PERFORMANCE OF WATER HEATING AND DISTILLATION USING FRESNEL LENS SOLAR COLLECTOR

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Abstract: The Vadodara is surrounded by good sunny areas and these areas can be a potential source for potable water. This study aims to design and construct a solar powered desalination system using Fresnel lens. The experimental study was conducted using water for the sample and desalination was carried out using the designed system. The Fresnel lens was made of acrylic plastic and was an effective solar concentrator. Solar still made of dark colored glass bottles were effective in absorbing the solar energy. the condenser system made of copper coil were effective in condensing the vapor at ambient temperature. The shortest time of vaporization of the water was at 293 sec. and optimum angle of position of the lens was 36.42°. the amount of condensate collected was directly proportional to the amount of water in the solar still. The highest mean efficiency of the designed set-up was 29.32%. the water produced by the solar powered desalination system using Fresnel lens passed the standards set by WHO (World health organization) for drinking water.

Index Terms - Solar desalination, distillation, solar energy, Fresnel lens

I. INTRODUCTION

Clean water is very important because the human body is composed principally of water which comprises about 60% of the body weight. The human body is dependent on water because it carries out the toxins from the vital organs, transfers the nutrients to the cells and provides a moist environment to the ear, nose and throat tissues. Humans need to drink an average of 2.5 litters of potable water per day in order to prevent dehydration [1].

Vadodara City is located in the western coast of the Arabian sea. VACIWA D(VADODARA City Water District) is an agency that is mandated to maintain and operate the water supply and distribution systems for domestic, industrial, municipal and agricultural uses within the district of Vadodara. It has to supply about 1.25 million litters of water per day to the consumers in order to meet the average daily requirement of human consumption excluding other water requirements like cooking, bathing and washing. Presently, the Vadodara district is suffering from the effects of El Niño and VACIWA claims that there will be a water crisis by 2025 if other alternatives for water resources are not found [2]. Unfortunately, VACIWA can only serve about 42% of the population within the service area and about 28% within the service area cannot be supplied with water [3]. As a result, many people still do not have access to adequate supply of potable water because there is insufficient supply of potable water. There is a need to look for other sources of potable water.

The sun's energy is a renewable energy source and this is free. Vadodara City receives on an average of 5.83kWh/m^2 / day of incoming solar radiation [4]. This energy can be used in many ways and they offer minimal environmental problems. This renewable energy resource can be used to power a household desalination system using Fresnel lens.

Solar powered desalination technology using Fresnel lens is not yet developed and used in the India. The plan to use the solar energy from the sun to power the desalination system is not new but the design of using Fresnel lens to speed up the evaporation rate has not been tested in the India. Harnessing the sun's energy to power the desalination system using Fresnel lens can be another alternative source for potable water; therefore this study was conducted in order to determine whether a solar powered desalination system using Fresnel lens can produce potable water.

II. Literature review

Mohamed Salah Mahmoud in the publication discuss about the utilization of Fresnel lens solar collector in water heating for desalination with help of humidification-dehumidification process [5]. Ali m el-masher and ate m el Baghdad said about in journal Declamation, the plant has a maximum capacity of 120 m3/d of distillate with a yearly average daily production of 100 m3/d [6]. Radha Krishna Lal in the publication said that comparative performance evaluation of an active/passive solar distillation system. the experiments has been conducted on south facing, single slope, solar still of 30° inclination of condensing cover, in summer climate for 24 hrs. on different five days for different five water depth from 0.04 to 0.18m.objective is to study the variation in internal heat transfer coefficients depend to water depth in the still.[7]. Leon J. Hastings says about investigation of 1.8 by 3.7 meter Fresnel lens solar collector [8]. IOP Publishing gives information on solar powered desalination system using Fresnel lens. Solar powered desalination system using Fresnel lens. the shortest time of vaporization of the salt water was at 293 sec and the optimum angle of position of the lens was 36.42°. The highest mean efficiency of the designed set-up was 34.82% [9].

III. Methodology

The study was divided into two phases. The first phase included the design and construction of the desalination system. The second phase of the study included the pilot testing of the solar powered desalination system and the testing of the parameters of the product from the solar powered desalination system as required by World Health Organization for drinking water quality. The first phase of the research design involved the design and construction of the desalination system. The design set-up of the desalination system included the solar concentrator, the solar still, the condenser tubes, and the condensate collector. The illustration for the design set-up of the desalination system is shown below.

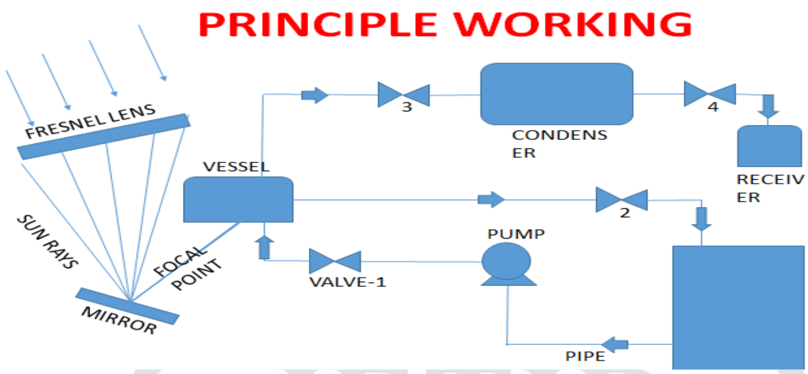

Figure 1. Working principle

The solar concentrator was composed of the Fresnel lens and its support. Solar concentrator used was Fresnel lens that was made of acrylic plastic and had the following dimensions: 1343 mm high and 1092 mm wide. The framed Fresnel lens was hinged to two galvanized iron pipes 857 mm high and spaced 792 mm apart. The hinges allowed the lens to rotate 360^0 in vertical motion. The galvanized iron stands were attached to a revolving disk made of galvanized iron pipe that rotated the panel in any direction and was about 190 mm high. The revolving disk was attached to two galvanized iron pipe supports spaced 792 mm apart. Galvanized iron was chosen because the stand had to be stable enough to support the lens even during windy conditions. See figure below.

Figure 2 Front view of experimental setup **Figure 3 Back view of experimental setup**

Efficiency = (Energy required for vaporization of distill recovered / Energy in sun's radiation that falls on the Fresnel lens) x 100%

The efficiency was calculated for the different amounts of salt water used based on the energy required for the vaporization of distillate recovered per energy in the sun's radiation that falls on the Fresnel lens. The formula of List was used to solve for the energy in the sun's radiation and software developed by David Lawrence was used to calculate for the conditions required by List's formula.

IV. RESULTS AND DISCUSSION

For the design set-up of the desalination system, the angle of inclination of the solar still with respect to the ground was maintained at 43° all throughout the experiment. Using this angle to distill the water proves that the sun's position does not very much in the India [7].
Results of the study showed that the mean angle of the lens was at 39.5°.Vaporization time occurred faster between 12.00 am to 2.00 pm. Angle of the position of the lens also did not very much at this period because Vadodara is situated on the equator so the sun's position does not very much in this location. The shortest time of vaporization was at 293 sec so the optimum angle of position of the lens was 36.42°.
Results of the condensate collected indicate that the amount of condensate collected was directly proportional to the amount of water in the vessel. Only about 25% of the water in the vessel evaporated and condensed. Evaporation is dependent on the solar energy emitted by the sun and this solar energy was affected because the experiment was performed during the rainy months. Furthermore, the sun moves farther from the equator during the last half of the year so the solar energy was not intense enough to increase the amount of vaporization. The figure below shows the relationship between the amount of condensate collected of the designed set-up and the amount of water in the vessel.

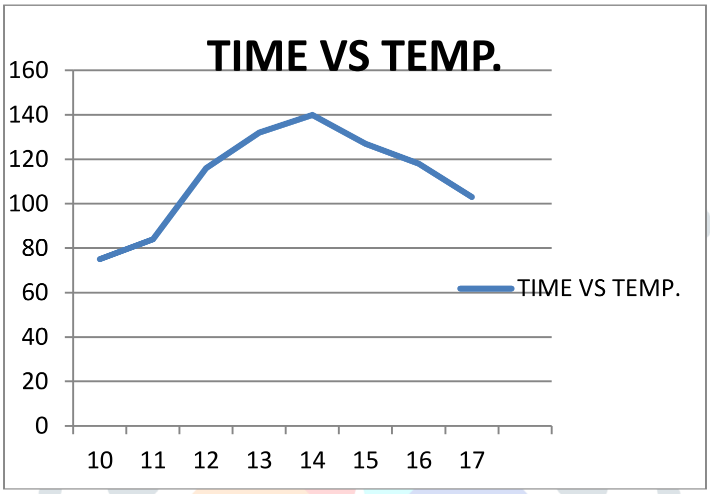

Figure 4 Temperature variations with black coating vessel.

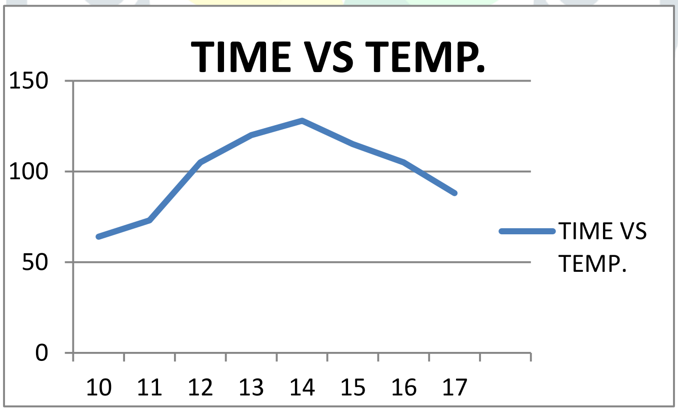

Figure 5 Temperature variations without black coating vessel.

The graph above shows that the amount of condensate collected is directly proportional to the amount of water in the vessel. This means that more condensate can be collected if the amount of water in the vessel was increased. The reason behind this is that there is less air space above the liquid when the amount of water in the vessel is increased. Less air space indicates that fewer vapor molecules would come into contact with the air molecules thereby increasing the amount of liquid to vaporize. When vapor molecules become entrapped with the gases in the air space, their kinetic energies decreases leading to condensation back into the solar still.

TABLE 1. Distillate output and temperature with respect to per hour (without black coating)

Sr.no.	TIME PER DAY (HR)	TEMPERATURE (°C)	DISTILLATE WATER (ML)

1	10.00	64	---------
2	11.00	73	---------
3	12.00	105	400
4	13.00	120	720
5	14.00	128	670
6	15.00	115	550
7	16.00	105	400
8	17.00	88	----------

TABLE 2. Distillate output and temperature with respect to per hour (with black coating)

Sr.no.	TIME PER DAY (HR)	TEMPERATURE (°C)	DISTILLATE WATER (ML)
1	10.00	75	----------------
2	11.00	84	------------
3	12.00	116	470
4	13.00	132	805
5	14.00	140	695
6	15.00	127	625
7	16.00	118	550
8	17.00	103	230

Table 3. Efficiency of the system

Amount of Saltwater [ml]	Efficiency [%]
470	11.18
805+695	29.44
550	16.82

Results of Table 3 shows that the greatest amount of water had the highest efficiency for the designed desalination set-up. This was due to the fact that the greatest amount of water in the experiment had the greater heat requirement. The amount of heat required to vaporize the water was dependent on the amount of condensate recovered. The energy required to vaporize the water increased because it was directly proportional to the amount of water used in the operation .The low efficiency of the designed set-up implies that the solar powered desalination system was dependent on the solar energy.

V. Conclusions

The design set-up for the solar powered desalination system using Fresnel lens can desalinate water. Fresnel lens made of acrylic plastic can be used as a solar concentrator for a solar powered desalination system. Solar stills inclined at 43^0 with respect to the ground can optimize the vaporization angle if location of operation is in the India. The shortest time of vaporization was at 293 sec and the optimum angle of position of the lens was 36.42^0. The amount of condensate collected was directly proportional to the amount of water in the solar still. The design set-up for desalinating the water using the Fresnel lens was effective in removing the pollutants. The design set-up for the solar powered desalination system produced a condensate that passed the standards set by WHO for drinking water.

VI. Acknowledgment

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