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Experimental Investigation for the Performance of Simple Solar Still in Iraqi North

Omer Khalil Ahmed, Ahmed Hassan Ahmed, Khalil Ibrahim Mohammad

Abstract- The aims of this research to present the possibility of using simple solar still to distillation of saline water in the northern areas of Iraq as well as to verify the reliability of research results published in the past to reach the standard adopted in determining the operational variables which affecting on the performance of solar still

A series of tests to demonstrate the effect of the thickness of water in the basin on the productivity of solar still, the study showed productivity distilled rely mainly on the thick layer of water and it was also noted that the presence of local wind reduces the performance of solar still, but slightly. The presence of dye in the water was reduced the productivity of still and therefore, this option is not desirable to reach an improvement in the still productivity, except in the case of the use of special pigments to absorb large quantities of solar radiation, which imported materials and increase the cost of distillation. It also increased the salinity of the water in the basin of still leading to reduction in productivity and this reduction increased with the increased concentration of salt.

Keywords- Effect of operational variables, Solar still , Performance of,.

I. INTRODUCTION AND LITERATURE REVIEW

Oceans and seas with their huge area and its great deeps considered the greatest reservoir of natural water, they contain 97 % of water on the earth, but this water contains 3.5 % salt of its weight, and because of the salt in ocean water, it is not able to be used in different aspects, such as drinking, agriculture and industry.World's consumption of water increase in recent years according to the scientific and civilized progress together with the increase in living standards, as a result of high cost of desalination station, the sights of scientists were toward using solar energy to find a solution of water shortage especially in the coastal countries, thus the middle east countries considered one of the places to use solar energy in desalination, because most of these countries have long coasts and a lot of solar radiation, there are two way to distilling water using solar energy, first of them is indirect way that depends on replacing electricity power generated by sun using solar cells instead of power used in desalination stations, there are many methods to get fresh water from salty water, such as reflective diffusion, freezing hydrate gases, electrical analysis and distilling by boiling, the second is the direct method (namely solar still) which studied in the research.

A solar still is a simple way of distilling water, using the heat of the Sun to drive evaporation from humid soil, and ambient air to cool a condenser film. The simple solar still depends on the process of slow evaporating of water not by boiling, as temperature doesn't reach boiling degree it is fixed between 50–60 °C. These stations processed under regular pressure, so they don't need any mechanical or electrical equipment, or control panels, therefore the cost of the still and its operation is low and its breakdown is null in comparison with others [1].

Rajvanshi [2] studied theoretically and practically the effect of a group of dyes on the productivity of solar distiller, the researcher used black, green and red dyes to color the salty water in the basin of still, the results showed that black dye was the best, increased productivity by 29 % when dye concentration was 172.5 ppm in comparison with others. Akash.et.al [3] conducted an experimental work on a single slope solar still and evaluated its thermal performance under Jordanian climate. The researcher applied a group of effects on the performance of the simple solar still under Jordanian environments by using various absorbing materials. The still has equal angle double-sloped covers with an effective basin area of 3 m^2. The materials used to enhance the absorptivity of water for solar radiation include dissolved salts, violet dye, and charcoal.

Tripathi and Tiwari [4] have proposed a thermal modeling of passive and active solar stills for different depths of water by using the concept of solar fraction. In this experiment, it is observed that the internal convective heat transfer coefficient decreases with the increase of water depth in the basin due to decrease in water temperature. Tanaka and Nakatake [5] found that the productivity of fresh water by solar distillation depends mainly on the intensity of solar radiation, the sunshine hours and the type of the still. Dinesh Kumar et.al [6] presents evaluation of performance of solar water distillation using solar still. Solar distillation represents a most attractive and simple technique among other distillation processes, and it is especially suited to small-scale units at locations where solar energy is considerable. in this we have calculated internal heat transfer coefficient and the mass output hourly basis. The effect of depth of water and inclination of tilted glass on water output is also evaluated.

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* Correspondence Author (s)
Omer Khalil Ahmed, Unit of renewable energy research, Technical institute/Hawija, Iraq.
Ahmed Hassen Ahmed, Unit of renewable energy research, Technical institute/Hawija, Iraq
Khalil Ibrahim Mohammad, Department of Physics, University of Kirkuk/ College of science, Iraq.

The aim of this research is to use the simple solar distiller to distill salty water in northern Iraq, in addition to achieve a reliability of the results published formerly to get a standard counted on defining the variables that effect on the performance of simple solar still.

II. THE EXPERIMENTAL WORK

The solar still used in this research consists of rectangular basin 1 m × 0.8 m, isolated from the outer sides and base, and the interior surface of its base is blackened to enable absorption of solar energy to the maximum possible extent. It has a top glass transparent cover, this cover is sloped at angle of 45° to enable the water vapor to distill and goes to side channels collecting water as in Fig. (1). Two models of the same shape were built to study the effects of the design variables on the performance of the simple solar still, placed together to insure the same climate environments and to get high reliability of the results, Fig. (2) is a photograph of two solar still that used in this study. Negative temperature coefficient, thermally sensitive resistor otherwise known as thermistors were used for the temperature measurements. Temperature variation causes two types of behavior in a thermistor; negative and positive response. The negative behavior in which the resistance decreases with elevation in temperature generates a more linear response and is more reliable for temperature measurement. Calibration of the thermistor was carried out by gradually varying the temperature and recording the corresponding resistance change. Data obtained regarding the temperature variation and the corresponding resistance are shown in Fig. (3). The equation of the calibration curve in Fig. (3) is:

$$T = -37.94 * \ln(R) + 199.69 \quad (1)$$

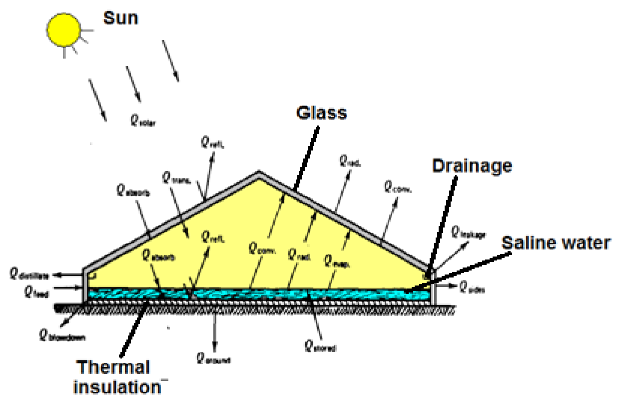

Fig. (1) simple solar still

Fig.(2) A photograph for solar still used in the study

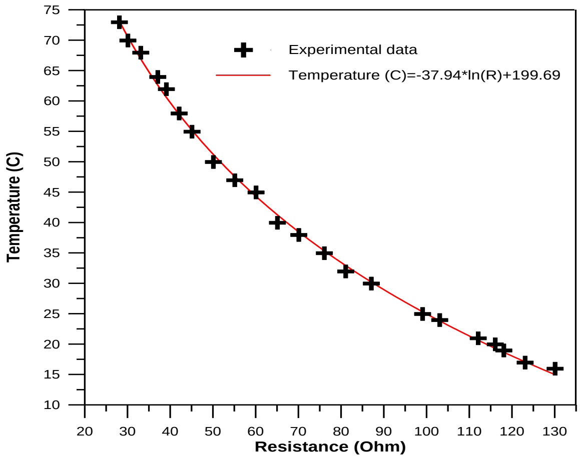

Fig. (3) The calibration curve of the thermistors

Arrays of thermistors were used to determine the temperature distribution within the body of the solar still, one sensor is used to measure water temperature in the basin of still, and two sensors to measure inner and outer temperature of the glass cover surface that facing the sun, two additional thermistors were used to measure the temperature distribution through the base which considered as a heat loss, also another sensor was fixed freely to measure the temperature the air inside the distiller, another one outside the distiller to measure the surrounding air temperature.

III. THEORETICAL STUDY

Solar still receives solar radiation at a rate of. I_o per unit area of the cover Fig. (1), absorbed a $\alpha_g I_o$ quantity of the glass cover (where α_g a quantity of glass cover absorbency, $\tau_g I_o$ was transmitted through the glass cover (where the τ_g is the transmittance of the glass cover), and the rest is reflected by the glass cover to the outer surrounding. The solar radiation that transmitted through glass cover is divided into two sections, the first is ($\alpha_w \tau_g I_o$) absorbed by the water of still, the second is ($(1-\alpha_w \tau_g) I_o$) reflected from the surface of water, which we will impose its transmittance directly to the outer surrounding without an internal reflections between the surface of the water and the glass cover. The amount of solar radiation absorbed by the water in the basin of the still to be offset by the loss of heat from water to glass cover by convection (q_c), radiation (q_r) and evaporation (q_e) also the still loses heat form from the base to the outer surrounding (q_b) also depletes the amount of heat (q_f) to raise the temperature interring the still and all of the previous heat quantities are per unit area of the cover, glass cover receives heat quantities q_c and q_r and q_e from the water at the base, the cover loses heat to the outer space by convection and radiation together at a rate q_{ga}.

The hourly efficiency of the solar still is calculated using the following definition [7]:

Effciency =

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$$\frac{\text{Heat Utilized Distillation}}{\text{Total Quantity of solar radaition incident on the still}} * 100 \quad (2)$$

$$\text{The hourly}(\%)\text{effeciency} = \frac{ml.\text{of water collected}*\rho*\lambda}{1000*1000*Hs*3600*A} * 100 \quad (3)$$

where:

ρ The density of water (kg/m^3)

λ Latent heat of vaporization (kJ/Kg) at water temperature (T_w) of still calculated by the following formula:

$$\lambda = 2501.67 - 238.9T_w \quad (4)$$

Hs Solar intensity (W/m2) which measured by weather station.

A Area of basin still (m2).

Theoretically, the production of distilled water output of the solar still depends on the theoretical mass transfer rate and vapor pressures of the basin and cover temperatures. It is estimated form the following relationship as given in Ref. [8]:

$$\dot{m}_{th} = 9.15 * 10^{-7} * hc * (P_{wb} - P_{wg}) \quad (5)$$

where $\dot{m}_{th}$ is the theoretical mass transfer rate in kg/m^2.s. , P_{wb} and P_{wg} are the vapor pressures of water in mm Hg at basin temperature (Tb) and glass cover temperature (Tg) both in degrees Kelvin. Where Pw and Pg are the vapor pressures at water and glass temperatures, respectively, and are given from the following relation [9]:

$$P(T) = \exp(25317 - \frac{5144}{T + 273.15}) \quad (6)$$

hc is the still convection coefficient. It is given by:

$$hc = 0.844 \left[(Tb - Tg) + \left(\frac{P_{wb}-P_{wg}}{2016-P_{wb}}\right) Tb\right]^{\frac{1}{3}} \quad (7)$$

The theoretical hourly productivity is calculated from the above equations using measured values of *Tb* and *Tg*, and compared with the experimental values.

IV. SOLAR RADIATION CALCULATION

The solar radiation which received by the solar still was calculated Davis Vantage Pro with weather station package used to collect weather data. The standard version of the weather station package contains a rain collector, temperature sensor, humidity sensor, solar radiation sensor, ultra-violet (UV) sensor and anemometer. Temperature and humidity sensors were mounted in a passive radiation shield to minimize the impact of solar radiation on sensor readings. In our study, solar radiation and wind speed data were taken from this station which shown in Fig.(4).

V.THE EXPERIMENTAL PROCEDURE

Due to the lack of information regarding solar still at local weather conditions, this work was concerned mainly with basic data collection. The tests were carried out at the Hawija technical institute (36 ºN latitude) on selected clear sunny days. The glass of the distiller has been cleaned from dust and filled with fresh water and directed toward south, taking measurements started at 9.00 a.m. to 4.00 p.m. Temperature degrees were taken every hour together with the distilled water which collected in a scale jar. Different kinds of tests have been carried on these two models include the following variables:

1. The impact of water thickness in the tank.
2. The effect of salt concentration of water tank.
3. The effect of dyeing water with different colors on the distilled water.
4. The effect of wind velocity on the performance of the still.

Fig.(4) The weather station that used in the study.

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VII. RESULTS AND DISCUSSIONS

In this section, the experimental and numerical results are presented for solar still. The field experiment on the experimental rig was carried out on the top roof of building, Hawija in Iraq. The daily production of distillated water was collected into a bottle every day.

A. The effect of water thickness on the reservoir

A group of tests have been carried out to show the effect of water thickness in the basin on the still productivity, Fig. (5) shows the change of still productivity (by litters) during the day, the fact that its productivity is higher when water thickness is 4 cm in comparison with 8 cm thickness, this due to the mass of the water in the reservoir with 4 cm thickness is lower which that the energy needed to raise its temperature, be less, this means that it is possible to raise the water temperature in the reservoir with 4 cm

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thickness to higher degree than with 8 cm thickness as shown in Fig. (6), that showed the change of water temperature in the reservoir in the two cases, we noticed that the water temperature in the reservoir with 4 cm thickness recorded higher degrees reached 64 °C at 2 p.m, while reservoir temperature with 8 cm thickness reached 62 °C at the same time.

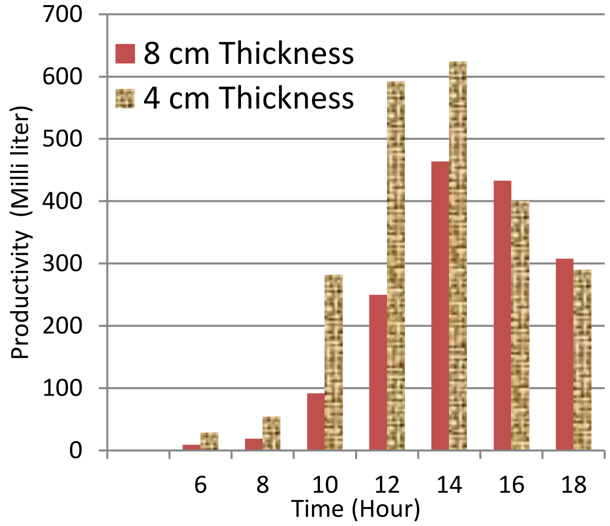

Fig. (5) Variation of still productivity during day for different water thickness

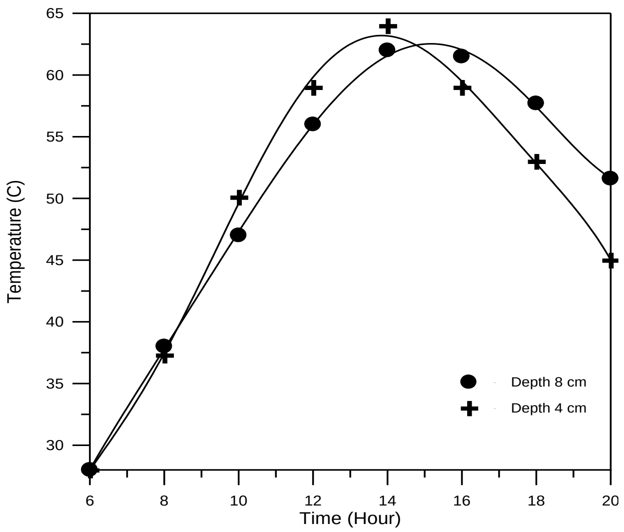

Fig.(6) Variation of still water temperature during the day for different thickness of water.

Fig. (5) shows that the productivity of the still reached its peak value at 4 pm in the two cases 4, 8 cm, then it reduced, this due to the decrease in sun radiation and increasing the heat losses from the reservoir because of the increase of its temperature to relatively high levels which makes the difference between its temperature and the temperature of surrounding air higher, this leads to a reduce in the quantity of absorbed energy by water in the reservoir, therefore, reduce its productivity, as we mentioned before that the highest degree was at 2 p.m this means that there is a contrast between the highest degree in the reservoir water and the highest productivity of the distiller which is two hours. Another test carried out to assure the reliability of the results, the water thickness was fixed in one of the reservoir with 2 cm and the other is 8 cm as shown in Figs. (7,8). The results were the same so the highest productivity of the reservoir was at 4 p.m when its thickness is 8 cm, while the highest productivity of 2 cm thickness was at 2 p.m, with a great increase in productivity in comparison with 8 cm thickness, this increase was 30.34 %, therefore the thickness 2 cm was the best to reach an acceptable results, this explains the good performance of 2 cm thickness in comparison with 8 cm thickness as shown in Fig. (8).

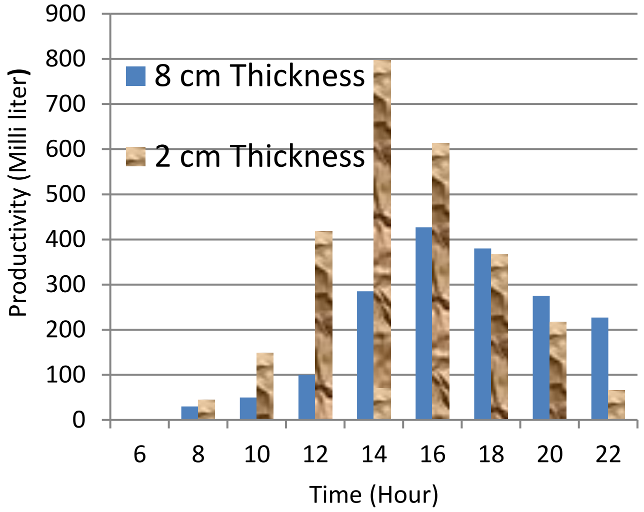

Fig. (7) Variation of still productivity during day for different water thickness.

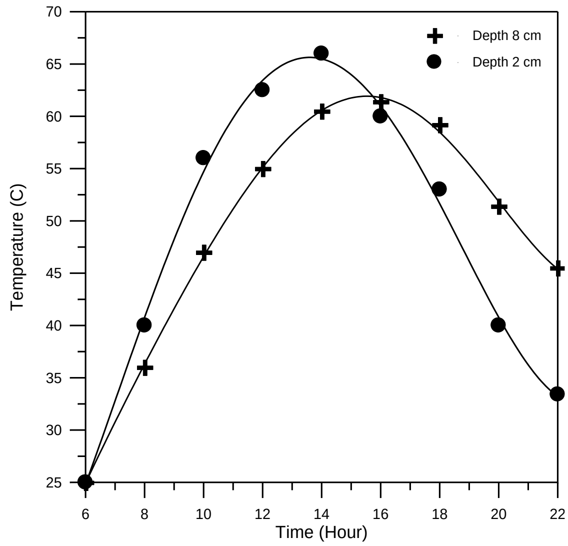

Fig. (8) Variation of still water temperature during the day for different two thickness of water.

Table (1) showed the difference of still efficiency for different thickness of water in the basin, this table showed the basin with 2cm thickness was more efficient than other thickness, also it is noticed that the efficiency reaches the highest values at different time for any thickness due to increase in solar radiation causes an increase in water temperature and then decreases after that due to declining rates of solar radiation and an increasing in heat losses.

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B. The effect of wind velocity on the still performance

The effect of exposing wind on the still was achieved by guiding a wind current to one model of still, while the other one without directing on it, the wind speed was 2 m\s and its oriented from the west as the prevailing wind velocity in the study region during the year. The results showed that outer wind reduces slightly the productivity of the still as in Table(2). Fig.(9) shows the slight increase in the still water temperature which is exposed to the outer wind in comparison with other model and this behavior explain the reducing in the productivity.

Table (1) The still efficiency for different thickness of water in the basin.

Time (Hour)	Hourly Efficiency %		
	2 cm Thickness	4 cm Thickness	8 cm Thickness
6	0.00	0.00	0.00
8	10.03	6.25	2.01
10	16.33	5.95	2.10
12	22.76	15.41	5.04
14	37.07	27.59	11.67
16	36.51	37.20	27.59
18	30.35	32.99	35.54
20	24.17	32.14	33.91
Daily Efficiency %	**22.15**	**19.69**	**16.84**

Table (2) Effect of wind on the still productivity

Time (Hour)	Productivity (Liter)	
	with wind	without wind
6	0	0
8	0.042	0.037
10	0.1	0.111
12	0.3	0.324
14	0.51	0.527
16	0.555	0.585
18	0.295	0.313
Total Productivity (Liter/Day)	**1.802**	**1.897**

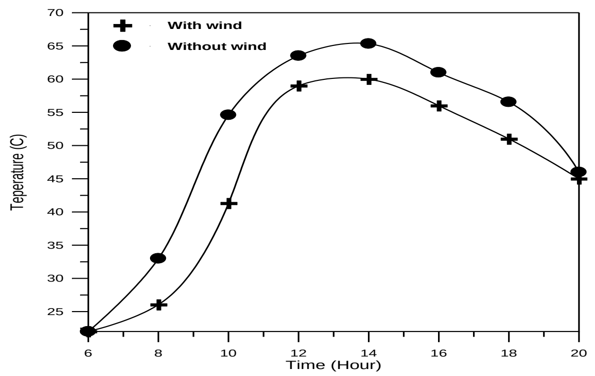

Figure (9) Effect of wind velocity on the water temperature of basin.

a. The effect of using dyes:

The different dyes such as (orange, red and black), which used to colored the salty water in the basin of the still and study their effect on its productivity. The results showed in Table (3), in the early hours of the day there is a drop in the productivity of the still (from 6 a.m to 10 a.m), then the productivity increases in comparison with ordinary still from 10 a.m to 3 p.m, after that, the productivity reduces till to dusk, this random attitude is complicated to explain, in order to have a clear and precise explanation of dye effect on the productivity, it is useful to use the principle of daily productivity to show the distilled water quantity produced as a whole by the still during day as shown in last row in Table (3), thus results show that the dye reduces the productivity, therefore this choice is not preferable to increase it, the results were on the contrary of the results published by the researcher[2], which showed an improvement of still productivity when using dye, and he used chemical materials have the ability to absorb sun radiation, this explains the increase in the productivity in comparison contrary to this research which used local dyes to color the water.

Table (3) Effect the dye types on the still Productivity (Mille liter)

Time (Hour)	Red dye		Orange dye		Black dye	
	With out	With	With out	With	With out	With
6	0	0	0	0	0	0
8	25	8	40	20	20	15
10	70	40	62	109	25	60
12	137	268	180	287	161	225
14	517	528	485	528	395	418
16	440	435	495	415	345	341
18	383	267	380	310	220	145
20	270	150	242	142	135	70
Productivity Liter/day	**1842**	**1696**	**1884**	**1811**	**1301**	**1274**

b. The effect of salt concentration:

A series of tests carried on to find out the effect of salt concentration on the productivity of the solar still, a measured quantities of salts added to the water in the still basin after dissolving it in water, two samples were taken, where one kilogram of salt added to the reservoir water in the first experiment, therefore salt concentration was 0.03125 Kg salt to each kilogram of water, the second experiment added three kilograms, so salt concentration was 0.09375 Kg to each kilogram of water, in both cases the other reservoir contains fresh water.

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The results showed in Table (4), the salt reduces the productivity of the still, the productivity continues to reduce as long as there is an increase in the salt concentration, the reduction ratio when using 0.03125 concentration was 14.32% while the reduction ratio become 21.89% when using 0.09375 concentration. The reduction in productivity is because of the reduction of temperature of salty water in the still in comparison with the other model which contains normal water as in Figs. (10,11).

Table (4) Effect the Salt concentration on the still Productivity (Mille liter)

Time (Hour)	Using 0.03125 kg salt/kg water		Using 0.03125 kg salt/kg water	
	Without salt	With salt	Without salt	With salt
6	0	0	0	0
8	30	18	23	15
10	140	104	38	24
12	165	141	160	100
14	380	320	410	350
16	600	535	515	400
18	340	300	325	260
Total Productivity (Liter/day)	1655	1418	1471	1149

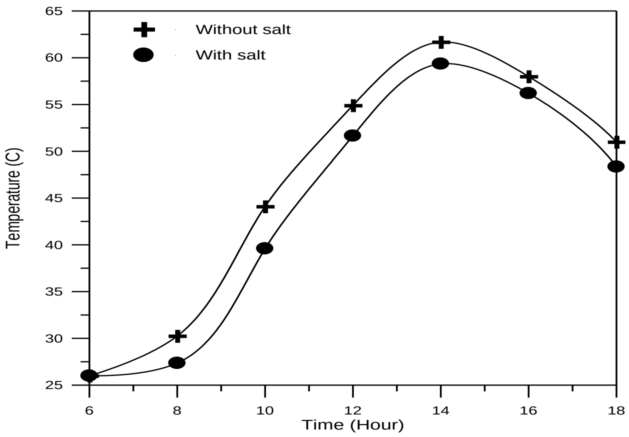

Figure (10) Variation of water temperature of still in the presence of salt concentration (0.03125 kg of salt per kg of water)

VIII.CONCLUSIONS AND RECOMMENDATIONS

From the previous results we deduce the following:

1. Still productivity depends mainly on the water thickness, water levels.
2. The outer wind causes a slight reduction in productivity which was ignored.
3. The use of dyes causes a reduction in the productivity so this is not recommended to improve choice the still productivity.
4. The increase of salt concentration in the reservoir water reduces the productivity and this diminish of productivity increases by the increase of salt concentration.

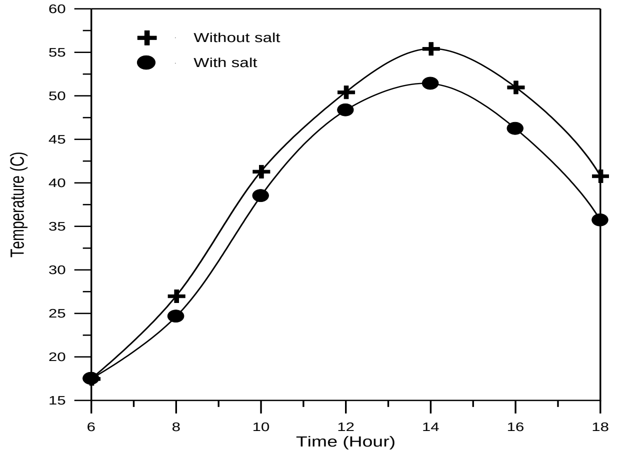

Figure (11) Variation of water temperature of still in the presence of salt concentration (0.09375 kg of salt per kg of water)

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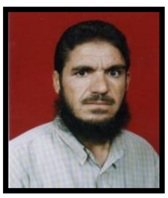
Omer Khalil Ahmed graduated from Tikrit university in Iraq as a mechanical engineer in 1999. He got PhD degree from Al-Nahrain university in 2006, He is an assistant professor on renewable energy in foundation of technical education in Iraq. Dean of Technical institute/Hawija. His special field of interest included renewable energy, heat transfer , fluid mechanics, power plant engineering, power system cost.



Ahmed Hassan Ahmed, graduated from Tikrit university in Iraq as a mechanical engineer in 1997. He got Msc degree from Tikrit university in 2001, He is an assistant professor on Heat transfer in foundation of technical education in Iraq. Dean of Technical institute/Hawija. His special field of interest included renewable energy, heat transfer, fluid mechanics.

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Khalil Ibrahim Mohammad, graduated from university of Mosul in Iraq as physicist in 1996, He got PhD degree from university of Mosul in 2006. He is a lecturer on physics in Kirkuk university in Iraq. His special field of interest included solar energy, laser technology, optics technology.