Performance Analysis of Water Distillation by Two Directional Slop Solar Still Roofs

Mr. Golden Kumar Singh
M.Tech Scholar, Department of Mechanical Engineering, RNTU, Raisen (MP), India

***Abstract* - Various experiments have been conducted to establish correlation among different parameters for water distillation by two directional slop solar still roofs. The experiment set has been installed on the roof of building in the month of April 2020, the experiment has been carried out at Sultanpur. All the data like solar radiation, wind velocity, temperature etc. has been calculated from different measuring devices has been used. For the optimal result we have done our experiment on the clear day and when the climate condition of the Sultanpur is warm as compared to other days. I have placed solar still in both East-West and North-South position to measure the different output in different orientation. The basin water, encompassing, glass cover, vapor and basin liner temperature are recorded hourly with the assistance of temperature sensors. There are seven temperature sensors are utilized as a part of the test setup. The breeze speed is additionally recorded by an anemometer. Hourly and day by day distillate yield is estimated with the assistance of estimating container. Analysis was completed early in the day 7:00 hrs. to 17:00 hrs also; hourly perusing has been gotten which is appeared in the chart. The production of solar still increases as we reduced the height of the water in the solar still. It is found in the experiment that the production of distilled water is 22% higher for 2cm water depth as compared to 4 cm water depth from 7:00 hrs. to 17:00 hrs.**

***Index Terms* - solar still; isolation; distillation; two directional slop solar still; solar enhancement; productivity enhancement.**

INTRODUCTION

Meeting the increasing demand for fresh water is a grand challenge. Desalination and water reuse have become two key solutions to addressing water shortage and sustainability. Utilizing solar powered treatment processes is especially appealing for the most arid and high irradiance regions in the world. In remote locations, where new technology is still not available, they are mostly dependent on distillation process for drinking water. Arabian alchemist, the earliest known people who used solar distillation to produce drinkable water in the sixteenth century. Arab alchemists have practiced solar distillation (1551) using glass vessels. For the very first time, for solar distillation process, Polished Damascus concave mirror was used [1]. However, Nicolo Ghezzi was first known documented reference and made a device in 1742[2], still no further information that he built it further.

Solar Still Developments until 1950

The desalination system in Las Salinas in Chile in 1872 is a major milestone in the history of desalination. The engineer Carlos Wilson designed and built a solar still covering an area of 4,700 m2 using glass and timber (Fig. below). The production rate was 4.9 kg of water per m2of glass surface on a summer day. This system was in operation for more than 40 years [5, 6].

The French scientist Auguste Mouchot experimented with conical concentrating solar systems for cooking, and among others, for distillation and published his results in 1869 and 1879 [6,7].

Talbert et al. [7] give a very detailed overview on the worldwide developments of Solar Stills until the 1970. The manual also includes very extensive descriptions of the built systems including operational challenges. Tiwari et al. [5] describes the fundamentals for heat- and mass-transfer as well as developments and improvements of Solar Stills until 2008.

Water Distillation

Distillation technologies were used for some years to provide fresh and potable water for labors in small industrial society in the past. After 1945, the demand for potable water was increased; this caused the increase in using distillation systems. Separating impure water from dissolved substance is possible by evaporating and then again condensing it. Evaporation procedure requires an external thermal source which can be provided by different sources such as solar energy [1-5], nuclear energy [6- 8] and other sources [9-12]. Solar energy is a renewable energy and the devices which are used to collect solar energy are most expensive and the large number of spaces is needed in order to storage the solar energy [13].

Solar Still

In this process, the sun radiation provides heat to evaporate water one of the different processes that can be applied to remove the impurities from water. Solar irradiation is the source of heat energy needed for this kind of work. In this process, the sun radiation provides heat to evaporate water and to separate the vapor from impurities that exist in the water, after that condense it as portable water under the glazing. However, the efficiency of a conventional solar still is low and made this system not so much popular. Numerous scientists have been working on the conventional solar still by modifying it in order to increase the efficiency of this kind of system. The efficiency of a conventional solar still's efficiency depends on solar irradiation, ambient temperature, weather conditions, heat loss and glazing material [15] Different designs have been made to make progress in performance of solar stills, some of them are multi-basin [16], double basin [17], wick basin [18] and multi-use environmental type [19] The efficiency of different solar stills depend on many parameters [20] Also, the water heighten. the 9 and raining cycle on basin affect the yield [21]. The yield increased by using black sand and black rubber in solar stills [22].

LITERATURE REVIEW

In order to improve fresh water, yield various tests and experiments were conducted. Some of these experiments are briefly explained in the following section, which are related to this work.

Using wicks increased the potable water production two to three times. In 2008, a study was performed by Assefi [25], which was about reviewing an analysis of solar desalination systems under this scope. This study was carried out on modeling and analyzing a single slope solar still in order to investigate the effect of water depth and inclination angle of the glass cover. Among the published experimental data, it was found that the highest productivity rate is obtained with solar humidification-dehumidification systems while that the lowest is obtained by using conventional solar stills with bare plate. Akash, et al [26]. Study the solar still system. This system had different absorber materials: they did an experiment with three variants; black absorber rubber mat, black ink, and black dye. The results showed that water production was increased by 60 % and 45 % for black dye and black ink respectively the total productivity rate of North Cyprus on 21st of March was obtained which were about 5.3 kg/m2.day. The total obtained productivity rates are compared with previous experimental studies and it was discovered that there is a difference of +3.37 on averages.

G.n. Tiwari and B.Rao used flowing water to investigate the performance of a solar still[5]. In this, they flowed a series of water on the side of glass cover. We can double the amount of distilled water you obtain by lowering the temperature of the glass cover. Flowing water is used to lower the temperature. Various studies have been made in order to increase the efficiency of the system.

H. Al-Hinai et al [6] carried out experimental and mathematical study. In their experiment they used mathematical model to obtain the yield under different variables like climate condition, design of the solar still and other operational values. The optimum design parameters needed for this solar still are

- A shallow water tank, 23° cover tilt angle,
- An insulation with a thickness of 100 mm
- An asphalt coating

The annual productivity rate of this solar still is 4.15 kg/m2 day. They carried out a cost analysis to calculate the cost of installing simple solar stills for the production of drinking water in remote areas. After making detailed analysis and calculations they claimed that when such a series of solar stills are used the unit cost for distilled water is $7.4 m/s2.

H. Aburideh et al [27] presented a trial investigation of a sun based still. This examination is occupied with the interior parameters on a twofold slant sun oriented still. They did these trials under various conditions. They have considered the variety of the distinctive working parameters of the sunlight based still. They have discovered that there is an immediate connection between the creation of refined water and the temperature of the water and glass. The refined water generation rate increments when the temperature of

water and glass cover temperature increments. Wind and climatic changes additionally influence the measure of water created. Wind and climatic changes diminish the measure of diffuse sun powered vitality which is gotten by the filthy water. The normal measure of refined water was estimated as 4 L/m2 day. F.Banat et al [28] examined the specialized possibility of delivering drinking water from seawater by utilizing a film refining module with a sun powered still. They utilized the moderately hot saline solution in the sun based still to bolster the layer module. They quantified the synergistic activity of the sunlight based still and the film module amid this new water generation. They completed two sorts of investigations as indoor and open-air tests. They examined the affectability of the sun powered motion to the salty water temperature, stream rate, salt fixation and sun-based illumination. It was found that the flux of water from the solar still was lower than 20% of the solar flux. The temperature of salty water significantly affected by the flux of both membranes' module and the solar-still. Meanwhile the effect of salt concentration was marginal.
H. N. Panchal and P. K. Shah [22] carried out an experiment to compare performance of solar still which has different plates. They used solar radiation from the sun to obtain the clean water from the sea water. In their experiment they used three identical solar stills which are shown in the employed a conventional solar still as the third one. They tested, recorded, and compared the findings of three solar stills under same climate conditions. Authors found out that the solar still which has aluminum plate increases distillate output by 45% and galvanized iron sheet by 15% when compared with conventional solar still.
Arun kumar T. et al [29] carried out a study to investigate whether the efficiency of the solar still is affected by air flow on tubular solar still. After this study they reported that there was an increase in the amount of distilled water for a compound parabolic concentrator-concentric tubular solar still (CPC-CTSS). There was a dramatic increase in the heating of saline water when CPC used. In order to produce larger amounts of distilled water they have put forward a new idea work on the characteristic properties of compound parabolic concentrator for desalination. A rectangular water tank made of copper with the dimension of 2 m × 0.025 m × 0.02 m was prepared, and this rectangular tank was installed at the focus of the CPC. They used two glass tubes in the shape of cylinder of whose lengths were 2 m but with two different diameters of 0.02 m and 0.03 m to cover the water tank. They used two different modes for this experiment; one mode is with air and one without air flow between inner and outer tubes. Throughout the experiment the air flow rate was kept at 4,5 kg/s. When the results of the experiment were analyzed, they came to a conclusion that the rate of water collection was 2000 ml/day with flow of air and 1445 ml/day without the flow of air and the efficiency of both systems were 18.9% and 16.2%, respectively.

LAY-OUT OF EXPERIMENTAL SET UP

Basin liner

The base of the solar still is made of black acrylic as it has good properties of absorbing solar radiation. It also stores water. When the sun rays pass to the basin through glass cover, water temperature increases slowly and after reaching specific temperature water evaporates inside the still. This basin liner should be leak-proof and should have high absorbance capacity. Fig.1 below shows Isometric view of the solar still.

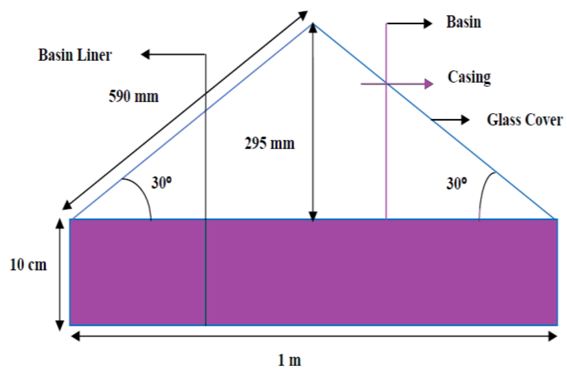

Fig. 1 Layout of Experimental set-up

Table 1-Technical specifications of the solar still

Basin area, m^2	1
Glass cover Thickness, mm	3.5
No. of Glass	2
Slope of glass	30°

Fabrication

First of all, Basin was prepared by a black acrylic sheet. Black is used so it absorbs the maximum solar radiation. Basin area is 1 m2 and height is 10 cm. Thus, inner basin overall size is 1m×1m×0.01m. We have used plywood as insulating material. 12 mm thickness of plywood is fabricated according to the basin size which results in increasing the outer basin size to 1.31m ×1.31m× 0.0255m.A frame was built to carry the above-mentioned instrumentations. we have used two 4 mm glass cover which are placed at 30° with horizontal. This glass cover is fixed with the still with the help of silicone sealant. Side of the still is made from the acrylic sheet as per the size of the solar still. We have made two drainage channels in V shape made from aluminum.

Fig. 2 Side view of Double Slope Solar Still

Experimental Procedure

In the month of April-2020, the experiment has been carried out. All the data like solar radiation, wind velocity, temperature measurement etc. has been calculated from different measuring devices has been used. For the optimal result we have done our experiment on the clear day and when the climate condition of the sultanpur is warm as compared to other days. I have placed solar still in both E-W and N-S position to measure the different output in different orientation. The basin water, encompassing, glass cover, vapor and basin liner temperature are recorded hourly with the assistance of temperature sensors. There are seven temperature sensors are utilized as a part of the test setup. The breeze speed is additionally recorded by an anemometer. Hourly and day by day distillate yield is estimated with the assistance of estimating container. Analysis was completed early morning in the day 7:00 hrs. to 17:00 hrs also, hourly perusing has been gotten which is appeared in the chart.

Heat Transfer in Solar still

There are two different modes of the heat transfer Internal and external heat transfer modes. The different heat interactions in the solar distillation unit have been explained below.

Internal heat transfer: The internal heat transfer mode, heat is transferred from the water to glass cover by radiation, convection and evaporation

- *Convective heat transfer:* There is no heat leakage as we have made this closed system to ensure the proper evaporation. The heat transfer is due to the buoyancy only i.e. free convection heat transfer occurs inside the still casing.

The rate of convective heat transfer (q_{cw}) is given by

$q_{cw} = h_{cw}(T_w\text{-}T_g)$

The value of convective heat transfer coefficient is depending upon the following parameters-

a. Operating temperature
b. Condensing cover geometry.
c. Flow characteristics of the fluid.

- *Evaporative heat transfer:*

The rate of evaporative heat transfer (q_{ew}) from water surface to glass cover surface is given by

$q_{ew}=h_{ew}(T_w\text{-}T_g)$

RESULT AND DISCUSSION

The temperature variation for 2 cm water depth for North-South as well as East-West orientation shown in Fig. 3. The basin temperature has been found higher for North-South orientation. The cumulative yield from the double slope, solar still is shown in Fig. 4. The yield is shown for 2 cm water depth (8 April) and 4 cm water depth (14 April) in the basin from 8:00 hrs. to 17:00 hrs. It is clear from Fig. that the yield is better for 2 cm as compared to 4 cm water depth in the basin. The production of distilled water is started earlier when depth is 2 cm because the basin water heating is faster than when depth is 4 cm.

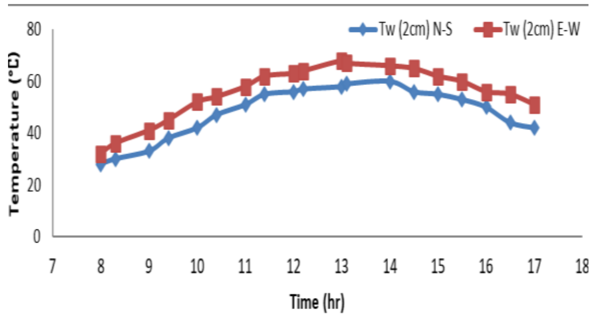

Fig. 3 Hourly temperature variation of basin water for East-West and North-South orientation

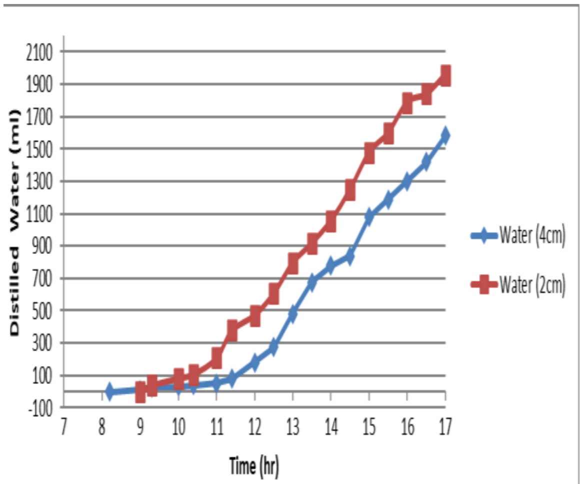

Fig.4 Cumulative yield of DSSS for 2 cm and 4 cm water depth

The Fig. 5 shows the temperature variation of the glass inner surfaces, basin water and vapour temperature for 2cm water depth on 8 April when still is placed E-W orientation. The ambient temperature is also shown in theFig. It can be observed in Fig. that the water temperature is more than the inner surface of east glass after 12:30hrs. due to this, the production of water from the east side is better than the west side.

The Fig. 6 shows the temperature variation of the glass inner surfaces, basin water and vapour temperature for 4 cm water depth on 14 April when still is placed E-W orientation. The sun rays only incident on the eastside, up to 11:30 hrs. not on the west side, therefore, the temperature of east glass i.e. Tgi (E) is greater than Tgi(W) and after that west side temperature increases when sun rays directly incident on west glass only. The rate of increase of Tgi (E) is decreased after 11:00 hrs. because of the temperature increases due to condensation of water on the glass surface. The Tgi (W) remains higher than Tgi (E) after 11:30 hrs. because there is heat addition by condensation (basin water is heated up to a temperature from starting of experiment time to 11:00hrs. for evaporation) as well as direct sun radiation. It is observed that at 12:30 hrs. There is no temperature difference between water and glass inner surfaces to maintain the temperature difference there is a spray of water on both glasses, therefore at 13:30 hrs. there is a decrement in glass surface temperature and due to this, the production rate is high at- this point.

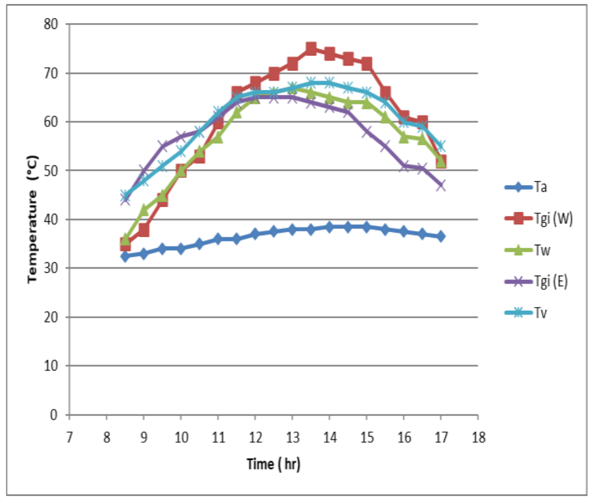

Fig. 5 Hourly temperatures variation of solar still for 2 cm water depth

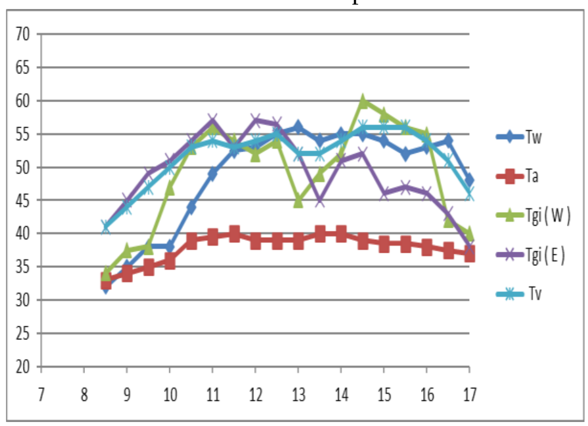

Fig. 6 Hourly temperatures variation of solar still for 4 cm water depth

Fig. 7 shows the cumulative water production from one side of double slope solar still. It can be noted that the production rate is increased from 12:30 hrs. to 14:00 hrs. and also from 16:00 hrs. to 17:00 hrs. because water sprays on the glass to maintain the good temperature difference between the glass surface and basin water.

The spray starts at 12:40 hrs. for maintaining temperature difference and after maintaining a temperature difference of 11.3°C at 13:00 hrs. the condensation rate is good and there is a production of about 120 ml between 13:00 hrs. and 13:30 hrs. Between 15:30 hrs.to 16:00 hrs. the production of water is very less, about 40 ml because there is a very less temperature difference between the glass surface and basin water also there is no spray of water. After that, there is a continuous spray of water from 16:00 hrs. to 16:30 hrs. to maintain temperature difference, due to the spray of water the temperature difference is of 9.2°C at 14:30 hrs. then there is a production of 80 ml of water in next 30 minute. Though the temperature of the water is higher at 15:30 hrs.(54.7°C) as compared to 16:30 hrs.(48.4°C).

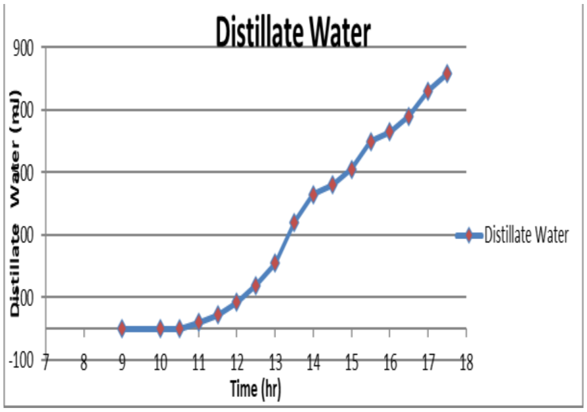

Fig.7 Cumulative water production from one side of double slope, solar still and effect of water spray on production rate

In our study we found that after cooling the one side of the glass cover the yield of that side cover is increased upto 22 %. Also, when we applied obstacle to one side of the glass it is found that temperature difference of that side relatively increased that's result in fast condensing and increasing the distilled output [29].

CONCLUSION

From the analysis following points have been observed:

1. For same water depth, the North-South orientation gives the maximum temperature for basin water. It is found to be 16% higher temperature of basin water for North-South orientation of still as compared to East-West orientation when water depth is 2 cm (from 8:00 hrs. to 17:00 hrs.). The East-West orientation production of solar still is found 51.54% higher than North-south orientation for 4 cm water depth.
2. The production of solar still increases as we reduce the height of the water in the solar still. It is found in the experiment that the production of distilled water is 22% higher for 2cm water depth as compared to 4 cm water depth from 8:00 hrs. to 17:00 hrs.
3. The rate of production increases with an increase in solar radiation and also increase in wind velocity up to critical value.
4. The rate of production increases with proper water spray on glass surface because it maintains a good temperature difference between water and glass surface, due to this the rate of condensation increases.
5. The solar distillation plants are one of the best solutions to supply fresh drinking water to small, isolated communities with no technical facilities.

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