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CONSTRUCTION AND PERFORMANCE EVALUATION OF A 10 LITRE OPTIMIZED SINGLE SLOPE, BASIN TYPE SOLAR STILL

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ABSTRACT This research is focused on construction and performance evaluation of a 10 Litre optimized solar still. Modelled using Engineering Equation Solver (EES), parameters such as the tilt angle, water depth and insulation thickness were optimized using MATLAB. The optimized solar still was constructed using insulator thickness of 50 mm and a collector tilt angle of 11.6^0 obtained from the thickness that provides the minimum heat losses and collector tilt angle that give optimum insolation. The performance of the solar still was validated by simulating and comparing with the experimental data obtained. Quality analysis of the water before and after treatment was carried out. Experimental results show that the daily distillate produced was about 10.0 litres/day/m^2, with efficiency of 64.99%. Results obtained for the untreated water are as follows: Total dissolved solids (TDS) 4.4 mg/lit; dissolved oxygen (DO) 17.5 mg/lit; biochemical oxygen demand (BOD) 15.5 mg/lit and Electrolytic conductivity (EC) 177.3 mg/lit. For the treated water, the TDS, DO, BOD and EC were reduced to 0.01, 5.5, 2.5 and 25.0 respectively, showing that the solar still is capable of improving the quality of undistilled water of very high TDS, DO, BOD and EC values to a level safe for drinking and other industrial purposes. Statistical analysis of the water and glazing temperatures gave RMSE values of 3.41^0C and 3.5^0C ,and NSE values of 0.9072 and 0.8306 between the model and the experimental results, implying good quality of fit between the experimental and the simulated data.

Keywords: Solar still; tilt angle; solar radiation; bottom loss coefficient; insulation thickness; distilled water

INTRODUCTION

One of the basic needs of human is water, alongside with food and air. Most water in the world is not hygienic for drinking after 20-30 years from today, except the water has been purified (Alpheshv *et al*., 2011). Groundwater and surface water are the two primary water sources. The water obtained from surface sources is mostly polluted by microbes, whereas ground water is usually safer, but may be also adulterated by harmful chemicals from human operations or from natural activities (industrial wastes, pesticides, fertilizers) (Argaw,2003).

Carbon absorption, ultraviolet radiation, reverse osmosis and filtration are some of the different types of purification processes, but distillation and boiling are the most reliable processes because they are natural processes which do not require the addition of chemicals. Water purification such as distillation is very important in areas where water resources or tap water are not acceptable for drinking without chemical treatment or boiling. Energy is therefore needed for boiling and distillation processes. Fundamentally, energy is used in four important sub-divisions of the Nigeria administration/economy which are: Agricultural sector, the industrial sector, the financial and the household sectors. By reason of the growing disparity amidst energy supply and demand, there exists a critical requisite to use the

various types energy derived from the sun (solar energy), wind and biomass (non-conventional energy sources). Energy from the sun is one of the most significant of these energy sources. The energy derived from the sun is renewable, limitless and abundance in supply. The sun's power (energy) is a thousand of times more than all commercial energy consumption on earth today and is approximately 1.8 X 10^{11}MW intercepted by the earth. In essence, on an on-going basis, solar energy has the capacity to present (supply) all current and future needs for energy in the world today, making energy from the sun the best hopeful in regard to non-conventional derivatives of energy (Aman *et al*., 2013). The structure used in solar distillation is called a Solar Still and a popular Solar Still has a slanting glass cover over a black painted, water-filled basin. As sunlight penetrates the device, the basin liner absorbs solar energy via convection and conduction, is transmitted to water. The reflection of the glass and water surface and the absorption from the tank wall (power is transferred to the floor) result in minor heat losses. Water vapour starts to collect on the glass cover as the water evaporates. As the build-up happens and the condensation beads become bigger, the adhesive forces are overcome by gravity and molecules of the pure water slide down the inclined glass plate to gather the pure water in a gutter and transfer it to a storage tank or spigot. Since evaporation is the purification process, this technology is efficient in removing all chemicals, organic and biological contaminants in the feed water. It is a technology that cannot only remove a very wide range of impurities in a single step, but is cheap, friendly to the environment and simple. Solar distillation is by far the most reliable, least expensive 99.9% real purification technique for most contaminated water kinds, particularly in developing countries where fuel is costly or scarce (Aman *et al.*, 2013). Solar distillation is used for the production of drinking water or distilled water for batteries of lead acid, laboratories, hospitals and business products such as rose water. Conventional boiling distillation consumes a lot of energy, while solar distillation uses the sun's free pure power.

An experimental analysis of the various designs of Solar Stills was carried out by Arunkumar *et al* (2012). In their experiment, they fabricated seven Solar Stills and observed their performances when operated at the same climatic conditions in converting impure water to a clean drinkable one. They concluded that the compound parabolic, concentrator-assisted tubular Solar Still exhibited an optimal yield. Aburideh *et al* (2012) conducted an experiential analysis of the effect of the internal parameters on a double slope plane Solar Still. They varied the Solar still's distinct working parameters and discovered that when the difference between the temperature of water and glass reduces, the distillate production rate increases. They also discovered that the presence of wind and the climatic changes influences the water distillate production and hence decreases the quantity of diffused thermal (solar) energy that is received by the saline water. Hence, concluded that the distilled water output was 4L/m^2/day. Ibrahim (2014) designed, constructed and carried out the performance comparison of three Solar Stills having varying absorber plates. The first still type had a submerged v-pattern absorber plate, the second and third Solar Stills were with and without submerged flat plate absorber respectively. The quantities of distillate output obtained at the third day of the experiment were 652 ml/day, 744 ml/day and 821 ml/day and their efficiencies were 80.89%, 83.82% and 81.98% respectively. He concluded that, the submerged v-pattern absorber still had the highest cost and the lowest quantity of distilled water while the submerged flat plate absorber still had the highest distillate output. He therefore recommended that additional research should be conducted using simulation for performance comparison of the three types of solar stills. Obayemi *et al.*, (2014) designed as well as fabricated the variable collector angle, single slope Solar Still using two solar stills having single slope, one of the solar stills was modified using a variable inclination (collector) angle. The experimental study was conducted latitude 11^0 20 in Samaru, Zaria-Nigeria, over a mean solar radiation duration. They observed that distillate peak yield occurred between the hours of 2pm and 3pm, while minimum yield was obtained between 8am and 9am. They also observed that the first Still with rigid collector angle produced a mean output of about 1.366litre/day/m^2 in comparison with the second one with variable collector angle (1.407 litre/day/m^2). They further analysed the result obtained from the two Solar Stills having single slope with the help of a paired T-test (statistical model) and concluded that no important distinction was observed between the first distillate still (39% efficiency) and the second solar still (42% efficiency). Similarly, Ugwoke *et al* (2015) worked on the performance evaluation of a Solar Still having 0.68m^2 collector area with glass cover's emissivity and the absorber plate's absorptivity of 0.85 and 0.93 respectively. The experiment carried out on the fifth day of the experiment yielded a maximum distillate of 2.3 liters and a maximum temperature of 54^{0}C. They therefore concluded that, as solar intensity increases, production distillate became higher. Also, a detailed ten years survey along with inquiry of the passive solar still design and efficiency parameters was carried out by Manchanda and Kumar (2015), where they find out, in their review of the different passive solar stills designs constructed as well as the performance evaluated by several scholars, that the passive solar still's fundamental stumbling block is the low performance in addition to low distilled water yield. They also pointed out some parameters that affects the efficiency of Solar Stills, these included: solar radiation, water depth, temperature of the surrounding air, material of the condensing cover and its direction plus cooling, external plus internal reflective surfaces, the system that tracks the sun, heat together with heat chamber material that are considered most effective. In their conclusion, they stated that, in spite of the huge efforts achieved with the passive still types, certain drawbacks such as optimizing the space in the midst of the surface of the water and the condensing cover on the tilted solar-still, insulation materials and its thickness needs to be improved in order to boost its thermal performance.

Zarzoum *et al* (2017) presented an experimental validation of a new concept of solar distiller with a condenser and coupled with water solar heater and air collector and humidifier to improve the yield of fresh water of the solar still system which was placed at fax in Tunisia. A mathematical model on heat and mass transfers of the optimized solar still system was presented in dynamic mode. The proposed mathematical models were used to predict the thermal performance of the solar still unit. The experimental validation revealed that the numerical prediction of the respectively water temperature, basin temperature and glass cover temperature of the new design was in good agreement with the experimental values, which proves the validity of the mathematical models established for the optimized solar still. An investigation of a new design of four lateral glass faces solar desalination unit have being carried out through Abbas *et al.*, (2018), where they reported a daily efficiency of 48% for ambient temperature 24. 9^0C.Their experimental results showed that a production from purified water enhance to about 6Litres/day for 10hours operation period.

From literature reviewed, standard single-effect basin still has been in use for long. However, it has the drawback of low efficiency in operation and low freshwater provision rates. There is, therefore need to improve the efficiency and productivity which could be done by optimization to get optimal insulation thickness and tilt angle which will improve the performance and lower the cost when applied to the design of a Solar Still. Hence this study is focused on construction and performance evaluation of an optimized 10 litre solar still basin using solar energy for distillation of water with a view to minimize losses of heat at the base and edge of the basin, the optimum thickness of the insulator will have to be determined. The size of the insulator thickness will be varied in order to identify the thickness that provides the minimum heat losses at the surface. Also, the tilt angle will be varied in order to calculate collector angle of tilt that will give (corresponds to) optimum insolation.

MATERIALS AND METHODS

Materials Selection

In order to construct an effective solar still, serious consideration was given to the choice of materials to be used. The materials chosen was structurally sound, safe and effective with regards to the capture of solar energy and retention of heat. Some of the materials that were used and the reason for the choice of such materials are as follows:

Still basin: It is very important that the material to be used for heating the absorbing still basin has high absorptivity and very low reflectivity and transmissivity. It should also have high thermal conductivity and be resistant to corrosion. The types of materials that can be suitable for the basin are as follows: silicon, mild steel plate, RPF (reinforced plastic fibre), G.I. (galvanized iron), Leather, Aluminium and copper. A black coated aluminium sheet that has thermal conductivity of 205W/m^{0}C (Ibrahim, 2014) was used.

Side walls: The walls should be made of low thermal conductivity materials and should be sufficiently rigid to hold their own weight and the top cover weight. Different materials can be used. They include: thermo-cool, concrete and wood. A composite wall of polystyrene (inside) and plywood (outside) was used for better insulation. Thermal conductivity of plywood is Kw = 0.147 W/m^{0}C while that of polystyrene Kt = 0.033W/m^{0}C (Ibrahim, 2014).

Channel: The condensate that is formed slides over the inclined top cover and collects in the passage. This passage which collects out the distilled water is called channel. The materials that can be used should have the following properties: Cheap and readily available, stable to corrosion and will not contaminate water. These materials are: aluminium sheet, galvanized iron, reinforced plastic fibre, polyvinyl chloride. In this work, polyvinyl chloride was used.

Glazing: The following are the features of a glazing material: Transparent to solar radiation, should have a clean and smooth surface, Non-absorbent and non-adsorbents to water. Materials that can be used are: Glass and polythene. The glazing material used in this work is glass because it can transmit up to 90% of the incident short wave radiations while its transmittance to the long wave heat radiation (5.0 to 50µm), in which the absorber plate discharge is negligible (Tiwari, 2002).

Seal: The seal is used in making the side walls and basin to be air tight. The type of sealant to be used should be cheap, readily available and be able to withstand high temperatures. Silicon seal was used for this work.

Design Parameter Optimization

The parameter used as the objective function for the collector tilt angle optimization is the total radiation on a tilted surface, H_T.

$$H_T = H.\left(1 - \frac{Hd}{H}\right) R_b + H\,d\left(\frac{1+\cos\beta}{2}\right) + H\,\rho\left(\frac{1-\cos\beta}{2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where all the terms in the equation are kept constant, the collector tilt angle β was varied to see the effect of the variation on the objective function (H_T). The result of the optimization is shown in figure 1.

Optimization of Insulator Thickness

The parameter used as the objective function for the optimization of insulator thickness is the bottom loss coefficient, (U_b).

$$U_b = \frac{K_{ins}}{L_{ins}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Also, all the parameters in the equation were kept constant while varying the insulation thickness to see the effect on the objective function, U_b. The result of the optimization is shown figure 2.

Parametric Studies on the Effect of Water Depth on the Performance of the Still

Theoretical equation used as objective function for the parametric studies was derived from experimental results adapted from (Tarawneh, 2007; Thakur and Pathak, 2017; Aljubouri, 2017). The equation is:

$$Y = 0.042 \times D^2 - 0.39D + 4.2 \ \ldots\ldots\ldots \text{(3)}$$

Where:

Y= productivity of the still in Litres/day

D = water depth to be varied

Efficiency of the Solar Still

The efficiency of the still is the ratio of the heat utilized in vaporizing water to the total solar radiation received by the transparent cover.

$$\eta = \frac{Q_e}{H_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

where Q_e (useful energy) is the heat used in vaporising water per unit basin area per unit time.

$$Q_e = \alpha_w \tau_g H_s - (q_r + q_e + q_b) \ldots\ldots\ldots \text{(5)}$$

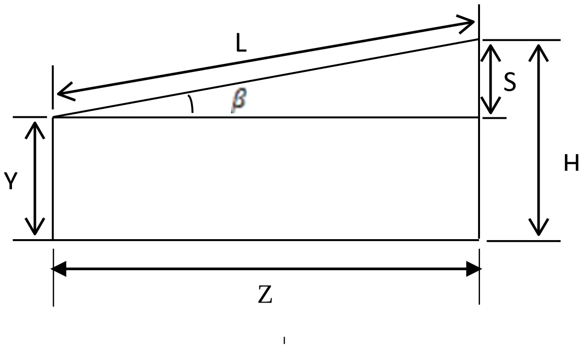
Where H_s is the solar radiation intensity on the horizontal surface, Q_e is the useful heat energy, α_g , α_w , absorptivity of transparent cover material and water respectively, τ_g is the transmissivity of the transparent cover material, q_b is the rate of heat lost from the base.

System design calculations

The physical dimensions of the solar still were calculated and are presented in the Table 1.

Table 1: System Design Calculations

Initial Data	Design Calculation	Remark
me = 10 kg, L = 2260 kJ H_s=16.1x10^{6}J/sm^2,η is assumed = 0.8	Collector Area (A_c) $A_c = \frac{m_e L}{H_s \eta} = \frac{10x2.26}{16.1x0.8} = 1.75m^2$	A_c= 1.75m^2
If length L=1.5m	Then, $A_c = L \times B$ This means that, $B = \frac{Ac}{L} = \frac{1.75}{1.5} = 1.17$	B = 1.17m

If $\beta = 11.6^{o}$ $Y = 0.2m$ $L = 1.5m$	 Using simple trigonometry, $Z = 1.5 \times \cos 11.6 = 1.47m$ $S = 1.5 \times \sin 11.6 = 0.302m$ $H = S+Y = 0.302+0.2 = 0.502m$	$Z=1.17m$ $S=0.302m$ $H=0.502m$

Construction Process: The construction was carried out in the Mechanical Engineering Department workshop of Ahmadu Bello University, Zaria. Table 2 enumerates the process of construction.

Table 2: Construction Process for the optimized Solar Still

S/N	Component	Materials	Process Description	Equipment Used
1	Still basin	Timber 50 mm x 50 mm x 3666 mm Wood Shavings Aluminum sheet. Nails Top Bond glue and Matte Black Paint	Two pieces of 900 mm x 900 mm were cut from a sheet of plywood of 2244 mm x 1122mm x 18mm. 4 pieces of 900 mm x 900 mm x 50 mm x 3666 mm cut to form angle at 21^0. Two (R) pieces cut from 1000mm x 1000mm x 18 mm to form insulation gap. 900 mm x 900 mm cut from 2244 mm x 1122 x 18mm to form still basin base. Aluminum sheet of 900mm x 900mm x 1mm for absorber. Absorber plate painted black on both sides. Wood	• Tape rule. • Straight edge • Panel Hand saw • Jack Plane • Hammer • Pinchers • Pair of scissors • Scriber • Work bench • Protractor

			shavings was used for base and side insulation. 900 mm x 900 mm x 4 mm (glass) glazing. Silicon was used for glazing edge to avoid heat losses.	
2	Side walls	Plywood and Polystyrene		• Measuring Tape. • Hammer • Square rule • Pair of scissors • Jig saw • Abrasive • Surface Grinder
3	Channel	polyvinyl chloride	Two (2) pieces of 253 mm x 18 mm was cut from 2244 mm x 1122 mm x 18 mm. One (1) 506mm x 253mm at an angle of 140 °, a centre point.	• Measuring tape. • Square rule • Pinchers • Hand grinder
4	Glazing	Glass		
5	Seal	Silicon		
6	Finishing of Solar Still surface	• Polystyrene • Body Filler • Aluminium foil • Hardener • Metallic ash paint • Black mat paint • Cellulose thinner Prymer	The outer surface of the drying cabinet was heavily insulated with polystyrene to minimize surface heat losses. Body Filler was coated on open joints and graded to 0.52 mm on the whole surface to seal invisible holes to avoid surface heat losses. Black matte paint was coated at 0.02 mm thickness on the absorber plate.	• Electric Abrasive grander • Generator air compressor • Scraper Air Blower (electric)

Test Procedure: Experiments were conducted for three days at the Mechanical Engineering workshop, Ahmadu Bello University, Zaria to assess the efficiency of the still by determining the following: The incident solar radiation and absorption by the still, the still's efficiency and capacity and Its distillate productivity. In the early hours of the day, the optimized solar still was supplied with raw water and assembled as shown in Plate 1. With thermocouple wires, the hourly measurements of the basin temperature, inner cover temperature and raw water temperature were evaluated. Calibrated cylinder, anemometer and calorimeter were also used to measure respectively the amount of distilled water produced, the hourly wind speed and the insolation (H_s).

RESULTS AND DISCUSSION

Performance Evaluation of The Constructed Optimized Solar Still

After construction, experimental tests were carried out on the optimized solar still to evaluate its performance. During the time of the test, the intensity of solar radiation, wind speed, ambient temperature, internal glass temperature, water temperature and quantity of hourly distilled water were measured for analysis of the performance of the optimized solar still. validation of the performance of the system was performed in two parts. Firstly, the system experimental results obtained during the 3-day experiment were compared with the simulated results. The aim was to obtain the trend and level of agreement between the experimental results and the simulated ones. Secondly, two statistical tools namely; the Root Mean Square Error (RMSE) and the Nasch-Sucliffe coefficient (NSE) were employed to analyse the predictive power of the simulation software. The RMSE measures the difference between values predicted by hypothetical model and observed values. That is to say it measures the quality of fit between actual data and predicted data from the model.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{model,i} - X_{obs,i})^2}{n}} \quad \ldots\ldots (6)$$

Where;

X_{obs} = observed values, X_{model} = modelled values, n = total number of observations

The Nash-Sutcliffe coefficient of Efficiency is defined as follows:

$$NSE = \frac{\sum_{i=1}^{n}(X_{model,,i} - X_{obs,i})^2}{\sum_{i=1}^{n}\left(X_{model,i} - \overline{X}_{obs}\right)^2} \quad \ldots\ldots (7)$$

Where; X_{obs} = observed values, X_{model} = modelled values, $\overline{X}_{obs}$ = mean of the observed value, n = total number of observation.

The lower the mean absolute error or the bias percentage value, the better the performance of the model (Neil, 2010). The experimental set-up is shown in plate 1.

Plate 1: Experimental setup of the constructed optimized solar still.

RESULTS OF SYSTEM SIMULATION AND EXPERIMENTED TEST

The results of the experimental tests (exp) carried out on the solar still and the corresponding simulated readings (sim) using Engineering Equation Solver are presented in Figures 4 –11. Results obtained from the experiment were compared with simulated results generated from the EES software.

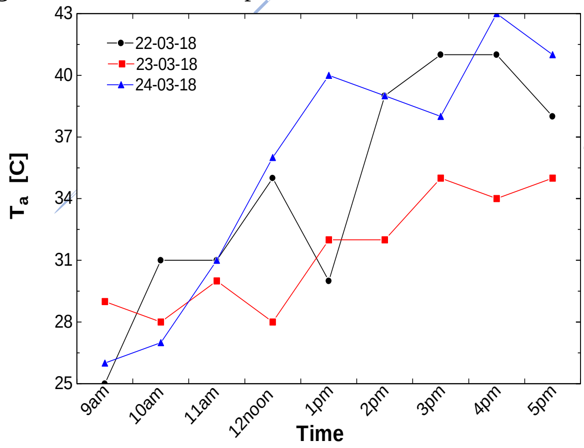


Figure 4: **Ambient temperature profiles**

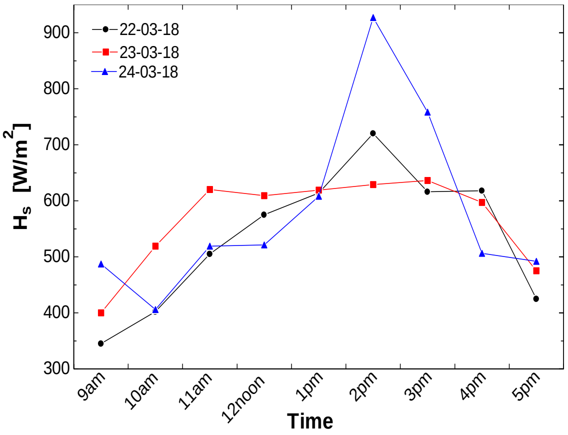


Figure 5: Solar radiation profiles

Figure 4 and Figure 5 show the results of the ambient temperatures and solar radiations of the experiments carried out on the 22nd, 23rd and 24th day of March 2018. From the results, it was observed that the ambient temperature increases from 25^{0}C at 9am when the experiment started to its peak (about 41^{0}C) in the afternoon hours, then decreased to its minimum at the evening hours. Similarly, the solar radiation increases from 345W/m^2 in morning hours to its peak about 720W/m^2 at 2pm, then decreases during the evening time.

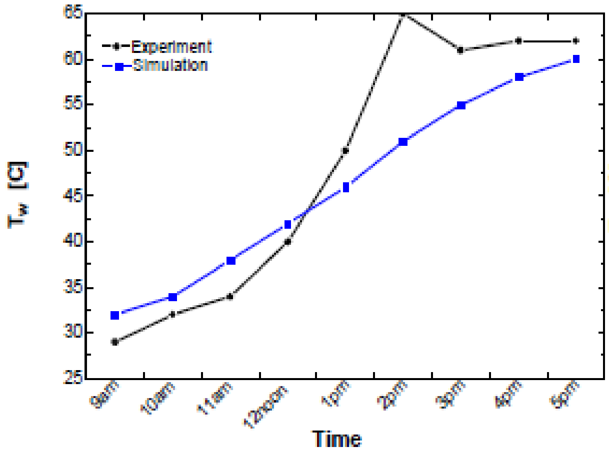


Figure 6: Water temperature profile for day 1

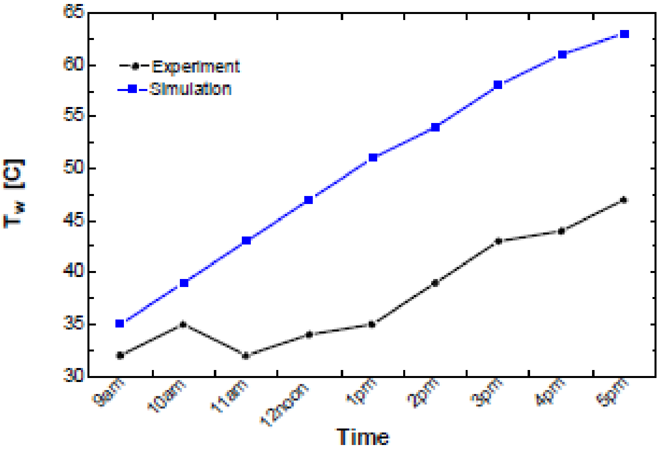


Figure 7: Water temperature profile day2

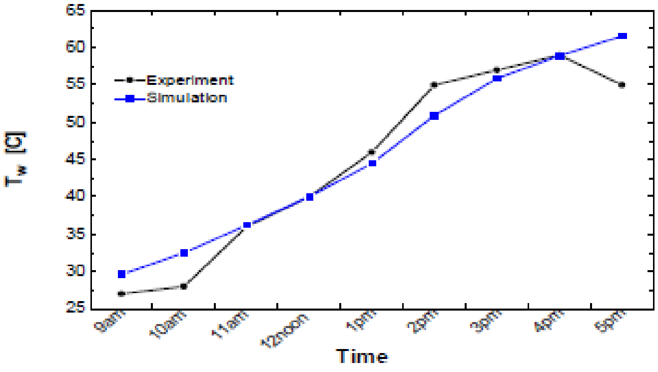


Figure 8: Water temperature profile for day 3

Figures 6-8 show the water temperature profiles for the experimental days (days 1, 2 and 3). The results of the simulation were compared with the experimental results. As anticipated, it follows the trend of solar radiation intensity. Despite not precisely matching the measurements, comparable patterns are followed. The most probable reason for the variation is that the intensity of solar radiation in the simulation does not account for natural attenuation. Similar observation was made by Kharea *et al.*, (2017).

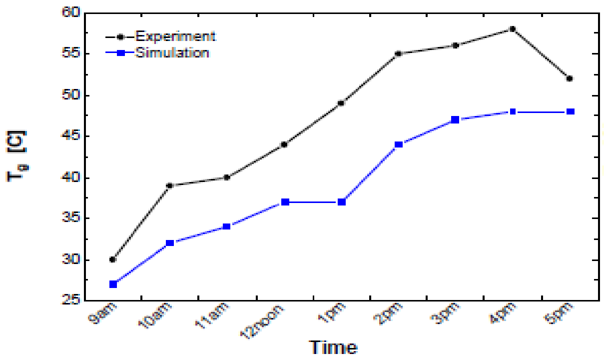


Figure 9: Glazing temperature profile for day1

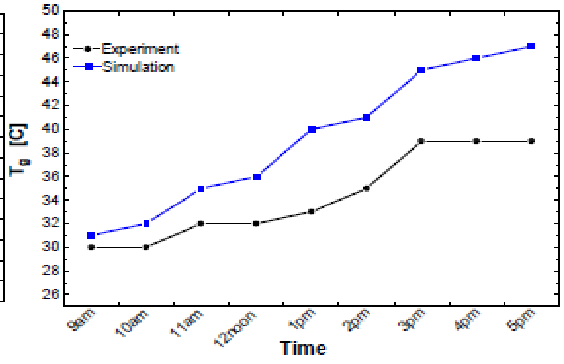


Figure 10: Glazing temperature profile day2

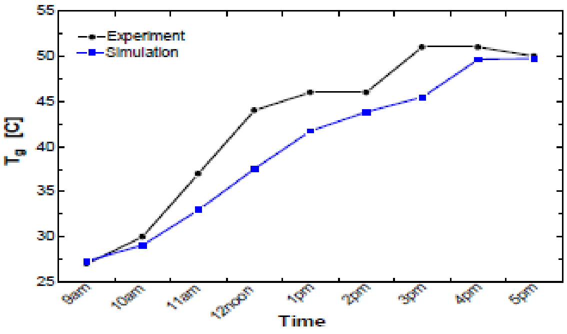


Figure 11: Glazing temperature profile for day 3

Figures 9-11 show that the comparison between experimental and simulated temperature measurements respectively, water and glass cover temperature for the three days of the experiment. It is seen that both the experimental and the simulated temperatures follow the same trend.

Analysis of The Predictive Power of The Simulation Software (EES)

The result of Table 3 and Table 4 shows a RMSE value of 3.41^{0}C and NSE value of 0.9072 between the model and the experimental results. This RMSE value means that the error between the experimental water temperature and the simulated water temperature is 3.41^0 C. The NSE value of 0.9072 indicates that the model can predict the water temperature with 90.72% degree of accuracy. This also implies good quality of fit between the experimental data and the simulated data since the closer the NSE value to 1, the better the predictive power of the model (Julien *et al*, 2013). While analysis in Table 4 gives the RMSE and NSE values of 3.50^{0}C and 0.8306 respectively. This value again implies that the error between the experimental glass cover temperature and the simulated temperature ls 3.50^{0}C. The NSE value of 0.8306 indicates that the model can predict the glass cover temperature with 83.06% degree of accuracy.

Table 3: Validation of simulated water temperatures with experimented results using the RMSE and NSE statistical tools for March 24, 2018

			RMSE Calculations		NSE calculations
Time	$T_{w_{sim}}$ (°C)	$T_{w_{exp}}$ (°C)	$T_{w_{sim}}$-$T_{w_{exp}}$ (°C)	$\left[T_{w_{sim}} - T_{w_{exp}}\right]^2$ (°C)	$\left[T_{w_{sim}} - \overline{T_{w_{exp}}}\right]^2$ (°C)
9am	30	27	3	9	219.04
10m	33	28	5	25	139.24
11am	36	36	0	0	77.44
12noon	40	40	0	0	23.04
1pm	44	46	-2	4	0.64
2pm	51	55	-4	16	38.44
3pm	56	57	-1	1	125.44
4pm	59	59	0	0	201.64
5pm	62	55	7	49	295.84
$\sum_{i=1}^{n} \mathbf{x}$	411	403	8	104	1120.76
Ave	45.7	44.8	0.9	11.6	124.53

Table 4: Validation of simulated glass temperatures with experimented results using the RMSE and NSE statistical tools for March 24, 2018

			RMSE Calculations		NSE calculations
Time	$T_{g_{sim}}$ (°C)	$T_{g_{exp}}$ (°C)	$T_{g_{sim}}$-$T_{g_{exp}}$ (°C)	$\left[T_{g_{sim}} - T_{g_{exp}}\right]^2$ (°C)	$\left[T_{g_{sim}} - \overline{T_{g_{exp}}}\right]^2$ (°C)
9am	27	27	0	0	237.16
10m	29	30	-1	1	179.56
11am	33	37	-4	16	88.36
12noon	38	44	-6	36	19.36
1pm	42	46	-4	16	0.16
2pm	44	46	-2	4	2.56
3pm	45	51	-6	36	6.76
4pm	50	51	-1	1	57.76
5pm	50	50	0	0	57.76
$\sum_{i=1}^{n} \mathbf{x}$	358	382	-24	110	649.44
Ave	39.8	42.4	2.7	12.22	72.16

Effect of Water Depth on the Performance of Still

The result of varying the yield produced and water depth is presented in Figure 3, which shows the effect of varying water depth (d) on the yield produced (P). From the figure, the yield produced per day decreases from 9.95Litres/day to 2.50Litres/day as the water depth increases from 2cm to 10cm.Water depth of 2cm gave the highest yield of 9.95Litres/day. The efficiency of the solar still was calculated to be 84.48% using equation 4.

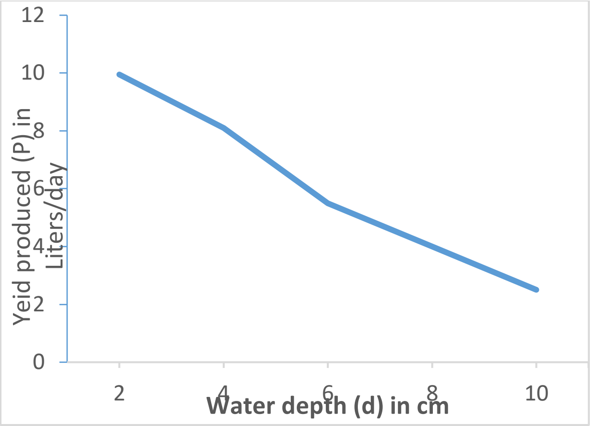


Figure 3: Variation of water depth on the yield produced

Water Quality Analysis

Water quality analysis was conducted to compare the Hydrogen ion concentration (pH), Total dissolved solids (TDS), Dissolved oxygen (DO), Biochemical oxygen demand (BOD) and Electrolytic conductivity (EC) of the water before and after distillation and compared with the World Health Organization (WHO) recommended distilled water standard. The water analysis test was carried out in the Department of Biochemistry, Ahmadu Bello University, Zaria.

Table 2: Water quality analysis of undistilled and distilled water

S/No	Test	Result		WHO
			Re sult	
		Undistilled water	Distilled water	Distilled water
1	PH	6.4	7.1	7.0-8.8
2	TDS (mg/lit)	4.2	0.01	Not exceed 0.1mg/lit
3	D.O (mg/lit)	17.5	5.5	Not exceed 13-14mg/lit
4	BOD (mg/lit)	15.5	2.5	
5	E.C (µs/cm)	177.3	25.0	5-50 µs/cm

Water quality of the distilled water was compared to the World Health Organization (WHO, 2011) Distilled Water Quality Standard. The distilled water is found to be safe for use in the Laboratory.

CONCLUSIONS

The optimized solar still was constructed and tested for performance evaluation. Experimental results show that the daily distillate produced was about 10.0 litres/day/m^2. The efficiency of the Solar Still was found to be 84.48%. The results of the 3-days experiment carried out revealed that the water temperature and glazing temperature profiles for the three days test period are in close agreement, thereby validating the model (EES) used for simulation. Also, from the result of water quality analysis of the water before and after distillation, it was observed that solar still is capable of improving the quality of undistilled water of very high Total Dissolve Solid, Dissolve Oxygen, Biochemical Oxygen Demand and Electrolytic Conductivity values to a level safe for drinking and other industrial purposes.

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CONFLICT OF INTEREST

Authors have declared that there is no conflict of interest reported in this work.

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