ENHANCEMENT OF SOLAR STILL EFFICIENCY USING BLACK INK

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ABSTRACT

This study investigates the effect of black ink on the performance of a solar still. A conventional solar still was modified by applying a layer of black ink on the basin surface. The black ink mixed in water enhances the absorption of solar radiation, leading to increased evaporation rates and distillate production. The performance of the black ink-based solar still was evaluated under various climatic conditions and compared with a conventional solar still. The results showed that the black ink-based solar still produced more fresh water than the conventional solar still. The increased performance is attributed to the enhanced absorption of solar radiation by the black ink into the still water. The study concludes that the use of black ink material is a simple and cost-effective method to improve the performance of solar stills. The black ink-based solar still has the potential to provide clean drinking water in remote and coastal areas where access to fresh water is limited.

Keywords: Solar Still, Desalination, Evaporation, Saline Water, Black Ink.

INTRODUCTION

In the current scenario, the availability of clean and potable water for the growing population is the biggest challenge. The increasing need of clean and drinkable water has created the necessity to look for new and sustainable water treatment technology. Solar desalination is the best alternative way to harness fresh water from saline water in arid or semi-arid regions. There are several methods of desalination through which fresh saline or brackish water is converted into drinkable water and each method has their own pros & cons. Out of these methods, solar desalination is one of the most prominent, cost effective and eco-friendly ways to obtain fresh water from saline water. In solar desalination process, solar still device with different configurations have been used to convert saline water into fresh water. Solar stills work on simple principles of evaporation by the solar radiation subsequently condensed water, thereby making it pure and suitable for drinking. Solar stills are simple, eco-friendly devices that utilize solar energy to purify water through the process of evaporation and condensation. Among the various designs of solar stills, the conventional single basin solar still is one of the most basic and widely used configurations. This type of solar still consists of a basin that holds the water to be purified, a transparent cover that allows sunlight to enter and trap heat, and a collection system for the distilled water. The working principle of a single basin solar still is based on the natural water cycle. When sunlight enters the still through the transparent cover, it heats the water in the basin, causing the water to evaporate. The water vapor rises and condenses on the underside of the transparent cover, which is typically cooler than the basin. The condensed water droplets then slide down the inclined cover and are collected in a trough or channel. One of the most significant parameters that decide the success of a solar still is its ability to absorb and utilize solar radiation efficiently. Efficiency of a solar still is controlled by the temperature gradient between the water surface and the ambient air. There are several approaches have been attempted to enhance solar absorption, including the utilization of nanofluids, phase change materials, and black coatings, etc. In this Most of technologies, are complex to use and costly, which may provide them economically infeasible for wide applications, particularly in distant and economically under-developed regions.

Despite its simplicity, the conventional single basin solar still has limitations in terms of efficiency and productivity. Various methods have been explored to enhance the performance of solar stills, including modifying the design, using different materials for the basin and cover, and adding substances to the water to increase its absorptivity of solar radiation. One such approach is adding black ink to the still water, which can potentially increase the rate of evaporation by absorbing more solar energy. While they can potentially provide advantages, conventional solar stills are plagued by poor thermal efficiency, which discourages widespread applications. Scientists and engineers have attempted different avenues to enhance solar still efficiency, including design innovation, the use of substitute materials, and the incorporation of energy-absorbing additives. The addition of black ink to the water in a solar still is a technique aimed at improving the efficiency of the distillation process. Black ink increases the absorptivity of the water for solar radiation, allowing more energy to be absorbed and converted into heat. This can lead to a higher water temperature, increased evaporation rates, and ultimately, a higher yield of distilled water. However, the optimal concentration of black ink and its long-term effects on the still's performance and water quality need to be carefully considered.

OBJECTIVES OF THE STUDY

This discussion aims to explore the design and operation of conventional single basin solar stills and the potential benefits and challenges of adding black ink to the still water. By understanding the principles behind solar stills and the effects of additives like black ink, we can develop more efficient and effective water purification systems that are suitable for various applications, particularly in regions with limited access to clean drinking water.

This study examines the application of black ink as an affordable and low-cost strategy of enhancing the efficiency of solar stills. It is predicted that the inclusion of black ink in the solar still basin will increase the solar radiation absorption, thus the evaporation rate and distillate yield. The high absorptivity of black ink renders it efficient in capturing solar energy, which aids in heat retention as well as rising water temperature.

The study investigates the effect of black ink on solar still performance based on a comparison of the yield of distillate from an ink-enhanced solar still and a normal solar still under varying climatic conditions. We investigated the effect of black ink on thermal efficiency of solar stills and temperature fluctuation patterns, evaporation rate, and overall heat retention efficiency of solar stills using black ink. We have also made the comparison of solar still distillate production using black ink and normal solar stills.

REVIEW OF LITERATURE

There are several literatures that suggests their own expertise to optimize the still performances by choosing different combinations permutations of design, insulation processes and heat absorbing materials. In the light of this, we have cited few works such as, Wiener, Khan, and Shah (2024), introduced a new approach to enhance the efficiency of solar stills through the addition of fabric-coated polyurethane rollers into the basin. From experiments, a daily average of distillate productivity was at 1.14 L/m², implying that it annually yields 416.54 L/m². More importantly, it was determined that the cost of producing the distilled water amounted to only $0.023 per litter, thereby making it both technologically viable and economic. Another work was reported by Kabeel et al., 2020 in which double basin solar still is used to enhance the productivity and performance. This work investigated the performance enhancement via material selection, glass cover angle optimization, and hybrid energy integration (e.g., photovoltaic-thermal collectors). The results are consistent with existing literature but emphasize cost-effective enhancements. The DBSS is a promising enhancement for solar desalination, with scope for further optimization in large-scale applications.

RESEARCH METHODOLOGY

This research builds on existing methods and provides a novel way to improve solar still efficiency, with future potential for optimizing material selection and system design. In this study, we have designed a single basin single slope solar still and it was installed at Maharaja Agrasen College, University of Delhi, India. The detailed methodology and discussion on the said experimental device given below:

EXPERIMENTAL SETUP

We have designed a single basin single slope solar still whose area is $0.33m^2$ to analyse the water, glass and basin temperature and corresponding yields. the solar still design parameters are listed in table1 given below:

Table1: Design parameters of single basin solar still

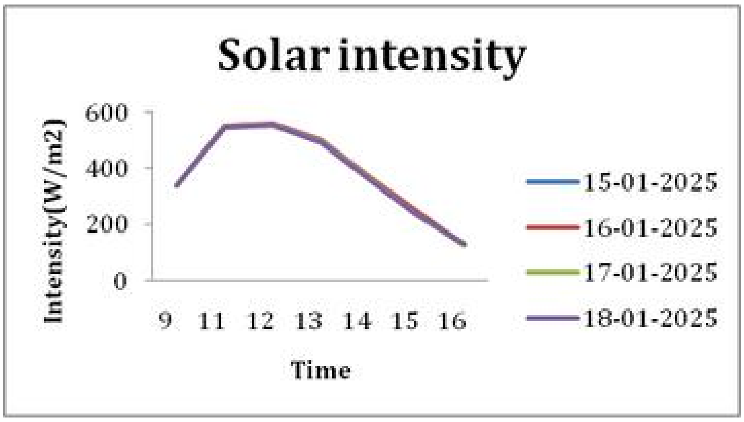
Length (L) of Metal Tray	82.5 cm

Breadth (B) of Metal Tray	40 cm
Height (H) of Wooden Box	38 cm
Small Height (h) of Wooden Box	11.5 cm
Diameter of Inlet Pipe	25 mm
Diameter of Outlet Pipe	3 cm
Angle of Inclination	30°
Black ink Concentration	0.03% per Litre

Figure 1: Schematics of solar still installed @ Maharaja Agrasen College, University of Delhi, India

Figure 3 represent the date wise time dependent intensity profile of solar still for the month of January. The intensity reading starts around 7:00AM and it was observed that it increases gradually till 12:00PM and then it decreases when sun sets around 6:00PM.

Figure 2:. Time dependent variation of solar intensity

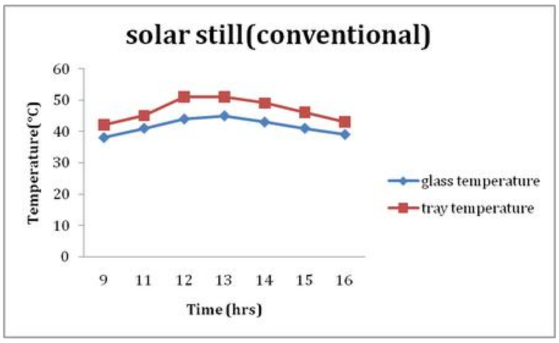


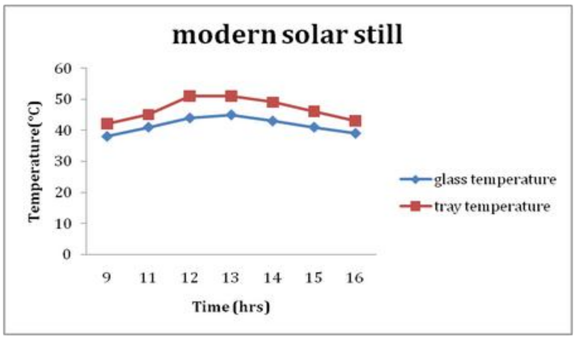
RESULTS AND DISCUSSION

In the chosen solar still, we have studied the thermal performance of our basin in two different situations. First, we have taken a conventional still whose basin having only saline water and second, black ink mixed with saline water. The experiments were conducted in the clear sunny days of month of January 2025 between 9:00 AM to 05:00PM. We have used one conventional type still and other is a modified still with same dimensions and same material and other factors. The modified still has water mixed with black ink with concentration of 0.3% per litter. The results show that solar intensity value reaches a maximum value of 560W/m^2 around 12:30 pm. and decreases gradually. It is due to the presence of abundant solar energy. This happens mutually for both the stills. As the solar intensity reaches a maximum value, the ambient temperature also reaches its maximum value during the peak hours of the day

Figure 3 represents the time dependent variation of glass and basin tray temperature of conventional and modern solar still. The still's tray temperature rises in direct proportion to the strength of the sun's rays, peaking at mid-day. For both stills, the surrounding temperature is constant. At 12.30 pm, the traditional solar still's maximum tray temperature of 51°C is reached. The surface water temperature of conventional solar still is, most of the time, higher than the basin temperature. Because solar radiation first falls on the glass and then falls on the basin water, due to its enormous heat capacity, it takes longer to heat up. The maximum surface water temperature of conventional solar still is 51°C at 12.30 pm. After 9.00 am, the glass cover's temperature is lower than the basin's and the water's surface temperatures. The average difference between tray temperature and glass temperature is 4°C. The peak temperatures of both the stills are nearly same and reach at same point but the tray temperature in black ink decreases very slowly after reaching the peak point while in conventional still it decreases gradually as shown in figure 3:

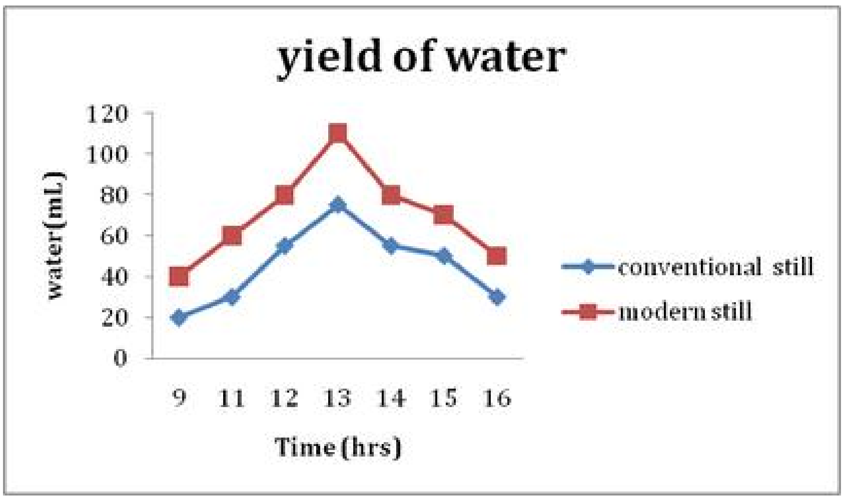
Figure 3: Time dependent variation of glass and tray temperature of (a) conventional solar still (b) modern (black Ink mixed with water) solar still





As the modern still is maintaining its temperature for long time it is also producing more yield compared to conventional solar still the yield of both the stills starts from 9:00AM and the increases during 1:00PM and then gradually decreases as the sun sets. The modern still gives up to 1.44L/m2 in comparison to conventional solar still which gives 0.94L/m2 the black ink with 0.3% concentration in water which increases the yield by 34.3% in winters of January 2025 as shown in figure 4:

Figure 4: Time dependent variation of water yield (ml) for conventional and modern (water & black Ink mixture) solar still



ERROR ANALYSIS

The analysis of errors in experimental physical measurements is known as error analysis. In order to calculate the percentage errors associated with measuring instruments. Such as Beaker and Laboratory Thermometer and presented the formula

$$Error = \frac{Accuracy\ of\ Minimum\ Instrument}{Value\ of\ Output\ Measured} \times 100$$

Table 2: Instruments For Experiment

Instrument	Accuracy	Range	Least Value Measured	Percentage Error
Lab Thermometer	+1°C	0°C–100°C	19°C	0%
Beaker	±1mL	0mL-1000mL	10 mL	0%

Thermal Efficiency

The formula used for calculating the thermal efficiency of the solar still is:

$$\eta = \frac{m \times L_{\gamma}}{A \times I \times t} \times 100$$

L_{γ} = *Thermal Effeciency of Solar Still* (%)
m = *mass of Distilled Water* (*kg*)
L_{γ} = *Latent Heat of Vaporisation of Water* (*usually* 2260 *kJ / kg*)
A = *Area of the Solar Still* (m^2)
I = *Solar Radiation Intensity* (W / m^2 *or* $kJ / m^2 - s$)
t = *Time Duration the still recieves sunlight* (*in seconds or hours*)

Using that formula the thermal efficiency of the conventional solar still during winter is 11% and the thermal efficiency of the modified solar still is 17% so by adding just black ink in concentration of 30 gram per L the thermal efficiency of the still is increased by 6%. Keeping all other parameters which include basin area, solar intensity, time duration etc. constant.

Cost Per Liter: The cost per litter calculation is

Cost per Liter Formula:

$$\text{Cost per Liter} = \frac{\text{Total Annual Cost}}{\text{Total Annual Water Output (Liters)}}$$

The cost per Litter of the above still with black ink in it is 2.67Rs/Litter

CONCLUSIONS

In this research, the effect of black ink on the efficiency of solar stills through improved solar radiation absorption was explored. The experimental outcomes revealed that the black ink-modified solar still, with 0.3% per litter of black ink, exhibited greatly enhanced water evaporation rates and distillate yield over a normal solar still. In particular, the improved still realized a 34.3% improvement in freshwater production and a 6% increase in thermal efficiency, which demonstrates the efficacy of black ink as a low-cost and readily available energy-absorbing material. The results reveal that the inclusion of black ink in solar stills is a straightforward yet effective method of enhancing desalination performance, presenting a feasible alternative for freshwater production in remote and water-limited areas. Cost analysis also provides evidence of economic viability of this process, costing ₹ 2.67 per liter, which makes it a cheaper option compared to traditional water treatment technologies. Future studies can aim to maximize ink concentration, assess long-term performance on system longevity, and investigate the use of other low-cost energy-absorbing materials. Overall, this research presents a promising direction for the improvement of solar desalination technology, toward sustainable and affordable clean water provision.

The result of this work has long-term significance in water purification activity in poor communities. Through determining the suitability of black ink as an absorber medium for solar energy, this research contributes to producing cost-effective and sustainable desalination technology. The suggested modification is non-energy-intensive and easy to retrofit in standard solar still systems, making it therefore an adoptable technology in water-deprived communities. Also, the result of this research can be applied to guide future research on the use of the same low-cost materials in optimizing solar desalination systems. Considering the increasing global interest in water purification technology powered by renewable energy, this research is consistent with global sustainability targets and seeks to enhance poor communities' access to clean drinking water.

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