the apparatus. Water catchment channel is made of 1.25 inch PVC pipe cut in sections to make a slot for the glass top. The dimensions of the base are 2ft by 4ft. The still has a holding capacity of 35 liters. Table 1 gives the materials used for construction and the breakdown of expenses for the construction of the still.

Table 1: Materials and Costs of Construction

Material Used	Measurements	Cost (Rs.)
Glass	2 ft x 4 ft	300
PVC Pipes	5 ft	100
End Caps	1in	20
Elbows (3 nos)	1in	20
Catchment tube	4ft 3in	20
Wood Glue	500g	220
Aluminum duct tape	10 m	300
Black Silicone (4 nos)	200 g	460
Funnel	-	20
Pipe	-	50
Primer	100 mL	250
Catchment Vessel	5 L	20
Wood	2 ft x 8 ft	700
Total (Rs)		2480

The water is filled up to 1 to 2 inches depth in the still and kept in the sun. Water evaporates and accumulates on the glass surface. The inclination of glass allows the water droplets to condense in the catchment channel and allows it to be collected in a container. It follows the basic principle of water cycle: evaporation and condensation. The water thus collected is pure and the excess water is left in the distillation still is re-exposed to solar energy the next day.

5. RESULTS AND DISCUSSIONS

Experiments were conducted using the constructed solar still for borewell water from the nearby areas. Table 2 gives the ambient air parameters measured for the days when the solar still was operated. The temperature and wind speed of the area was also noted and is presented in Figures 1 and 2. The humidity of the ambient air is given in Figure 3. It was observed that the ambient minimum temperature in the area during the experimental period ranged between 15^{o}C to 19^{o}C during nighttime and the maximum temperature during the day between 29^{o}C and 32^{o}C. The daily averaged windspeed was in the range of 9km/hr to 16km/hr.

Table 2: Ambient Air Parameters

Date	Daytime (^{o}C)	Nighttime (^{o}C)	Windspeed (km/hr)	Humidity (%)
Feb24	30	15	9.3	66
Feb25	29	19	10.0	64
Feb26	30	15	16.0	68
Feb27	30	16	8.0	65
Feb28	31	16	13.0	44
Mar01	32	18	11.0	38

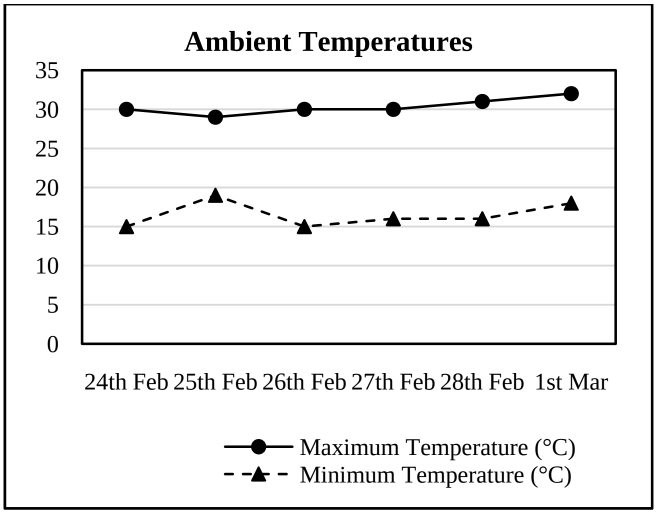

Figure 1: Ambient Temperatures in the area

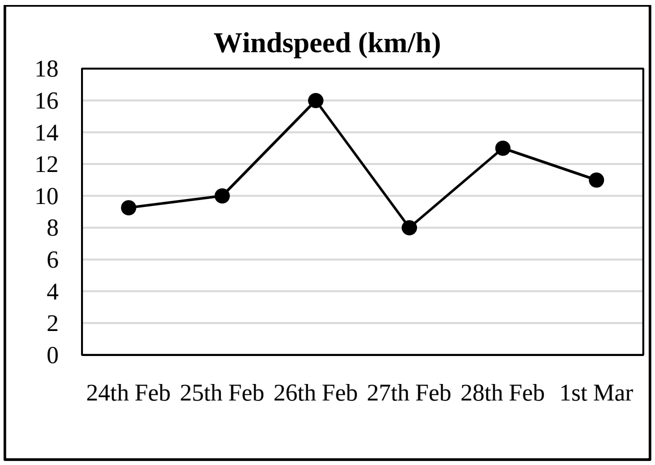

Figure 2: Windspeed in the area

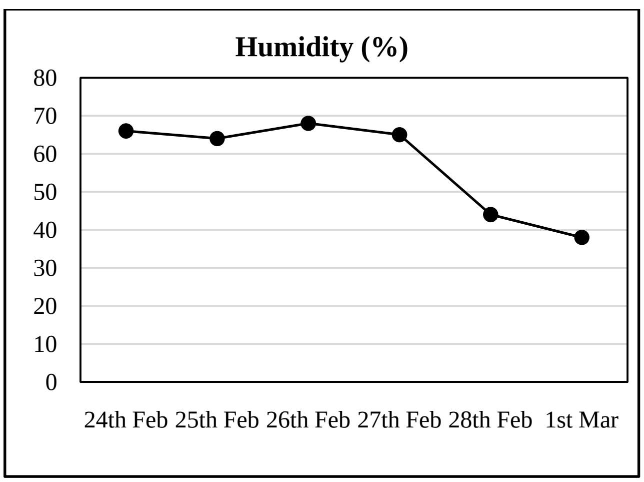

Figure 3: Ambient Air Humidity (%)

The humidity is noted to be higher on the days when the temperature is lower and vice versa. The humidity ranged from 64% to 68% for the first four days and dropped substantially to 44% and 38% for the next two days with the increase in the ambient temperature.

The solar still was operated for 8 hours for first 3 days and 9 hours for next three days based on the availability of sunlight as shown in Figure 4.

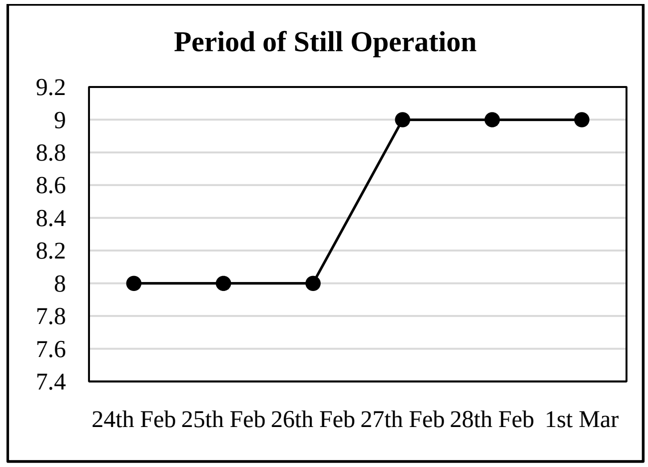

Figure 4: Hours of operation

The amount of water obtained after condensation is presented in Table 3 for each day of operation of the solar still. It was noted that for each liter of feed water maximum 30% of purified water was obtained after condensation. The output percentage ranged from 22.5% to 30%. Figure 5 shows the output of purified water with respect to feed input for each day of operation.

Table 3: Condensed water collected

S. No.	Input (Lt)	Output (Lt)	Output (%)
Day1	1	0.23	23.0
Day2	2	0.45	22.5
Day3	3	0.74	24.7
Day4	1	0.30	30.0
Day5	2	0.50	25.0
Day6	3	0.85	28.3

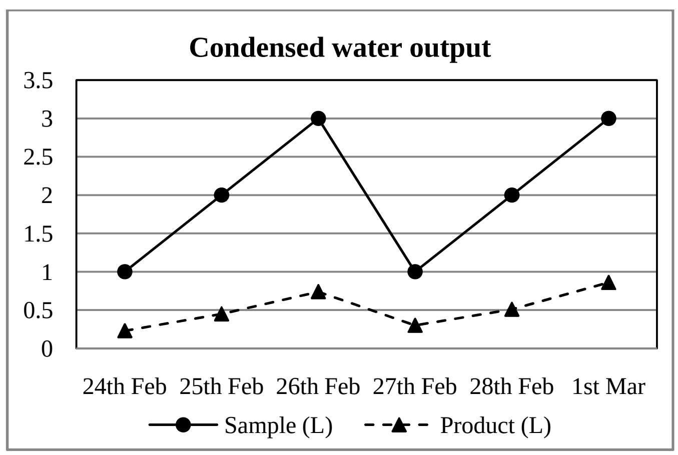

Figure 5: Condensed water output

The total dissolved solids (TDS) of the feed input samples and the condensed output water was tested to check the purity of the product. Figure 6 show the feed input and output TDS of the condensed purified water.

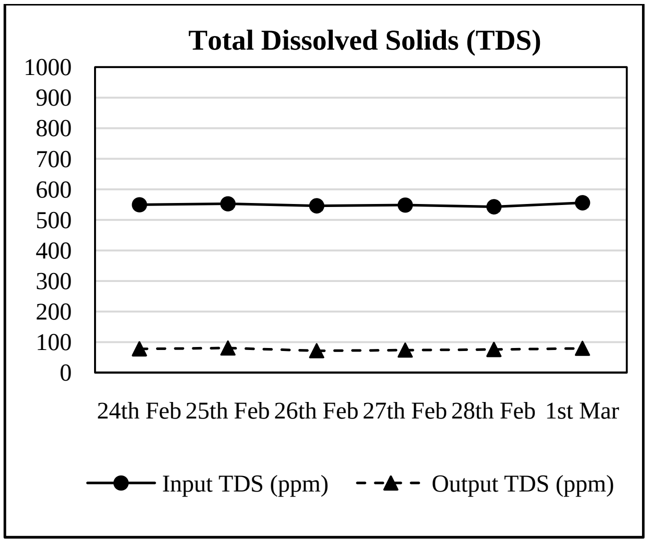

Figure 6: TDS of output water

It was observed that the average TDS of the feed water was approximately 550ppm whereas the output TDS ranged from 74 to 81 ppm as given in Table 4. This shows that the water was purified and is as per the drinking water limits. The salt removed was approximately 85% from the feed input water.

Table 4: Total Dissolved Solids

S. No.	Input (ppm)	Output (ppm)	% reduction
Day1	550	78	85.8
Day2	553	81	85.4
Day3	546	72	86.8
Day4	549	74	86.5
Day5	543	76	86.0
Day6	556	80	85.6

Solar Still Production

The daily distilled water output is the amount of energy utilized in vaporizing water in the still per day over the latent heat of vaporization of water. For the present project the solar still production was found out to be 0.139 Lt for 1 Lt of input water.

Solar Still Efficiency

Solar still efficiency is the amount of energy utilized in vaporizing water in the still over the amount of incident solar energy on the still. For the present project the solar still efficiency was calculated to be 29%.

Cost Analysis:

In India, for household drinking purposes for a small family approximately Rs. 100 is spent daily. The solar still is a one-time investment model. If a still is installed in every household in rural area, the breakeven period will be approximately 2 months. This will however lead to an alternative solution for drinking water supply which subsequently will reduce the health related problems.

6. CONCLUSIONS

In the present project a portable passive solar still was constructed and experiments carried out to purify borewell water of nearby area. The main conclusions of the present project are as follows:

1. Approximately 5litres of saline water in an 8 hour period is produced using the constructed solar still.
2. The production rate varies accordingly with respect to solar intensity. Amount of water collected primarily depends on the peak temperature and length of duration of highest temperature during the day.
3. The solar still design tested in this study confirms production of high quality drinking water from source water of very poor quality.
4. The solar distillation plants are relatively inexpensive low temperature technology system, and would be one of the best solutions to supply fresh drinking water to small isolated communities with no technical facilities.
5. No plastic waste is generated, no pollution is created as there is no use of fossil fuels and the only source of power requires is the sun.

India is a country with a majority of region being tropical and having a much longer summer than the other seasons. Installation of one still per household could save them huge amounts of money on water bottles, or hospitals. It is true that while this still, like other scientific models has its disadvantages, it’s advantages cannot be neglected. This project is one step forward to clean water consumption, which is one of the foremost concerns of this country.

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