Journal of Advanced Mechanical Sciences (JAMS)
ISSN: 2583-3790 (Online)
"J. Adv. Mech. Sci., vol. 1, no. 4, pp. 114-124, December 2022"

A Review on Materials and Methods Used to Improve Absorption and Condensation on the Solar Desalination Process

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Article received: 21/11/2022, Article Revised: 17/12/2022, Article Accepted: 18/12/2022
Doi: 10.5281/zenodo.7454717

Abstract

The water on the earth's surface covers 71% of its area. However, due to the enormous changes in the environment brought on by human activities like population increase, pollution, industrial growth, etc., potable drinking water is no longer available. There is a need to produce drinking water using a variety of methods in order to transform brackish water into drinkable water. The solar still's low production of drinking water is its principal flaw. With the use of cutting-edge technologies including nano coatings, nano fluids, porous materials, phase-change materials, fins, flat plate collectors, sensible heat storage, etc., this study shows how solar still production may be increased. Future researchers will benefit from this review's expanded understanding as they work to implement numerous clever strategies to increase the desalination process's production rate.

Keywords: *Nano Particle, Nano Coating, Heat Storage, Phase Change Material, Fins.*

1. INTRODUCTION

Freshwater consumption is one of the primary requirements for the survival of all humans on Earth. Even while 70% of the surface of the world is covered by water, just 3% of it is freshwater. The oceans and seas hold the remaining 97%. Researchers are working to find a solution to the problem of water scarcity and to preserve the supplies of fresh drinking water all over the world [1-2]. To convert brackish water into drinkable water, desalination technique by renewable energy-driven process is the best way to overcome the fresh water scarcity with zero environmental impact, because solar energy generates zero carbon emissions. The desalination process for the conversion of salt water into safe drinking water by utilising the solar energy can be made using solar still and it is easy to handle with minimum maintenance and do not require any skilled labour [3]. In order to increase the yield of drinking water and solar still efficiency, different enhancement method have been studied including design modifications, smart coating technologies, utilization of phase change material (PCM), nano material, nano fluid, carbon based material, etc. for improved heat enhancement to enhance the solar still's evaporation and condensation. With the considerable advancements in science and nanotechnology, the solar still's productivity is increased by incorporating coating technology into the absorber [4-5].

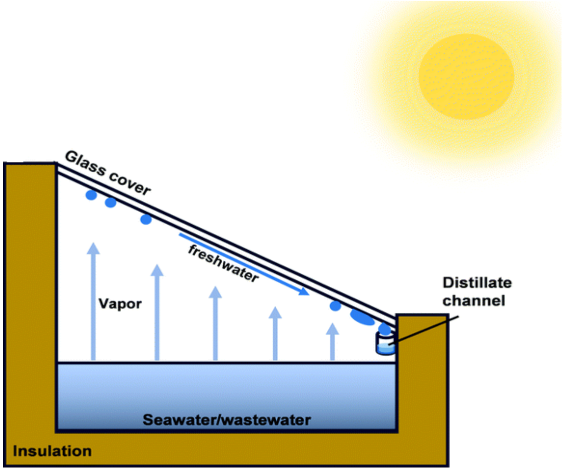

Figure 1. Solar Still

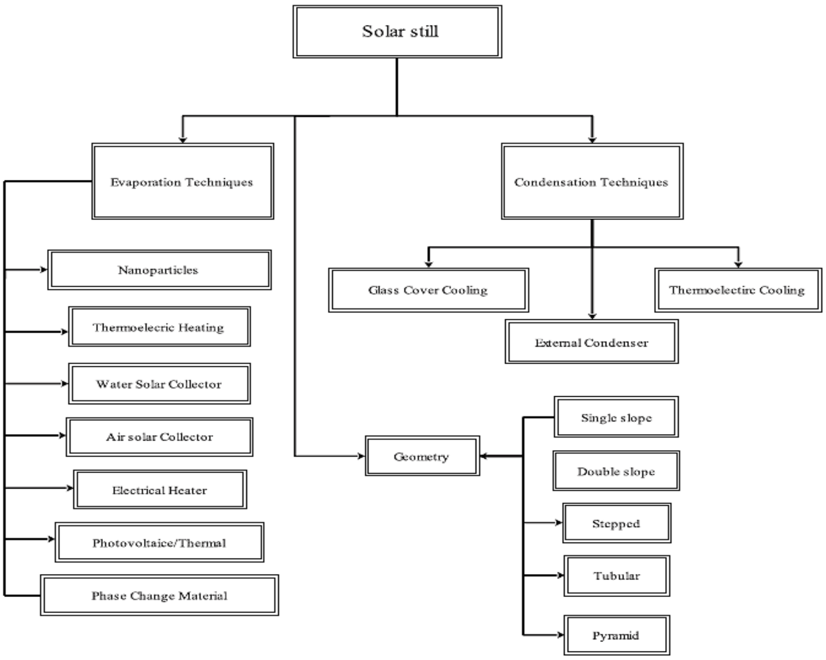

Figure 2. Classification of different evaporation and condensation techniques [6]

2. EFFECT OF COATING ON IMPROVING PRODUCTION IN SOLAR STILLS

Selimefendigil et al. [1] investigated a single-slope solar desalination system that used CuO nanoparticles in both the absorber coating and latent heat storage unit. A standard solar still, a solar still with thermal energy storage unit, a solar still with latent heat storage unit embedded with different nanoparticles, and a solar still with a TES unit integrated absorber coating with CuO nanoparticles were all employed in the trials. As a result, when compared to traditional solar still, the combined employed system boosted the productivity of the solar still by up to 26.77%.

Thakur et al. [7] studied about black paint (BP), 10 weight percent reduced graphene oxide (RGO), and a glass cover covered with nano-silicon as two design improvements to improve the evaporation and condensation of the solar still absorber coating. By coating the glass cover with RGO and nano-silicon, the solar still's output is increased. The combined impacts of the nano-silicon condenser and the RGO coated absorber significantly improved the energy efficiency of the solar still after that.

Zanganeh et al. [8] examined the solar still with the surface condensate covered with nanoparticles and with various tilt angles. The investigation was compared with drop wise and filwise condensation over the surface with and without nano-coating. The findings shown that, in comparison to film wise condensation, the solar still with nano-coated surface increased the production of fresh water in drop wise condensation.

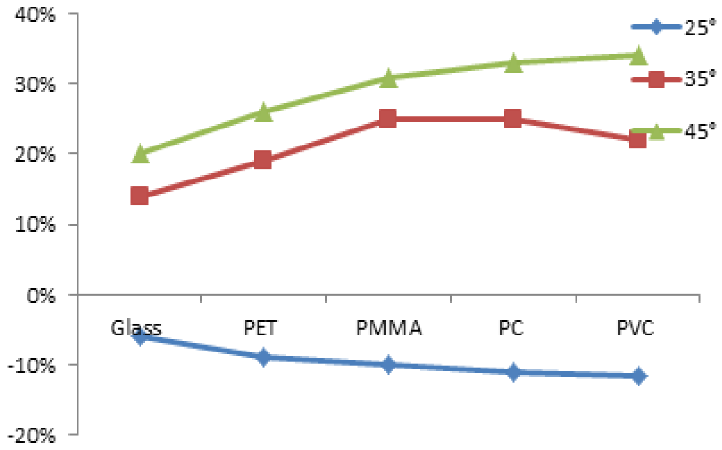

Figure 3. Percent change in the fresh water production from film to dropwise in solar still [8]

Shanmugan et al. [9] evaluated the solar still's output with the absorber plate coated with TiO_2 and Cr_2O_3 nanoparticles. Kabeel et al. [10] examined that CuO nanoparticles used with black paint in weight concentrations ranging from 10% to 40% increased the solar still's productivity. Shatar et al. [11] drop wise condensation mechanism is achieved by modifying the solar still surface with water based polysiloxane sealant at the solar still cover collection side and furthermore reduced the glass cover edge's tendency to pool, which boosts the flow rate of fresh water for drinking.

3. IMPACT OF EXTENDED SURFACES FOR THE HEAT TRANSFER ENHANCEMENT IN SOLAR STILL

Table 1 presents the results of the most current investigation on the enhancement of heat transmission using solar stills.

Table 1: Effect on Extended Surface Techniques on Solar Still

Author name	Modification Incorporated	Results
Modi et al. [12]	Incorporated hollow fins and wick-segments single-basin dual-slope solar stills	Wick-segments - 10.22% and Hollow-fins 21.64%,
Kabeel et al. [13]	Pyramidal solar stills with PCM and hollow round fins	101.5%
Panchal et al. [14]	Single slope solar stills with vertical and inclined fins	Inclined fins - 26.77% and Vertical fins - 24.19%
Sathish Kumar et al. [15]	Pin-fin still Pin-finned still that stores energy	64% and 95%

4. IMPACT OF MODIFICATION IN THE ABSORBER OF THE SOLAR STILL

Abdullah, et al. [2] modified the solar still absorber plate in convex shape with different convex heights and the various wick materials, Nano (Ag) black paint, and Nano phase transition material (paraffin wax + Ag) were also examined.

Step 1 - A conventional solar still has been tested and compared with convex heights of 5, 10, 15, and 20 cm.

Step 2 - Cotton and jute wicks have both been tried and evaluated.

Step 3 - Utilized and studied is traditional black paint as well as nano black paint (Nano-Ag).

Step 4 - Paraffin wax as PCMs consists of 2.5% Silver (Ag) nanoparticles in mass fraction (Totally= 975 g paraffin wax PCM + 25 g Ag) was tested with the convex SS and placed beneath the convex absorber with a 3 cm wideness.

The daily output of the convex solar system rises as the convex height increases until it reaches its maximum at 15 cm. After that, the output started to decline once more when the convex height exceeded 15 cm. Additionally, the jute wick outperformed the cotton wick with the convex solar still. For jute and cotton wicks, the convex solar still's thermal efficiency at 15 cm height was about 41.2% and 40.8%, respectively. Additionally, the convex surface's black paint was painted with Ag nanoparticles to boost daily productivity by 72% over a standard solar still. Additionally, utilising a thermal energy storage medium combined by 2.5 weight percent of silver nanoparticles and Nano black paint increased the convex solar still's daily productivity.

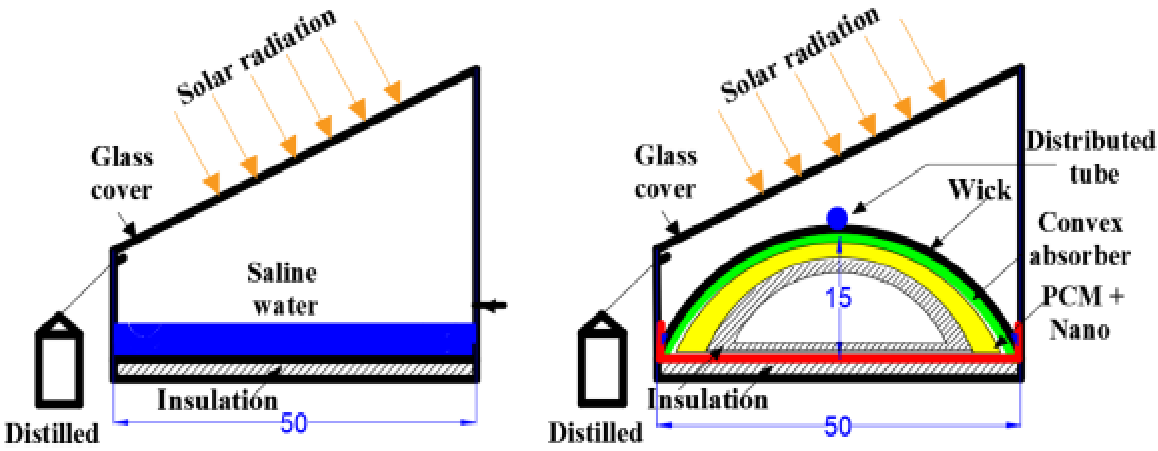

Figure 4. Schematic of a convex absorber-equipped conventional solar still and a modified solar still [2]

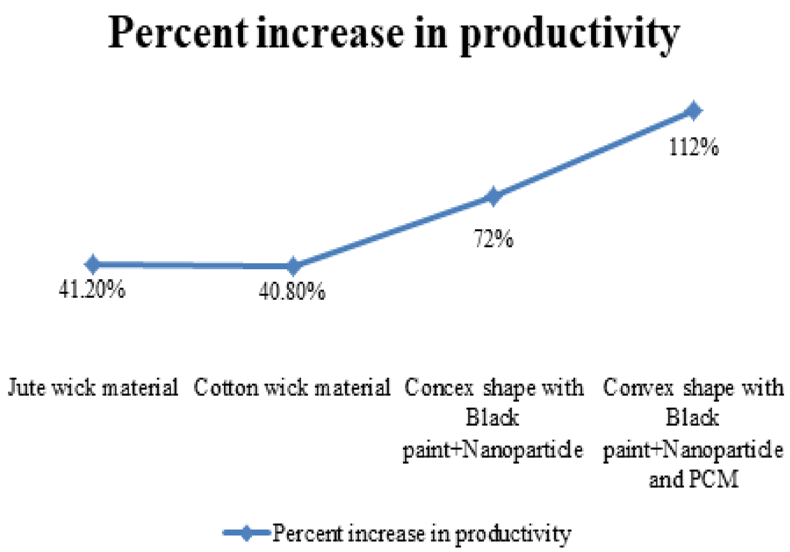

Figure 5. % of productivity improvement with improved solar stills

The modified double slope solar still (SS) with two independent modified absorber plates and an exterior copper condenser was studied by Nehar et al. [4]. (ECC). Because they raise the plate's area of the surface, rectangular and triangular channels are utilised to modify absorber plates. This improves the water's ability to absorb in the basin and hastens water evaporation. In order to boost condensation rate, ECC is made to provide more cold surface area in addition to glass surface.

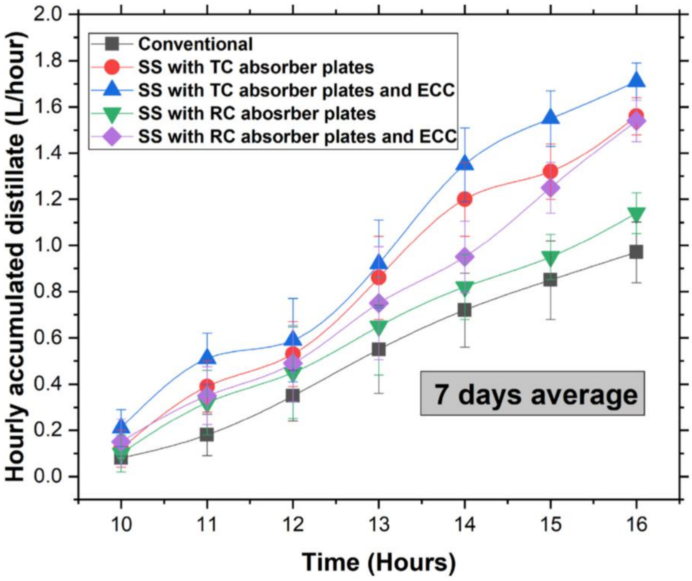

Figure 6. Cumulative distillate for all SS changes that was collected throughout the course of several trial days. [4]

By floating the porous wick material with different basin geometries, Darbari et al. [16] examined the performance of the solar still. The thermocol substance helps the porous wick absorber, made of jute fabric, float in the basin. Three modified solar stills and three various absorber geometries are considered by the MSS. the three porous wick layers that, respectively, make up the absorber surface of MSS-1, MSS-2, and MSS-3 and have teeth with flat, triangular, and semicircular shapes. The performance of these solar stills are evaluated (named by CSS) in comparison to the conventional single slop solar still, whereas the CSS device only generates this amount of freshwater in the final stages of operation. In terms, the daily yield, the MSS-3 gadget exceeds the other modified stills, producing 65% more than the CSS.

Fayaz et al., 2022 [17] employed metallic titanium particles to raise the surface temperature of the absorber plate; the solar still's performance was increased. Black paint has been mixed with Ti particles in varying proportions, and the mixture has been put to an absorber plate. The 7 wt% Ti specimen painted in black reached the greatest 100.39^{o}C temperature with 1000 W/m^2 of solar radiation in an enclosed space, which is 54.35% higher than black paint-coated aluminium plate and 11.87% higher than bare aluminium plate. Comparing the 7 wt% Ti specimen's temperature, an aluminium plate painted black, it climbed to 77.58^{o}C. Due to substantial convective heat losses, further concentration increases did not result in a rise in surface temperature.

5. IMPACT OF HEAT STORAGE SYSTEM TO SOLAR STILL

Selimefendigil et al. [1] examined the effects of using copper oxide (CuO) nanoparticles in both the absorber coating (painted with matt black colour) and the TES unit on the performance on a single-slope solar still.

Exp. 1 - SS, SS/TES, and SS/NeTES attained energy efficiency metrics are 15.96%, 17.25%, and 18.07%, respectively.

Exp. 2 - Efficiency values of 18.39% and 19.30% were obtained for SS/NeTES and SS/NeTES-BP, respectively.

- TES unit and black paint integration increased cumulative production by 26.77% over a standard solar still.
- Between 1.25 and 2.01% of average energy efficiency indicators were achieved.

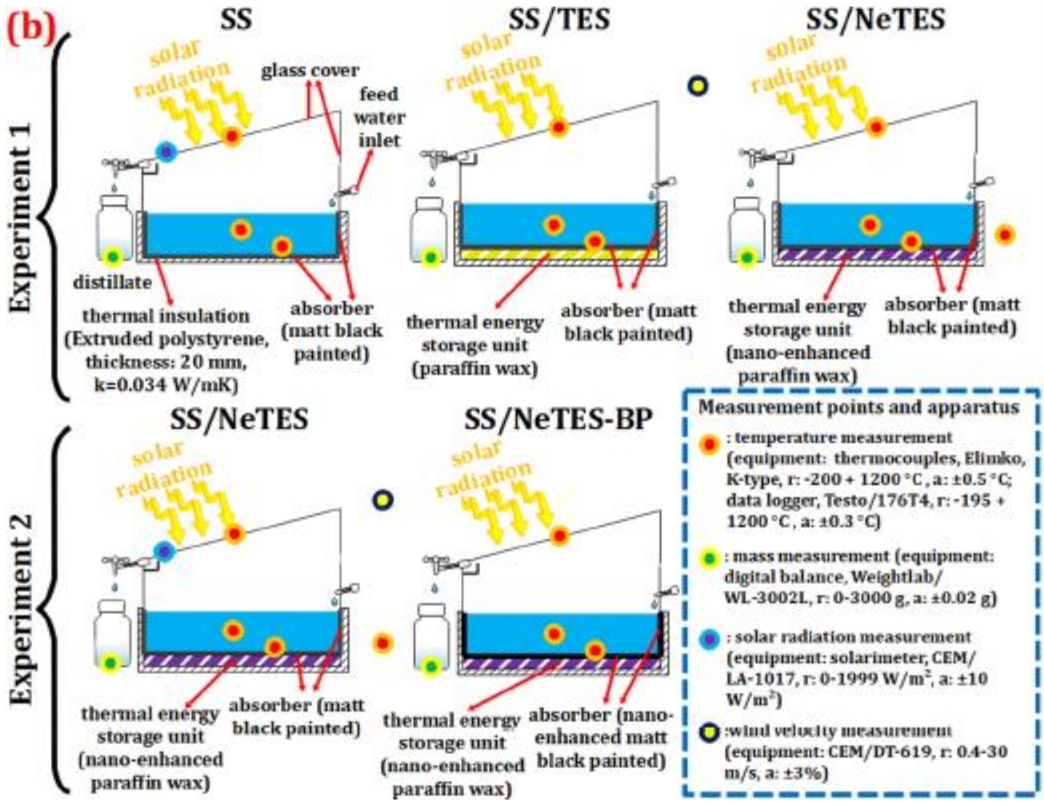

Figure 7. Solar still with several modifications - Schematic representation [1]

Table 2: Thermal Properties of Paraffin Wax

Thermal Properties	Value
Temperature of the melting	54.82 °C
Density (liquid phase)	775 kg/m^3
Latent heat of fusion	185.48 kJ/kg
Density (solid phase)	840.60 kg/m^3
Specific heat (solid phase)	2.684 kJ/kg °C
Specific heat (liquid phase)	2.74 k J/kg °C
Thermal expansion coefficient	7.84 X 10^{-3}/°C
Prandtl number	1001.23
Kinematic viscosity	8.31 X10^{-5} m^2/sec
Viscosity	6.3 X10^{-3}
Thermal conductivity	0.15 W/mK

Sathish Kumar et al. [15] investigated the Paraffin wax capsules as PCMs using the capsulation technique in the solar still's regenerative heat exchanger for quicker and more consistent charging and discharging due to its porosity. Paraffin wax has Al_2O_3 added to it to increase heat conductivity. Water flow is improved with the use of aluminium baffles, extending the hot and cold phases.

The heat dispersion rate in the heat transfer fluid is greatly increased by the use of paraffin wax capsules in heat exchangers, demonstrating the viability of using paraffin wax as a storage medium. Addition of alumina powder increases heat transfer efficiency up to 40%. Capsule structure of the paraffin wax increases the speed of charging and discharging. Efficiency is higher when the flow rate is high (25 lit/hr) than 20 lit/hr. Flake graphite nanoparticles (FGN), PCMs and film cooling were used to modify the solar still. Sharshir et al. [18]. When compared to the traditional still, the production increased by as much as 73.8%. The yield of fresh water increases when the water depth is 0.5 cm when it is 2 cm.

Sathish Kumar et al. [15] improved the efficiency of the solar till by attaching square pipes to the basin liner as fins. The square pipe fins' hollow spaces and the thin layer of paraffin wax underneath the basin liner were used as energy storage spaces. The traditional still has been tested for three different water depths, namely for 2, 3, and 4 cm. For the relevant water depths, the masses are 10 kg, 15 kg, and 20 kg, respectively. Identical water masses preserved in the modified still were used for experiments with fins alone and fins. The modified stills' efficiencies increased by 64% and 95%, respectively, with fins alone and fins combined with energy storage [19-25].

6. CONCLUSION

The least expensive method to produce water is by solar desalination process. Phase change material (PCM), black paint coating, black paint blended with nanoparticles coating, wick materials, nanoparticles with PCM, modifications to absorber, attachment of external surfaces which improves the production of fresh water and increases the efficiency of the solar still, are some of the research methods used for this process [25-30].

From this study, the following conclusions are made:

- By using wick material, the evaporation rate is enhanced and thus it is used to improve the production rate.
- Nanoparticles blended with black paint coating over the absorber plate increase the absorption rate and thus increase the solar still efficiency.
- Paraffin wax as PCM and PCM combined with nanoparticles considerably boost the maximum productivity of the solar still by raising thermal conductivity.
- Nanoparticles are used in solar stills because they increase thermal conductivity, absorption rate, daily efficiency, and freshwater yield [31-33].

Acknowledgement/Funding Acknowledgement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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