

Experiment Investigation of Desalinate of Saline Water Using Solar Humidification-Dehumidification Process

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Abstract:

This Experimental work deals with the desalination of saline water using solar energy being a renewable source, based on the principle of humidification-dehumidification. As the name implies Solar Humidification-Dehumidification Desalination System comprises the heating of saline water and then collecting the condensed vapors (distillate) from it to produce Drinkable water. Suitable and economic solar collector and humidifier dehumidifier were designed and fabricated to investigate the different environmental & operating conditions on the productivity of freshwater. Experimental Setup comprises of a Solar-Water heater, a parabolic type trough collector of Single-Axis, a flat plate collector type air pre-heater, a spray humidifier, and a de-humidifier. The variation in productivity of the system seems to be maximum at a particular time during a day and then decreases as the time elapses. The maximum freshwater production was obtained to be 7.7 kg during the experiment. The performance of the SHDDS depends upon air humidification, Collector's outlet temperature, inlet mass flow rate (Ma) of air into air pre-heater with a temperature of sprayed water in the humidifier unit.

Keywords: Parabola Trough Collector, solar air heater, humidifier and dehumidifier chamber

INTRODUCTION:

Fresh water is one of the fundamental requirements of life for human. Due to weather change and pollution at present more than 2000 million people has no regular access to sufficient safe water. According to one estimate, about 79 per cent of water available on earth is salty Therefore conversion of saline water into fresh water through desalination using solar energy is a good idea to fulfill the requirement [1]. Technologies that are used for desalinate of water is organized into two category as thermal and membrane technology. Both technologies need power to operate and to produced desalinate water. Some invigilators come up with the crux that the performance of the system depend upon various parameters i.e. humidifier area and operating conditions like feed water flow rate, flow rate of saline water and flow rate of air [2-4]. Cemil yamal and Ismail Salmus found theoretically that the system productivity is increased by 8% with double pass flat-plate solar type air- heater & decreased around about 30% without using double pass solar air-heater [5]. Guofeng Yuan et al presented 1000 L/day system which is based on solar Humidification Dehumidification desalination and found that when solar intensity reaches to 550 w/m² then water production reaches to 1200L/m² [6]. Shabbo Hou and Hefei Zhang has carried his investigation on a process based on basin type hybrid solar de-salination system and multi-effect humidification cum de-humidification unit and results show that the system Gain Output Ratio rises by 2-3% at least by using rejected waste water [7]. Imed Houcine, discovered another de-salination method while working on an air multiple effect humidification de-humidification and investigated the principle parameters with experiment. The experimental set up consist of eight stage heating-humidification unit comprises of air solar collector, heat exchanger, spray humidifier and dehumidifier system to simulate the seawater experimentally [8]. Efat Chafik developed a new process for solar desalination. The main idea was in this process is to humidify air in several stages in order to load more water vapors, to obtain more desalinate saline water (sea water). For economical and suitable process several equipments had developed like collector, humidifier and dehumidifier in order to use this desalination process [9]. M.S Hatamipour and Eslamimanesh has done economical study on

humidification and de-humidification desalination (HDD) System with reverse osmosis system to estimate the benefits of humidification and de-humidification desalination over RO and investigate that the energy recovered by HDD unit is around 75%. The results based on Exact economic analysis were also obtained using COMFAR-III module for different economical parameters [10]. A.M.I Mohamed and El-Minshawy done theoretical investigation on de-saline system that utilize air humidification and de-humidification desalination principle. A comparison study shows that production time of desalinate water and performance depends upon different seasons. The productivity of Desalinate water also increases with day time till a best possible value and after that it decreases. The highest Pure water productivity is found to be 42% with high direct solar radiation (in summer season) falls on the collector [11]. Hassan E.S Fath and Ahmad Ghazy had used numerical approach to find out the Solar desalination unit's Performance using humidification & de-humidification and shows the effect desalination unit's Productivity with different operational, environmental and design parameters. The results reflect that the Productivity increases with increase in ambient temperature as well as Solar Intensity but decreases with increase in wind speed. Also, the dehumidifier effectiveness has an insignificant influence on system productivity [12]. Pradeep Kumar K V et al Experimental set up of parabolic trough collector with its sun tracking system is designed and manufactured. In order to optimize the performance of a collector, various reflecting materials were used and results shows that under dry weather condition, the efficiency of Mirror collector is around 8% more than that of Aluminum [13]. Santosh Vyas and Dr. Sunil Punjabi designed solar flat plate type air-heater of size 1m×0.5m×0.1m to find out the overall thermal efficiency with simulator having solar intensity of 6000w/m², with three different design of absorber i.e. plane absorber, transverse V-porous ribs and inclined V-porous ribs and comes up with the overall thermal efficiency of these design as 14.91%, 17.24% and 20.04% respectively [14]. Amir Hermatian et al done study to find out the efficiency of flat plate collector of absorber area 2m × 1m × 0.5mm with orientation as a window shade to increase air contact area. The experiments were conducted for both natural and forced convection and found that in forced convection the efficiency of a collector is lower than that of natural convection [15].

The objective of the experiment was to investigate the desalinate the saline water using solar humidification dehumidification desalination system according to the weather conditions of LPU Jalandhar, Punjab (N31° 15' 17.98'') (E 75° 42' 56.382'').

EXPERIMENTAL SETUP

The Solar Humidification Dehumidification Desalination System is shown in Figure 1. It consists of parabola trough collector, air preheater and humidifier and dehumidifier chamber. The experiment set up consist of following components:

1. Parabola trough collector
2. Receiver tube
3. Air pre heater
4. Humidifier dehumidifier chamber



Figure 1: Experimental Setup

- 1. Parabolic Trough Collector** used in this experiment consists of a reflector sheet; receiver and a glass cover (glazing). Highly polished aluminum sheet is used as a reflector which is in the shape of parabola. The material of the receiver is a copper because it is a good conductor of heat. The solar radiations reflected by the parabolic reflector are focused on the receiver tube for heating the saline water flowing through the copper tube.

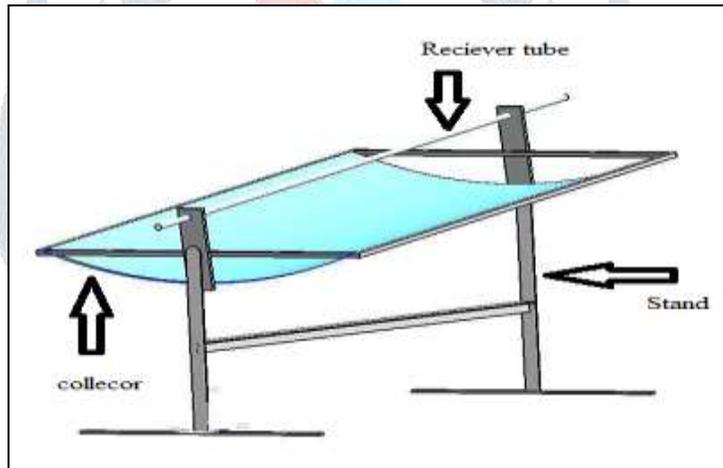


Figure 2: Parabola Trough Collector

Sr. No.	Design of the PTC	Dimensions(m)
1	Collector length (m)	1200
2	Collector width (m)	1200
3	Rim angle (degree)	180
4	Focal length (m)	0.3
5	Absorber diameter (m)	0.025

Table 1: Specification of Parabolic Trough Collector:

2. **Receiver Tube** is used for heating the saline water flowing through it. All solar radiations are concentrating on the receiver tube for the transfer of heat coming from sun. In this experiment the material of the tube is copper because copper is a good conductor of heat.

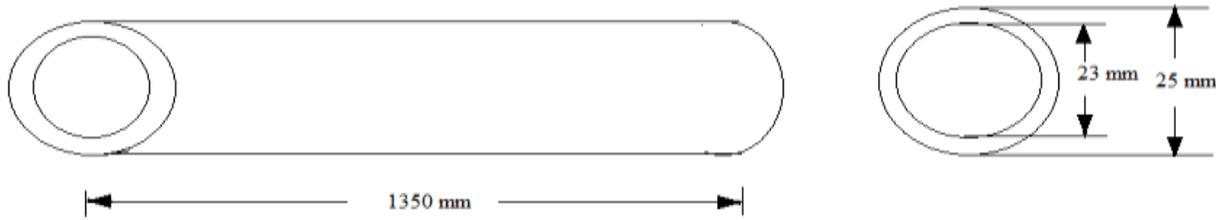


Figure 3: Receiver Tube

3. **Solar Air Heater** used in this experiment is flat plate collector of area $1.02\text{m} \times 1.02\text{m}$ and thickness is 0.06 m . The material of the absorber that is used in the FPC is cell polycarbonate sheet.

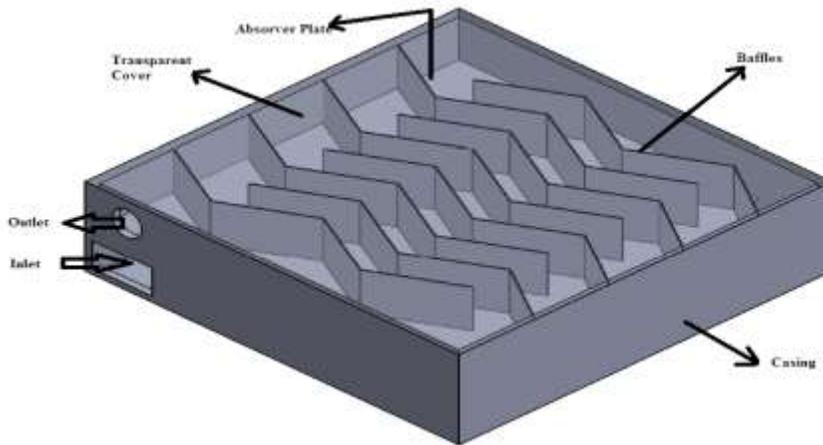


Figure 4: Solar Air Heater

The specification of solar flat plate collector as follow:

Sr. No.	Components	Specifications
1	Dimension of the collector	$1.02\text{m} \times 1.02\text{m} \times 0.06\text{m}$
2	Dimension of the absorber plate	$1\text{m} \times 1\text{m} \times 0.06\text{ m}$
3	Thickness of the absorber tube	0.06m
4	Thermal conductivity of the material	$0.19\text{-}0.22\text{ W/mk}$
5	No of flow paths	2
6	Baffle angle	90
7	Bottom insulation thickness	0.019m
8	Conductivity of the insulation	0.06 W/mk

Table 2: Specification of FPC

RESULT AND DISCUSSION

The experiment has been conducted in April'15 and May'15. Every day, the collector is placed in the Solar radiations during 9:00AM and readings were obtained from 9:30AM to 4:30PM at an interval of every 30minutes. Experiments were conducted in order to investigate the performance of desalination system under variable operating conditions at lovely professional university, Punjab by varying the mass flow rate of air and that of saline water for four days 28th, 29th of April and 01st, 04th of May. Four different cases were considered to determine the performance of the desalination system which have been discussed below:

CASE 1: Day 1: Saline Low Water Mass flow rate (M_w) and Low Air Mass flow rate (M_a) (28/04/15)

Obtained values such as ambient temperature, intensity of radiation, collector inlet and outlet temperature, air through solar flat plate type collector during a day in April (28/04/15) at lovely professional university has been represented in Figure 5. Although the measured values show sinusoidal trends with shifting of solar intensity after every half an hour.

On 28th April, experiment was conducted and found that the maximum intensity of light was 1287W/m² at 12:30 PM and the ambient temperature ranging from 32^oC to 38^oC. The maximum temperature achieved for saline water and air were 63^oC and 62^oC respectively.

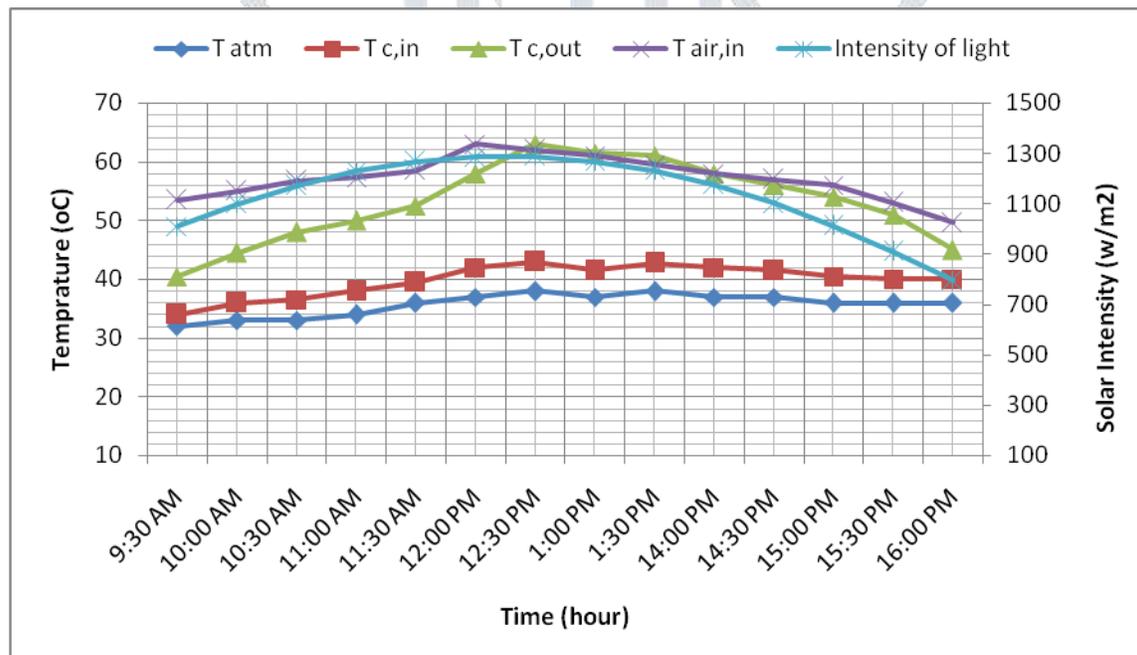


Figure 5: Temperature variation for water, air including intensity of light w.r.t time

Figure 6: The Productivity variation through the day (28/04/15)

During the day 28th April, the mass flow rate of air(M_a) were kept at 0.0481 kg/s with mass flow rate of water (M_w) as 0.00416 kg/s respectively. The maximum production of fresh water was 1.5 kg and the total production of fresh water was approximately 4.9 kg.

CASE 2: Day 2: High Water Mass Flow Rate (M_w) with Low Air Mass Flow Rate (M_a) (01/06/15)

On 1st May, experiment was conducted and observed that the maximum solar intensity comes out to be 1291 W/m^2 at 12:00 PM and the ambient temperature ranging between 30^oC to 35^oC. The optimal temperature of saline water as well as that of air were noted as 57^oC and 66^oC respectively. The mass flow rate of water and mass flow rate of air were kept 0.00834kg/s and 0.0481kg/s during the whole day and conducted the reading after every half an hour.

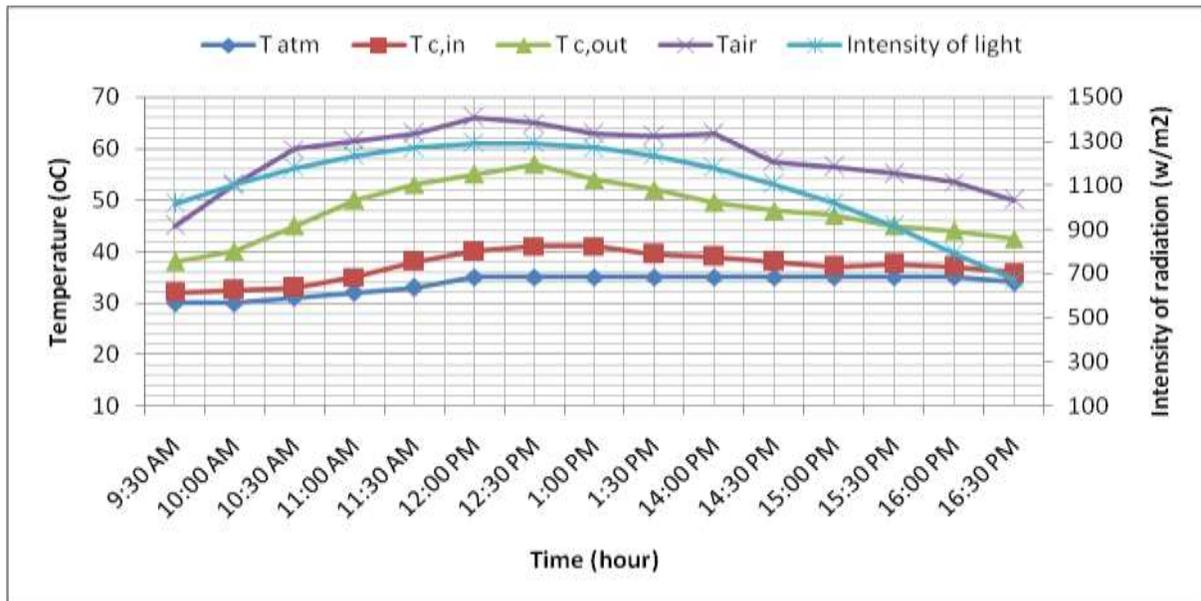


Figure 7: Variable Temperatures for Water, Air and intensity of light w.r.t time

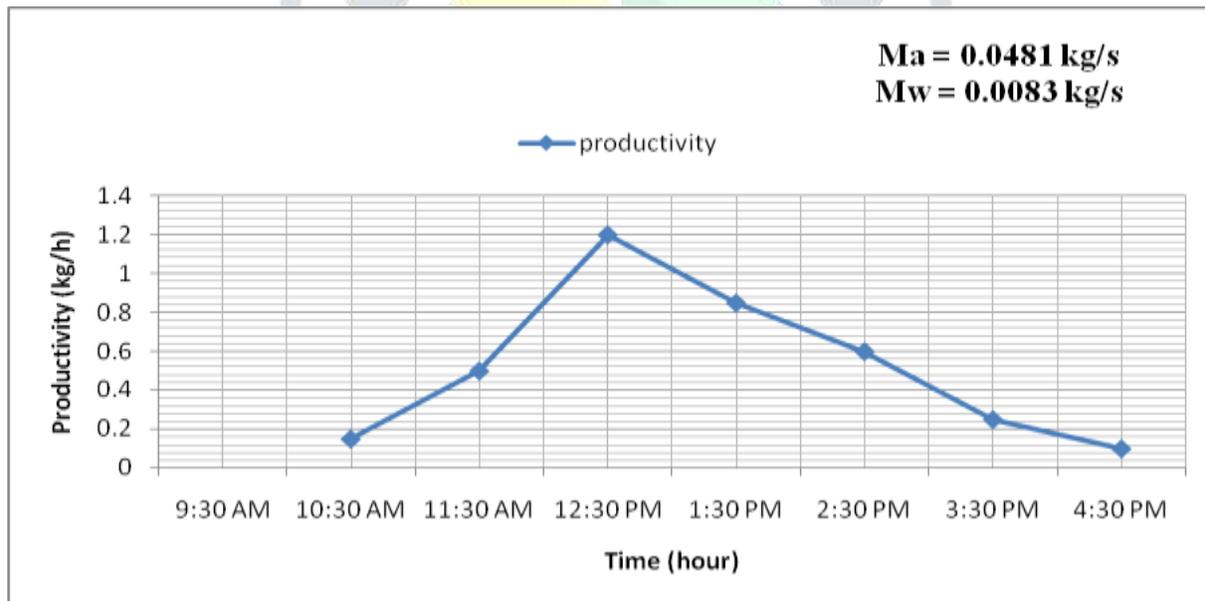


Figure 8: The Productivity variation through the day (28/04/15)

During the day 1May, the Mass flow rate of air and water (M_a & M_w) were kept at 0.0481kg/s and 0.0083kg/s. The maximum fresh water production was 1.2 kg during the day time and the total production of fresh water was approximately 3.65 kg.

CASE 3: Day 3: Low Water Mass Flow rate (M_w) with High Air Mass Flow rate (M_a) (29/04/15)

On 29 April, experiment was conducted and found that the maximum intensity of light was 1288 w/m² at 12:00 PM to 12:30 PM and the ambient temperature in the range of 29^oC to 38^oC as shown in figure 9. The maximum temperature achieved for saline water and air were 60^oC and 61.5^oC respectively. The water mass flow rate (M_w) and that of the air were kept at 0.0042kg/s and 0.07696kg/s during the whole day and conducted the reading after every half an hour.

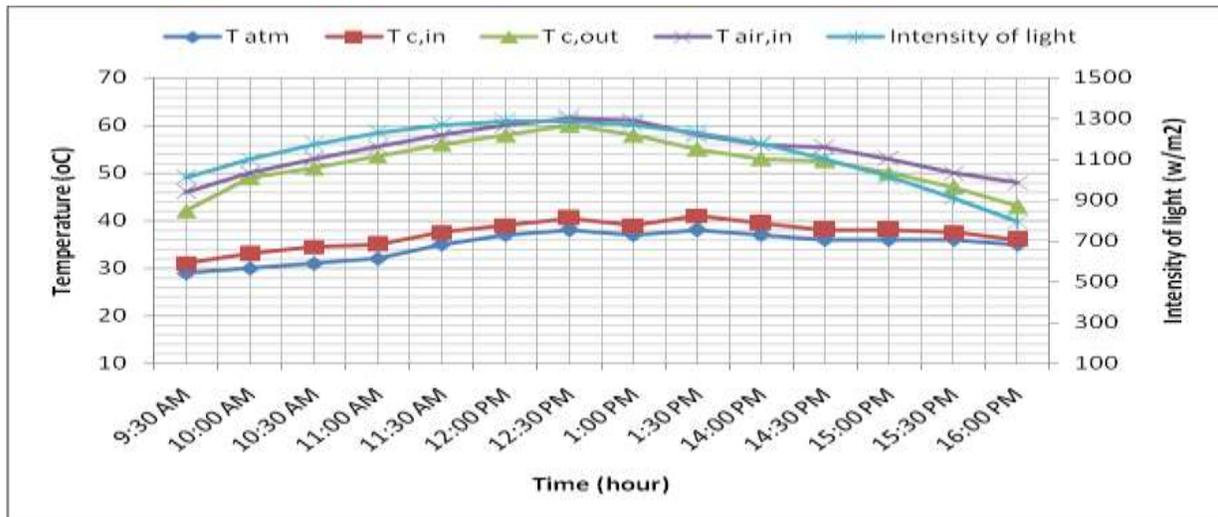


Figure 9: Temperature variation for Water, Air and Intensity of light w.r.t time

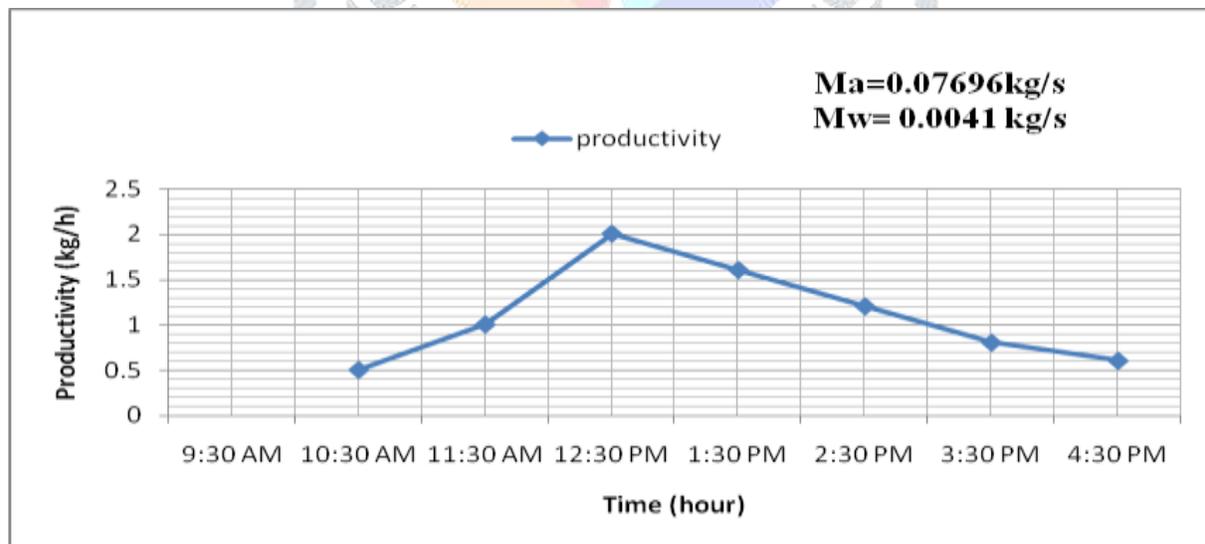


Figure 10: The Productivity variation through the day (29/04/15)

During the day 29th April, the Air Mass flow rate (M_a) and that of Water (M_w) were kept at 0.07696kg/s and 0.0041kg/s. During the day time the maximum production of fresh water comes out to be 2.0 kg and the net total production of fresh water was approximately 7.7 Kg.

This increase in production of fresh water may be due to increase in the mass flow rate of air increase the mass and heat transfer coefficient and increase the content of water vapour which results in increase the production.

CASE 4: Day 4: High Water Mass Flow rate (M_w) with High Air Mass Flow rate (M_a) (04/05/2015)

On 4th May, experiment was conducted and it has been observed that the maximum solar intensity was 1295 W/m² at 12:00 PM to 12:30 PM and the atmospheric temperature ranging from 32°C to 39°C, shown in fig. 11. The max. temperature achieved for saline water and air were 62°C and 64°C respectively. The water and air mass flow rates were kept at 0.0084kg/s and 0.07696 kg/s during the whole day and conducted the reading after every half an hour.

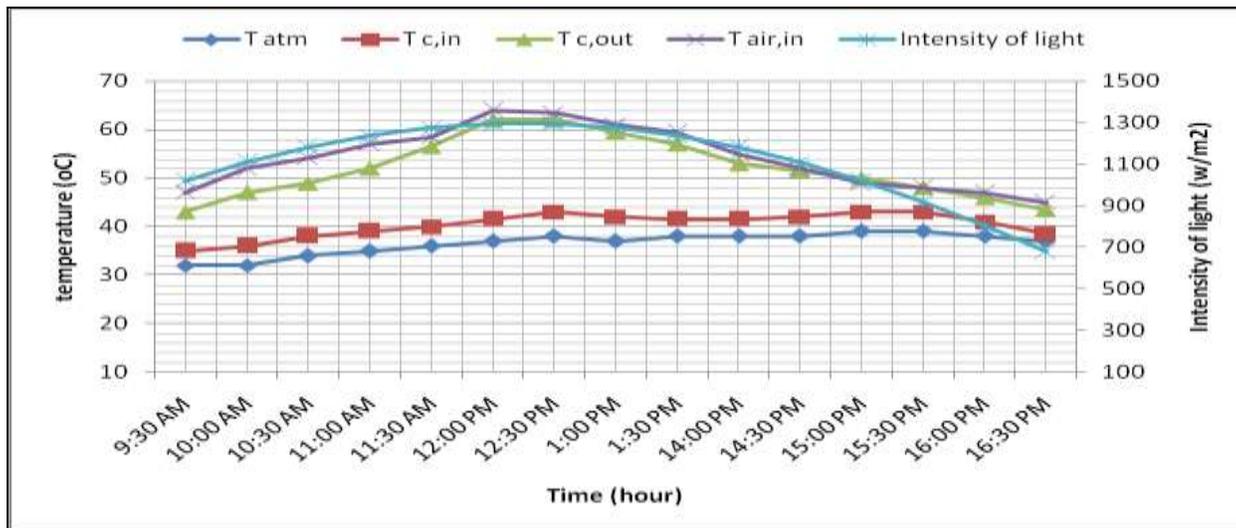


Figure 11: Temperature variation for water, air and intensity of light w.r.t time

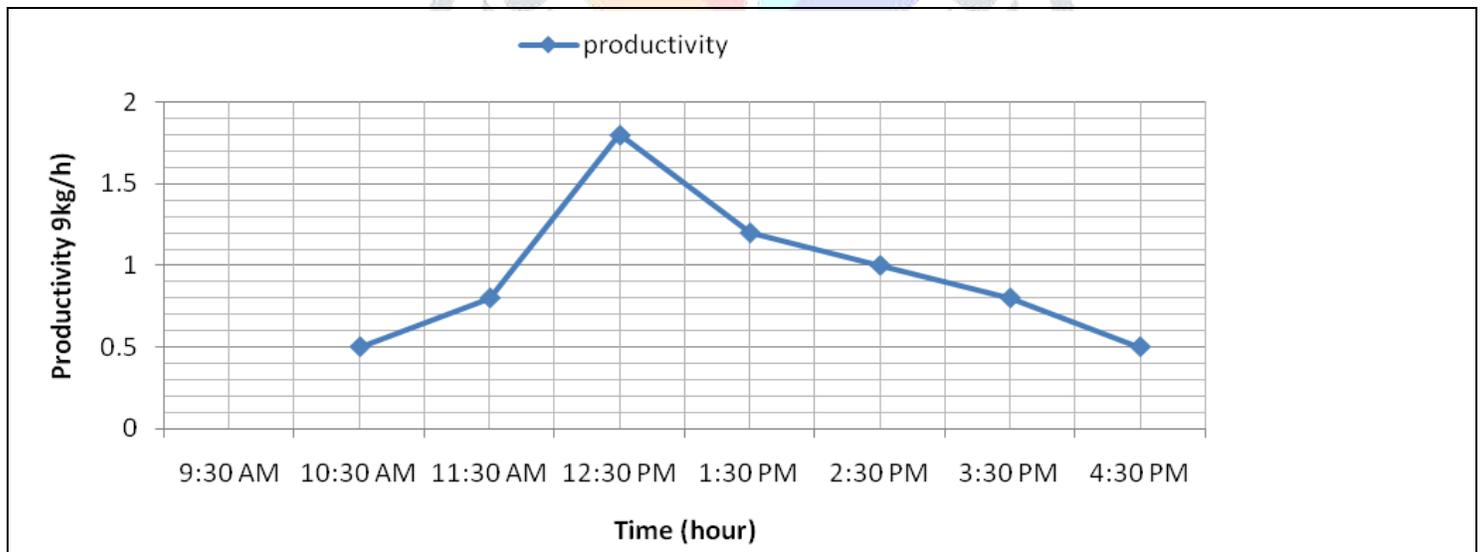


Figure 12: The Productivity variation through the day (04/05/15)

During the day 4th May, mass flow rate (M_a) of air and water (M_w) were kept at 0.07696 kg/s and 0.0084Kg/s. The max. production of fresh water during the day was 1.8Kg and the total net production of fresh water was approximately 6.5Kg.

This decrease in the production may be due to increase in mass flow rate of saline water to 0.0084Kg/s, the temperature of the saline water inlet to the humidifier is decrease, leading to decrees the vaporization that will decrease the productivity of water.

The Effect of Saline water flow rate (M_w) on unit Productivity

Figure 13 shows that the variation of productivity of fresh water with mass flow rate (M_w) of saline water. In first case when the saline water's mass flow rate was 0.0042 kg/s then total accumulative production of fresh water was 7.7 kg and when the flow rate (M_w) of saline water is increased to 0.0084 kg/s then the productivity of water is 6.5kg. This decrease in the productivity is because of increase in the water mass flow rate with decrease in saline water inlet temperature to the humidifier which decreases vaporization and hence result in decrease in water productivity

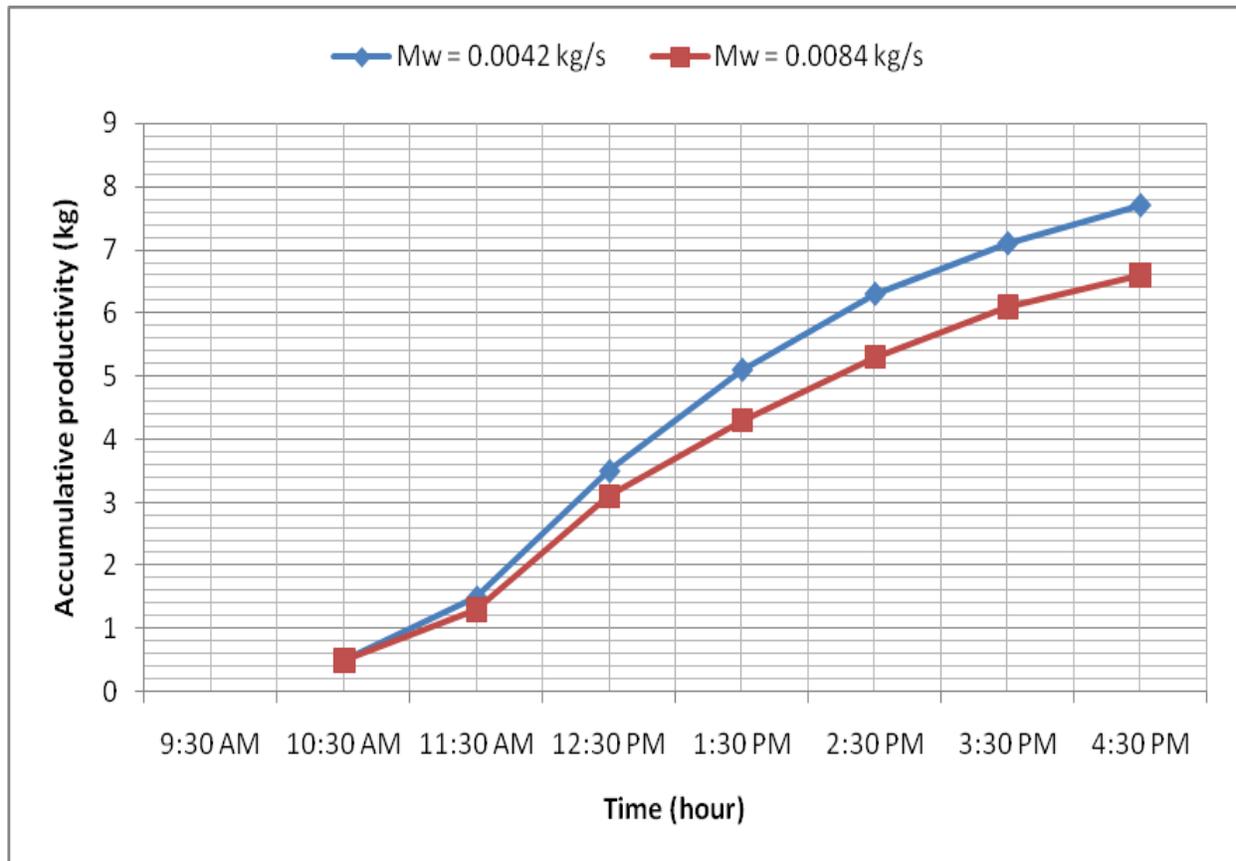


Figure 13: Saline Water Mass flow rate (M_w)

Air flow rate (M_a) on unit productivity

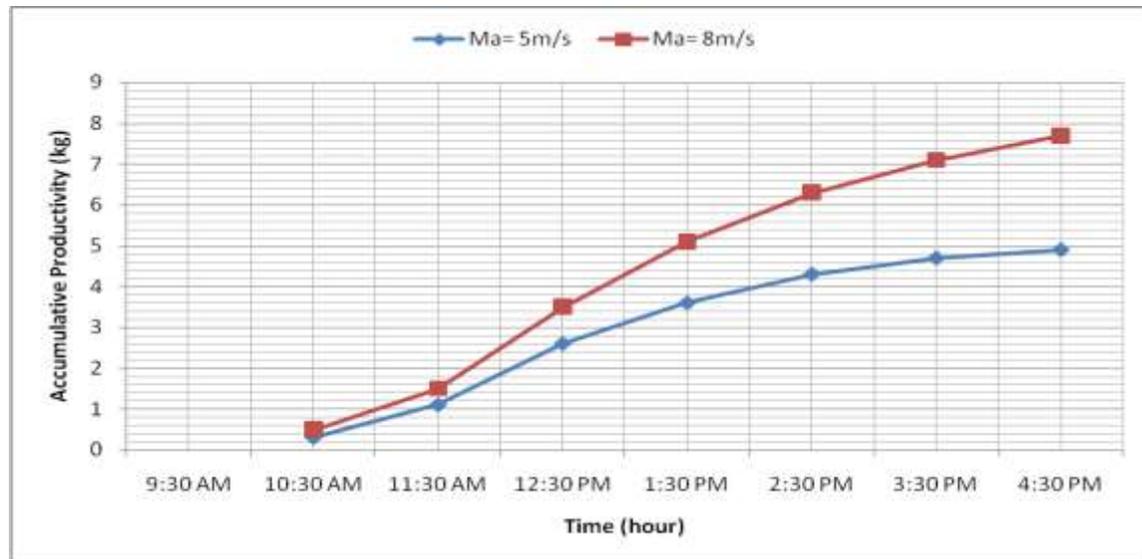


Figure 14: Effect of Air flow rate on productivity

Figure 14 shows that effect of Air flow rate (M_w) on unit productivity with constant Saline water flow rate (M_w). In the very first case when mass flow rate (M_a) of air was 0.0481kg/s then the accumulative productivity of fresh water was 4.9kg and in second case when the flow rate (M_a) of air was 0.07696kg/s then total accumulative productivity was 7.6 kg. This increases the productivity of water due to increased mass flow rate of air, which further enhances the heat transfer coefficient(h) and hence increases the water vapour content and hence the productivity.

CONCLUSION

In these experimental results, Different parameter has been considered to check the unit productivity i.e. mass flow rate (M_w) of saline water and (M_a) air. From results, it has been found that there is strong effect of saline water temperature and air temperature on unit production. Either increase flow of air or decrease flow rate of water increases the productivity of fresh water and concluded that:

- With increase in saline water and air temperature that will increase unit productivity
- With hike in air's mass flow rate, heat transfer coefficient along mass transfer coefficient also increases which results into formation of more water vapour in the air.
- With increase in solar intensity both the air temperature and saline water temperature increases.
- The maximum fresh water production comes out to be 7.7 kg/day at 0.07696 kg/s as a mass flow rate of Air and 0.0042 kg/s as a mass flow rate of Saline Water

The minimum production of fresh water was 4.9 kg/day when the mass flow rate (M_a) of air and saline water were 0.0481Kg/sec and 0.0084Kg/s respectively

REFERENCES

- [1] B H Khan, Volume second, "Non-Conventional Energy resources" pages 144,146
- [2] Naser K. Nawayseh et al [1997], "A simulation study to improve the performance of solar humidification dehumidification desalination unit constructed in Jordan" Science Direct Elsevier; pages 277-284
- [3] Y J Dai et al [2001], "Parametric analysis to improve the performance of solar desalination unit with humidification" Science Direct Elsevier; pages 107-117

- [4] J Orfi et al [2006], “Air humidification dehumidification for a water desalination using solar energy”; Science Direct Elsevier; pages 471-481
- [5] Cemil Yamal and Ismail salmus [2006], “Theoretical investigation of humidification dehumidification desalination system configured by a double pass flat plate solar air heater” Science Direct; pages 163-177
- [6] Guofeng Yuan et al [2011], “Experiment study of a solar desalination system based on solar humidification dehumidification process” Science Direct Elsevier; pages 92-98
- [7] Shabbo Hou and Hefei Zhang [2007], “A hybrid solar desalination process of the multi-effect humidification dehumidification and basin type unit”; Science Direct Elsevier; pages 552-557
- [8] Imed Housine et al [2003], “Experiment Study of a Multi Effect Humidification Solar Desalination Technique”, Science direct Elsevier, 170: 209-221.
- [9] Chafik E, “design of plants for solar desalination using multi stage heating/humidification technique”, Science direct Elsevier, 168: pages55-71.
- [10] Eslamimanesh, M.S. Hatamipour, November 2008, “Economical study of a small-scale direct contact humidification–dehumidification desalination plant”, Science direct Elsevier,250; pages 203-207
- [11] A.M.I Mohamed, N.A El-Minshawy, Jun 2011, “Theretical investigation of solar Humidification-dehumidification system using parabolic trough concentrators”, Science direct Elsevier, 52: pages 3112-3119
- [12] Hassan E.S Fath and Ahmad Ghazy [2001], “solar desalination using humidification dehumidification technology”, Science direct Elsevier, pages 119-133
- [13] Pradeep Kumar K V et al [2013], “Design, Fabrication and Experiment Testing of Solar Parabolic Trough Collectors with Automated System Tracking Mechanism” international journal of research in aeronautical and mechanical engineering, page 37-55
- [14] Santosh Vyas and Dr. Sunil Punjabi (2014), “Thermal Performance Testing of Flat Plate Solar Air Heater using optical Measurement Technique”, IJMECH, Vol 3, No 4.
- [15] Amir Hermatian et al (2012), “Experiment Analysis of Flat Plate Solar Air Collector Efficiency” Indian journal of science and technology, ISSN: 0974- 6846

