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IMPROVING SOLAR STILL EFFICIENCY USING A ROTATING COTTON MESH FABRIC: A CASE STUDY IN KIRKUK CITY, IRAQ

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Abstract. *This research aims to improve the performance of solar distillation systems by incorporating a rotating cotton cloth into the distillation chamber. This contributes to enhancing the thermal efficiency of the system by improving heat distribution and accelerating the evaporation process. Experimental results showed that the highest water production was achieved at a rotation speed of 0.2 rpm, reaching 1840 ml/day, followed by a rotation speed of 0.5 rpm (1755 ml/day), and a rotation speed of 1 rpm (1670 ml/day). The study also demonstrated that environmental factors such as solar radiation intensity, temperature, humidity, and wind speed significantly affect system efficiency. The research concludes that the rotating cloth technology represents a promising solution for improving the efficiency of solar desalination systems, especially in areas with high solar radiation such as Kirkuk city, Iraq.*

Key words: *conventional solar still, thermodynamic analysis, solar radiation intensity, Energy economic analysis, optimization techniques.*

ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ СОНЯЧНОГО ДИСТИЛЯТОРА ЗА ДОПОМОГОЮ ОБЕРТОВОЇ БАВОВНЯНОЇ СІТЧАСТОЇ ТКАНИНИ: ПРИКЛАД МІСТА КІРКУК, ІРАК

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Анотація. *Метою цього дослідження є підвищення ефективності систем сонячної дистиляції шляхом використання обертової бавовняної тканини в камері дистиляції. Це сприяє підвищенню теплової ефективності системи завдяки кращому розподілу тепла та прискоренню процесу випаровування. Виходячи з результатів проведених експериментальних досліджень, найбільший обсяг виробництва води досягається при швидкості обертання 0,2 об/хв, що становить 1840 мл/добу. При швидкості 0,5 об/хв продуктивність становить 1755 мл/добу, тоді як при швидкості 1 об/хв — 1670 мл/добу. В ході дослідження також продемонстровано, що такі фактори навколишнього середовища, як інтенсивність сонячного випромінювання, температура, вологість та* *швидкість вітру, суттєво впливають на ефективність системи. Отримані результати свідчать про те, що технологія застосування обертової тканини є перспективним рішенням, що дозволяє підвищити ефективність роботи системи сонячного опріснення води, особливо в регіонах з високою інтенсивністю сонячного випромінювання, таких як місто Кіркук (Ірак).*

Ключові слова: *традиційний сонячний дистилятор; термодинамічний аналіз; інтенсивність сонячного випромінювання; енергетично-економічний аналіз; методи оптимізації.*

Abbreviation	Items	Unit
CSS	Conventional solar still	-
SSSMC	Suggested solar still mesh cotton	-
S	Standard deviation	-
m_{ew}	The yearly yield from the solar still system	kg/m^2.year
P	Solar still system's annual production	L/m^2. year
$I_{(t)}$	Solar radiation intensity	W/m^2
CRF	Factor for the sinking fund	-
SFF	The factor for the sinking fund	-
FAC	The first annual (yearly) cost	$
CS	The manufacturing and installation capital cost	$
ASV	The value of annual salvation	$
AC	Annual (yearly) cost	$
AMC	The cost of annual maintenance	$
YCPL	The yearly cost per liter	$
η	Thermal efficiency	-
h_{fg}	The average latent heat	J/kg

INTRODUCTION

The availability of high-quality drinking water is a crucial factor in promoting the social and economic development of any country. Saltwater constitutes approximately 97% of the total water available on the Earth's surface [1]. Saltwater cannot be used for industrial, agricultural, or drinking purposes. Hence, the urgent need to convert saltwater into pure, usable water. To achieve this, desalination is the ideal option, as it involves heating, evaporation, and condensation processes. Solar stills are among the most prominent devices available for achieving effective and efficient desalination [2]. Having clean drinking water is essential for human health. Solar distillation is an economical and effective solution for desalination using solar energy. It harnesses the sun's radiation to heat and evaporate salt water, then condenses the steam to produce fresh water. This technology represents a sustainable way to produce clean drinking water in areas suffering from water scarcity [3]. Solar distillation is a vital application in freshwater production, particularly in rural and remote areas. This system relies on simple technologies to convert salty or polluted water into fresh water, without the need for fuel or non-renewable energy sources [4]. Solar distillation relies on a principle similar to that of natural rainfall. Solar radiation heats the water inside the distillation tanks, causing it to evaporate and separate impurities, salts, and other substances. When the temperature of the water vapor drops, it returns to its liquid state and is collected as pure water[5]. There are many factors that influence the production of freshwater using solar stills, including operating and design conditions, as well as the surrounding environment. Among these factors, some environmental conditions, such as humidity, solar radiation intensity, and ambient air temperature, are difficult to control and directly impact the efficiency of these devices [6][7]. Several researchers have studied the impact of environmental conditions on the efficiency and performance of solar stills. A recent study demonstrated that environmental factors, such as solar radiation intensity and ambient air temperature, play a pivotal role in improving or reducing freshwater production, underscoring the importance of these variables in improving system efficiency [8],[9]. Another study found that the distillation rate increases with increasing solar radiation intensity and ambient temperature. However, the study indicated that increasing wind speed leads to a decrease in the efficiency of the condensation and evaporation processes, negatively impacting the performance of the solar still [8]. In this context, researchers have found that adding certain materials, such as black cloth, to a distillation system can enhance its efficiency. Studies by Gad et al. [10] have shown that using black cloth as a heat-absorbing material enhances evaporation efficiency and increases freshwater production, making this technology a promising solution for improving the performance of solar stills. Essa et al. [11] study showed that the use of black cloth increases heat absorption in solar stills, enhances evaporation efficiency, and increases freshwater production. Mohamed et al. [12] found that black fabric contributes to accelerating the evaporation process and increasing productivity due to its solar radiation absorption property. After studying the effect of black cloth on still performance, additional experiments were conducted to improve productivity and increase system efficiency. Among these experiments was the use of rotating cloth. The researchers Abdullah et al. [13] conducted a study on adding a rotating black cloth belt to a solar still, which increased water productivity by up to 300% compared to conventional stills. Also, Haddad et al. [14] study demonstrated that using a vertical rotating cloth in a solar still improved productivity by 51.1% in winter and 14.72% in summer. In addition, Essa et al. [15] investigated the effect of adding rotating fabric systems inside solar stills, and the results showed that this modification significantly increased water productivity by up to 315% compared to conventional stills. These studies have demonstrated the importance of using rotating fabric as an effective tool for improving the performance and efficiency of solar desalination systems. Although the rotating cloth is effective in improving the productivity of solar stills, studies have not addressed the effect of rotating mesh cotton inside the solar still. This study, being conducted in the city of Kirkuk, Iraq, aims to fill this gap by examining the effect of rotating mesh cotton through a full cycle of two minutes on the performance of the solar still.

Explaining the concept of improvement

In this research, a solar distillation system was improved by incorporating a moving black fabric within the distillation chamber. The fabric rotates one full cycle every two minutes, contributing to the improved thermal efficiency of the system. This moving fabric increases the system's heat absorption, enhancing evaporation, as proposed by Qader et al. [16][17]. These modifications are expected to lead to a significant increase in water production, especially in areas with high solar radiation, such as Kirkuk city in Iraq.

Experimental setup

Fig. 1 illustrates the design of the solar still used in this study, which includes two monoclinic solar stills in Kirkuk, Iraq (latitude: 35.4686, longitude: 44.38933). To optimize solar radiation absorption, the solar panels were oriented southward, with an area of 1 m^2 per panel. Considering Kirkuk's geographical location, the glass covers of the stills were tilted at a 35˚, in line with the local latitude. 1 cm thick Russian plywood was used to construct the main structure of the still.

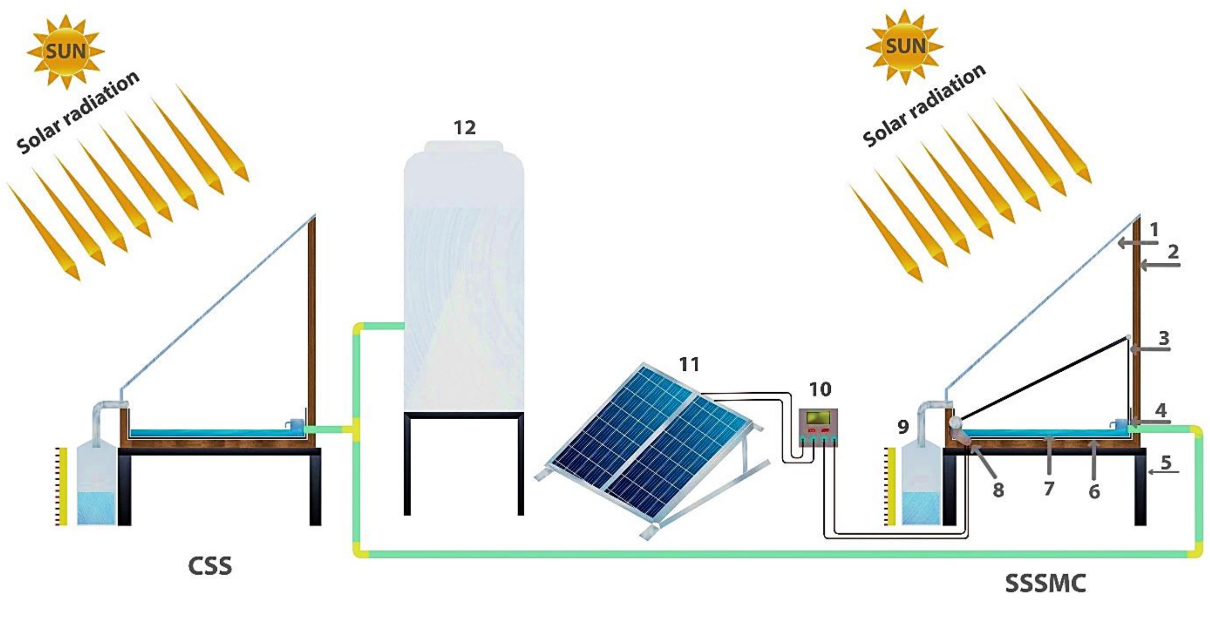

Fig. 1. Schematic diagram of the suggested solar still mesh cotton (SSSMC) and conventional solar still (CSS). 1) Transparent Plexiglas cover; 2) MDF; 3) Cotton cloth; 4) Water basin; 5) Metal legs; 6) The water basin; 7) The basin water; 8) Motor 12 volt; 9) Graduated cylinder; 10) Control unit; 11) Solar panel; 12) Feed water tank

To ensure system efficiency and reduce energy waste, a silicone rubber strip was installed around the edges of the clamps to prevent vapor leakage. Furthermore, the wooden structure was painted matte black, including the interior surfaces of the basins, to further enhance heat absorption. A black mesh fabric (1 × 0.5 m) was installed within the system to enhance solar radiation absorption and accelerate the evaporation process. A 12 V motor was also installed to enable the black fabric to rotate one full cycle in 2 min. This continuous movement of the fabric helps distribute heat evenly across the system surface, preventing heat buildup at specific points, accelerating evaporation, and reducing heat loss. To reduce heat loss, glass wool insulation was used around the edges of the system, which contributed to reducing thermal leakage. A channel was designed within the distiller to improve water flow, while maintaining the water level in the basin at approximately 1 cm, ensuring optimal evaporation conditions. The experimental trials were conducted from August 1 to 3, 2025, in the extremely hot environment of Kirkuk. Figs. 2 and 3 illustrate the complete experimental setup, including the location of the solar panels, the position of the black mesh fabric, and the insulation properties, providing a realistic visualization of the system used in this study.

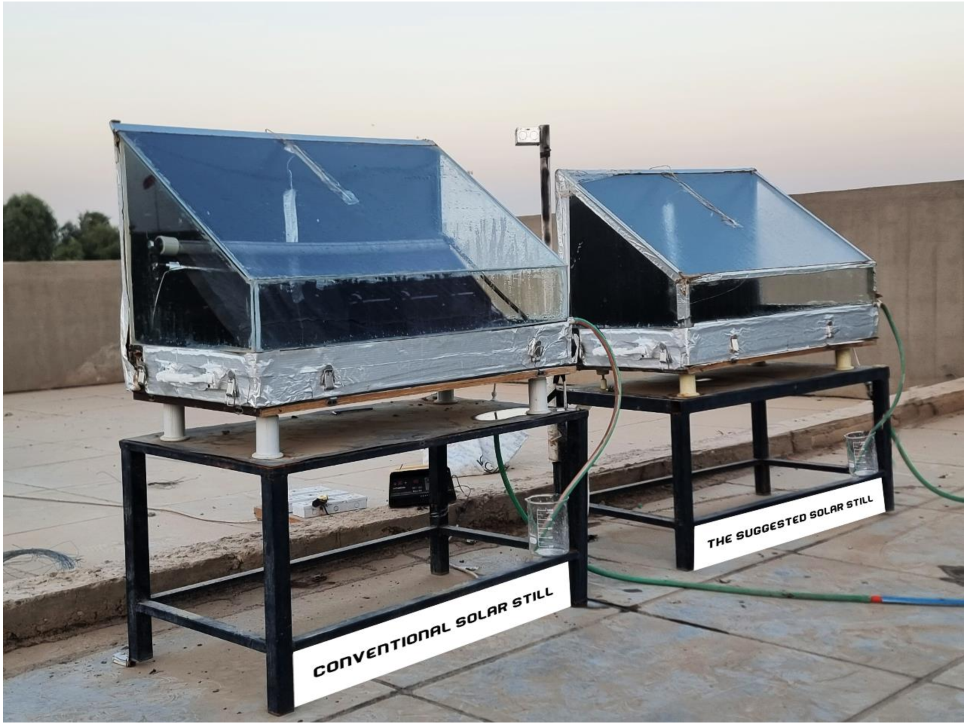

Fig. 2. A photograph of the suggested solar distiller and the conventional solar distiller

Modified model

The proposed solar distillation system uses a cotton mesh fabric that rotates one full rotation in two minutes. This rotation occurs in three stages, with the fabric rotating at speeds of 0.2, 0.5, and finally, 1 rpm. This rotation significantly improves the thermal efficiency of the system. It evenly distributes heat across the surface of the cotton fabric, improving the absorption of solar radiation and its conversion to heat, thereby raising the temperature of the water inside the tank and increasing the evaporation rate. Furthermore, the fabric rotation helps improve the interaction between the fabric and water, thereby enhancing the evaporation process. It also reduces the effect of unbalanced heat buildup within the system, improving heat retention and reducing heat losses to the surrounding air through conduction. Consequently, fabric rotation increases the overall productivity of the system, improving the overall efficiency of solar distillation.

Fig. 3. Cotton mesh connected to a 12V motor inside the improved solar still

Method of experimentation

The experimental setup of the solar stills for both systems was designed to evaluate their efficiency. To optimize solar light absorption, the stills were oriented southward, and silicone rubber was used to seal the glass lids to ensure vapor resistance. A constant water level was maintained in the tanks, adjusted to approximately 1 cm using a regulated piping system. During the experiment, measurements were taken hourly from 8:00 to 18:00. A (K) type data logger was used to measure temperatures at multiple locations, while wind speed was measured hourly using an anemometer. Ambient air temperature was also measured using a mercury thermometer. Hourly solar radiation intensity was measured using a TM heliometer, as shown in Fig. 4.

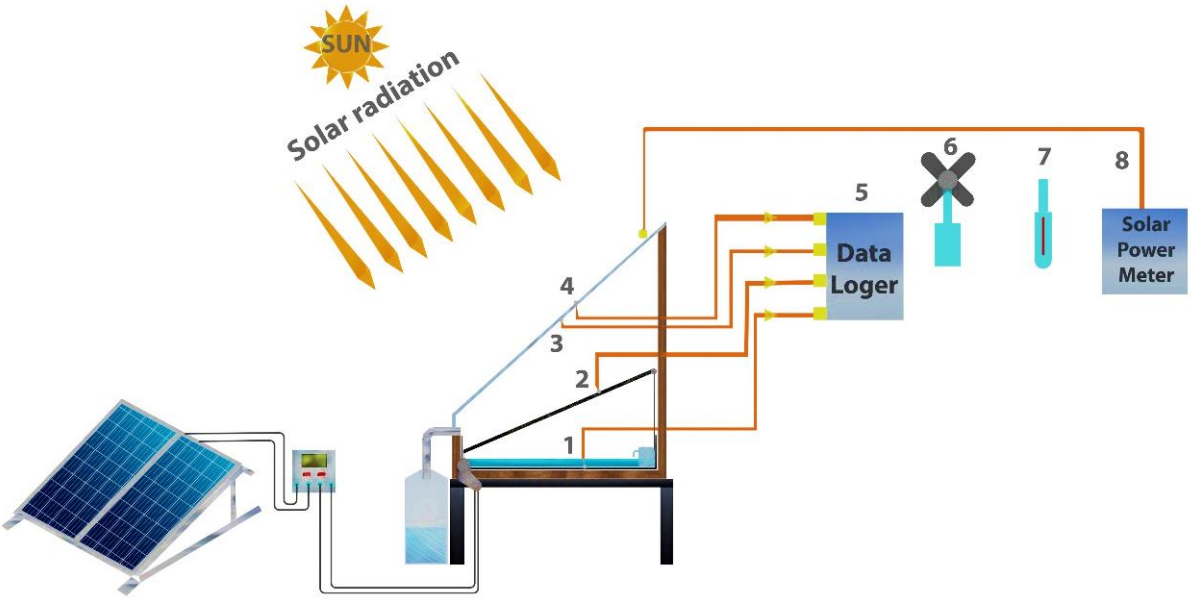

Fig. 4. A schematic diagram of the measuring devices

Uncertainty analysis

Uncertainty analysis is an essential step to ensure the reliability of experimental results. It is necessary to verify the accuracy of each measuring instrument used in the study before proceeding with the uncertainty analysis [18]. Table 1 shows the accuracy values and measurement ranges associated with each measuring instrument. The uncertainty analysis was then performed using the equations shown below.

$$\text{Standarddeviation}(S) = \sqrt{\frac{\sum_{i=1}^{n}(xi - x\prime)^2}{n-1}} \quad (1)$$

$$\text{Standarderror}(S.E) = \frac{S}{\sqrt{n}} \quad (2)$$

$$\text{Error\%} = \frac{S.E}{X\prime} \times 100 \quad (3)$$

$$X\prime = \frac{\sum_{i=1}^{n} Xi}{n} \quad (4)$$

The measured value (Xi), the average of the measured values (X′), and the number of measurements (n) are the basic inputs to the formula.

Table 1. Accuracy, measurement error and range for each device

Equipment	Accuracy	Measuring range	Error range%	Unit
Anemometer	85%	0-25	1.5	m/s
Data logger	98%	−200-1370	1.9	^{0}C
TM solar power meter	98%	0-2000	1.9	W/m^2
Thermocouple	98%	−100-200	1.9	^{0}C

RESULTS AND DISCUSSIONS

Productivity rate at a speed of 1 rpm

At a fabric rotation speed of 1 rpm, the experiment demonstrated a significant improvement in the efficiency of the solar still compared to the CSS system. In this context, the impact of several environmental factors on productivity was analyzed, as shown in Fig. 5. The relationship between solar radiation intensity and temperature during the experiment period is shown. At 13:00, solar radiation peaked at 1010 W/m², while the temperature recorded 48.6°C. The positive relationship between these two factors demonstrates the effect of the heat generated by solar radiation on the evaporation process inside the solar still, which contributes to accelerating the process and increasing productivity.

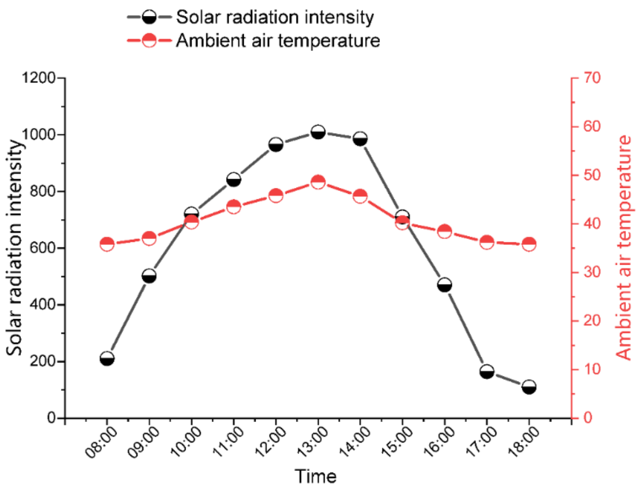

Fig. 5. Relationship Between Solar Radiation Intensity and Temperature at 1 rpm

Fig. 6 shows an analysis of the relationship between relative humidity and wind speed. The data indicates that humidity was high in the morning hours and then gradually decreased throughout the day, which contributed to improving the evaporation process. Wind speed was low most of the time, which reduced surface cooling and thus supported the evaporation process. These environmental factors significantly contributed to enhancing the efficiency of the improved system.

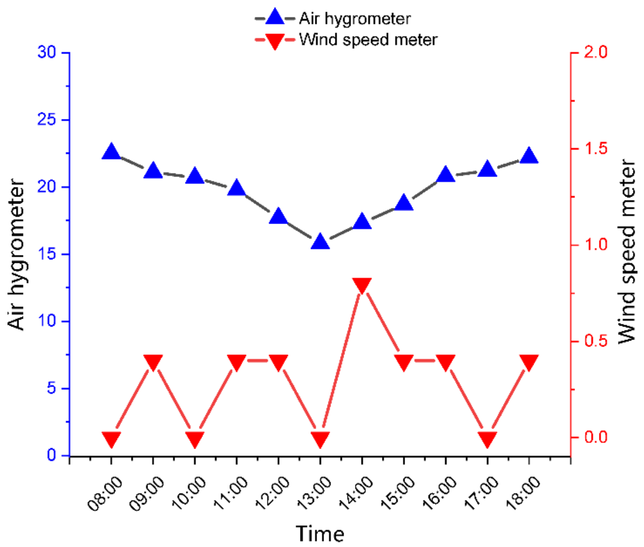

Fig. 6. Relationship Between Relative Humidity and Wind Speed at 1 rpm

Fig. 7 shows the relationship between the productivity of the improved still and that of the conventional still. It clearly indicates that the improved design achieved significantly higher output, reaching 1670 ml/day compared to 1000 ml/day for the conventional system. This enhancement in productivity can be attributed to improved heat distribution within the still, facilitated by the movement of the fabric. The fabric motion reduced heat loss and promoted faster evaporation, thereby increasing overall distillate production.

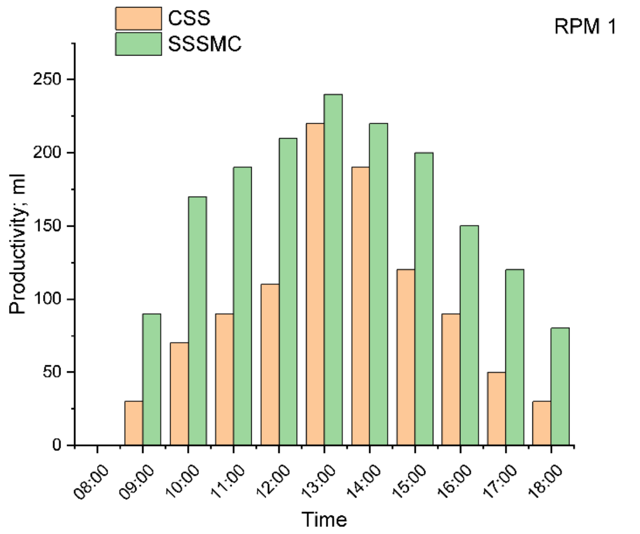

Fig. 7. Productivity comparison of an improved solar still versus a conventional model at a rotation speed of 1 rpm

It can be concluded that the combined effect of intense solar radiation and high temperatures, along with low humidity and limited wind speed, significantly improved the still's throughput at 1 rpm, making the improved still more efficient at water production compared to the conventional system.

Productivity rate at a speed of 0.5 rpm

At a cloth rotation speed of 0.5 rpm, the experiment demonstrated improved still productivity compared to the CSS system. The effect of several environmental factors on performance was analyzed. Fig. 8 shows the relationship between solar radiation intensity and temperature. The solar radiation intensity was 1002 W/m² at 13:00, a level sufficient to enhance evaporation. At the same time, the temperature reached 49°C, which helped accelerate the evaporation process and improve productivity. The relationship between these factors indicates that the heat generated by solar radiation played a significant role in increasing the evaporation rate inside the still.

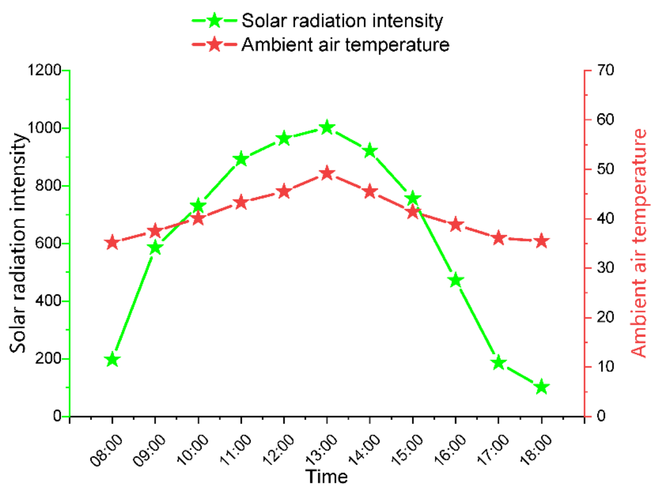

Fig. 8. Relationship between solar radiation intensity and temperature at 0.5 rpm

Fig. 9 shows the relationship between relative humidity and wind speed. In this case, the relative humidity was lower than at other speeds, which helped effectively improve evaporation. Furthermore, the wind speed was low most of the time, reducing the cooling effect on the surface and thus helping raise the temperature inside the still and increase evaporation.

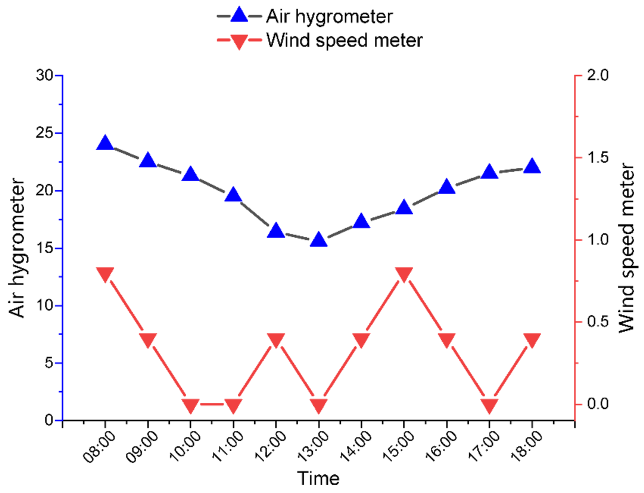

Fig. 9. Relationship between relative humidity and wind speed at (0.5 rpm)

Fig. 10 shows the relationship between productivity in the improved still and productivity in the conventional still. The data show that the productivity of the improved still was 1755 ml/day, a significant improvement over the 955 ml/day in the conventional system. This productivity increase is due to improved fabric movement, which contributes to more even heat distribution within the system.

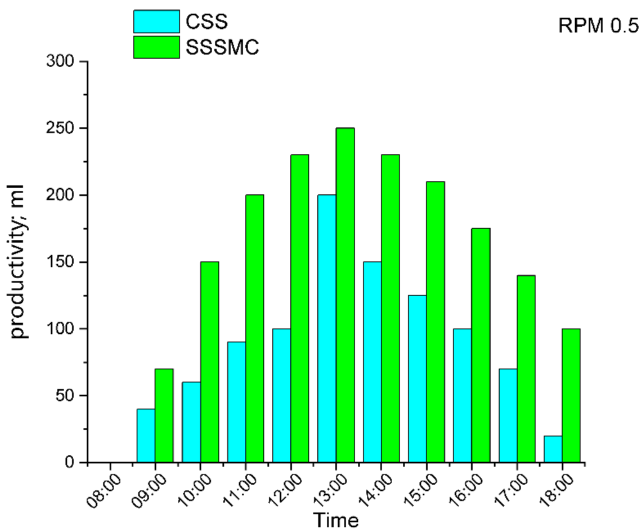

Fig. 10. Productivity of improved solar still vs. conventional solar still at 0.5 rpm

Productivity rate at a speed of 0.2 rpm

At a cloth rotation speed of 0.2 rpm, the experiment showed higher productivity compared to other speeds (0.5-1 rpm), with a total production of 1840 ml/day, outperforming both the 0.5 rpm speed, which produced 1755 ml/day, and the 1 rpm speed, which produced 1670 ml/day. The effect of several environmental factors on the distiller's performance was analyzed. The relationship between solar radiation intensity and temperature is shown in Fig. 11. The solar radiation intensity reached 1065 W/m² at 13:00, which helps accelerate evaporation and increase productivity. The relationship between these factors indicates that solar radiation had a significant effect on raising the water temperature and increasing the evaporation rate inside the distiller.

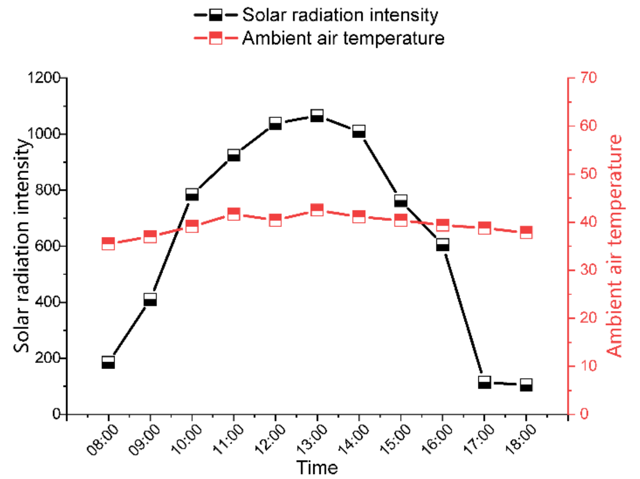

Fig. 11. Relationship between solar radiation intensity and temperature at 0.2 rpm

Fig. 12 shows the relationship between relative humidity and wind speed. In this case, the relative humidity was low, which helped improve evaporation effectively, while the wind speed was at low levels most of the time, which helped reduce surface cooling and increase evaporation. These environmental factors played a significant role in increasing the thermal efficiency of the solar still.

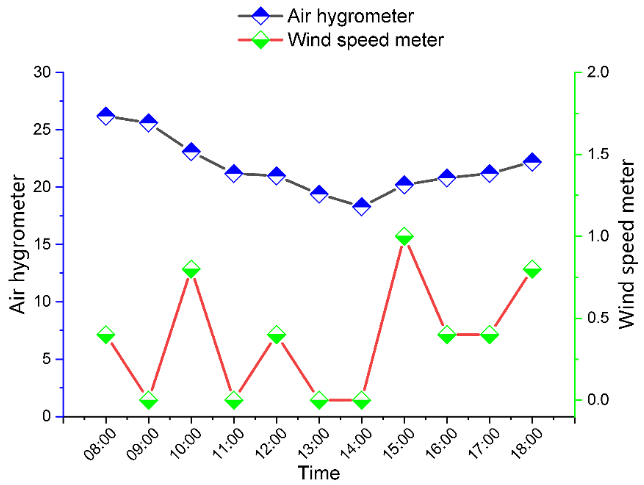

Fig. 12. Relationship between relative humidity and wind speed at 0.2 rpm

Fig. 13 shows the relationship between the productivity of the improved still and the productivity of the conventional still. At 0.2 rpm, productivity was the highest among the three speeds, reaching 1840 ml/day, higher than the productivity achieved at 0.5 rpm (1755 ml/day) and 1 rpm (1670 ml/day). This significant improvement in productivity is due to the effect of slow fabric movement, which increased heat absorption and reduced heat loss in the system, resulting in continuous evaporation throughout the day.

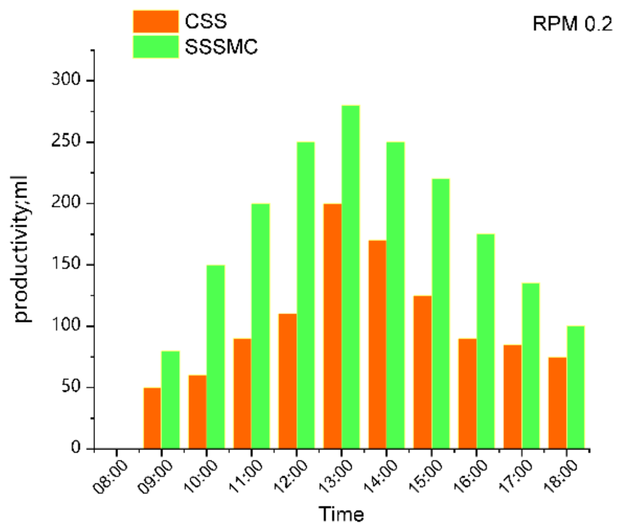

Fig. 13. Productivity of the improved solar still versus a conventional solar still at 0.2 rpm

The effect of moving cloth rotation speed on heat distribution and evaporation efficiency in solar still systems

Analyzing the temperatures of the moving fabric at different rotation speeds as shown in Fig. 14 for the following rpms: (0.2, 0.5, and 1), a clear effect on heat distribution is evident. At 0.2 rpm, the temperature starts at 45.7°C and reaches 84.1°C halfway through the cycle, then gradually decreases to 54.9°C, reflecting the increased thermal energy and accelerated evaporation due to slower movement. At 0.5 rpm, the temperature starts at 41.4°C and reaches 77.7°C halfway through the cycle, then decreases to 50.1°C, indicating accelerated evaporation but with faster heat loss at the end. At 1 rpm, the temperature starts at 41.4°C and reaches 70.3°C halfway through the cycle, then decreases to 53.2°C. The rapid temperature decrease reduces evaporation efficiency compared to slower speeds.

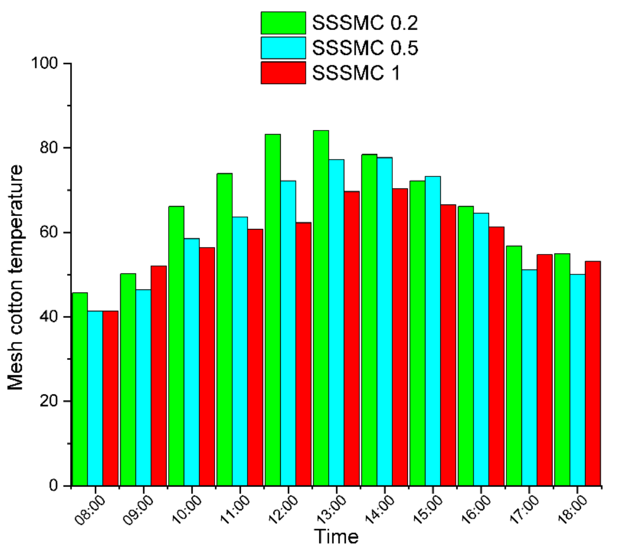

Fig. 14. Temperature distribution at different fabric rotation speeds (0.2, 0.5, 1 rpm)

The productivity of SSSMC at speeds of 0.2, 0.5, and 1 rpm

Comparing the output of distillers at different fabric rotation speeds (0.2, 0.5, and 1 rpm), significant results are evident in the effect of fabric movement on productivity, as shown in Fig. 15. At 0.2 rpm, the highest output of 1840 ml/day was recorded. This is due to the even heat distribution that improves evaporation and increases solar energy absorption, boosting productivity. At 0.5 rpm, the output was 1755 ml/day, showing an improvement over the conventional system. However, the heat is distributed unevenly, resulting in a slight decrease in productivity compared to the 0.2 rpm system. At 1 rpm, the output was the lowest of the three speeds, at 1670 ml/day. Although the fabric absorbs more solar energy, the rapid movement results in heat being lost before it can be utilized for evaporation, reducing the system's efficiency.

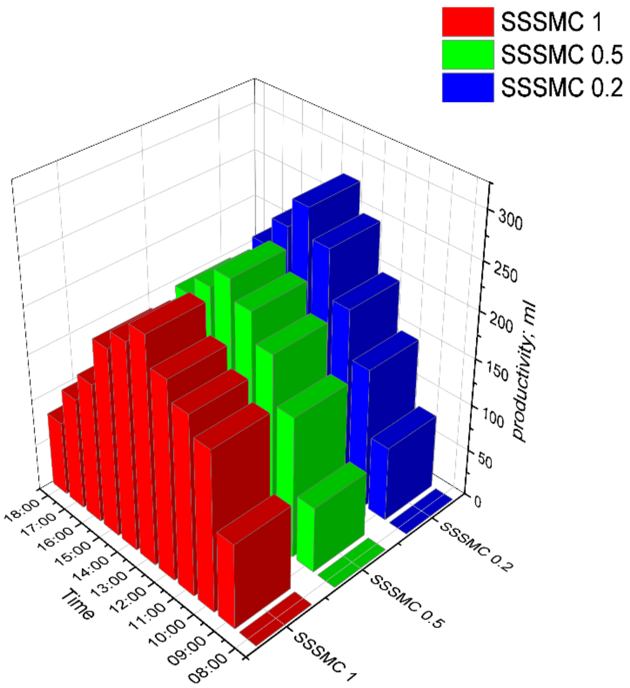

Fig. 15. Productivity of cotton mesh fabric at different rotation speeds (0.2, 0.5, 1 rpm)

The performance analysis of active and passive solar distillation systems is primarily based on evaluating their thermal efficiency. According to the referenced study, a distinctive assessment method is employed to determine the thermal efficiency of passive solar distillers [19].

$$\eta_{ss-th} = \frac{m_{ew} * h_{fg}}{i_{(t)s} \times A_s} \tag{5}$$

h_{fg} is the average latent heat in (J/kg).

$$h_{fg} = 10^3[2501.9 - 2.40706 \times T_w + 1.192217 \times 10^{-3} \times T_{bw}^2 - 1.5863 \times 10^{-5} \times T_w^3] \tag{6}$$

$$m_{ew} = \frac{h_{ev}(T_w - T_g)A_s}{h_{fg}} \quad (7)$$

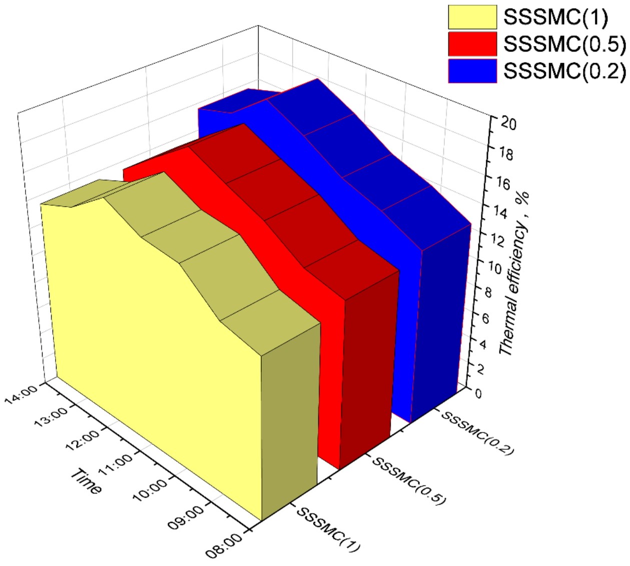

Fig. 16. Hourly efficiency of the improved still at speeds of 1, 0.5, and 0.2 rpm

Analysis of production cost

Besides the primary goal of increasing daily desalinated water production using solar energy, it is also important to consider production costs. In this context, Fatah et al. [20] conducted an economic analysis to identify the main factors affecting the annual cost of producing one liter of desalinated water. These factors included: capital cost (CS), depreciation fund factor (SFF), first annual cost (FAC), annual scrap value (ASV), annual cost (AC), annual maintenance cost (AMC), and the annual cost per liter of production (YCPL). These factors were calculated according to established economic methods. The details are in Tables 2–5, respectively.

$$\mathrm{CRF} = \frac{i(1+i)^n}{[i(1+i)^n - 1]} \quad (8)$$

$$\mathrm{SFF} = \frac{i}{[i(1+i)^n - 1]} \quad (9)$$

$$\mathrm{FAC} = \mathrm{SC} \times \mathrm{CRF} \quad (10)$$

According to Shehata et al. [21], the salvage value of desalination using solar energy is equal to 0.2 of the capital cost of manufacturing and installation. Based on this, ASV is calculated as follows:

$$\mathrm{ASV} = \mathrm{S} \times \mathrm{SFF} \quad (11)$$

The AMC constitutes fifteen percent of the initial annual cost. According to the study by Kapil et al. [22], the annual cost was determined according to the following equation:

$$\mathrm{AC} = \mathrm{FAC} + \mathrm{AMC} - \mathrm{ASV} \quad (12)$$

Finally, YCPL is as follows:

$$\mathrm{YCPL} = \frac{\mathrm{AC}}{\mathrm{P}} \quad (13)$$

In this case, P represents the solar still system's annual production.

Table 2. Manufacturing and installation capital cost of solar stills, $

Type of material	Quality	CSS ($)	SSSBC ($)
Wooden board with a thickness of 1.8-cm	2 m^2	30	30
Plexiglass cover with a thickness of 0.3-cm	1.2 m^2	10	10
Silicone glue	2 pieces	3	3
Aluminum waterway	2 pieces	5	5
Aluminum basin	1 piece	15	15
Solar still base	1 piece	10	10
Thermal insulation glass wool	2 pieces	5	5
Heat-resistant black paint	2 pieces	4	4
Cotton cloth	1 m		5
Cotton fabric structure			20
Motor	12 volt		25
Mechanical water float	1 piece	1	1
The total cost		84	139

Table 3. Unit costs analysis for water produced, $

Standards	CSS	SSSMC
Solar still life expectancy, n	10	10
Interest rate per year, i	12	12
Capital cost (CS), $	84	125
The factor for the recovery of capital (CRF)	0.1769	0.177
The factor for the sinking fund (SFF)	0.0569	0.057
The first annual (yearly) cost (FAC), $	14.505	14.87

The worth of salvage (S), $	16.4	16.8
The value of annual salvation (ASV), $	0.933	3.36
The cost of annual maintenance (AMC), $	2.175	2.18
Annual (yearly) cost (AC), $	15.748	13.68
Yearly yield from the solar still system	474.5	670.6

Table 4. Yearly cost per liter (YCPL), $

CSS	SSSMC (1)	SSSMC (0.5)	SSSMC (0.2)
0.0349	0.778	0.739	0.705

Table 5: Experimental Setup Dimensions

Tools	Value
Solar still area	1 m²
Glass tilt angle	35°
Glass thickness	4 mm
Glass wool insulation thickness	1 cm
Black paint	Matte
Black cloth buckle	Matte cotton
wood fish	1 cm
waterproofing material	Thermal silicon
Water basin length	0.98 m
Water basin width	0.48 m
Motor	12 volt

Conclusions

This experimental study evaluated the thermal and economic performance of a single-slope solar still integrated with a rotating cotton mesh fabric under the climatic conditions of Kirkuk (35.4686°N, 44.38933°E) during 1-3 August 2025. The SSSMC was compared with a CSS of identical basin area 1 m². The results demonstrated a substantial and measurable improvement in freshwater productivity due to the incorporation of the rotating fabric. The daily distillate yield reached 1840 ml/day at 0.2 rpm, 1755 ml/day at 0.5 rpm, and 1670 ml/day at 1 rpm, compared with 955-1000 ml/day for the conventional still. At the optimum rotational speed of 0.2 rpm, productivity increased by approximately 84–92% relative to the CSS, while even at 1 rpm the improvement remained within 67–75%. Thermal measurements confirmed that lower rotational speed enhanced heat retention and evaporation efficiency; the fabric temperature peaked at 84.1°C at 0.2 rpm, compared with 77.7°C at 0.5 rpm and 70.3°C at 1 rpm, indicating that slower movement allowed greater solar energy absorption and reduced convective heat losses. Peak solar radiation during testing ranged from 1002 to 1065 W/m², with ambient temperatures approaching 49°C, and low relative humidity conditions further supported evaporation. Despite identical environmental conditions, the rotating mesh configuration consistently outperformed the conventional system, confirming that the performance enhancement was primarily attributable to design modification. Although the capital cost increased from $84 for the CSS to $139 for the modified system, the significant increase in annual water yield reduced the effective cost per liter, with the lowest yearly cost per liter corresponding to the 0.2 rpm configuration. Finally, integrating a low-speed rotating cotton mesh fabric markedly improves thermal efficiency, evaporation stability, and freshwater productivity, making it a technically simple and economically viable enhancement for solar desalination systems operating in high solar radiation regions.

Recommendations

Application in diverse environments: Conducting field studies in areas with different climates to evaluate the generalizability of the system results.

Fabric rotation mechanism improvement: Studying improvements to fabric rotation speed to suit local conditions to increase efficiency.

Improving thermal insulation: Working to improve the thermal insulation properties of the system to reduce heat loss and increase the efficiency of the distillation process.

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