The Performance of Flat Plat Collector of Single Slope Solar Still with 9, 12 cm Water Depth

Suraj Singh[1], Prasenjeet Mukherjee[2], Raji, N. Mishra[3]

[1]Research Scholar, [2]Assistant Professor, [3]Associate Professor
(PCRT) People's University, Bhopal (M.P.) India

Abstract: **The work was motivated by the increasing awareness of the need for enhancing water supplies schemes in arid lands featuring an appropriate technology for solar energy use in the desalination field in India. The conventional desalination technologies like multi stage flash, multiple effect, vapor compression, iron exchange, reverse osmosis, electro dialysis are expensive for the production of small amount of fresh water, also use of conventional energy sources has a negative impact on the environment. Solar distillation represents a most attractive and simple technique among other distillation processes, and it is especially suited to small-scale units at locations where solar energy is considerable. The present work is related to effect of design and climatic parameters on performance of domestic type integrated single slope solar still with and without flat plat collector with 9 & 12 cm water depth. From the present experimental study it has been concluded that water depth, inclination of glass cover gives significant effect on yield of single slope solar still. Experiments of still with flat plate collector have also been performed and it has been noticed that there is considerable effect of flat plate collector on the performance of still. Though solar still have not been successfully commercialized as yet, with the ongoing research efforts, they can be modified and improved for future domestic applications.**

1. Introduction

The fresh water crisis is already evident in many parts of India, varying in scale and intensity at different times of the year. The fresh water crisis is not the result of natural factors, but has been caused by human actions. India's rapidly rising population and changing lifestyles also increases the need for fresh water. Intense competition among competing user's agriculture, industry and domestic sector is driving the ground water table deeper and deeper. Widespread pollution of surface and groundwater is reducing the quality of fresh water resources. Fresh water is increasingly taking centre stage on the economic and political agenda, as more and more disputes between and within states, districts, regions, and even at the community level arises. Nearly One million children in India die of diarrhea diseases each year directly because of drinking unsafe water and living in unhygienic conditions. Some 45 million people are affected by water quality problems caused by pollution, by excess fluoride, arsenic, iron or by the ingress of salt water. Millions do not have adequate quantities of safe water, particularly during the summer months. In rural areas, women and girls still have to walk long distances and spend up to four hours every single day to provide the household with water [1]. Scarcity of fresh water problems are facing many arid zones of Gujarat and Rajasthan, luckily these places are getting more amount of solar energy, apart Gujarat and Rajasthan that in western India, which face water shortage and have huge underground saline water sources, certain regions in Haryana state and Maharashtra states also have underground saline water in spite of high rain fall [2]. The village peoples are facing lot of difficulties to get fresh water for their family needs. All families the women and children are responsible for collecting and storage of water. The quality of drinking water also not suitable for human health, it was found by tested the village water samples at Guru Kripa test house at Ajmer district. After analyzing in all the aspects authors concluded that, the village peoples are expecting suitable low cost purification devices for getting pure drinking water [3]. Desalination of brackish water and seawater to provide the needed drinking water fulfill a basic social need and it does this without any serious impact on the environment. The conventional desalination technologies like multi stage .ash, multiple effect, vapor compression, iron exchange, reverse osmosis, electro dialysis are expensive for the production of small amount of fresh water, also use of conventional energy sources has a negative impact on the environment. Solar distillation provides partially support humanity's needs for fresh water with free energy, simple technology and clean environment. Solar stills have a good chance of success in India for lower capacities which are more than 20 km away from the source of fresh water and where the TDS of saline water is over 10,000 ppm or where seawater is to be desalted [4]. India, being a tropical country, is blessed with plenty of sunshine. The average daily solar radiation varies between 4 and\ 7 KWh per square meter for different parts of the country. There are on an average 250–300 clear sunny days a year. Thus, it receives about 5000 trillion kWh of solar energy in a year. The annual global radiation varies from 1600-220 kW/m^2. The highest annual global radiation is received in Rajasthan and northern Gujarat. In spite of the limitations of being a dilute source and intermittent in nature, solar energy has the potential for meeting and supplementing various energy requirements Solar energy systems being modular in nature could be installed in any capacity as per the requirement. This paper presents of an overall review and technical assessments of various passive and active solar distillation systems in India. The assessment also recommended some research areas in the field of solar distillation, leading to high efficiency are highlighted and finally expressed the economic analysis of solar stills briefly.

Distillation has long been considered a way of making salt water drinkable and purifying water in remote locations. As early as the fourth century B.C., Aristotle described a method to evaporate impure water and then condense it for potable use. Arabian alchemists were the earliest known people to use solar distillation to produce potable water in the sixteenth century. However, the first documented reference for a device was made in 1742 by Nicolo Ghezzi of Italy, although it is not known whether he went beyond the conceptual stage and actually built it. The first modern solar still was built in Las Salinas, Chile, in 1872, by Charles Wilson. It consisted of 64 water basins (a total of 4459 square meters) made of blackened wood with sloping glass covers. This installation was used to supply water (20,000 L/day) to animals working mining operations. After this area was opened to the outside by railroad, the installation was allowed to deteriorate but was still in operation as late as 1912-40 years after its initial construction. This design has formed the basis for the majority of stills built since that time [5].

During the 1950s, interest in solar distillation was revived, and in virtually all cases, the objective was to develop large centralized distillation plants. In California, the goal was to develop plants capable of producing 1 million gallons, or 3775 cubic meters of water per day. However, after about 10 years, researchers around the world concluded that large solar distillation plants were too much expensive to compete with fuel-.red ones. Therefore, research shifted to smaller solar distillation plants. In the 1960s and 1970s, 38 plants were built in 14 countries, with capacities ranging from a few hundred to around 30,000 L of water per day. Of these, about one third have since been dismantled or abandoned due to materials failures. None in this size range is reported to have been built in the last 7 years. Despite the growing discouragement over community-size plants, McCracken Solar Company in California continued its efforts to market solar stills for residential use. Worldwide interest in small residential-units is growing, and now that the price of oil is ten times what it was in the 1960s, interest in the larger units may be revived. Although solar distillation at present cannot compete with oil-.red desalination in large central plants, it will surely become a viable technology within the next 100 years, when oil supplies will have approached exhaustion [6].

1.1 Classification of solar distillation systems

On the basis of various modifications and mode of operations introduced in conventional solar stills, these solar distillation systems are classified as passive and active solar stills. In the case of active solar stills, an extra-thermal energy by external mode is fed into the basin of passive solar still for faster evaporation. The external mode may be collector/concentrator panel waste thermal energy from any chemical/industrial plant etc. If no such external mode is used then that type of solar still is known as passive solar still [7, 8, 9].

Different types of solar still available in the literature are conventional Solar Stills, Single-slope Solar Still with Passive Condenser, Double Condensing Chamber Solar Still, Vertical Solar Still, Conical Solar Still, Inverted Absorber Solar Still, Multi-Wick Solar Still, and Multiple Effect Solar Still [10. 11, 12].

2. Experimental Set up

Fig 1: Experimental setup of solar still (23^o) with collector

The experimental setup was installed at Agriculture University of Jabalpur as shown in picture given below. This place has been selected due to open space no shadow zone during sun shine hours. Experiments are performed for still (23^o) attached with and without flat plate collector with different depth of water to three consecutive days. Different parameters such as temperatures at water surface, inner & outer surface of glass and ambient condition, global and diffuse radiation and yield are recorded hourly.

3. Result and discussion

3.1. Effect of Water Depth of 9 cm on Yield of Single Slope Solar Still

3.1.1. Variation of ambient temperature and relative humidity for 9 cm water depth-

Figure 6 shows the variation of ambient temperature (T_a) and relative humidity (γ_a). This observation was performed in the month of august with 9 cm depth of water in the single slope solar still.

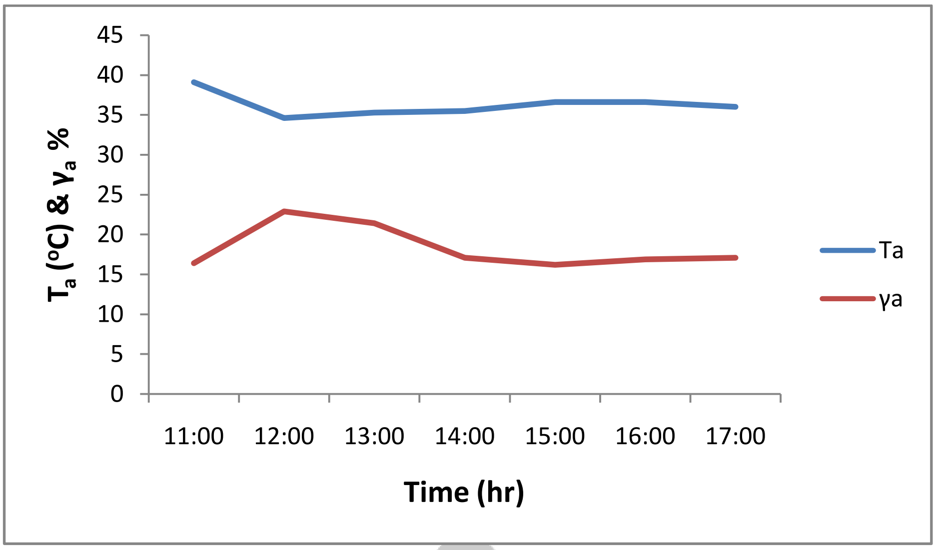

Fig 2 : Variation of ambient temperature (T_a) & relative humidity (γ_a) for 9 cm water depth

Here the values of T_a and γ_a at 11:00 am is 39.1°C and 16.4% respectively whereas at 17:00 hr it was changed up to 36.0°c and 17.1% respectively.

3.1.2. Varaition of Ambient Temperature, Global and Diffuse radiations for 9 cm water depth-

Fig 7 shows the variation between global radiation and diffused radiation with respect to time. It also performed in the month of August and it was examined that global radiation is always more than diffused radiation. The maximum value of global and diffuse radiation are 1038 w/m^2 at 13 hour and 374 w/m^2 at 14:00 hour repectively. The minimum value of global and diffuse radiation are 100.4 w/m^2 at 17 hour and 92.6 w/m^2 at same time. The ambient temperature increases with global radiation.

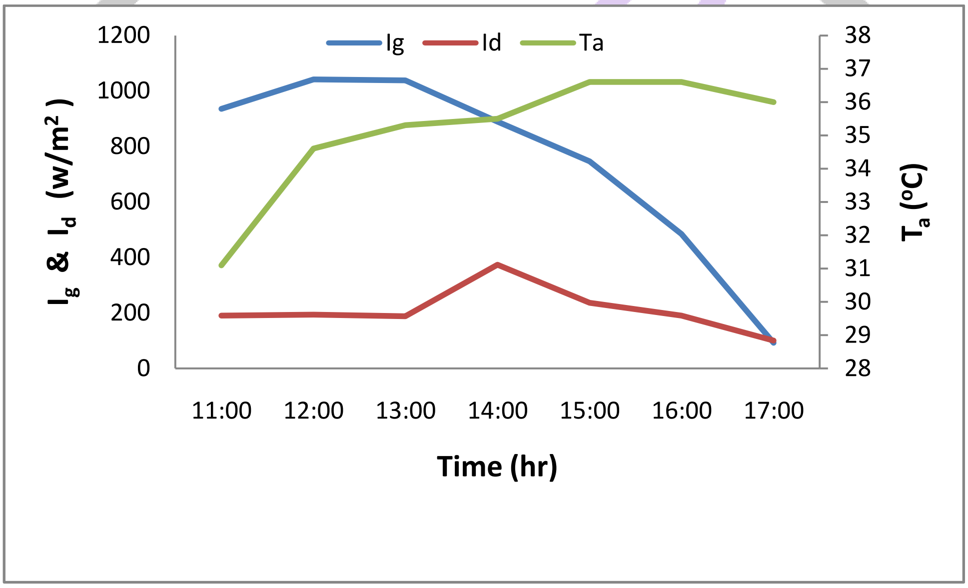

Fig 3 : Varaition of Ambient Temperature, Global (I_g) & Diffuse (I_d) radiations for 9 cm water depth

During the experiment maximum ambient temperature 36.6°C is found at 15 hours whereas minimum 31.1°C at 11 hours.

3.1.3. Variation of Global, Diffuse radiations and yield for 9 cm water depth-

Figure 8 shows the variation between global radiation, diffused radiation and yield. This figure shows the yield of the single slope solar still at 9 cm water depth.

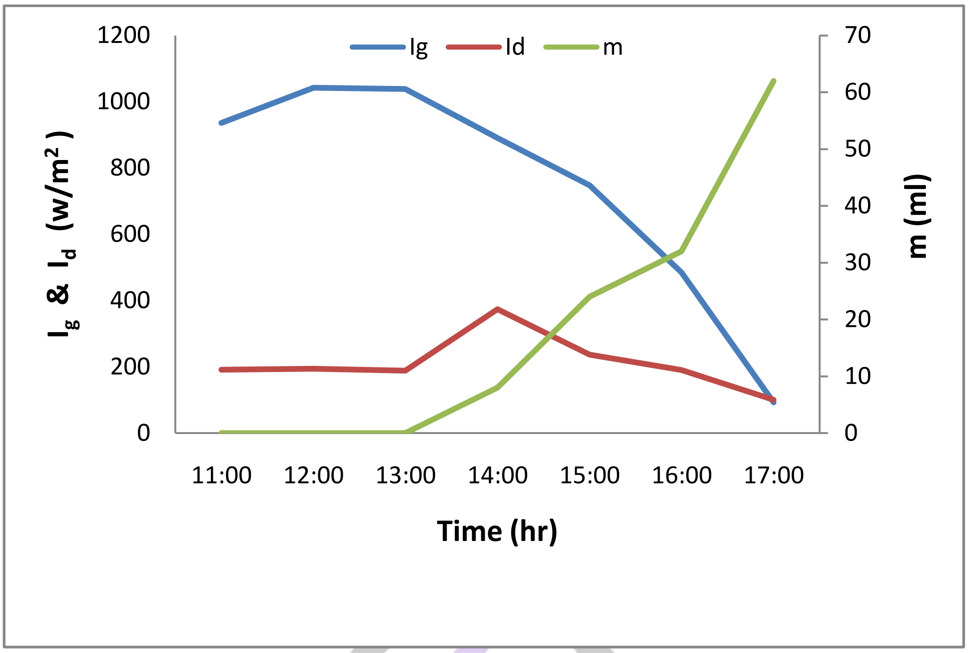

Fig 4 : Variation of Global (I_g), Diffuse (I_d) radiations & yield (m) for 9 cm water depth

The value of I_g is greater than I_d between 11:00 to 13:00 hr and no yield is present, but after that it suddenly increased and reached up to a level of 62 ml at 17 hour . Total yeild during the day is 126 ml which is lower than the first day of experiment. This is found bacause of amount of water increased. The higher quantity of water needs more energy for distillation process.

3.1.4. Variation of Water Temperature, Inner Surface of the Toughened Glass, Outer Surface of the Toughened Glass and Yield for 9 cm water depth-

Figure 9 shows the variation of temperature of water inside the still (T_w), inner surface of the toughened glass (T_{gi}), outer surface of the toughened glass (T_{go}) and yield (m) with respect to time.

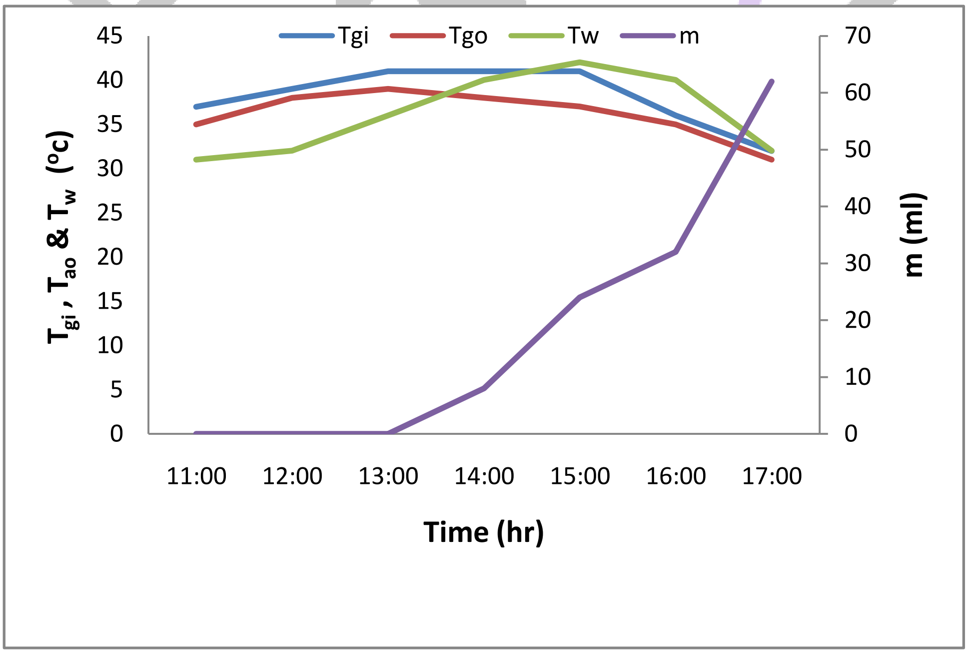

Fig 5 : Variation of water (T_w), Inner Surface of the Toughened Glass (T_{gi}), Outer Surface of the Toughened Glass (T_{go}) & Yield (m) for 9 cm water depth

The total yield is 126 ml between 11:00 to 17:00 hr. Water temperature and inside glass temperature at the 11:00 hr is 31 °C and 37°c while at l7:00 it becomes 32 °C and 32 °C which is almost same. But the maximum temperatures of water temperature and inside glass are 42 °C and 41 °C respectively.

3.2. Effect **of Water Depth of 12 cm on Yield of Single Slope Solar Still**

3.2.1. Variation of ambient temperature and relative humidity for 12 cm water depth-

Figure 10 shows the variation of ambient temperature and relative humidity. This observation is performed in the month of August with 12 cm depth of water in the single slope solar still.

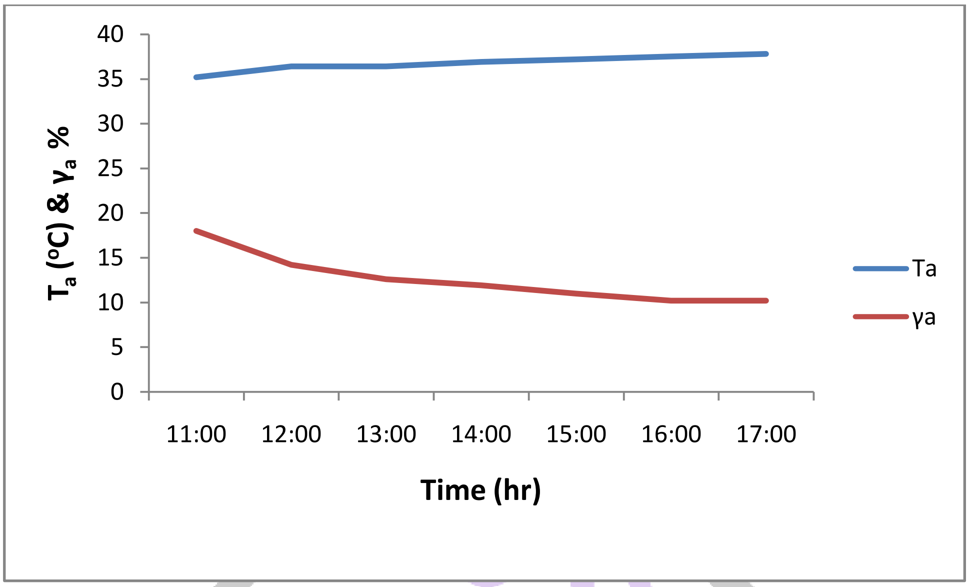

Fig 6 : Variation of ambient temperature (T_a) & relative humidity (γ_a) for 12 cm water depth

The value of ambient temperature at 11:00 hr is 35.2 ^{o}C and at 17:00 hr it becomes 37.8 ^{o}C. The relative humidity is decreased from 18% to 10.2 %during 11hrs to 17hrs. the maximum ambient temperature and relative humidity is found 37.8 ^{o} C and18.%

3.2.2. Varaition of Ambient Temperature, Global and Diffuse radiations for 12 cm water depth-

Fig 11 shows the variation ofambient temperature with respect to global and diffuse radiations for 12 cm water depth. It also performed in the month of August. The maximum value of global and diffuse radiation arefound 1108 w/m^2 at 12 hour and 304 w/m^2 at 14:00 hour repectively. The minimum value of global and diffuse radiation are 90 w/m^2 at 17 hour and 88 w/m^2 at same time.

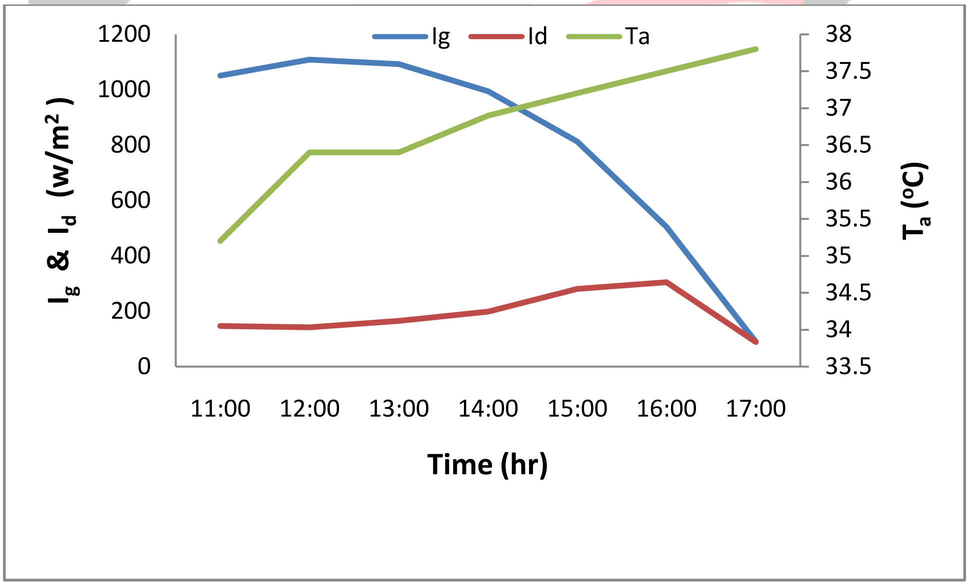

Fig 7 : Varaition of Ambient Temperature, Global (I_g) & Diffuse (I_d) radiations for 12 cm water depth

The ambient temperature increases with global radiation. During the experiment maximum ambient temperature 37.8^{o}C is found at 17 hours whereas minimum 35^{o}C at 11 hours.

3.2.3. Variation of Global, Diffuse radiations and yield for 12 cm water depth-

Figure 12 shows the variation between global radiation ,diffused radiation and yield of the single slope solar still with respect to time.

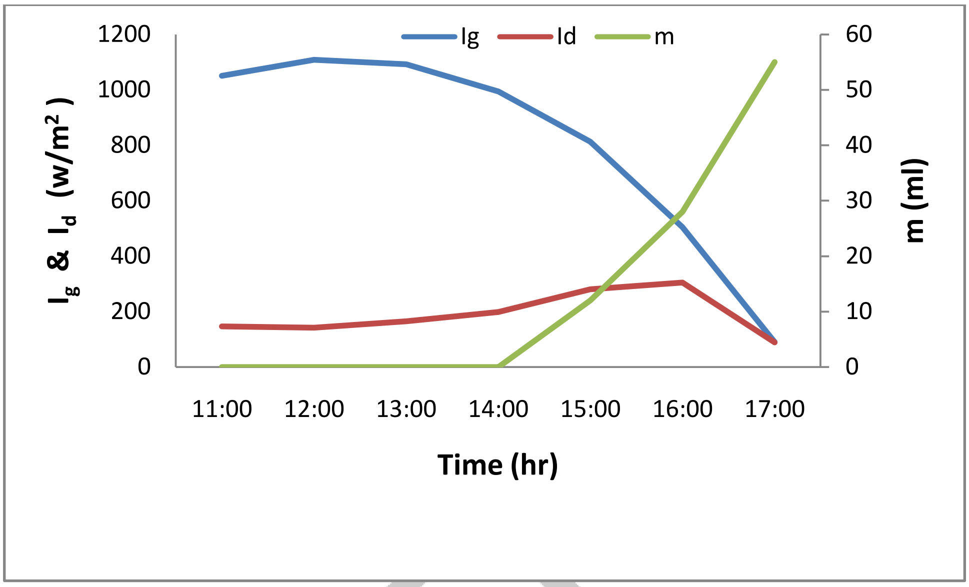

Fig 8 : Variation of Global (I_g), Diffuse (I_d) radiations & yield (m) for 12 cm water depth

The total yield obtained from this is 95 ml.which is quite less as the depth of the solar still is increased.

3.2.4. Variation of Water Temperature, Inner Surface of the Toughened Glass, Outer Surface of the Toughened Glass and Yield for 12 cm water depth-

Figure 13 shows the variation of water temperature, inner surface of the toughened glass, outer surface of the toughened glass and yield for 12 cm water depth with respect to time.

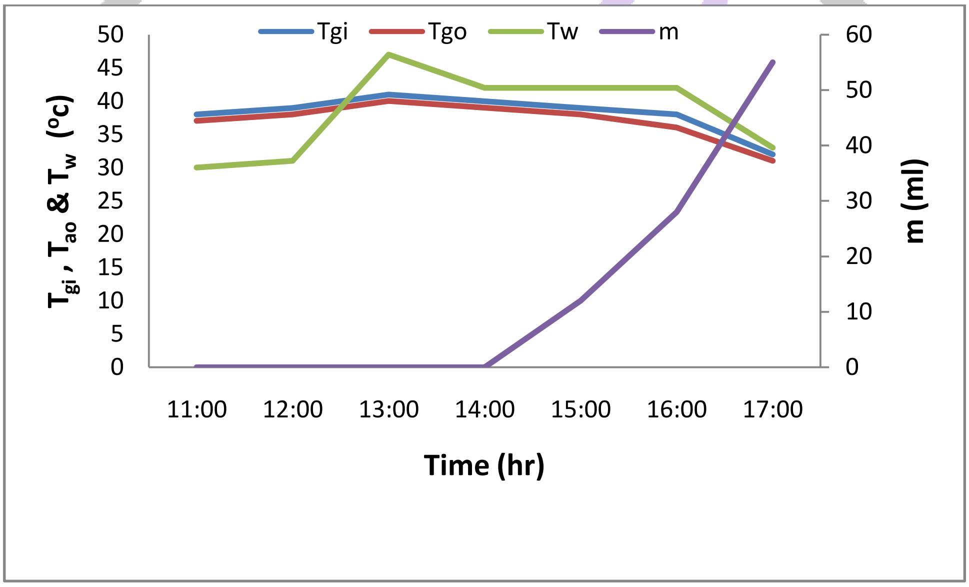

Fig 9 : Variation of water (T_w), Inner Surface of the Toughened Glass (T_{gi}), Outer Surface of the Toughened Glass (T_{go}) & Yield (m) for 12 cm water depth

As the experiment is started at 11:00 hr andthere is no yield during 11 hrto 14 hr but from 14 hr yield suddenly increased and reached to a total of 95ml at 17:00 hr, as the experiments is performed between 11:00 to 17:00 hr. where as in T_{gi} and T_w there is slightly variation in both the values. It has been noticed that as the depth of the solar still is increased the yield obtained dereased and the value of T_{gi} is greater than T_{go}.

3.3. Effect of Water Depth of 9 cm on Yield of Single Slope Solar Still with Flat Plate Collector

3.4.1. Variation of ambient temperature and relative humidity for 9 cm water depth-

Figure 18 shows the variation of ambient temperature (T_a) and relative humidity (γ_a). This observation was performed in the month of september with 9 cm depth of water in the single slope solar still **with Flat Plate Collector**.

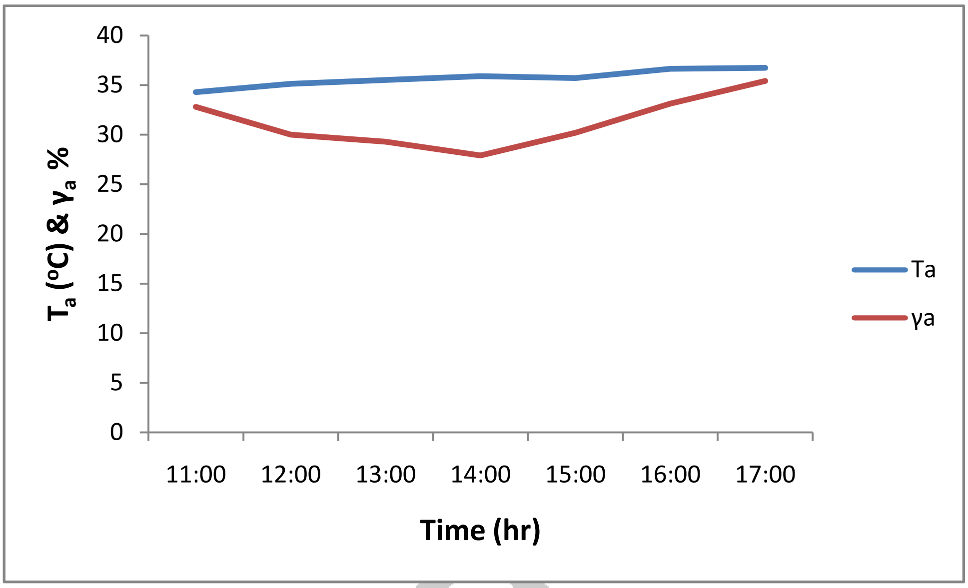

Fig 10 : Variation of ambient temperature (T_a) & relative humidity (γ_a) for 9 cm water depth

Here the values of T_a and γ_a at 11:00 am is 34.27°C and 32.8% respectively whereas at 17:00 hr it was changed up to 36.72°c and 35.1% respectively.

3.3.2. Varaition of Ambient Temperature, Global and Diffuse radiations for 9 cm water depth-

Fig

19 shows the variation between global radiation and diffused radiation with respect to time. It also performed in the month of September. The maximum value of global and diffuse radiation are 970 w/m^2 at 13 hours and 302 w/m^2 at 15:00 hours repectively. The minimum value of global and diffuse radiation are 220 w/m^2 at 17 hour and 90 w/m^2 at same time. The ambient temperature increases with global radiation.

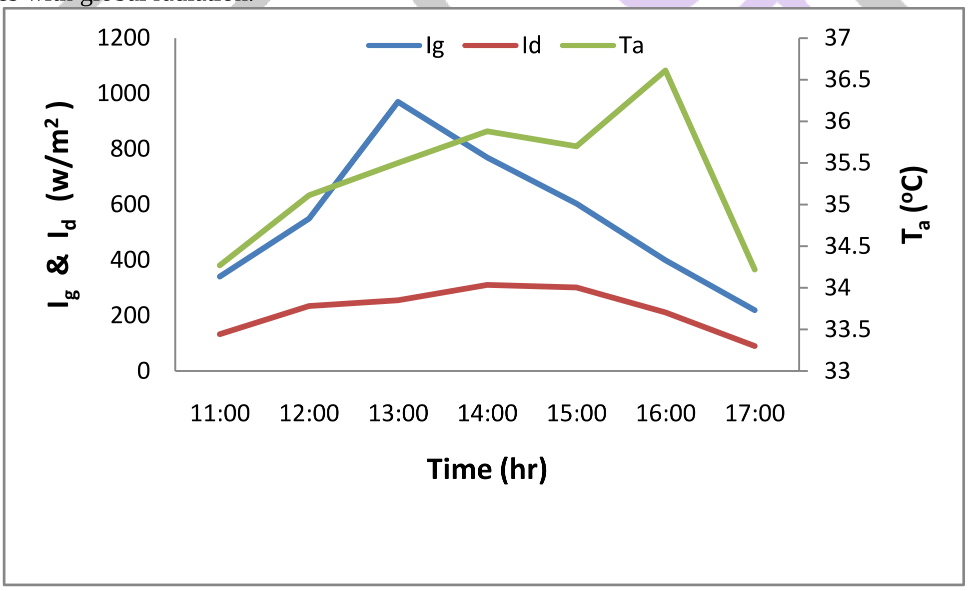

Fig 11 : Varaition of Ambient Temperature, Global (I_g) & Diffuse (I_d) radiations for 9 cm water depth

During the experiment maximum ambient temperature 36.6°C is found at 14 hours whereas minimum 34.22°C at 17 hours.

3.3.3. Variation of Global, Diffuse radiations and yield for 9 cm water depth-

Figure 20 shows the variation between global radiation, diffused radiation and yield. This figure shows the yield of the single slope solar still **with Flat Plate Collector** at 9 cm water depth.

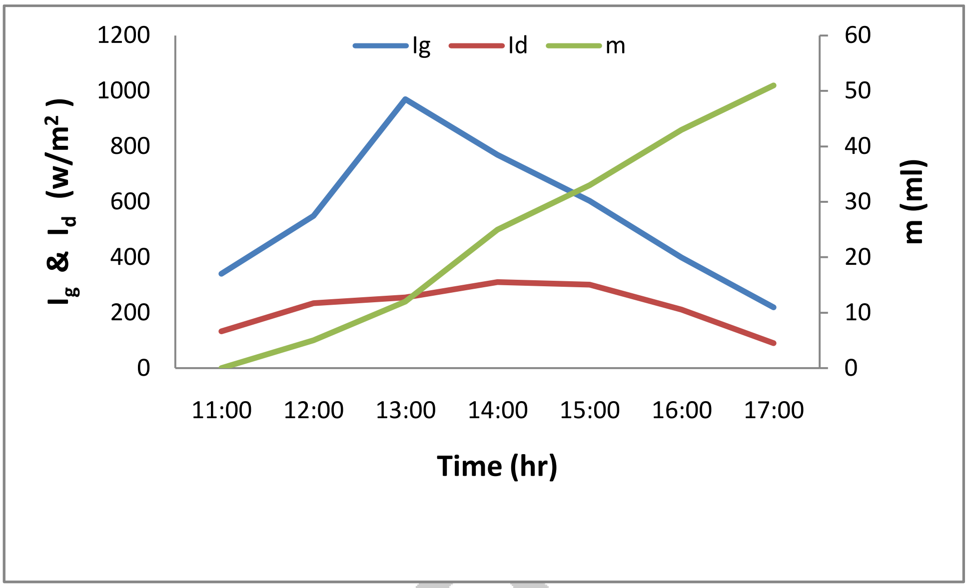

Fig 12 : Variation of Global (I_g), Diffuse (I_d) radiations & yield (m) for 9 cm water depth

The value of I_g is greater than I_d between 11:00 to 17:00 hrs but yield start from 12 hrs, and after that it suddenly increased and reached up to a level of 51 ml at 17 hour. Total yeild during the day is 169 ml which is lower than the first day of experiment.

3.3.4. Variation of Water Temperature, Inner Surface of the Toughened Glass, Outer Surface of the Toughened Glass and Yield for 9 cm water depth-

Figure 21 shows the variation of temperature of water inside the still (T_w), inner surface of the toughened glass (T_{gi}), outer surface of the toughened glass (T_{go}) and yield (m) with respect to time for single slop solar sill **with Flat Plate Collector**.

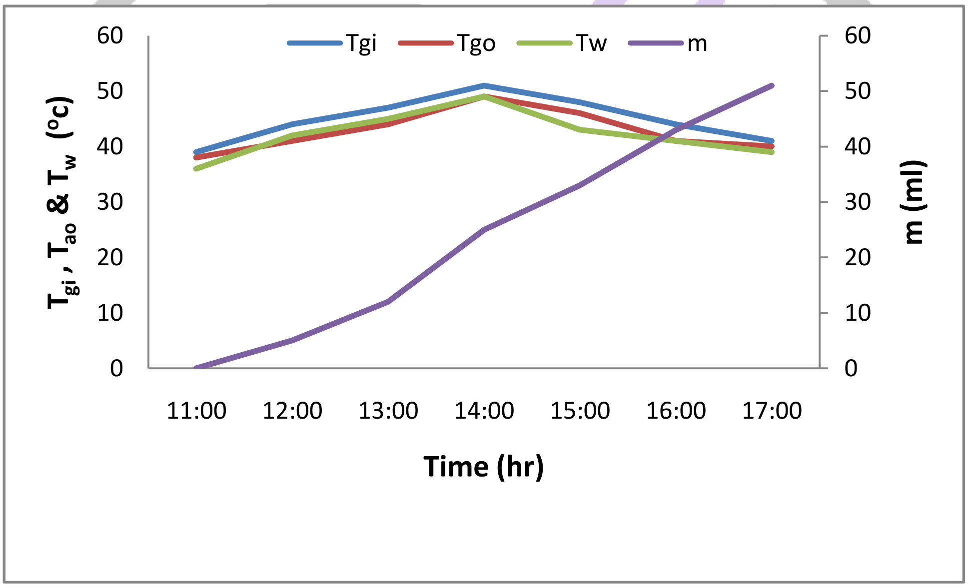

Fig 13 : Variation of water (T_w), Inner Surface of the Toughened Glass (T_{gi}), Outer Surface of the Toughened Glass (T_{go}) & Yield (m) for 9 cm water depth

The total yield is 169 ml between 11:00 to 17:00 hr. Water temperature and inside glass temperature at the 11:00 hr is 36 ^{o}C and 39^{o}C while at l7:00 it becomes 32 ^{o}C and 32 ^{o}C which is almost same. But the maximum temperatures of water temperature and inside glass are 39 ^{o}C and 41 ^{o}C respectively.

3.4. Effect of Water Depth of 12 cm on Yield of Single Slope Solar Still with Flat Plate Collector

3.4.1. Variation of ambient temperature and relative humidity for 12 cm water depth-

Figure 22 shows the variation of ambient temperature and relative humidity. This observation is performed in the month of September with 12 cm depth of water in the single slope solar still **with Flat Plate Collector**.

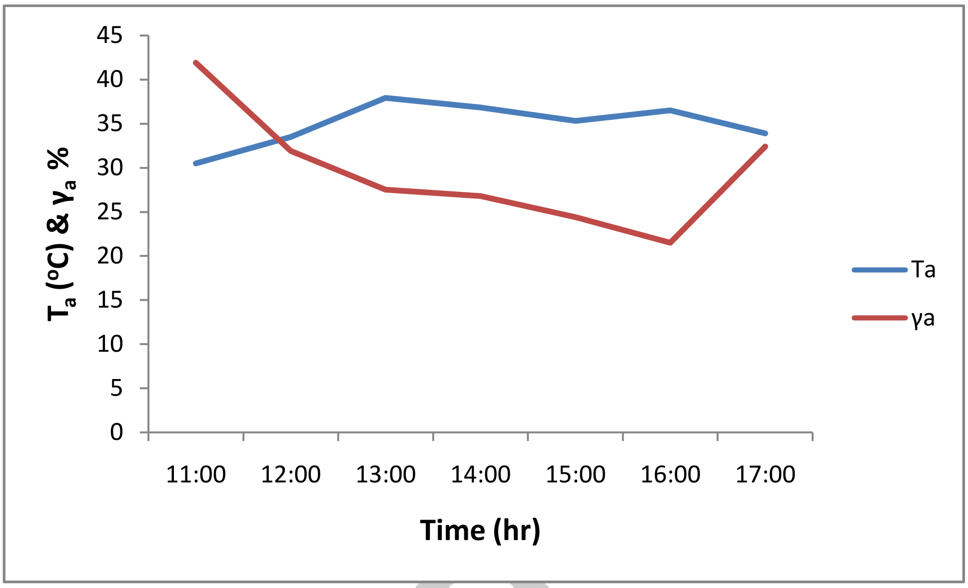

Fig 14 : Variation of ambient temperature (T_a) & relative humidity (γ_a) for 12 cm water depth

The value of ambient temperature at 11:00 hr is 30.5 ^{o}C and at 17:00 hr it becomes 33.9 ^{o}C. The relative humidity is decreased from 41.9% to 32.4.2 %during 11hrs to 17hrs. T he maximumambient temperature and relative humidity are found 37.9 ^{o} C and 41.9.%

3.4.2. Varaition of Ambient Temperature, Global and Diffuse radiations for 12 cm water depth-

Fig 23 shows the variation ofambient temperature with respect to global and diffuse radiations for 12 cm water depth. It also performed in the month of September .The maximum value of global and diffuse radiation arefound 1028 w/m^2 at 12 hour and 328 w/m^2 at 15:00 hour repectively. The minimum value of global and diffuse radiation are 241 w/m^2 at 17 hour and 62 w/m^2 at same time respectively.

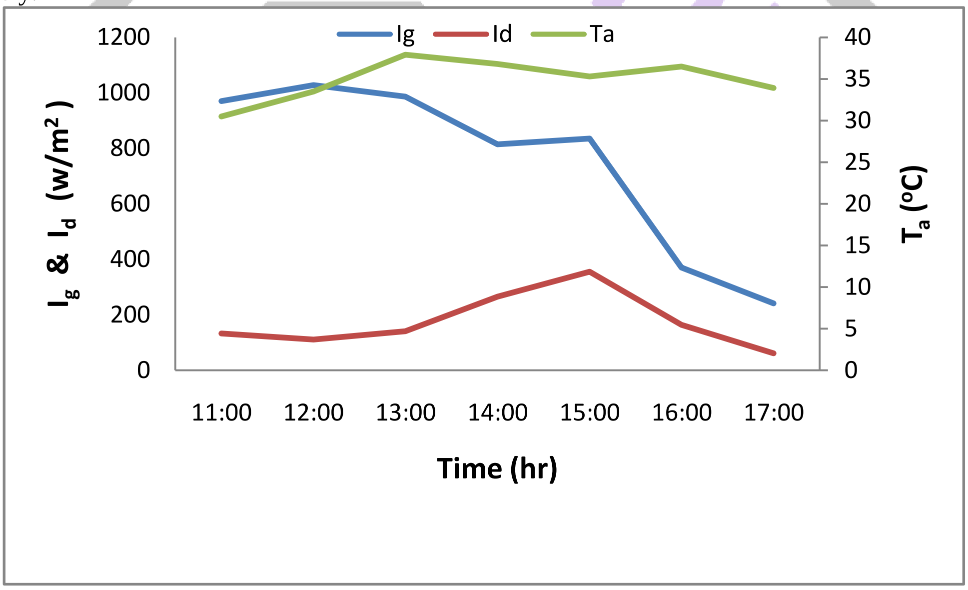

Fig 15 : Varaition of Ambient Temperature, Global (I_g) & Diffuse (I_d) radiations for 12 cm water depth

The ambient temperature increases with global radiation. During the experiment maximum ambient temperature 37.9^{o}C is found at 13 hours whereas minimum 30.5^{o}C at 11 hours.

3.4.3. Variation of Global, Diffuse radiations and yield for 12 cm water depth-

Figure 24 shows the variation between global radiation ,diffused radiation and yield of the single slope solar still **with Flat Plate Collector**.

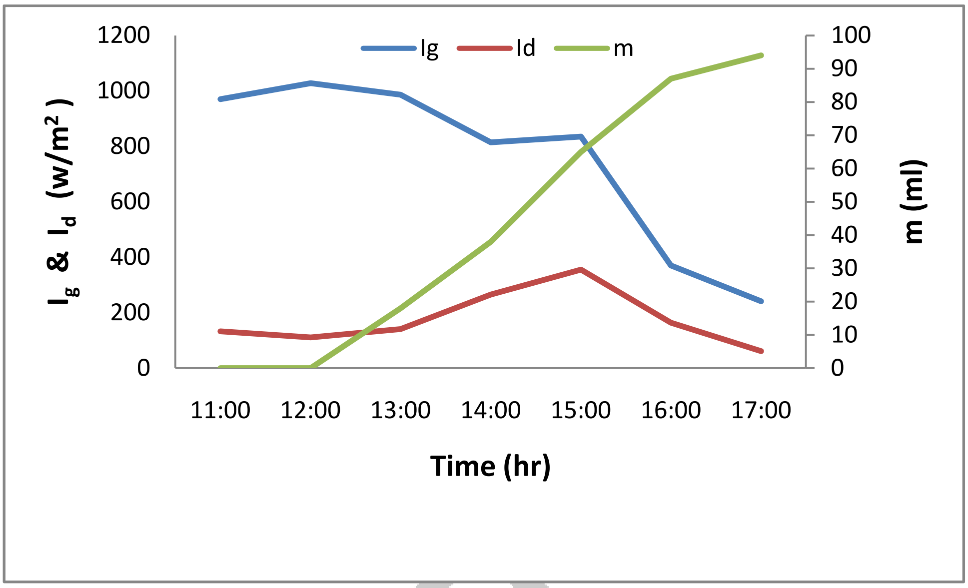

Fig 16: Variation of Global (I_g), Diffuse (I_d) radiations & yield (m) for 12 cm water depth

The total yield obtained from this is 302 ml which is quite less than first day of experimentation but higher than second day of experimentation because of availability of good solar intensity during the third day of experiment.

3.4.4. Variation of Water Temperature, Inner Surface of the Toughened Glass, Outer Surface of the Toughened Glass and Yield for 12 cm water depth-

Figure 25 shows the variation of water temperature, inner surface of the toughened glass, outer surface of the toughened glass and yield for 12 cm water depth with respect to time.

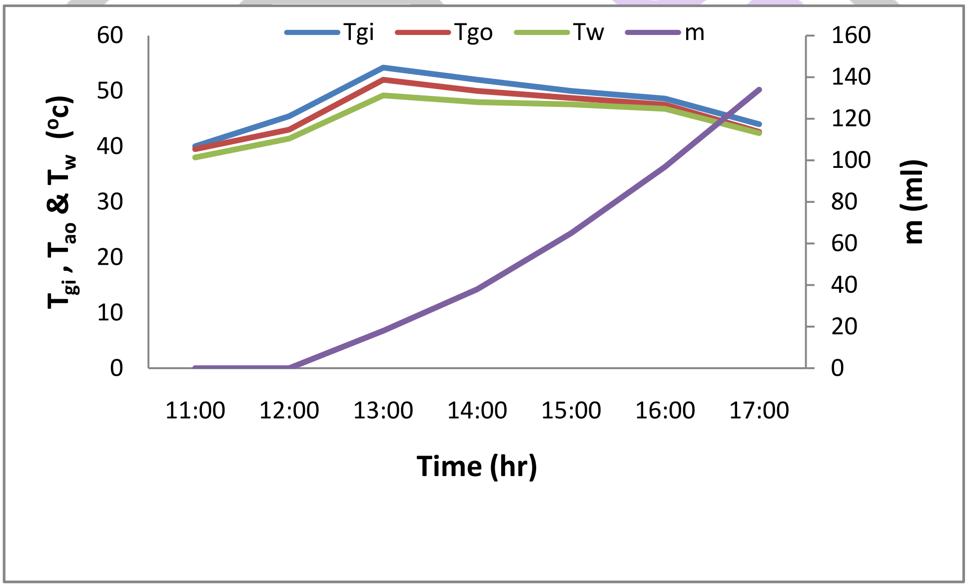

Fig 17 : Variation of water (T_w), Inner Surface of the Toughened Glass (T_{gi}), Outer Surface of the Toughened Glass (T_{go}) & Yield (m) for 12 cm water depth

As the experiment is started at 11:00 hr andthere is no yield during 11 hrto 12 hrs but from 13 hrs yield suddenly started and increased upto a label of 94 ml at 15 hrs. Total yield obtained during the day is 302 ml. T_{gi} and T_w have slightly variation in values. It has been noticed that as the depth of the solar still is increased the yield obtained dereased and the value of T_{gi} is greater than T_{go}. The higher value of $T_{gi,}T_{go}$ and T_w are 54 ^oC, 52 ^oC and 49 ^oC during the experiment.

4. Effect of yield with different water depth with and without collector-

4.1. Effect of yield on 6 cm water depth on still with and without collector-

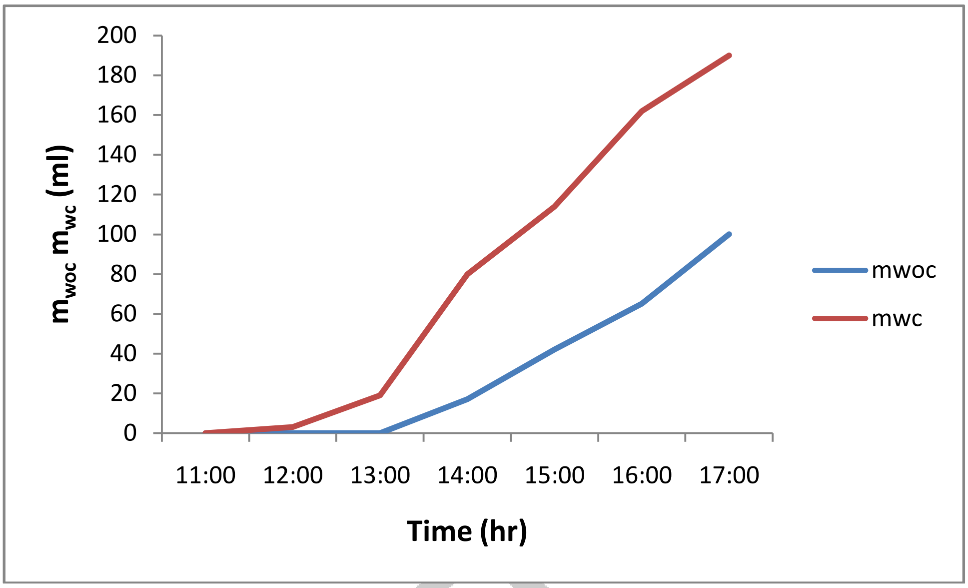

Fig 18: Variation of yield on 6 cm water depth for single slope solar still with and without collector

Figure 26 shows the variation of yield m_{woc} and m_{wc} for a single slope solar still for a 6 cm water depth at inclination angles of 23^o with and without collector. It is observed that the yield m_{wc} using the flat plate collector is more compared to that of without collector as the case of preheating of water occurs resulting more yield. During the period from 11:00 to 15:00 hrs there is low yield of m_{wc} and after that sudden increment also observed and 15 hours achieved maximum. A total yield m_{woc} and m_{wc} is obtained 224 ml and 568 ml without and with collector respectively. Result shows the effectiveness of the flat plate collector to increase the efficiency of the system.

4.2 Effect of yield on 9cm of water depth on still with and without collector-

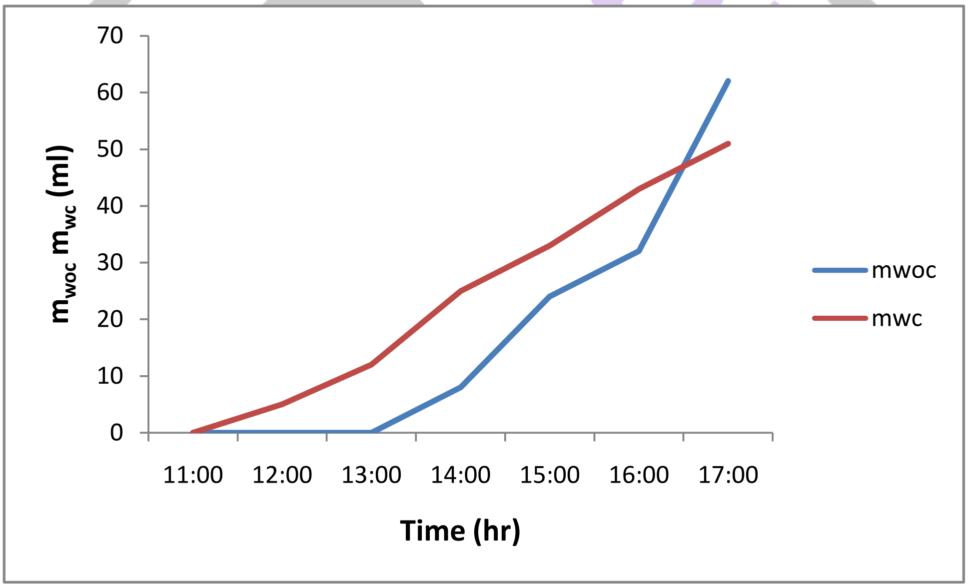

Fig 19: Variation of yield on 9 cm water depth for single slope solar still with and without collector

Figure 27 shows the variation of yield m_{woc} and m_{wc} for a single slope solar still having 9 cm water depth at inclination angles of 23^o. The yield m_{wc} of solar still with collector is observed more as compared to solar still without collector. Total yield m_{woc} and m_{wc} is obtained 126 ml and 169 ml without and with collector respectively. The total yield also decreases in the both cases due to increase of water depth as 9 cm because more water requires more heat energy for heat gain.

4.3: Effect of yield on 12 cm of water depth on still with and without collector-

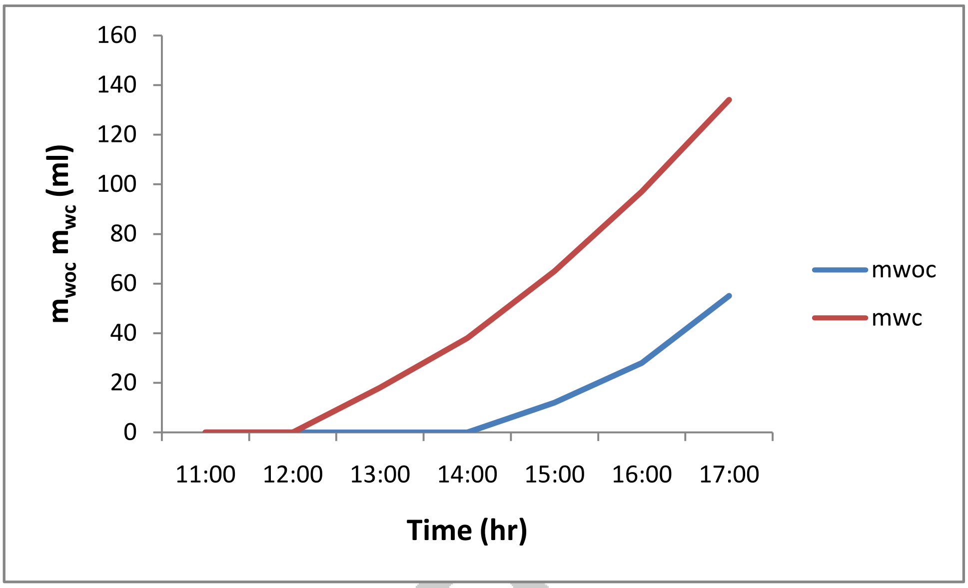

Fig 20: Variation of yield on 12 cm water depth for single slope solar still with and without collector

Figure 28 shows the variation of yield m_{woc} and m_{wc} for a single slope solar still for a 12 cm water depth at inclination angles of 23^o. In both cases, both day climatic conditions were clear sky that's why yield obtained was good. But due to increase of water label as 12 cm yield is less as compared to 6 cm water depth. Total yield m_{woc} and m_{wc} is obtained 95 ml and 352 ml without and with collector respectively.

4. Conclusion

It is concluded that the low water depth in solar still leads to fast rise in temperature and consequently high evaporation rate thus more yield in the absence of any storage capacity. The yield for two different cases with three defferent water depdth is illustrated in this work. The value of yeild is found higher at 9 cm water depth of in both the cases. The lowest yeild obtained when solar still was not connected with flat plat collector. After experiment and observations it is conclude that solar still becomes more efficient with flat plate solar collector at 9 cm water depth label. Hourly variation of daily distillate output depends upon how the radiation is distributed throughout the day. In the performed experimental location the still which is inclined at 23^o yields more without collector effect as it is the latitude of the location of Madhya Pradesh.

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