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Modification In Technology of Solar Water Distillation for Improving Performance Through Design of Rotating Cylinder

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Abstract

A solar still uses sunlight to turn salty or dirty water into clean drinking water by evaporation and condensation. It is one of the best solutions for drinking water shortages and environmental issues, as well as being affordable and friendly to the ecosystem. The primary issue with using traditional solar power is still how inefficient it is. Prominent goal of experiment is to do alteration in existing solar still. A rotating hollow cylinder inside the basin that was partly submerged was added to the modified solar still. The cylinder's top portion remained in the path of the sun while the lower portion remained submerged in water. The cylinder's top portion absorbed heat from the sun's rays, and as it descended, it transferred that heat to water, increasing the rate of evaporation and, in turn, the solar panel's productivity. The rate of water evaporation has risen because the rotating cylinder has a larger surface area for collecting solar radiation. Throughout the tests, the cylinder rotated at 1, 3, 5, and 10 rpm. The outcome of the experiment demonstrated that the efficiency of the solar still improved with a reduction in the cylinder's rotating speed. One revolution per minute (rpm) of the cylinder was discovered to be ideal in modified solar stills, where output increased by 92% over conventional solar stills.

Keywords: Solar still, solar water distillation, solar energy, renewable energy, water purification, sustainable energy

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INTRODUCTION

Global water shortage is an issue. Water shortage issues affect roughly two thirds of the world's population annually for at least one month. There are more than 2 billion people living in nations with insufficient water sources [1]. The most valuable and helpful energy source is solar energy. Solar energy is a cost-effective, ecologically friendly, and clean energy source when compared to other energy sources [2]. For addressing issues related to globalization, such as rising energy consumption and water scarcity, it is a very profitable resource. The availability of clean water is a major issue in the world because it is decreasing over time as a result of climate change and population development [3]. In civilized areas, it is easy to find clean drinking water, but in many remote areas of the world, it is difficult to find. Due to the manufacturing sector's quick expansion, drinking water pollution is rising. To create pure drinking water from brine and impure water, solar water distillation is an inexpensive and environmentally friendly method. The use of water distillation technology reduces carbon gas emissions because it uses no fuel [4]. Impure water is heated by solar energy, which causes it to evaporate and separate salts and impurities. Water vapour strikes the glass, condenses, and returns as drops of liquid [5]. Numerous studies have shown that improved design, operating conditions, and environmental factors can improve the efficacy of solar distillates. Since it is impossible to regulate environmental variables like insolation, humidity, and ambient air temperature, design and operating parameters can be taken into account to enhance performance [6, 7, 8]. The effectiveness of solar power facilities varied depending on their configurations or designs [9]. Pyramidal solar panels still performed better than single-tilt solar panels, and double-tilt solar panels were more productive than single-tilt solar panels because they had a bigger glass cover area [10, 11, 12]. Dual solar boilers performed 40% better than solo solar boilers [13]. In comparison to east-west direction, the efficiency of double-slope solar installations was greater in the north-south direction. Additionally, at the same water level, north-south double-slope solar panels were higher than single-slope solar panels. Productivity and water intake grew as the water depth shrunk [14, 15, 16]. The rate of water evaporation rose as a result of the black absorbers' or paints' increased absorption of heat from the sun [17]. For the experimental site in Vallabh Vidyanagar, Dist. Anand, Gujarat, India, a glazing angle of 25o was chosen because it is near to the site's latitude [18]. The efficacy of the solar still was also impacted by the thickness of the glass coating. In general, solar energy production increases with glass coating thickness. It was established that 4 mm was the ideal glazing width for glass with thicknesses of 3, 4, 5, and 6 [19, 20, 21]. The research demonstrated the heat loss and area calculations for a double-slope solar installation in comparison to a modified solar installation [22]. To increase the solar still's production, a hollow cylinder can be positioned inside the tank with some water in it. In order to allow the heated surface of the rotating cylinder to travel through the water and cause the water to evaporate, the hollow cylinder spins at a very low speed. Comparing the efficacy of a single-tilted solar system with and without a rotating cylinder, it was found that the former performed better. The rotating cylinder's forced convective heat transmission was the cause [23]. The rate of water evaporation can be increased through forced convection, which will eventually increase productivity [24]. Double slope solar stills with rotating cylinders were taken into consideration for this research because they consistently had a higher productivity or output than single slope solar stills [25].

The solar still used a hollow rotating cylinder to expand the surface area that the sun heated, increasing the area of evaporation in the process. Water in the basin will come into touch with the rotating cylinder's heating surface, causing more water to evaporate. It was investigated how the Modified Solar Still's (MSS) productivity and efficacy were affected by the hollow cylinder's rotational speed. According to the experimental findings, output was higher than with a conventional solar still. Traditional and updated solar stills' side views are depicted in Figs. 1 and 2, respectively. Figure 3 displays a 3D perspective modified solar still.

There are still single slope and double slope solar panels on the market. In this research, a double slope solar still with a hollow cylinder that slowly rotates inside a solar water unit was developed. In this experiment, the traditional solar still (TSS) is a double-slope solar still without a revolving cylinder, and the modified solar still is a double-slope solar still with a rotating cylinder. (MSS). Following the addition of a rotating cylinder, the production of a double slope solar still was calculated.

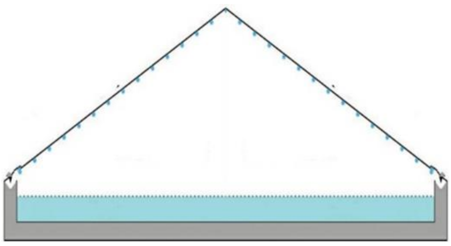

Figure 1. Traditional solar still

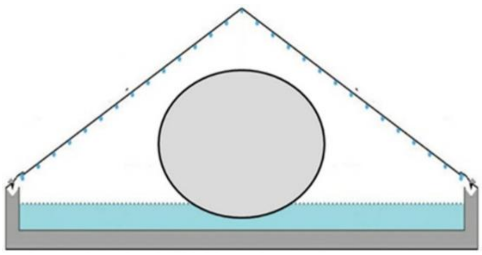

Figure 2. Modified solar still

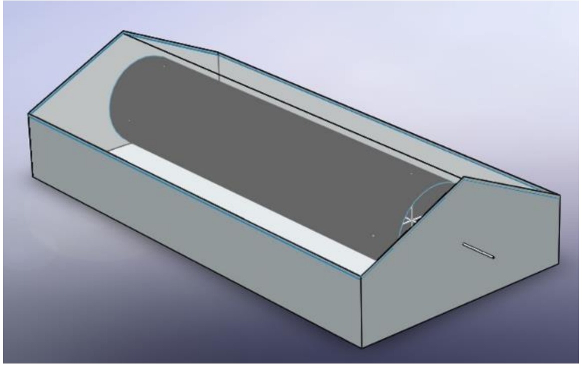

Figure 3. 3D view of modified solar still

Figure 4. Pictorial view of modified solar still

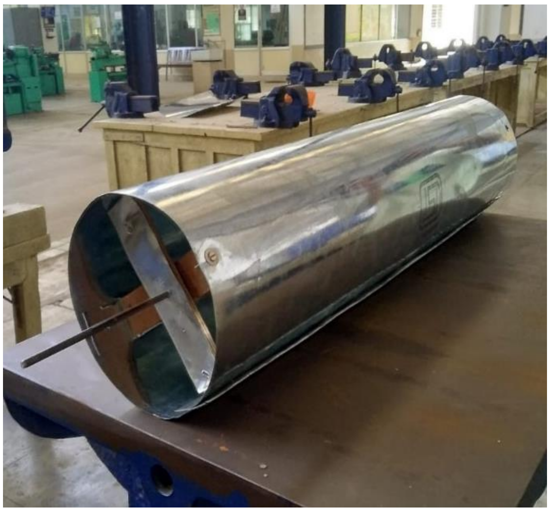

Figure 5. Pictorial view of cylinder

EXPERIMENTAL SETUP

Galvanized iron sheet that was 0.40 mm thick was used to construct the structure of the basin of the double slope solar still. It was used to fill a receptacle with contaminated water. Galvanized iron sheet was also used to create a cylindrical cylinder. Galvanized iron sheet was placed on a mild steel shaft with a diameter of 4 mm to create a hollow cylinder that can be rotated with the aid of a bearing to provide smooth rotation. Figures. 4 and 5 show, respectively, the pictorial views of the adapted solar still and cylinder.

The basin's interior surface and the cylinder's exterior were both painted black. A coating in black was used to capture the most heat possible.

To stop water from leaking out of the basin, silicon glue was applied to every connection. Insulation was created using thermocol sheets that were 30 millimetres thick. The floor and sides of the G.I. sheet basin received thermocol sheet application. The upper glass cover, which has a 4 mm thickness and 90% transmissivity, was employed. On the upper sides, there was a 25 degree slope. A wooden frame supported the top glass lid. From the interior sides of the glass covers, PVC channel was used to gather water droplets. In order for water droplets to roll down and gather in a plastic jar easily, PVC channels were given a slight incline.

The cylindrical cylinder was rotated by a 12 volt DC motor. The motor's rotational speed can be changed by using a gear train system, a speed controller switch, potentiometers, or an Arduino. By coupling, the engine is connected to the cylinder shaft. The trial was run to determine the productivity of the modified solar still at 10, 5, 3, and 1 rpm of the cylinder.

Figure 6. Complete experimetal setup

Table 1. Required components.

Components	Quality
Galvanized iron sheet’s basin	0.40 mm thick
Galvanized iron sheet’s drum	0.25 mm thick
Glass cover	4 mm thick, 90% Transmissivity
Thermocol	30 mm thick, Insulation
Steel rod	4 mm thick
PVC pipe	10 mm diameter
Black paint	Black colour
Silicone glue	Leakage proofing
DC- motor 12 V + converter	12 V
Solar Cell	20 W

The entire experimental apparatus is shown in Fig. 6, and the necessary parts and other specifics are shown in Table 1.

METHODOLOGY

After making all the required preparations, the setup was placed in direct sunlight. In order to receive the most solar radiation during the day, the arrangement was oriented North-South. The glass top was chosen with a 25 degree angle of inclination because the location's latitude is 23o. The glass covers on both sides were set on a wooden frame after the solar still's basin had been refilled with impure water. To prevent heat loss, 30 mm thick thermocol sheets were placed over the basin's exterior sides.

A 12 volt DC motor provided movement for the hollow cylinder. The DC motor was operated by an electrical source with an AC to DC converter. Additionally, a solar cell may be used to feed a motor with DC current during the day. The engine and cylinder shaft were mechanically connected. 10, 5, 3, and 1 rpm were the cylinder's rotational rates.

In April 2022, the trial was carried out. Observations were made for a specific cylinder spinning speed between the hours of 8 am and 8 pm. The amount of output water and basin water temperature at a particular time were the primary observations. Prior to using modified solar stills, the experiment was run on conventional solar stills (TSS). (MSS).

The experiment was conducted with the rotational speed of the cylinders set to 10, 5, 3, and 1 rpm in that sequence. Water production was measured from 8:00 am to 8:00 pm every 1.5 hours. Refer table 2 for quantity of purified water.

Table 2. Quantity of output water for every 1.5 hours.

Time	Purified output water (ml)				
	TSS	MSS			
		10 rpm	*5 rpm*	*3 rpm*	*1 rpm*
8:00 am	-	-	-	-	-
9:30 am	-	-	5	10	20
11:00 am	25	30	40	60	80
12:30 pm	80	100	120	170	200
2:00 pm	180	210	280	360	430
3:30 pm	320	350	480	580	650
5:00 pm	470	510	680	790	870
6:30 pm	550	600	840	930	1050
8:00 pm	600	650	900	1000	1150

Table 3. Quantity of output water in TSS & MSS (10, 5, 3, 1 RPM) at the end of day.

	TSS	MSS (10 RPM)	MSS (5 RPM)	MSS (3 RPM)	MSS (1 RPM)
Output Water (ml)	600	650	900	1000	1150

RESULT & DISCUSSION

Productivity

Water began to evaporate gradually, and over time, the amount of purified water produced increased. Due to the ambient temperature being at its highest in the afternoon, the measured maximum rate of water evaporation occurred between 2:00 and 3:30 pm.

At the conclusion of the day, TSS was used to produce 600 ml of purified water. By using MSS at the end of the day, a total of 650 ml, 900 ml, 1000 ml and 1150 ml of purified water were produced at corresponding speeds of 10 rpm, 5 rpm, 3 rpm and 1rpm as shown in Table 3.

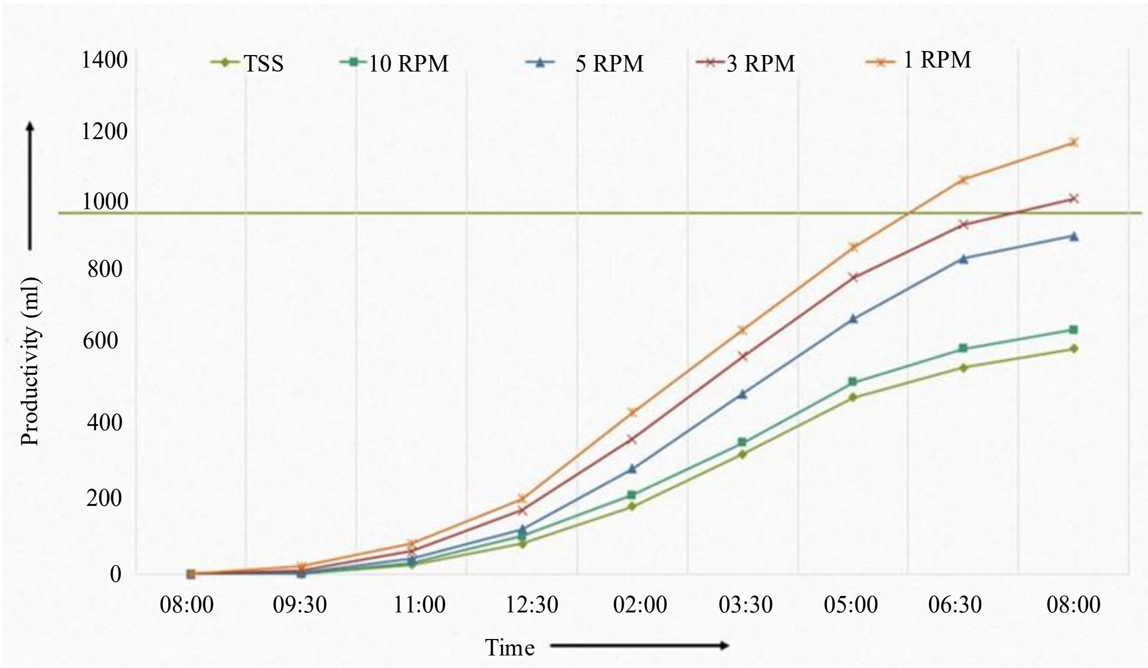

Figure 7. Variation of productivity with time.

Table 4. Quantity of output water in TSS & MSS.

	TSS	MSS
Quantity of output water (ml)	600	1150

Table 5. Quality of input & output water

	Input water	Purified water
pH	7.5	7.0
TDS	750 ppm	50 ppm
Hardness	2.4 NTU	0.4 NTU

Water Quality

As quality indicators for both input and purified water, pH value, Total Dissolved Solid (TDS), and hardness were evaluated. Table 5 displays the quality metrics that were noticed. For input and filtered water, the measured pH was 7.5 and 7.0, respectively. The removal of salts from input water resulted in a slight pH decrease for purified water. It was found that TDS significantly decreased from 750 ppm for raw water to 50 ppm for purified water. Because of the decrease in TDS, the water is fit for ingesting. The third step involved checking the water's hardness. The incoming water's hardness was 2.4 NTU. Higher alkalinity water is not fit for human consumption. Input water was found to be 2.4 NTU.

The productivity (output of filtered water) for TSS and MSS varies over time in Figure 7. Productivity has been found to improve over time. TSS had produced less output over a specific period of time than MSS. In MSS, productivity grew as cylinder rpm decreased. At one revolution per minute, the most pure water was produced. There was a 92% increase in output for MSS at 1 rpm compared to TSS.

Water Quantity

According to the experimental findings, the TSS produced 600 ml of clean water at the end of the day, while the MSS produced 1150 ml. The amount of purified water collected for the MSS was about 92% higher than the TSS and 550 ml higher than the TSS. Additionally, Table 4 displays it.

CONCLUSION

Conclusions to be drawn from the experimental results are following:

- The rate of water purification was significantly higher for modified solar still as compared with traditional solar still. Hence the modified solar still yields higher productivity.
- At lower speed of rotation of the cylinder of modified solar still, the rate of evaporation of water was increased because lower rotational speed had offer more time for heating of the upper part of the cylinder by sun rays and also more time for convection heat is transfer from the bottom part of the cylinder to water. For the experimented values of cylinder rotational speed, 1 rpm had offered the highest productivity of purified water.
- When compared to a conventional solar still, a modified solar still had an efficiency of 92% higher.

Hence, use double slope solar still is advisable with a rotating cylinder at a lower speed of rotation of the cylinder than traditional solar still for water purification.

Data Availibility Statement

The authors confirm that the data supporting the findings of this study are available within the article.

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