Int. J. Nonlinear Anal. Appl.
Volume 12, Special Issue, Winter and Spring 2021, 1355-1366
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2021.5712

Study of optimum performance of solar still process under weather conditions of Baghdad

Rana Mohammed Rasheed[a,*], Shmoos Abd Al Sattar Jabbar[a], Nada Mahdi AL Hussiny[b], Ahamed Mohammed Rasheed[c]

[a] *Civil Engineering Department, Al–Esraa university college, Baghdad, Iraq*
[b] *Building and Project Management Department, Al–Esraa university college, Baghdad, Iraq*
[c] *Refrigeration and Air-Conditioning Engineering Department, Middle Technical University, Baghdad, Iraq*

(Communicated by Madjid Eshaghi Gordji)

Abstract

The solar still method desalinates salt water by using direct solar radiation from the sun. It operates on the evaporation and condensation concept. The tenant is a water basin (which receives the seawater) that is fully insulated on all sides and sealed with a clear glass top that allows solar energy to enter. When a sunbeam strikes the salt water in the basin, evaporation occurs, resulting in vapor rising to the top and being caught by the cover glass above the sink; therefore, condensate develops on the bottom of the cover glass and is collected as the distillate. The purpose of this project is to determine the performance of solar still under real weather conditions of Baghdad. In this work, a single slop type of solar still has fabricated and tested during April-May under outdoor weather conditions in Baghdad. The results of the experimental demonstration show that the daily production of fresh water by solar still with area (0.3375) (m^2) is about (800 ml).

Keywords: Solar energy, solar radiation, evaporation & condensation process.

1. Introduction

Humans need clean water on a daily basis, and this would be impossible without aquatic life. Provision of safe drinking water is becoming an increasingly pressing problem in many parts of the

*Corresponding author

Email addresses: rana.mohamed@esraa.edu.iq (Rana Mohammed Rasheed), shmoos@esraa.edu.iq (Shmoos Abd Al Sattar Jabbar), nad@esraa.edu.iq (Nada Mahdi AL Hussiny), ahmedmohammedr8@yahoo.com (Ahamed Mohammed Rasheed)

Received: February 2021 *Accepted:* August 2021

globe. Global population expansion, along with increased industrial and agricultural activity, contributes to the depletion and contamination of fresh water supplies. Drought and desertification are likely to exacerbate the issue globally [5].
It cannot be emphasized how critical it is to provide clean drinking water. Water is a plentiful natural resource that accounts for three-quarters of the Earth's surface area. However, only approximately 3% of all water sources are considered to be safe to drink. Humans have access to less than 1% of fresh water; the remainder is snow. Even this tiny fraction (groundwater, lakes, and rivers) is believed to be enough to sustain life and vegetation on Earth. 30% of fresh water is found underground, mostly in deep, difficult-to-reach aquifers. Together, lakes and rivers comprise little more than 0.25 percent of fresh water; lakes hold the majority of them [3].
Groundwater is the only source of drinking water in remote and arid regions. Potable water is very rare in dry areas, and the ability of these regions to support human habitat is highly dependent on how this water is supplied. In certain instances, the salinity of the water is likely to be too high to qualify as fresh drinking water; instead, it is referred to as salt water. The salinity of brackish water varies geographically. In such situations, fresh water must be carried great distances or linked to a costly water distribution network, which imposes a significant financial burden on a limited number of people. Nowadays, contamination of rivers and lakes as a result of industrial waste and sewage disposal has resulted in a shortage of fresh water in a number of megacities and cities worldwide [1].
Salinity is a critical feature in this study. Generally, salinity is represented in parts per million (ppm). Excessive issues result in taste problems, gastrointestinal discomfort, and laxative consequences. The World Health Organization (WHO) recommends a maximum salinity of 500 mg/liter or parts per million (PPM) in drinking water [15].
The rapidly increasing energy demand and environmental concerns have shifted the emphasis to renewable energy sources. Sun energy is more cost effective than fossil fuels in distant regions with limited population, little rainfall, and plentiful solar energy. Simple solar energy may still provide people without access to drinking water with water for consumption and cooking. Distilled water may also be utilized in industrial applications due to its superior health benefits. It is a straightforward procedure that may be performed by untrained people. Additionally, since it requires less maintenance, it may be utilized anywhere with fewer issues. Solar water desalination still has a significantly lower solar energy productivity of just 2-5 L/m^2/day than other conventional desalination systems. The difficulty is determining how to increase the quantity of water produced by solar stills [12].
Various factors influence the solar distillation process's efficiency and productivity. Variable solar array designs, such as water depths, salt content, and position, may improve the pace of distilled water production, various absorbers, and evaporation techniques. In this context, the rate of evaporation of distilled water is enhanced by the use of solar energy that still consists of copper plates rather than cast iron. Additionally, efforts are being made to improve water productivity by painting the aquarium black and incorporating solar thermal storage materials such as tiny stones into the water.

2. Related Work

(Anwar and Deshmukh, 2020) [4], they say, people are acquainted with the potential for renewable energy from the birth of humanity. The sun, which is the primary source of energy, has been esteemed at many places of the world such as Greek, Incas, Egypt, and India from the prehistoric time.
(Porta-Gandara et al., 2020) [13], they concluded that solar energy still works like the water cycle of nature. It consists of a brine basin, an absorbing plate for water evaporation, a supporting structure, a steam condensing glass cover, a distillate collection basin and an insulation. Single-slope basin and

basin are still widely known as conventional or conventional solar distillation.
El-Ghetany et al. 2021, [7], they found that the system could produce distilled water 5616 L/day, 6048 L/day, 6134 L/day and 7128 L/day if TiO_2 was used at a concentration of 0 mg/L, 75 mg/L, 80 mg/L and 100 mg/L, respectively. The experimental pilot unit was installed at the Solar Energy Department, National Research Center, and Giza, Egypt. Several test runs are performed to measure all the particular parameters that affect system performance. The tested system can make a positive contribution to desalination units especially in rural and isolated communities.

3. Methodology

Study of numerous research papers in the economic, environmental and economic field's External economic analysis of solar distillation is collected from many reputable peer-reviewed journals. The reference list of the downloaded articles is critically checked to search for additional papers related to the focused study, and then the classification of solar distillation systems is studied and appropriate mathematical equations are developed, and then the design, implementation and construction of the solar distillation system and its operation with the practical experiments required in this study.

4. Solar Still Processes

Solar distillation is a renewable energy source that utilizes the sun's inherent energy to cleanse water. The solar distillation method obtains the energy required for refining from the sun rather than from more expensive sources such as fossil fuels, electric power, and so on [10].
Because accessible fresh water is fixed to the ground and demand for it is growing daily as a result of population growth and fast industrialization, there is a fundamental and pressing need to get fresh water from existing saline/saline water or from inside the earth. Desalination is a simple and effective method of obtaining fresh water from saline water. Due to the dispersion of solar radiation, the primary drawbacks of solar thermal energy in big desalination plants are the poor productivity, low thermal efficiency, and huge land area needed. Regardless of the financial consequences, using fossil fuels raises environmental issues. Desalination may be accomplished directly or indirectly via the use of solar energy.
Solar energy is still utilized to deliver clean, drinkable water to the people around the globe. While some solar panels are installed in houses to assist decrease energy bills and pollution, others are installed in impoverished regions throughout the globe where there are no alternative sources of safe drinking water.

5. Classification of solar distillation systems

5.1. Active Solar Stills

In the case of active solar distillation, additional thermal energy of the water is fed into the basin to create a faster evaporation rate. A broad classification of solar snapshots is described above. Furthermore, active solar stills are categorized as:

- High-temperature solar still: The basin is fed with hot water from the solar collector panel.
- Solar Preheating Water Distillation: Hot water is fed into the basin at a constant flow rate.
- Natural solar still: hot water is introduced into the basin once a day.

5.2. Passive Solar Distillation

In passive solar distillation, the distillation is done purely by direct sunlight. Dual ramps and ramps solar stills are the traditional low temperature passive solar stills, operating at temperatures below $60°C$. Single slope solar still is more common and efficient than double slope solar distillation [9]

a) Normal Temperature Rang ($< 60°C$)

- Conventional Solar still
  - Signal Slop Solar still
  - Double Slope Solar still
  - Symmetrical
  - Non-Symmetrical
- Inclined Solar still

b) High Temperature Rang ($> 60°C$)

- Solar still in the Horizontal Basin
- Inclined Basin Solar is still operational
- Solar still has a regenerative effect
- Still using vertical solar energy
- Solar Condensing Spherical still

In this work will be Design and manufacture of solar glass distillation units for water desalination and Conducting an experimental test of solar energy under meteorological conditions in Baghdad for study the performance of solar still under weather conditions of Baghdad.

6. Mathematical models analysis

The heat transport model for a single slope solar device was created by taking into account the following components: the volume of the water basin, the volume of saltwater, and the thickness of the glass cover. Each of these components acts as a thermal subsystem that is susceptible to the process of heat transfer equilibrium. As a result, each subsystem will produce an equilibrium relation or equation for the average heat energy process. The average temperature of each discrete solar component is used to calculate these process equilibrium equations. The following assumptions are made prior to deriving the mathematical model:

- A consistent volume of sea water is maintained in a set solar basin.
- Solar distillation has no vapor leakage.
- The insulation (which is adequately insulated) and the glass cover (which is sufficiently thin) have a minimal heat capacity.

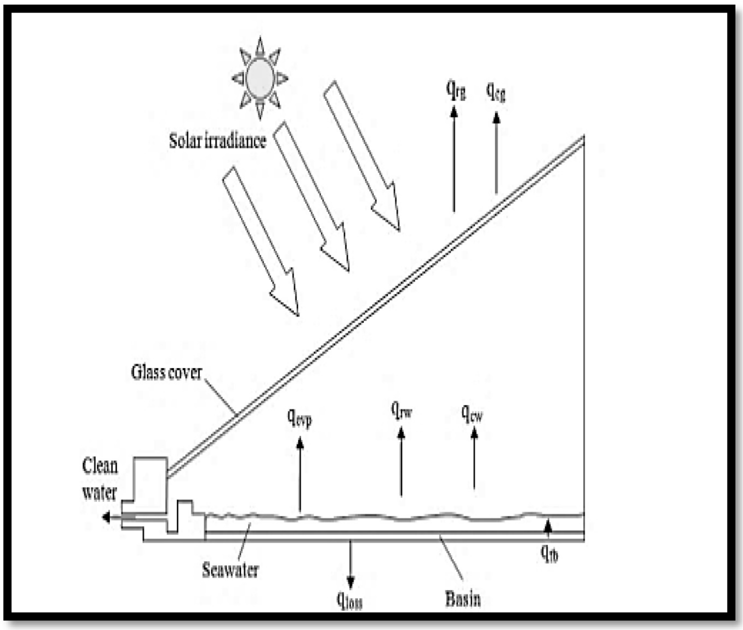

Figure 1: Interaction of Energy quantities in single slope solar still.

- There should be no temperature gradients between the air, the glass, the steam, or the depth of sea water in the aquarium. Additionally, the thickness is thin enough that heat transmission is instantaneous and there is minimal thermal gradient.
- Condensation of the film kind happens on the cover glass.

As a result, the derivation of the rate of transfer of heat for each component of the solar system components as fixed (6.1) and (6.2) and (6.3). Figure 1 also shows the different amounts of heat transfer in the solar single slope.

Glass cover:

$$A_g\alpha_g G + A_w(q_{rw} + q_{xw} + q_{evp}) = A_g(q_{rw} + q_{cg}) \tag{6.1}$$

Seawater:

$$A_w\alpha_w G + A_b q_{tb} = (MC)_w \frac{dT_w}{dt} + A_w(q_{rw} + q_{xw} + q_{evp}) \tag{6.2}$$

Basin:

$$A_b\alpha_b G = A_b(q_{tb} + q_{loss}) \tag{6.3}$$

Where: A_b is area of basin (m^2), A_g is area of glass (m^2), A_w is area of glass cover and seawater (m^2) and α_b is the absorptivity constants of the basin, α_g is the absorptivity constants of the glass, α_w is the seawater's absorptivity constants, G is the solar irradiance (W/m^2), and q_{rw} is the rate of heat transfer. of radiation q_{cw} is the rate heat transfer seawater convection process, q_{evp} Rate heat transfer seawater evaporation process, q_{rg} Rate heat transfer glass cover radiation process, q_{cg} q_{tb} total basin heat transfer, q_{loss} heat loss (W/m^2), $(MC)_w$ is the rate of seawater heat capacity per unit area ($J/m^2.°C$) during evaporation. T_w denotes the temperature of seawater in degrees Celsius.

6.1. Glass Cover Heat Transfer Coefficients

The connection between the glass cover's surface area, the surface area of the water in the basin, and the basin's area is as shown in equations (6.4) and (6.5). The heat transfer rates for the glass cover specified in equation (6.3) may be further extended by include the total heat transfer rate for the glass cover as specified in equation (6.6).

$$A_w = A_b \tag{6.4}$$

$$A_g = A_b sec\ \theta \tag{6.5}$$

$$q_{tg} = q_{rg} + q_{cg} = (h_{rg} + h_{cg})(T_g - T_a) \tag{6.6}$$

Where: θ is the slope angle (rad), q_{tg}, q_{rg}, q_{cg} are the total radiation and convection of glass cover heat flux (W/m^2), h_{tg}, h_{rg}, h_{ch} are the total radiation and convection coefficient of heat transmission via a glass cover $(W/m^2.°C)$, T_g are the glass cover and T_a ambient (outside solar still) temperatures $(°C)$.

6.2. Basin Heat Transfer Coefficients

Thermal energy transfer initially from the solar distillation basin to the sea water and then finally to the cover glass. (6.7) and (6.8) show the relationship between the total heat flow of the basin, $q_{tb}(W/m^2)$, and the heat flow loss of the basin, $q_{loss}(W/m^2)$ with respect to the total heat transfer coefficient of the basin, $h_{tb}(W/m^2.°C)$ and coefficient of aquarium heat loss, $h_{loss}(W/m^2.°C)$.

$$q_{th} = h_{th}(T_b - T_w) \tag{6.7}$$

$$q_{loss} = h_{loss}(T_b - T_w) \tag{6.8}$$

6.3. Seawater Heat Transfer Coefficients

When heat energy is transmitted from sea water to the sun's glass covering, the processes of radiation, convection, and evaporation occur. The total heat flow of sea water, $q_{tw}(W/m^2)$ is also represented by (6.9) with h_{tw} as the total seawater heat transfer coefficient $(W/m^2.°C)$.

$$q_{tw} = q_{rw} + q_{cw} + q_{evp} = h_{tw}(T_w - T_s) \tag{6.9}$$

6.4. Heat Transfer Temperature Governing Equation

Each of the specified heat transfer rates is replaced into (6.1), (6.2), and (6.3), correspondingly. When these three equations are solved using the starting condition, $t = 0s, T_w = T_{w0}$ and $T_g = T_{g0}$, the governing equations for the system temperatures yield:

$$T_g = \frac{a_g G\ sec\theta + h_{tg} T_a sec\theta + h_{tw} T_w}{h_{tg} sec\theta + h_{tw}} \tag{6.10}$$

$$T_b = \frac{a_b G + h_{tb} T_w + h_{loss} T_a}{(h_{tb} + h_{loss})} \tag{6.11}$$

$$T_w = \frac{A_b f(t)}{z(MC)_w}[1 - exp(-zt)] + T_{wo} exp(-zt) \tag{6.12}$$

6.5. Critical Clean Water Mass and Solar Still Efficiency

The mass flow rate of evaporated seawater, $M_{evp}(kg/s)$ and instantaneous efficiency, of solar stills are also calculated using the evaporation heat flux of seawater in (6.13) and (6.14) respectively, where h_{fg} is the latent heat of evaporation $(kj/kg.C)$.

$$M_{evp} = \frac{h_{evp}}{hf_g}(T_w - T_g) \tag{6.13}$$

$$\eta = \frac{q_{evp}}{G} = \frac{h_{evp}(T_w - T_g)}{G} \tag{6.14}$$

Where: q_{tw} is the total basin heat transfer coefficient, h_{tb} is the total basin heat transfer coefficient, h_{loss}, Is the basin heat loss coefficient, T_b is the basin temp., hf_g is the evaporation's latent heat $(kj/kg.C)$, and η is the efficiency [6].

7. Materials and Methods

7.1. Description of the system

The solar still test unit consists of four main components as the following:

- The salt water plastic tank contains salt water.
- Plastic tubes (diameter = 0.5 in) used to connect the salt water storage tank with the solar still basin, and also to connect the solar still basin to the fresh water storage tank.
- A glass solar still basin with single slop of top cover (inclination angle of the top is 45°). The basin is placed lower than the salt water storage tank in order to receive the salt water based on the gravity force (without using pump). The basin has a rectangular shape with slopped top and the underneath of the basin is insulated by glass wool in order to prevent the heat losses from the basin. The basin's top is slanted at a particular degree to balance the two primary forces acting on condensed water film: gravity force and adhesive force between condensed water film and the glazing's inner surface. This design forces the condensed water film to glide over the glazing's inner surface. Reduce this angle and a water film will develop, dropping back into the water basin, while raising the inclination angle of the glazing will result in the breakup of the water film. The black sheet (used as a black body) is a metal sheet painted by matt-type black paint and placed underneath of the bottom glass of the basin. The black body has been used to absorbs the incoming solar radiation as maximum as possible with low reflected rays. The basin also contents a water floater used to adjust the water in the basin at specific level.
- Small plastic container used to collect the fresh water.

The specifications of the parts of the solar still are presented in Table 1.

7.2. Experimental test

In this research, a solar still system was constructed, installed, and tested in Baghdad under real-world weather circumstances. Experiments were conducted for about 10 hours daily between 8:00 a.m. and 5:00 p.m. from (4/4/2020) to (6/5/2020). Meteorological data such as ambient temperature, wind velocity, humidity, and cloud cover were gathered from all experimental measures in order to assess the solar stills' performance in Baghdad's weather circumstances. The studies demonstrate how environmental factors affect the daily production and efficiency of solar stills. We

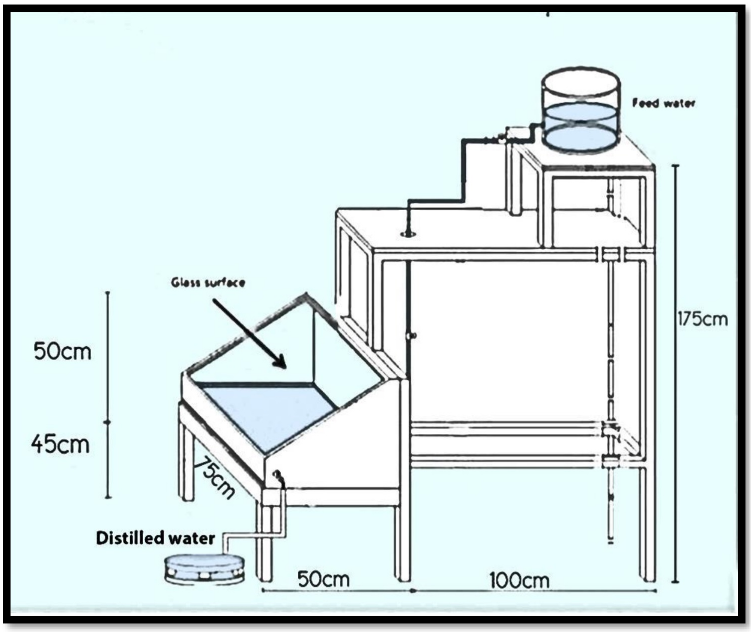

Figure 2: The experimental setup of the solar still.

Table 1: Specification of the solar still.

Part	Material	Dimensions
Solar still basin	Glass	$50 \times 75 \times 45cm$
Black sheet	Metal	$75 \times 50 \times 30cm$
Top glass cover	Glass	$77 \times 66cm, Thickness\ 6mm$
Salt water Tank (25L)	Plastic	$30 \times 45 \times 30cm$
Pipes	Plastic	0.5 in
Structure	Aluminum	$175 \times 45 \times 75cm$

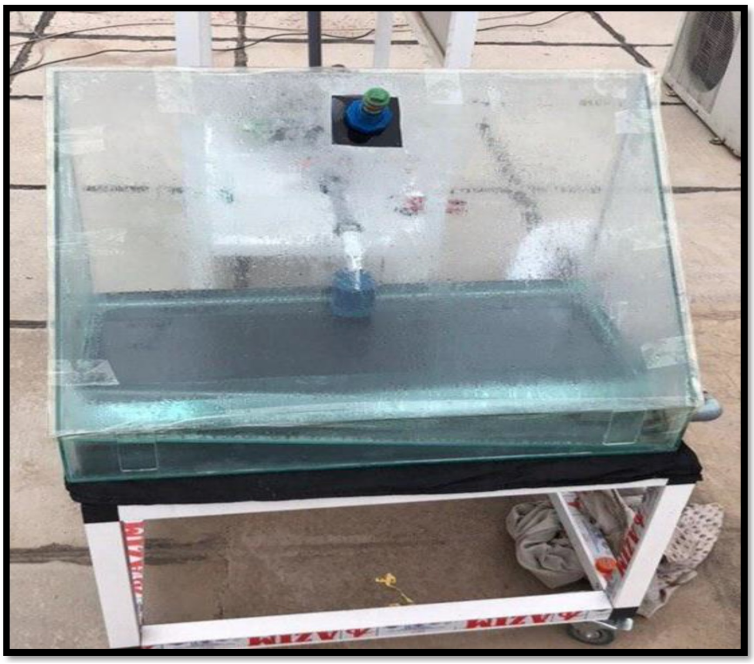

Figure 3: A glass solar still basin.

Table 2: Weather conditions during the test [11]

Data	Wind velocity	Outdoor temperature	Humidity
2020/4/5	5 km/h	$26C^{\circ}$	53%
2020/4/10	7 km/h	$28C^{\circ}$	27%
2020/4/11	11 km/h	$26C^{\circ}$	26%
2020/4/12	8 km/h	$27C^{\circ}$	28%
2020/4/14	10 km/h	$28C^{\circ}$	16%
2020/4/15	9 km/h	$29C^{\circ}$	28%
2020/4/16	3 km/h	30°	29%
2020/4/17	5 km/h	$33C^{\circ}$	16%

utilize water and add salt to it; 35gm of salt is added to each liter of water and delivered to the on-site feeding tank. Solar radiation heated the water in the still, condensed the water vapor on the inner glass surface, and the water droplets slid over the glass [8, 14].
The glass cover is set at a 45° angle to maximize water production in general and, more significantly, to maximize water productivity. This raises the angle of inclination for glass, thus increasing water production overall. This angle is selected to balance the two primary forces acting on condensed water: gravity force and the adhesive force between the condensed water and the glass's inner surface. This design forces the condensed water layer to glide over the glass's inner surface. Reduce this angle and a water film will develop that drops back into the water basin; increase the angle of inclination of the glass and the water film will collapse. Both factors decrease distilled water's production [2].

8. Results and Discussions

The experiments were conducted at April to May 2020, The glass-encased solar still is operational from 8:00 a.m. to 5:00 p.m. Daily measurements of distilled water output are conducted to determine the impact of each parameter on still productivity. The weather conditions are presented in Table 2 [11].

8.1. Effect of solar radiation on the productivity

Figures 4, 5, and table 3 illustrate the fluctuation in solar radiation during the experiment's chosen day in April 2020 during the rainy season. Solar radiation was at its peak at 17:00 during the operation time and started to decline afterwards. On a clear day with virtually no cloud cover, even a little layer of cloud may substantially decrease solar energy. Thus, increasing the sun's intensity raises the temperature of the sea water in the trays, which improves production, and it is shown that the highest temperature occurred around midday, when solar radiation was at its greatest, and started to drop as solar radiation decreased. The output of distilled water clearly rose from the lowest readings in the early morning to the highest values in the afternoon; the greatest yield of distilled water from the sun remained steady between 3:00 and 4:00 PM. This outcome happened because the water temperature in the system is low in the early morning, necessitating more solar energy and delay time to warm it up.

8.2. Effects of wind velocity

Wind speed is a significant element influencing system productivity through the condensing cap's temperature. As shown in Figure 5, lower wind speeds improved the system's efficiency relative to

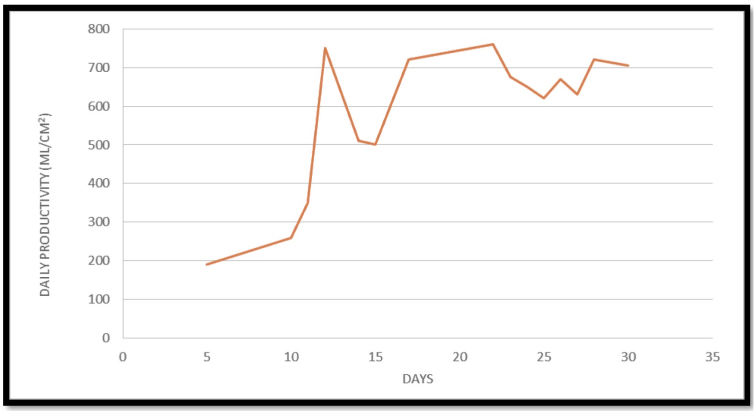

Figure 4: The daily productivity for the new design single solar still.

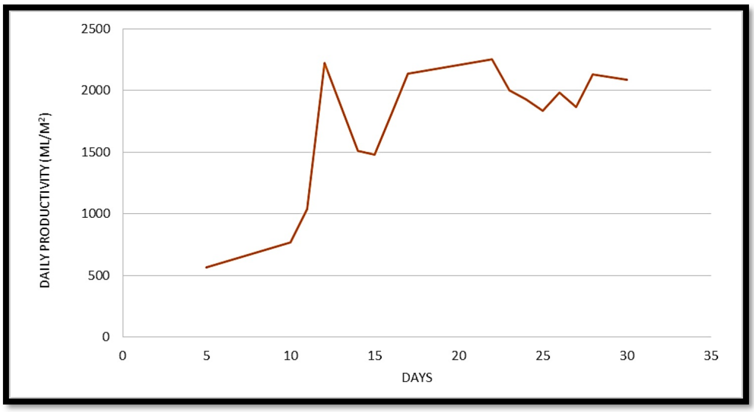

Figure 5: The daily productivity for the new design single solar still.

Table 3: Weather conditions during the test [11]

Days	Daily productivity (ML/M^2)	pH	Electrical conductivity $(\mu s/cm)$
5	650	6.8	750
10	720	7.0	670
15	1490	7.2	690
20	2300	7.4	660
25	1850	7.0	620
30	2100	6.8	600

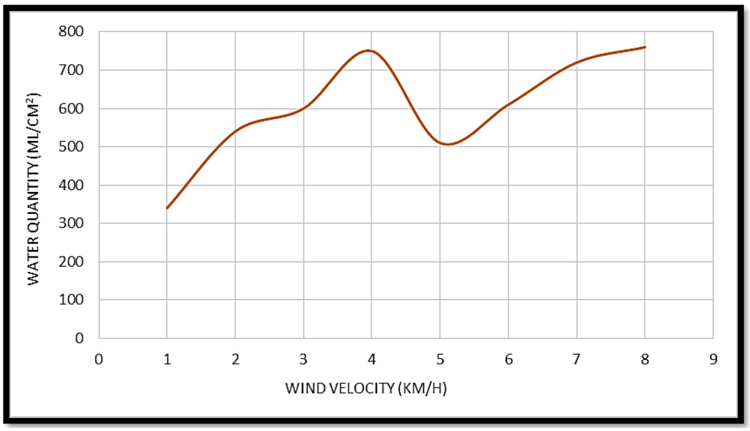

Figure 6: Wind velocity's effect on production

higher wind speeds, whereas higher wind speeds decreased production rate. The reason is that when the wind speed is high, heat loss from the cover to the ocean increases due to convection; thus, wind speed has a significant effect on productivity; however, the wind blew on the glass cover, increasing the temperature difference between it and the ocean, causing it to evaporate more quickly. Increased wind speed increases convective heat loss from the covers to the ocean, which improves solar energy output by chilling the glass cover and therefore the rate of condensation [2].

9. Conclusion

This paper concludes in the productivity of solar stills slope with single mode passive. It has been relying on some important variables such as water temperature change during the day for several days; still it covers the tilt angle and depth of the water inside the basin as well as static and distilled water specifications. Found the following conclusions:

The manufacture, installation and testing of the solar distillation system under real weather conditions in Baghdad. Tests were conducted about 10 hours a day from 8:00 am to 5:00 pm on (04/04/2020) to (05/06/2020).

The glass cover is placed at a 45-degree slant to maximize visibility the productivity of water in general, and most importantly. This leads to an increase inclination angle of the glass, which increases the productivity of water in general.

Solar radiation was shown for the experiment's chosen day variation in April 2020 during the rainy season. Throughout the operational time, the max solar radiation per hour was high at 17:00 and began to decline later.

Increased water yield is clearly distilled from the smallest early morning readings to the highest levels in the afternoon.

Lower wind speed improved the system's efficiency in comparison to higher wind speeds, while increasing wind speeds decreased the production rate.

Electrical conductivity (750- 600) because it was added to the amount of salt to the water inside the system.

The productivity of water in general pH (6.8-7.4) as a distilled water.

Acknowledgments

The authors acknowledge sanitary and chemistry laboratory civil engineering department in AL-Esraa University College. Special thanks to those who contributed directly or indirectly for fulfillment

this work.

References

[1] S. Abdallah, O. Badran and M.M. Abu-Khader, *Performance evaluation of a modified design of a single-basin solar still*, Desalination 219(1-3) (2008) 222–230.

[2] M.S.S. Abujazar, S. Fatihah and A.E. Kabeel, *Seawater desalination using inclined stepped solar still with copper trays in a wet tropical climate*, Desalination 423 (2017) 141–148.

[3] I. Al-Hayek and O.O. Bardan, *The effect of using different designs of solar stills on water distillation*, Desalination 169 (2004) 121–127.

[4] K. Anwar and S. Deshmukh, *Parametric study for the prediction of wind energy potential over the southern part of India using neural network and geographic information system approach*, Proc. Inst. Mech. Eng. Part A J. Power Energy, 234(1) (2020) 96–109.

[5] O.O. Badran and M.M. Abu-khader, *Evaluating thermal performance of a single slope solar still*, Heat and Mass Transfer, 43(10) (2007) 985–995.

[6] Y.K. Beng, O.C. Meng and S.-S. Kim, *Theoretical and experimental behaviour of single slope solar still heat transfer*, J. Appl. Sci. Process Engin. 4(1) (2017).

[7] H.H. El-Ghetany, H.M. Elgohary and Y.M. Mohammed, *Performance improvement of solar water distillation system using nanofluid particles*, Egypt. J. Chem. 64(8) (2021) 4425-4431.

[8] M.K. Gnanadason, P.Se. Kumar, G. Sivaraman, J.E.S. Daniel, *Design and performance analysis of a modified vacuum single basin solar still*, Smart Grid and Renewable Energy 2 (2011) 388–395.

[9] B. Gupta, T.K. Mandraha, P.J. Edla and M. Pandya, *Thermal modeling and efficiency of solar water distillation: A review*, Amer. J. Engin. Res. 02(12) (2013) 203–213.

[10] A.J. Khalifa and A.M. Hamood, *Performance correlations for basin type solar stills*, Desalination, 249(1) (2009) 24–28.

[11] K. Lavanya, A.J. Obaid, I.S. Thaseen, K. Abhishek, K. Saboo and R. Paturkar, *Terrain mapping of LandSat8 images using MNF and classifying soil properties using ensemble modelling*, Inter. J. Nonlinear Anal. Appl., 11(Special Issue) (2020) 527–541.

[12] K. Murugavel, K.K.S. Chockelingam and K. Srither, *Progresses in improve the effectiveness of the single basin passive solar still*, Desalination 220(1-3) (2008) 677–686.

[13] M.A. Porta-Gándara, J.L. Fernández-Zayas and N. Chargoy-del-Valle, *Solar still distillation enhancement through water surface perturbation*, Solar Energy 196 (2020) 312–318.

[14] C. Tenthani, A. Madhlopa and C.Z. Kimambo, *Improved solar still for water purification*, J. Sustainable Energy Envir. 3 (2012) 111–113.

[15] G.N. Tiwari, H.N. Singh and R. Tripathy, *Present status of solar distillation*, Solar Energy 75(5) (2003) 367–373.