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SIZING AND EXPERIMENTAL STUDY OF A SOLAR STILL FOR THE PRODUCTIVITY OF WATER DESALINATION IN SOUTH-WEST OF ALGERIA – BECHAR

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Abstract: Algeria, like many countries belonging mostly to the Third World, has considerable water resources saline (salt content ranging between 1500 and 2000 ppm, exceeding the required standards for drinking water and therefore unfit for consumption). We must therefore think of making use these huge reserves interested in desalination techniques. The stain majored is therefore to achieve a distiller solar plan which meets these needs in drinking water. The absorber surface of the modified solar still is coated with black enamel paint and covered with copper chips. The evaporation rate of the water in the solar still is directly proportional to the exposure area of the water. Thus the productivity of the solar still increases with the free surface area of the water in the basin. The distillate yield was found to have improved considerably, especially when the water depth was high. The study also indicated some design features that would further enhance the improvement in output due to the modification made, the evaporation rate is proportional to the temperature of the free surface area of the water only. A general model based on heat transfer balances in each component of the system was developed to predict the mass of freshwater. The efficiency of this still was about 65% and can produce about 5.13 l/m2 per day, experimental studies and the outcomes are discussed in the article. We propose a new design of the cascading solar desalination still with obstacles and preheating of inlet water.

Keywords: solar plan, desalination, water resources saline, Solar energy, heat transfer, the evaporation, experimental study.

التصميم والدراسة التجريبية لجهاز التقطير الشمسي لإنتاجية تحلية المياه في جنوب غرب الجزائر – بشار

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الملخص: الجزائر، مثل العديد من البلدان التي تنتمي معظمها إلى العالم الثالث، لديها موارد مائية مالحة كبيرة (يتراوح محتوى الملح بين 1500 و2000 جزء في المليون، وهو ما يتجاوز المعايير المطلوبة لمياه الشرب وبالتالي غير صالحة للاستهلاك). لذلك يجب أن نفكر في الاستفادة من هذه الاحتياطيات الضخمة المهتمة بتقنيات تحلية المياه. لذلك فإن تخصص البقعة هو تحقيق خطة التقطير الشمسية التي تلبي هذه الاحتياجات في مياه الشرب. السطح الماص للقطع الشمسي المعدل مطلي بطلاء المينا الأسود ومغطى برقائق نحاسية. لا يزال معدل تبخر الماء في الشمس متناسبًا طرديًا مع مساحة التعرض للمياه. وبالتالي فإن إنتاجية الطاقة الشمسية لا تزال تزداد مع

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زيادة مساحة السطح الحرة للماء في الحوض. وجد أن ناتج التقطير قد تحسن بشكل كبير، خاصة عندما كان عمق الماء مرتفعًا. أشارت الدراسة أيضًا إلى بعض ميزات التصميم التي من شأنها تعزيز التحسن في الإنتاج نتيجة التعديل الذي تم إجراؤه، حيث يتناسب معدل التبخر مع درجة حرارة مساحة السطح الحرة للماء فقط. تم تطوير نموذج عام يعتمد على موازين نقل الحرارة في كل مكون من مكونات النظام للتنبؤ بكتلة المياه العذبة، وكانت كفاءة هذا حوالي 65 % ويمكن أن تنتج حوالي 5.13 لتر/ م 2 في اليوم. تناقش الدراسات التجريبية والنتائج في المقالة. نقترح تصميمًا جديدًا لتحلية المياه بالطاقة الشمسية المتتالية التي لا تزال تواجه عقبات والتسخين المسبق لمياه المدخل.

الكلمات المفتاحية: خطة الطاقة الشمسية، تحلية المياه، موارد المياه المالحة، الطاقة الشمسية، نقل الحرارة، التبخر، الدراسة التجريبية.

I. Introduction

The drinking water needs in the world rose continuously, while supplies are fast dwindling. The demand for fresh water is growing at an annual rate of around 4%, while over a third of humanity already have no access to water. Faced with this crisis of water supply that is beginning to be felt acutely throughout the world, in addition to the economic sustainable development, appropriate solutions must be considered in order to be ready to face this challenge threatens the very existence of man [1,2]. Several designs of solar stills have been built over the past century. Development of economical solar still with high productivity is a major challenge. Various researchers worked to improve the productivity of solar still; some of those are by, changing basin geometry [3,4], reducing heat losses in the still [5,6], augmenting heat collection by con- centrator and reflectors [7,8], preheating of inlet water [9,10], maintaining optimal flow rate, achieving drop wise conden- sation [11,12]

However, the desalination units classic requires electricity or heat relatively high which is often non-existent in these regions. The use of solar energy for desalination has a number of problems. In addition, if the water needs are relatively small (some m3 a few dozen m3) direct solar distillation is an interesting solution especially when skilled labor is available [13,14,15]. The various factors affecting the performance of the solar still are solar intensity, wind velocity, ambient temperature, water– glass temperature difference, free surface area of water, absorber plate area, temperatures of inlet water, glass angle, still orientation and depth of water. The solar intensity, wind velocity, ambient temperature cannot be controlled as they are meteorological parameters whereas the remaining parameters can be varied to enhance the productivity of the solar stills.

L'objectif principal de cette étude est d'analyser le rendement thermique d'un distillateur solaire. Et prévoir l'effet des températures sur le début de l'eau douce distillat. Also, the goal of this work is to get an acceptable amount of distilled water daily so that we can develop this solar distillation,

II. THEORETICAL STUDY

II.1. Support

A metal has been produced with the required dimensions, take above the tray outer solar plan we have produced and we put the wheels for ease of travel as follows figure 2

II.2. Description mounting

- lays on the bottom of the external tank to paste the four sides with a special glue that allows a good seal.
- We do the same with the second tray (inside) and more stuck on the recovery of the distilled water in the latter.
- Lays on polystyrene in the bottom and four side walls of the external tank with the required dimensions to the number represented by (6), and raises the internal tray, after you put the pipes feeding and recovery of the distillate.
- Lays on the cover glass on the two ferries.
- Finally we set the distiller in the media figure.

II.3. Description and principle of operation

Distillers and solar are part of the same unit and the thermal energy is used only once. This facility consists of a basin covered with a black absorbing layer and a recovery in transparent glass or plastic may be steep (Fig.1).

The temperature increase due to the greenhouse effect that warms the water that evaporates. The evaporation capacity grows as the temperature increases until the air reaches its saturation vapor: relative humidity is 100%. The water vapor that contains the hot air is cooled by the atmosphere and condenses the material. There is a formation of drops of water flowing to the bottom of the glass in a gutter leading to the storage tank.

II.4. Operational characteristics

The choice of a solar distiller depends mainly on size , known operating characteristics. We distinguish:

a. The rate of distillate production or distiller:

The quantity of distilled water produced by the distiller by (m2) surface evaporation per day

b. The overall efficiency (%) given by the:

The ratio between the amount of heat for evaporation on the total solar irradiance on the sensor plane.

$$\eta_g = q_e / G_H .A \quad (1)$$

With

$$q_e = D.L \quad (2)$$

c. The internal efficiency (%) defined by the expression

It is the ratio between the amount of heat for evaporation and the amount of heat actually received by the water body.

$$\eta_i = q_e / q_{water} = D.L / q_{water} \quad (3)$$

With

$$q_{water} = (\tau_v \alpha_e + \tau_v \tau_e \alpha_f) * G.A = \alpha_t G.A \quad (4)$$

II.5. Heat balance of a solar plan

In figures (4) and (5) we include the different temperatures and different amounts of heat transferred to or involved in the energy balance of a solar distiller.

In steady state, we can write in the window, after SFEIR [7]:

$$q_{r,ev} + q_{c,ev} + q_{e,ev} + q_v - q_{c,v} - q_{r,v} = 0 \quad (5)$$

for the tray and the film of water to be distilled from SFEIR [7]:

$$q_e - q_{r,ev} - q_{c,ev} - q_{e,ev} - q_{c,e} = 0 \quad (6)$$

The heat flux absorbed by the glass from SFEIR written [7]:

$$q_v = \alpha_v \beta H_H$$

The flux absorbed by the bottom of the tray and the film of water is written according to SFEIR [7].

$$q_e = \tau_{v,s} .\tau_{e,s} .\alpha_{b,s} .H_H \quad (7)$$

The heat flux lost through the glass by convection according to Bernard, Mengay and Schwartz [8] is:

$$q_{c,v} = h_{c,v} (T_{i,glass} - T_a) \quad (8)$$

With

$$h_{c,v} = 5{,}7 + 3{,}8V \quad (9)$$

Bernard, Mengay and Schwartz [8] proposes the following expression for the flux lost by radiation by the glass:

$$q_{r,v} = \sigma * 0{,}85 * (T_{i,glass} - T_a) \quad (10)$$

While the radiant heat flow between the tray and the glass can be expressed by:

$$q_{r,ev} = 0{,}9 \sigma (T_{water}^4 - T_{i,glass}^4) \quad (11)$$

Or:

σ : Is the Boltzmann constant STEFAN and its value equal to (5,67$\times 10^{8}$ w/m^{2}K)

The heat flux by convection between the tray and the glass from SFEIR [7] is:

$$q_{c,ev} = h_{c,ev}(T_{water} - T_{i,glass}) \qquad (12)$$

With

$$h_{c,ev} = 0,9\Big[(T_{water} \quad T_{i,glass}) + \frac{p_e(T_{water}) \quad p_v(T_{i,glass})}{267 \quad p_e(T_{eau})} T_{water} \Big]^{1/3} \qquad (13)$$

Or: $p_e(T_{water})$ and $p_v(T_{i,glass})$ are the saturated vapor pressure, respectively, water temperature and the temperature of the glass, $p_e(T_{water})$ and $p_v(T_{i,glass})$ must be expressed as (KPa).

According to SFEIR [7], $p_e(T_{water})$ and $p_v(T_{i,glass})$ are given by the following relations:

$$p_v(T_{i,water}) = \quad 16,037 + 1,8974T_{i,water} \; 0,0699T_{i,water}^2 + 0,0012T_{i,water}^3 \quad 5,8511*10^{\;6} * T_{i,water}^4 \qquad (14)$$

$$p_v(T_{i,glass}) = \quad 16,037 + 1,8974T_{i,glass} \; 0,0699T_{i,glass}^2 + 0,0012T_{i,glass}^3 \; 5,8511*10^{\;6} * T_{i,glass}^4 \qquad (15)$$

To calculate $p_e(T_{water})$ and $p_v(T_{i,glass})$ temperatures T_{water} and $T_{i,\,glass}$ must be expressed as (°C).

❖ The flow through evaporation - condensation between the tray¬ and the glass from SFEIR [7].

$$q_{e,ev} = 6,3*10^{\;3} p_e(T_{water}) \quad p_v(T_{i,glass}) L_v h_{c,ev} \qquad (16)$$

L_v: This is the latent heat of vaporization of water. It is given according to KIRLLIN, SYRCHEV, SHEIDLIN [9] by the following relationship:

$$L_v = 3153,0047 - 2,3865T_{water} \qquad (17)$$

❖ The heat flux lost by the bottom of the distiller outwards from SFEIR [7] is:

$$q_{c,e} = (T_{water} - T_a) / R_f \qquad (18)$$

R_f : The thermal resistance of the bottom tray

$$R_f = 2*\frac{e_v}{\lambda_v} + \frac{e_p}{\lambda_p} \qquad (19)$$

❖ The amount of distilled water is given after SFEIR [7] by the following relationship:

$$D = \frac{q_{e,ev}}{L_v} \qquad (20)$$

❖ The performance of the distiller is given by the following relationship:

$$\eta = \frac{D * L_v}{H_H} \quad (21)$$

After the heat balance is given the dimension of the solar distiller.

III. Sizing

The apparatus shown in figure 1 represents the different parts of the solar distiller.

Both sides of the external tank shown in Figure 1-by-number (1) are ordinary glass, with a slope of 12 degrees and dimensions (10cm * 99.5cm * 31.8cm * 102.6 cm with a thickness of 5 mm) [16,17].

Both sides of the internal tray represented in the figure-1-by the number (2) figure 1 are ordinary glass, with a slope of 12 degrees and dimensions (95.5 cm* 8.3cm * 28.3cm cm with a thickness of 5 mm).

The plaque on the front panel of the external tank represented by number (3) in Fig-1- is glass and dimensions (10.5cm * 99.6 cm with a thickness of 5 mm).

The plate of the front of the tray internal represented by number (4) in Fig-1-is glass and dimensions (93.6cm * 8.3cm with a thickness of 5 mm).

The two plates are drilled front to put the pipe recovery distillate (0.8 cm diameter).

The plate of the rear face of the external tank distiller represented by number (10), also glass and dimensions (31.8cm * 99.6cm) with a thickness of 5 mm.

The plate of the rear tray internal distiller represented by number (8) in Fig-1-is also glass and size (28.3cm * 9.36cm) with a thickness of 5 mm.

The two plates of the back are placed breakthroughs for

the pipe feeding water distillation diameter of 0.8 cm.

The recovery is represented by the number (5) in Fig-1-is used for the recovery of distillate, produces V for this form gives a good flow of distilled water, it is glass because it is steel.

The bottom of the external tank distiller represented by number (12) in Fig-1-, glass is 5 mm in thickness and size (99.6 cm 100.5 cm).

The bottom of the tank's internal distiller represented by the number (9) in Fig-1-, glass is 5 mm in thickness and size (94.6 cm*96.5 cm).

The top plate represented by number (7) in Fig-1, it is ordinary glass of 5mm thickness and size (104 cm 106.6 cm), its main role is to prevent the value of water produced from escaping to the atmosphere and condense on its inner surface. This surface is inclined to allow water droplets to run off the collector (recovery).

The black plate represented by number (11) in Fig-1-, is steel (galvanized iron) thick and 0.1 dimensions (95.5 cm 93.6 cm) we painted a color black to absorb maximum sunlight and reflect the minimum of sunlight.

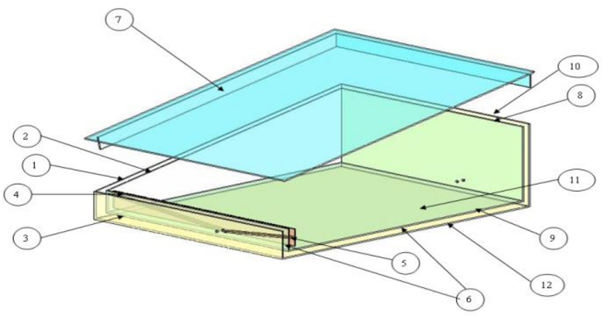

Fig (1) represents the different parts of the solar distiller.

Fig (2) solar plan

IV. RESULTS

A climate marked by the Algerian Sahara desert warmly the air and frequent sand storms and so I chose these days the lack of sand storms which reserved sun rays.

April 20th, 2019

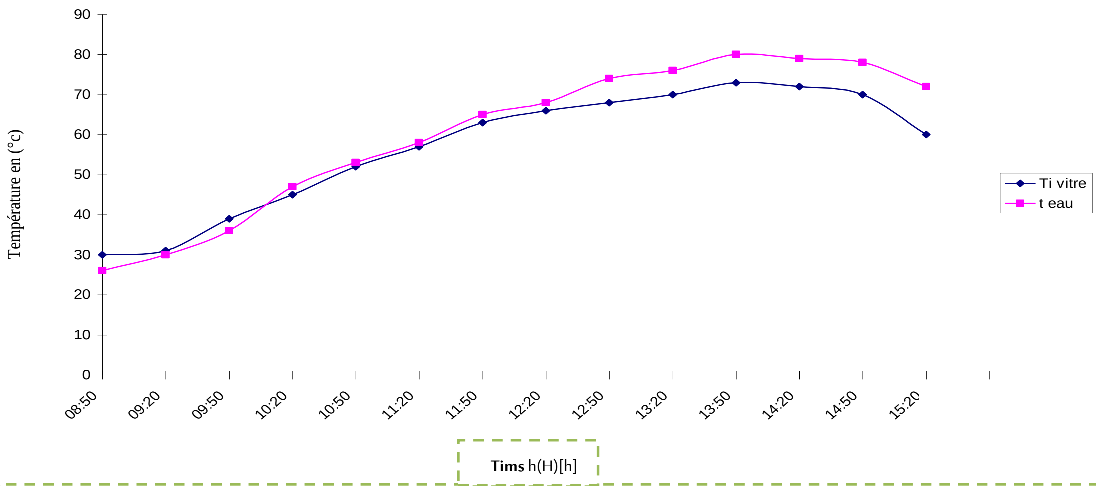

Figure 3-1: Variation of temperature inside surface of glass and the water temperature .

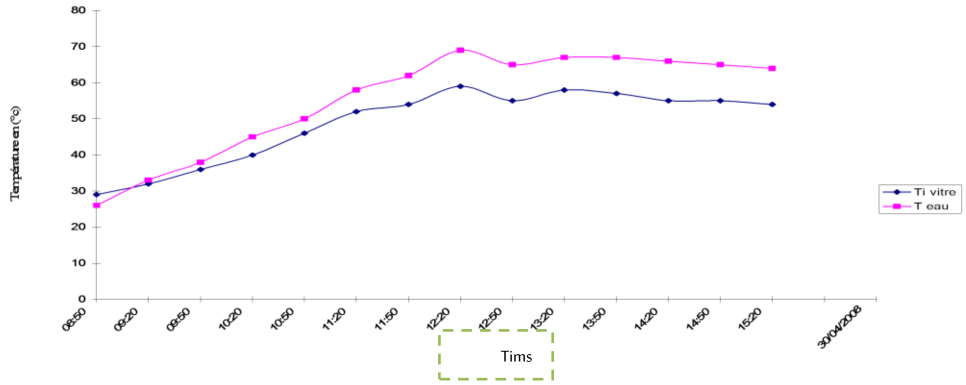

Figure (V-16) : Variation de Température de l'eau et Température de la surface interieure de vitrage

Figure 3-2 :Variation of temperature inside surface of glass and the water temperature .

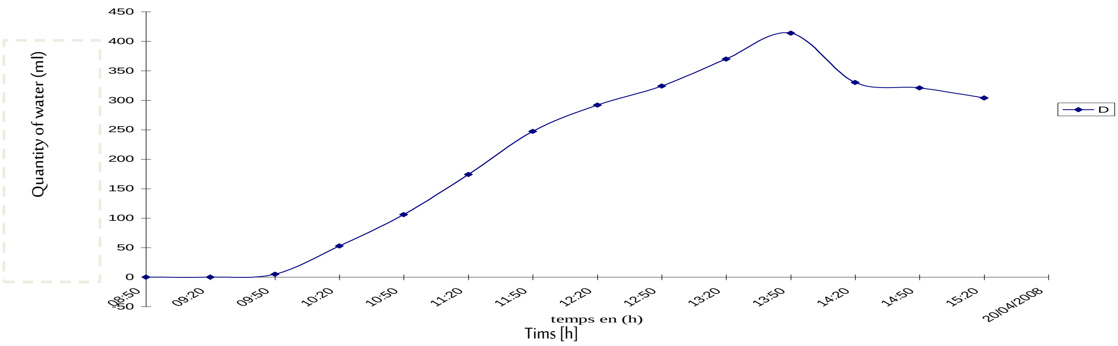

Figure (V-6): Variation de la Quantité d'eau distiller

Tims

Figure 3-3 :The amount of water distillation

April 30th, 2019

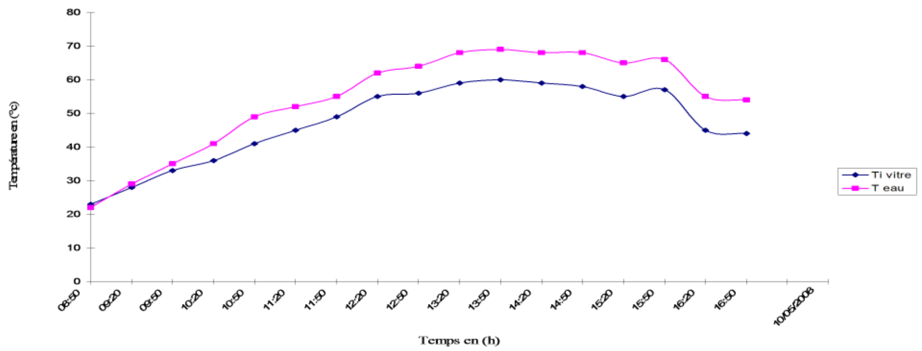

Figure (V-31) : Variation de Température de l'eau et Température de la surface interieure de vitrage

Tims [h]

Figure 3-4: Variation of temperature inside surface of glass and the water temperature .

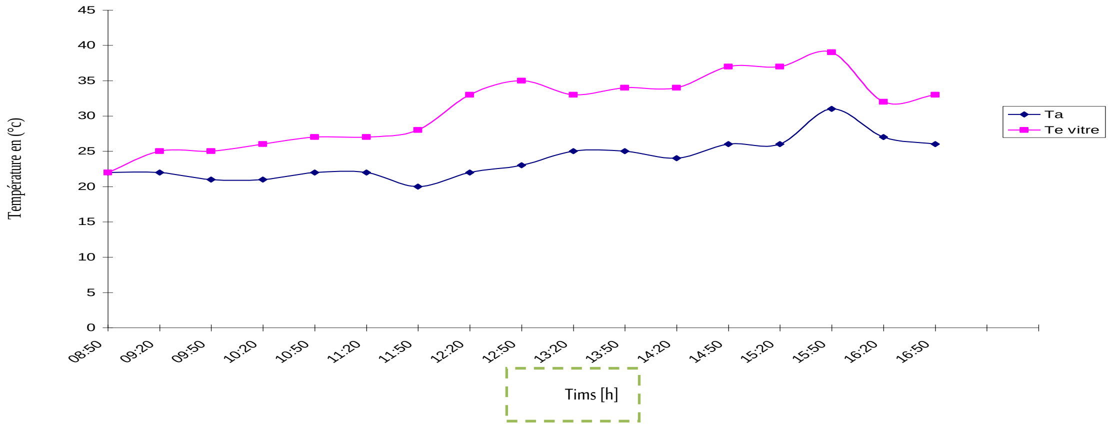

Figure 3-5: Change in ambient temperature and the temperature of the outside surface of glass.

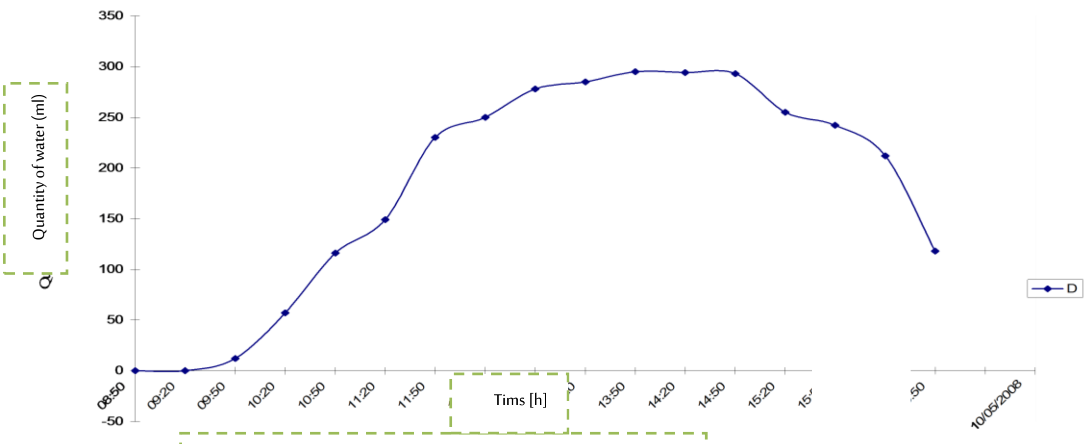

Figure 3-6: The amount of water distillation

Figure (V-33) :Variation de la Quantité de l'eau distillé

May 10th, 2019

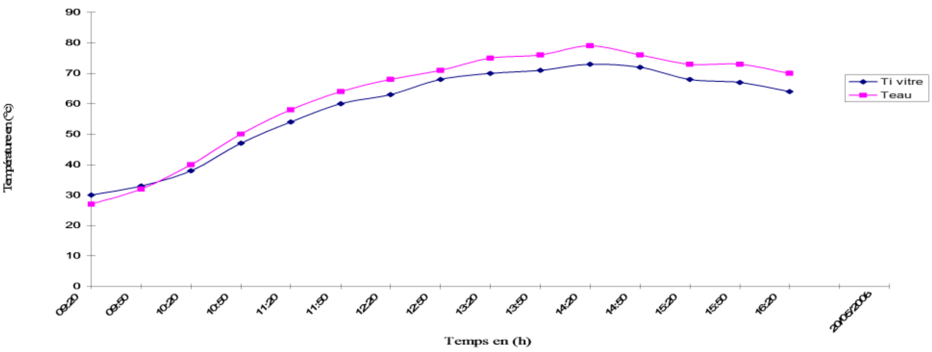

Figure (V-49) : Variation de Température Tims [h] rature de la surface interieure de vitrage

Figure 3-7: Variation of temperature inside surface of glass and the water temperature .

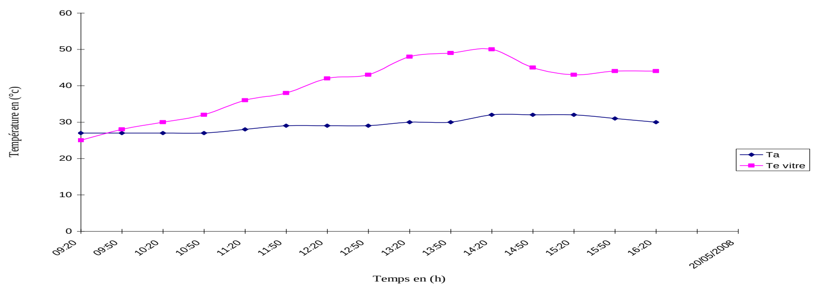

Figure (V-50) : Variation de la Température ambiante et la température de vitrage externe

Tims [h]

Figure 3-8: Change in ambient temperature and the temperature of the outside surface of glass.

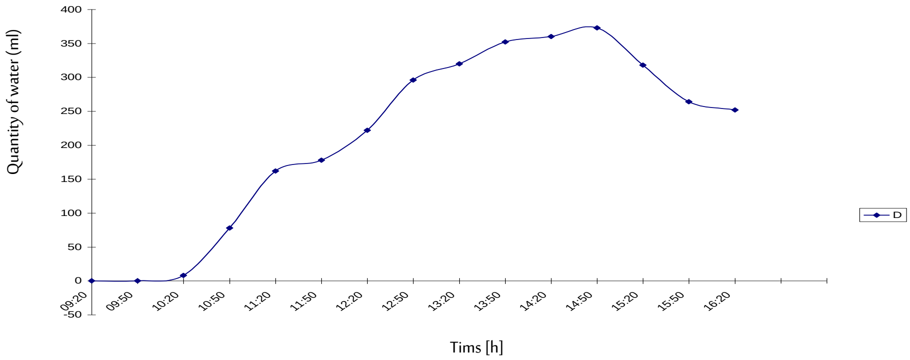

Figure 3-9: The amount of water distillation

May 31st , 2019

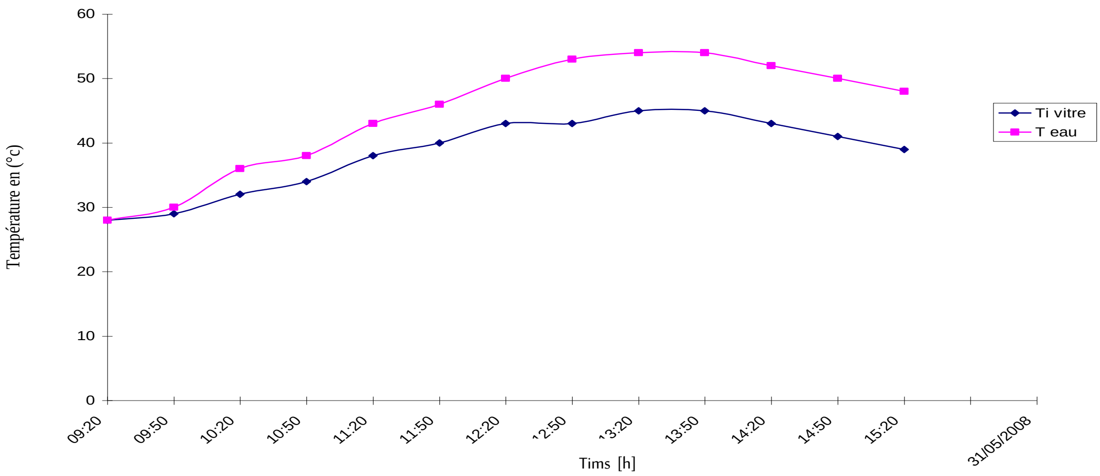

Figure 3-10: Variation of temperature inside surface of glass and the water temperature .

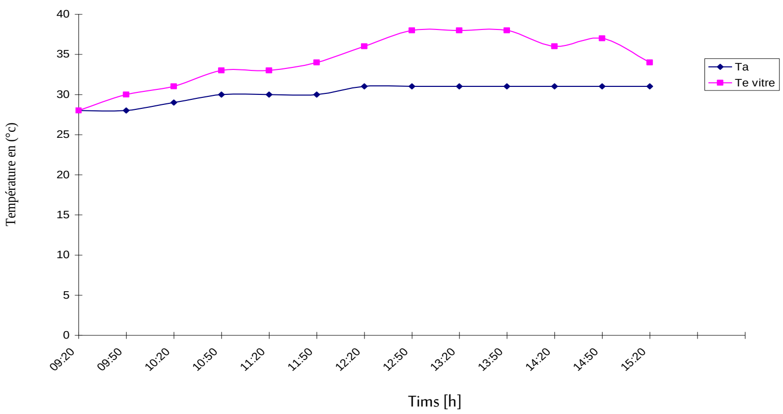

Figure 3-11: Change in ambient temperature and the temperature of the outside surface of glass.

V. DISCUSSION

V.1. Change in water temperature and the temperature of the inner surface of glass on a time basis

- There is the change in water temperature and the temperature of the inner surface of glass is low and does not exceed 10 degrees c.
- We note that the temperature of the inner surface of glass is slightly higher than the temperature of the water. Usually after one hour and a half (1h 30m) both temperatures are same. The water temperature starts to increase slightly compared to the temperature of the inner surface of glass until the end of the levy.

Note

14h 50mn to both temperature decreases because the flow of solar radiation is tilted relative to the surface.

V.2. Change the room temperature and the temperature of the external surface of glass on a time basis

It is found that the room temperature and the temperature of the external surface of glass is almost the same at the beginning of sampling values. After a few moments, the surface temperature of glass become slightly in comparison to that of the ambient temperature. At the end of sampling the two temperatures tend to become equal.

Note

The flow of radiation focuses directly on the outer surface of glass. (This is why low temperature compared to the outside temperature glazing).

V.3. Change of flow on a time basis

Distillation 1h usually begins after the beginning of the experiment.

The amount of flow increases to a maximum value between 12h30mn and 14h30mn. Then, it starts to decline until it becomes too small (especially when the levy lasted until 21h).

The results mean, the produc- tivity increases with increase in the water temperature, the distillate output of solar still is maximum for 60°C water temperature. The hourly dis-tillate output of the solar still is estimated from the knowledge of different temperatures and thermo phys-ical properties of water. Further, the experiments are performed to analyze the system performance during field application.

Further, it has been observed that the productivity of the solar still increases with increase in the inlet water tem- perature. The same system can also be modified to make use of other energy sources for preheat- ing of water like industrial waste heat and biomass.

Analysis conducted at the chemical laboratory at the University of Tahri Mohammed Bechar (Algeria) has given the findings:

TABLE (1) L apparatus used is the multi parameter C861.

	Conductivity	TDS	Salit	PH
The normal water	14.11 $\mu s / cn$	8.37mg/l	0.8	8.28
The Water Distillation	14.13 $\mu s / cn$	8.38mg/l	0.9	7.52

VI. CONCLUSION

The present study an attempt has been made to solve the problem of productivity of the single slope horizontal, The completion of a solar distiller plan at our university forced us to make a very good choice in regard to the materials of these components because of a very high temperature, The absorber surface of the solar still is coated with black enamel paint and covered with copper chips, and the flexi glass has undergone a distortion and it was a take-off joints and . This resulted in augmented evaporation rate and in turn productivity of the system. the amount of distilled water daily is almost 3200ml/ day.

Further, it has been observed that the productivity of the solar still increases with increase in the inlet water temperature. In the current study a separate solar water heater is used to heat the inlet water. The same system can also be modified to make use of other energy sources for preheating of water like industrial waste heat and biomass.

The passive heat transfer augmentation technique of surface texturing using the raw copper chips is very eco-nomical. The performance of the existing solar still can be improved by this retrofitting.

Further, it is recommended to check the performance of the solar still using different texturing materials with different density. It is also suggested to investigate the durability of coating materials and surface texturing tech- nique for longer exposure to sunlight. And effect of water depth and still orientation on productivity for passive solar distillation

Nomenclature

A: Area sensor (glass area) [m^2]

q e:Amount of heat used for evaporation per unit time W

L : Latent heat of water [W]

G H: Normal component of the global solar irradiance on the sensor plane.

q e : Heat flux used for evaporation of water [W]

q water: Heat flux actually received by the water. [W]

α_t : being the absorption coefficient shadow of the water.

α_e, α_f : Respectively the factors of absorption of water and bottom of the distiller.

τ_e, τ_v : Respectively the factors of transmission of water and the glass.

Ta : Room temperature [°C]

Ti, glass : Temperature inside the glass [°C]

T_e, glass : Temperature outside the window [°C]

T water : Water temperature distillation[°C]

$q_{c,v}$: Heat flux lost through the glass by convection to the outside [W]

$q_{r,v}$: Heat flux lost by radiation through the window to the outside [W]

$q_{r,ev}$: Radiant heat flow between the bottom of the tray and glass [W]

$q_{c,ev}$: Heat flux by convection between the bottom of the tray and glass [W]

$q_{e,ev}$:Heat flux by evaporation - condensation between the bottom of the tray and glass [W]

$q_{c,e}$: Flux lost by the bottom of the trying distilled water. [W]

α_v : The coefficient of absorption of the glass, see Table (1) according to Bernard, Mengay and Schwartz

β : The coefficient that takes into account the effect of dust is estimated at about 0.5%, according to Bernard Schwartz Mengay .

H_H: It is the solar radiation on a horizontal plane.

$\tau_{v,s}$: The coefficient of transmission of the glass

$\tau_{e,s}$:The coefficient of transmission of the water table

$\alpha_{b,s}$:The coefficient of absorption is of the tray.

$h_{c,v}$: The coefficient of heat transfer from SFEIR [7] we can write [m°C/W]

$h_{c,ev}$: The coefficient of heat transfer by convection. [m°c/W]

L_v :This is the latent heat of vaporization of water. It is given according to KIrllin, Syrchev,

e_v : The thickness of glass =0,5Cm.

λ_v : Conductivity of glass =0,03W/m^{2}K.

e_p: The thickness polystyrene.

λ_p : Polystyrene Conductivity = 0,045W/m^{2}K

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