Experimental Investigation and Parameter Analysis of Solar Still with the Different Wick Materials

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ABSTRACT: *This paper aims to produce freshwater from saline water with the help of solar still. Different solar wick materials still absorb the sunlight and convert the heat energy, such as black sheer mesh fabric, light black cotton fabric, light jute fabric, black velvet fabric, and 4 mm thick sponge sheet. The wick materials sheets were wholly immersed in the saline water covering the total still basin area. The net basin horizontal active area of the solar still is 0.48 m², and the glass cover's tilted angle was fixed at 36º. From this arrangement, it has been found that by the use of various wick materials, the productivity rate differs from each other, and among these wick materials, light black cotton is the most effective wick material for solar still productivity increment. The pH value measures the final quality of the freshwater.*

KEYWORDS: *Solar still; Wick materials; Solar intensity; pH value.*

INTRODUCTION

In the current scenario, people were facing water scarcity problems every day. So we need to move some alternative solutions to produce the drinking water. In the world, 97 % of the water available in the ocean cannot be drunk and used for other irrigation purposes. Some governments took action for converting seawater into drinking water with Reverse Osmosis System. The RO the method has a very high cost and electric power supply to run the plant. RO has only operated by only on coastal places, and it will need routine maintenance. Solar still is one of the alternative methods to produce drinking water at a low cost. Normally the conventional method of stills, the productivity was very less. The output (quality and quantity of water) of the stills was not accurate.

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There were only approximate values. Electrical Water purification equipment and machines are high in cost. Different types of wick materials and coatings such as an insulated metallic GI sheet, black epoxy paint, and white enamel paint can increase water productivity in more heat regions example, Jaipur, India [1]. The performance of 'V' Shape solar still analyzed the glass temperature, ambient air temperature, and solar radiation were mentioned during the summer days [2]. Stepped solar still formed the depth is 5mm, and the tray width is 120mm tray width finally concludes the optimum design parameters. Stepped basin solar still consists of a solar collector, hot water collecting tank, external and internal reflector, and condenser. Using materials, which is for energy storage purposes, additives and sponges can be improved, the stepped solar still performance [3]. Most countries need clean and safe water for their daily needs. So they are using high-cost purification methods like reverse osmosis, UV, and electrodialysis. This research can improve solar water production in high volume in a future era [4]. Food processing industries regenerate their wastewaters by regenerating the nano bacterial cellulose, which is also one of the cost-effective water purification methods [5]. Based on the above literature survey, the water purification process contains high capital cost, and this research objective is to produce fresh water through the single slope solar still with minimum cost. Generally, climate conditions were different between the countries based on their geographical location, and here rainfall will be done in the entire year. Some countries have different climate structures like winter and summer, and here the winter rainfall has provided a sufficient groundwater level to manage the summer season. But some countries have fully, and 80% summer climate happens in the particular year, they will need fresh water to lead their lives, which we can implement our solar still to produce the freshwater continuously.

EXPERIMENTAL SECTION

Solar still is one of the methods which can use contaminated water for freshwater production. Normally the household's contaminated water has contained the pH Value is 11.5. it contained a more pH value because it is mixed with some alkaline. The basic working principles of still solar distillation are evaporation, condensation, and difference in basin material temperature. The absorption

Table 1: Material Selection and Properties.

Aluminum	Corrosion resistance, low weight, long life and easy cleaning.
Plywood	Thermal resistance and insulation for side and bottom walls.
Carbon black paint	Complete distillation and increase the absorption of the radiation.
Glass	Absorbing the sunlight, covering the top of the still.

Fig.1: Solar Still Construction.

of solar thermal radiation heats the unpalatable water in the basin. Due to this, air convection current is formed by the effect of temperature and salinity differences in the basin. The net basin horizontal active area of the solar still is 0.48 m², and the glass covers tilted angle was fixed at 36º.

The Solar still frame is prepared of aluminum materials due to its good corrosion resistance and less weight. Analysis of the different wick materials to increase the productivity of freshwater [10]. Analysis of characteristics of wick materials like porosity, absorbency, water repellence, capillary rise, and heat transfer coefficient is shown in Table 1. The validation of experimental results is analyzed. The cost analysis is Calculated to predict socio-economic development. Fig. 1 shows the experimental setup of the solar still.

Table 2 shows the properties of the wick materials. In this work, we select the Wick Materials are Light black cotton fabric, Light jute fabric, Black velvet fabric, 4mm thick Sponge sheet, and Black sheer mesh fabric.

The light black cotton sheet has more absorbed the saline water and solar power, which quickly evaporated the water from still. Jute fiber was eco-friendly and reusable, and also it has a functional water absorption capacity

Table 2: Wick Materials for Solar Still.

S.No	Wick Material	Properties
1	Black cotton	soft, absorbent, and breathable natural fiber, a good conductor of heat
2	Black velvet	Heavy, durable fabric with a strong sheen, Absorbent
3	Jute cloth	Coarse fiber, organic, 100% biodegradable and eco-friendly
4	Sponge sheet	Cleaning aid of Soft and porous material, absorbent, High retention ability
5	Sheer cloth	Allows sunlight to pass through during daylight

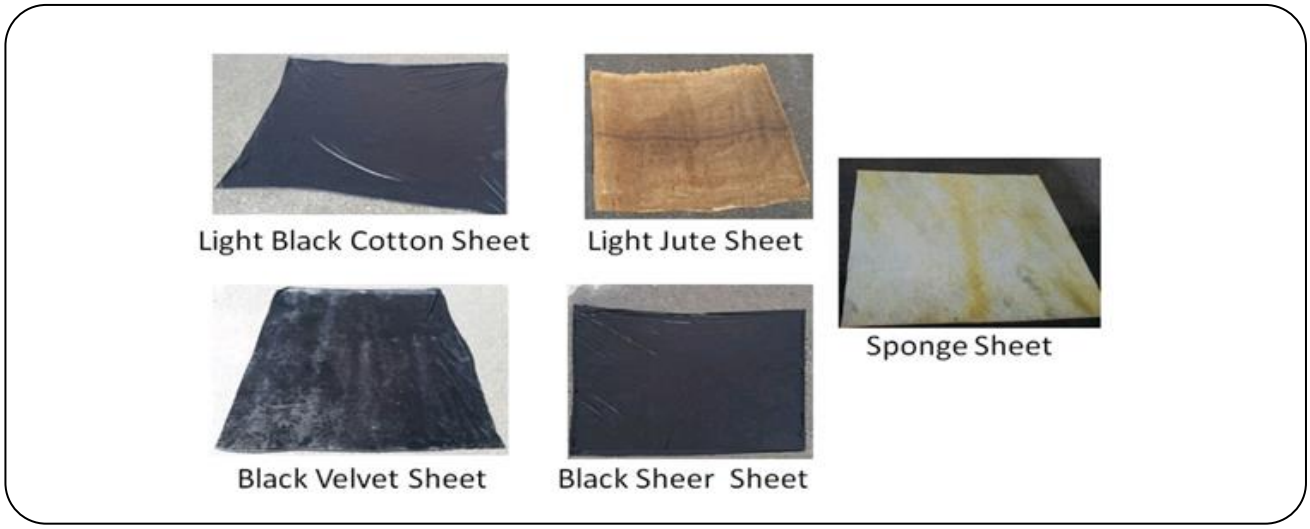

Fig.2: Various Wick Materials.

and moderate thermal conductivity. The sponge sheet has very light materials. It can absorb more amount of water due to its high interior space. Black velvet and black sheer have good thermal conductivity, But it has a moderate water absorption capacity compared with a light black cotton sheet [11].

The convection, evaporative, and radiation heat transfer from the water to the glass

$$Q_{c,w-g} = h_{c,w-g} A_b \left(T_w - T_g\right) \quad (1)$$

$$Q_{e,w-g} = h_{e,w-g} A_b \left(P_w - P_g\right) \quad (2)$$

$$Q_{r,w-g} = \sigma \varepsilon_{w-g} A_b \times \left[\left(T_w + 273.15\right)^4 - \left(T_g + 273.15\right)^4\right] \quad (3)$$

$$h_{c,w-g} = 0.884\left[\left(T_w - T_g\right) + \frac{\left(T_w + 273.15\right)\left(p_w - p_g\right)}{\left(268900 - p_w\right)}\right] \quad (4)$$

$$h_{e,w-g} = 16.27\times10^{-3} \times h_{c,w-g}\left[\frac{\left(p_w - p_g\right)}{\left(T_w - T_g\right)}\right] \quad (5)$$

$$Q_{r,w-g} = \sigma \varepsilon_{w-g} A_b\left[\left(T_w + 273.15\right)^4 - \left(T_g + 273.15\right)^4\right] \quad (6)$$

The heat loss from the basin to the surrounding is given as

$$Q_b = U A_s \left(T_w - T_{atm}\right) \quad (7)$$

The instantaneous water production of the still is given as

$$h_{fg} = \left(2503.3 - 2.398\times T\right)\times 1000 \quad (8)$$

Table 3: Production Rate of All Tests and Percentage Enhancement

S.No	Wick Materials	Light Black Cotton	Light Jute	Black Velvet	Sponge Sheet	Black Sheer Cloth
1	Solar still with wick materials production rate (lit/day)	4.4	4.0	3.8	3.5	3.6
2	Percentage enhancement	36.9%	23%	20%	11.5%	16.8%

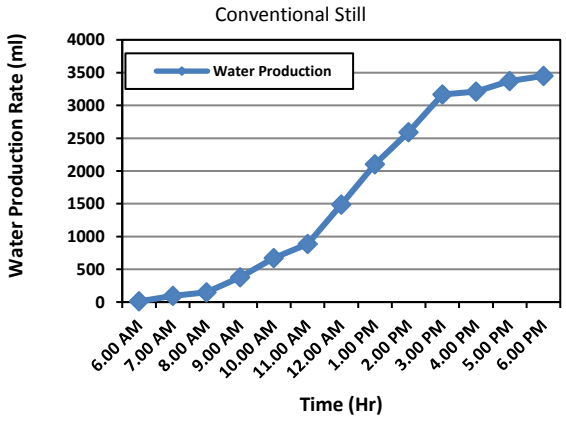

Fig.3: Performance of Conventional Still.

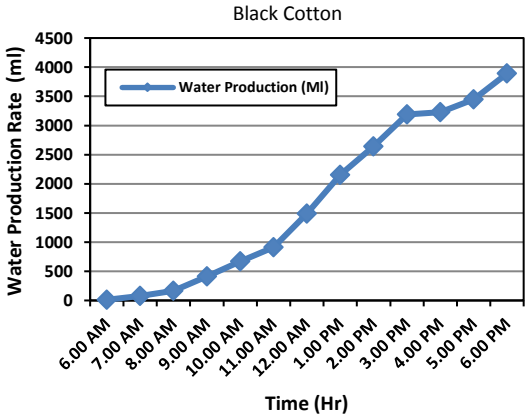

Fig. 4: Performance of Block Cotton.

The partial pressure of water vapor at the water and inner glass temperature is

$$m_e = Q_{e,w-g} / h_{fg} \quad (9)$$

$$P_w = \exp\left[25.317 - \left(5144/\left(273 + T_w\right)\right)\right] \quad (10)$$

$$P_g = \exp\left[25.317 - \left(5144/\left(273 + T_g\right)\right)\right] \quad (11)$$

RESULTS AND DISCUSSION

After the experiments successfully conduct various wick materials, we can predict the pure water production per day. Table 3 shows the production rate per day with different wick materials. Light black cotton materials can help to produce the 36.9 % enhancement. Sponge sheet material production rate was very low (20 %) enhancement.

In India, summer session sunlight effectively starts the morning at 6 AM. So this experiment was conducted between the morning at 6 AM and the evening at 6 PM, It is Totally 12 hours. The following graph shows the individual performances of different wick materials. The performance of the wick materials is compared with the conventional still.

Conventional still have produced the 3450 ml water per day shown in Fig. 3. The evaporation temperature reaches 100°C at 12.30 PM, which is used to accelerate the production rate.

Black cotton wick materials have produced a high amount of freshwater in solar still shown in Fig. 4. It reaches the maximum range of temperature 100°C within a short period due to its heat-absorbing capacity.

Figs. 5 and 6 show the water production capacity of solar still in different temperature ranges.

Fig. 7 shows the performance ranges of black velvet, which is produced 3397 ml of water per day. Compare with other wick materials, black velvet produces the minimum rate of water.

Fig. 8 mentions the solar intensity of the various wick materials. The solar intensity level was very high in black cotton, and the solar intensity level was very low in sponge materials.

Many ways are possible to produce pure water in the present scenario. But the pureness will be defined by the pH value. The refined drinking water level should be at 7. Table 4 shows the pH value of saline and pure water. The hardness value of the purified water is 37.5 ppm.

Typically, the seawater hardness level is 6630 ppm. As per WHO rules, the soft water hardness range is 0-60 ppm. This research work produces the purified water hardness range is 37.5 ppm, which is slightly hard water and can be usable for drinking.

Table 4:pH value of saline and pure water.

S.No	Test Taken	Result
1	pH value of saline water	11.2
2	pH value of purified water	6.9
3	The hardness value of purified water	37.5 ppm

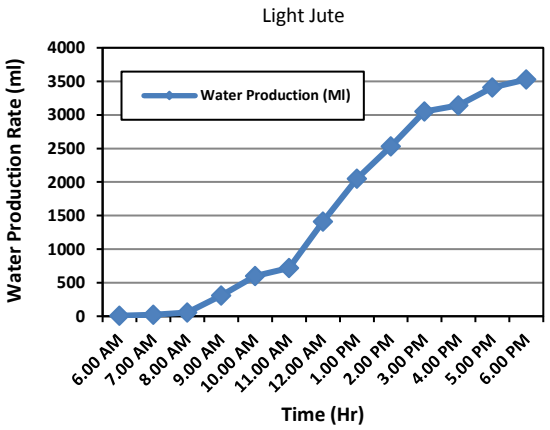

Fig.5:Performance of Light Jute.

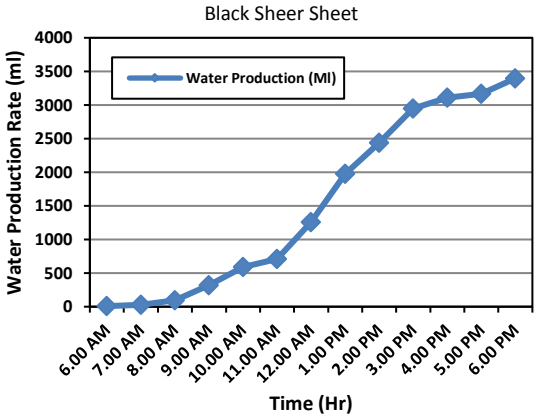

Fig.7:Performance of Black Sheer Sheet.

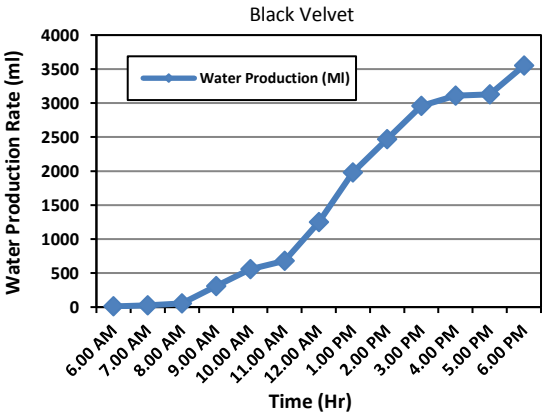

Fig.6: Performance of Black Velvet.

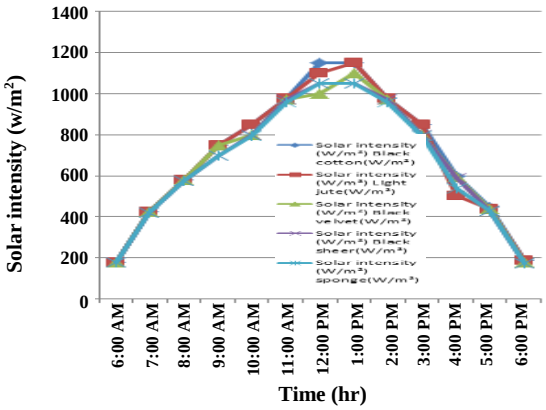

Fig.8: Solar intensity of the various wick materials.

CONCLUSIONS

The results show the design can still produce 3 to 4 L of pure water per day. The light black cotton fabric is one of the perfect wick materials to provide a high amount of fresh water from saline water 4.4 Liter. The water scarcity problem is a big threat to human life. RO plant was only able to provide the drinking water for 30% of the people in the world. Solar can still produce the drinking water in everyone's residential place with a minimum amount and maintenance. This research only shows how we should improve the solar still for effective production using perfect wick material. From our research can conclude that black cotton has good heat-absorbing capacity and a high water production rate. They still can be used not only to produce pure water; it also maintains an eco-friendly system. This still can produce 4.4 liters per day, we make this system with a minimum saline water reservoir tank, but it can modify based on the requirement of fresh water.

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REFERENCES

[1] Khare V.R., Singh A.P., Kumar H., Khatri R., Modelling and Performance Enhancement of Single Slope Solar Still Using CFD, *Energy Procedia*,**109:** 447-455 (2017).

[2] Suneesh P.U., Jayaprakash R., Kumar S., Denkenberger D., Performance Analysis of "V"-Type Solar Still with Tilt Wick and Effect of Wick Coverage, *Cogent. Eng.*,**4(1)**: (2017).

[3] Malik A., Manchanda H., Kumar M., Kumar R., Recent Advancements In Stepped Solar Still & Its Performance Parameters, *Int. J. Res. Appl. Sci. Eng. Technol.*, **5**: 2116-2122 (2017).

[4] Patil B.L., Hole J.A., A Review on different Domestic Designs of Solar Stills, *Int. J. Multidiscip. Curr. Res.*, **4**: 1131-1138 (2016).

[5] Hamid M., Babaeipour V., Imani M., Bahrami A., Dissolution and Regeneration of the Produced Nano Bacterial Cellulose of Food Industries Wastewaters by a Cost-Benefit Method, *Iran. J. Chem. Chem. Eng. (IJCCE)*, **38(3)**: 9-21. (2019).

[6] Zhang S., Yang Y., Li X., Bian W., Impact of Organic Matter on Biofilm Growth and Microbial Community, *Desalin. Water Treat.*, **66**:10-16 (2017).

[7] El-Halwagi M. M.., A shortcut Approach to the Design of Once-Through Multi-Stage Flash Desalination Systems, *Desalin. Water Treat.*, **2**: 43-56 (2017)

[8] Panchal H., Sadashivuni K., Sathyamurthy R., Mevada D., Developments and Modifications in Passive Solar Still: A Review, *Desalin. Water Treat.*, **143**: 158-164(2019).

[9] Tiwari G.N., Effect of Water Depth on Daily Yield of The Still, *Desalination*, **61(1)**: 67–75 (1987).

[10] Jahanpanah M., Sadatinejad S.J., Kasaeian A., Jahangir M.H., Sarrafha H., Experimental Investigation of The Effects of Low-Temperature Phase Change Material on Single-Slope Solar Still, *Desalination*, **499**: 114799 (2021).

[11] Murugavel K.K., Srithar K., Performance Study on Basin Type Double Slope Solar Still With Different Wick Materials and Minimum Mass of Water, *Renew. Energy*, **36(2)**: 612-620 (2011).

[12] Daraei A., Treatment of Textile Waste Water with Organoclay, *Iran. J. Chem. Chem. Eng. (IJCCE)*, **32(2)**: 67-70 (2013).

[13] Nikazar M., Jamshidi M., Reuse of Refinery Treated Wastewater in Cooling Towers, *Iran. J. Chem. Chem. Eng. (IJCCE)*, **27(4)**: 1-7 (2008).

[14] Modirshahla N., M Tabatabaii S., Removal of Emulsified and Dissolved Traces of Organic Compounds from Industrial Wastewaters Using Natural and Synthesized (NaA and NaM) Zeolites, *Iran. J. Chem. Chem. Eng. (IJCCE)*, **23(1)**: 51-56 (2004).