International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 846
ISSN 2229-5518

Physicochemical Parameter Influences on Distilled Water Production for a simple and modified hot box solar still

H. Moungar[1,2,] A. Azzi[2], Y. Sahli[1] , A. Mediani[1] and A. Haida[1]
[1]Thermal & Thermodynamics Conversion Division, *Research Unit in Energies Renewable Energies in the Sahara Medium, Development Centre of Renewable Energies*, CDER ADRAR, Algeria Tel: +213(0)49965168, Fax: +213(0)49960492
[2]*Materials and Renewable Energy Laboratory L.M.E.R . Abu Bekr-Belkaïd University Tlemcen L.M.E.R, Tel: 213 43 28 56 89,*
houcinemgn@gmail.com

Abstract— several researchers studied the internal and external parameters influence at the solar distiller production. This study investigates the Physicochemical Parameters Influence on distillate production. On the other hand, the physicochemical parameters pH, total dissolved solid TDS, resistivity, salinity and conductivity, which are measured both after and before desalination on pH meter type METTLER TOLEDO SG78.This experience main aim is the study of the obvious influence in the solar distiller production. So, it's found that the physicochemical parameters have a significant effect in the solar still production, mainly pH and salinity. In the end, technical or chemical solutions have been proposed to optimize the solar distiller production when the basin is saturated on salt water.

Keywords-- Solar Still, Distilled Water, Physicochemical Parameters, Domestic Solar Hot Water, immersed fins.

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1 INTRODUCTION

Generally, Fresh water represents only 3% from the general water quantity in ground. Furthermore, only 1% can be used as a pure drinking water. The remaining quantity either is iced or deeply hidden in the ground. In arid areas which are characterized by dryness, the surface water quantity is generally brackish like some areas in the South of Algeria such as Adrar, Bouda and Reggane ...etc. The solar desalination process could contribute effectively to the drinking water provision quantity in these cities. There are several solar distiller types, among these types, the single basin double slope solar still (SBDSS) which is characterized by a high yield compared to other existing types, The solar still performance improvement studies are divided into two types, the first type deals with internal improvements: geometric configurations (design, geometric dimensioning, orientation... etc.), meteorological (solar radiation, ambient temperature, wind speed ... etc.), conception materials (absorber, transparent cover, insulation ... etc.), the second is related to external improvements (water preheating, solar concentrator, glass cooling system ... etc.). Several experimental and theoretical research tasks are realised in this domain for the water production amelioration.

The first type which is based on internal improvements contains the research major part [1-4]. The solar distiller optimal geometry is unconventional, which is mainly occurred due to the climate diversity (desert, continental, coastal ...etc.) and the climatic condition variations (wind speed, ambient temperature, solar radiation ...etc) of a geographic site to another. Al-Hinai et al. [1] have presented a theoretical model and a numerical study for predict the simple SBDSS water productivity in several different climate, design and operational parameters in Oman Sultanate. The presented numerical study resulted by the heights show that the glass cover optimal tilt angle is 23° and the optimal insulation thickness is 0.1 m. Okeke et al. [2] have studied the coal and charcoal effects on the solar distiller performances. The solar still was tested in Nigeria, it is oriented towards EAST –WEST direction. The solar distiller without adding coals case has a nocturnal production greater than the diurnal production. The coals addition increases the diurnal solar still production. Coal and charcoal ameliorate the solar still performances, as well as charcoal deposits on the basin bottom, greatly reduce the reflection and increase the amount of solar energy absorbed by the solar collector. Cooper [3] has presented a theoretical study to predict the characteristic parameters influence in the double slope single basin solar still production in Australia. The effects of the water depth, wind speed, the distiller insulation, the glazing slope and the climatic conditions are studied in both solar still cases; the first has a single glass covert and the second have a double glass covert. The simulation results indicate that the water depth has a little effect on the SS productivity, The good insulation will improve the distiller production in low water depth cases, the higher wind speed and ambient temperature increases slightly the solar still production, the double glazing has a negative effect in the solar still production and the basin water temperature increase then the glazing temperature reduction increases the solar distiller productivity. Belhadj et al. [4] have studied numerically the effect of adding a condensation cell at the single basin double slope solar still. The system performance was compared with a conventional solar still in Algeria at Adrar city. The proposed modification improves the solar still productivity.

The second type is based on external improvements [5-10]. Bechki et al. [5] have experimentally studied the intermittent cover shadow effect on the SBDSS production in the South of Algeria. This developed modification has improved the solar still production. Al-Hayek et al. [8] has studied externally two types of solar distillers, one simple with a vertical mirror and the other with doubles slopes, in the Jordan climatic condition. They found that the distiller with a reflector mirror has a productivity superior than that with simple solar still, the water thickness reduction and the addition of dyes increase the distilled water production. Kabeel et al. [6] have presented an experimental and theoretical study of the two types of solar distillers tested simultaneously; a conventional simple solar still and a stepped distiller, under the Egyptian climate condition. They studied influence of tank width and water depth on the solar distiller performances. The stepped solar still was coupled with a vacuum tube solar collector. To increase the solar radiation attenuation they used a wick on the stepped distiller vertical sides. It's found that the modified solar still have greater production than the simple. Veropoulos et al. [7] proposed a theoretical and experimental study of a hybrid solar desalination system, composed of a coupled distiller with vacuum tube water heater system. The system was tested in Egyptian climate condition. They conclude that the coupled system have a significantly higher production compared to the distiller without coupling, moreover, the solar water heater allows providing warm water starting from its storage tank. Rahul et al. [9] have presented a comparative study between single slope solar still (SS) and the inverted absorber solar still (IASS) which is the solar still box type with a curved reflector placed under the basin to heat both upper and lower sides. The distillers were experimented simultaneously in Oman. They concluded that the SS production is the best one and the optimal water depth was 0.01m which can be recommended for use in the solar stills. Morad et al. [10] have presented a comparative study between a simple solar still and solar still integrated with flat plate solar collector in Egypt. They studied influence of glazing and water thickness with and without glass cover cooling. The experimental results revealed that the active solar distiller has a fresh water productivity maximal and a great internal thermal efficiencies compared with passive solar distiller under 1 cm water depth and 3mm glass thickness with cover cooling of 5 min on and 5 min off.

In the above works usually the evaporation phenomenon is related to the water surface, the convective heat exchange coefficient and the gradient of the temperature between the absorption plate and the glass, where the basin salt water concentration was not considered.

In this paper we present a study of physicochemical parameters influence on the solar still production. Knowing that by time, the basin water becomes saturated with salt water that automatically reduces the solar distiller production. For this reason, we propose the following experiment.

2 EXPERIMENTAL METHOD

The daily produced distillate water was measured by a graduated cylinder. The physicochemical analyses were effected with on pH meter type METLLER TOLEDO SG78 .

Through this experiment we have measured the PH, total dissolved solid TDS, resistivity, salinity and conductivity of water after and before desalination. A daily extraction of 40 ml from salt water in the two solar distillers and from their produced distilled water during the end of June and July month. Four samples of 50 ml graduated glass beaker were used, at each sample the physicochemical parameters have been measured, and these values were recorded in the notepad, as well as the study of the influence of these parameters on production. The flow radiation and temperatures of the single basin double slope solar sill was measured by data acquisition type FLUKE 2629 relied with pyranometer type KIPP&ZONEN and thermocouples type K respectively. The glasses cover dimension was 57x131 cm and 4mm thickness tilted 15° the solar sill basin dimension 93x125 cm and the saline water thickness in the solar still was between 2.5 & 3 cm in all test, a glass wool 5cm thickness is used to insulate the solar distiller. The solar still was tested during the period from 04/03/2015 to 18/08/2015, in the experimentation platform of the URERMS ADRAR South of Algeria characterized by its latitude 27°53'59"N, longitude -0.28°and Altitude 264 meters compared to the sea level. The soil albedo is 0.2.

3 RESULTS AND DISCUSSION

The water pH, TDS, Salinity, Resistivity and conductivity before and after distillation for the two distillers were measured in July, in order to study the influence of its parameters on the distiller productivity. All results measurement have presented and descuted below.

3.1. pH influence

In the SBDSS with finned flat plate immersed in the basin water: we show clearly the solar still production increase when the pH value is less than 7.5 until reaching the maximum value (8.5 liters) when the pH was between 7.5 and 7.9, for the pH value greater than this value the solar still production decrease. Basing on theoretical calculations the proposed mathematical third order polynomial correlation with $R^2=0.9978$ as it is shown in the figureN°2.

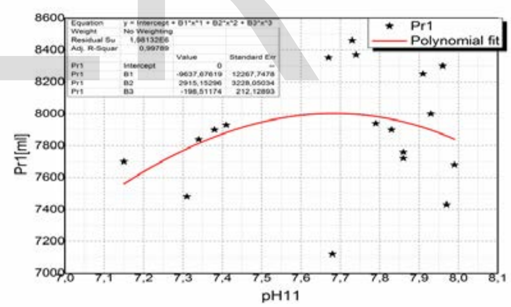

Figure N°2 The modified distiller production according to the basin water pH .

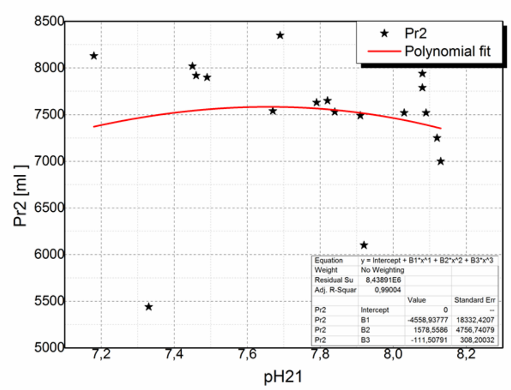

Figure N°3 The simple distiller production according to the basin water pH

Figure N°3 shows that the SBDSS production increases with pH until reaching the maximum value when pH was between 7.4 and 7.8, for pH value greater than this value the solar still production decreases, Basing on theoretical calculations the proposed mathematical third order polynomial function between pH and solar still production was presented in the same figure with R^2=0.990.

The produced water pH was between 6 and 7.5 and between 5.5and 6.5 for the modified and simple solar still respectively a mathematical liner correlation of the daily pH of distillate water was presented with R^2=0.997 & 0.995 for the modified and simple solar still respectively as it is shown in the figure N°4.

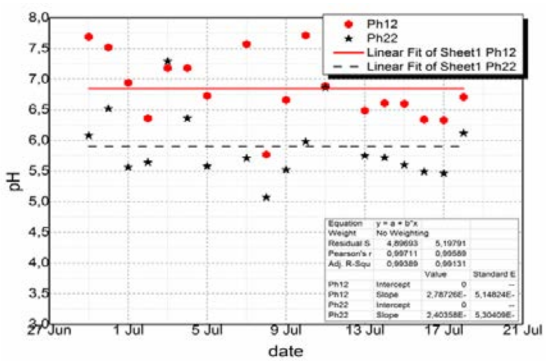

Figure N°4 Produced distilled water pH

The proposed solution is that the SBDSS works in the optimal value and we should replace the salt water in the basin periodically, the next chemistry solution is the adding of a weak acid or a strongest base (alkaline) in the salt water in the basin.

By Comparison, the two solar still productions show that the solar still with immersing fined flats plats have a rate of production better than the solar still without fins production.

3.2. Water resistivity influence

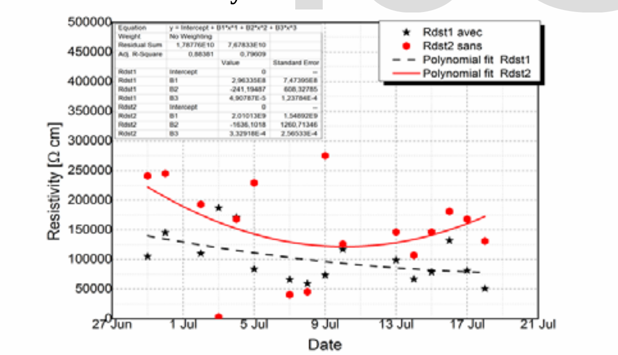

Figure N°5 : The two distiller's produced water resistivity

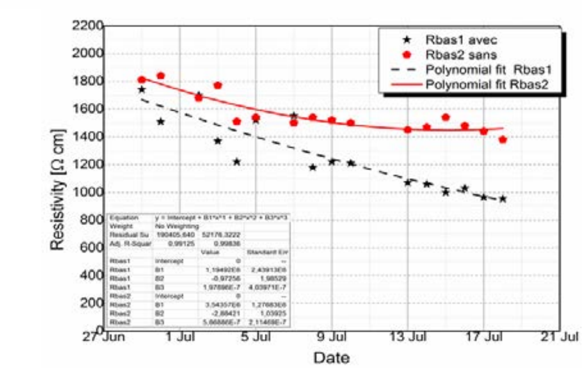

Figure N°6 : The two distiller's basin water resistivity

The first finding shows that the produced distilled water resistivity had strong increases compared to the initial value, it's the case of the two distillers their value was ranging 15x104~25x104 [Ωcm] and 5x104 ~15x104 . It can be caused by the salt ions liberated in the basin during vaporization. Secondly the results show that production and resistivity are inversely proportional. the daily distilled water resistivity decreases gradually to reach a minimal value 125000 and 100000 [Ωcm] for the modified and simple solar distiller respectively above these values the solar stills production increases as it is showed in the figure N°5.

FigureN°6 shows that the daily salt basin water resistivity decreases when water becomes saturated with ions liberated by evaporated water. Their value was between 103~1.8x103 [Ωcm].

The produced distilled water as function of the basin salt water resistivity as shown in the figures N°7 and N°8, it's showed that the solar distiller production reached the maximum value when the basin salt water resistivity was between 1305~1566 [Ωcm], apart from this values, the solar distiller production has clearly decrease. In this reason it's demonstrated that the basin salt water resistivity has a significant effect in the solar distiller production.

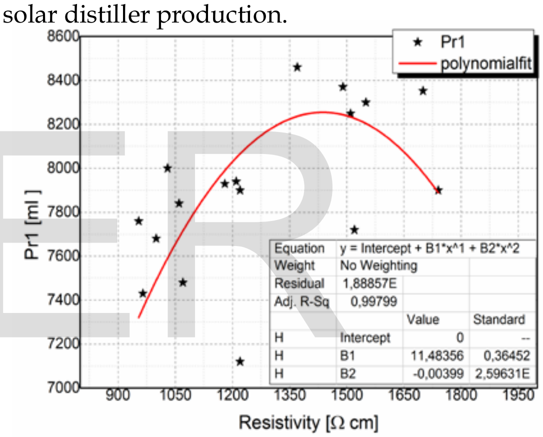

Figure N°7 The modified distiller production according to the basin water resistivity

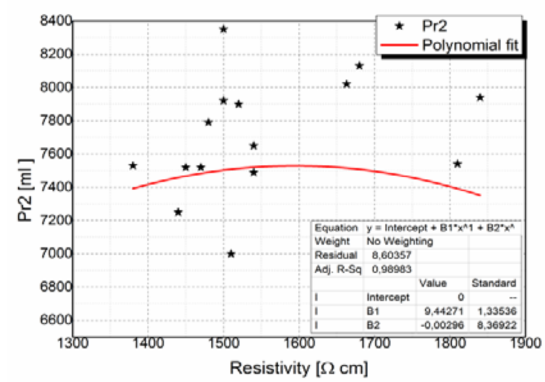

Figure N°8 Tthe simple distiller production according to the basin water resistivity

3.3. Water salinity influence

Fig N° 9 shows the daily basin water salinity evolution, It's observed that day after day, the brackish water salinity increases linearly so that it reaches a value of 500 mg/l, 350 mg/l for the modified and simple solar distiller respectively. When the basin water salinity increases progressively, the water became saturated by ions released during evaporation, a white crystal bed appears in water surface and it will be an obstacle to the solar radiation attenuation at the solar still absorber. This is the first suspects who engender the distilled water production decreases; the second suspect is the salt concentration increases. The modified solar distiller has a strongest water salinity than the simple solar distiller basin water, it can be caused by metallic fins (Al) immersed in the SBDSS. A mathematical correlation describing the daily water salinity variation for the modified and simple solar distiller was presented in the same figure.

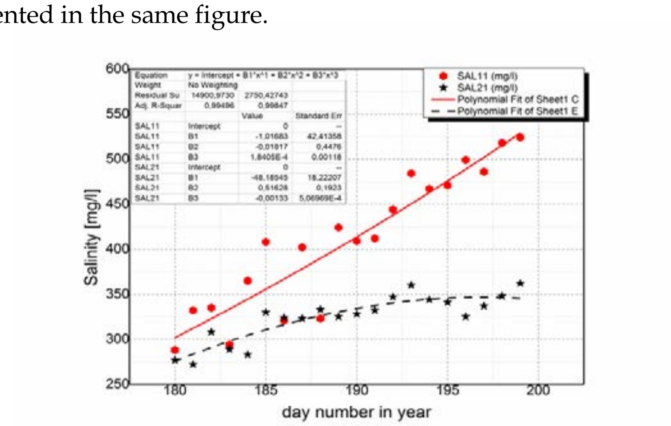

Figure N°9 Daily basin water salinity

Figures N° 10 and N°11 shows the brackish water salinity effect on the solar distiller production for the modified and simple distiller respectively; it was showed clearly that the brackish water salinity increases, decreases the solar distiller production. Basing on theoretical calculations the proposed mathematical correlation between produced distilled water and the basin water salinity was presented in the same figures. The daily distilled water salinity as it is shown in the Figure N°12. Their value was less than 8 mg/l, based at the OMS fresh water norm, fresh water salinity must be less than 5 g/l, where the produced distilled water has a salinity less 8 mg/l, The daily produced distillate water 8 [liter/m² day] can be mixed with a big quantity of salt water to be a fresh water, as it is renowned the distilled water is too poor in mineral substances.

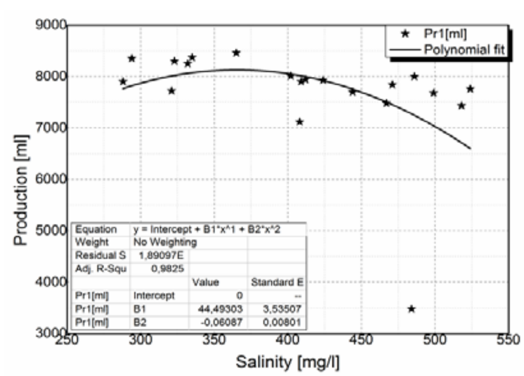

Figure N°10 Distillate production as function as basin water salinity for the modified solar still

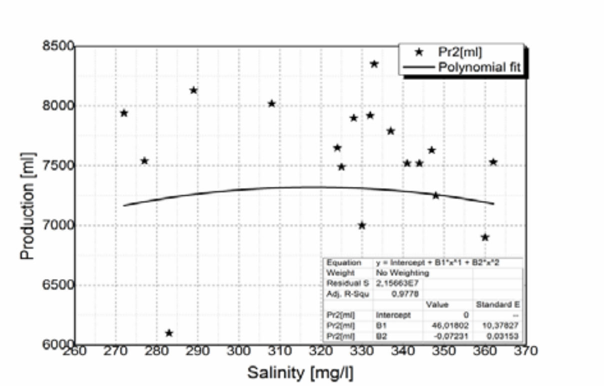

Figure N°11 Distillate production as function as basin water salinity for the simple solar still

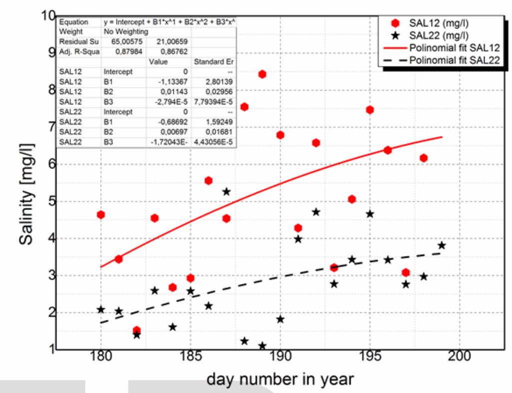

Figure N°12: Daily distillate water salinity for the modified and simple solar still

Figures N°13 and N°14 shows the total dissolved solid (TDS) influence at the basin water salinity. The cumulated salts released during evaporation increase the basin water salinity gradually, It is noted that the organic substance presented in the basin water is less than 10 mg/l, this value it's considered negligible in front of the salts substance presented in the brackish water which is about 300~500 mg/l. Basing on theoretical calculations the proposed mathematical linear correlation describing the basin water salinity as function as TDS variation was presented as follow: $TDS = F.S + Ns$

For the modified distiller;

$F = 0.000948545\ ,\ \ Ns = 0.01231$

For the simple distiller;

$F = 0.00086441\ ,\ \ Ns = 0.03522$

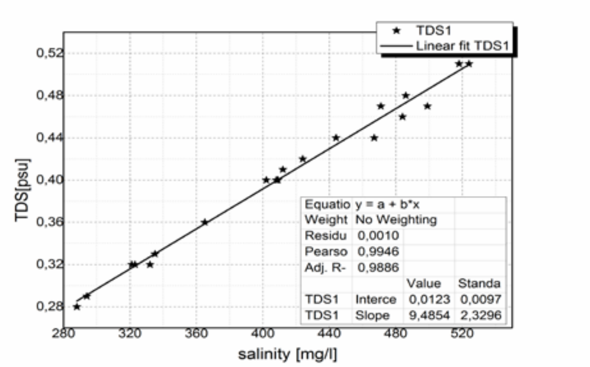

Figure N°13,: The total dissolved solid as function as basin water salinity for the modified solar still

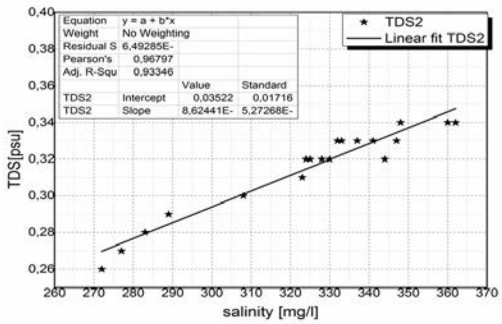

Figure N°14,: The total dissolved solid as function as basin water salinity for the simple solar still

4 Conclusion

Several researchers have investigated the effects of the externals and internals parameters on the solar stills performance, in this work we present the water physicochemical analysis after and before desalination have enabled us to show clearly the influence on the distiller production. Besides a mathematic correlation between its parameters and the solar distiller production was presented. The solar still productivity reached the maximum value when the water pH value was included between 7.5 and 7.8, the proposed solution to optimize the solar distiller production; is to replace the salt water in the basin periodically, the other chemical solution is the addition of a weak acid or a strongest base (alkali) at the basin salt water. The basin water salinity must be low than 350 mg/l, 450 mg/l for the modified and simple distiller respectively. The solar still with immersing fined flats plats have a production rate that exceeded 8 [liters/m² day] in July, Which is better than the solar still without fins production. It is found that when pH is between 7.5 and 7.8, the other parameters automatically change, as well as the solar distiller have a maximal production.

Acknowledgments

The present work was effectuated in 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

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