Comparative Study of Three Solar Desalination Units Based on Theoretical and Experimental Approach

H. Moungar[1]*, A. Azzi[2], Y. Sahli[1], A. Haida[1]

[1] Research Unit for Renewable Energies in the Saharan region (URERMS) Renewable Energy Development Center (CDER), 01000, Adrar, Algeria, Division for Thermal and Thermodynamic Conversion, Research Unit for Renewable Energies in the Saharan region, Adrar, Algeria

[2] Research Unit of Materials and Renewable Energies (U.R.M.E.R) Abou Bekr Belkaïd University - Tlemcen

*Corresponding author; Email: houcinemgn@gmail.com

Article Info

Article history:

Received 22 April 2019
Revised 26 May 2019
Accepted 28 May 2019

Keywords:

Solar Still
Distilled Water
immersed fins
Radiative flux
shadow

ABSTRACT

This work presents a theoretical and experimental study of a double slope still with and without immersed fins compared to the single solar still monthly production. The influences of the distance between fins, fin heights, fin numbers and water layer thickness on the solar still production have been widely researched. From the obtained results, the distance between fins has no significant effect on the still productivity. Moreover, for fin heights from 2 to 5 cm, cause the productivity raising, when the fin heights are from 6 to 8 cm found an increasing in the still production. A larger fin numbers lead to a rising in the produced water amount. The water quantity augmentation in the basin makes the water productivity decreasing. The experimentally obtained results during the day June 11, 2016, show that the solar still with immersed fins productivity was about 15 to 27 % higher than that of the simple solar still, under the following conditions, i.e. mw = 42.61 kg, h1 = 3.6 cm, Vw = 3.5 m/s, lw = 5 cm and Nfins = 12.

NOMENCLATURE

Symbol		**Index**	
Υ_p	*Azimuthal angle of the plane °*	$_w$	*Water*
Υ_s	*Solar azimuth °*	$_v$	*Vane*
G_1	*Radiation received by a 15 ° inclined plane facing the south*	$_p$	*Plate*
G_2	*Radiation received by a 15 ° inclined plane facing the north*	$_s$	*Saline*
G_3	*Radiation received by a vertical plane W/m²*	$_{is}$	*Isolation*
m_w	*Mass of water Kg*	$_c$	*Convective*
l_w	*Fin width m*	$_r$	*Radiative*
l_{w0}	*Length of the normal to shaded surface m*	$_e$	*Evaporation*
l	*Length of fins m*	$_{ar}$	*Rear*
H	*Height of fins m*	$_{ce}$	*Sky*
N_{fins}	*Number of fins*	A_{fi}	*Fins surface*
A_p	*Flat plat surface m²*		

I. Introduction

Fresh water represents only 3% from the total amount of water available on earth. Only 1 % of this quantity is usable, the rest is in the glace form or buried underground. Arid regions are characterized by droughts; they are poor in superficial water, which is generally saline. This is the case of some regions in southern Algeria, namely Bouda, Abadla, etc.

Using the solar desalination process could offer economic and environmental benefits for the drinking water supply system in these regions. Several research works have investigated, experimentally and theoretically, the parameters influencing the productivity of different configurations of a solar still.

[1] Proposed the periodic cooling of the glazing cover of the distiller. [2] Studied the shadow effect of the reflector on the productivity of the distiller [3,4,5] Investigated the effect of height, thickness and number of fins on the production of an ordinary distiller; this caused the production of distilled water to increase by 13.7 %, compared to a simple distiller. A theoretical and experimental study of a double slope solar still, with and without fins immersed in the basin, is conducted in the present work, while taking into account the shading effect of vertical surfaces on the productivity of distilled water.

II. Experimental result

Figure 1: Experimental bench; a) solar still with fins, b) simple solar still, c) single solar still

The present work intends to present an experimental study on a solar hot-box distiller, made of a mixture of glass wool and resin to ensure good thermal insulation. Polyurethane foam, 5 cm thick, was use to reduce thermal losses from rear and side walls. This was done in order to increase the productivity of the distiller and to extend its period of operation during the diurnal period, while taking advantage of the energy stored in the basin.

The temperatures have been measured using thermocouples connected to a Fluke 2680 Series data acquisition system. The irradiation intensity has been measured using a Kipp & Zonen pyranometer. Various series of tests carried out during the period extending from March 04, 2015 to August 18, 2015. The temperatures, intensity of the radiative flux and quantity of distillate produced were evaluate, and a physico-chemical analysis of water is carried out before and after the distillation. Two panes of dimensions 57 cm x 131 cm, inclined at an angle of 15 °, and a basin of dimensions 93 cm x 125 cm were also used; this gives a surface area of 1.16m². The tests were carried out on the experimental platform of the Research Unit for Renewable Energies in the Saharan region (URERMS), in the town of ADRAR.

Figure 2 illustrates the evolution of ambient temperature and the intensity of the total horizontal radiative flux for the days of January 20 and July 15. It has noted that the ambient temperature follows the evolution of the solar radiation with a small offset at the maximum value.

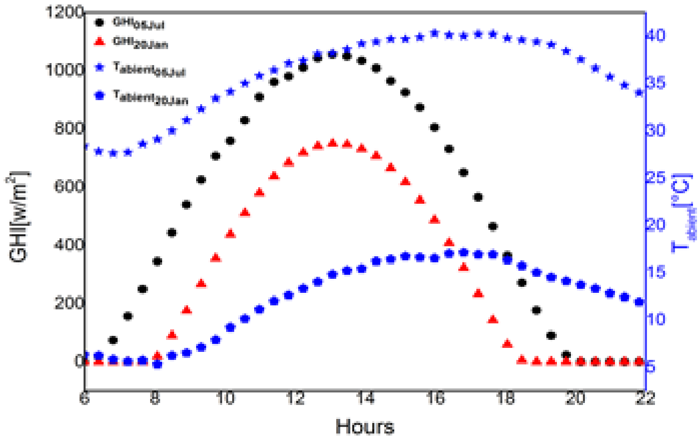

Figure 2: Ambient temperature and intensity of the overall horizontal irradiation flux.

Figure 3 shows the variation in the temperatures T2, T3, T4, T5, T6 and T7 of the different components in the distiller, namely the temperatures of the basin, horizontal plate, vertical plate, water, inner and outer faces of glass, for the day of July 05. It can clearly have noted that the temperatures follow the evolution of the solar radiation and that the temperature of the plate and that of brine are very close; however, the temperatures of the inner and outer faces of the glazing are significantly lower than that of brine, by 10 to 20 °C. The temperature gradient between glass and brine has a considerable effect on the productivity of the distiller.

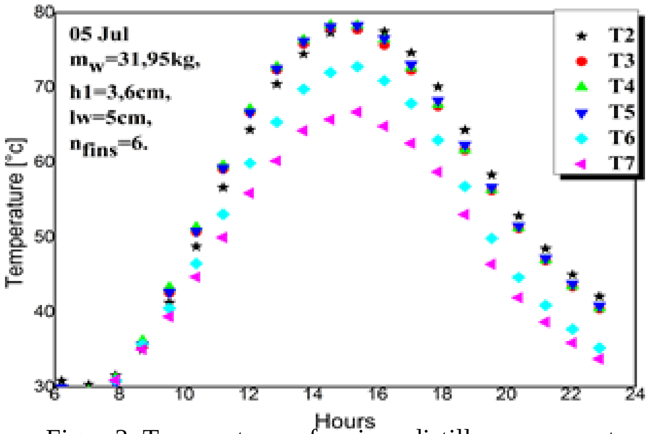

Figure3: Temperatures of various distiller components

It was found that the temperature of the cover glass coincides with the measured temperature of the inner face of this same cover. As for the temperature of brine, according to the results of Figure 4, it can be seen that from 8 a.m. to 1 p.m. the mathematical model describes very well the system, and the curves overlap. In the afternoon, the calculated values are slightly higher than those measured. This discrepancy may be explained by the simplifying assumptions made in the modeling of the system.

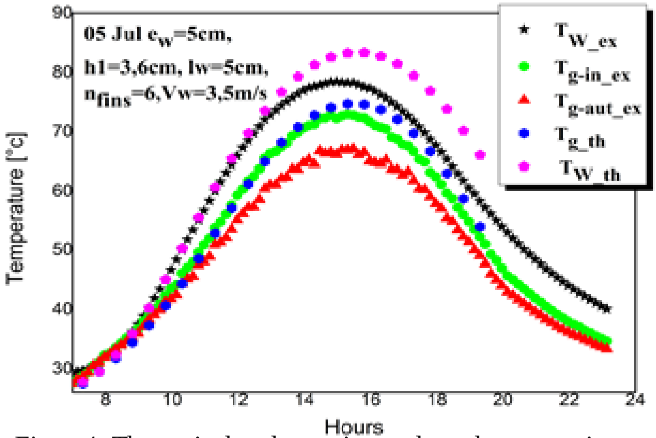

Figure4: Theoretical and experimental results comparison.

Figure 5 illustrates the production of the distiller for brine thicknesses equal to 2, 3, 5, 6, 7 and 8 cm, corresponding to briny water masses in the basin of 21.3, 31.95, 42.61, 53.26, 63.92, 74.57 and 85.22 kg, respectively. It has been found that the water mass increasing in the basin, from 21.3 to 53.26 kg, causes an increase in the productivity of the distiller. Beyond the mass of 53.26 kg, the opposite effect occurs, i.e. the production decreases.

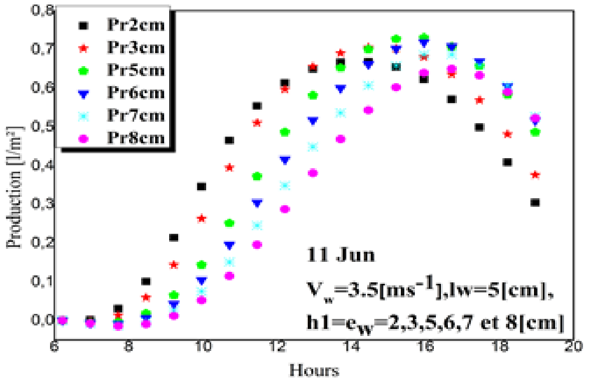

Figure 5: Production of the distiller for different thicknesses of brine

Figure 6 depicts the production of the distiller for a distance between fins of 5 and 8 cm. In both cases, the brine thickness varied from 3.6 to 5 cm, for the day of June 11. It has been found that the distance between fins does not have a significant effect on the productivity of the distiller.

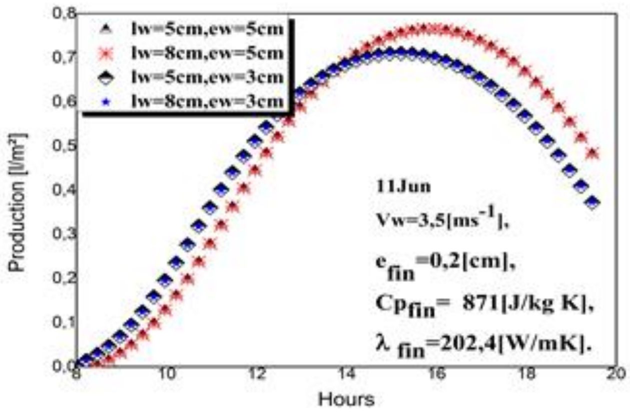

Figure 6: Influence of the distance between fins on production.

Increasing the number of fins resulted in a rise in the production of the distiller, and this can have explained by the increase in the heat exchange surface since the absorption plate receives a greater amount of solar energy compared to the case without fins (Figure 7).

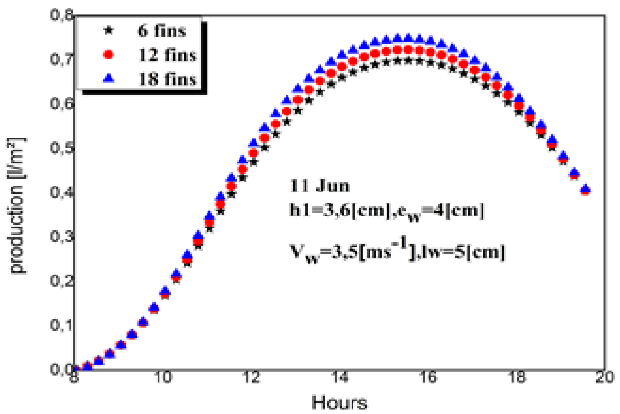

Figure 7: Influence of the number of fins on production.

The entire production of the modified and simple solar still increases with 3% and 1% respectively compared to the single slope solar still production. The July production is about 200 kg, as shown in figure 8.

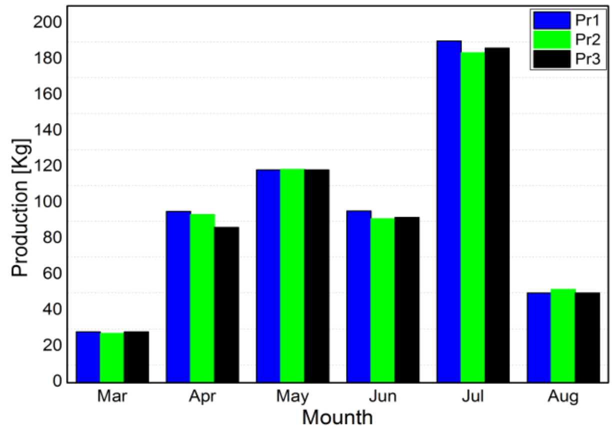

Figure 8: Monthly solar sill's production.

III. Cost estimation

The total annual cost is estimated at about 6587.37 DZD, and costs estimation of the various components is given in Table 1. For example, if the interest rate is 8% and the system life is 5 years, the annual production is close to 2499.5281 kg, gives a product cost of 2.64 DZD. Knowing that the average latent heat needed to evaporate one kilogram is 0.65 kWh, we will need 1624.7 kWh to produce 2499.5281 kilograms of distilled water. According to the annual cost of 6587.37 DZD, the cost of one kWh will be 4.05 DZD / kWh. It has been found that the lifetime increasing and the interest rate decreasing caused a decrease in the unit price. As shown in figure 9.

TABLE 1
The various components solar still Cost estimation

Materials	Quantity	Price
Polyurethane foam	2	5 000,00 DZD
Silicone adhesive	3	1 200,00 DZD
Glass of 3mm	$2m^2$	4 915,20 DZD
Resin	5kg	3 000,00 DZD
Glass wool for the thermal insulation (0.05 m thickness)	$2m^2$	2 000,00 DZD
Labour cost (2 workers, **4** day)		9 600,00 DZD
Total **cost**		25 715,20 DZD
Various accessories 10%		2 571,52 DZD
The capital cost of the system CC		28 286,72 DZD
Depreciation value S (25% CC)		**7 071,68 DZD**

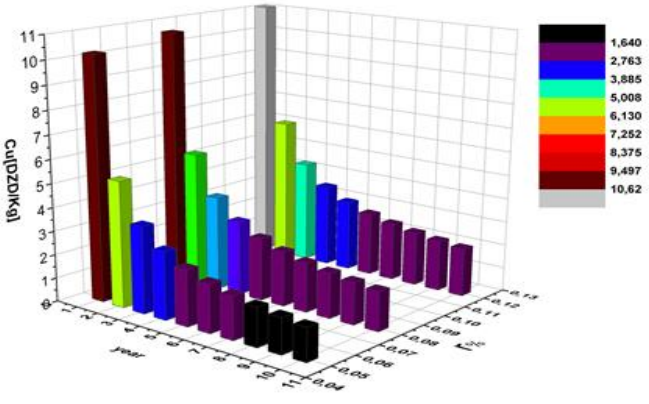

Figure 9: the lifetime and the interest rate influence on the unit price

IV. Conclusion

The present work presents a theoretical and experimental study of a double slope solar distiller, with fins immersed in the basin.

The influence of distance between fins, height of fins, the number of fins and the mass of water in the basin, on the production of the distiller were investigated. The obtained results show that the distance between fins does not have a significant influence on the productivity of the distiller. Concerning the height of fins, it was established that an increase in the height of fins:

• from 2 to 5 cm, induces an increase in productivity,

• from 6 to 8 cm, induces the opposite effect.

An increase in the number of fins causes an increase in the quantity of distillate. Therefore, it is possible to install the highest number of fins while taking into account the feasibility of the system. The increase in water mass in the basin causes a decrease in productivity. For the day of June 11, and under conditions where h1 = 3.6 cm, Vwind = 3.5 m/s, lwater = 5 cm, Nfins = 12 and for a mass of water of mwater = 21.3, 31.95, 42.61, 53.26, 85.22 kg, the production of the distiller, with immersed fins, increased by 21, 25, 27, 27 and 15%, respectively, compared to that of a conventional distiller. The estimated cost per kg of distillate was between 10,6 DZD for the first year and 1,6 DZD for ten year lifetimes.

Acknowledgements

The present work it was supported by the solar distillation laboratory at the Thermal and Thermodynamics Conversion Division, within the Research Unit Energies in Renewable Energies in the Sahara Medium. Development Centre of Renewable Energies, Adrar, Algeria. Authors would like to extend his thanks to URERMS for its support in implementing the project

References

[1] M.M. Morad, Hend A.M.El-Maghawry, K.Wasfy. «Improving the double slope solar still performance by using flat-plate solar collector and cooling glass cover.» Desalination 373 (2015) 1–9. 373 (2015): 1-9.

[2] Benhammou M, Moungar H, Marif Y, Belhadj M.M. «Effet des paramètres géométriques d'un réflecteur plan vertical sur les performances d'un distillateur solaire mono-incliné couplé à un condenseur séparé.» Nature & Technology c, n° Issue 11 (June 2014).

[3] Rahul Dev, G.N. Tiwari. «Characteristic equation of the inverted absorber solar still.» Desalination 269 (2011): 67–77.

[4] Tanaka , H, et Y Nakatake. «Theoretical analysis of a basin type solar still with internal and external reflectors.» Desalination 197 (2006): 205–216.

[5] A.A El-Sebaii, M.R.I Ramadan, S.Aboul-Enein, M.El-Naggar. «Effect of fin parameters on single basin solar still performance.» Desalination 365 (2015): 15-24

[6] A.E. Kabeel, A. Khalil, Z.M. Omara, M.M. Younes. «Theoretical and experimental parametric study of modified stepped solar still.» Desalination 289 (2012): 12-20.

[7] A.E. Kabeel, Z.M. Omara, F.A. Essa. «Enhancement of modified solar still integrated with external condenser using Nano fluids: an experimental approach.» Energy Conversion and Management 78 (2014): 493-498.

[8] C. E. Okeke, S. U. Egarievwe, and A. 0. E. Anmalu. «Effects Of Coal And Charcoal On Solar-Still Performance.» Enqy 15, n° 11 (1990): 1071-1073.

[9] Cooper, P I. «Digital Simulation Of Transient Solar Still Processes.» Solar Energy 12 (1969): 313-331.

[10] Cooper, P, I. «The Absorption Of Radiation In Solar Stills.» Solar Energy 12 (1969): 333-346.

[11] D. Bechki, H. Bouguettaia, J. Blanco-Galvez, S. Babay, B. Bouchekima, S. Boughali, H. Mahcene. "Effect Of Partial Intermittent Shading On The Performance Of A Simple Basin Solar Still In South Algeria." Desalination 260 (2010): 65–69.

[12] Eduardo Rubio, Jose L. Fernàndez, Miguel A. Porta-Gàndara. «Modeling thermal asymmetries in double slope solar stills.» Renewable Energy 29 (2004): 895–906.

[13] H. Al-Hinai, M.S. Al-Nassri, B.A. Jubran,. «Effect of climatic, design and operational parameters on the yield of a

simple solar still, » Energy Conversion and Management 43, n° 13 (September 2002): 1639-1650 .

[14] Hassan E.S. Fath, H.M. Hosny. «Thermal Performance Of A Single-Sloped Basin Still With An Inherent Built-In Additional Condenser. » Desalination 142 (2002) 19-27 142 (2002): 19-27.

[15] H. MOUNGAR, A. AZZI, Y. SAHLI , A. HIEDA, « Immersed fins influence on the double slope solar still production in south algeria climatic condition. » NTERNATIONAL JOURNAL OF HEAT AND TECHNOLOGY, Vol. 35, No. 4, December 2017, pp. 1065-1071, DOI: 10.18280/ijht.350444

[16] Imad Al-Hayek a, Omar O. Badran. «The effect of using different designs of solar stills on water distillation.» Desalination 169 (2004): 121-127.

[17] K .Voropoulos, E .Mathioulakis, V .Belessiotis. «A hybrid solar desalination and water heating system .» Desalination 164 (2004): 189-195.

[18] M. Mustapha Belhadj, H. Bouguettaia, Y. Marif,M. Zerrouki. «Numerical study of a double slope solar still coupled with capillary film condenser in south Algeria. » Energy Conversion and Management 94 (2015): 245–252.

[19] H. Moungar, A. Azzi, Y. Sahli, A. Hieda, «Double Slope Solar Still with Immersed Fins: Theoretical and Experimental Study», U.P.B. Sci. Bull., Series C, Vol. 80, Iss. 1, 2018 ISSN 2286-3540

How to cite this paper:

Moungar H, Azzi A, Sahli Y, Haida A. Comparative Study of Three Solar Desalination Units Based on Theoretical and Experimental Approach. Algerian Journal of Renewable Energy and Sustainable Development, 2019, 1(1),112-118. https://doi.org/10.46657/ajresd.2019.1.1.11