

ENHANCEMENT THE SOLAR DISTILLER WATER BY USING PARABOLIC DISH COLLECTOR WITH SINGLE SLOPE SOLAR STILL

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ABSTRACT

Water desalination is the method of saltwater separating into two parts by using various types of energy. This paper offers an experimental work for solar distillation system to the production of drinking water by single slope solar still integrated with a parabolic dish. The result was compared with different solar still designs in the literature. The proposed solar thermal performance of the suggested solar still has been investigated to show its applicability in Iraq, Najaf (32.1N°, 44.19E°) during winter session (Nov., Dec., Jan.) 2018-2019. The assessment based on the effects of operational parameters, including solar irradiance, ambient temperature, wind speed, absorption wall temperature. A copper helical conical coil was used to compare steam condensation generated from the evaporator. The productivity of this study was 11.45 L.day⁻¹, 8.2 L.day⁻¹ freshwater with and without coil condenser respectively, and average direct solar irradiance was 753.6 W.m⁻². Comparison different types of solar stills, especially those that have used as concentrators of solar irradiance, with comparable periods of work time, indicate excellent performance. Also, this system can be considered acceptable because it can provide distilled water from the use of materials available in local markets and low cost, enough to cover the daily needs of water for at least two adults.

Keywords: Dual Axis, Parabolic Dish, Solar Still, Thermal Generation, Water Distillation

INTRODUCTION

The most important problems facing people today are population growth; the total number of people according to the latest statistics exceeded 7.6 billion in 2018. The new generation is therefore vulnerable to major crises, including water shortages energy supply, economic crisis and environmental issues. As a result of this rapid population growth, water resource withdrawals will increase by 50% in developing countries and 18% in developed countries by 2025. It is necessary to monitor and reduce water consumption while maintaining the expected quality in the case of water use [1–3].

Water is the basis of the continuity of life on earth and is a vital component of the environment. Distribution of water is about 96.54% of water containing high salt ratios, 2.53% is freshwater can used for drinking in various aspects of life. However, only a small percentage of up to 0.36% of clean water is available for human uses and can be accessed directly. Where a large amount of water is in the form of ice mass in the North and South poles and the remaining ones are in the way of groundwater and a small part located above the ground [4]. Water shortage is one of the most significant crises that will occupy the front of global attention in the coming period, because of population expansion and industrialisation has led to increasing demand for clean water[5,6]. In Europe, over 25% of fossil fuel is used in buildings, which used about 93% for warming and cooling just 7%, so the employment of solar energy to warm buildings generally in Europe can fundamentally lessen fuel utilisation, as well Contaminated [7]. In buildings, water is used in adaptations and evaporative air conditioning systems, for less pollution and less energy consumption[8,9].

"Desalination" is a term that refers to multiple procedures for purification, removal of salinity and pollutants from water and makes it drinkable. Water purification is one of the ways increasingly used to provide clean drinking water around the world. Due to the increasing demand for new energy sources and environmental considerations, sustainable sources of renewable energy are required [10]. Solar distillation system is one of the most suitable solutions that world has begun the switch to because of the low cost of installation and maintenance of plants. In addition to the few pollutants produced so it can be considered environmentally

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friendly. Many factors in the Earth atmosphere or climate conditions reduce the reflection and absorption of solar irradiance, such as ozone, water vapor, oxygen, dust particles or pollution [11],[12]. Fluid boiling has played an essential role in many technological applications because of its superior performance in heat transfer.

The main reason for using these catalysts is to increase the efficiency of the distillation system, where the test results gain an increase in the amount of freshwater productivity when using these materials. Saline desalination using solar concentrates is considered the most suitable option due to high-temperature concentration and thus high evaporation rate and then intensification of desalinated water[13]. As it knows that Iraq has two great rivers (Tigris and Euphrates), but still a large part of the people lacks freshwater where desalination plants available using fossil fuels relatively old or outside the service without any maintenance, causing suffering and increasing demand for clean water. The objective of using the focus system is to enhance and improve the efficiency and productivity of solar energy. Where solar irradiance focuses on the absorbent part temperature was rises, so the evaporation rate increases for saltwater and condenses into the pure water [14]. Most applications using solar stills only face a significant problem, which is a decrease in the production of desalinated water, so the current research aim, to design and manufacture a solar parabolic dish that is a dual solar tracking with solar still single fixed on a focal point, the study of production from freshwater. Also, compare the result with other literature using solar even and verification of the quality of the water produced and analysed for the knowledge of the level conforming to the corresponding international health standards.

LITERATURE REVIEW

Abed et al.[15] noticed by experimental investigation for solar trough collector and solar still, the productivity of freshwater increase 5 % over traditional solar still systems when integrated with parabolic trough collector. V. I. Sytar et.al[16]recommended using phase change material in the main components of solar energy conversion devices to thermal energy, which increases the level of reliability and durability. Salim H. et. al [17] introduced a model in the Matlab program to compare the proportional integrator derivative controller and artificial neural networks to control the boiler of the steam power plant. The results showed that using of ANN gives more control than PID controller. Stefanovic et al.[18]through an experimental study of the factors in the optimal conditions when using a parabolic solar dish with a heat-absorbent model has a spiral shape, where they found that the optimum temperature of the system used 212.3 °C is an excellent thermal model encourages the use of concentrated solar energy. The mathematical analysis and simulation of an electric power plant in Iran were designed to analyse sensitivity to environmental emissions, exergy efficiency, and power costs. The result showed that combined cycle power plant efficiency was based on different design standards including input temperature for gas turbine, compressor pressure ratio, and pinch point temperature which helped to improve efficiency by 8.12%, while the overall system exergy decreased by 7.23%[19–21]. Omara and Eltawil[22] tested a model contracting from a parabolic dish with a diameter of 1m, single solar still unit to find the amount of freshwater productivity when with and without preheated for brackish water, when analyzing the experimental results, 244% and 347% increase observed more than the conventional type with preheating and without use on preheating, respectively. The complexity of the boiling process encouraged many researchers to conduct extensive research in this area. Because of the unknown properties hidden in the boiling phenomenon, many researchers have experimented with many different materials[23,24]. Also, Cooling systems are critical sectors in energy cycles, and their thermal performance is an indispensable challenge for heat transfer experts. Work fluid, dominant heat transfer mechanisms and operating conditions are also other vital parameters that continuously affect the quality and efficiency of a cooling system [25–29]. Heat and mass transfer in porous media is saturated with significant development in heat transfer research in recent years and is considered a fundamental theme in heat and mass lectures [30]. D. Al-shamkhi et al. [31] presented a new way to reduce losses by placing airbags in the shape of diameters and semi-circular and different in front of the assembly tube to affect the heat transfer process. Arunkumar et al. [32] designed solar still combined with dish concentrator has a hemispherical shape and used phase change materials to enhance freshwater productivity and the conclusion was that the cooling of glass top receiver was less effective than use of variable PCM on the production of fresh water.

METHODOLOGY OF SOLAR DISTILLATION**Solar Still Reviews**

Solar distillation using still type remains a simplest way to generate freshwater, using solar irradiance to heat evaporation from humid soil, and ambient air to cool condensed film. In a solar still, impure water is contained outside the collector, where it is evaporated by sunlight shining through the clear cover. The pure water vapour condenses on the cool inside cover surface and drips down from the weighted low point, where it is collected and removed.

Various designs of the solar still with and without concentrator that was used to produce desalinated water were reviewed in Table 1. It has included the test period, the type of design used, the location, the working hours and the total amount of water vaporised. This study to be comprehensive, consideration was given to the various influences and climatic conditions that may affect the estimated productivity or effectiveness on the system used.

Table 1. Review categorisation solar stills and productivity fresh water

Ref.	Design specifications	Geographical location	Country	Period	Experimental time	Productivity per day (kg. m ⁻² . day ⁻¹)
Tanaka [33]	Solitary impact still and a glass plate were utilised as a second section to allow monitoring of the fumigation fuse attached to the first section.	33.3N°, 130.5E°	Japan	Oct.,2005	08:00 - 17:00	4.19
Eldalil [34]	The system has the twofold slanted front of 30° tendency with a flat and complete compelling territory of 2.064 m ² and helical copper cables.	21.5 N°, 44 E°	Saudi Arabia	Sep, 2006	06:00 - 12:00	2.21
Tanaka [35]	The pot is still composed of 5 mm glass thickness with inner and outer reflector.	33.3N°, 130.5 E°	Japan	Feb., 2007	08:45 - 17:00	3.09
Chaouchi et al. [36]	The experimental device made out of a parabolic dish and receiver like hollow.	33.55 N°, 10.1 E°	Tunisia	2008	09:00 - 18:00	2.34
El-Sebaï et al [37]	Solar still with implicit reasonable capacity material (sand).	21.53 N°, 39.2 E°	Saudi Arabia	Apr. – Jun, 2009	06:00 - 18:00	3.91
Kannan et al. [38]	The vapour adsorption type solar still framework includes a vapour adsorbent bed.	10.1 N°, 78,2 E°	India	Jan – Jun, 2010	09:00 - 17:00	3.7
Alaudeen et al. [39]	The setup involves a wooden box with a square area of 1.21 m ² .	10.1 N°, 78,2 E°	India	Feb.- May, 2011	09:00 - 17:00	3.6
Omara and Eltawil [22]	Hybrid of the solar concentrator with new evaporator gatherer for saline water desalination.	31.07 N°, 30,57E°	Egypt	July – Sep, 2011	09:00 - 18:00	6.7
Arunkumar et al. [40]	Semi-circular solar pot is still associated with the underlying PCM as a capacity.	13.09 N°, 80,27E°	India	2012	09:00 - 18:00	4.46

Table 1. Review categorisation solar stills and productivity fresh water (continued)

Mohammed, AJ. [41]	The still has comprised of a bowl with the region of (0.075 m ²).	30N°, 47.5E°	Kuwait	June,2013	09:00 - 15:00	6.27
T. Miqdam et al. [42].	Introduced a simple distillation system accompanied by a concentrating unit.	33.3N°, 44.38E°	Iraq	Jan.,2014	09:00 - 15:00	4.31
R.Velraj et al.[43]	compares a single-slope solar still, a compound conical concentrator solar still, and a compound parabolic concentrator–tubular solar still.	13.09N°, 80.27 E°	India	2015	08:00 - 17:00	6.1
Abed, F.M. [44]	Enhance the multistage sun-oriented stills innovation combined with the solar-based.	35.2N°, 44.19 E°	Iraq	Aug., 2015	08:00 - 17:00	4.94
G.Prado et al [45]	A 62-cm galvanised dish diameter has a two-axis solar tracking with receiver made from borosilicate glass and a water salinity	18.7°S, 48.8W°	Brazil	Feb., 2016	09:00-16:00	4.95
A.Chorak et al.[46]	Experimental characterize of the solar MED system under design conditions is	35.4N°, 5.48E°	Algeria	2017	09:00 - 15:00	11.3
M. Bahrami et al.[47]	Presented a solar parabolic dish collector system with a new design of a solar still.	30.4N°, 51.3 E°	Iran	2018	9:30-16:30	10.5
(Present work)	Parabolic dish and Solar still single slope.	32.1N°, 44.19 E°	Iraq	Nov. Jan., 2018-2019	9:00-16:00	11.4

Iraq Meteorological Data

Iraq's geographic location is within the area exposed to high solar irradiance, and the sun's brightness continues for relatively long hours, as shown in Table 2 [48]. The studies found that Iraq exposed to more than

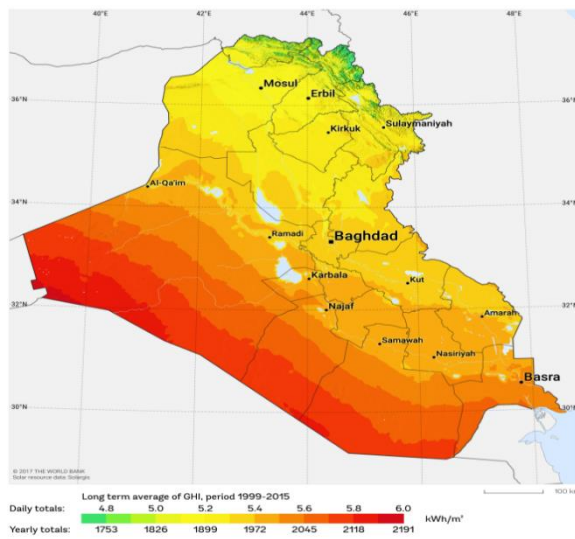


Figure 1. Iraq solar annual horizontal irradiation map [49]

3000 hours of solar irradiance per year in Baghdad alone, where the average percentage of solar irradiance was 333.1 W.m^{-2} at the beginning of the year to 732.4 W.m^{-2} in the middle of the year as shown in Figure 1 [49].

In the 1980s, Iraq drew up an ambitious plan to use solar energy for electricity generation. The first legislation on the use of renewable energy was issued in 1982. The first solar panels were installed at the Solar Energy Research Center in Jadiriya, Baghdad, in 1986.

Undoubtedly, the multiple wars and economic sanctions on Iraq for more than three decades have made the ambitious plan collapse, and stop development and work in the field of renewable energy. The stoppage continued until 2009 when the Iraqi Ministry of Electricity announced a plan to install 6,000 solar-lamps to light Baghdad's streets. After the collapse of international oil prices and the rise of ISIS in 2014, this project was abandoned. Interest in solar energy returned in November 2017, when the government announced the creation of expression of interest (EOI) for public private partnership (PPP) to build about 700 MW of solar power plants by the end of 2018.

Sahlin, Assaad et al.[50] estimated the climate qualities measure of dry lamp temperatures, solar intensive and wind velocity for Najaf, Iraq at (32.1N° , 44.19E°) at one year starting from (April_2015 to March_2016), the gathered information demonstrated that the measure of solar vitality in Najaf city is more critical and utilization than wind energy. Furthermore, the investigation confirmed that regular solar intensive over daily data is higher inside monthly (Apr. to Aug.) and lower over the winter, the max solar irradiance recorded on 8 June as 587 W.m^{-2} . The most elevated daily max and monthly average wind velocities were 16.3 m.s^{-1} and 4.9 m.s^{-1} on August, 30 and June, 18 separately though, the base breeze speed was recorded 0.2 m.s^{-1} on May, 26.

Table 2. Mean monthly total sunshine (hours) over year and solar irradiance (S.I) in Iraq for the period (1983–2012) [42]

Month	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Avg.
Sunshine, h	313.1	310.8	356.5	396	418.5	423	437.1	409.2	366	313	303	294.5	361.7
S.I, W.m^{-2}	333.1	348.2	469.1	541.4	726.8	732.4	731.6	861.2	560	435.4	289.1	245.1	506.3

Experimental Setup

The work designed to compare solar distillation productivity between the parabolic concentrator and other solar still systems, so the tests carried out at Engineering Technical college of Al Najaf; AL- Furat AL- Awsat Technical University located in Iraq, Najaf (32.1N° , 44.19E°). They implemented in December 2018 from the 09:00 am to 04:00 pm, where Figure.2 show a schematic system diagram from parabolic dish concentrator and receiver.

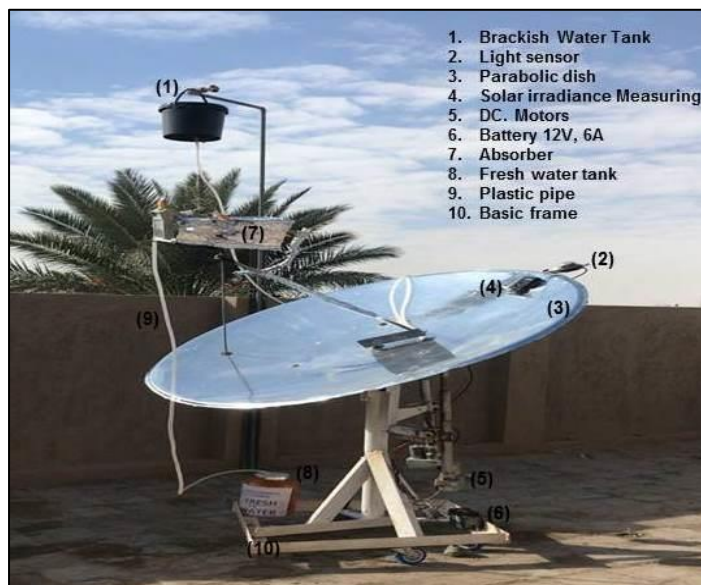


Figure 2. Direct photograph for components of the distillation system

Parabolic dish concentrator reflects incoming direct solar irradiance to a receiver situated at the focal point of the dish. Inside the receiver, the saline water is vaporised by the exceptional warmth made by the focused solar irradiance on the base of the receiver. The produced water vapor stream up and gathers in a conical spiral coil to condensate vapor and collected out as freshwater. The effect of the conical spiral coil to condensate and without condensate of feed saline water to the receiver on the distillate productivity was investigated.

The solar distillation collector consists of a satellite parabolic dish to concentrate radiation, made from galvanised steel. It has a diameter 1.5 m; the focal length was 0.92 m and surface area with 1.76 m² aperture area. It utilised a more relevant measurement of dish accessible in the market to give a more prominent fixation radiation focus conceivable, so getting the high temperature at focus area. The reflective material used from the aluminium foils and have reflectivity about 76% [51]. The type of dish has a prepared structure, yet has one axis movement. Therefore it was fabricated design to enable plate to move in dual-axis; these developments allow the parabolic to track sunlight, in Table3 show geometrical parabolic dish system[52]. The dish can navigate to follow the altitude and azimuth of the sun by two motors.

The tracking system consists of an electronic controller for a dual-axis solar tracker with LCD, where many working status and parameters can appear. The controller has tracking accuracy (≤ 1) therefore, can identify fourth side and control the vertical actuators to move, along these lines, understand the solar collector gatherer to pursue the daylight and dependable face to the day-light sensor inside the waterproof shell to protect it from the outer effect. Two motors sized at 450 mm/18" Stroke 12 V DC solar tracking linear actuators with the possibility of maximum pull load is 1200 N/120 kg, and maximum push load is 1500 N/150 kg.

The receiver fabricated from galvanising steel with 0.5 mm thick and 0.045 m² basin areas. It has shaped as single slope solar still with dimensions 0.3 m length, 0.15 m width, 0.2 m high from the backside and 0.1 m tall from the front side. The single slope solar still covered by the glass at 0.006 m to avoid damage from vapour pressure rise inside the tank. It was located at a focal point to collect reflected radiation from the parabolic dish. Also, it contained two valves: first to inlet saline water and joined with the external tank by a plastic tube. The other plug to outlet freshwater and merged with an outer conical spiral coil from copper with 3.5 m length, a 0.15 m height, 0.22 m top coil diameter, 0.06 m bottom coil diameter, pipe coil thickness was 0.002 m and 6 coil loops combined for condensing generated steam. The distilled water is collected in a bottle to measure the daily productivity of freshwater. The outer area of the receiver is wholly insulated using rock wool to minimise losses has thermal conductivity (0.0343 W.m⁻¹. k⁻¹), except for the exposed part of the solar irradiance concentration with a black chrome coating to increase thermal absorption.

Table 3. Characteristics of the parabolic concentrator

Parameter	Value	Unit
The diameter of a parabolic dish (d)	1.5	m
The depth of the concentrator dish	0.15	m
The focal length of the dish	0.92	m
Aperture area of the dish	1.76	m ²
Rim angle of the dish	41.75	degree
Ratio (f/d)	0.626	-

Instrumentation and Error Analysis

To study collector efficiency should record the primary data that gives an impression about system depending on measuring tools. The primary data recorded are water temperature entering the absorber, distilled pool heat that exit from the absorber, a temperature of the absorber glass surface and ambient temperature. Besides recorded how much of direct solar irradiance reach on the dish, wind speed, amount flow rate of water entering absorber, a temperature of the absorber base exposed to the concentration and the productivity distillation of the system. To measure temperature of the water inside and outside receiver, the temperature of the dry glass surface obtained by using thermocouples- type K, which has a wide range of measuring temperature from (-270 to 1260) °C and thermocouples are joined with data logger temperature modal ELD-Mod.9710 with auto range (-60 to 1200) °C. To calculate direct solar irradiance reached on the parabolic dish was measured by the model (Protek - DM-301), it has the range to measure solar intensity from (0 to 2000) W.m⁻². The temperature on absorber exposed part for solar concentration measured by digital infrared thermometer

gun with laser model (MASTECH-MS6520B). It has a long-range (-20 to 500) °C with emissivity is 0.95, as shown in Table 4.

Table 4. Accuracies and error for various measuring instruments

Instrument	Accuracy	Range	Error %
Thermocouple (K)	(± 1) °C	(-270 to 1260) °C	1
Digital thermometer	(± 0.2%) °C	(-60 to 1200) °C	0.75
Solar meter	(± 0.7%) W.m ⁻²	(0 to 2000) W.m ⁻²	1.5
Infrared thermometer	(± 1.5%) °C	(-20 to 500) °C	1
Anemometer	(± 0.2%) m.s ⁻¹	(0.2 to 35) m.s ⁻¹	1.5

THEORETICAL CONSIDERATION

Theoretical analysis is essential for determining the productivity and effectiveness of the dish system where the effect of environmental factors that determine the number of heat losses and benefits from the system calculated and used as described below [15,16].

To calculate solar energy Q_s for parabolic dish follows:

$$Q_s = G_b \cdot A_{ap} \quad (1)$$

where: A_{ap} and G_b are the concentrator aperture area that receives solar irradiance and the beam solar irradiance reach to dish respectively.

Also, to know how much useful heat received from absorber Q_u as shown in Figure. 4

$$Q_u = Q_a - Q_l \quad (2)$$

where: Q_l is heat losses for the receiver part, and Q_a represents the heat energy that absorbed by absorber wall. So, to describe the optical efficiency, η_o which equal [55]:

$$\eta_o = Q_a / Q_s \quad (3)$$

From another side, the optical efficiency product many properties of materials dish and receiver [56]:

$$\eta_o = \lambda \rho \alpha \tau \gamma \cos \theta \quad (4)$$

where λ are the factor of un-shading, ρ is reflectance materials for the dish, α is transitivity – absorptivity for a product used, γ is the receiver intercept factor, and θ is angle incidence irradiances on the dish.

The total heat loss is the sum of three types of heat losses: heat loss by conduction, $Q_{loss, cond}$, heat loss by convective $Q_{loss, conv}$ and heat loss by radiation $Q_{loss, rad}$ [57]:

$$Q_{loss} = Q_{loss, cond} + Q_{loss, conv} + Q_{loss, rad} \quad (5)$$

Convection heat loss is given[57]:

$$Q_{loss, conv} = h_c A_a (T_s - T_{amb}) \quad (6)$$

where: A_a the absorber's surface area of the bottom side.

Radiation heat loss can be determined.

$$Q_{loss, rad} = h_r A_a (T_s - T_{amb}) \quad (7)$$

where,

$$h_r = \varepsilon \sigma (T_s + T_{amb})(T_s^2 + T_{amb}^2) \quad (8)$$

So, the useful energy Q_u can rewrite as:

$$Q_u = \eta_o \bar{G}_b A_{ap} - U_t A_a (T_s - T_{amb}) \quad (9)$$

where,

$$U_t = h_c + h_r \quad (10)$$

Also, can be express for daily productivity P_d and efficiency η_d as [21, 22] :

$$P_d = \sum P_h \quad (11)$$

$$\eta_d = [(P_d h_{fg,w}) / (C_R A_{ap} \sum \bar{G}_b) \Delta t] \times 100 \quad (12)$$

where P_h is productivity per hour, $h_{fg,w}$ is average latent heat per day for water vaporization, C_R is geometrical concentration ratio (A_{ap} / A_a) and the last term is Δt that refer to the interval time during solar irradiance measured.

ECONOMIC ANALYSIS

To study effectiveness of the system, the user must know its manufacturing cost that covering capital, operating and maintenance costs over a certain period [39]. All materials used in design, construction and measurement calculated as follows:

- Analysis of the value of the parts used.
- Fees for installation.
- Annual production quantity

Capital Cost

In the capital cost was included, purchase of the materials used in the test, installation costs, construction, welding, paints. As shown in Table 5. The prices of materials were available in the local market and the exchange rate was (1\$ =1198 ID) according to the price of the Central Bank of Iraq (CBI) in 2018 [60].

Annual Freshwater Production

- Assumed the operating system period is 8 hours during the day (where night production ignored).
- Assumed 45 days the system is outside the service, where there is a period of maintenance during the year (15 days) and also the assumption of a severe climate (30 days). So the annual output of the distilled water was estimated to be (320) days as equation below:

$$P_y = \sum_1^{320} P_d, i \quad (13)$$

- The average daily freshwater output during the experiment period (three months) is (10.5) L.day⁻¹.

Therefore, the average annual output is about:

$$P_y = 3360 \text{ L. year}^{-1}.$$

Table 5. The total capital investment cost of the solar dish distillation

Item description	Unit	Quantity	Unit cost (\$)	Total cost (\$)
The receiver (material + chrome coating + insulation + construction fee)	-	1	30	30
Concentrator (aluminum layer + parabolic dish)	m ²	1.76	15	26.4
Helical coil condenser	m	3.5	3.2	11.2
Chassis of the system	-	1	30	30
Carrier wheels	-	4	2	8
DC motor	-	2	12.5	25
Tracking system (control + light sensor)	-	1	179	179
Electric source (battery 12 v)	-	1	10	10
Pipes and fittings	-	1	15	15
Welding and installation fee	-	-	20	20
Total cost			354.6 \$	

Operating Costs

Operating costs are the materials paid by the owner of the system at the start of the plant and during actual operation. Operating expenses include the following items;

Amortization Charges

The amortization factor (A_m), represents the conversion of the investment cost of the operating project into regular financial payments over a period, which is given by Jaluria [61]:

$$A_m = \frac{(1+a)^{Lt}}{(1+a)^{Lt}-1} \tag{14}$$

where, (a) is the annual interest rate of the bank, which is assumed that 12% and (Lt) is the lifetime of the system and estimated to be five years.

Operating and Maintenance Costs

The O&M costs include the included cost, periodic cleaning of reflector and receiver, maintenance of suspended parts, saltwater supply, heat exchangers and others, which is considered 10% of annual capital investment.

Calculation Procedures

The methodology for calculating the total cost (T_C) is based on the value of salvage units, which will be zero at the end of the amortization period. The total cost is calculated from [62];

$$T_C = C_o + C_{main} + C_{fix} \tag{15}$$

C_o is the cost of operation; C_{main} is the cost of maintenance; C_{fix} is the fixed charges cost, it is calculated as follows;

$$C_{fix} = A_m . C_c \tag{16}$$

C_c is the capital cost; hence.

Therefore, the (TC) was calculated as 488.25 \$.

The cost of water produced (CWP) from the solar thermal desalination system is determined:

$$CWP = \frac{TC}{Pd . a . 365} \tag{17}$$

where, (a) is plant availability which was taken as 85%. Then CWP for fresh water was calculated as 0.14 \$/kg.

The payback period (PbP) was calculated from equation:

$$PbP = \frac{TC}{Pd \cdot CWP} \quad (18)$$

Therefore, the payback period was calculated as 332.14 days.

STATISTICAL ANALYSIS

In order to conduct statistical analysis in this study, Pearson Correlation coefficient (r) was used. This type of statistical method is used to investigate a linear relationship between a quantitative variable and a continuous variable. Pearson's coefficient enables researchers to visualize the strength and direction of the relationship between the two variables (x, y) ranging from (-1 to 1). In the absence of an association between the two variables, the value is closer to zero, either if the approach to (-1) or (+1) represents a negative or positive high an association between these variables. The effect of solar radiation with other parameters (ambient temperature and wind speed), also outer water temperatures with absorber temperatures was statistically controlled to see the amount of linear convergence between them and given by:

$$\frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (19)$$

Here \bar{x} , \bar{y} is a deviation from the average observation [63,64].

RESULTS

Environmental Conditions for Experimental Work

Experimental work was done under local conditions of Najaf-Iraq during the winter session from Nov. 2018 to Jan. 2019. Present work aims to investigate the impact of different weather data and to influence the productivity of freshwater, and the variables include solar irradiance G_b , ambient temperature T_{amb} , absorber temperature T_{abs} and production rate per hour P_d . The distillation plotted as a function of the parameters mentioned overtime for days on Nov 2018, Dec 2018 and Jan 2019 with and without effect conical spiral coil condenser. The time for measuring the environmental and operational variables of the desalination system was from 09:00 to 16:00. The climate data was readied and recorded on November 2018, where the amount of solar irradiance filed at the beginning of the test time was 579.35 W.m⁻² at 09:00 am and gradually increased until it reached its maximum value of 914.2 W.m⁻² at 13:00 hour, and then it began to decline due to the movement of the solar path towards sunset. As for the other variables, the ambient temperature and wind speed reached the highest values in the afternoon were 22.4 °C and 2.7 m. s⁻¹ respectively. Besides, the rise in temperature of the receiver surface that led to steam generation after half an hour of each experiment. The gradual increase in the amount of solar irradiance leads to a rise in water temperature within the absorbent part. The variable climate data recorded in December 2018 identified. Where the highest value recorded for the amount of beam solar irradiance reaching to concentrator was 876.42 W.m⁻² at 13:00 hour and also the highest amount of desalination during this time was 1.85 L.h⁻¹.

Also, other environmental variables recorded are ambient temperature, and wind speed during were they different between the rise, and the decrease was 18.3°C, 1.3 m. s⁻¹ respectively at 13:00. While the maximum ambient temperature was 18.7 °C at noon, and the maximum wind speed was 2.7 m. s⁻¹ at 14:00. Climate data recorded on January 2019 showed a variation in the amount of solar distillation output, where the maximum amount of direct solar irradiance reaching the dish was 854.13 W.m⁻² and 839.7 W.m⁻² at 12:00 to 13:00 hours, respectively. The maximum temperature and wind speed recorded was 20.2 °C, 0.9 m. s⁻¹ at 09:00 am, 1:00 pm respectively, where Figure. (3- 5) show the variation of ambient temperature and solar irradiance and Figure. (6- 8) shows the variation of wind speed and solar irradiance during experimental time.

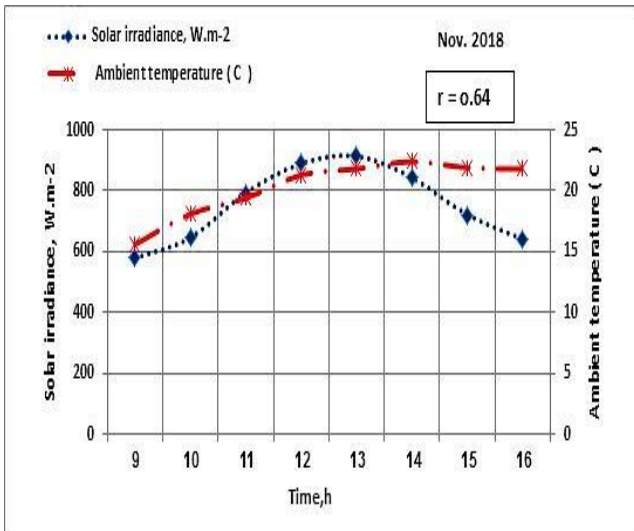


Figure 3. Variation of ambient temperature and solar irradiance on November 2018

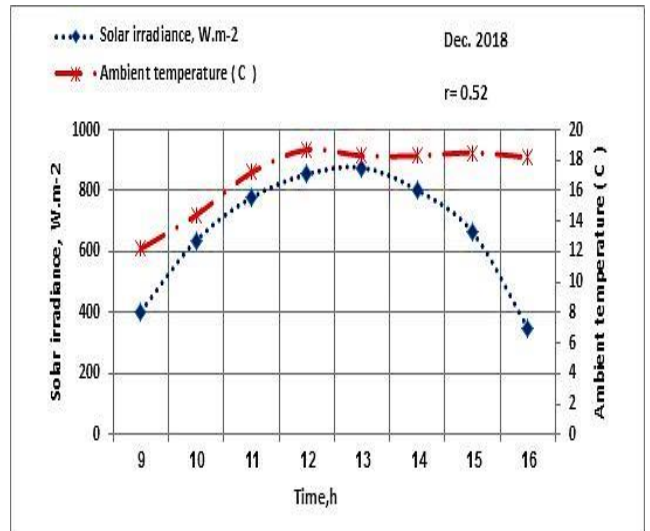


Figure 4. Variation of ambient temperature and solar irradiance on December 2018

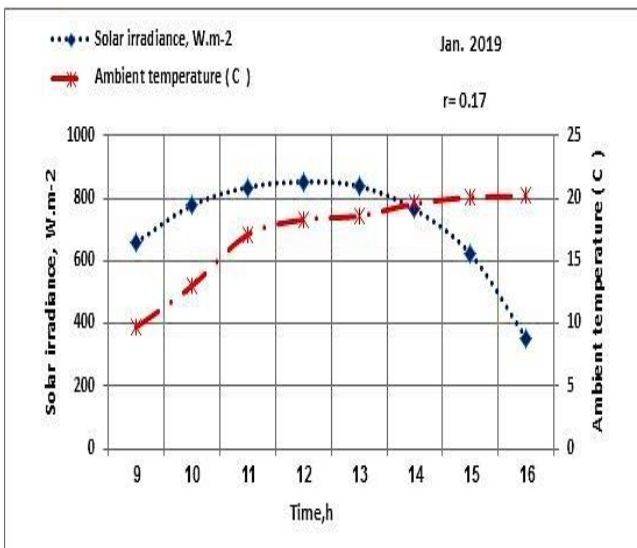


Figure 5. Variation of ambient temperature and solar irradiance on January 2019

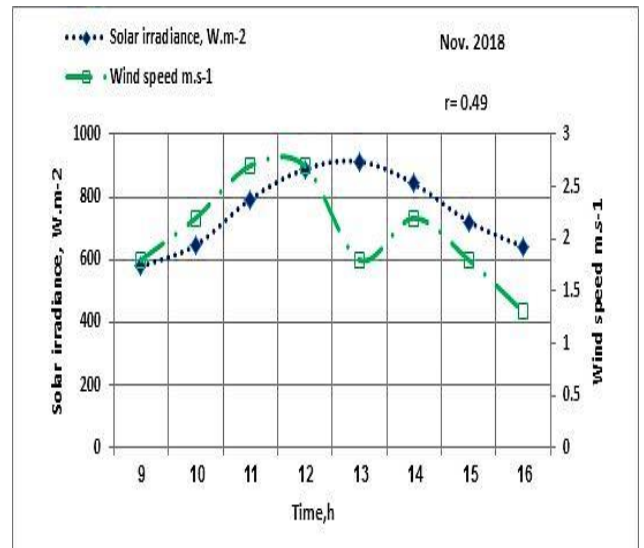


Figure 6. Variation of wind speed and solar irradiance on November 2018

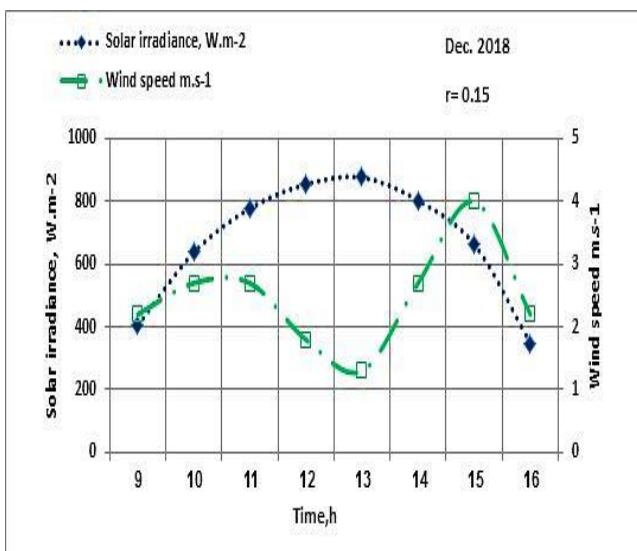


Figure 7. Variation of wind speed and solar irradiance on December 2018

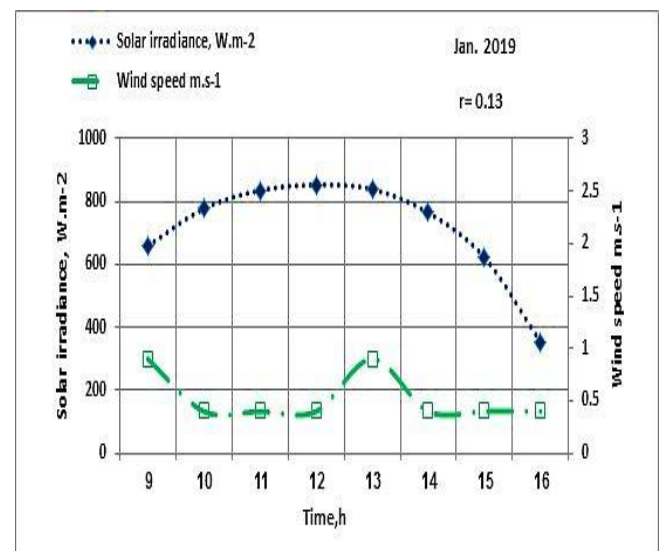


Figure 8. Variation of wind speed and solar irradiance on January 2019

Distillation Productivity by Using Parabolic Dish Integrated with Single Slope Solar Still

A parabolic dish provides a high reflective solar irradiance, thus giving high temperatures absorbent from receiver part and almost enough to generate steam for the solar distillation process, even although changing weather conditions from low temperatures or high wind speed. Figures. (9,10) Shows daily distillation productivity per different experimentally time with and without condenser coil unit, respectively. Productivity rate was at maximum value when solar irradiance was the highest amount and total productivity in Nov. 2018 from freshwater was 11.45 L.day⁻¹ and 8.2 L.day⁻¹ with and without condenser respectively. Average productivity in Dec.2018 was 9.7 L.day⁻¹, 6.3 L.day⁻¹ with and without a coil condenser, respectively. Also, the highest amount of distillation during this day was 1.65 L.h⁻¹ at 13:00 at maximum solar irradiance was 876.42 W.m⁻², which is an essential indicator of solar desalination system, shows that effect of other variables is less than affect amount of direct solar irradiance that reaches to a concentrator. The productivity of the system in Jan.2019 was 10.35 L.day⁻¹, 7.1 L.day⁻¹ with and without condenser respectively.

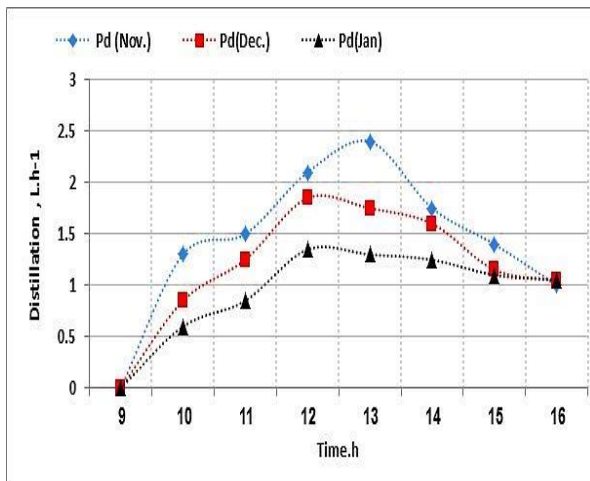


Figure 9. Productivity variation with time with condenser

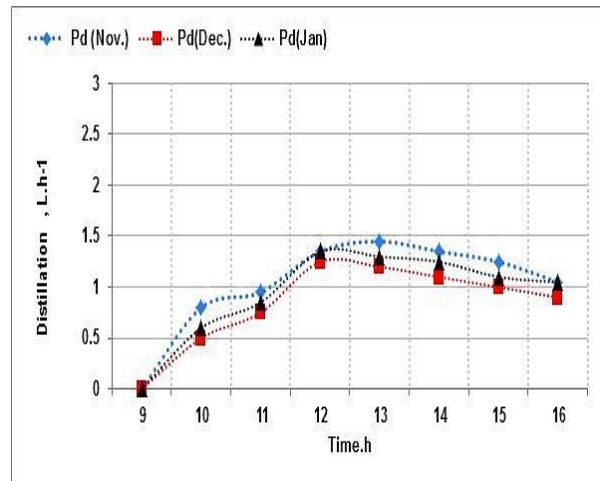


Figure 10. Productivity variation with time without condenser

The Temperature of Receiver's Wall and Effect It on Productivity Distillation

The temperature of the absorber wall T_{abs} exposed to solar irradiance has a significant impact on the amount of distilled water. Where the higher temperature of the receiver's wall increases productivity despite the high thermal losses from the absorbent part [53]. This effect explains that necessary condition for high productivity is the amount of temperature receiver's wall exposed to radiation. Therefore, the highest productivity observed when the maximum temperature reached to the drywall and was 2.1 L.h⁻¹ at 321.46°C respectively as shown in Figure 11.

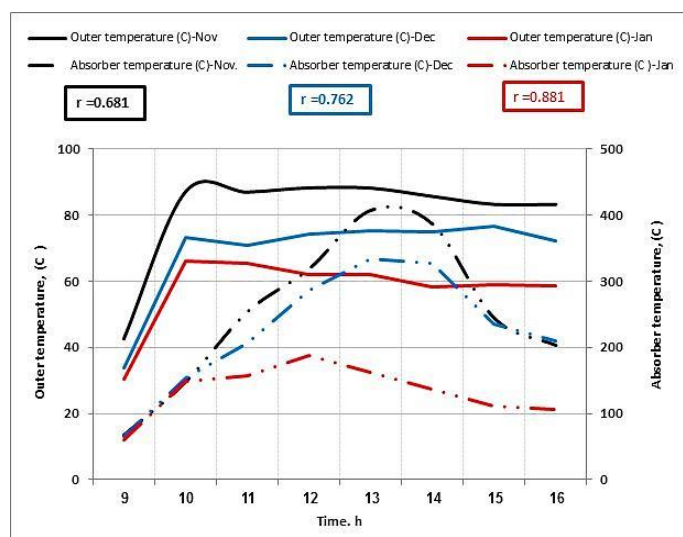


Figure 11. Variation in outer water temperature with absorber wall temperature

Effect of Variables on Useful Energy and Thermal Losses

Useful energy is an essential factor in evaluating the performance of the system so it must calculate effects that can give a substantial amount of them. Therefore, the useful energy is a function of temperature change and mass flow rate. Thus, results showed maximum, and minimum useful power for the distillation system was 1090.9 W, 419.63 W, in Nov. 2018 and Jan.2019, respectively, as shown in Figure 12.

Solar irradiance that reaches the surface of a solar collector is reflected in the direction of instrument installed at concentration point of collector that called (focal point) and then converted into useful thermal energy. However, like all thermal systems, there are thermal losses generated by different modes such as loss of heat by wind, losses by conduction metal parts and radiation losses.

In Figure 13 Shown thermal losses of different months for the distillation system, where the highest amount of thermal losses was observed in November was 39.88 W at 1:00 pm, due to a high amount of solar irradiance reaching solar collector with relatively high wind speed and lowest thermal losses was 19.78 W in December when most top speed of the wind. Maximum overall heat loss coefficient occurs at minimum ambient air temperature.

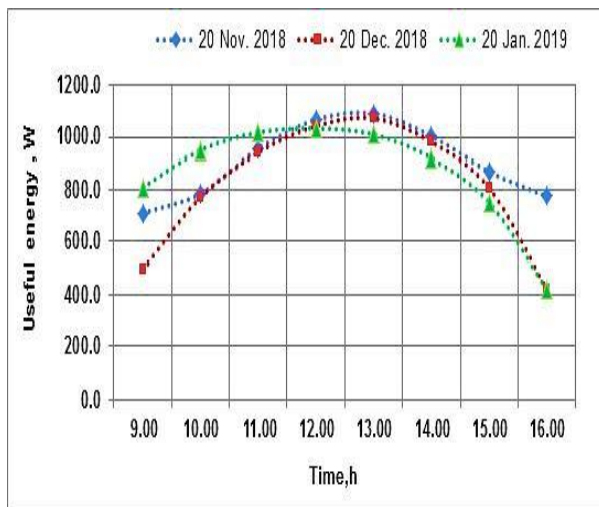


Figure 12. Variation useful energy with time for distillation system

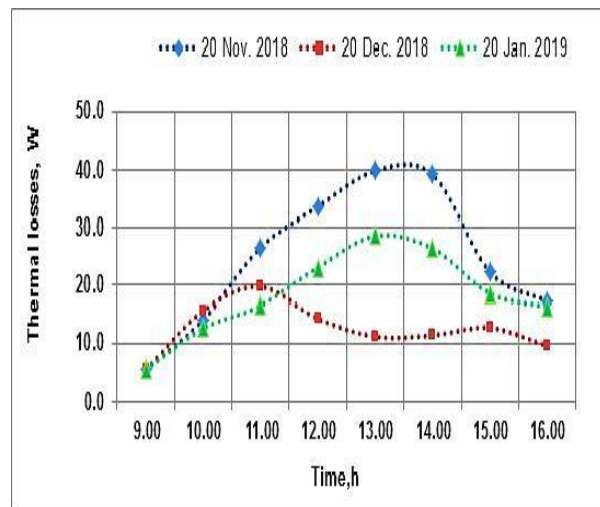


Figure 13. Thermal losses for dish collector

Convection and radiation losses cause loss and conduction loss negligible due to use of thermal insulation covering around the receiver. An absorbent surface is also coated with black paint to minimise any expected losses and absorb most of the reflected radiation from the compound. In general, thermal losses are basics work of any system and are always present when there is a difference between the temperature of the environment and the temperature of the receiver. High thermal losses can be explained at midday due to an increase in the amount of solar irradiance, which increases the difference in temperature between ambient and receiver. Also, the speed of wind plays a significant factor in amount of heat losses and thus decrease thermal efficiency of the system.

CONCLUSIONS AND RECOMMENDATIONS

This study prepared according to the environmental and climatic conditions of the city Najaf - Iraq, at (32.1N°, 44.19E°). Designed and manufactured a system consisting of a parabolic dish integrated with novel single slope solar still to desalinate saltwater and know the amount of productivity during the winter. Therefore, a reference to the above results can be mention in the following conclusions:

- The most effective parameters on the amount of distillation are the amount of solar irradiance falling on concentrator and temperature of the absorber wall.
- The results of the experiments show no significant effects of ambient temperature and wind speed on solar concentration. So, the productivity achieved if high levels of solar irradiance are available even in cold days.
- The condenser coil raising fresh productivity water from 8.2 L.day-1 to 11.45 L.day-1 so worked efficiently about 39.6 %.

- Average daily freshwater output during the experiment period (three months) is (10.5) L.day⁻¹. Therefore, the average annual production of about $P_y = 3360$ L.year⁻¹.
- According to test quality of freshwater resulting from solar distillation, it considered suitable for human uses and met standard report of WHO (World Health Organization).
- When comparing the results in this experiment with the different types from solar still in Table 1, especially those that used the concentration, the performance results were reasonably good.
- From the above conclusion, the present study can be considered as a starting point for enhances solar distillation by using parabolic concentrates; the following recommendations may be helpful:
 - Recommended to use materials for the manufacture of concentrates and absorber light weights, to reduce the energy consumption from solar tracking and also the system is more flexible and less expensive.
 - Preferable to use materials with proper insulation to reduce thermal losses.

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