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Comparative Study on Hemispherical Solar Still with Black Ink Added

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Abstract— Water is the basic need for man to sustaining life on the earth. With the passage of time due to technical usage and their waste disposal along with ignorance of human being caused water pollution, which led the world towards water scarcity. To resolve this problem Solar Distillation is one of the best Techniques from available another techniques. But, due to its lower productivity it cannot be commercial in the market. So that Lots of work can be done to improve the solar still efficiency or productivity. This experimental has been carried out to measure the effect of black ink on the hemispherical solar still. With different water depth and constant proportion of ink in the water and with same depth of water increasing the proportion of ink in the water has been compared to the simple hemispherical solar still. From this experimental study, it has been observed that the productivity of hemispherical solar still increased with decreasing the water depth. The productivity of hemispherical solar still has been increased with 1.25% black ink added up to 17% to 20%, and for 2% black ink added it increased up to 25%.

Keywords— passive, hemispherical solar still, black ink, polycarbonate glass, condensing glass cover, Active solar still, absorbing material.

INTRODUCTION

Water is the basic need for sustaining life on the earth. With the passage of time due to technical usage and their waste disposal along with ignorance of human being caused water pollution. This led the world towards water scarcity. Due to water pollution the surface and underground water reservoirs are now highly contaminated. Most of the human dices are due to brackish water problem. Around 1.5 to 2 million children are dies and 35 to 40 million people are affected by water borne dices. However the increasing industrial activities may lead to a situation where by countries need to reconsider their option with respect to the management of its water resources. Around 3% of the world water is potable and this amount is not evenly distributed on the earth. So, developed and under developed countries are suffering the problem of potable water.

Distillation is an oldest technique to distillate brackish or salty water in to potable water. Various technologies were invented for desalination from time to time and it has been accepted by people without knowing future environmental consequences. Desalination techniques like vapour compression distillation, reverse osmosis and electrolysis used electricity as input energy. But in the recent years, most of the countries in the world have been significantly affected by energy crisis because of heavy dependency on conventional energy sources (coal power plants, fossil fuels, etc.), which has directly affected the environment and economic growth of these countries. The changing climate is one of the major challenges the entire world is facing today. Gradual rise in global average temperatures, increase in sea level and melting of glaciers and ice sheets have underlined the immediate need to address the issue.

All these problems could be solved only through efficient and effective utilization of renewable energy resources such as solar, wind, biomass, tidal, and geothermal energy etc. The alternative solution of this problem is solar distillation system and a device which works on solar energy to distillate the water is called solar still. Solar still is very simple to construct, but due to its low productivity and efficiency it is not popularly used in the market. Solar still is working on solar light which is free of cost but it required more space.

SOLAR DISTILLATION SYSTEM

G.N .Tiwari et al reviewed the present status of solar distillation systems for both passive and active models. In this field a large group of authors reported that the passive solar distillation system is a slow process for purification of brackish water. The yield of this still is about 2L/day per m^2 of still area, which is much less and may not be economically useful. However, there is a method to increase the yield by integration of solar collector into the basin. This is generally referred to as active solar stills. These may be flat plat collector, solar concentrator or evacuated collector. These collectors may produce temperatures within the range of 80–120°C depending upon the type of solar collector. However, the range of temperature within solar stills is reduced to about 80°C due to high heat capacity of water mass within the basin. Hence there is a practical application of such active systems to extract the essence of medicinal plants placed under the solar still at about 80°C. The systems used for extraction of the essence of medicinal plants have become economical. [1]

Salah Abdallah et al. worked to measuring the Effect of various absorbing materials on the thermal performance of solar stills. From this Experiment they found that there is a strong need to improve the single slope solar still thermal performance and increase the production rate of distilled water. Different types of absorbing materials were used to examine their effect on the yield of solar stills.

These absorbing materials are of two types: coated and uncoated porous media (called metallic wiry sponges) and black volcanic rocks. Four identical solar stills were manufactured using locally available materials. The first three solar stills contain black coated and uncoated metallic wiry sponges made from steel quality AISI 430 type and black rocks collected from Mafraq Area in north-eastern Jordan. The fourth still is used as reference still which contains no absorbing materials (only black painted basin). The results showed that the uncoated sponge has the highest water collection during day time, followed by the black rocks and then coated metallic wiry sponges. [2]

On the other hand, the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.

V.K. Dwivedia et al. can compare the internal heat transfer coefficients in passive solar stills by different thermal models by an experimental validation. In this paper, an attempt has been made to evaluate the internal heat transfer coefficient of single and double slope passive solar stills in summer as well as winter climatic conditions for three different water depths (0.01, 0.02 and 0.03 m) by various thermal models. The experimental validation of distillate yield using different thermal models was carried out for composite climate of New Delhi, India (latitude 28°35′N, longitude 77°12′E). By comparing theoretical values of hourly yield with experimental data it has been observed that Dunkle's model gives better agreement between theoretical and experimental results. Further, Dunkle's model has been used to evaluate the internal heat transfer coefficient for both single and double slope passive solar stills. With the increase in water depth from 0.01 m to 0.03 m there was a marginal variation in the values of convective heat transfer coefficients. It was also observed that on annual basis output of a single slope single slope solar still is better (499.41 l/m^2) as compared with a double slope solar still (464.68 l/m^2). [3]

SangeetaSuneja et al. measured n Effect of water depth on the performance of an inverted absorber double basin solar still. They perform transient analysis of a double basin solar still has been presented. Explicit expressions have been derived for the temperatures of various components of the inverted absorber double basin solar still and its efficiency. The effect of water depth in the lower basin on the performance of the system has been investigated comprehensively. For enunciation of the analytical results, numerical calculations have been made by them using meteorological parameters for a typical winter day in Delhi. They observed that the daily yield of an inverted absorber double basin solar still increases with the increase of water depth in the lower basin for a given water mass in the upper basin. [4]

G.N. Tiwari et al. worked on Computer modelling of Passive/Active Solar Stills by using inner Glass Temperature. Expressions for water and glass temperatures, hourly yield and instantaneous efficiency for both passive and active solar distillation systems have been derived. The analysis is based on the basic energy balance for both the systems. A computer model has been developed by them to predict the performance of the stills based on both the inner and the outer glass temperatures of the solar stills. In this work two sets of values of C and n (C_{inner}, n_{inner} and C_{outer}, n_{outer}), obtained from the experimental data of January 19, 2001 and June 16, 2001 under Delhi climatic condition, have been used. It is concluded that (i) there is a significant effect of operating temperature range on the internal heat transfer Coefficients and (ii) by considering the inner glass cover temperature there is reasonable agreement between the experimental and predicted theoretical results. [5]

Bhagwanprasad and G N Tiwari et.al. Perform an analysis of a double effect active solar distillation unit has been presented by incorporating the effect of climatic and design parameters. Based on an energy balance in a quasi-steady condition, an analytical expression for hourly yield for each effect has been derived. Numerical computations have been carried out for a typical day in Delhi, and the results have also been compared with single effect, active solar distillation unit. It has been observed that there is a significant improvement in the performance for a minimum flow rate of water in the upper basin. [6]

T. Arunkumaret.al. Working on An Experimental Study on a Hemispherical Solar Still and This work reports a new design of solar still with a hemispherical top cover for water desalination with and without flowing water over the cover. The daily distillate output of the system was increased by lowering the temperature of the cover by water flowing over it. The fresh water production performance of this new still was observed in Sri Ramakrishna Mission Vidhyalaya College of Arts and Science, Coimbatore (11° North, 77° East), India. The efficiency was 34%, and increased to 42% with the top cover cooling effect. Diurnal variations of a few important parameters were observed during field experiments such as water temperature, cover temperature, air temperature, ambient temperature and distillate output. Solar radiation incident on a solar still is also discussed here. [7]

Basel I. Ismail et al. represents a Design and performance of a transportable hemispherical solar still. A simple transportable hemispherical solar still was designed and fabricated, and its performance was experimentally evaluated under outdoors of Dhahran climatic conditions. It was found that over the hours of experimental testing through daytime, the daily distilled water output from the still ranged from 2.8 to 5.7 l/m2 day. The daily average efficiency of the still reached as high as 33% with a corresponding conversion ratio near 50%. It was also found that the average efficiency of the still decreased by 8% when the saline water depth increased by 50%. [8]

S. Siva kumar et. al. worked on a single basin double slope solar still made up of mild steel plate with different sensible heat storage materials like quartzite rock, red brick pieces, cement concrete pieces, washed stones and iron scraps. Out of different energy storing materials used, ¾ in. quartzite rock is the more effective. [9]

Yousef H. Zurigat et. al. Worked on regenerative solar still. They have been observed that the Insulation has higher effect on the regenerative still compared to simple still. Productivity will increase up to 50% if the wind speed was increase from 0 to 10 m/s. [10]

Hiroshi Tanaka et. al. represented a theoretical analysis of a basin type solar still with an internal reflector (two sides and back walls). They have observed that the benefit of vertical external reflector would be smaller or even negligible. The daily productivity with external reflector was 16% greater than that with the vertical external reflector. [11]

Badshah alam et. al. represented the comparative evaluation of the annual performance of single slope passive and hybrid (PVT) active solar stills. Higher yield obtained from the active solar still and ratio depends on the climatic conditions during the year. Efficiency of 9.1- 19.1% was obtained by the active solar still while the passive solar still performed at 9.8-28.4% during the year. [12]

EXPERIMENTAL STUDY OF SOLAR STILL

Experimental measurements were performed to evaluate the performance of the solar still under the outdoors of Mehsana climatic condition. Mehsana has geographical condition as latitude 23˚13'N and Longitude 72˚39' campus area. Entered assembly was made air tight with the half of a silicone gel. Basin of solar still has been constructed from 14 gauge of galvanized iron steel. Condensing glass cover made up of clear type polycarbonate material. Thickness of the polycarbonate condensing cover was 2mm.The basin liner is black oil painted on the inner surface of the basin. This has the dimension 0.08m² effective absorber area of flat based circular section. Thickness of insulation was 10 mm in each side and the thermocol used as insulating material to minimize the heat loss over the sides of the basin. One water inlet, condensing water outlet and excess water outlet was provided in the basin. After the black coating of the basin scale was fixed in the basin wall with the help of solution to measure the Depth of water. Thermocouple was inserted from water inlet hole and located in different place of the still before fixed the glass cover. They record the different temperature such as inner surface of glass cover, basin water, vapour temperature inside the still and atmospheric temperature outside the still.

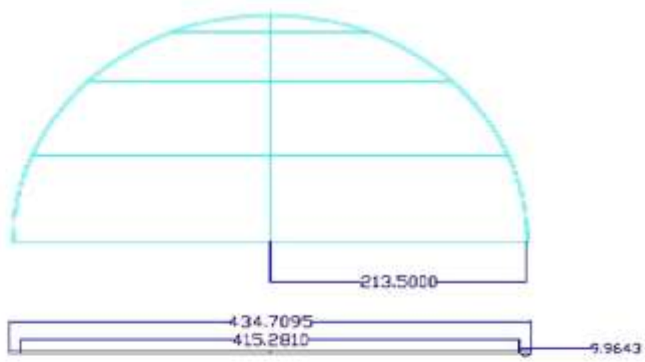

Fig 2 Hemispherical Polycarbonate Condensing Cover diagram

Before the commencement of each test the basin was filled with saline water using the inlet port and hemispherical cover was cleaned from dust. The water depth was kept 0.5cm, 1cm, 1.5cm respectively and ink add in proportion of 1.25% water and depth is 0.5cm,1cm,1.5cm respectively. The experiment was carried out on sunny day. The temperature of glass cover vapour, inside water temperature and atmosphere temperature was measured by J-type thermocouple and record to the note. Daily Solar radiation was measured by solarimeter in w/m^2. The distil water was collected hourly in the measuring jar. Experiment was carried out in month of March and April, Experiment starting from 9 AM TO 5 PM in sunny days. The Maximum amount of potable was collected at 1pm to 2: 30pm. This simple hemispherical results can compared to the with ink proportion used in water.

PHOTOGRAPH OF EXPERIMENTAL SETUP

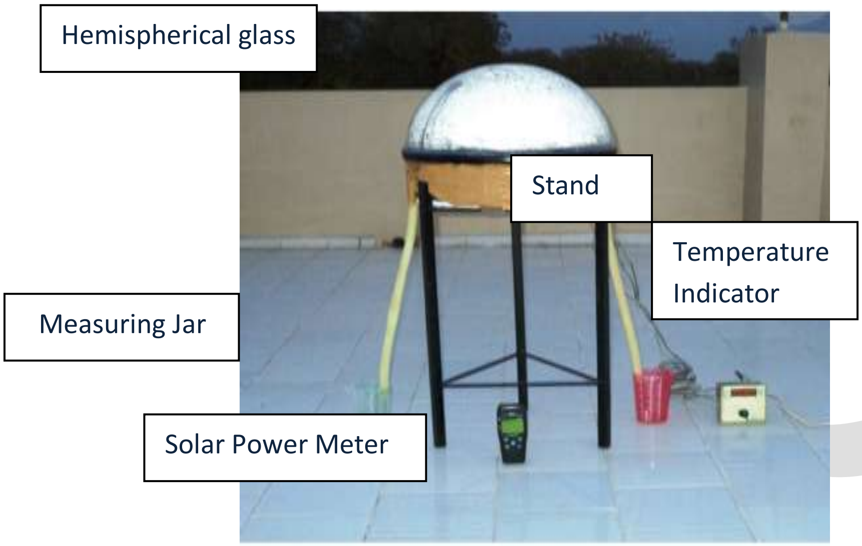

Fig 3 Photograph of Experimental Setup

RESULT AND DISCUSSION

Typical results of the variation of the saline water temperature and glass cover temperature and ambient temperature have been measured during reprehensive day of testing. Temperature difference between the water and cover has similar trends, as they increase in the morning hours to maximum value around noon time. They start to decrease late in the afternoon. This is due to increase of solar irradiance in the morning and the decrease after 2.00 pm. After assembling the solar still, a set of experiments were performed to test its efficiency and productivity per hour per day. The experiments were carried out on days of bright sunny days. The amount of water and some temperature values was measured from 9:00AM to 5:00PM in campus area. Some factors are affecting on the active solar still are: solar radiation intensity, ambient temperature, wind velocity, humidity, condensing glass cover inclination, solar collector inclination, solar collector area, absorber material, etc.

The quantity of fresh water obtained from the solar still was 1.5 l/m^2. 2^{nd} day of March the still area for 0.08m^2 has 1.5 cm of water depth. Total Mass of water obtained from the solar still was 255ml and it comes as a 3.180 L/m^2.The Hemispherical still has 0.5 L/m^2 day on the day of 9^{th} day of March the still area with 0.08m^2, Total mass of water gain was 270 ml. Figure 5.1, Figure 5.2, Figure 5.3 and Figure 5.4 Figure 5.5, Figure 5.6, Figure 5.7 and Figure 5.8 shows the graph of hourly variation of solar radiation, mass of distilled water ml during the day 2^{nd} and 9^{th} of the march, 2014. The maximum solar radiation is in between 12:00 to 14:00 and the ambient temperature maximum in between 13:00 to 14:00 of the day period and drastically change in the solar radiation can shows the weather effect.

A hemispherical solar still has been fabricated and tested with and without black ink. Black ink is also an absorptive ink. So, if it is used in the form of mixture with proportion of water then it's helpful to increase the productivity in the solar still. It was the best absorbing material used in terms of water productivity. I hope to the resulted in an enhancement of about 60%.

WITHOUT ABSORBER INK

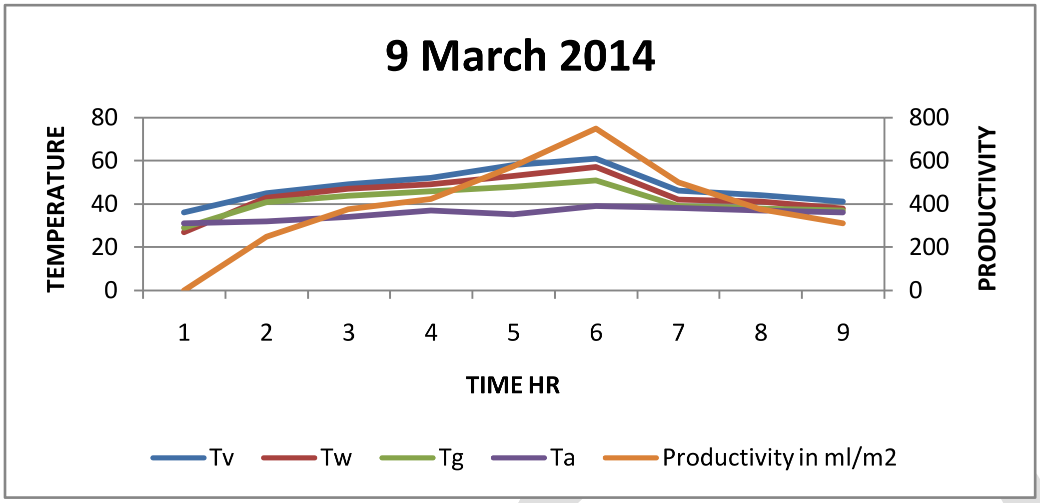

Fig 4 hourly variations in temperature and productivity during the day water depth 0.5 cm

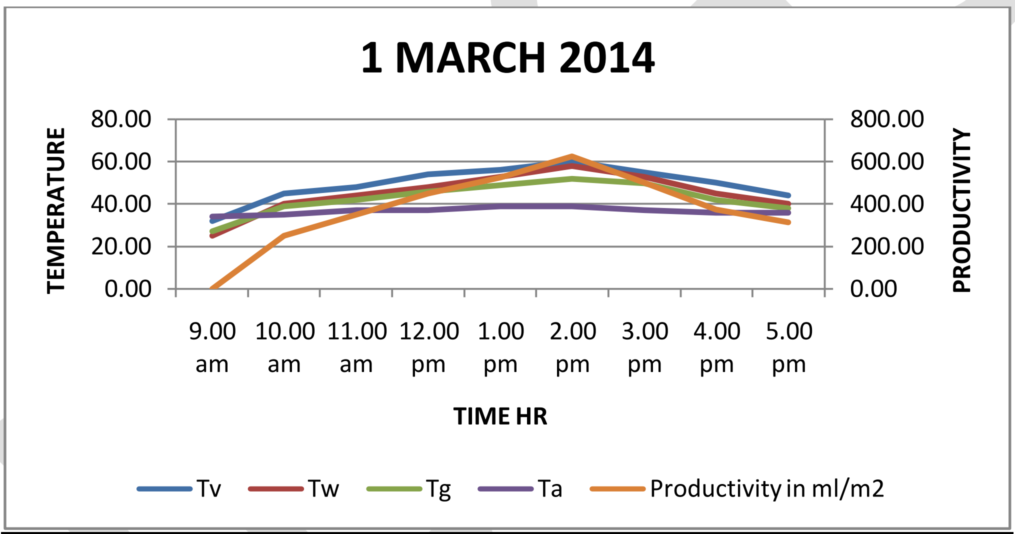

Fig 5 hourly variations in temperature and productivity during the day water depth 1 cm

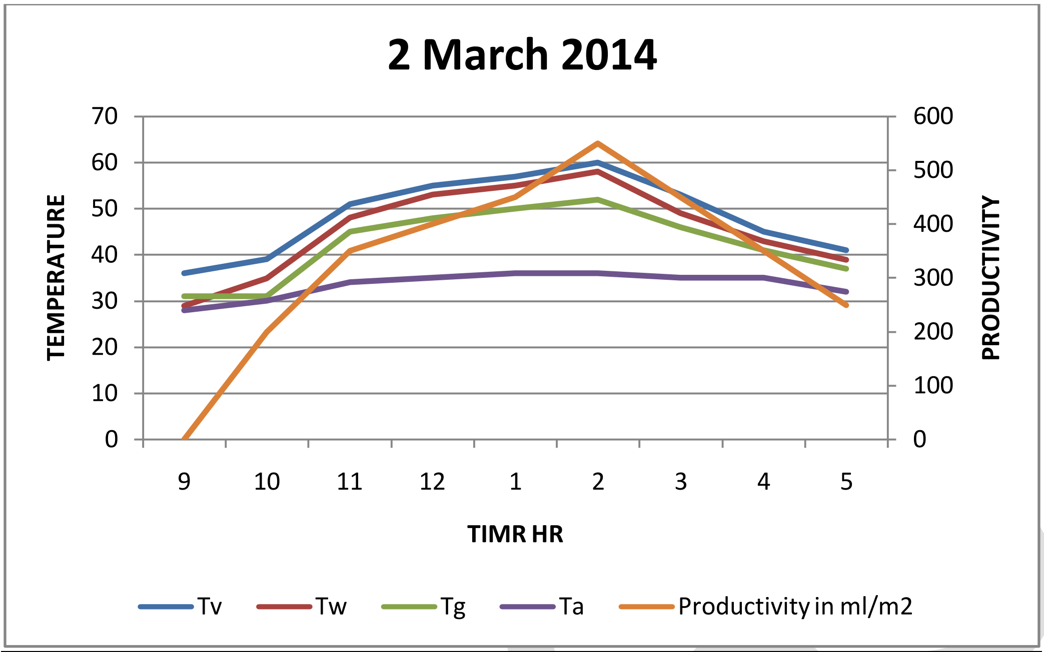

Fig 6 hourly variations in temperature and productivity during the day water depth 1.5 cm

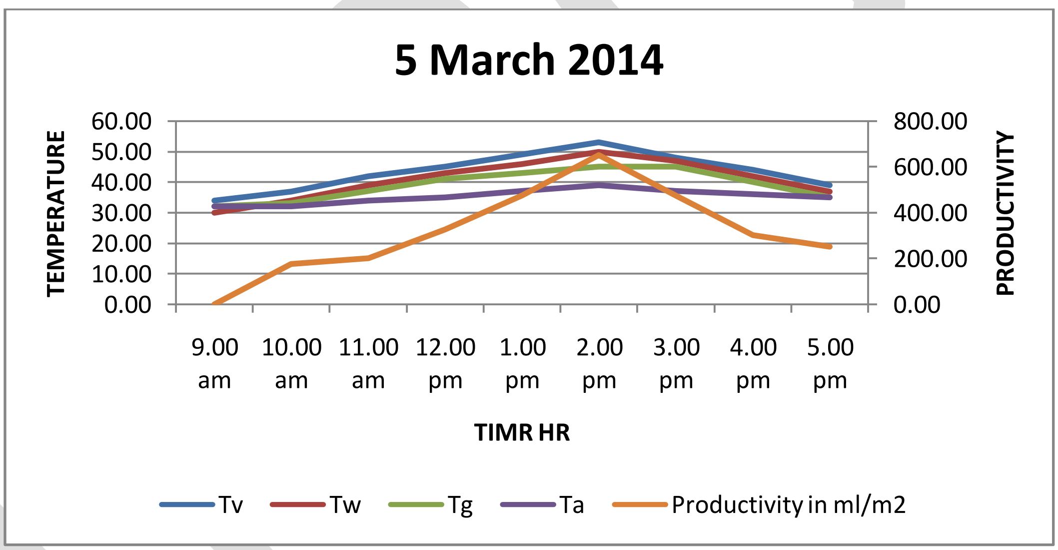

Fig 7 hourly variations in temperature and productivity during the day water depth 2 cm

Figure 4, Figure 5, Figure 6 and Figure 7 shows without absorber material ink the hourly production rate of distilled water during the day period from 9:00 to 17:00. Maximum production in solar still was in between 13:00 to 14:00. From this observation of experiment 9:00 to 17:00 hour of the day, the temperature difference between basin water surface and inner surface of glass cover was increasing from 9:00 and maximum at the 13:00 to 14:00 after peak value the ambient temperature will reduced and solar radiation intensity also reduced, so for that temperature of water in the basin and glass cover also decreases. So, from the part of this study observed that if the temperature difference between basin water and inner surface of glass cover of the still will increase than the productivity of the still increases. The average productivity was 2.8 l/m^2/day. After the peak value of productive output the productivity was continuously decreases.

WITH ABSORBER INK

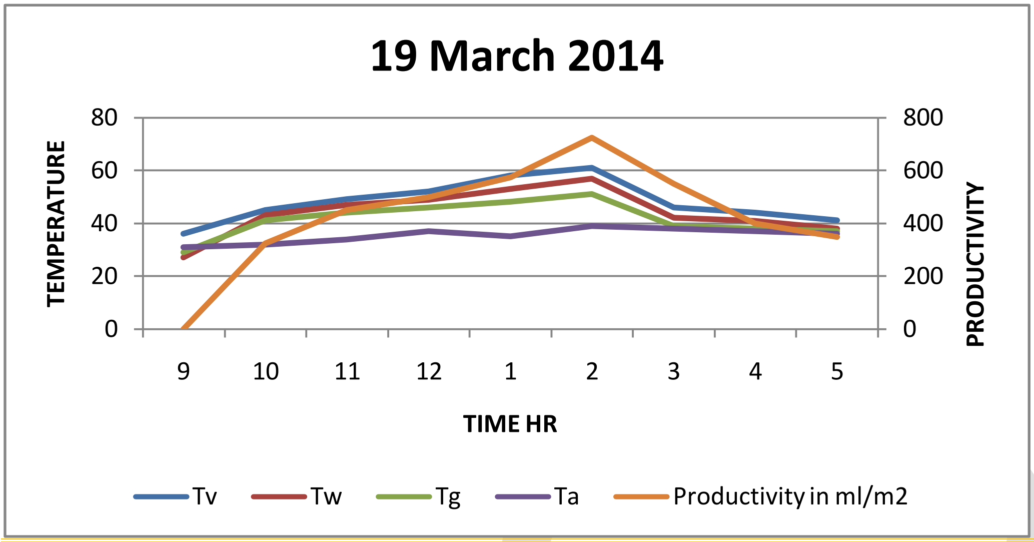

Fig 8 hourly variations in temperature and productivity during the day water depth 0.5 cm with 1.25% ink

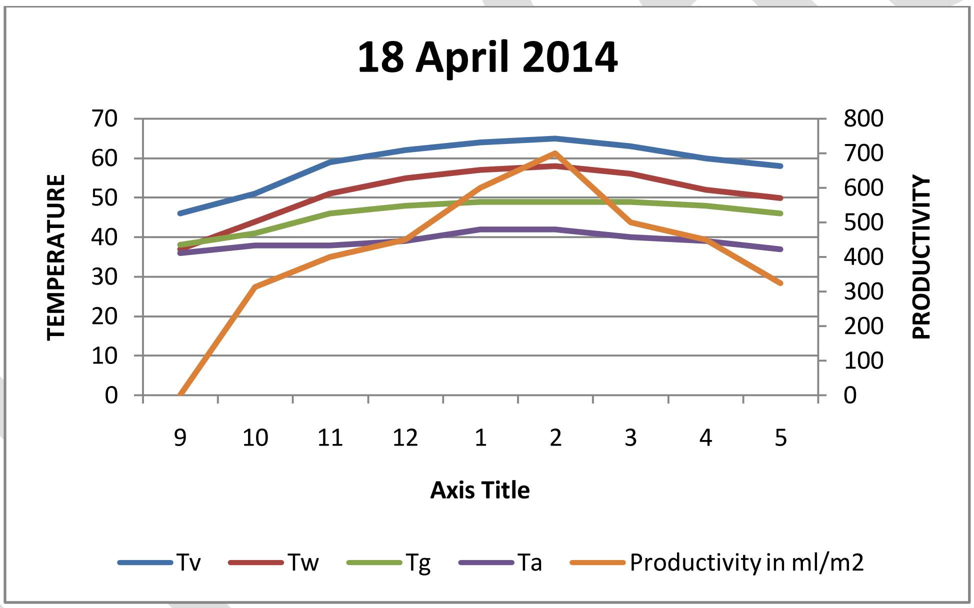

Fig 9 hourly variations in temperature and productivity during the day water depth 1 cm with 1.25% ink

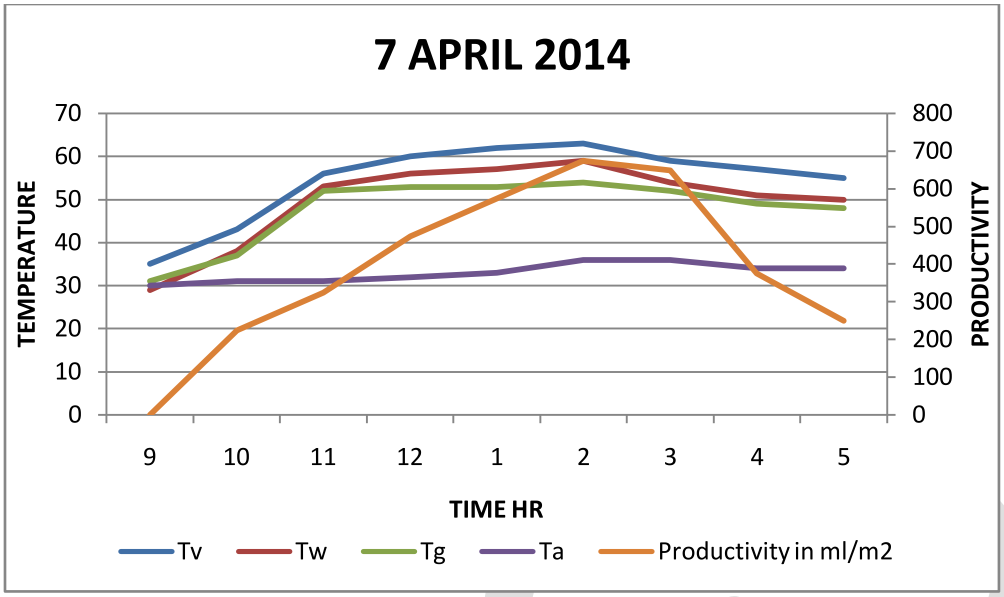

Fig 10 hourly variations in temperature and productivity during the day water depth 1.5 cm with 1.25% ink

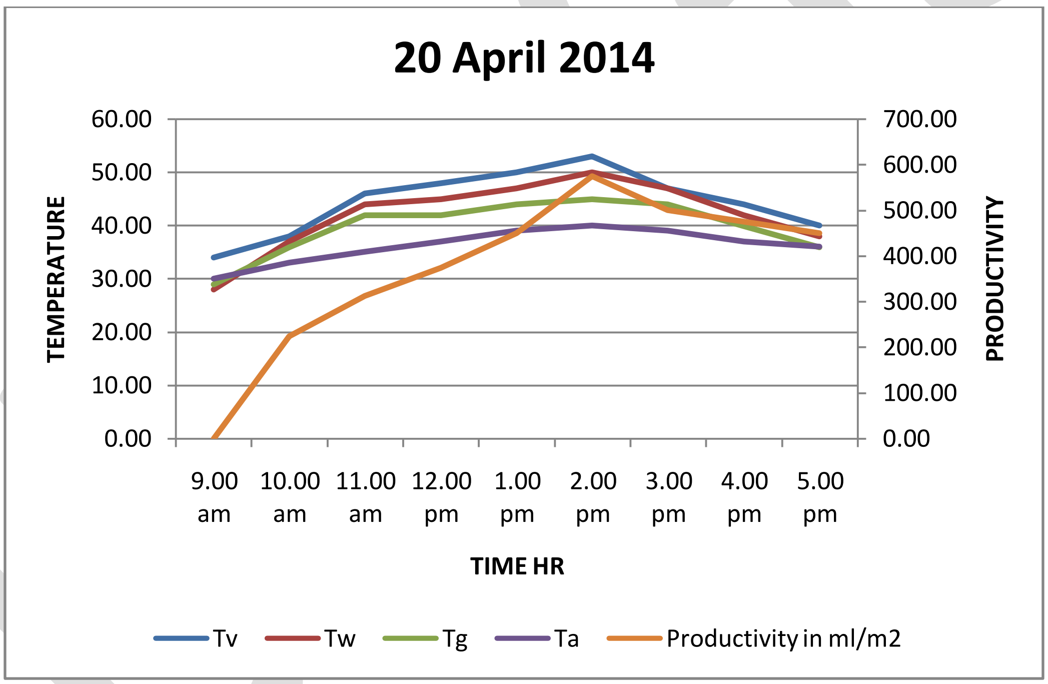

Fig 11 hourly variations in temperature and productivity during the day water depth 2 cm with 1.25% ink

Figure 8, Figure 9, Figure 10 and Figure 11 shows the variation in productivity of distilled water with respected to variation in temperature and time. The productivity of this solar still converted in to the ml/ m^2. As compared to without ink the hemispherical productivity has been increased up to 17 to 20% with the help of only 1.25% ink added. The productivity of the solar still with ink added also gives the maximum productivity in-between 1:00 pm to 2:00 pm and the temperature difference between water and glass surface has been increase as compared to the without ink added solar still.

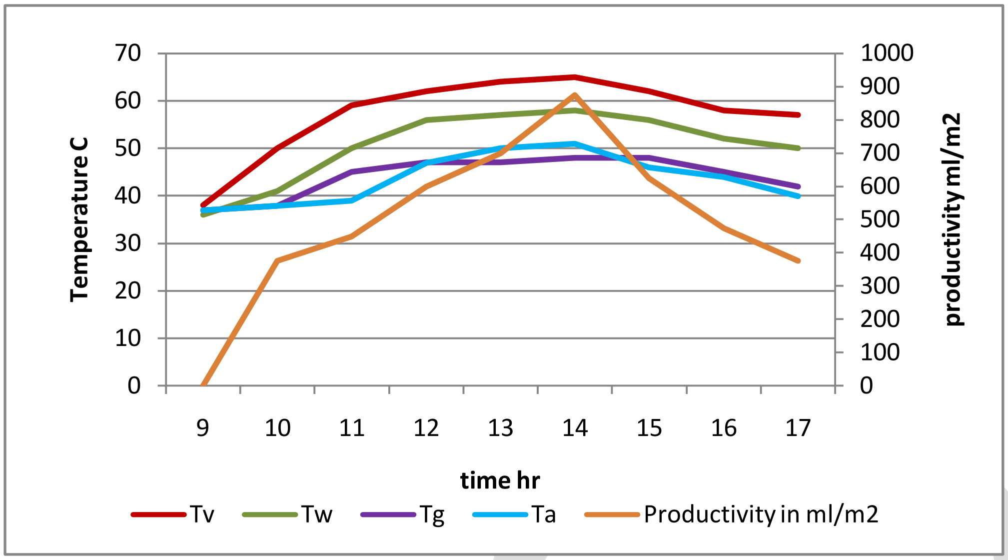

Fig 12 hourly variations in temperature and solar radiation the day water depth 1 cm with 2% ink

Figure 12 shows that the increment of different temperatures and productivity of solar still with respected to the increment in solar radiation during the day period. From this figures it has been observed that the temperature difference between water and glass cover increased with increasing the ink proportion with water. Also, the productivity has been increased with increasing the ink proportion with the water as inlet in the hemispherical type solar still.

CONCLUSION

From this experimental study conclude that the productivity of the hemispherical was increases due to decrease in water depth. Productivity of the solar still has been increased due to increase in temperature difference between water surface and inner surface of condensing glass cover. And maximum productivity of drinking water was collected during 1:00 to 2:00 pm in the sunny days. From this experiment it has been observed that with increasing in ink proportion with water that productivity of the hemispherical solar still gets increased and as compared to without ink added. The productivity of hemispherical has been increased with 2% ink added up to 25% and with 1% ink added 17% to 20%. The productive output distilled water has been tested in laboratory and the results shows that it is useful for the drinking water.

FUTURE SCOPE

- This work will be carried out with $1m^2$ area and compared to the slope type solar still.
- Measure the effect of different proportion of ink added with water for different depth of water.
- Also, measures the effect of ink added in active hemispherical solar still and compares the results with passive hemispherical solar still.
- Compares to the acrylic glass and polycarbonate glass to flat circular base hemispherical solar still.

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