Effect of Rubber Thickness on the Performance of Conventional Solar Stills under El Oued city climate (Algeria)

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Abstract – *Our study focuses on examining the performance of conventional solar stills in an arid region, specifically investigating the impact of rubber material and its thickness on the distillation process. Four solar stills were tested, including a reference solar still (SSR) and three modified solar stills (MSS1, MSS2, and MSS3) with rubber thicknesses of 1 cm, 2 cm, and 3 cm, respectively. The experimental findings clearly demonstrate a notable difference in distilled water productivity between varying rubber thicknesses. The outputs of MSS1, MSS2, and MSS3 were measured at 1105 ml/day, 1010 ml/day, and 955 ml/day, respectively, all surpassing the output of SSR, which was recorded at 830 ml/day. These results indicate that the utilization of rubber with varying thicknesses positively impacts the productivity of the solar still, leading to higher distilled water yields compared to the reference configuration.*

Keywords*:* Solar energy, Water productivity, Salty water, Solar radiation.

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I. Introduction

Water treatment is the process of purifying and conditioning water to make it safe, clean, and suitable for various purposes, including drinking, industrial use, and environmental protection. It involves a series of physical, chemical, and biological processes to remove contaminants, impurities, and harmful substances from water sources such as rivers, lakes, groundwater, and even wastewater.

Water treatment using chemical or biological methods involves the application of various processes to remove contaminants and ensure the provision of safe and clean water for consumption and other purposes. Chemical methods often include the addition of coagulants, disinfectants, and chemicals that aid in the removal of suspended particles, organic matter, and harmful microorganisms. These chemicals can assist in flocculation, sedimentation, and disinfection processes. On the other hand, biological methods utilize natural processes involving microorganisms to degrade and remove pollutants from water. Both chemical and biological methods play vital roles in treating water from various sources, ensuring its quality and safety for human use and environmental protection [1-2].

Solar distillation is a simple and effective method of purifying water using the energy from the sun. It involves the process of evaporating water through solar heat and condensing the vapor to produce clean, drinkable water. Solar distillation takes advantage of the sun's energy to separate impurities and contaminants from the water, making it a sustainable and environmentally friendly solution for obtaining safe drinking water, particularly in areas with limited access to clean water sources [3-5]. To enhance the efficiency of solar stills, researchers have explored various approaches. One strategy involves incorporating high thermal conductivity materials into the water being treated, which helps to enhance heat transfer and improve distillation rates [6-15]. Additionally, some studies have explored the use of biological materials [16-22]. Furthermore, the utilization of natural materials, and other simple and complex techniques, has been investigated [23-31]. These innovative approaches contribute to the continuous development of solar still technology.

The main objective of our research is to evaluate the potential of rubber as an enhancement material in solar distillation and investigate the influence of rubber thickness on the distillation process. By varying the thickness of the rubber used in solar stills, we aim to determine its impact on the overall performance and productivity of the distillation system.

II. Materials and Methods

II.1. Experiment

The experiment was conducted on a specific date, 05/06/2023, with consistent climatic conditions and geometric dimensions, except for the variation in rubber thickness (1cm, 2cm, and 3cm), its pieces are deposited an interior in the solar still as shown in Figure 1. The experiment involved the use of 3 liters of salty water, and various measurements were taken including the solar radiation, ambient temperature, and temperature of the inner and outer glass cover, water temperature, and atmospheric conditions. The amount of distilled water produced was measured hourly from 8:00 in the morning until 18:00 in the evening. This comprehensive experimental analysis aims to assess the influence of rubber thickness on the performance of conventional solar stills in an arid region, providing valuable insights into the efficiency of different rubber thicknesses under controlled conditions.

II.2. Experience setup

In this study, the setup and instrumentation procedures for the solar distillation experiment are described. The process involves placing a water balance on a table to support the four solar distillers, ensuring their alignment and straightness. The tubes are positioned, and 3 liters of water are added to each distiller. The glass cover is thoroughly cleaned to remove impurities, and it is placed level with the distillers. Thermal collectors are installed on the internal and external glass surfaces, and the distillers are tightly sealed to prevent thermal leaks.

Figure 1. Experience setup

III. Experimental result

III.1. Evolution of ambient temperature and solar radiation

Figure 2 displays the variations in solar irradiance and ambient temperature during the testing of the distillers. The maximum solar irradiance of 1001 W/m^2 was recorded at 12:00h, gradually decreasing until sunset. Similarly, the ambient temperature followed a similar pattern, with the highest temperature of 34 °C occurring at 01:00h, followed by a gradual decrease during the sunset hours. The average daily solar irradiance and ambient temperature throughout the testing period were calculated as 750.01 W/m^2 and 30.4 °C, respectively. These findings provide insights into the environmental conditions during the distiller testing, illustrating the temporal dynamics of solar irradiance and ambient temperature.

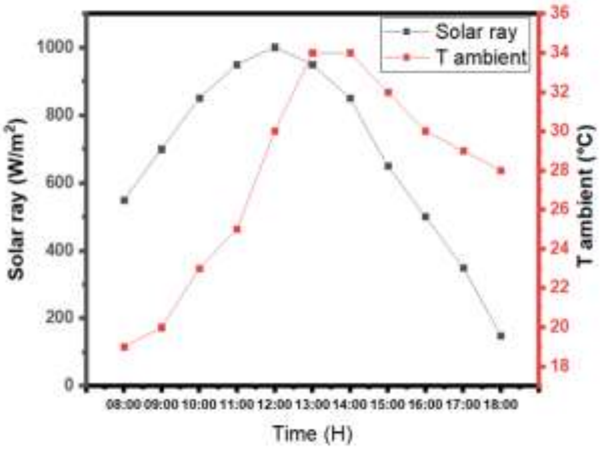

Figure 2. Evolution of ambient temperature and solar radiation

III.2. Evolution of inner surface temperature

The experiment was conducted from 8:00h to 14:00h, under consistent climatic conditions. Initially, at 8:00h, all the glass covers exhibited the same temperature of 28°C. As the experiment progressed, the temperatures gradually increased, reaching their maximum values at 13:00h, with the following recorded temperatures: SSM3 (45°C), MSS2 (42.9°C), SSM1 (42.5°C), and SSR (41.9°C). Subsequently, between 13:00h and 14:00h, the temperatures showed a decrease while maintaining the same order of temperatures for each solar still as shown in Figure 3. This analysis aims to provide insights into the impact of rubber thickness on temperature fluctuations throughout the day in conventional solar stills, contributing to a better understanding of their thermal behavior.

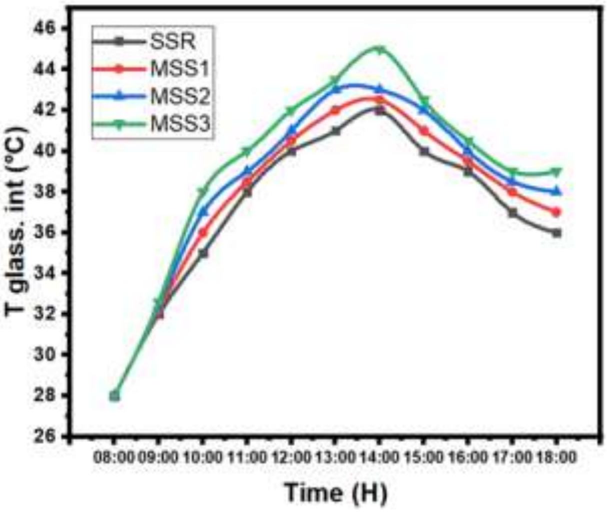

Figure 3. Glass inner surface temperature evolution

III.3. Evolution of water temperature

The temperatures in solar stills with different rubber thicknesses were investigated. The experiment commenced with an initial temperature of 27.5°C, in Figure 4. Subsequently, between 8:00h and 12:00h, the temperatures progressively increased. Notably, from 12:00h to 14:00h all solar stills reached their respective maximum temperatures: MSS3 (62.5°C), MSS2 (59°C), SSM1 (57.5°C), and SSR (55°C). Subsequently, between 14:00h and 18:00h, a gradual drop in temperature was observed across all solar stills, while maintaining the previous order of temperatures for each still. This detailed analysis sheds light on the temperature behavior of conventional solar stills with varying rubber thicknesses throughout the day, contributing to a comprehensive understanding of their thermal performance

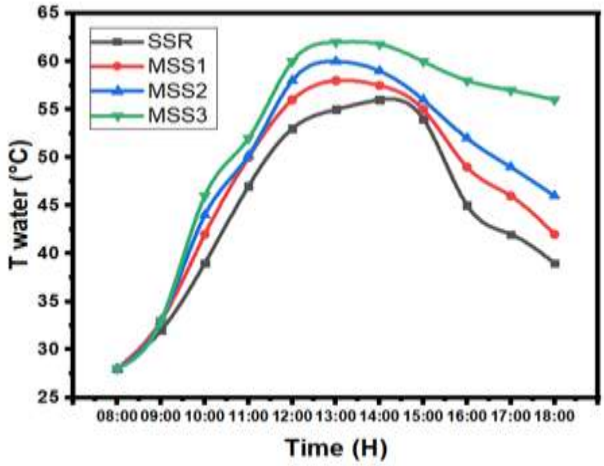

Figure 4. Water temperature evolution

III.4. Evolution of accumulation output

Figure 5 provides valuable insights into the relationship between rubber thickness and water output in conventional solar stills. It is evident from the figure that the water output deviates significantly in the MMS3 solar stills compared to the others. The final accumulated productions for each still are as follows: MSS3 (1105 ml/day), MSS2 (1010 ml/day), SSM1 (955 ml/day), and SSR (830 ml/day). The figure clearly demonstrates the influence of rubber thickness on the output of the solar stills, revealing a direct correlation between increasing rubber thickness and higher water output.

These findings highlight the importance of considering rubber thickness as a factor in optimizing the performance of conventional solar stills, as it can significantly impact the overall water production.

III.5. Evolution of hourly output

The observations indicate that at 8:00h, no distilled water was produced. However, starting from 9:00h the amount of distilled water began to increase across all solar stills, with a value of approximately 15 ml as shown in Figure 6. Between 9:00h and 01:00h, the production of distilled water reached its maximum values: SSM3 (160 ml), MSS2 (143 ml), MSS1 (142 ml), and SSR (135 ml). Subsequently, from 15:00h to 14:00h, the amount of distilled water decreased in each solar still, while maintaining the previous order of temperatures for each still.

These observations provide insights into the temporal variations in distilled water production in conventional solar stills, highlighting the peak production period and subsequent decline during the latter part of the day.

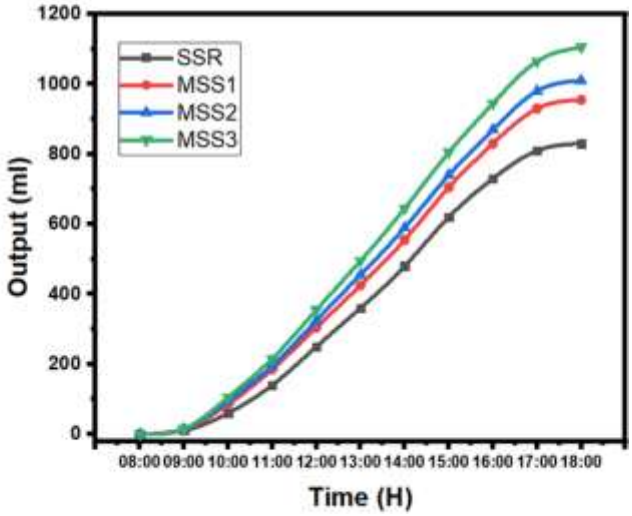

Figure 5. Water accumulation output evolution

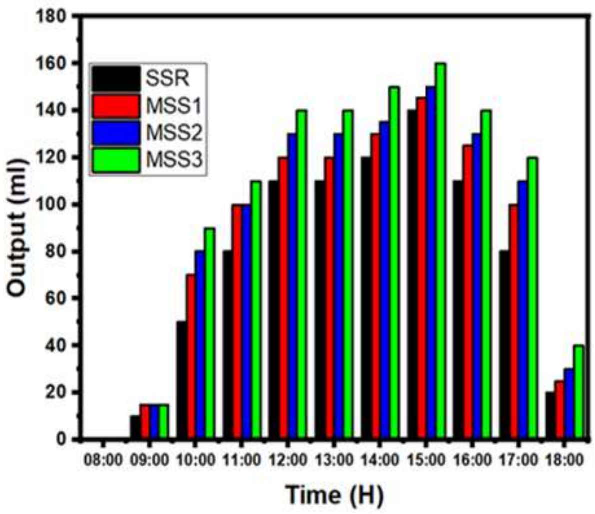

Figure 6. Water hourly output evolution

IV. Conclusion

Our study has investigated the effect of rubber thickness on water output in conventional solar stills. The experimental results clearly demonstrate the impact of rubber thickness on the distillation process. The accumulated water productions for different rubber thicknesses were as follows: SSM3 (1105 ml/day), MSS2 (1010 ml/day), MSS1 (955 ml/day), and SSR (830 ml/day). It is evident that as the rubber thickness increases, there is a corresponding increase in water output.

This finding emphasizes the importance of considering rubber thickness as a critical parameter in solar still design and operation. By optimizing rubber thickness, it is possible to enhance the water productivity of conventional solar stills. Therefore, our study highlights the significance of further research and development in this field to improve the efficiency of solar distillation systems for sustainable water production.

Declaration

- The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.
- The authors declare that this article has not been published before and is not in the process of being published in any other journal.
- The authors confirmed that the paper was free of plagiarism.

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