Integrated Performance Analysis of Latent Heat Storage and Finned Type Solar Distiller

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***Abstract*—Lack of adequate of fresh water has become a serious problem in several countries of the world. Availability of clean water is going to become one of the most pressing resource issues of the country. Even though there are various technologies available for purification of water harnessing solar energy fits the purpose for future problems. Distillation is one of many processes available for water purification, and solar energy is one of several forms of heat energy that can be used to power this process. In this research work, the performance of solar concentrated distiller with latent heat storage capacity is compared with solar concentrated distiller with trays on the basin. Paraffin wax is used as the latent heat storage material. Experiments are conducted for improving productivity and this is done by various factors like heat storage capacity, exposure area and maintaining low depth. Hourly Productivity of the concentrated solar distiller is obtained for experimental duration 9AM to 5AM water was measured every hour by maintaining lower depth. Overall productivity was improved by a maximum of 48% by using various modifications.**

***Index Terms*—Paraffin wax, latent heat storage, concentrated solar distiller, distillation.**

I. Introduction

Fresh water is essential for sustainable food production as well as all living ecosystem. About 97% of available water sources are saline and include harmful bacteria and 2% is frozen in glaciers and polar ice caps. Hence, only 1% of the world's water is useable for drinking and domestic usages [1]. The quality of life of the world population largely depends on energy at its disposal, not only in quantity but also in quality. It is determined by the choice of modes of production, distribution and consumption. Resolve the crucial energy in the world by providing men energy that they need on their housing and production sites is certainly a factor of peace. In these circumstances, made to find a source of energy other than those of fossil energies and responding to environmental requirements, seems crucial. Energy storage plays important roles in conserving available energy and improving its utilization. Latent heat storage material and sensible storage materials play a vital role in conservation of energy. Delyannis [2] presented a historic background of desalination and renewable energies. Various technologies are being used for desalination such as multi-stage flash, multiple effect, vapour compression, reverse osmosis, ion exchange, electro dialysis, phase change and solvent extraction [3]. These technologies are costly, especially when the large amount of fresh water production is not desirable. On the other hand, using conventional energy sources (hydrocarbon fuels) to drive these systems have harmful environmental impacts. Various types of solar still have been investigated by researchers [3–7] El-Kassaby[8] studied the complete design and fabrication for a distilled water apparatus using a line concentrator of parabolic reflector type. Ortega et al. [9] studied effect of concentrator as vapour generator for solar-ammonia and water adsorption refrigerator. Rabl [10-12] compared parabolic concentrator and studied the effect of maximum concentration. Phadatare [13] proposed that basin water depth is having significant effect on productivity of the solar still. Investigations show that, the water depth is inversely proportional to the productivity of still. Tripathi and Tiwari [14] inferred that the convective heat transfer coefficient between water and inner condensing cover depends significantly on the water depth of the basin. It is also observed that more productivity was obtained during the off shine hours as compared to day time for higher water depths in solar still (0.10 and 0.15 m) due to storage effect. Dimri et al. [15] conducted theoretical and experimental analysis of a solar still integrated with flat plate collector with various condensing cover materials. Tiwari et al. [16] inferred that, the internal heat transfer coefficients should be determined by using inner glass cover temperature for thermal modeling of passive and active solar stills. Kaygusuz [17] also carried out a theoretical and experimental study to determine the performance of PCM storage, and the variation of the outlet temperature with different values of NTU (the number of transfer units of the storage unit) for water-based solar heating systems. Tiwari et al. [18] presented an analysis of PCM storage for a water heater by incorporating the effect of water flow through a parallel plate placed at the solid-liquid interface. Wick type solar stills [19], a plastic water purifier [20] and stepped solar still were developed. The materials that improve the heat transfer were studied by velmurugan et al [21]. The parabolic concentrator solar distiller with latent heat storage material and distiller with trays were studied. The comparisons between the distillers were based on the productivity. The materials like sponges, pebbles, mild steel billets are used to enhance the heat transfer. The latitude of Madurai were the experiment is conducted was 10 °.

II. Experimental Setup

In this experimental setup, performance of solar concentrated distiller with latent heat storage material was compared with solar concentrated distiller with tray basin. Valves are used to control the flow of saline water to the

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basin of the concentrator. Basin of length 0.9m and diameter 0.15m is provided for evaporating the saline water. It is fabricated of 2 mm thick GI sheet and coated with black paint to increase the absorption of heat. Parabolic concentrator of length 1m and width 0.5m, depth 0.125m is used to concentrate solar thermal energy to the basin made out glass mirror. These dimensions were calculated based on which concentration of sunlight focuses on the basin. Concentrator is tilted to various angles manually every hour. Basin is covered with double slope glass cover for condensing the distilled water. One of the basin is enhanced with pipes containing paraffin wax, which acts as latent heat storage material for the system. And another basin has segmented fins on the basin, which improves the exposure area of the basin. Comparison of performance is based on productivity of the distiller between 10 A.M to 5P.M. Glass cover is inclined in 10 degree on both sides. Leather sheet was used to prevent leakage from any gap between the glass covers and the still box Poly Vinyl Chloride (PVC) tubes were used to discharge the distilled water from each unit to the bottles. The inlet water was fed into the still using flexible hoses. Schematic diagram of solar distiller was shown in Fig. 1. Various modifications done are explained.

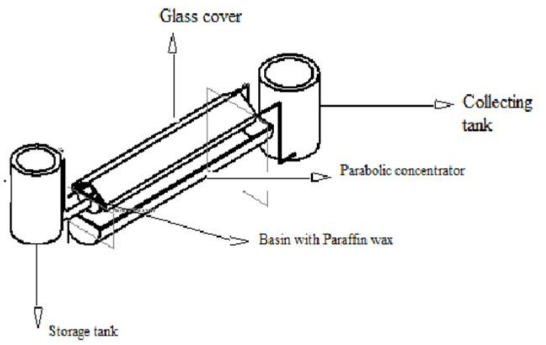

Fig. 1. Schematic diagram of solar concentrated distiller

A. Solar distiller with paraffin wax

Paraffin wax was filled in small tubes and fitted onto basin to improve the latent heat storage capacity of the solar distiller. There by improves the heat storage capacity of the basin shown in Fig 2.

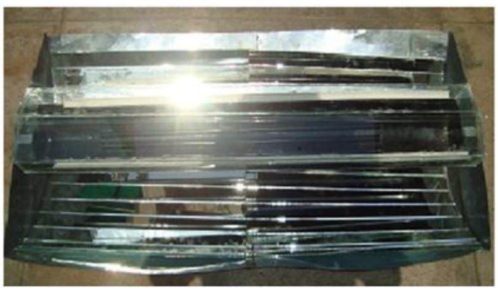

Fig. 2. Solar distiller with paraffin wax

B. Solar Distiller with Finned Type

The concentrated parabolic solar distiller provided with trays in the basin is studied. The evaporation rate is improved by the contact area of the basin, as the trays section acts a fin shown in Fig 3.

C. Solar Distiller with Sponges

To increase water exposure area, sponges were used in solar distiller. The exposure area of the basin of solar still increases due to the capillary action. This will increase the evaporative area as well as evaporation rate.

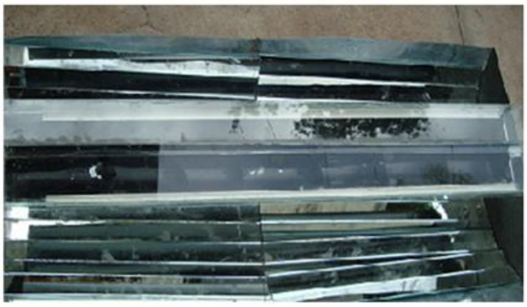

Fig. 3. Solar distiller with finned basin

D. Solar Distiller with Sponges and Pebbles

Pebbles were added to previous modification along with sponges in the solar distiller. It was observed that the productivity of still increased due to the higher volumetric heat capacity of the pebbles.

E. Solar Distiller with Mild Steel Billets

Mild steel billets having high thermal conductivity are added to both the set up ,it leads to heat storage capacity of the basin is improved. Productivity based on all the modifications was studied.

III. Results and Discussions

Performances of the solar desalination units are compared with various modifications of sponges, pebbles and mild steel billets were studied. Productivity of the system for depth of 1 cm and 2 cm depth are measured.

A. Solar Distiller without Modifications

The graphs drawn below illustrate the variation of productivity with time for various depths without modifications in solar distiller shown in Fig 4.

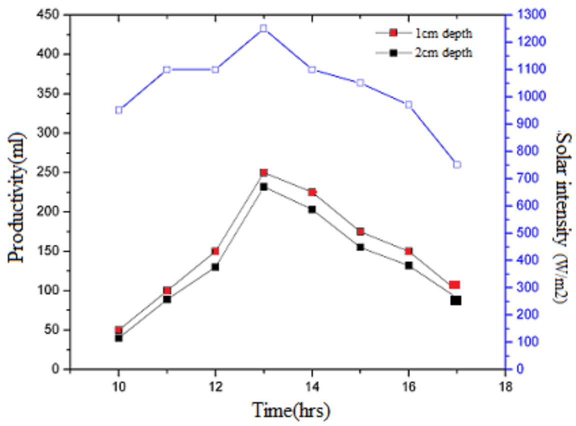

Fig. 4. Productivity of solar distiller without modifications

B. Solar Distiller with Paraffin Wax and Trays

The graphs drawn below illustrate the variation of productivity with time for various depths in distillers containing paraffin wax and trays in Fig. 5 and Fig. 6. The water output increased in lower depth for each hour due high heat transfer. The productivity was about 33.75% for latent heat storage and 15.11% increased for basin with trays.

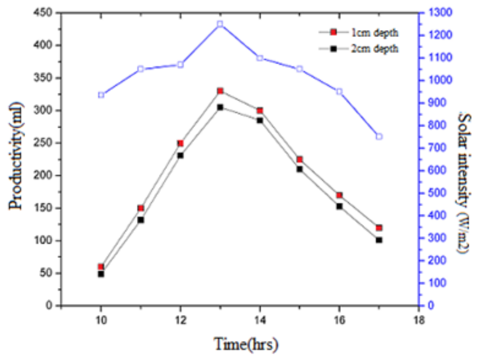

Fig. 5. Productivity of solar distiller with paraffin wax

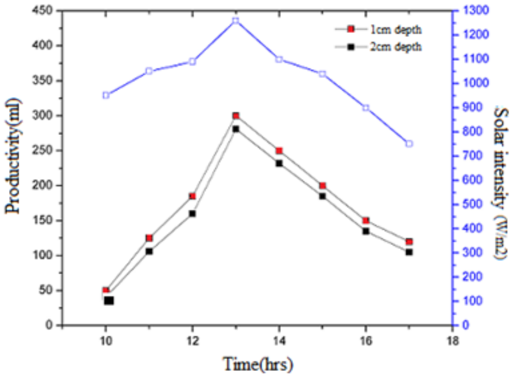

Fig. 6. Productivity of solar distiller with trays

C. Solar Distiller with Sponges

It is observed that due to the presence of sponges, the water output is increased to 40.83% in latent heat storage distiller and 19% increase in tray basin type, while comparing with the plain basin type shown in figure 7 and figure 8.

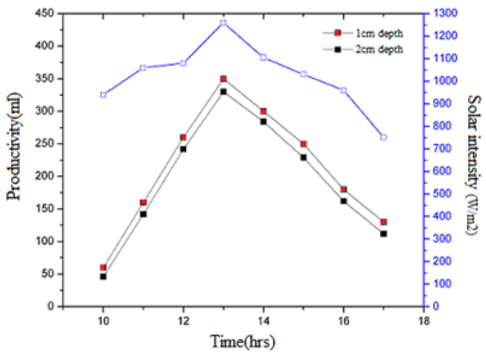

Fig. 7. Productivity of paraffin wax distiller with sponges

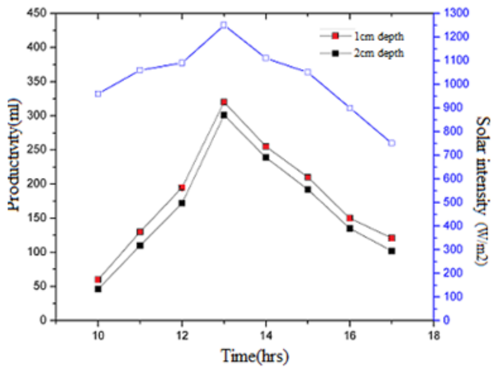

Fig. 8. Productivity of finned distiller with sponges

D. Solar Distiller with Sponges and Pebbles

Due to the presence of sponge and pebbles, the overall water output is increased to 42.85% in latent heat storagesolar distiller and 25.12% increase in productivity for tray type basin, when compared to conventional distiller shown in Fig 9 and Fig 10.

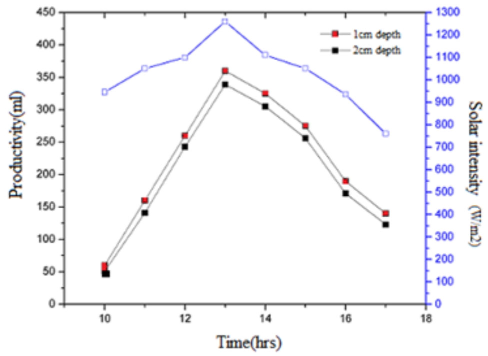

Fig. 9. productivity of paraffin wax distiller with sponges and pebbles

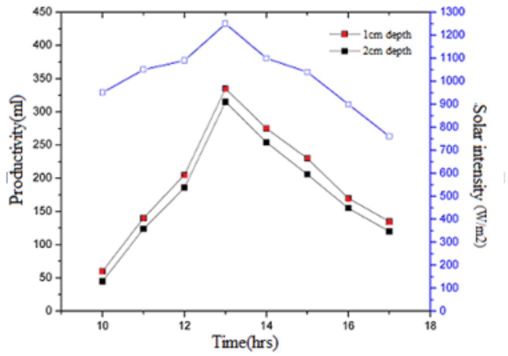

Fig. 10. productivity of finned distiller with sponges and pebbles

E. Solar Distiller with Mild Steel Scraps:

Due to presence of Mild steel scraps, heat storage capacity and thermal conductivity of metal increases the productivity to the maximum of 48.08% in latent heat storage type and 29% increase in tray type distiller, when compared to the convention setup shown in Fig 11 and Fig 12.

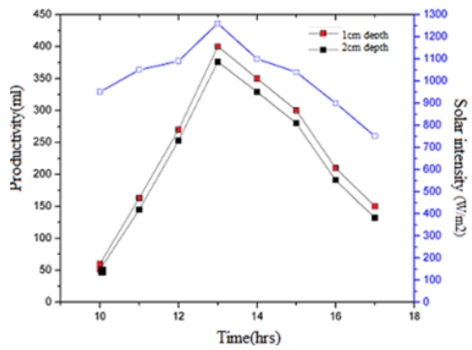

Fig. 11. productivity of paraffin wax distiller with mild steel billets

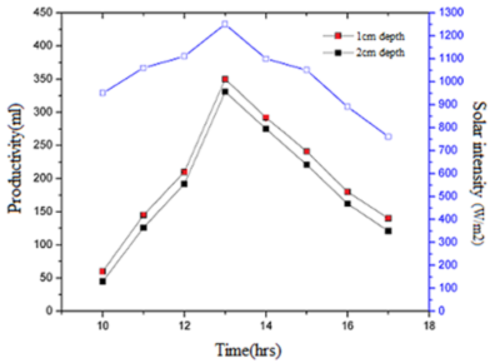

Fig. 12. productivity of finned distiller with mild steel billets

TABLE I: INCREASE IN PRODUCTIVITY DUE TO VARIOUS MODIFICATIONS

Type of modification	Increase in productivity -Paraffin wax	Increase in productivi -finned
Without	33.75	15.11
Sponges	40.83	19
Sponges and pebbles	42.85	25.11
Mild steel scraps	48.08	29

IV. CONCLUSION

After the series of experiment conducted in solar distillers, Analysis was made between two types of basin. Sponges were added to increase the exposure area by capillarity effect. It is observed that due to the presence of sponges, the water output is increased to 40.83% in latent heat storage distiller and 19% increase in tray basin type, while comparing with the plain basin type. Due to the presence of sponge and pebbles, the overall water output is increased to 42.85% in latent heat storage solar distiller and 25.11% increase in productivity for tray type basin, when compared to conventional distiller. Mild steel scraps, which have good heat storage capacity and thermal conductivity. When mild steel scrap is added it increases the productivity to the maximum of 48.08% in latent heat storage type and 29% increase in tray type distiller when compared to conventional type.

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