Scholars Bulletin *(Engineering)*
An Official Publication of "Scholars Middle East Publishers"
Dubai, United Arab Emirates
Website: http://scholarsbulletin.com/
ISSN 2412-9771 (Print)
ISSN 2412-897X (Online)

Enhancing the Productivity of a Single Slope Solar Water Distiller by Cooling the Transparent Cover

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Article History
Received: 05.01.2018
Accepted: 20.01.2018
Published: 30.01.2018

DOI:
10.21276/sb.2018.4.1.11

Abstract: Water distillation and provision of drinking water takes a high percentage of electricity generated in many countries of the world. Solar distillation benefits from the sun's free energy in purifying salty or contaminated water and making it drinkable. In this study, a single distillation was produced and a distillate production was studied in the Spring of Baghdad-Iraq in 2017. A fan used to cool the glass cover was used at 12 noon. In other experiments, the lid was sprayed with water to cool. The results showed that the cooling of the glass cover in both methods caused the distillation of the distillate yield, but in the case of water, the improvement was greater.
Keywords: Solar distillation, fan, glass cover, single slope still..

ITRODUCTION

All the peoples and countries of the world suffer from climate change due to the phenomenon of the greenhouse, causing dehydration and increase the salinity of fresh water [1, 2]. The phenomenon of climate change has become a reality and tangible [3]. The most important cause of this phenomenon is human intervention in the environment. Human activities such as the burning of fossil fuels such as oil, gas, and coal caused the increase of carbon dioxide in the air, causing the phenomenon of the greenhouse that resulted in climate change [4]. The fossil fuel itself has become a major problem that threatens the economic security of both producing and exporting countries because of fluctuating price, causing a major economic recession in recent years [5].

Reducing the use of fossil fuels for energy production is very possible by turning into renewable and environmentally friendly energy sources. Wind power can be used to produce electricity [6]. The use of biofuels represents an important alternative to fossil fuels in energy production and operation of vehicles as well [7]. Solar energy can be used in many ways to produce energy either through solar chimneys [8, 9], concentrated plants [10, 11], or using solar cells [12-17].

Water is the largest part of the earth and at the same time of the human body, which it needs for its life and also for the life of plants and animals; it needs for domestic, industrial and agricultural purposes [18]. Although water covers up to 70% of the globe, drinking water has only a negligible proportion and does not exceed only 0.62% of the world's water [19]. The world's drinking water resources are small and unevenly distributed. As the world's population grows rapidly, the lack of water is becoming a worrying problem [20].

The desalination process is carried out using high energy, which constitutes a large part of the energy produced, as in a country such as Saudi Arabia it reaches 22% of the production. The growth in demand for potable water means increased demand for energy followed by an increase in burning fossil fuels and an increase in environmental problems and air pollution and poor quality [21-23]. The use of renewable energies in water distillation is a possible and promising solution [24, 25].

Solar energy is clean, free, and available almost everywhere. This energy is environmentally friendly and does not cause bad emissions [26]. Direct solar distillation can be an ideal solution to the freshwater problem in a country such as Iraq [27]. Although this country is one of the world's richest oil and gas reserves, it suffers from significant environmental pollution [28]. Four decades of mismanagement, successive wars and economic blockade have caused the country's environmental degradation to deteriorate [29]. Besides, all the infrastructure of the power generation were damaged and lack to maintenance, which made the electricity provided stopped several times in the day [30]. Also, the lack of processing of electricity and intermittent interruption made the Iraqi citizen to the use of personal and collective generators that are fueled with gasoline and diesel, which increased the air pollution and increased the environment deterioration [31-33].

Switching to produce power whether electric or thermal from the sun, is today a major alternative to reducing environmental damage for nearly half a century [34].

Iraq is fully qualified to use solar energy because the average daily solar intensity is between 700-1050 W/m and the hours of sunlight ranging from 3000 to 3500 hours/year, with an accident power of 5-6 kWh/day [35]. The use of solar distillates with simple technology does not require high competencies and skills in design, manufacturing, operation and maintenance [36].

The simple single slope solar distiller is used to purify salt and brackish water and convert it into potable water; it is very simple technique both on the construction or operation [37]. However, what distinguishes this type of distillate is a low production that does not exceed 2 to 5 liter/m^2/day only. This productivity makes this system not economical [38].

Many researchers have tried to increase the productivity of this type of distillate using multiple methods. The methods are used to increase the stored thermal energy as Ref. [39] who used hot water from a solar saline pond to improve the productivity of a simple distiller. Ref. [40] stored heat as a latent heat using paraffin wax as a phase change material (PCM) in the base and sides of the distiller. This process increased the distillate yield and increased its working hours by two hours after sunset. The latent thermal energy storage in the distillates still faces many disadvantages such as high cost, low thermal conductivity, and stability of the physical properties of the variable-phase material after many melting and freezing cycles [41, 42].

Ref. [43] tried to increase the thermal conductivity of the PCM by adding the aluminum powder to the paraffin wax. While Ref. [44] used a solar concentration system, with the addition of paraffin wax of the distiller. In both cases, the productivity of the distillates used increased compared to a simple solar distiller, but the researchers in both studies did not study the stability of the PCM with long-term use.

The most disadvantages related to using solar energy are the impact of climate conditions on its application as the variation in the wavelengths of the solar radiation [45, 46], dust deposition [47] and humidity [48]. In this study, we will try to increase the productivity of a simple solar distiller by cooling the glass cover by air and water. The aim of this study is to introduce simple method to enhance the productivity of the still without the need for additional costs.

Expermental setup

A simple single slope solar distiller with a horizontal basin made of galvanized iron was constructed. The length of the base is 1 m and the width is 0.5 m, and the height from the end is 36 cm. A small channel was connected to collect the distilled water from the transparent lid and tilt it on the distilled sides. The height of the front edge is 11 cm height; the glass cover tilts from the horizon at a 30 degree angle. To ensure that the steam inside the distillator is fully stored and to prevent leakage, plastic filler with a width of 1 cm and a thickness of 3 mm was used. The silicone material is added to the plastic fill to ensure that the generated vapor is not released. The glass cover is placed on fillers. The interior surface of the tub has been painted in glossy black to increase the absorption of solar energy.

The distilled water from the transparent lid was collected in a slanting assembly channel. Four thermocouples were installed on each side of the transparent envelope and their average readability was taken to represent the temperature of the transparent cover. Distilled water is discharged from the distiller through a fixed opening on one side of it. This hole is connected to a 1.27cm (1/2 inch) polyethylene tube that is extended inside the assembly channel to ensure that the steam stays without leaking out. The metal still was placed inside a wooden box made of 2 cm thick slabs. Glass wool was used to isolate the aquarium thermally. A fan (6 in dia. and 120 W) was used to cool the distiller's transparent cover.

Many thermocouples type K were used to measure variable temperatures within the distiller, and these thermocouples were calibrated in the laboratory. Because the temperature of the transparent cover is very important in this study, four thermocouples were distributed on the lid, two on the outside and two on the inner surface. The average readings of the thermocouples were taken as the temperature of the cover. Another thermocouple was also installed in the galvanized wall of the distillation tank to measure its temperature, and another thermocouple in the brackish water inside the basin. The water temperature from the tank to the distillator was measured by the constant mercury thermometer in the conduction tube. The heat of the external atmosphere was done using a mercury scale thermometer fixed in the shade.

The distiller connected to a tank containing contaminated water and the distiller was fixed facing to the south. A float was used to adjust the water flow rate to the desired value and to maintain a constant flow of water so that the basin remained at a height of 1 cm. Different temperatures and distillates were measured and measured at intervals of one hour. The quantities of water collected by a 2 liter vessel were measured from the beginning of the new day.

The following equations were used in calculating convection and evaporation energies [49, 50, 51]:

Radiation energy (q_r) evaluated by the equation:

$$q_r = \varepsilon_w \sigma \left(T_B^4 - T_s^4\right) \quad W/m^2 \qquad (1)$$

Convection energy (q_c) evaluated by the equation:

$$q_c = 0.884\left[(T_B - T_{Cm}) + \frac{(P_B - P_{Cm}) \times T_B}{268 \times 10^3 - P_B}\right]^{\frac{1}{3}} (T_B - T_{Cm}) \ \frac{W}{m^2} \qquad (2)$$

Evaporation energy (qe) evaluated by the equation:

$$q_e = 4.52 \times 10^{-3} \left[q_c \ \frac{P_B - P_{Cm}}{T_B - T_{Cm}}\right] \quad W/m^2) \qquad (3)$$

The Heat transferred from the transparence cover to the surrounding by convection and radiation evaluated by the equation:

$$q_{ca} = h_{ca}\left(T_g - T_a\right) + \varepsilon_g \sigma \left(T_g^4 - T_a^4\right) \ W/m^2 \qquad (4)$$

The hourly efficiency (η_h) evaluated by the equation:

$$\eta_h = \frac{P \times h_{fs}}{I \times A} \qquad (5)$$

Test procedure

A single slope simple solar distiller was constructed and its performance was tested springtime of Baghdad city-Iraq, 2017. Three cases were tested, which are:

Case 1: simple solar distiller, which considered the base of comparison.

Case 2: simple solar distiller, which its glass cover was cooled by means of a fan, starting From 12 PM till sunset.

Case 3: simple solar distiller, which its glass cover was cooled by water, starting from 12 PM till sunset.

RESULTS AND DISCUSSIONS

Solar distillate production of a single type is considered one of the simplest types of distillates. Solar distillates are affected by weather factors, ambient temperature, solar radiation intensity, wind speed, and relative humidity.

Figure 1 show distiller productivity distribution of the three studied cases during the day. According to literature, the productivity of distillation increases from zero (l/m^2) and peaks at 2 p.m. and then decreases to zero at sunset. However, as shown in Figure 1, distillate production decreased at 12 am and continued to decrease during the next two hours, rising relatively at 3 p.m. This situation led to a decrease in distillate production as it is expected to be the highest productivity during this period. This subject was studied in detail by the Ref. [20]; the researcher has shown that the reason for low productivity at this period is the high temperature of the transparent cover, which prevents steam condensation or impedes it causing this situation. The use of the fan and water to cool the transparent lid has increased the productivity of the simple solar distillation. The yield of solar distillate has increased by 9% and 22% compared to the first case. This result is expected, as the cooling the transparent cover increases the temperature difference between the evaporator (the basin) and the condenser (glass cover). This increase causes an increase in the distillate production as confirmed by the Ref. [27].

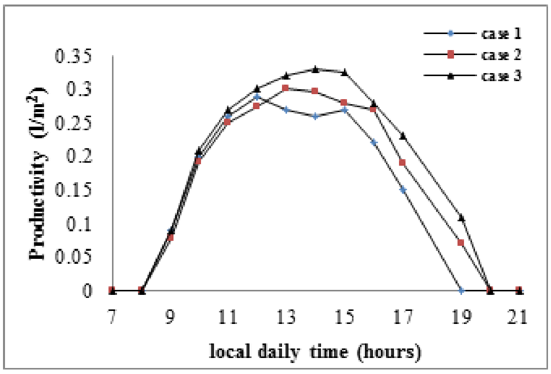

Fig-1: the studied distillers' productivity during the day

The distiller depends on solar radiation in its work, as the solar intensity increases, the metal basin temperatures will increase, then the transferred energy from this metal basin to the brackish water will be increased causing higher evaporation, and more energy will be transferred to the transparence covers (which stayed almost cooler) by condensation process. Figures 2 and 3 show that Q_e and Q_C will be increased during the day as well as cooling the transparent cover will increase these energies by enhancing the condensation process.

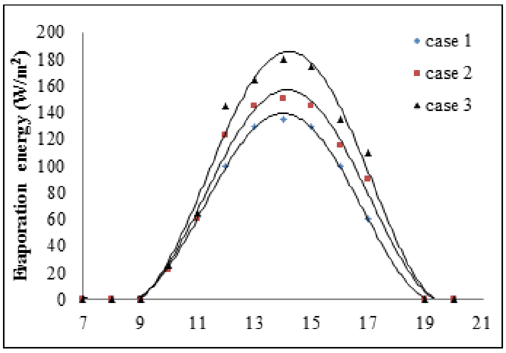

Fig-2: distillers' evaporation energy distribution through the day

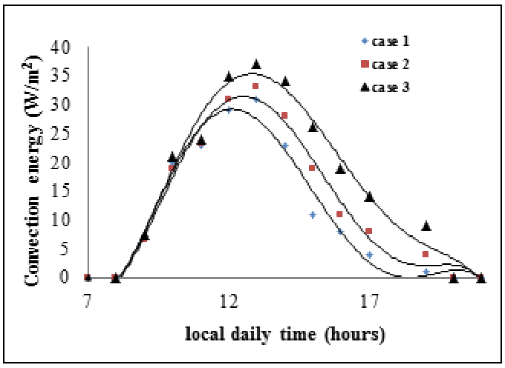

Fig-3: Convection energy distribution through the day

The increase in evaporation and condensation processes will lead to an increase in the transparent cover temperature, the difference between the cover and air temperature will be increased causing higher heat transfer from the cover to the surrounding.

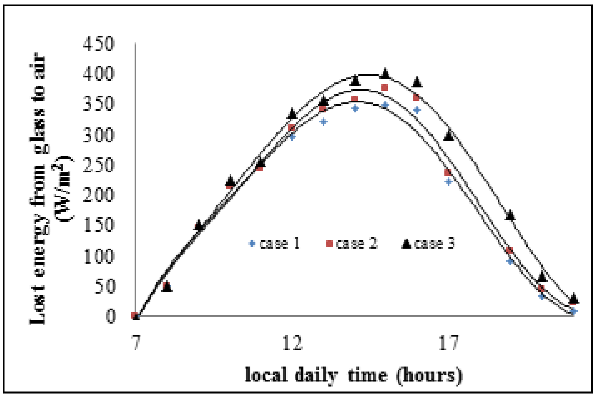

Fig-4: lost energy from the glass covers to the air during the day

This process leads to higher Q_{ca}. The more distillate productivity the more heat gained by the transparence cover and more Q_{ca} to the surroundings with vapor condensation rising. By this process, the heat gained in the condensation process will be dispersed by the cover. The cover disperses this heat to the ambient air, and the cooler air means better dispersion. In the case if the air temperature is high, then the transferred energy from the cover to the air will reduce affecting the condensation process causing lower productivity. Using the fan and water enhanced the heat transferred from the transparency cover to air.

Figure 5 shows the system hourly efficiency distribution during the day. The systems hourly efficiency depends mainly on the solar intensity variation and the condensation process. As the figure reveals, the hourly efficiency of the system reduce the interval from 12 to 2 p.m. while using fan cooling or water cooling enhances the system efficiency clearly.

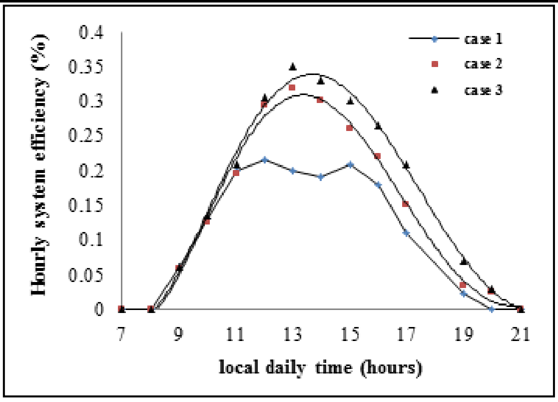

Fig-5: the distiller hourly efficiency distribution through the day

CONCLUSIONS

In this experimental work, the aim was focused on increasing the productivity of a simple single slope solar distiller by cooling the transparent cover of the distiller. The cooling was done using forced air moving by means of a fan, and using water cooling. The study conclusions can be summarized by the following:

The productivity of the simple solar distiller used in the tests was enhanced by cooling the transparent cover with fan and water after 12. The distiller productivity is related mainly to the solar radiation variation during the daytime, also, the evaporation and convection energies increased and reduced according to the solar radiation behavior. The transparent cover temperature increases because of condensation process; this increase turns into an obstacle to condensation if the lid does not cool.

REFERANCES

1. Al-Maamary, H. M. S., Kazem, H. A. & Chaichan, M. T. (2016). Changing the energy profile of the GCC States: A review. International Journal of Applied Engineering Research (IJAER), 11(3), 1980-1988.
2. Yaseen, B. R., Al-Asady, K. A., Kazem, A. A., Chaichan, M. T. (2016). Environmental impacts of salt tide in Shatt al-Arab-Basra/Iraq. IOSR Journal of Environmental Science, Toxicology and Food Technology, 10(1-2), 35-43. DOI :10.9790/2402-10123543
3. Al-Maamary, H. M. S., Kazem, H. A., Chaichan, M. T. (2017). Climate change: the game changer in the GCC region. Renewable and Sustainable Energy Reviews, 76, 555-576. http://dx.doi.org/10.1016/j.rser.2017.03.048.
4. Chaichan, M. T., Al-Hamdani, A. H., Kasem, A. M. (2016). Enhancing a Trombe wall charging and discharging processes by adding nano-Al2O3 to phase change materials. International Journal of Scientific & Engineering Research, 7(3), 736-741.
5. Al-Maamary, H. M. S., Kazem, H. A., Chaichan, M. T. (2017). The impact of the oil price fluctuations on common renewable energies in GCC countries. Renewable and Sustainable Energy Reviews, 75, 989-1007.
6. Kazem, H. A., Chaichan, M. T. (2017). Wind resource assessment for nine locations in Oman. International Journal of Computation and Applied Sciences IJOCAAS, 3(1), 185-191.
7. Chaichan, M. T. & Ahmed, S. T. (2013). Evaluation of performance and emissions characteristics for compression ignition engine operated with disposal yellow grease. International Journal of Engineering and Science, 2(2), 111-122.
8. Chaichan, M. T. & Kazem, H. A. (2011). Thermal storage comparison for variable basement kinds of a solar chimney prototype in Baghdad - Iraq weathers. International journal of Applied Science (IJAS), 2(2), 12-20.
9. Ahmed, S. T. & Chaichan, M. T. (2011). A study of free convection in a solar chimney sample. Engineering and Technology Journal, 29(14), 2986-2997.
10. Chaichan, M. T. & Abass, K. I. (2012). Practical investigation for improving concentrating solar power stations efficiency in Iraqi weathers. Anbar J for Engineering Science, 5(1), 76-87.
11. Chaichan, M. T., Abass, K. I., Kazem, H. A., Al-Jibori, H. S. & Abdul Hussain, U. (2013). Novel design of solar receiver in concentrated power system. International J. of Multidispl. Research & Advcs. in Eng. (IJMRAE), 5(1), 211-226.
12. Al-Waeli, A. H. A., Sopian, K., Kazem, H. A. & Chaichan, M. T. (2017). PV/T (photovoltaic/thermal): Status and future prospects. Renewable and Sustainable Energy Review, 77, 109-130.
13. Al-Waeli, A. H. A., Kazem, H. A., Sopian, K. & Chaichan, M. T. (2017). Techno-economical assessment of grid connected PV/T using nanoparticles and water as base-fluid systems in Malaysia. International Journal of Sustainable Energy. DOI: 10.1080/14786451.2017.1323900
14. Al-Waeli, A. H. A., Chaichan, M. T., Kazem, H. A., Sopian, K. (2017). Comparative study to use nano-(Al2O3, CuO, and SiC) with water to enhance photovoltaic thermal PV/T collectors.

Energy Conversion and Management, 148(15), 963-973.
15. Al-Waeli, A. H. A., Sopian, K., Chaichan, M. T., Kazem, H. A., Ibrahim, A., Mat, S. & Ruslan, M. H. (2017). Evaluation of the nanofluid and nano-PCM based photovoltaic thermal (PVT) system: An experimental study. Energy Conversion and Management, 151, 693-708.
16. Al-Waeli, A. H. A., Al-Mamari, A. S. A., Al-Kabi, A. H. K., Chaichan, M. T., Kazem, H. A. (2016). Evaluation of the economic and environmental aspects of using photovoltaic water pumping system. 9th International Conference on Robotic, Vision, Signal Processing & Power Applications, Malaysia.
17. Al-Waeli, A. H. A., Sopian, K., Kazem, H. A. & Chaichan, M. T. (2017). Photovoltaic thermal PV/T systems: A review. International Journal of Computation and Applied Sciences IJOCAAS, 2(2), 62-67.
18. Maroo, S. C. (2006). Theoretical analysis of solar driven flash desalination system based on passive vacuum generator. M Sc. Thesis, University of Florida, USA.
19. Toufic, M., Hassan, F., Zeina, A. & Arslan, K. (2011). Techno-economic assessment and environmental impacts of desalination technologies. Desalination, 266, 263-273.
20. Chaichan, M. T. (2016). Enhancing productivity of concentrating solar distillating system accompanied with PCM at hot climate. Wulevina, 23(5), 1-18.
21. Joseph, J., Saravanan, R. & Renganarayanan, S. (2010). Studies on a single-stage solar desalination system for domestic applications. Desalination, 173, 77-82.
22. Funsho, A. M., Hashim, H. & Edris, P. (2010). Distributed energy resources and benefits to the environment. Renewable and Sustainable Energy Reviews, 14, 724–734.
23. Kalogirou, S. A. (2005). Seawater desalination using renewable energy sources. Progress in Energy and Combustion Science, 31(3), 242-281.
24. Chaichan, M. T., Kazem, H. A., Abass, K. I., Al-Waeli, A. A. (2016). Homemade solar desalination system for Omani families. International Journal of Scientific & Engineering Research, 7(5), 1499-1504.
25. Bogdan, M. D., Szabolcs, V. & Armando, C. O. (2010). Experimental study of natural convection heat transfer in microencapsulated phase change material slurry, Energy, 35, 2688-2693.
26. Yoshiyuki, S., Tomo, O., Yohei, Y., Yukio, Y., Ayako, T. & Takao, M. (2010). City-level energy and CO2 reduction effect by introducing new residential water heaters, Energy, 35(12), 4880-4891.
27. Abass, K. I. (2005). Distillation enhancement using solar water heater. M. Sc. Thesis, University of Technology, Baghdad, Iraq.
28. Kazem, A. A., Chaichan, M. T. & Kazem, H. A. (2014). Effect of dust on photovoltaic utilization in Iraq: review article. Renewable and Sustainable Energy Reviews, 37, 734-749.
29. Alwaely, A. A., Al-qaralocy, H. N., Al-Asadi, K. A., Chaichan, M. T., Kazem, H. A. (2015). The environmental aftermath resulted from chemical bombardment of Halabja Territory for the period 1988-2014. International Journal of Scientific & Engineering Research, 6(9), 40-44.
30. Chaichan, M. T. & Kazem, H. A. (2012). Status and future prospects of renewable energy in Iraq. Renewable and Sustainable Energy Reviews, 16(1), 6007–6012.
31. Al-Waeely, A. A., Salman, S. D., Abdol-Reza, W. K., Chaichan, M. T., Kazem, H. A. & Al-Jibori, H. S. S. (2014). Evaluation of the spatial distribution of shared electrical generators and their environmental effects at Al-Sader City-Baghdad-Iraq. International Journal of Engineering & Technology IJET-IJENS, 14(2), 16-23.
32. Chaichan, M. T., Kazem, H. A., Abid, T. A. (2016). The environmental impact of transportation in Baghdad, Iraq. Environment, Development and Sustainability. DOI: 10.1007/s10668-016-9900-x.
33. Chaichan, M. T. and Al-Asadi, K. A. H. (2015). Environmental impact assessment of traffic in Oman. International Journal of Scientific & Engineering Research, 6(7), 493-496.
34. Chaichan, M. T., Abass, K. I. (2015). Performance amelioration of a Trombe wall by using phase change material (PCM), International Advanced Research Journal in Science, Engineering and Technology, 2(4), 1-6.
35. Chaichan, M. T., Kazem, H. A., Kazem, A. A., Abass, K. I., Al-Asadi, K. A. H. (2015). The effect of environmental conditions on concentrated solar system in desertec weathers. International Journal of Scientific and Engineering Research, 6(5), 850-856.
36. Murugavela, K., Chockalingama, K., Sritharb, K. (2008). Progresses in improving the effectiveness of the single basin passive solar still. Desalination, 220, 677–686.
37. Srithar, K. & Mani, A. (2004). Analysis of a single cover FRP flat plate collector for treating tannery effluent. Appl. Therm. Eng., 24, 873–883.
38. Kazem, H. A., Aljibori, H. S., Hasoon, F. N. & Chaichan, M. T. (2012). Design and testing of solar water heaters with its calculation of energy. Int. J. of Mechanical Computational and Manufacturing Research, 1(2), 62-66.
39. Chaichan, M. T. & Abass, K. I. (2012). Productivity amelioration of solar water distillator linked with salt gradient pond, Tikrit Journal of Engineering Sciences, 19(4), 24-34.
40. Chaichan, M. T., Abass, K. I., Kazem, H. A. (2016). Design and assessment of solar concentrator distillating system using phase

change materials (PCM) suitable for desertec weathers. Desalination and water treatment, 57(32), 14897-14907. DOI: 10.1080/19443994.2015.1069221

41. Ki-bum, K., Kyung-wook, C., Young-jin, K., Ki-hyung, L. & Kwan-soo, L. (2010). Feasibility study on a novel cooling technique using a phase change material in an automotive engine. Energy, 35, 478-484.
42. Francis, A., Neil, H., Philip, E. & Mervyn, S. (2010). A review of materials, heat transfer, and phase change problem formulation for latent heat thermal energy storage systems (LHTESS). Renewable and Sustainable Energy Reviews, 14, 615–628.
43. Chaichan, M. T. & Kazem, H. A. (2015). Using aluminum powder with PCM (paraffin wax) to enhance single slope solar water distillator productivity in Baghdad-Iraq winter weathers. International Journal of Renewable Energy Research, 1(5), 151-159.
44. Chaichan, M. T. & Kazem, H. A. (2015). Water solar distiller productivity enhancement using concentrating solar water heater and phase change material (PCM). Case Studies in Thermal Engineering, Elsevier, 5, 151-159.
45. Kazem, H. A. & Chaichan, M. T. (2016). The impact of using solar colored filters to cover the PV panel on its outcomes. Bulletin Journal, 2(7), 464-469. DOI: 10.21276/sb.2016.2.7.5.
46. Kazem, H. A., Yousif, J. H., Chaichan, M. T. (2016). Modeling of daily solar energy system prediction using support vector machine for Oman. International Journal of Applied Engineering Research, 11(20), 10166-10172. Kazem, H. A. & Chaichan, M. T. (2016). Experimental effect of dust physical properties on photovoltaic module in northern Oman. Solar Energy, 139, 68-80. http://dx.doi.org/10.1016/j.solener.2016.09.019
47. Kazem, H. A. & Chaichan, M. T. (2016). Experimental effect of dust physical properties on photovoltaic module in northern Oman. Solar Energy, 139, 68-80.
48. Lof, G. O. G. (1960). Design and operating principles in solar distillation saline water (conversion). Adr. Chem. Serial No. 27, 156 - 165.
49. Cooper, P. I. (1973). The maximum efficiency of single effect solar stills, solar Energy, 15, 205-217.
50. Sayigh, A. A. M. (1977). Solar energy engineering, Academic press. New York, Ch. 20, 431-464.