International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 1 ǁ January 2023 ǁ PP. 401-407

"Experimental Study on Thermal performance of solar concentrator using Paraffin wax as Phage Change Material (PCM) at different depth of water"

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Abstract
Renewable energy is playing very important role to meet the energy crisis age. We depend on energy to energy and some of external, eternal resources, among us we feel that, the energy crisis is responsible for a looked by our technical officer and engineers into generating the energy sources. In this Practical, an experimental study has been carried out on the thermal performance of solar concentrator using paraffin wax by PCM. The research was performed in lab condition Using paraffin wax. The solar concentrator consists of a unique system. The system consists of Solar Concentrator, thermocouple K - Type, water tank with container of phase change material PCM. TH is copper tube which consists of two parts. The first part is called the evaporator which is set inside evacuated tube. The second part is called the condenser which is put in the water tank. The paraffin wax is used as PCM, located in container which represents interior walls of the water tank. The PCM works in two phases: solid and liquid. The average temperature of the water tank with wax is less than the temperature without wax during the charging and is higher than without wax during the discharge. The generation of fresh water for three days in the month of September involved timing between 10:00 hours morning to 5:00 hours evening with different depth of water. The maximum amount of water generated about 0.976 liters for 1 centimeter's depth of water, 0.785 liters for 2 centimeters and 0.686 liters at 3 centimeters depth.
After addition of paraffin wax through PCM method we observe that the capacity of water along with volume and flow is higher as compared to without addition which have been recorded as at1 centimeter's depth of water – 1.03 liters at 1 centimeter's depth of water – 0.898 liters at 1 centimeter's depth of water – 0.776 liters.
Hence, after addition of paraffin wax, we found the efficiency increased by 27.92%, 21.75% and 15.95% for different depth of water such as 1 centimeter, 2 centimeters and 3 centimeters. Hence, we come to conclusion that by increasing the temperature with solar sunlight radiation up to 2 PM the generating capacity of water increases as higher as possible as recorded and calculated in this thesis.
Keywords: *Parabolic Solar Concentrator, Solar dish, Thermal storage system Phase change material (PCM), Conical distiller, Concentrating efficiency and Distiller productivity.*

Date of Submission: 11-01-2023 Date of acceptance: 27-01-2023

I. INTRODUCTION

Energy and water are two basic requirements for human civilization. The demand for energy and water could double or even triple, as the global population rises and developing countries expand their economies by the end of 21st century. Today the world is challenged to provide sufficient pure water resources for human needs. Recent reports show that the groundwater levels and rainfall are in decline [1]. The man has been still dependent on rivers, lakes, and underground water reservoirs for freshwater requirements in domestic life, agriculture, and industry. However, the use of water from such sources is not always potable or desirable on account of the presence of a large number of salts and harmful organisms. The impact of many diseases afflicting mankind can be drastically reduced if fresh hygienic water is provided for drinking. The energy consumption is being categorized on the living standards, user and Sector developments which could be use on daily basis.

These can be as follows:

- Agriculture sector
- Industry Sector
- Domestic sectors (House and offices)
- Transport Sector

- Drinking and portable water.

Consumption of a large amount of energy in a country indicates increased activities in these sectors. This may imply better comforts at home due to use of various appliances, better transport facilities and more agricultural and industrial production. All this amount to a better quality of life. Therefore, the per capita energy consumption of a country is an index of the standard of living or prosperity (i.e., income) of the people of the country. Energy needs as growing economy means the energy is one of the such part of GDP, the whole word is depending on the energy and energy one of the growing economies. As earlier we have explained about the crisis of conventional energy in 1973. Economic growth is requirements for all develops and developing countries, and energy is most important for economic growth. However, the connectivity between economic growth and increased energy demand is not always a equal or straight Line. As we come to notice that under present conditions, 10% increase in India's Gross Domestic Product (GDP) would force at increasing demand of 14% on present energy scenario. In this para we would like to explain about the, the ratio of energy requirement to GDP- gross domestic product which is very useful indications. The high ratio of both GDP and energy depends on a strong impassive of energy on GDP growth. The developed countries, by focusing on energy efficiency and lower energy-intensive routes, maintain their energy to GDP ratios at values of less than 2. The ratios for developing countries are much higher.

The main aim of this experiment is to analyze the thermal performance of solar concentrator using Phase change material. As the paraffin wax is good thermal storage material and it store the thermal heat for quite long time which can be used for stabilizing the temperature after sunset equal of temperature during day time (Sunlight). This method helps a lot to distilled the water and even keep fresh water after sunset. This process can be executed when the radiation of sunlight come to solar dish, the solar dish reflects all the sunlight rays to focal point which is the form of heat which receives the heat from sun light through solar dish. The receiver is kept on focal point which is the major part to utilize 80% of sunlight and transfer the heat to water to water. As per the thermodynamics rule, the heat transfer of fluid occurs from high medium to low medium thus, after 2 PM the thermal performance of solar radiation goes down. Hence to perform the system going well we uses the paraffin wax which is mixed with water in tube. The paraffin wax is in the solid form when we we brought it in to process as the temperature increases the paraffin wax change it phase gets changed in to liquid form which can maintain its similar temperature up to 6 to 7 hours.

Solar concentrator is a static equipment that has been installed in open areas facing towards the sunlight observes the collected rays of sunlight from a large area and focusing on to a smaller receiver or exit. A conceptual representation of a solar concentrator used in harnessing the power from the sun to generate electricity. The various materials are used to prepare the complete assembly of the solar concentrator which depends on the usage. For solar thermal, most of

the concentrators are made from mirrors while for the BIPV system, the concentrator is either made of glass or transparent plastic. These materials are far cheaper than the PV material. The cost per unit area of a solar concentrator is therefore much cheaper than the cost per unit area of a PV material. By introducing this concentrator, not only the same amount of energy could be collected from the sun, the total cost of the solar cell could also be reduced. Arizona Public Service has concluded that the most cost-effective PV for commercial application in the future will be dominated by high concentration collector incorporated by high-efficiency cell. The solar concentrator function is to observe the sunlight from the sun on dish and directly reflect to focal point to observe the heat as the same way focal point receives the heat and it delivered to receiver on which the container or storage being kept. It’s very much efficient during sunny days as its one of the non – conventional source of energy.

Design of parameters of parabolic concentrating solar thermal desalination device:

The parabolic dish is designed in such a manner that it is being affecting by various parameters such as surface area of parabolic dish, sizing of parabolic dish, heights of stand, geometric, and area concentration ratio in addition to solar radiation parameter and thermal properties of the receiver.

The surface area of dish concentrator is defined as the area of solar concentrator divided by the solar energy incident. The complete system is depended upon the area of dish the sunrays incident on this. The surface area of parabolic dish concentrator system is given by

$A_{conct.} = \pi/4 * D^2_{Conct.}$

The focal length is used to concentrate the all-sun radiation a point which called focal point and at same place the receiver is kept. Thus, the focal length of the system can be governed as: -

Focal length = 1/4. a.

Aperture area of receiver can be defined as the area of container kept on focal point and the aperture is used to concentrate maximum to maximum solar intensity radiation which acts as the working fluids and the mathematical form can be given as

$A_{rceiver.} = \pi/4 * D^2_{receiver.}$

Concentrator ratio is the ratio which can be defined as the area of concentrator upon area of receiver. The concentric ratio plays very important role to find the efficiency of the system.
The ratio can be expressed in the form as
C = Aconct. / Arceiver.

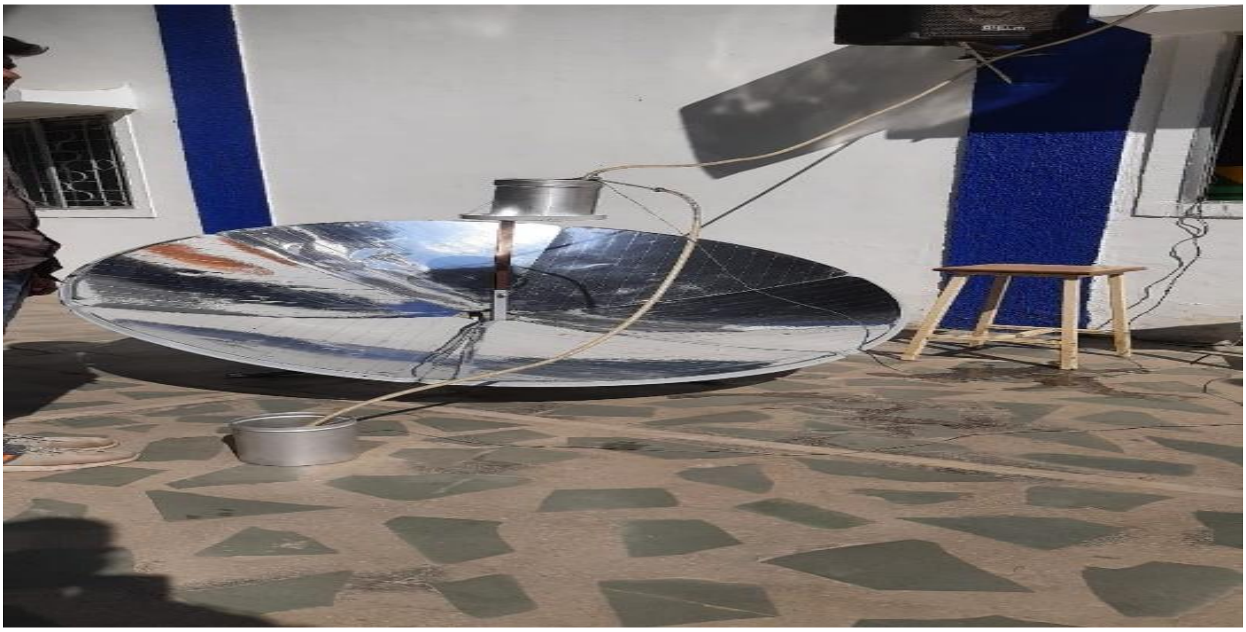


Fig.1 - Parabolic concentrating solar thermal desalination device.

For Solar Concentrated system, the system is fabricated and set up is done in such away that
that the device called dish is placed facing to south as maximum radiation can be faced from south side only. The parabolic concentrating solar device consists of a parabolic dish concentrator, evaporating vessel, condensing unit with glass tube, stand, and distillate jar. The parabolic dish concentrator uses a parabolic mirror that focuses incoming solar radiation on a receiver mounted above the dish at its focal point. The heat exchanger made up of aluminum container is fixed in front of the focal point. The container was insulated with glass wool to prevent the heat dissipation from exchanger. The Aluminum container is enclosed with the copper tube which emersed in paraffin wax. Thus, here the paraffin wax is acting as latent heat storage of material for the system. The face of the container is shield with the two-glass sheet & kept facing to concentrator dish. The distance between these two glass sheets is maintained distance about 1.0 CM. The Container is shielded to restrict the flow of melting paraffin wax outside of the container when it is at high temperature as shown in fig. 1.
Once the complete system comes into operation all parameters is be noted for analysis. Since the temperature gets varied due to phase change materials and for that we install a four numbers of thermocouple K-Type to record the temperature of complete system. Four Numbers of thermocouple is installed at the surface of condenser to assure the temperature distribution for all transparency cover area. Two Thermocouple fixed to outer surface of condenser & another two is installed inner side of surface condenser. The average cover temperature is being obtained by means of these thermocouples' readings. To measure the temperature of distiller basin a single thermocouple is fixed with the basin bed. To measure the temperature of wax inside the distiller, two thermocouples is used. The temperature of brackish water is measured by mercury thermometer which is installed with connecting pipe. For knowing & tracing the phase change process of paraffin wax four thermocouples were distributed in the heat exchanger. Two thermocouples used for concentrator Wax & another one is for concentrator hot water measurements. The atmospheric temperature surrounding the system is also measured with mercury thermometers which being kept at shade.

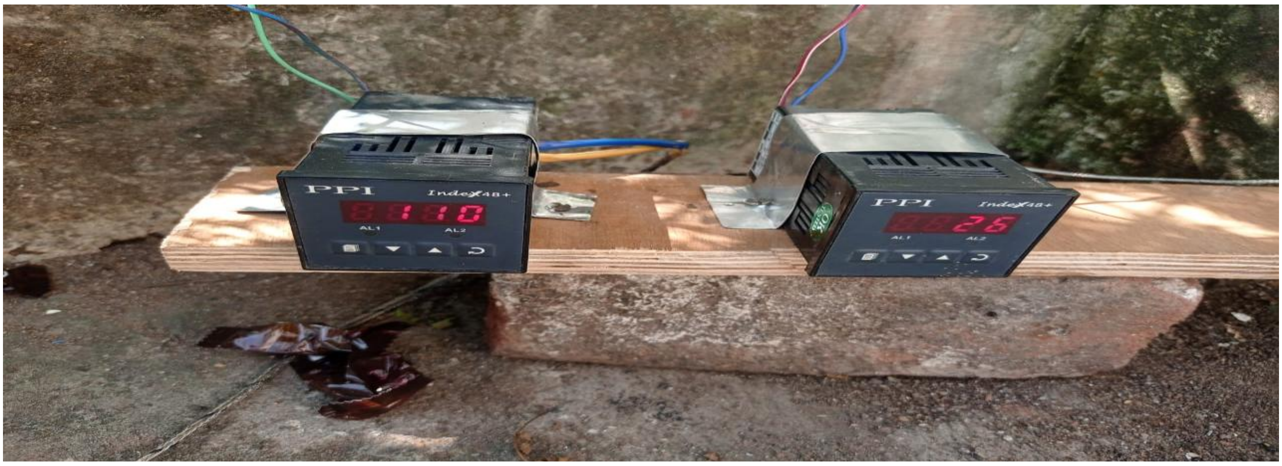


Fig. 2 – Thermocouple K-Type

Thermal Analysis and Models:
The cumulative stored distilled water is measured with help of cylindrical gallon having capacity of about 5 or 7 liters. The measurement of water through gallon is done on every one-hour interval.
The data of incident radiation rays being determined and mathematically written as: -
$X^2 = 4 f Y$
X = Radius of Solar concentrator
Y = Depth of solar concentrator
F = Distance of focal point

Convection heat transfer process:

$$hc, w - gi = \left[\{Tw - Tgi\} + \left(\frac{(pw - pgi)(Tw + 273.15)}{268.9 * 1000 - Pw} \right)^{1/3} \right]$$

Radiation Heat transfer process:

$$\varepsilon eff = (1/\varepsilon w + 1/\varepsilon g - 1)^{-1}$$

Heat Transfer by the evaporation process:
qe, w-gi = he, w-gi (Tw – Tgi)

The Top heat transfer loss:
The overall top heat loss coefficient from water mass to the atmosphere through the glass cover is written as;

$$Ut = (ht,w-giut,gi -a)/ (ht,w-gi + ut,gi -a)$$

The heat transfer loss from bottom and side:
The heat loss from bottom and side between water to atmosphere by the means of insulation at the bottom of basin being occurred due to three reasons which are radiation, convection, and conduction. Since the solar concentrated still is mounted on the stand thus the sequence of heat loss from bottom and side is being occurred in the series of convection, conduction, and radiation to environment.
Therefore, the heat loss between base liner and the water mass by convection method is written by:
qw = hw (Tb-Tw)

Yield of Solar concentrator still:
The yield of solar concentrated steel is recorded hourly and can be written in the form of mathematical equation as;

$$\eta(Mew) = {(qew - gi)}\big/{hfg \ x \ 3600}$$

Models:
The most popular thermal model is the Dunkel's model which are being used to determine and evaluate the co-efficient heat transfer for the concentrated solar steel. Dunkel's used the Nusselt-Rayleigh empirical co – relation developed by the Jackob in 1957 which was for enclosed free convection air and it is expressed as

$$Nu = C^* \, R\alpha^n \text{ with } C = 0.075 \text{ and } n = \frac{1}{3}$$

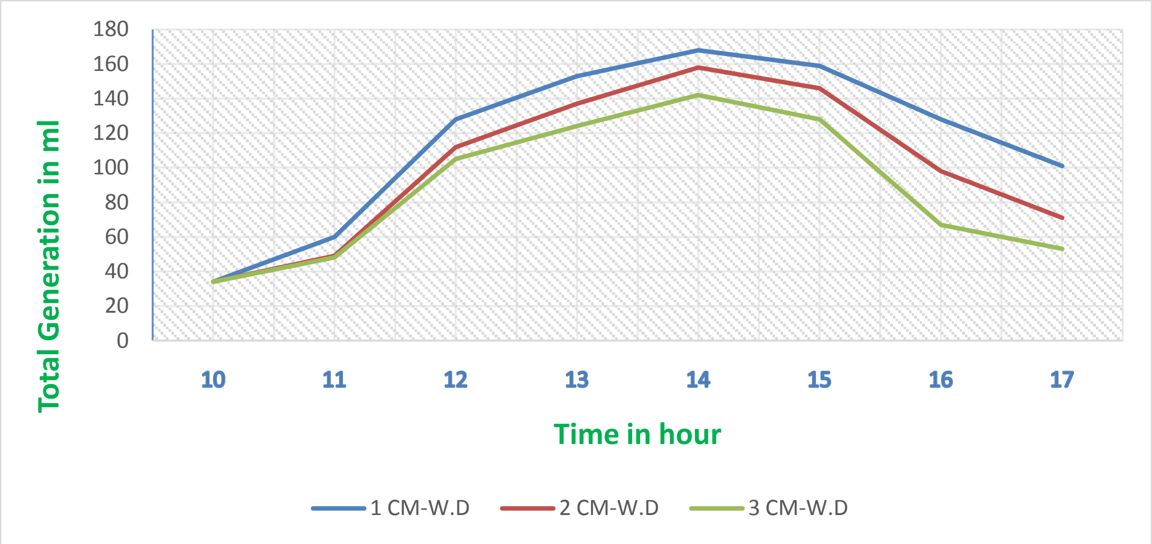
The executive thermal model is the Kumar and Tiwari Model (1996) and this model was used to evaluate the co-efficient of internal heat transfer based on simple linear analysis. These models are quite good realistic and the assumed value of constants C & n are used to determine the Nusselt number which is non-dimensional which co-relates the convective heat transfer.

The Nusselt number heat transfer co-efficient by convective method is written as;

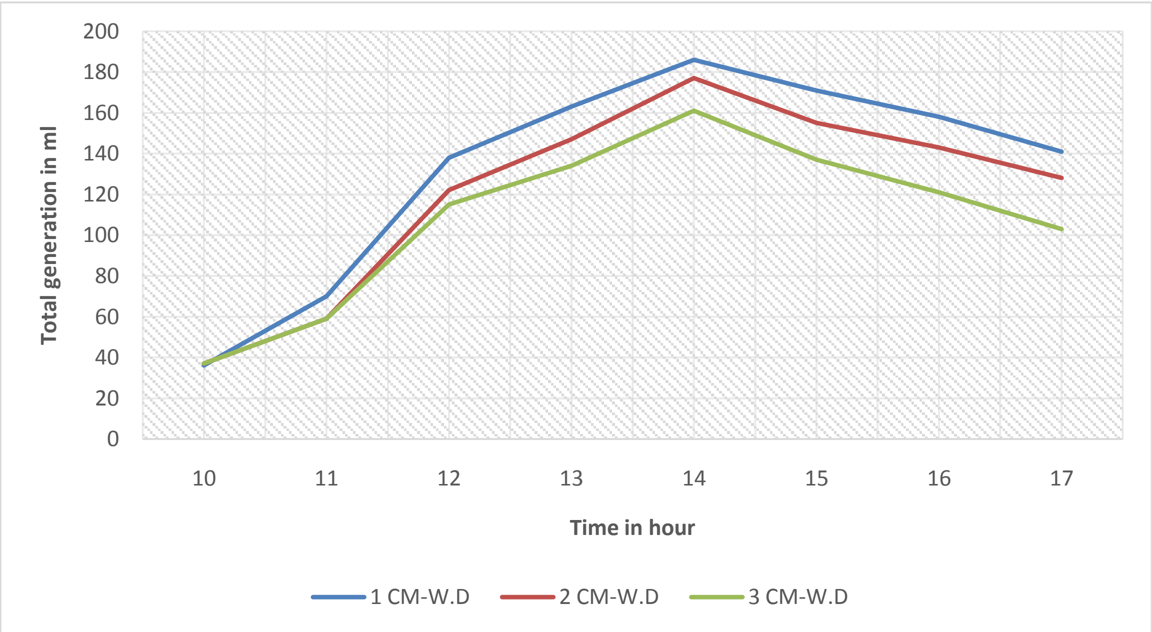
$$Nu = \frac{hc,w-g\ df}{Kf} = C(GrPr)n$$

II. RESULT AND DISCUSSION

The change in temperature with respect to time maintaining the depth of water as 1 centimeter, 2 centimeters, 3 centimeters as recorded on hourly basis as in plotted graph 5.7 and 5.8 without adding wax and with adding wax. From plotted graph we come to understand and observe that the productivity of distilled water by solar concentrated still is directly dependent on the total amount of incident sunlight solar radiation. This above temperature varies with respect to local timing and is being recorded for three days and the Graph is plotted as:



Graph - 5.7 – Total generation of water at varying depth in the absence of paraffin wax

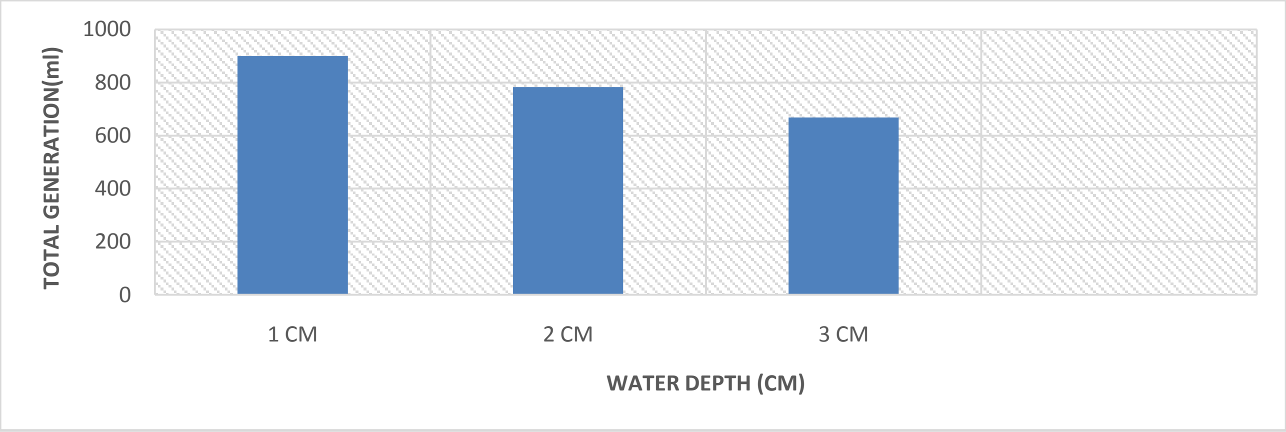


Graph - 5.8 – Total generation of water at varying depth in the presence of paraffin wax

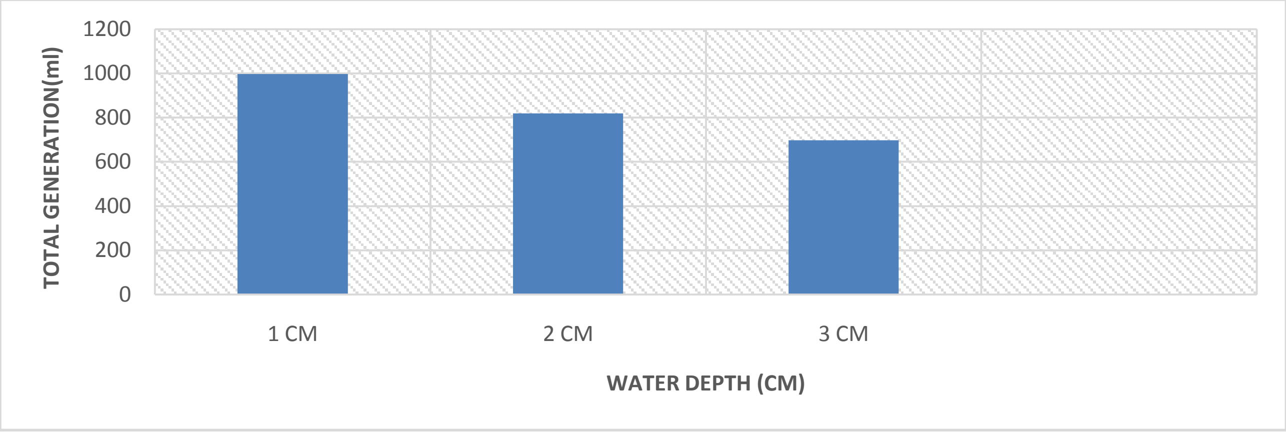
Cumulative comparable data for production of condensate and vapor with respect to depth of water:

The Cumulative rate of production of vapor and condensate is being shown by plotting data graph 5.9 that is without adding of paraffin wax and graph 5.10 with addition of paraffin wax with respect to the water depth.

Graph - 5.9 – Total generation of water at varying depth in the absence of paraffin wax



Graph - 5.10 – Total generation of water at varying depth in the presence of paraffin wax



Hence, on comparing with the graph and total production for eight hours of a day between 10:00 PM to 5:00 PM we come across the result that the production of condensate and vapor through the system is being depend on lesser depth of water and radiation of sunlight observed. Hence with lesser depth of water even adding paraffin wax the productivity rate is higher.

III. CONCLUSION

In this practical slope basin concentrated still with area of basin is being included with 0.6 m² and solar concentrated dish with area 0.07 m² is used. The generation of fresh water for three days in the month of September involved timing between 10:00 hours morning to 5:00 hours evening with different depth of water. The maximum amount of water generated about 0.976 liters for 1 centimeter's depth of water, 0.785 liters for 2 centimeters and 0.686 liters at 3 centimeters depth.

After addition of paraffin wax through PCM method we observe that the capacity of water along with volume and flow is higher as compared to without addition which have been recorded as follows:

At 1 centimeter's depth of water – 1.03 liters
At 1 centimeter's depth of water – 0.898 liters
At 1 centimeter's depth of water – 0.776 liters

Thus, we observed that maximum capacity of water being generated with depth of 1 centimeter water therefore we come to conclude that desalination of water is inversely proportional to depth of water in the basin.

Hence, after addition of paraffin wax, we found the efficiency increased by 27.92%, 21.75% and 15.95% for different depth of water such as 1 centimeter, 2 centimeters and 3 centimeters. Hence, we come to final conclusion that by increasing the temperature with solar sunlight radiation up to 2 PM the generating capacity of water increases sa higher as possible as recorded and calculated in this thesis.

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