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# Cooling Effect on a solar still condenser

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**Abstract** – *This research delves into the quantitative impact of design modifications on solar still performance, specifically examining the role of fins on the glass cover. Comparative analyses were conducted on two solar stills, SSref (Solar Still reference) and SSmod (Solar Still modified with fins), considering temperature variation, energy transfer, energy evaporation, hourly water output, and internal efficiency. SSmod consistently exhibited superior performance, maintaining lower temperatures (peak difference of 10 °C), achieving an average energy transfer of 555 W/m², a higher energy evaporation rate (335 W/m² on average), and an increased hourly water output (0.59 mL peak). The internal efficiency for SSmod averaged 0.741%, surpassing SSref's 0.713%. These quantified results highlight the crucial contribution of fins in enhancing distillation processes, providing a valuable foundation for designing solar stills with improved energy efficiency and resource utilization.*

***Keywords****: Solar energy, Energy efficiency, Energy transfer, Internal efficiency, Glass cover.*

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## I. Introduction

Access to clean and safe drinking water is a critical global concern, with many regions grappling with a severe lack of drinking water. One effective approach to address this issue is through groundwater treatment, which involves comprehensive processes such as water filtration, purification, disinfection, and even distillation. Groundwater treatment is pivotal in removing impurities, contaminants, and harmful microorganisms that may compromise the quality of water. Water filtration employs various techniques to strain out particles and pollutants, while purification methods ensure the removal of chemical impurities. Water disinfection is crucial for eliminating harmful microorganisms that can cause waterborne diseases. In addition, water distillation, both conventional and solar distillation, plays a significant role. Conventional distillation involves heating water to create steam and then condensing it back into liquid form, effectively separating contaminants. Solar distillation harnesses the sun's energy for evaporation and condensation, providing a sustainable and energy-efficient solution to produce clean, potable water. In combating the lack of drinking water, the integration of these groundwater treatment methods offers a comprehensive and adaptable strategy to ensure water security for communities worldwide. [1-6].

Solar distillation stands out as a sustainable and energy-efficient method for converting impure or saline water into clean, potable water. In the quest to enhance the efficiency of solar distillation, researchers are actively exploring innovative strategies, and one prominent approach involves the strategic use of materials with high thermal conductivity. This tactic aims to optimize heat transfer within the solar distillation system, thereby improving distillation rates and overall efficiency. The integration of materials with high thermal conductivity acts as efficient conduits for heat, facilitating the rapid evaporation of impurities and contaminants in the water. This, in turn, expedites the condensation process, resulting in a more efficient production of purified water.

The combination of solar distillation and the use of materials with high thermal conductivity represents a promising synergy, offering a sustainable solution to water treatment challenges while harnessing advanced materials for improved performance [7, 8].

Moreover, researchers have ventured into exploring the potential of utilizing natural materials along with employing both simple and sophisticated techniques to augment the performance of solar distillation systems. This holistic approach seeks to harness the inherent properties of readily available resources and employ sustainable methods to elevate water evaporation processes. By integrating elements from nature and combining them with cutting-edge technologies, researchers aim to create solar still systems that are not only technologically advanced but also environmentally conscious and resource-efficient [9-15]. This multifaceted exploration underscores the dedication to advancing solar distillation technology through a comprehensive and sustainable lens.

The exploration of biological natural materials in the realm of solar distillation research has evolved into a central focus, presenting a promising avenue for innovation. Within this investigation, a diverse array of materials such as plant fibers, nuts, dates, olives, and sponge pieces has drawn significant attention due to their distinctive properties. Plant fibers, characterized by their inherent strength and thermal resilience, offer more than just structural reinforcement; they also introduce the potential for improved durability and enhanced thermal properties in solar distillation systems. Meanwhile, the inclusion of nuts, dates, and olives in the research has demonstrated their capacity to contribute to heightened energy absorption within the solar stills. This phenomenon, in turn, augments the heat necessary for the critical process of water vaporization, thereby potentially increasing overall efficiency. The ongoing scrutiny and exploration of these biological natural materials signal a dynamic and comprehensive approach to advancing solar distillation technology, holding the promise of addressing key challenges and optimizing the performance of water treatment systems [16-23].

The glass cover of a solar still plays a central role in determining the efficiency and effectiveness of the entire distillation process. Serving as the primary interface between sunlight and treated water, the glass cover facilitates the crucial processes of evaporation and condensation. Its transparency allows solar radiation to penetrate and initiate the evaporation of impure or salty water, while the enclosed space created by the glass cover promotes the condensation of evaporated steam into purified water. This is why several studies have been focused on this part of the solar still [24-28].

Cooling the glass cover of a solar still is a critical aspect that significantly impacts the overall efficiency and performance of the distillation process. Effective cooling measures not only contribute to maintaining a temperature differential necessary for sustained evaporation but also enhance condensation rates, leading to increased water production. By actively managing the temperature of the glass cover, the system can operate at its maximum potential, promoting higher energy efficiency and an augmented yield of purified water. This emphasis on cooling strategies underscores the importance of implementing innovative techniques to regulate the thermal dynamics of the solar still, ultimately improving its reliability and performance in providing a sustainable source of clean and potable water [28-30].

The objective of this work is to compare the output of a solar still with cooling of the condenser (the glass cover) and another still without cooling and to also see the effect of cooling on the temperature difference between the water in the pool and the temperature of this cover itself.

## II. Methodology

Two similar solar stills (50 x 50 cm) were exposed to the sun during the month of June at the University of El Oued in southeastern Algeria as shown in Figure 1. One was designated as the reference solar still (SSref), while the other was modified and referred to as the modified solar still (SSmod). The latter solar still is equipped with fins on the glass cover (condenser) with the aim of cooling this cover, intending to increase the condensation of water vapor, in other words, to enhance the output of the solar still SSmod. Measurements of ambient temperature, both inside and outside the glass covers, as well as the water in the basin, were recorded every hour, and the quantity of water produced by both solar stills was also noted.

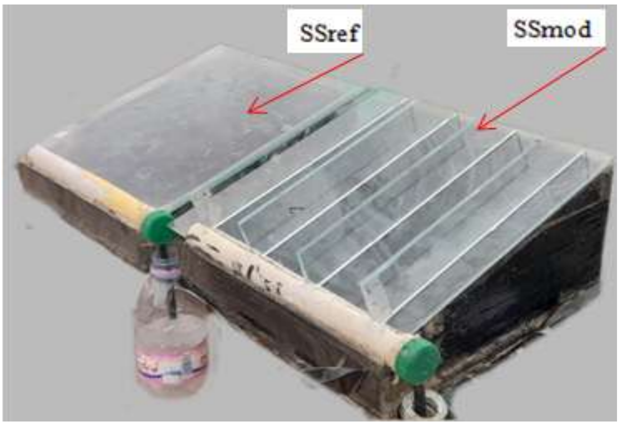


Figure 1. Experimental setup

# III. Results

*III.1. Solar radiation and ambient temperature*

The experimental study commenced at 18:00h and concluded at 17:00h. The variation in solar radiation exhibited a notable pattern throughout the day. Starting at 500 W/m² in the morning, it steadily increased, reaching its peak at 12:00h with an intensity of 1009 W/m$^2$. This solar radiation profile provided a comprehensive understanding of the energy influx during the experiment. Simultaneously, the ambient temperature followed its own trajectory as shown in Figure 2. Beginning at a comfortable 22°C, it gradually rose and reached its maximum of 35°C at 12:00h. This temperature trend adds another layer of insight into the environmental conditions during the study. As the experiment progressed, both solar radiation and ambient temperature experienced a decline. By the end of the observation period, solar radiation decreased to 350 W/m$^2$, signifying a reduction in available solar energy. The temperature, too, exhibited a decrease, with expectations of reaching a minimum value of 30°C.

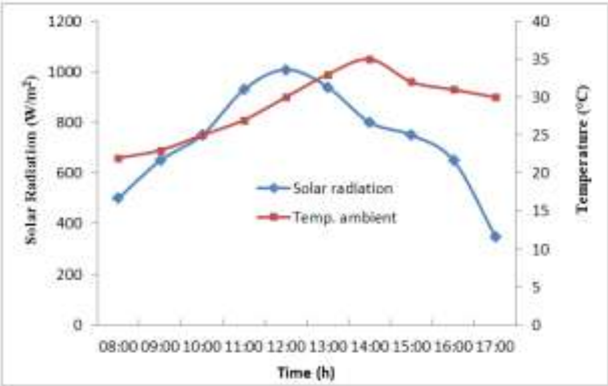


Figure 2. Evolution of solar radiation and ambient temperature

*III.2. Temperature variation of glass*

Figure 3 illustrates the temporal evolution of glass cover temperatures for distillators SSref and SSmod. Notably, SSref consistently exhibits higher temperatures than SSmod throughout the experiment, with a notable difference observed at 9:00h (27 °C for SSref, 25 °C for SSmod) and peak temperatures between 13:00h and 14:00h (75 °C for SSref, 65 °C for SSmod). This temperature contrast is attributed to the presence of fins, showcasing the potential impact of design modifications on heat exchange efficiency. The findings underscore the significance of thoughtful design in optimizing distillation processes, offering insights for enhanced energy efficiency and resource utilization.

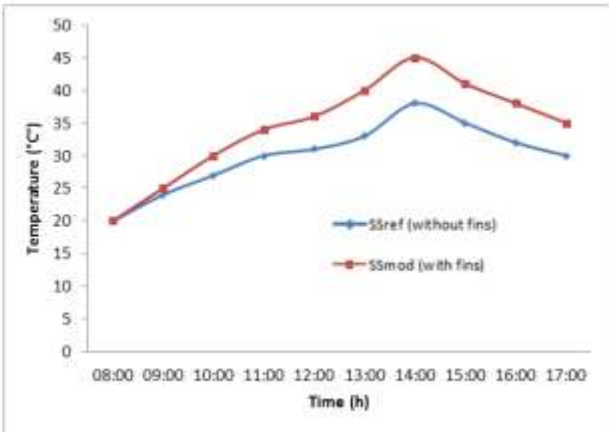


Figure 3. Evolution of glass temperatur

*III.3. Evolution of quantity of energy transferred*

The energy transfers through the glass cover are graphically depicted in Figure 4. The figure illustrates a compelling trend, showcasing that the quantity of energy exchanged by the finned cover (SSmod) consistently surpasses that of the cover without fins (SSref) throughout the entire experiment. Notably, this pattern holds true until the concluding phase of the experiment, where a momentary shift is observed, and the quantity of energy exchanged by SSref briefly becomes higher. However, on average, the energy exchange for SSmod remains notably superior, measuring at 555 W/m², compared to the average of 400 W/m² for SSref. This observation underscores the consistently positive impact of the fins in enhancing the overall energy transfer process.

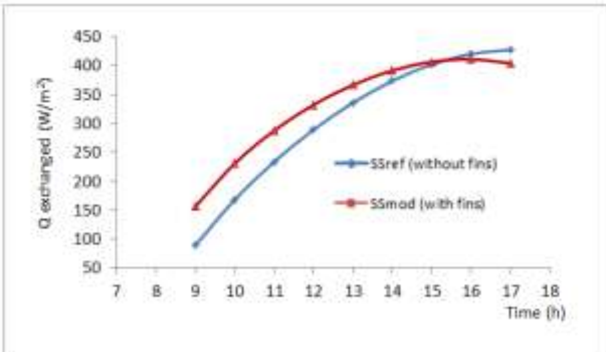


Figure 4. Evolution of quantity of energy transferred

*III.4. Variation of energy evaporated*

Figure 5 represents the variation in the quantity of energy evaporated by the two solar stills. We notice that this quantity was very close at the start of the experiment then the quantity of SSmod became higher and this superiority persisted until the end of the experiment. The average of this energy for SSmod is 335 W/m$^2$ and 306 W/m$^2$ for

SSref, which favors the use of fins on the glass covers of solar stills.

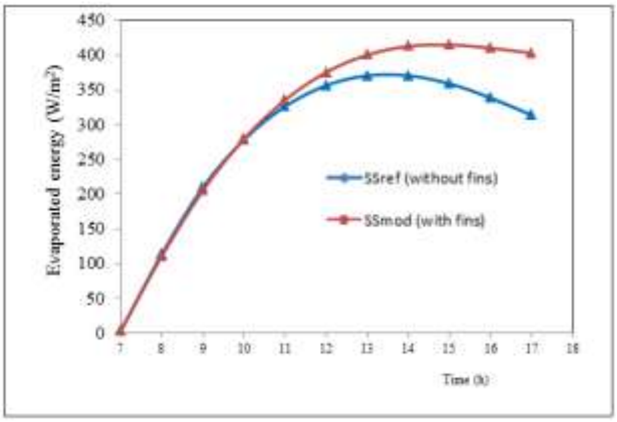


Figure 5. variation in the quantity of energy evaporated

### *III.5. Hourly output of pure water*

Figure 6 illustrates the hourly output of pure water for both the SSref and SSmod stills over the course of the experiment. The graph indicates that the SSmod still consistently yields a higher output of pure water compared to the SSref in each measurement.
At 14:00 hours, the highest output value is recorded, with 0.59 mL of pure water for the SSmod still and 0.75 mL for the SSref. This difference in output can be attributed to the fins on SSmod, which enhances the thermal performance and efficiency of the distillation process, as observed in the previous Figure 6. The total accumulation values are 473 ml for SSmod and 412 ml for SSref.

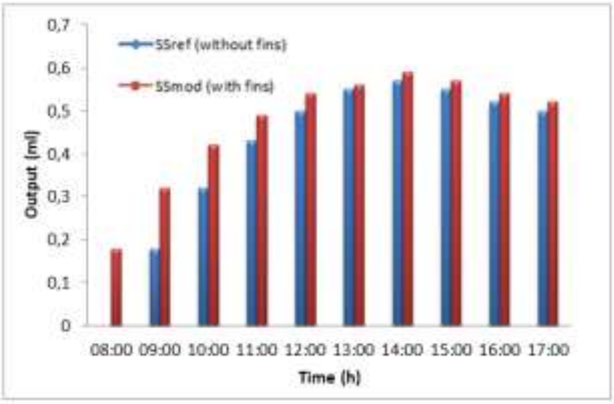


Figure 6. Evolution of hourly output (with / without fins)

### *III.6. Evolution of internal efficiency*

Figure 7 depicts the temporal evolution of the internal efficiency of the two distillators, SSref and SSmod. It is evident that the efficiency of SSref consistently surpasses that of SSmod throughout the experiment. Particularly noteworthy is the peak efficiency observed between 12:00h and 13:00h, reaching 0.84% for SSmod and 0.80% for SSref. The average efficiency for SSmod is 0.741%, while for SSref, it stands at 0.713%. This observed efficiency discrepancy between the stills prompts a closer examination of contributing of fins.

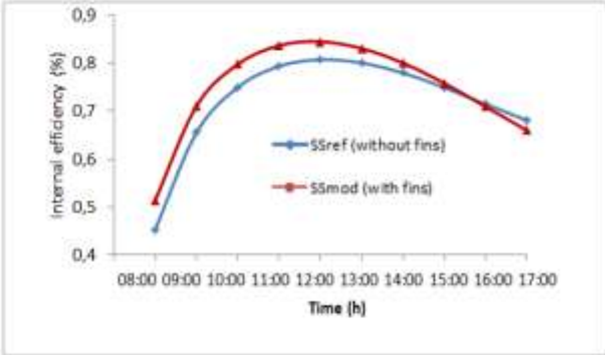


Figure 7. Evolution of the internal efficiency

## IV. Conclusion

This study underscores the substantial impact of design modifications, particularly the incorporation of fins, on the performance of solar stills. In the temperature variation analysis, SSmod consistently maintained lower temperatures than SSref, with a peak difference of 10 °C. The energy transfer dynamics revealed an average exchange of 555 W/m² for SSmod, significantly surpassing SSref's average of 400 W/m². The quantity of energy evaporated favored SSmod with an average of 335 W/m² compared to SSref's 306 W/m². The hourly water output demonstrated the superiority of SSmod, yielding 0.59 mL at its peak, as opposed to SSref's 0.75 ml. Internal efficiency analysis indicated SSmod's average efficiency of 0.741%, outperforming SSref's 0.713%. These findings collectively emphasize the positive influence of fins on distillation processes, offering a comprehensive perspective on the quantitative benefits of design optimization.

## 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.

## References


[1] A. Khechekhouche, F. Bouchmel, Z. Kaddour, K. Salim, A. Miloudi. "Performance of a Wastewater Treatment Plant in South-Eastern Algeria." International Journal of Energetica, Vol. 5, no. 2, 2020, pp. 47-51. https://dx.doi.org/10.47238/ijeca.v5i2.139.

[2] Asma Khelassi-Sefaoui, A. Khechekhouche, M. Zaoui-Djelloul Daouadji, H. Idrici. "Physico-Chemical Investigation of Wastewater from the Sebdou-Tlemcen Textile Complex, North-West Algeria." Indonesian Journal of Science & Technology, 2021. https://doi.org/10.17509/ijost.v6i2.34545

[3] A. Khechekhouche, B. Benhaoua, Z. Driss, M. E. Attia, M. Manokar. "Polluted Groundwater Treatment in Southeastern Algeria by Solar Distillation." Algerian Journal of Environmental and Sciences, Vol. 6, no. 1, 2020. https://aljest.org/index.php/aljest/article/view/288.

[4] K.Sadasivuni, H. Panchal, A. Awasthi, M. Israr, F .A. Essa, S. Shanmugan, M. Suresh, V. Priya, A. Khechekhouche "Ground Water Treatment Using Solar Radiation-Vaporization & Condensation-Techniques by Solar Desalination System," International Journal of Ambient Energy, 2020. DOI: 10.1080/01430750.2020.1772872.

[5] H. Panchal, K. K.Sadasivuni, C. Prajapati, M. Khalid, F.A. Essa, S. Shanmugan, N. Pandya, M. Suresh, M. Israr, Swapnil Dharaskar, A. Khechekhouche; "Productivity Enhancement of Solar Still with Thermoelectric Modules from Groundwater to Produce Potable Water: A Review." Groundwater for Sustainable Development, 2020. DOI: 10.1016/j.gsd.2020.100429.

[6] A. Miloudi, A. Khechekhouche, I. Kermerchou," Polluted Groundwater Treatment by Solar Stills with Palm Fibers", JP Journal of Heat and Mass Transfer, Vol. 27, pp. 1-12. https://doi.org/10.17654/0973576322020

[7] A. Khechekhouche, B. Benhaoua, AE Kabeel, M. Attia, W. El-Maghlany. "Improvement of Solar StillProductivity by a Black Metallic Plate of Zinc as a Thermal Storage Material." Journal of Testing and Evaluation, Vol. 49, no. 2, 2019. https://doi.org/10.1520/JTE20190119.

[8] A. Khechekhouche, A. Bellila A. Sadoun, I. Kemerchou, B. Souyei, N. Smakdji, A. Miloudi., "Iron Pieces Effect on the Output of Single Slope Solar Still." Heritage and Sustainable Development, Vol. 4, no. 2, 2022.

[9] A. Khechekhouche, B. Benhaoua, M. Manokar, R. Sathyamurthy, A. E. Kabeel, Z. Driss "Sand Dunes Effect on the Productivity of a Single Slope Solar Distiller." Heat and Mass Transfer Journal, Springer Nature, Vol. 56, no. 4, pp. 1117-1126, 2020. https://doi.org/10.1007/s00231-019-02786-9.

[10] A. Khechekhouche, A.E. Kabeel, B. Benhaoua, M. Attia, Emad M.S. El-said., "Traditional Solar Distiller Improvement by a Single External Refractor under the Climatic Conditions of the El Oued Region, Algeria." Desalination and Water Treatment, Vol. 117, pp. 23-28, 2020. https://doi.org/10.5004/dwt.2020.24832.

[11] D. Khamaia, R. Boudhiaf, A. Khechekhouche, Z. Driss. "Illizi City Sand Impact on the Output of a Conventional Solar Still." ASEAN Journal of Science and Engineering, Vol. 2, no. 3, 2022, pp. 267-272.

[12] A. Bellila, A. Khechekhouche, I. Kermerchou, A. Sadoun, A. Siqueira, N. Smakdji "Aluminum Wastes Effect on Solar Distillation." ASEAN Journal for Science and Engineering in Materials, Vol. 1, no. 2, 2022.

[13] A. Khechekhouche, A. M. de Oliveira Siqueira, Nabil Elsharif. "Effect of Plastic Fins on a Traditional Solar Still's Efficiency." International Journal of Energetica, Vol. 7, no. 1, 2022.

[14] A. Bellila, I. Kemerchou, A. Sadoun, Z. Driss. "Effect of Using Sponge Pieces in a Solar Still." International Journal of Energetica, Vol. 7, no. 1, 2022, pp. 41-45. http://dx.doi.org/10.47238/ijeca.v7i1.197.

[15] D. Djaballah, B. Benhaoua, A.E. Kabeel, A. Abdullah, M. Abdelgaied, A. Khechekhouche," Experimental study of the role of surface tension in enhancing the performance of solar stills using different designs of plastic fins," Solar Energy, Vol. 262, no. 2023, pp. 111835, https://doi.org/10.1016/j.solener.2023.111835.

[16] I. Kemerchou, I. Mahdjoubi, C. Kined, A. Khechekhouche, A. Bellila, G. Isiordia., "Palm Fibers Effect on the Performance of a Conventional Solar Still." ASEAN Journal For Science And Engineering In Materials, Vol. 1, no. 1, 2022.

[17] A. Sadoun, A. Khechekhouche, I. Kemerchou, M. Ghodbane, B. Souyei. "Impact of Natural Charcoal Blocks on the Solar Still Output."

Heritage and Sustainable Development, Vol. 4, no. 1, 2022, pp. 61–66.

[18] A. Brihmat, H. Mahcene, D. Bechki, H. Bouguettaia, A. Khechekhouche, S. Boughali, "Energy Performance Improvement of a Solar Still System Using Date and Olive Kernels: Experimental Study." CLEAN - Soil Air Water, December 2022. https://doi.org/10.1002/clen.202200384

[19] A. Khechekhouche, A. Zine, A.E. Kabeel, Y. Elmashad, M. Abdelgaied, A. Laouini, W. El-Maghlany, "Energy, Exergy Investigation of Absorber Multilayered Composites Materials of a Solar Still in Algeria." Journal of Testing and Evaluation, Vol. 51, no. 5, 2023, pp. 13. https://doi.org/10.1520/JTE20220577.

[20] S. Temmer, A. Khelef, M. H. Sellami, R. Cherraye, A. Khechekhouche, S. E. Laouini, "Effect of Different Carbon Types on a Traditional Solar Still's Output." Desalination and Water Treatment, In press 2022-2023.

[21] A. Khechekhouche, N Smakdji, A. E. Kabeel, M. Abdelgaied, M. Ghodbane, A. Allal, R. Sathyamurthy, "Impact of Solar Energy and Energy Storage on a Still's Nocturnal Output." Journal of Testing and Evaluation, Vol. 51, no. 6, 2023, p. 10. DOI: 10.1520/JTE20220701.

[22] I. Kermerchou, A. Khechekhouche, N. Elsharif, " Effect of Rubber Thickness on the Performance of Conventional Solar Stills under El Oued city climate (Algeria)," Journal of Energetica, Vol. 8, no. 1, 2023, pp. 2543-3717.

[23] A. Bellila, Z. Rahal, A.S. Smolyanichenko, A. Sadoun,"Cellulose cardboard effect on the performance of a conventional solar still" International Journal of Energetica, Vol. 8 no.1, 2023.

[24] A. Khechekhouche, Z. Driss, B. Durakovic. "Effect of Heat Flow via Glazing on the Productivity of a Solar Still." International Journal of Energetica, Vol. 4, no. 2, 2019, pp. 54-57.

[25] A. Khechekhouche, B. Boubaker, M. Manokar, R. Sathyamurthy, A. E. Kabeel. "Exploitation of an Insulated Air Chamber as a Glazed Cover of a Conventional Solar Still." Heat Transfer - Asian Research, Vol. 48, no. 5, 2019, pp. 1563-1574. DOI: 10.1002/htj.21446.

[26] A. Khechekhouche, B. Benhaoua, Z. Driss. "Solar Distillation between a Simple and Double-Glazing." Revue de Mécanique, Vol. 2, no. 2, 2017. DOI: 10.5281/zenodo.1169839.

[27] R. Cherraye, B. Bouchekima, D. Bechki, H. Bouguettaia, A. Khechekhouche. "The Effect of Tilt Angle on Solar Still Productivity at Different Seasons in Arid Conditions-South Algeria." International Journal of Ambient Energy, 2020. https://doi.org/10.1080/01430750.2020.1723689.

[28] A. Khechekhouche, M. Manokar, R. Sathyamurthy, F.E. Milad Sadeghzadeh, A. Issakhovm., "Energy, Exergy Analysis, and Optimizations of Collector Cover Thickness of a Solar Still in El Oued Climate, Algeria." International Journal of Photoenergy, Vol. 2021, Article ID 6668325. https://doi.org/10.1155/2021/6668325.

[29] Z.M. Omara, A.S. Abdullah, A.E. Kabeel, F.A. Essa,"The cooling techniques of the solar stills' glass covers – A review," Renewable and Sustainable Energy Reviews, Vol. 78, 2017, pp. 176-193, https://doi.org/10.1016/j.rser.2017.04.085.

[30] H. Ghani Hameed, "Experimentally evaluating the performance of single slope solar still with glass cover cooling and square cross-section hollow fins," Case Studies in Thermal Engineering, Vol. 40, 2022, pp.102547, https://doi.org/10.1016/j.csite.2022.102547.

[31] H. Aghakhani, S.M. Ayatollahi, M.R. Hajmohammadi, "Proposing novel approaches for solar still performance enhancement by basin water heating, glass cooling, and vacuum creation, " Desalination, Vol. 567, 2023, pp. 117011, https://doi.org/10.1016/j.desal.2023.117011