Nexo Revista Científica
Vol. 36, No. 05 (Especial), pp. 42-50/Noviembre 2023

ISSN-E 1995-9516
Universidad Nacional de Ingeniería

http://revistas.uni.edu.ni/index.php/Nexo
http://dx.doi.org/10.5377/nexo.vXXiXX.XXXX

Aqua balls effect on solar still productivity using water blended

Efecto de las bolas de aqua sobre la productividad de un destilador solar utilizando agua mezclada

Mohammed Qasim Hadi [1*], Mutaz H. Taher [2], Zainalabden A. Ibrahim[2]

[1] Engineering faculty, Thi Qar University, Thi-Qar, 64001, Iraq
[2] Department of Bureau Affairs, University of Thi-Qar, Thi-Qar, 64001, Iraq
[*] m.hadi@utq.edu.iq

(received: 18-septiembre-2023; /accepted: 15-octubre-2023)

ABSTRACT

With the use of filter ball, the performance regarding the rowing motor solar still is examined. The belt is rotated by a DC motor (6W) that is powered through a small photovoltaic (PV) system. Also, research is done on how employing porous media affects the rowing filter still's performance. The best rowing filter performance, without or with porous media, was found to be achieved at the 30-minute OFF time, according to the results. Additionally, the rowing filter ball in solar still produced 183% more in total compared to standard distiller did. Tow rowing shafts in solar still: New mechanism of desalination Absorbent materials in the stills increase water absorption, and absorb heat when exposed to solar radiation. These materials serve as heat storage media and increase the wetted surface area. The water yield for CSS is improved by 188% when the AQUA balls balls are agitated within the water in the still basin.

Keywords: Solar still, porosity, wastewater, photovoltaic, productivity.

RESUMEN

Con el uso de una bola de filtro, se examina el rendimiento del alambique solar del motor de remo. La correa gira mediante un motor de CC (6 W) que se alimenta a través de un pequeño sistema fotovoltaico (PV). Además, se realizan investigaciones sobre cómo el uso de medios porosos afecta el rendimiento del filtro de remo. Según los resultados, se descubrió que el mejor rendimiento del filtro de remo, sin o con medios porosos, se lograba con un tiempo de APAGADO de 30 minutos. Además, la bola de filtro de remo en el destilador solar produjo un 183% más en total en comparación con el destilador estándar. Remolque de pozos de remo en destilador solar: Nuevo mecanismo de desalinización Los materiales absorbentes en los destiladores aumentan la absorción de agua y absorben calor cuando se exponen a la radiación solar. Estos materiales sirven como medios de almacenamiento de calor y aumentan la superficie húmeda. El rendimiento de agua para CSS mejora en un 188% cuando las bolas AQUA se agitan dentro del agua en el recipiente destilado.

Palabras claves: Destilador solar, porosidad, aguas residuales, fotovoltaica, productividad.

1. INTRODUCTION

An extremely basic solar device, referred to as a single basin solar still is utilized for the conversion of the available brackish or wastewaters into the potable water. Locally accessible materials could be used for simply manufacturing such a device. In addition, maintenance is inexpensive and doesn't need skilled labor. It might be a good way to deal with the problem of drinking water. Yet, because of its poor productivity, it is rarely widely utilized. As a result, many projects are started to raise the still's productivity.

Through increasing the water's evaporative surface area, corrugated (Omara et al., 2015, 2016) and fins (Omara et al., 2011) increased freshwater production of the solar still (Abujazar et al., 2018). Lastly, adding nanoparticles (NPs) to saline water increased the mixture's thermal properties, increasing the freshwater production regarding the solar distiller (Kabeel et al., 2014a, 2014b). When put to comparison with conventional distillers, the performance of solar stills with integrated moving parts, like rowing motor or a rowing arm, is superior. This occurs as a result of the rotating portion regarding the rowing motor breaking the forces of surface tension and switching from free to forced modes of evaporation. The evaporation rate may rise as a result of such actions. (Kabeel, 2009; Kabeel et al., 2012) found that the conventional distiller contained a rotating motor. The suggested fan reduced water surface tension and increased the productivity of freshwater produced by solar still output. Utilizing such method, productivity increased by 25% at 45 rpm fan speed. According to (Omara et al., 2017), when the water depth decreases, the fan speed must also decrease. Furthermore, (Abdullah, Essa, et al., 2019; Malaeb et al., 2016) increased the freshwater productivity by 250% for both of them, by adding a rotating drum within solar distiller. (Haddad et al., 2017) suggested a vertical rowing filter belt inside distiller while considering alternative rotating motors inside the solar still. Additionally, water tension forces in basin were broken and the evaporative surface area increased as a result of wick belt rotating. Heat transfer coefficients were thus improved. Subsequently, the rates of evaporation and condensation have been increased. Consequently, winter productivity increased by 51.1%.

To enhance the freshwater distillate, (Gad et al., 2011) have employed a horizontal rowing filter belt inside the distiller in different research. (Abdullah, Alarjani, et al., 2019) looked at the impact of a wick belt rotating within the distiller both vertically and horizontally at various OFF times. They came to the conclusion that 30 mins was the optimal OFF-peak time for productivity. Using nanofluids, freshwater distillate has been enhanced by 315%. (Abdel-Rehim & Lasheen, 2005) also suggested adding a rotating shaft within the solar distiller to increase the productivity. In July, they improved the still's efficiency by 5.5%.

2. EXPERIMENTAL CASES AND PROCEDURES

Bassra, Iraq was the site of experimental work (Dhi Qar Coordinates: 31.1042° N, 46.3625° E). Tests have been conducted in 2020's summer. The east-west axis was fixed in both of the studied solar stills for maximizing their capacity to collect solar rays. Simultaneous measurements have been made of the variables influencing the solar distiller's performance, including ambient temperature, air speed, water and glass temperatures, and solar radiation. Furthermore, hourly records of freshwater distillate were made. Both distillers' environmental and operating conditions have been set for providing an accurate comparison.

The depth regarding the basin water within solar stills was 1 cm. In contrast, the water level in rowing shaft basin in the disc solar still has been 8 cm. The rotating discs have been dipped from bottom into discs' basin of water. Also, the discs' lower part was dipped into discs' basin in the morning. After that, discs start rotating at the indicated speed. An active technique is the alternative that was employed in this work for improving the still's evaporation and productivity. The term "active technique" refers to the process of agitating the basin water with additional materials by means of an electrical motor in order to improve solar exposure and evaporation. For achieving this, a J-star aquarium bio balls filter media has been introduced to the water, while a rowing motor was fixed to the basin, as seen in Figure (1). The motor comes with a specially made plastic pedal that has a 12 W power rating, a frequency of 50 Hz, an input voltage range of 220-240 V, and a rotation speed of 30 RPM. The filter media utilized in bioballs are black in color, 3.04 g in weight, and 16 mm in diameter. There were 660 balls utilized in all, weighing 1320 grams prior to soaking and 2006.4 grams after being saturated with water.

Figure 1. The utilized rowing motor and J-star aquarium bio balls filter media

For the purpose of examining and contrasting the performance related to solar desalination systems, a total of two solar stills have been developed and built. The first one is a typical still (one basin), measuring one meter squared (0.5m 2m). The high-side wall is 49cm deep and the low-side wall is 20cm high. The still is composed of 1.5 mm thick iron sheets. To improve absorptivity, black paint is applied to the coated surfaces of the basin. For minimizing heat loss from the still to the ambient, sawdust that is 4 cm thick is used for insulating the still from the bottom to the side walls. A wooden frame provides support for the layer of insulation (Holman, 2012).

Figure 2. black porous balls

As seen in Figs. 1 and 2, the setup includes two solar stills (a modified solar still with porous balls and a reference still), a feedwater tank, and a rowing motor. The water that came from the feeding tank had fed the two distillers. The performance regarding the rowing arm still was assessed as well as contrasted with reference still. The projected areas of the two solar distillers are 0.5 m2. Furthermore, as shown in Fig. 2, the back and front sides of each stills have heights of 45 and 20 cm, respectively. Copper sheet with a 1.5mm thickness has been used in order to make the solar distillers. For capturing as much of the absorbed solar rays as possible, they have been painted black. Additionally, a 5 cm thick layer of glass wool insulation has been used for the two distillers between the basin still body and the wooden box. The distiller's tilting channel was used for gathering the condensed droplets, which were then directed for accumulating outside the basin still. Also, a 4mm thick glass sheet with a copper steel frame that has been welded to distillers to serve as a glass cover seat covered the two solar stills. However, there were still a few designable changes in modified solar. The first alteration consists of two rotating discs that are mounted to at the back side wall (i.e. the higher wall) of the rowing arm solar still. The flask used to make the rowing arm had a circular cross section with 0.5 mm thickness and 20 cm diameter. A bearing bracket was used to secure the rotating shaft on rotating shafts. The arm was rotated by two small DC motors, each rated for 3 W. A speed control mechanism was used for regulating and controlling the rotating discs' speed. A black paint has been applied to the rotating discs to increase solar rays absorption. Water in discs basin and water in distiller basin were separated by a barrier inside the discs still. Consequently, the water level in the basin holding discs has been greater than that of distiller basin. The small discs' basin had dimensions of 10cm height, 5cm width, and 100 cm long, whereas water inside the still basin has been of 1cm height, 45cm width, and X 100cm long.

Freshwater has been gathered outside the distillers, and a pipe and valve located at the distiller bottom were used in order to manually manage the excess drain.

3. MEASURING INSTRUMENTS

The variables influencing the solar distiller's performance have been measured using the following instruments: a modular programmable logic control unit, a graded flask, a data-logging solar power meter, a van type anemometer, and K-type thermocouples. Using a data-logging solar power meter with a range between 0 and 5000W/m2, solar radiation has been measured. The temperature was recorded at various distilling points using thermocouples. The thermocouple readings were converted to digital values using G4L-CUEA modular programmable logic control (MPLC). Additionally, the van type anemometer has been used for monitoring air speed, which ranged between 0.4 and 30 m/s. Additionally, a 1.5 L calibrated, graded small bottle was used for recording the distillate.

4. RESULT

As the discs rotate, the top part becomes the lower part and vice versa. Consequently, the surfaces regarding the rowing arms developed a thin layer of water. Due to the fact that it heats up rapidly, the film evaporated immediately. Additionally, every 24 hrs, the freshwater distillate was gathered as well as recorded. The steps have been used for the experiments. Testing the convention solar stills' performance has been the first step. The performance regarding the solar stills with porous balls as well as rowing arm (30 rpm) operating speeds was tested in the second phase of experiments. Under various operating conditions, the impact of change to the rowing filter on thermal performance related to the still has been examined (various operating durations of rowing filter belt and utilizing NPs). Through evaluating the behavior regarding the factors, like solar radiation, temperatures, and daily fresh-water yield, the current still performance is evaluated. In addition, the modified rowing filter solar still's performance is compared with that of the conventional still through testing.

The hourly temperatures as well as the solar intensity readings related to the solar stills without Aqua balls are shown in Fig. 4. The figure highlights a total of four points of observation. First, compared to a typical distiller, the temperature of the water inside wick basin is lower. This could be because direct solar ray still strikes the water from the regular solar system. With regard to the modified wick still, some of the solar rays are absorbed by wick material. At 1:00pm, water temperature in traditional distiller is approximately 8

C higher in comparison to that of the wick solar still. Second, around 3:00 pm, the conventional distiller's water temperature dropped substantially faster compared to wick solar still's. This is due to the fact that the presence of wick material over basin water causes a higher radiation-induced heat loss in the conventional still compared to that in modified distiller. With regard to the modified wick still, there is less heat loss as well as a slower rate of temperature decline. Third, at sunset, the water temperatures in the two systems are about comparable. Fourth, the temperature of the glass in modified still is higher compared to that in conventional still. Glass temperatures regarding the rowing filter solar still are approximately 0–2 C higher compared to those regarding the conventional still, as seen in Fig. 4 (0oC at 8:00am and 2oC at 1:00pm). This is due to the solar still's rowing filter producing high rates of evaporation and condensation. The next section will provide the justifications for raising the rates of condensation and evaporation. Figure 5 depicts the immediate fluctuations in the productivity related to the Aqua balls' basin stills. As seen, during the start of tests, productivity is at its lowest. This is because the water hasn't warmed up yet and is at room temperature. Following that, the modified as well as the traditional distillers' freshwater productivity begins to progressively rise with the increase in solar intensity, reaching 1000mL and 420mL at noon, respectively.

Furthermore, as Fig. 4 illustrates, freshwater productivity starts to decrease in the afternoon as a result of a decrease in solar radiation. As can be quantitatively seen in Fig5, the hourly distillate related to the rowing filter solar still is higher than that of traditional solar still. There are five basic arguments in support of this enhancement. The surface area regarding the rowing filter still that is prepared for absorbing the solar radiation is larger than that of conventional still, which is the primary reason. In contrast to conventional still, which has a surface area of just 0.5m2, the rowing filter still has a surface area of about 0.81m2 (0.35m2 for front vertical wick + 0.46m2 for the upper horizontal wick). The minimal quantity of saline water across the wick surface is the second explanation. Because of this, modified still's water evaporation rate is higher than that of the traditional basin still. Thirdly, because the modified rowing filter distiller has a larger surface area exposed to solar intensity, its evaporation rate is enhanced.

For instance, the rowing filter still has evaporative area of 1.17m2, whereas reference still's surface area of evaporation is 0.5m2 (the surface area of saline water in basin). The upper horizontal wick's 0.46 m2 plus front vertical wick's 0.35 m2 as well as the back vertical wick's 0.36m2 make up the evaporation area. Evaporation happens on both of the wick's surfaces since it is hanging between the pulleys. The total evaporation area could thus be calculated as 2_1.17 = 2.34 m2. The evaporation rate related to the modified solar distiller is higher than that of standard solar distiller. The fourth reason is that the solar still with rowing filter has a larger condensation area than a conventional basin still. For instance, condensation forms at the glass cover alone in a traditional still, but with regard to a modified distiller, condensation forms at the glass cover on four sides (the two sides, the top glass cover, and the back side, which serves as a condenser).

Furthermore, it is noted that the temperature on the glass's back side is 10 C lower compared to the temperature on the top glass cover due to the fact that the vertical wick belt that sits in front of it shields it from direct solar radiation. The high temperature differential between the glass and the water causes a high rate of condensation to form on the glass's back side, as can be seen. Moreover, it is observed that the modified distiller exhibits a lower rate of freshwater production decline compared to traditional distiller. The fifth reason is that the rowing filter belt disrupts the basin water surface's boundary layer, potentially boosting water evaporation (Elashmawy, 2020). Furthermore, this could be the result of wick belt's rotation impact, which changes free evaporation into forced evaporation and raises the rate of evaporation. Fig. 5 shows the hourly collected distillate regarding the solar distillers at BLENDING. Also, the rowing filter still yields more than the reference still, as was noticed. For the modified and reference distillers, the daily fresh-water distillate is 7080 and 2080mL/m2, respectively, with a 240% enhancement. This could be the result of water's thin coating decreasing the water mass's heat capacity. Additionally, utilizing wick materials increases the surface area of evaporation as well as the coefficients of heat transfer. Furthermore, in comparison with the reference still, the modified wick still's response to solar radiation is higher due to wick material's reduced thermal capacity. Next, the evaporation rates regarding the modified still are enhanced. Furthermore, the reference still's heat transfer rates between basin liner and water are inferior to those of modified wick still's between wick material and water. This increases the productivity of the output. Fig. 6 shows the hourly fluctuation in tested solar stills' blending productivity. The findings of the 30-minute OFF-peak time are chosen for this section since, as will be discussed in the following section, it produces the most freshwater, as seen in Figs. 9 and 10. The distillate exhibits a comparable tendency to that found in Fig. 5, albeit with different numbers, as can be seen in Fig. 6. The modified still's maximum productivity is 1110 mL, while the reference still's is 360 mL. Figure 6 shows the hourly aggregated output yield regarding the modified as well as standard solar stills at add Aqua balls. It can be seen that the rowing filter still has a higher yield than reference still. With a 300% improvement percentage, the reference and modified stills produce 2210 mL/m2 and 8780 mL/m2, respectively, on a daily basis.

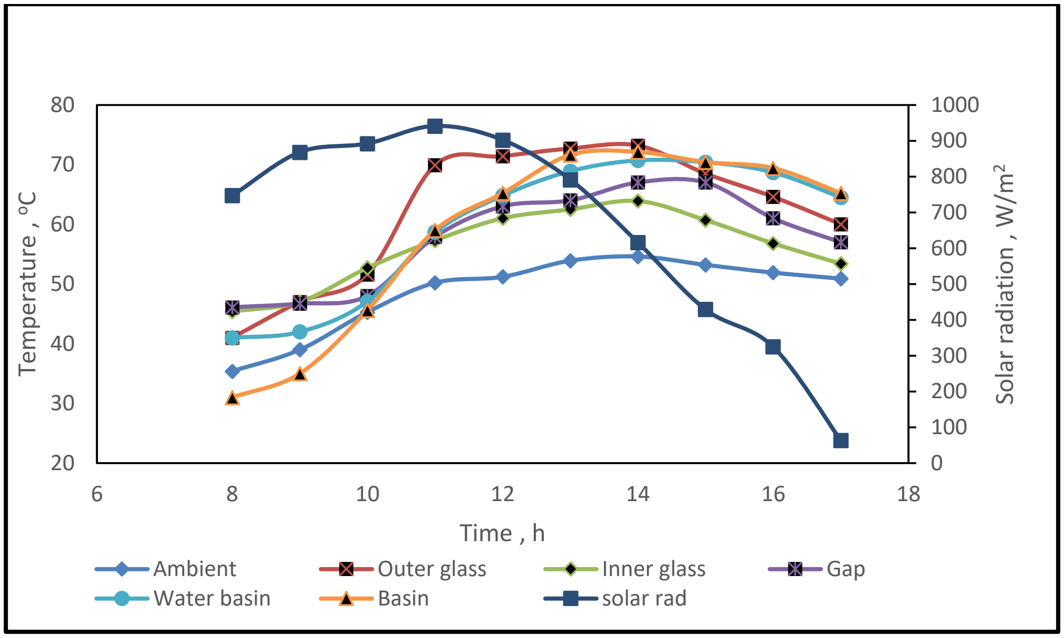

Figure 3. Hourly temperature and solar intensity fluctuations in the distillers with blending

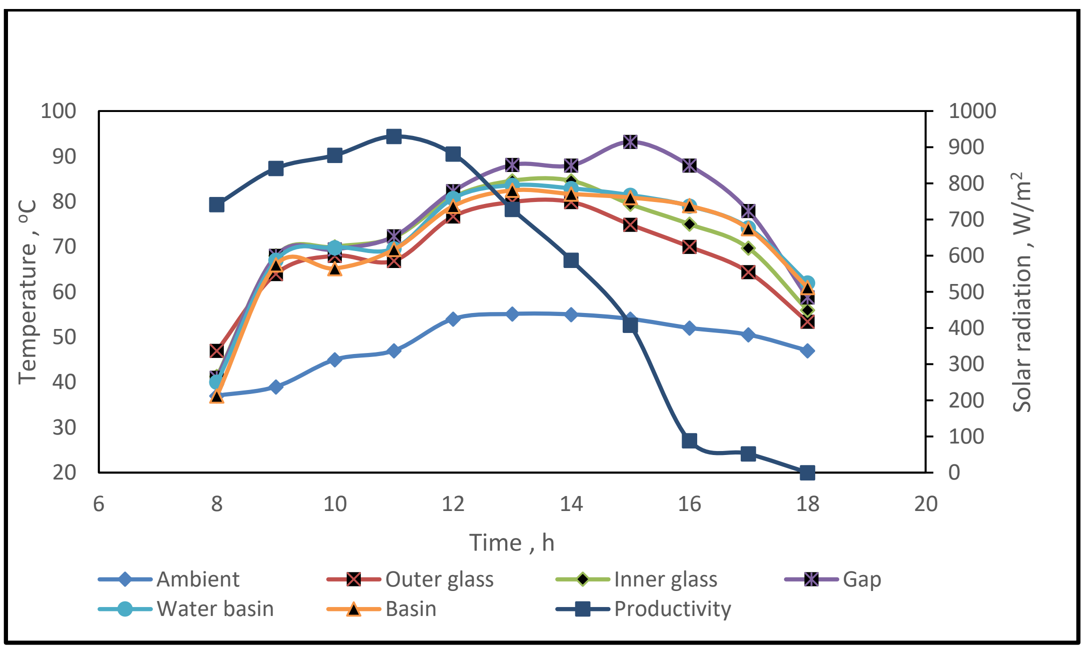

Figure 4. Hourly temperature and solar intensity fluctuations in the distillers with blending

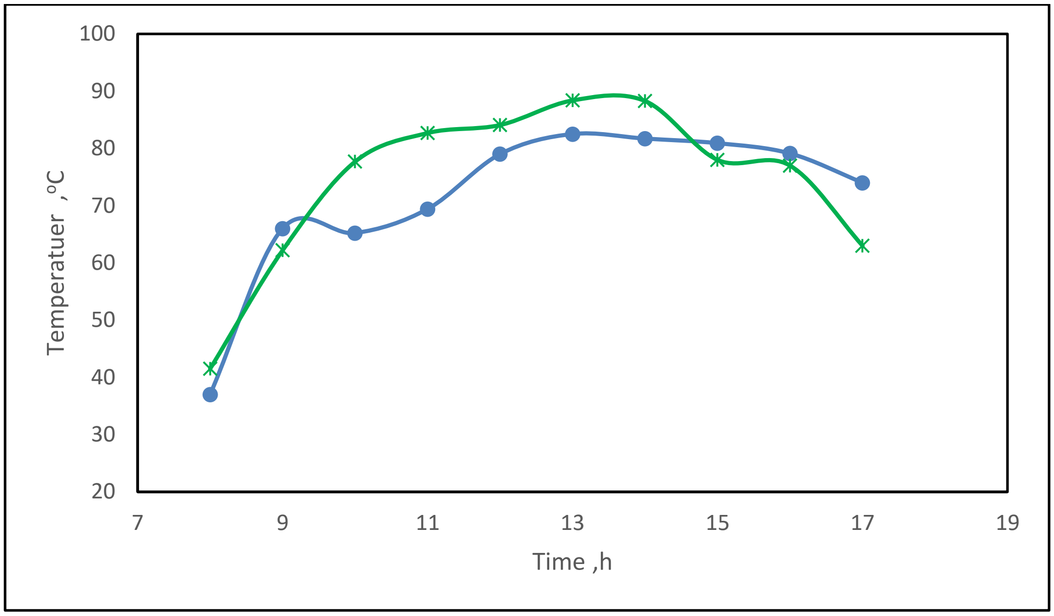

Figure 5. Comparison between daily distillate rise of modified distiller with and with no Aqua balls.

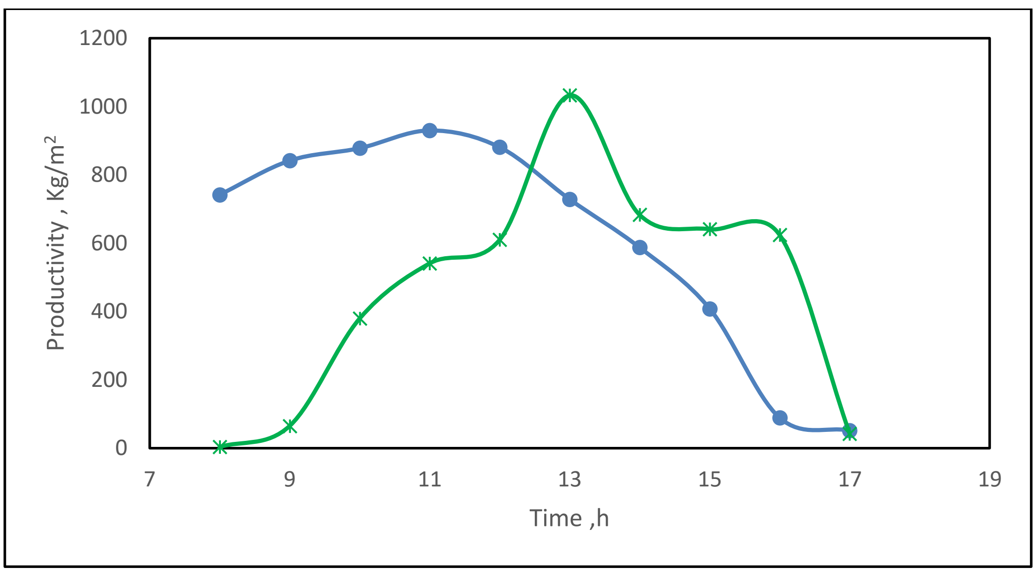

Figure 6. Hourly productivity fluctuations in the basin stills with the blending and comparing.

5. CONCLUSION

Solar still is a device used to obtain pure drinkable water depending on renewable energy. The principle of operation of the solar still is based on the evaporation and condensation of water the hydrologic cycle (rainfall cycle). In this study the performance of the solar stills with deferent conceptual design have been investigated the experimentations conducted under outdoors weather conditions. The theoretical investigation evaluates the enhancement possibilities of the solar still with stepped design by simulating the model in ANSYS – FLUENT 15 software. Then, the physical models were built, based on the results obtained from the simulation. The experimental part consists of constructing three solar stills: a conventional type solar still serves as a bench mark for the comparison with the other stills, two identical stepped solar stills the first without any modified and other stepped solar still with energy storage material (aqua ball) to enhance the productivity even more. These adding modifications were: aqua ball to investigate the effect of design and operating parameters on the productivity of the conventional and stepped solar still. The study found out that adding the aqua ball enhances the yield by 51.7% compared to the conventional type. The conventional stepped still (without any adding) of the current study produced on average (1075- 1335.7 Kg/m3).

REFERENCES

Abdel-Rehim, Z. S., & Lasheen, A. (2005). Improving the performance of solar desalination systems. *Renewable Energy*, *30*(13), 1955–1971.

Abdullah, A. S., Alarjani, A., Abou Al-sood, M. M., Omara, Z. M., Kabeel, A. E., & Essa, F. A. (2019). Rotating-wick solar still with mended evaporation technics: Experimental approach. *Alexandria Engineering Journal*, *58*(4), 1449–1459.

Abdullah, A. S., Essa, F. A., Omara, Z. M., Rashid, Y., Hadj-Taieb, L., Abdelaziz, G. B., & Kabeel, A. E. (2019). Rotating-drum solar still with enhanced evaporation and condensation techniques: comprehensive study. *Energy Conversion and Management*, *199*, 112024.

Abujazar, M. S. S., Fatihah, S., Ibrahim, I. A., Kabeel, A. E., & Sharil, S. (2018). Productivity modelling of a developed inclined stepped solar still system based on actual performance and using a cascaded forward neural network model. *Journal of Cleaner Production*, *170*, 147–159.

Elashmawy, M. (2020). Experimental study on water extraction from atmospheric air using tubular solar still. *Journal of Cleaner Production*, *249*, 119322.

Gad, H. E., El-Gayar, S. M., & Gad, H. E. (2011). Performance of a solar still with clothes moving wick. *15th International Water Technology Conference, IWTC*, 28–30.

Haddad, Z., Chaker, A., & Rahmani, A. (2017). Improving the basin type solar still performances using a vertical rotating wick. *Desalination*, *418*, 71–78.

Holman, J. (2012). *Experimental methods for engineers*. McGraw-Hill New York.

Kabeel, A. E. (2009). Performance of solar still with a concave wick evaporation surface. *Energy*, *34*(10), 1504–1509.

Kabeel, A. E., Hamed, M. H., & Omara, Z. M. (2012). Augmentation of the basin type solar still using photovoltaic powered turbulence system. *Desalination and Water Treatment*, *48*(1–3), 182–190.

Kabeel, A. E., Omara, Z. M., & Essa, F. A. (2014a). Enhancement of modified solar still integrated with external condenser using nanofluids: An experimental approach. *Energy Conversion and Management*, *78*, 493–498.

Kabeel, A. E., Omara, Z. M., & Essa, F. A. (2014b). Improving the performance of solar still by using nanofluids and providing vacuum. *Energy Conversion and Management*, *86*, 268–274.

Malaeb, L., Aboughali, K., & Ayoub, G. M. (2016). Modeling of a modified solar still system with enhanced productivity. *Solar Energy*, *125*, 360–372.

Omara, Z. M., Abdullah, A. S., & Dakrory, T. (2017). Improving the productivity of solar still by using water fan and wind turbine. *Solar Energy*, *147*, 181–188.

Omara, Z. M., Hamed, M. H., & Kabeel, A. E. (2011). Performance of finned and corrugated absorbers solar stills under Egyptian conditions. *Desalination*, *277*(1–3), 281–287.

Omara, Z. M., Kabeel, A. E., Abdullah, A. S., & Essa, F. A. (2016). Experimental investigation of corrugated absorber solar still with wick and reflectors. *Desalination*, *381*, 111–116.

Omara, Z. M., Kabeel, A. E., & Essa, F. A. (2015). Effect of using nanofluids and providing vacuum on the yield of corrugated wick solar still. *Energy Conversion and Management*, *103*, 965–972.

PROFILE OF THE AUTHORS

Mohammed Qasim Hadi: Obtained a Master's degree in Material Sciences Engineering and Technology of Materials from Saint-Petersburg State Technical University of the Ministry of Education and Science of the Russian Federation. Currently serving as a lecturer assistant at Thi Qar University.

Mutaz H. Taher: Holds a Master's degree in Materials Engineering from UTM and currently works as a lecturer assistant at Thi Qar University. futhermore working asa Manager of the Department of Bureau Affairs at Thi Qar University.

Zainalabden A. Ibrahim: holds a master's degree in mechanical engineering and currently works at the Presidency of Thi Qar University. Futhermore, Deputy of the Department of Bureau Affairs and graduate of the College of Engineering at Thi Qar University.