Experimental Investigation of a Tubular Solar Still

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***Abstract*: Restoration of saline water is indispensable to conserve the thirst of millions of people. Water desalination is one of the primary solution for obtaining potable water from seas and ocean beds. For transition of saline water into drinkable water through natural process is a complex task and need cautious attention regarding selection of the method. Uses of different desalination modelling tools are very crucial for understanding the scenarios on future performance and its sustainability. An in-depth study has been performed to desalinate the saline water which is available in ample in amount. In today's scenario many people living in arid, desert and coastal regions people lack potable drinking water which is must for livelihood. Under this obstinately demanding condition the study include review, different practical alignments, conditional setup, mathematical modelling and output analysis. Careful investigation was conducted to examine the primary desalination process needs supplementary measure to keep the demand and purity of water alive throughout the year including different environmental impact.**

***Keywords*: Desalination, Mathematical modelling, Output analysis, Sustainability.**

1. Introduction

More than two-third of the earth's surface is covered with water. Most of the available water is either present as seawater or icebergs in the Polar Regions. More than 97% of the earth's water is salty; rest around 2.6% is fresh water. Less than 1% fresh water is within human reach. Even this small fraction is believed to be adequate to support life and vegetation on earth. Nature itself provides most of the required fresh water, through hydrological cycle. A very large-scale process of solar distillation naturally produces fresh water. The essential features of this process are thus summarized as the production of vapour above the surface of the liquids, the transport of vapour by winds, the cooling of air vapour mixture, condensation and precipitation. This natural process is copied on a small scale in basin type solar stills.

The availability of potable water is a main problem for the communities who will be living in arid new regions or especially for people in remote region (i.e. deserts). These regions are recognized by a high intensity of solar radiation, which makes the direct use of solar energy represents a promising option for these communities to reduce the major operating cost for pumping drinking water. The solar energy can be utilized to obtain drinkable water from salty or brackish water through the use of solar still to capture the evaporated (or. distilled) water by condensing it onto a cool surface (shell), and the output will be clean water.

2. Methodology

As per the block diagram mentioned in fig.1 this system is feed with the salt water by the storage tank with the help of pipes in a controlled rate. When the sunrays fall on the system the water in the tray is heated and is evaporated which then settles on the upper side of the shell after the condensation. This condensate when gets heavier slides down and is collected at the bottom which is collected in the collecting tank.

The thermocouple in the system will measure the temperature of different areas and will be displayed on the display unit.

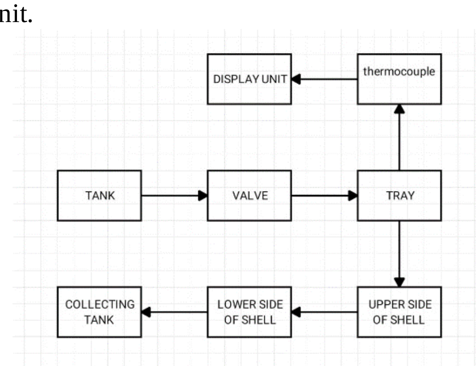

Fig. 1. Block diagram

3. Production Principle of TSS

Production principle of TSS is illustrated in the Fig. 2. The system mimics the natural cycle. The solar radiation is passes through the transparent Polycarbonate sheet and falls on the basin where the water to be purified is heated with the help of solar radiation. This heated water gets converted into vapour and rises upward. The Polycarbonate sheet has less temperatures as compared to the system as in the open surrounding air flows over it which helps to keep the Polycarbonate sheet cool. The vapour settles on the transparent sheet as the condensate. The condensate when gets heavier it slides downward with respect to the shell wall. This water is then guided toward the outlet port. This is achieved by little slant positioning of the shell. The outlet port guides the purified water into the collecting tank.

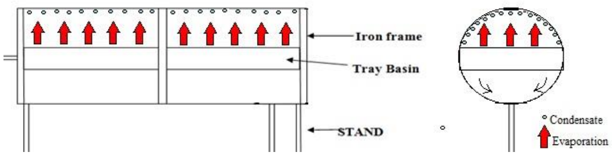

Fig. 2. Production principle of TSS

4. Design, Construction and Field Experiment

A. *Components*

1) Shell

The shell is hollow cylinder which consist of three metal ring and four metal rods as a structure which is covered with poly carbonate sheet. The dimension of shell is 50CM diameter and 100CM of length. The purpose of shell is to allow the sunlight to pass to it and it also trapped the water vapors within the system.

2) Basin

A tray is installed inside the shell with supporting medium. The tray is made up of sheet metal and the dimension are 46CM *98CM*5CM and the thickness of sheet metal is 1MM. This tray stores the salt water inside purification unit.

3) Valve

This valve is installed between salt water tank and tray. The vale is used to restrict flow of water from storage tank to tray. It helps to maintain the level of water in tray.

4) Tank

A plastic tank which stores the saline water is connected to tray. The connection is made with rubber pipe.

5) Thermocouple

The thermocouple of the range 0ºC to 100ºC is used to sense the temperature of different units in the system.

6) ph Meter

A simple and speedy device to measure the acidity and alkalinity of a fluid. A pH meter acts as a volt meter that measures the electrical potential difference between a pH electrode and a reference electrode and displays the result in terms of the pH value of the solution in which they are immersed.

7) TDS Meter

A TDS meter is a small hand-held device used to indicate the Total Dissolved Solids in a solution, usually water. Since dissolved ionized solids, such as salts and minerals, increase the conductivity of a solution, a TDS meter measures the conductivity of the solution and estimates the TDS from that reading.

B. *Design and Construction of TSS*

The TSS as shown in Fig. 3. consists of a cylindrical metal frame which is covered with the transparent Polycarbonate sheet. The basin is installed in the shell slightly below the center of the shell with the help of metal rods. The inlet is given to the basin with the help of pipe from the storage tank. There is a control valve connected in between the basin and the storage tank to control the feed rate into the basin. The structure is mounted on the stand in such a way that the shell is tilted so the water could flow in one direction towards the outlet. The pipe is connected to the outlet and the pipe finally is connected to the collecting tank. Both the sides of the cylinder are insulated with the thermocol and foam board to isolate the system.

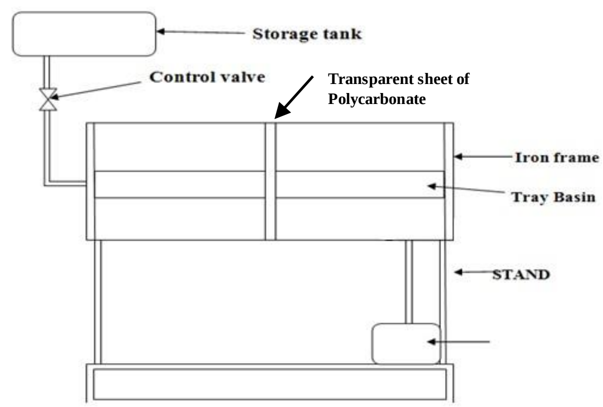

Fig. 3. Schematic diagram of TSS

C. *Field Experiment*

The field experiment has been carried out on the roof top of Library of the Rajiv Gandhi College of Engineering, Nagpur. The system was supported with the metal stand. The water collected was stored in the plastic collecting tank which was covered with the wet cloth to keep the container cool and so that to achieve good efficiency. The setup was tested for two days while on first day the tray was not painted and second time the tray was painted with black enamel paint. One end of the shell was fixed permanently while the other end was detachable so that adjustment could be made if needed, for cleaning and also for replacement purpose. The enamel paint was used because it has more heat absorbing tendency. The system was tested for 7hrs from 10:00 am to 5:00 pm, both the days. The weather conditions were same on both the days. The hourly output was measured to calculate the time at which maximum efficiency is achieved. The total efficiency was also calculated.

5. Working

The salt water from the tank is feed too the tray which is mounted inside the shell. The valve is used to controlled the level of water to be feed into the tray. When the sunrays fall on the water in the tray the water get heated as a result of which little portion of water get vaporized. As the shell is sealed the water vapor does not leaks out of the system hence the water vapor is in constant in contact with polycarbonate sheet. The air flow over the poly carbonate sheet takes the heat and the water vapor which are in contact with poly carbonate sheet gets condensed and settles to wall of sheet. Slowly when ample amount of water vapor settles at one point it becomes a water droplet and due to circular shape, it slides in the downward direction with the help of gravitational force. Due to slope of shell the water slides towards the partially open side of shell, where there is outlet which is connected to collecting tank and the fresh water is collected in this tank.

6. Calculation

A. *First Calculation*

$$\eta_{th\,hour} = \frac{\lambda_{fg} \times \dot{m}_{dis} \times 100}{A_{bs} \times I_t \times 3600}$$

λ_{fg} = 2300KJ/Kg = 2300×10^3 J/Kg
$\dot{m}_{dis1}$ = 0.080 Kg
A_{bs} = 0.4508 m^2
I_t = 740 w/m^2

For 10 am

1) $$\eta_{th\,hour} = \frac{2300 \times 0.080 \times 100}{0.4508 \times 740 \times 3600}$$

$$\boxed{\eta_{th\,hour} = 15.32\%}$$

A. *Daily Efficiency for Day 1*

$$\eta_d = \frac{\lambda_{fg} \times \dot{M}_{dis1} \times 100}{A_{bs} \times I_t \times 3600}$$

λ_{fg} = 2300KJ/Kg = 2300×10^3 J/Kg
$\dot{M}_{dis1}$ = 1.09Kg
A_{bs} = 0.4508 m^2

$$\therefore \eta_d = \frac{2300\times10^3 \times 1.09 \times 100}{0.4508 \times 6460 \times 3600}$$

$$\boxed{\eta_d = 23.91\%}$$

B. *Daily Efficiency for Day 2*

$$\eta_d = \frac{\lambda_{fg} \times \dot{M}_{dis1} \times 100}{A_{bs} \times I_t \times 3600}$$

λ_{fg} = 2300KJ/Kg = 2300×10^3 J/Kg
$\dot{M}_{dis1}$ = 1.390 Kg
A_{bs} = 0.4508 m^2

$$\therefore \eta_d = \frac{2300\times10^3 \times 1.390 \times 100}{0.4508 \times 6565 \times 3600}$$

$$\boxed{\eta_d = 30.00\%}$$

Where:
1) λ_{fg} = Latent Heat
2) $\dot{m}_{dis}$ = Hourly mass flow rate
3) $\dot{M}_{dis1}$ = Daily mass flow rate
4) A_{bs} = Area in m^2
5) I_t = Actual absorbing radiation solar energy in W/m^2
6) $\eta_{th\,hour}$ = Hourly Efficiency
7) η_d = Daily Efficiency

Table 1
Without Black Paint

Sr.no.	Time	Solar intensity $I_s(W/m^2)$	Ambient T_a ^0C	Absorber T_{abso} ^0C	Basin water T_{bw} ^0C	Cover outlet T_{co} ^0C	Cover inlet T_{ci} ^0C	Distilled water [ml]
1	10am	740	27	29	28	27	25	80
2	11am	850	29	33	31	30	29	90
3	12noon	1060	34	39	38	32	30	170
4	1pm	1140	36	47	45	37	35	200
5	2pm	960	33	46	44	35	34	180
6	3pm	750	30	42	40	33	31	165
7	4pm	550	29	39	37	30	29	135
8	5pm	410	27	37	36	29	27	70

Table 2
With Black Paint

Sr.no.	Time	Solar intensity $I_s(W/m^2)$	Ambient T_a ^0C	Absorber T_{abso} ^0C	Basin water T_{bw} ^0C	Cover outlet T_{co} ^0C	Cover inlet T_{ci} ^0C	Distilled water [ml]
1	10am	785	28	32	30	28	27	100
2	11am	860	30	38	35	31	30	120
3	12noon	1080	35	45	43	36	34	210
4	1pm	1150	36	54	51	37	36	260
5	2pm	980	34	52	49	37	36	220
6	3pm	750	31	48	46	34	32	200
7	4pm	540	25	44	41	30	25	170
8	5pm	420	28	40	38	30	28	110

Table 3
Efficiency Table

Sr.no	TIME	Efficiency without black paint %	Efficiency without black paint %
1	10am	15.32	18.05
2	11am	15.00	19.77
3	12noon	22.72	27.55
4	1pm	24.86	32.04
5	2pm	26.57	31.81
6	3pm	31.17	37.79
7	4pm	34.78	44.61
8	5pm	24.19	37.11

7. Result

The results are collected and plotted together, so many comparisons are done to illustrate the TSS performance and production distilled water rate. An hourly variation between ambient temperature and solar intensity, as normal trend the Ambient temperature increases until it reaches the maximum value in the mid-day of then it starts to decrease, also solar radiation takes the same trend.

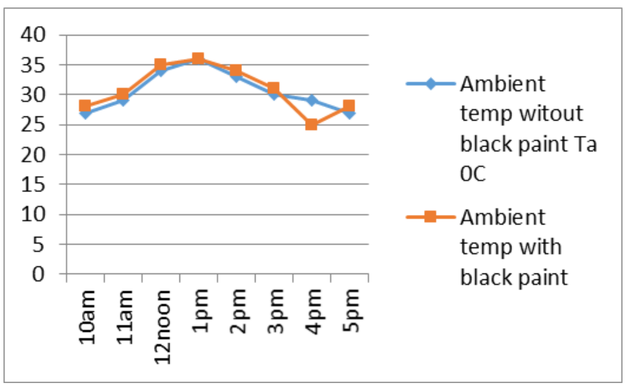

Fig. 4. Comparison of recorded ambient temperature with and without black paint with respect to time

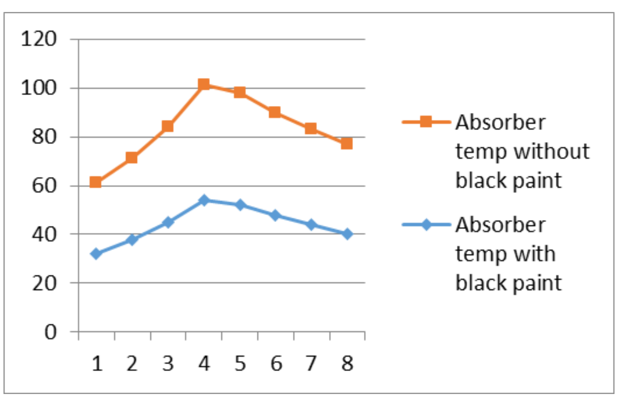

Fig. 5. Comparison of absorber temp with or without black paint with respect to time

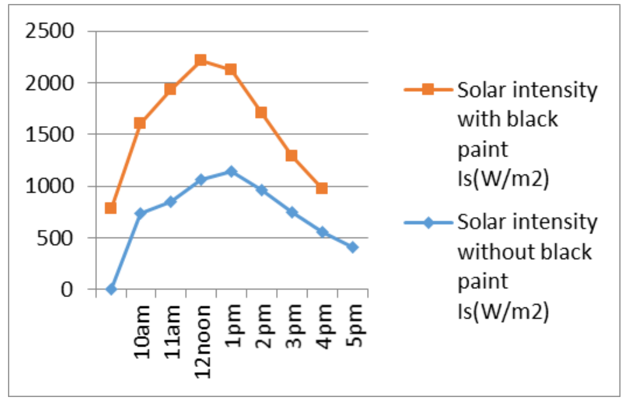

Fig. 6. Diurnal variation of solar intensity with and without point obtained in premises

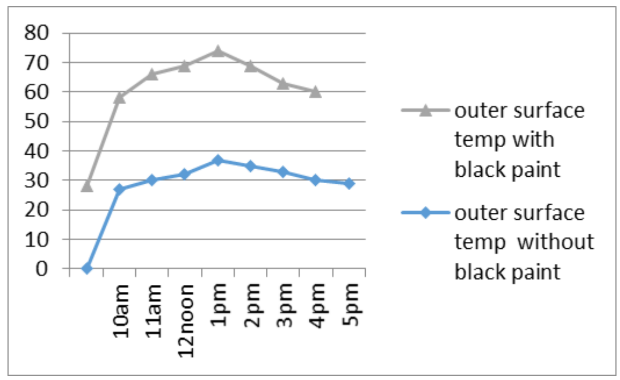

Fig. 7. Comparison of outer surface temp puff tubular shell with or without black paint with respect to time

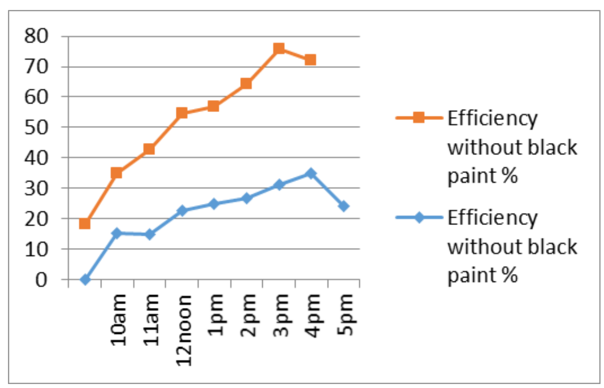

Fig. 8. Comparison of efficiency of the system with or without block paint with respect to time

8. Conclusion

Desalination method is a method where salt is removed from the saline water and at the same time all the contaminants are also removed. Solar energy is promising source to achieve this. This is due to various advantage involved in solar still desalination. The solar still desalination involves zero maintenance cost and no energy cost as it involves only solar energy which is free of cost. It is found from the experimental analysis that increasing the ambient temperature from 32C to 40C will increase the productivity by approximately 12% to 23%, which shows that the system performed more desalination at higher ambient temperature. It was observed that when depth of water increases from 1cm to 3 cm the productivity decreases by 5%. These result shows that the water mass (water depth) has an intense effect on the distillate output of solar still system. Solar still productivity can also increase by use of reflector by 3%.

The use of mirror reflector will increase the temperature of solar still basin; such as increase in the temperature is because of the improvement in solar radiation concentration. The solar radiation increase from 0MJ/msq/hr to 6MJ/msq/hr has increased the productivity of the still by 15% to 32%. However, the increase of solar radiation parameter will increase the solar energy absorbed by basin liner. The main disadvantage of this solar still is low productivity or high capital cost per unit output of distillate. This could be improved by a number of actions e.g. using internal and external mirror, using parabolic collector, reducing heat conduction through shell or reusing the latent heat emitted from the condensing vapour on the carbonate sheet. Capital cost can be reduced by using different designs and new materials for construction of solar still.

9. Future Scope

By applying latest innovation in utilization of solar energy, it is possible to achieve zero energy solar still concept for which the present study will be useful. Effective use of solar still practiced in every area where the need of potable water is must.

If requirements of the individual are fulfilled with the help of freely available solar energy and energy efficient and the use gadgets, the entire water scarcity can be tapered off with the help of solar energy itself without support of any other energy source. Thus, the green solar energy can play a major role in future water blessings to make them environmentally sustainable. The availability of the solar energy is basis for further studies related to effective utilization of it. Similarly, there is tremendous scope in increasing the efficiency of existing solar still. The future study in these areas will be helpful for sustainable development.

The recommended additions for future studies are:

- Installation of parabolic collectors to improve the efficiency of the system.
- Addition of copper chips to increase the heat absorbing capacity.
- By using heat absorbing materials we can improve the efficiency.
- Addition of heater to improve heating rate of water.
- By using proper saline water in spite of tap water we get better output.
- By giving proper inlet, outlet valve of water supply and use of sprinkler on the surface of still we can improve condensation process.

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