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AREA OPTIMIZATION OF SOLAR COLLECTOR AND BASIN FOR ADSORPTION DESALINATION

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Abstract: Water is very limited in the arid regions like the Middle East, South Asia and countries where water is in polluted state like India. Due to impure drinking water more than 5 million people die per year according to WHO report. So all these factors indicates that there is need to develop or identify a technique to produce pure water. In this experiment, a solar still is designed and fabricated to produce distilled water from atmospheric air and an attempt is done to optimize the areas of collector and basin. In the designing of solar still box, the area of collector and basin are kept as 0.426 m^2 and 0.372 m^2 respectively. The average height gap between material basin and collector is designed to be 0.28 m and inclination given to the collector glasses is 30^0. Experiments were performed for the production of water considering different area of basin and the collector area is completely considered to obtain maximum radiation. Experimental results shown that the maximum water produced when the basin area is considered 80% of the total area (0.296 m^2 of 0.372 m^2) and collector area is 100% (0.426 m^2). The maximum water produced in a day was 168 ml/kg of desiccant material.

Keywords: Atmospheric water production, area optimization of solar still, desiccant material, silica gel

I. INTRODUCTION

The three major requirements for human beings to survive are shelter, clothing and food. There are many alternate for the first two requirements but the third one have very limited alternates and is of utmost importance. The food should be of clean and non-infecting nature. Water is the most important part of the food as it is used for cooking, drinking and cleaning. As per the survey of the World Health Organization (WHO), out of the total water present on the earth, 97.5% water is salty and rest of i.e. 2.5% is the fresh water. Out of this quantity, about 70% is in frozen state at the polar ends of the earth and remaining 30% is not fully accessible. So, only less than 1% fresh water is available for direct human use. Water is in most limited condition in the arid regions like the Middle East, South Asia and countries where water is in polluted state. Due to unsafe drinking water more than 5 million people die every year as per WHO report. So all these factors indicates that there is need to develop or identify a technique which is suitable for arid places especially villages.

India has enough water assets, yet because of its unequal dispersion in term of geological and occasional spread joined with the unfavorable effect of environmental change and administration has put the circumstance needing crisp water. It is becoming important day by day to treat water as a valuable resource and adopt measures for its efficient utilization for achieving the net societal benefit. In India, the use of water efficiently is very poor in areas such as agriculture, industry and domestic activities. The production of fresh water is more strongly pronounced in states like Gujarat and Rajasthan and the state like New Delhi have water in polluted state.

The alternate for water production is the use of water-air technology where neither, salty water is present, nor infrastructure is there. Atmospheric air is a huge and renewable source of fresh water. The atmosphere contains about 12,900 km3 of fresh water, whereas liquid water resources of inhabited lands are about 12,500 km3 (Beysens D and Milimouk I, 2000). Atmospheric air is primarily composed of nitrogen (78%) and oxygen (21%) with varying amounts of water vapors. Water vapor, however, depends upon factors like density, geographical location, altitude, time of day and season. By volume, water vapor is 4% of the atmospheric gas mixture and by mass it is 3% of the air. (Barry and Chorley, 1971)

The most general techniques for producing the water from atmospheric air are:

1. Production of water through environmental air by utilizing vapor compression refrigeration system.

2. Production of water through environmental air by utilizing radiative cooling.

3. Water production by using convection induced or controlled in a structure.

4. Water production by using desiccant materials.

Experiments have been conducted on **Solar Stills** to generate the water from atmospheric air by using the solid desiccant materials and experiment are done at combination of varying area of basin and collector. The experimental results are helpful to find the performance of solar stills for the generation of water and to optimize the area combination of collector and basin of solar still.

II EXPERIMENTAL PROCEDURE

The experimental setup is shown in Fig 1. It consists of a solar still. The solar still is consists of following main parts:

Fig.1. Experimental Setup

(1) Absorbent container: A well insulated container called as Solar still has been used where the absorbent material or the contaminated water is stored for the generation of pure water. The size of the box is 0.62 m X 0.60 m X 0.37 m, the top collector area is **0.426 m^2** and basin area is **0.372 m^2**. It is double slope solar still in which two slopes has been provided for both side collection of water.

(2) Glazing: A glass of 3mm thickness is utilized to glaze. This is additionally going about as a Condenser amid the recovery procedure. Glass permits the sun beams of shorter wavelength to go inside the solar stills and traps the beam of longer wavelength which comes in the wake of warming the strong desiccant material. It is utilized to make the greenhouse effect inside the Solar Still.

(3) Connecting pipe: Connecting pipe is attached between water collecting tray and bottle. This gives a way to the stream of condensed water drops.

(4) Water Measuring Container**:** A water estimating barrel is utilized outside the Solar Still for the accumulation of water. The water comes straightforwardly from the water gathering tray through the associating channel to the container. There is arrangement of estimating blemishes on the compartment which shows the gathered amount of the water. The base amount of water that can be estimated is 10 ml.

(5) Desiccant material: Silica gel is utilized as a strong desiccant material for the water generation from the air. For this reason, 1 kg of silica gel has been utilized. At the point when the silica gel is in the recovered frame, at that point it is demonstrated by the blue color and when it is in the adsorbed shape, at that point it is shown by the pink color. This color changing sign is because of the cobalt chloride. Whatever remains of the properties of silica gel are in Table I as given by Swambe Chemicals Pvt., Ltd. India.

Table I Properties of Silica Gel

Product	**Silica Gel Blue Crystals**
Size	3-5 mesh
Assay (as SiO2)	98.48 %
Ph	5.8 %
Bulk Density	0.585 g/ml
Loss on drying	1.2 %
Friability	99.5 %
Chloride	0.002 %
Cobalt	0.5 %
Adsorption Capacity	35.82 %

A. Measuring Devices and Instruments

(1). Temperature of material, inner side of the glass, outer side of glass, and inside the Solar still:

Temperature of material, inner side of the glass, outer side of glass, and inside the Solar still were measured using a digital infrared thermometer shown in Fig.2.

Fig. 2 Digital infrared Thermometer

(2) Solar radiation intensityThe solar radiation intensity was measured during the day time with a Pyranometer model. It has a dome shaped top sensor to sense the sun's radiation from all direction. The sensor is placed on the experimental setup and radiation is recorded though a display meter in Watt/meter^2 shown in Fig 3a & 3b.

Fig. 3 (a) Pyranometer sensor and (b) display meter

(3) Adsorption of moisture

Adsorption of moisture during the experiment was measured with the help of a digital weighing machine having maximum capacity of 50 kg, minimum capacity of 1 g, and resolution of 0.001 kg. The weighing machine is shown in Fig 4.

Fig. 4 Photograph of weighing display meter

B. Methodology

- To execute the wok on experimental setup, the solid desiccant material i.e. silica gel is set on the basin of solar still.
- For the adsorption process, the glass of still are opened at 19:00 hr in the evening.
- The adsorption procedure begins on the grounds that the vapor weight on the surface of the desiccant material (adsorbent) is lower than the environmental air.
- This procedure is proceeded up to late night till the equilibrium conditions, i.e., when the vapor weight on the adsorbent surface is same as that of environmental air accomplished..
- At the beginning of the day at 09:00 hrs, the glasses are shut and setup is presented to the sun beams for the vaporization procedure.
- As the desiccant material's temperature increases, the vapor weight distinction between the surface of the desiccant material and the quality of the internal space of the container increments. Hence, adsorbed moisture is exchanged to the demeanor of the inward space and builds the vapor weight.
- As the sun radiation expands, mass exchange of vapor from material to the quality of internal space increments and ranges to equilibrium condition.
- Water vapor condenses along inner part of glass and after coalition small water drops forms on the same place
- After that the water droplets moves along side edges of glass where water collection tray is fitted.
- Because of inclination in water collection tray, water moves towards the water measuring container with the help of connecting pipe. The measure of gathered water is estimated physically at 30 min interval.
- For the area optimization, the surface area of desiccant material is varied by increasing the quantity of the material with respect to the constant glass area.
- The performance with different area ratio is analyzed and the optimized area is determined for the maximum generation of water.

III RESULTS AND DISCUSSIONS

For the optimization of area, experiment is done on daily basis i.e. 09:00 hr to 16:00 hr in which the surface area of glass cover kept constant i.e. 0.426 m^2 and the basin area is varied so that the solar radiation will be maximum. In the Experiment, 5 different areas of basin with respect to the glass area is taken into consideration and the best combination of both the area (glass cover surface area and basin surface area) is determined for the maximum productivity of water.

1. Case I: Basin area is 1/5th of the Total Surface Area

In this case, the collector area of the solar still is kept constant and the surface area of the basin is kept as 1/5th of the total surface area i.e. the absorbent material (silica gel) is placed on the measured area 0.074 m^2. (Outer surface area = 0.426 m^2, Basin's surface area = 0.074 $m^{2)}$. Now at this state, the experiment is performed and all relevant parametric reading has been recorded.

1(a) Variation in desiccant material temperature and solar intensity with time

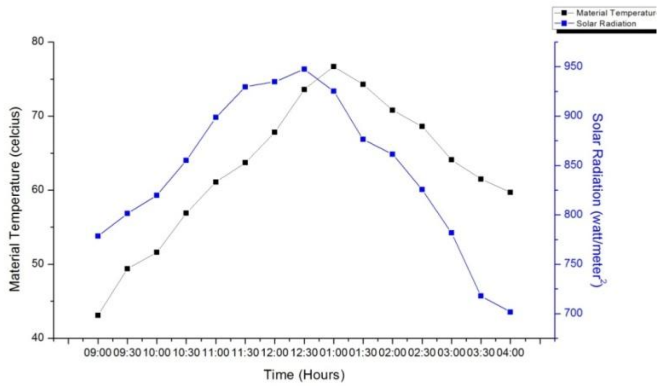

Fig.5.1 Variation in desiccant material temperature and solar intensity with time

Figure 5.1 shows that the maximum temperature of the absorbent is 76.7^{0}C at 01:00 hr and minimum temperature is 43.1^{0}C at 09:00 hr and Figure 5.2 shows that the maximum outer glass temperature is 63.8^{0}C at 12:30 hr and minimum temperature is 41.2^{0}C at 09:00 hr. Solar radiation varies from 701.6 W/m^2 to 947.5 W/m^2. Productivity of water at this state is 71 ml/kg/day shown in Figure 5.3.

1(b) Variation in outer glass temperature and solar intensity with time

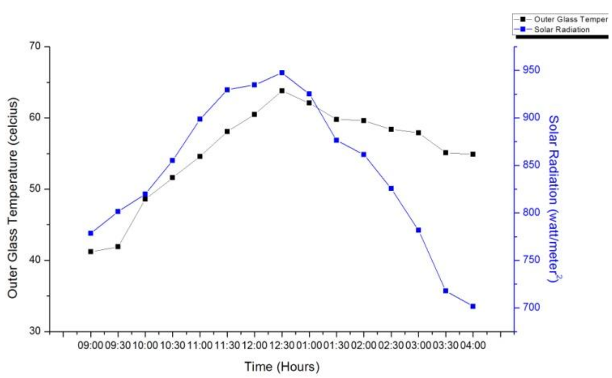

Fig. 5.2.Variation in outer glass temperature and solar intensity with time

1(c) Variation in Water Production and solar intensity with time

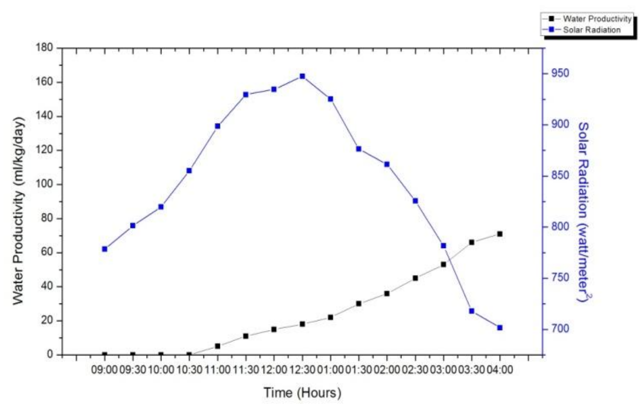

Fig. 5.3 Variation in water production and solar intensity with time

2. Case II: Basin area is 2/5th of the Total Surface Area

In this case, the collector area of the solar still is kept constant and the surface area of the basin is kept as 2/5th of the total surface area i.e. the absorbent material (silica gel) is placed only on the measured area 0.148 m^2 (Outer surface area = 0.426 m^2, Basin's surface area = 0.148 m^2) Now at this state, the experiment is performed and all relevant parametric reading has been recorded.

2(a) Variation in desiccant material temperature and solar intensity with time

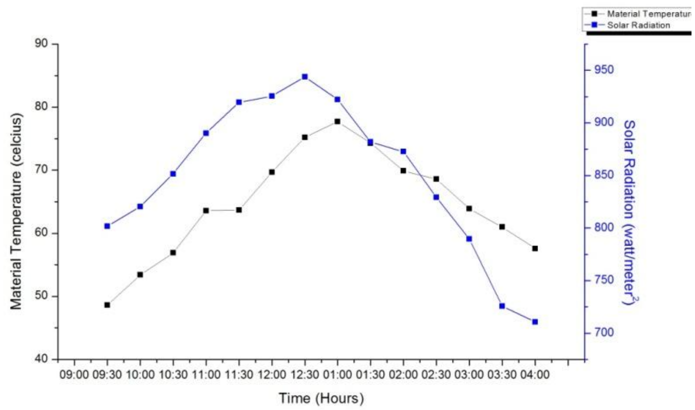

Fig.6.1 Variation in desiccant material temperature and solar intensity with time

Fig 6.1 shows that the maximum temperature of the absorbent is 77.7^{0}C at 01:00 hr and minimum temperature is 41.4^{0}C at 09:00 hr and Fig 6.2 shows that the maximum outer glass temperature is 64.2^{0}C at 12:30 hr and minimum temperature is 42.6^{0}C at 09:00 hr. Solar radiation varies from 710.7 W/m^2 to 940.9 W/m^2. Productivity of water at this state is 95 ml/kg/day shown in Figure 6.3.

2(b) Variation in outer glass temperature and solar intensity with time

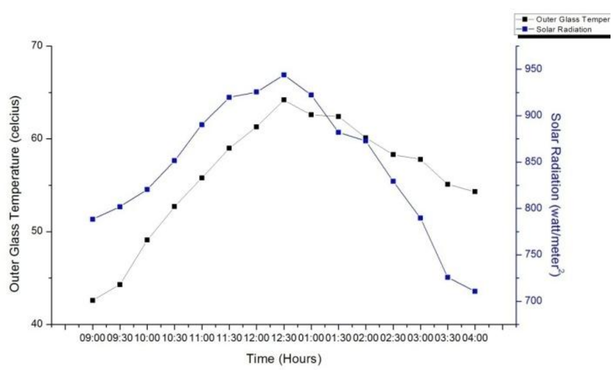

Fig. 6.2.Variation in outer glass temperature and solar intensity with time

2(c) Variation in Water Production and solar intensity with time

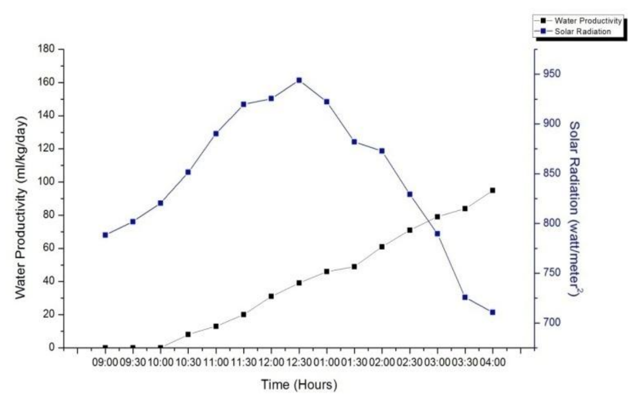

Fig. 6.3 Variation in water production and solar intensity with time

3. Case III: Basin area is 3/5th of the Total Surface Area

In this case, the collector area of the solar still is kept constant and the surface area of the basin is kept as 3/5th of the total surface area i.e. the absorbent material (silica gel) is placed only on the measured area 0.222 m^2. (Outer surface area = 0.426 m^2, Basin's surface area = 0.222 m^2) Now at this state, the experiment is performed and all relevant parametric reading has been recorded.

3(a) Variation in desiccant material temperature and solar intensity with time

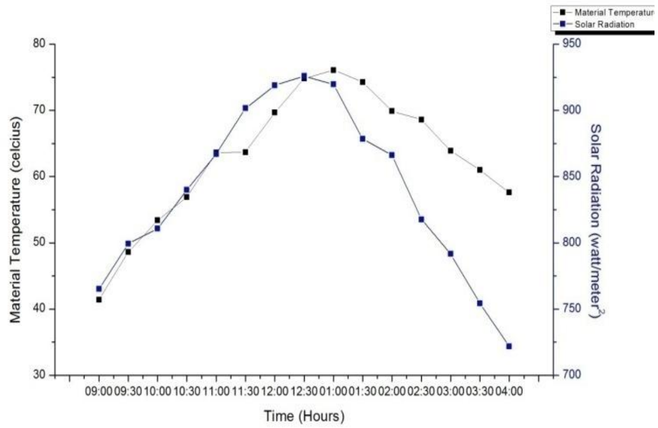

Fig 7.1 Variation in desiccant material temperature and solar intensity with time

Fig. 7.1 shows that the maximum temperature of the absorbent is 76.4^{0}C at 01:00 hr and minimum temperature is 40.1^{0}C at 09:00 hr and Figure 7.2 shows that the maximum outer glass temperature is 63.8^{0}C at 12:30 hr and minimum temperature is 41.2^{0}C at 09:00 hr. Solar radiation varies from 721.8 W/m^2 to 925.9 W/m^2. Productivity of water at this state is 145 ml/kg/day shown in Figure 7.3.

3(b) Variation in outer glass temperature and solar intensity with time

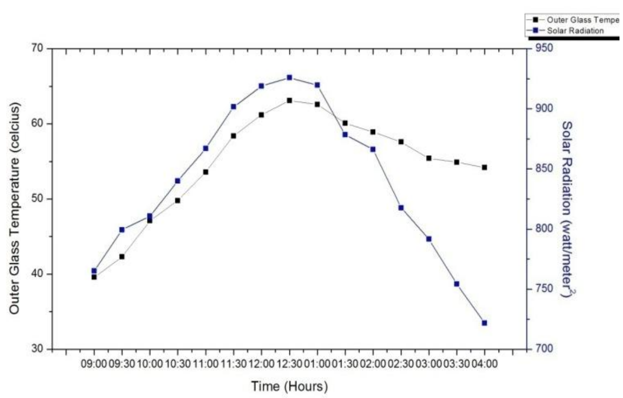

Fig 7.2.Variation in outer glass temperature and solar intensity with time

3(c) Variation in Water Production and solar intensity with time

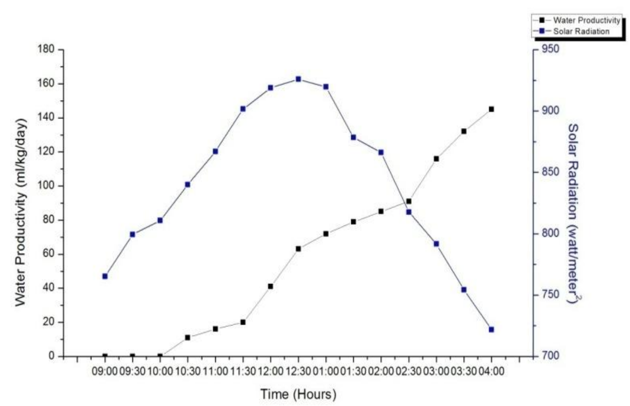

Fig. 7.3 Variation in water production and solar intensity with time

4. Case IV: Basin area is 4/5th of the Total Surface Area

In this case, the collector area of the solar still is kept constant and the surface area of the basin is kept as 4/5th of the total surface area i.e. the absorbent material (silica gel) is placed only on the measured area 0.296 m^2.(Outer surface area = 0.426 m^2**,** Basin's surface area = 0.296 m^2). Now at this state, the experiment is performed and all relevant parametric reading has been recorded.

4(a) Variation in desiccant material temperature and solar intensity with time

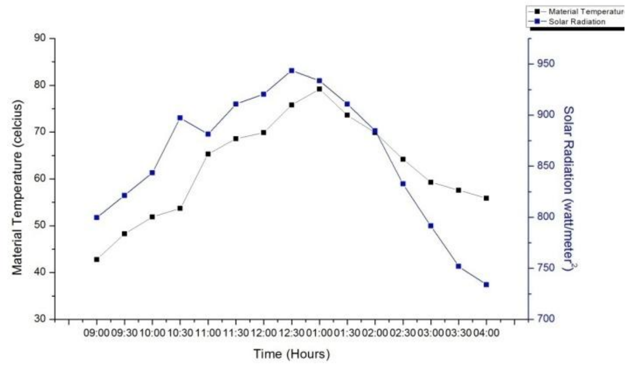

Fig. 8.1 Variation in desiccant material temperature and solar intensity with time

Fig. 8.1 shows that the maximum temperature of the absorbent is 79.2^{0}C at 01:00 hr and minimum temperature is 42.8^{0}C at 09:00 hr and Fig 8.2 shows that the maximum outer glass temperature is 63.9^{0}C at 12:30 hr and minimum temperature is 43.6^{0}C at 09:00 hr. Solar radiation varies from 733.6 W/m^2 to 943.7 W/m^2. Productivity of water at this state is 168 ml/kg/day shown in Figure 8.3.

4(b) Variation in outer glass temperature and solar intensity with time

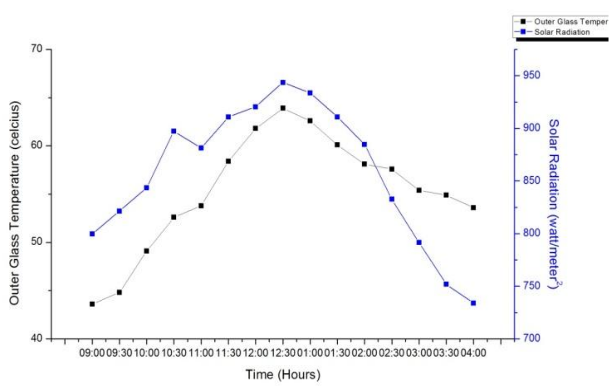

Fig. 8.2.Variation in outer glass temperature and solar intensity with time

4(c) Variation in Water Production and solar intensity with time

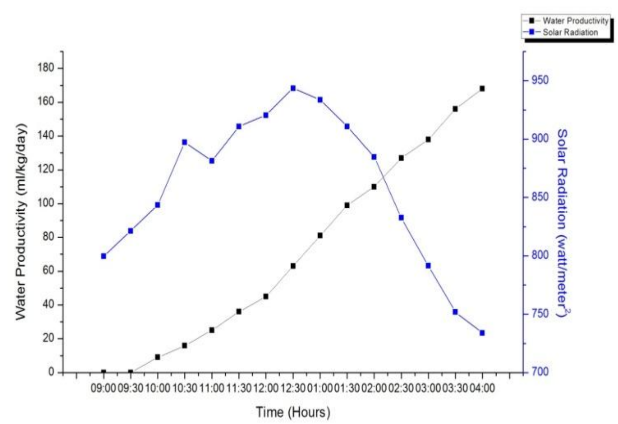

Fig. 8.3 Variation in water production and solar intensity with time

5. Case V: Basin area is Total Surface Area

In this case, the collector area of the solar still is kept constant and the surface area of the basin is kept as 4/5th of the total surface area i.e. the absorbent material (silica gel) is placed only on the measured area 0.372 m^2. (Outer surface area = 0.426 m^2, Basin's surface area = 0.372 m^2) Now at this state, the experiment is performed and all relevant parametric reading has been recorded.

5(a) Variation in desiccant material temperature and solar intensity with time

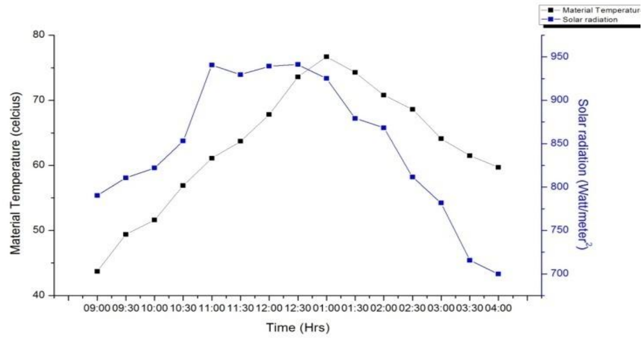

Fig. 9.1 Variation in desiccant material temperature and solar intensity with time

Fig. 9.1 shows that the maximum temperature of the absorbent is 75.9^{0}C at 01:30 hr and minimum temperature is 43.7^{0}C at 09:00 hr and Figure 9.2 shows that the maximum outer glass temperature is 63.4^{0}C at 12:30 hr and minimum temperature is 41.6^{0}C at 09:00 hr. Solar radiation varies from 699.8 W/m^2 to 941.2 W/m^2. Productivity of water at this state is 151 ml/kg/day shown in Figure 9.3.

5(b) Variation in outer glass temperature and solar intensity with time

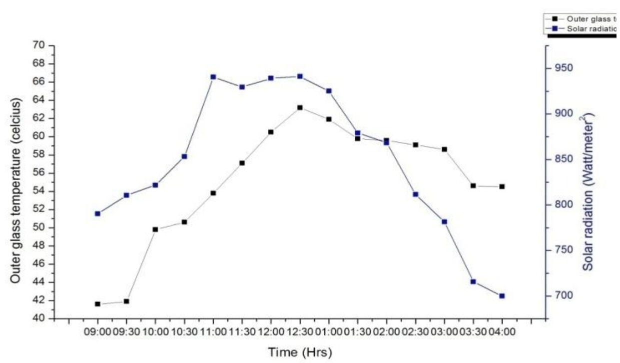

Fig. 9.2.Variation in outer glass temperature and solar intensity with time

5(c) Variation in Water Production and solar intensity with time

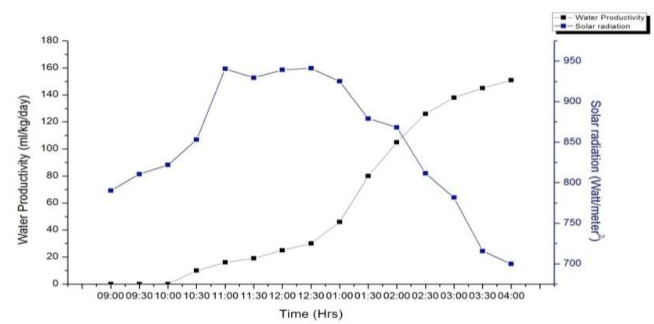

Fig. 9.3 Variation in water production and solar intensity with time

6. Comparison of Productivity of water with varying Basin Area

From above results, water production through different area has been compared and shown in Figure 4.16**.**

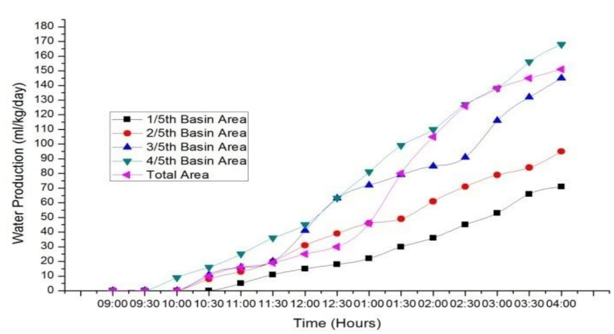

Fig.10. Variation of water production through different area with time

Above results depicts that the production of water through atmospheric air utilizing desiccant material (Silica Gel) is found maximum by placing Silica gel in 80% area (4/5th Basin Area) of the total basin area i.e. 0.296 m^2 of 0.372 m^2 (0.62 x 0.60) and the upper glass area is kept fully open to absorb maximum radiation (0.472 m^2). And the maximum water produced was 168 ml/kg/day in this state.

IV CONCLUSIONS AND FUTURE SCOPE

A. Conclusions

The experimental outcomes amid the procedure of adsorption and recovery have demonstrated the following essential conclusions:

(1) Experimental aftereffects of Solar still have demonstrated that water can be generated from the environmental air by keeping average height gap at 0.28 m, angle of inclination as 30^0, thickness of the glass as 3mm, and utilizing single coating

(2) Result shown that from variation of the surface area of basin keeping the glass surface area as constant, the maximum water production has been obtained at covering 80% of the total basin area i.e. 0.296 m^2 of 0.372 m^2 and collector area is 0.472 m^2

(3) The maximum water produced from the above condition was 168 ml/kg/day.

B. Scope of Future Work

(1) In the existing experimental set-up, research work can be done on the condensation side along with making the system more leak proof.

(2) Also, calcium oxide, calcium chloride, charcoal, composite desiccant materials and liquid desiccant materials can be used instead of silica gel as an adsorbent for the production of water from atmospheric air.

(3) For using the experimental system as per the regional conditions, the design parameters have to be investigated by covering a wide range of climatic conditions.

(4) Efficiency of the solar still can be determined using different desiccant material like calcium chloride, charcoal, silica gel and comparison can be obtained accordingly.

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