Amelioration of the Performance of Glass Solar Still Using Different Absorbers in Adrar

Bahous NASRI[1,3], Djelloul BENATIALLAH[2], Slimane KALLOUM[1], Ali BENATIALLAH[1]

[1]Department of Material Science, Faculty of Science and Technology, University Ahmed Draïa, Adrar, Algeria
[2] Department of Mathematics and Computer Science, Faculty of Science and Technology, Laboratory of Sustainable Development and Computer Science (LSDCS)، University Ahmed Draïa Algeria
[3]National Agency for Hydraulic Resources, POBox 364 – Adrar, Algeria

bnasri14@gmail.com

Article Info

Article history:

Received 22 November 2020
Revised, 09 December 2020
Accepted 13 December 2020

Keywords:

Adrar
Arid areas
Local material
Productivity
Single slope solar still

ABSTRACT

The present work aims at improving the performance of a glass solar still using different new absorbers (enameled sheet metal, blackened sponge, blackened gravel, clay, charcoal and quicklime) as sensible heat storage systems under the desert climatic conditions of Adrar. Most of the solar stills studied up to now are made of sheet metal with a black coating. The main disadvantage of these systems lies in their high corrosion and water contamination by the rust of the metal used and some toxic elements. Two solar stills were designed, constructed and tested in this study in order to compare the efficiencies of the different solar desalination systems. The first one is a glass solar still with sensible heat storage materials and the second one is a conventional solar still. The solar still studied was fabricated from cheap locally available glass and healthy materials. The hourly water and glass temperatures, productivity, and efficiency of the still were measured and evaluated experimentally. Moreover, a comparison between the different materials used as absorbers was carried out as well. From the results, it was observed that the system could produce 5.6 l/m²/day of fresh water; it was also found that metal was the best absorber as it exhibited the highest productivity as compared with the other absorbers. However, the maximum volume produced by the conventional solar still was only 4.88 l/m² per day. The lowest productivity, of about 1.6 l / m² /day, was observed with quicklime. In addition, physical analysis of distillate output shows that the quality of water produced is better.

I. Introduction

Generally, potable water represents only 2.5 % from the general water quantity on the planet. Fresh water has become an increasingly important factor in the development of any country. No one denies that safe drinking water is vital to life and is indispensable to our well-being. It is also a basic requisite for further agricultural, industrial and energy□related developments [1].

The supply of drinking water has become difficult in many countries, thus, access to safe drinking water, is expected to become in the world as fundamental economic and social rights and unfortunately this is not currently the case. whatever its origin, superficial or underground water, water used for the consumption is not always acceptable, due to, its excessive salinity or an another pollution [2].

In Algeria, the insufficient of water resources resulted in a shortage which is generalized in all the territories of the country. Population growth, arid Saharan climate, followed by an increase of the exploitation of water resources, to meet basic needs for urban, agricultural and industrial aggravated the situation. Currently, Algeria was considered already among the countries classified in water stress since 2007 [3].

In the past few years, the southern region of Algeria has witnessed a rapid population increase, along with a remarkable expansion in the irrigated land and industrial development. This situation has led to overexploitation of groundwater. Consequently, this has caused a significant water table drawdown and well pumping as well as serious groundwater quality degradation due to salt water intrusion for example [3].

In the arid zones of Algeria, man has always depended on underground water reservoirs for fresh water needs, but using water from such sources is not always possible due to its dissolved salts content.

Some sophisticated techniques, such as ion exchange, reverse osmosis and electrodialysis, have been adopted for water purification. Unfortunately, these are generally costly methods that require a lot of equipment and energy. Solar distillation of brackish water is a more convenient and practical alternative that may help to meet the increasing fresh water demands in these regions [4].

During the second half of the 20th century, the water resources from the North Western Aquifer System (NWAS) increased and resulted in a significant increase in water demand that went from 0.6 to 2.5 billion m3/year in the three neighbor countries [5].

The intense evolution of water withdrawal from the NWAS aquifer has generated a number of major problems such as the strong interference between countries, the disappearance of artesian water, drying up of natural outlets, such as the foggaras, excessive increase in the pumping depths and the increasing salinity of water (5.2 g /l) [6].

The solar still may provide the most appropriate solution for those zones where plenty of solar energy is available but the quality of water is bad. The working principle of a solar still consists of using the solar irradiance in order to create a greenhouse effect that brings brackish water to evaporation and condensate it in order to eventually obtain freshwater [7].

A solar still is a very simple apparatus that helps to get potable water by distilling saline water, such as seawater or brackish water. Solar stills are normally used for small-scale drinking-water supplies needed in remote isolated areas, where there is plenty of solar energy and the sources of saline water are available, or in some special situations where other sources of energy are not available [8]. Solar stills are cheap and require minimal maintenance; however, their main problem lies in their low productivity [9].

Solar energy is the main source through which life is sustained on earth. Algeria is a vast and sunny territory, especially in its Saharan region appropriate to the development of solar energy application. The Algerian desert is the most exposed region in the world to sunlight [10] and [11]. It may receive between 2500 and 4000 hours of sunshine per year. The town of Adrar receives a substantial amount of solar radiation with long sunshine hours, high temperatures and high solar radiation intensity (7 kwh/m²/day) [12].

A large number of researchers around the world have previously attempted to enhance the productivity of passive solar stills. The productiveness of a solar still can be improved through action on the characteristics of the absorber and condenser [13] and [14].

It is interesting to know that the productivity of a still may be improved by the use of heat storage materials or phase change materials; this approach has been proposed by several authors, [15].

For the purpose of improving the production of fresh water in a solar still, Al-harahsheh et al. [15] carried out an experimental study on a solar still containing a phase change material, PCM that is connected to an external solar collector. They found out that the increase in basin and PCM temperatures are directly proportional to the solar energy input, which is similar to a typical solar irradiation trend. The excess input solar energy is stored in the sensible PCM Sodium Thiosulfate Penta Hydrate (STSPH) as latent heat that keeps the system operating during the night time. These same authors also indicated that this unit was capable of producing 4.3 l/m²/day; 40% of that amount was produced after sunset. Also, the addition of PCM to the system allowed improving the water production capacity by about 23%. In addition, the energy stored in the PCM could be used to heat the water in the tank for a certain period of time, resulting in an 86% improvement in performance.

For the same reason, Nasri et al. [16] proposed and carried out an experimental study using locally available materials in the southern region of Algeria, such as gravel, polyethylene, and sand, as heat storage systems in glass solar still. This attempt results in an enhancement of solar still productivity by 32.20 % compared with a conventional still. The same authors have used a black polyethylene film to enhance absorber capacity and hence to improve the productivity of glass solar still. The results show that the productivity of still was between 4.04 and 4.48 l/m²d, [3].

Kumar et al. [17] investigated a novel system by combining an inclined solar still with a triangular pyramid solar still. Moreover, Elango et al. [18] suggested a new approach to enhance the productivity of a solar still supplied with a basin made up of glass. Similarly, Murugavel et al. [18] and [19] made an attempt to evaluate different passive methods to enhance the efficiency of the solar still basin. They reported that the performance of the solar still depends on the direction and inclination of the transparent cover material, its thickness and temperature. The water depth, as well as the material used in the basin, also affects the performance of the still. Likewise, Velmurugan et al. [20] conducted a number of experiments on a single-basin solar still. They used 450 pieces of sponge and five fins in the distiller. The results obtained showed that the solar still with fins enhanced its productivity by 29.6% as compared to the conventional one.

Sellami et al. [21] conducted an experimental study on the performance of a solar still, using an additional inner heat storage system by covering the absorber surface with layers of blackened sponge. They found out that a 0.5 cm thick sponge layer increased the yield of the solar still by 58 %.

Deshmukh and Thombre [22] investigated experimentally the effect of sand and servotherm medium oil as a phase change material (PCM), which was added as a heat storage medium, to improve the performance of a solar still through the increase in freshwater productivity.

Yousef and Hassan [23] presented some methods for a single-basin solar still with and without phase change material (PCM) placed underneath the basin liner of the still.

Furthermore, Kabeel et al. [24] investigated the possibility of improving the yield of a conventional solar still through the use of a mixture of paraffin wax and graphite nanoparticles. As a result, a 94.52 % gain was obtained with the addition of 20% graphite nanoparticles mass concentrations and 80% of paraffin wax.

Kabeel et al. [25] conducted an experimental investigation of a conventional basin solar still, integrated with a latent heat thermal energy storage system, which was designed with the view of enhancing the still productivity, using sensible heat energy storage knitted with jute cloth wrapped over the entire surface of the material under different water mass. Afterwards, the phase change material (PCM) was added to a concentrator-coupled hemispherical basin solar still in order to augment its efficiency and distillate yield. Two modes of operation, namely a single-slope solar still without the PCM and a single-slope solar still with the PCM, were experimentally investigated by Arunkumar et al. [26]. The resulting experimental data indicated that the thermal storage in the concentrator-coupled hemispherical basin solar still increased the productivity by 26%. It was therefore concluded that the productivity greatly increased due to the presence of the phase change material within the still.

The present paper aims to assess the performance of a single-basin glass solar still, using locally available eco-friendly materials, for the production of unpolluted fresh water suitable for drinking. This system was entirely fabricated with locally available cheap glass. The experiments were carried out for the purpose of studying the effect of different absorbers, such as the sensible heat storage materials, in order to increase the basin absorptivity, and consequently enhancing the solar still productivity. Also, the effect of different environmental and operational parameters, such as the solar intensity, wind speed and ambient temperature, on the still productivity was also examined.

II. Experimental methodology

II.1. Solar still description

Two solar stills were designed and constructed; the first one was made with a cheap 4 mm thick glass and the second one is a conventional solar still made of galvanized 3 mm thick metal sheet. The glass solar still consists of a basin with interior painted black, and various absorbers, such as enameled sheet metal plate, blackened sponge, tinted black gravel, clay, charcoal and quicklime, used as sensible heat storage systems, to ensure maximum solar irradiance absorption. The basin area is 0.50 m × 0.50 m (0.25 m²). The top wall is provided with a 4 mm thick glasscover. The side and bottom walls of the basin are covered by an insulation material, like a 4 cm thick polystyrene layer, to prevent convective heat losses; the assembly is placed on a 16 mm thick wooden box. The entire solar still is kept in the north-south (N-S) direction at 10° inclination. Figure 1, presents the photographic view of the glass solar still under study.

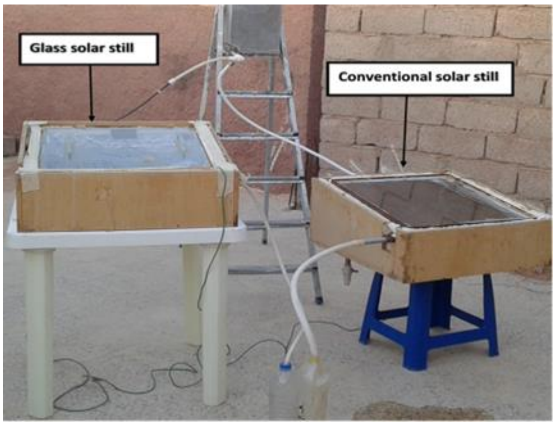

Figure 1. Photos of the conventional solar still and glass solar still under study

With the aim of increasing the yield of the solar still, different materials have been tried as heat storage systems. According to the same methods used by the authors [16]. (Figure 2), presents the photos of the different absorbers that were used in various experiments.

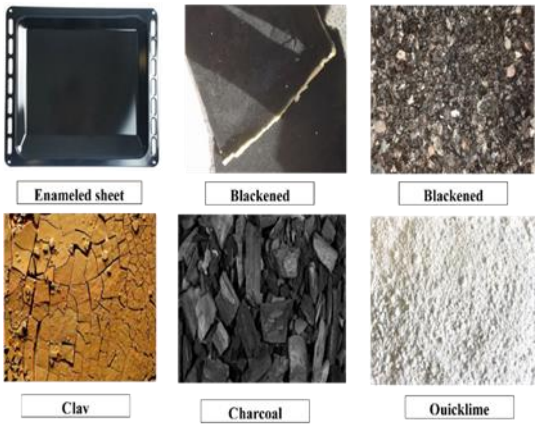

Figure 2. Photographs of different absorbers

The basin is filled with water from a galvanized sheet metal tank with a capacity of 10 L. This is done by gravity and the distillate is recovered through the channel that is placed at the end of the basin roof. Silicone was used to ensure the correct sealing between the various constituents of the distiller. Figure 3, shows a schematic drawing of the solar still.

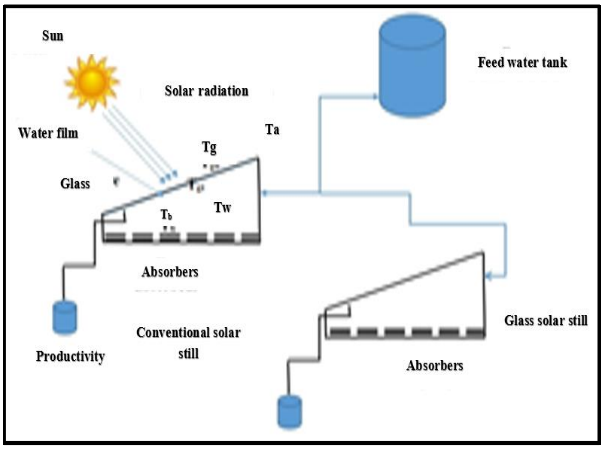

Figure 3.Schematic diagram of the solar still

II.2. Experimental setup and procedure

The experimental data were recorded on the still basin, from 7 a.m. to 7 p.m., at 30 to 60 minutes' time intervals. The experiments were carried out during the period of April and May of the year 2018 in Adrar, a town located in the southwestern part of Algeria. The system was oriented in a north-south direction in order to receive maximum solar radiation during the test days. The temperatures measured during the experimentation were the ambient temperature, saline water temperature, and glass temperature. These temperatures were measured with calibrated k-type thermocouples connected to a digital temperature indicator (Data Acquisition Unit - Fluke 2625A Hydra Series II). The solar radiation intensity impinging on the system surface was evaluated by a Kipp & Zonen CMP21-type pyranometer. The wind speed was estimated by means of an NRG 40C anemometer. In addition, graduated measuring containers, with volumes ranging from 0 to 1000 ml, were used to determine the volume of condensate water at the output. The water depth in the solar distiller was fixed at 1 cm. The accuracies and uncertainties of the measuring devices used in this study are summarized in (Table 1).

Table 1.Accuracies and uncertainties of the measuring instruments

Instrument	Accuracy	Range	% Error
Thermocouples	± 1 °C	−100 to 500 °C	1.4
Pyranometer	± 1 W/m2	0–2500 W/m2	0.1
Anemometer	< 0.1 m/s	1–96 m/s	2.0
Glass bottle	± 10 ml	0 –1000 ml	0.6

III. Results and discussion

The variation of the measured solar irradiance as a function of time is illustrated in (Figure 4). It is worth noting that the solar radiation intensity increases during the morning hours; the highest value, i.e. 1042.256 W/m², was reached at 1.00 p.m. on 05 May. This same figure also indicates that solar irradiation is more intense between 11 a.m. and 1 p.m., but is weaker after 5 p.m.

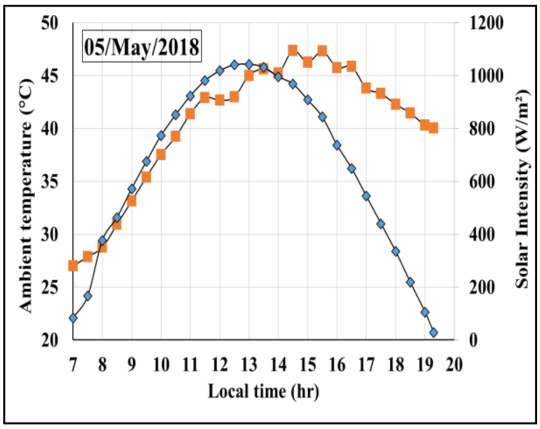

Figure 4. Hourly variation of ambient temperature with time

The variation of ambient temperature and solar radiation over time is shown in (Figure 4). One can clearly see that this temperature increases in the morning to reach a maximum value of 47.364 °C at 2.00 p.m., which corresponds to a solar intensity of 1042.25 W/m². After 3.00 p.m., the ambient temperature gradually decreases as the solar radiation intensity goes down, though the air temperature remains quite high even after 7 p.m., which favors condensation until 8 p.m.

Figure 5, depicts the variation of wind speed with time during the test day. This figure indicates that the wind speed was in the range between 0.478 and 5.443 m/s, and the maximum value was reached at 5 h 30 min p.m.

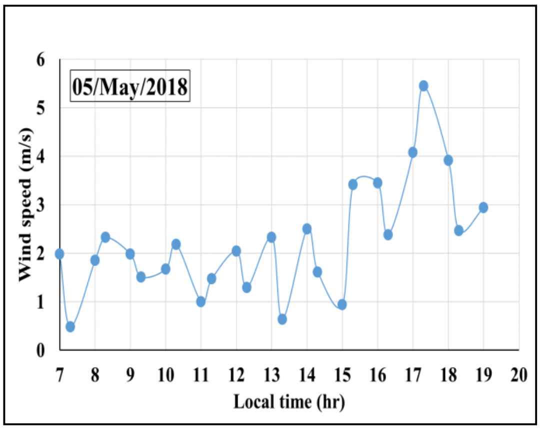

Figure 5. Wind speed variation during the test day

Comparisons between the hourly freshwater productivities for both solar stills, i.e. the solar still with sensible heat storage materials (SHSM) and the conventional one, during the test period are illustrated in figures 6, 7 and 8. These figures clearly show the hourly variation of freshwater productivity of the glass solar still integrated with different absorbers (enameled sheet metal plate, during the first and second days, sponge, blackened sponge, gravel, black-painted gravel, clay, black-painted gravel, charcoal and quicklime), during the experimental days. One can easily notice that the distilled water productivity increases slightly in the morning, which is certainly due to the amount of heat stored within the materials integrated in the distiller. After 12 a.m., productivity rapidly rises as a result of the heat transmittedto water by the materials used. In the first part of the tests, black polyethylene was used as an absorber in the basin and the productivity was around 4.48 l/m²/day [3].

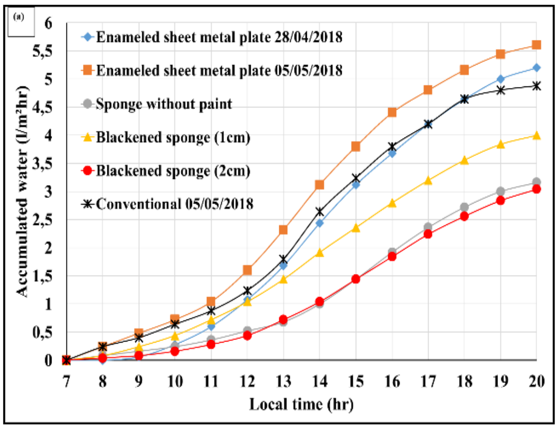

Figure 6. Variation of fresh water productivity for the solar still integrated with different absorbers (a)

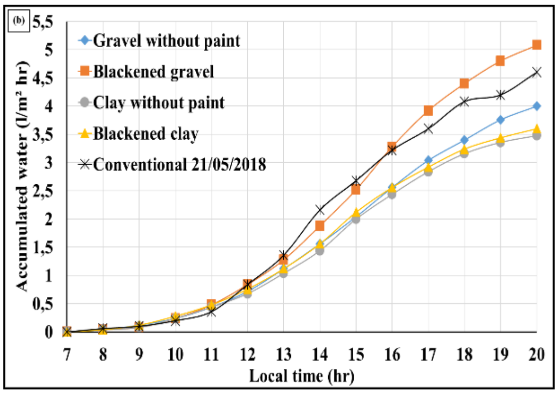

Figure 7. Variation of fresh water productivity for the solar still integrated with different absorbers (b)

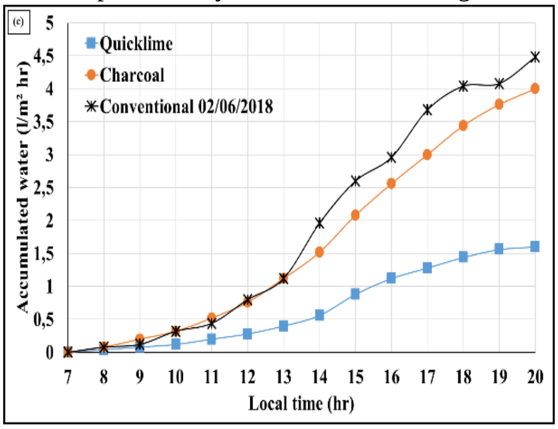

Figure 8.Variation of fresh water productivity for the solar still integrated with different absorbers (c)

Figure 9, illustrates the comparison of the daily accumulated water productivities which were found equal to 1.6, 3.04, 3.16, 3.48, 4, 4, 4, 5.08, 5.2, and 5.6 l/m²/day for quicklime, blackened sponge (2 cm), sponge without paint, clay, blackened sponge (1 cm), charcoal, gravel, blackened gravel, and enameled sheet metal plate 1 and enameled sheet metal plate 2, respectively. On the other hand, the productivity of the conventional still was between4.88 and 4.48 l / m². The accumulated water productivity of the suggested solar still was increased by 20 %, 14 %, and 12 %, when metal and blackened gravel were used as absorbers, as compared to the productivity of a conventional solar still; this is certainly due to the higher basin water temperature. Similarly, the distilled water productivity of the glass solar still was increased by 25%, 16% and 14%, when sheet metal and blackened gravel were used as absorbers, respectively, as compared to all the other absorbers. Note that the metal absorber produces the maximum distillate output with 5600 ml/m²/day. Furthermore, the lowest productivity was observed with quicklime. Similar results were also obtained by Sellami et al. [27], in Ouargla, a town in southeastern Algeria, which is in agreement with our results.

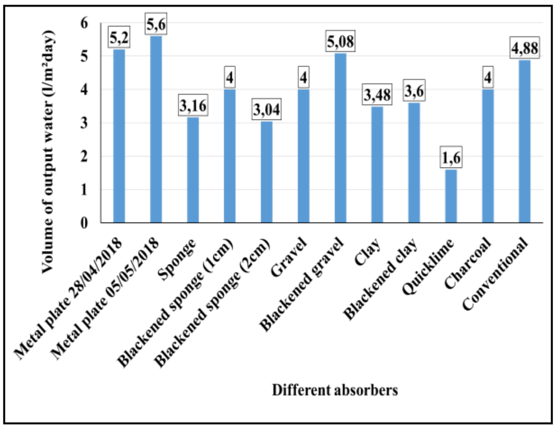

Figure 9.Daily productivity of the solar still with different absorbers

Furthermore, figures 10, 11 and 12 present the experimental results of the hourly variation of basin water temperature for different absorbers used in the basin-type solar still, on one side, and those of the conventional still, on the other. It is clearly seen that the charcoal absorber gave the maximum basin water temperature value of 82.65 °C at 2.00 p.m.; this is followed by the blackened sponge absorber (1-cm-thick layer) for which the basin water temperature reached 82.35 °C at the same time of 2:00 p.m. The lowest temperatures were recorded for sponge without paint, in which case the maximum basin water temperature of 69.06 °C was attained, at about 2.00 p.m. However, the maximum basin water temperature obtained with the conventional solar still was about 74.56 °C. Therefore, one may conclude that in general, the basin water temperatures reached with the different absorbers in the solar still are approximately similar for all tests.

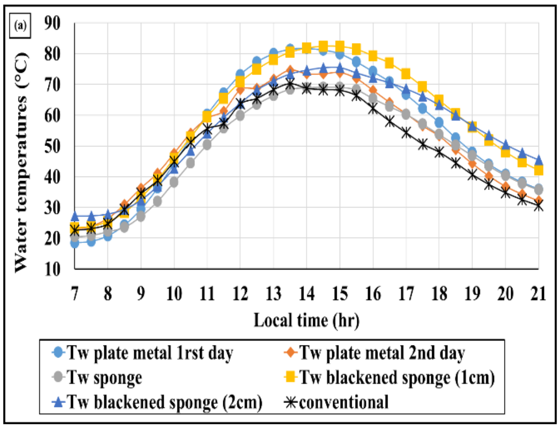

Figure 10. Evolution of basin water temperature with time for different absorbers (a)

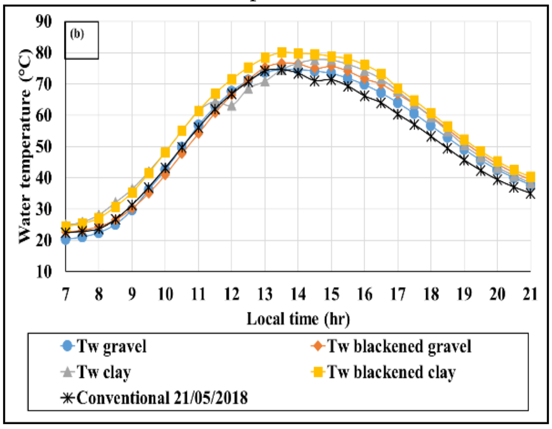

Figure 11. Variation of basin water temperature over time for different absorbers (b)

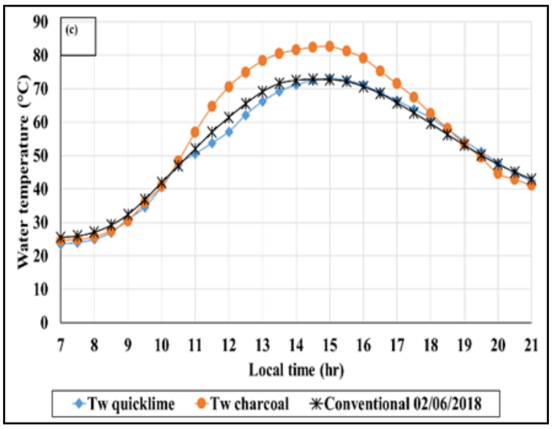

Figure 12. Variation of basin water temperature with time for various absorbers (c)

Figures 13, 14 and 15 show the comparison between the glass cover temperatures, with different absorbers used in the basin solar still, and that of the conventional still. It is easy to note that the temperature of glass (75.79 °C) covered with a metal sheet absorber is higher than that of the others; this is certainly caused by the radiation deflected towards the glass covered with metal. From these results, one can state that the glass cover temperature is always lower than that of the basin water. Note the temperature variations in the two cases are similar, whichmeans that the inner face of glass is heated with water vapor, which is not the case for the outer face.

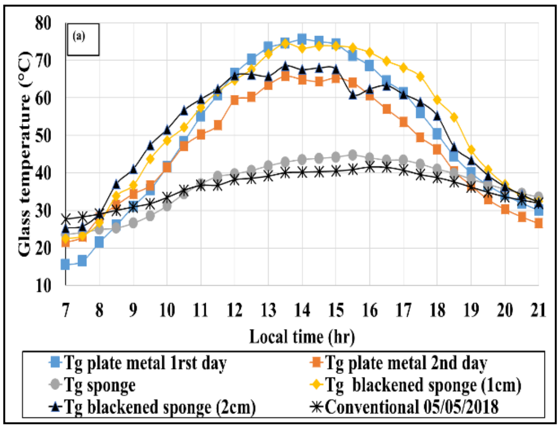

Figure 13. Hourly variation of the glass temperature using different absorbers

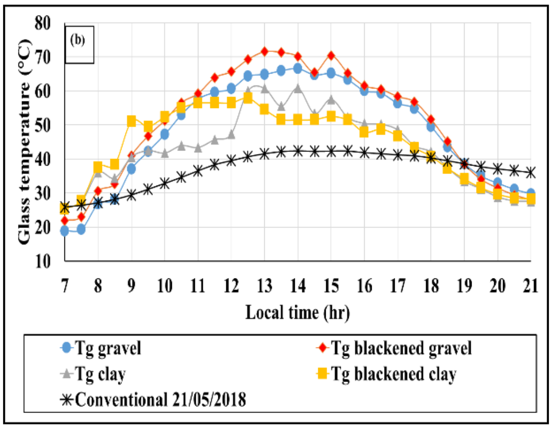

Figure 14. Hourly variation of the glass temperature using different absorbers

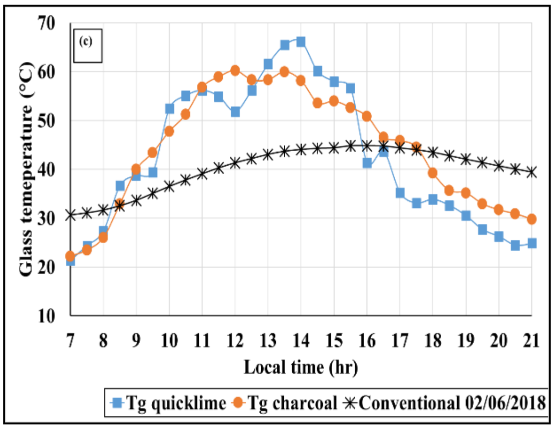

Figure 15. Hourly variation of the glass temperature using different absorbers

III.1. Water quality analysis

The physicochemical analyses were carried out for distilled water and raw water samples; the results obtained were then compared. The tests and analyses were performed at the Laboratory of the National Agency for Water Resources (ANRH in Adrar), Algeria. In addition, the various physical and chemical parameters of water samples were tested and analyzed.

The electrical conductivity (EC) and pH were measured in situ using a WTW 31.5i conductivity meter and a WTW 31.5i pH meter. The others physical and chemical parameters, including total dissolved solids (TDS), total hardness (TH), as well as the chlorides, sulfates, and nitrates levels were analyzed according to standard analysis methods. The different chemical characteristics of the tested water samples obtained from the analysis are shown in (Table 2).

Table 2.Chemical and physical characteristics of saline and distilled water samples

Parfametres	Distilled water output	Saline water input	Efficiency still (%)	WHO guidelines
pH value	6.80	7.57	10	6.5 - 8.5
EC (ms/cm)	0.02	4.90	99.59	2.8
TDS (mg/l)	16.047	3040.20	99.47	1000
TH (mg/l) as $CaCO_3$	10	1160	99.13	500
Cl^- (mg/l)	6.01	860	99.09	250
SO_4^{2-} (mg/l)	4.0	1070	99.62	250
NO_3^- (mg/l)	0.30	60.68	96.28	50

The results of the analysis show that groundwater is of bad quality and unsafe to drink before treatment by distillation. The groundwater is characterized by a very high salinity, which is equal to 3.040 g/l and is higher than the permissible limit of 1 g/l, a very high total hardness (1.160 g/l), as well as nitrate, chloride, sulfate levels that exceed the limit values.

After distillation, the analyses indicated that all physical and chemical parameters were under the permissible limits and are in accordance with the Algerian recommendations for drinking water [28], and the WHO drinking-water quality standards [29]. The physical and chemical analyses revealed that distilled water contains fewer minerals and is physically and chemically good. It is therefore possible to say that the water obtained is drinkable and complies with the WHO standards and guidelines [28] and [29]. It is worth pointing out that the water produced by the solar still is very poor in mineral salts; it is therefore advisable to mix two volumes of distilled water with one volume of brackish water to obtain three volumes of drinkable fresh water; this gives an additional quantity of 1022 l/m²/year.

III.2. Cost estimation of the solar still

The design of a solar still for rural remote areas must have the lowest cost possible; it should be made out of natural and locally available materials. The cost of the various parts making up the solar still system with current prices in the study area is estimated at 10,000 Algerian Dinars (74.21 Euro), while the real manufacturing price is 6700 DZA (48.61 Euro). (Table 3) shows the actual fabrication cost of the distiller.

Table 3.Actual cost of components

Materials	Quantity	Cost in Algerian Dinars (DZA)	Cost in Euro (100 = 15000 DZA)
Ordinary glass	2 m²	1000	7.25
Metal plate	1 m²	1200	8.71
Sand	5 kg	Free	
Gravel	5 kg	Free	
Wooden box	2 m²	3000	21.76
Accessories and workforce		1500	10.88
Total		6700	48.61

III.3. Cost analysis

Rahbar and Esfahani [30] calculated the first annual cost (FAC) of a solar still as:

$$FAC = P(CRF) \qquad (1)$$

Where CRF is the capital recovery factor and P the capital cost of the solar still. CRF is defined as [30] and [31].

$$CRF = \frac{i(i+1)^n}{(i+1)^n - 1} \qquad (2)$$

Where n is the lending interest rate from the bank and I the lifetime of the still. The interest rate is generally around 17 % for Algerian banks. Regarding the lifetime of the solar still, it is approximately twenty years. The first annual salvage value (ASV) of the still is expressed as [31].

$$\mathrm{ASV} = (\mathrm{SFF}) \times \mathrm{S} \qquad (3)$$

Where S is the salvage value of the still and SFF the sinking fund factor. The salvage value S was estimated by Rashidi et al. [31] as:

$$\mathrm{S} = 0.17 \times \mathrm{P} \qquad (4)$$

However, the SSF is expressed as [29]:

$$\mathrm{SFF} = \frac{\mathrm{i}}{(\mathrm{i}+1)^{\mathrm{n}} - 1} \qquad (5)$$

Furthermore, the annual maintenance cost (AMC) is defined in [30]. Only the absorber layer can be changed.

$$\mathrm{AMC} = 0.05 \times (\mathrm{FAC}) \qquad (6)$$

Therefore, the total annual cost (AC) of the solar still may be deduced as:

$$\mathrm{AC} = \mathrm{FAC} + \mathrm{AMC} - \mathrm{ASV} \qquad (7)$$

Hence, the cost per liter (CPL) of fresh water produced by the solar still is:

$$\mathrm{CPL} = \frac{\mathrm{AC}}{\mathrm{M}} \qquad (8)$$

Here M is the mean annual production of water [30]. Admitting that the average annual production is 5.6 l/m²/day (during the winter period the production is negligible, because it is limited to the three months of January, February and March, during which the observed productivity is 4 l/m²/day), one finds that the annual production is around 2044 l. It is interesting to note that the price of a liter of distilled water on the market is 30 Algerian Dinars (0.22 Euro), and its price when produced in our solar still amounts to 0.77 Algerian Dinars (0.0057 Euro);

also, the total annual production cost is estimated at 54 750 Dinars. These findings allow us to state that the investment expenses and costs may be recovered after three months (90 days) only. The above mentioned results are all summarized in (Table 4). Consequently, the production of distilled water using a glass solar distiller fabricated with locally available materials is 40 times cheaper than that obtained by other means, such as electricity produced by fossil fuel power plants.

Table 4. Cost analysis for a cheap glass solar still

Type	(n)	(i)	CRF	P	S	FAC	SSF	ASV	AMC	AC	M	CPL (Euro/l/m²)	CPL (DZA)
Glass solar still	10	0.17	0.21	48.61	8.263	10.20	0.04	0.330	0.510	10.38	2044	0.0057	0.77

III.4. Comparative analysis with previous studies

The comparison between the glass solar still, developed in the present study, and some other solar stills previously developed by other authors [17], [18], [32], [33] and [34] is shownin (Table 3). The results presented in the table below suggest that our findings are in good agreement with those of other investigations. The results presented in the table below suggest that our findings are in good agreement with those of other investigations.

Table 5. Comparison between our results and those obtained in other works

Reference	Solar still	Absorber	Daily freshwater output (kg/m²)	Increase in daily productivity (%)
Sharshir et al. [32]	Conventional solar still	Graphite and copper oxide	4 - 7	44.91 - 53.95
Elango and Murugavel [18]	Glass solar still	Black coating	4.40 – 5.32	17.38 – 41.14
Rajaseenivasan et al. [34]	Glass basin solar still	Sand – Metal scrap – Charcoal	3.46 – 3.61	26.74 – 33.7
Ouar et al. [33]	Conventional solar still	Bitumen– Charcoal – Black ink	4.166 – 4.644	6.14 – 18.32
Nasri et al. [16]	Glass solar still	Black polyethylene – Sand - gravel	3.84 – 5	16.67- 32.20
Present study	Glass solar still	Metal-sponge-gravel clay and charcoal	1.6 – 5.6	12 – 25

IV. Conclusion

A new solar still was experimentally investigated and tested using different absorbers, namely enameled sheet metal plate (1st and 2nd day), sponge, blackened sponge, gravel, black-painted gravel, clay, black-painted gravel, charcoal and quicklime.

The distillate yields for these different absorbers were studied and compared. It turned out that the solar still with the sheet metal plate absorber gives the highest distillate output; it is 25 % higher than that obtained with the other absorbers. Blackened gravel comes right after, its output is 16 % higher than that of the other absorbers; the lowest productivity of the still was observed with quicklime with only 1.6 l/m²/day. During the second day, the distillate productivity of the still with the metal sheet absorber was 5600 ml/m² for a collector area equal to 0.25 m²; it was 5200 ml/m² on 28 April. Also, for blackened gravel absorber, the output was 5080 ml/m² per day, and it was 4000 ml/m² per day for charcoal. In addition, the TDS level can be used for assessing water suitability for drinking. Feed water with TDS equal to 3040.20 mg/l may be treated and distilled to give water with a TDS level around 16.047 mg/l, hence a treatment efficiency of about 99.35%.

Acknowledgements

The authors would like to thank the anonymous reviewers for their careful reading of this manuscript and their helpful and constructive comments that will greatly contribute to improving the final version of this article. Their gratitude extends also to the Editors of the Algerian Journal of Renewable Energy and Sustainable Development" (AJRESD), and to all who participated in the realization of this work.

References

[1] M. Hendriks, Introduction to Physical Hydrology. OUP Oxford, 2010.
[2] K. Sekkoum et al., « Water in Algerian Sahara: environmental and health impact », in Advancing Desalination, IntechOpen, 2012, p. 198‑ 216.
[3] B. Nasri, A. Benatiallah, S. Kalloum, et D. Benatiallah, « Experimental study of solar still using local material in south of Algeria », AIP Conf. Proc., vol. 1968, p. 030024, 2018.
[4] M. Boukar et A. Harmim, « Performance evaluation of a one-sided vertical solar still tested in the desert of Algeria », Desalination, vol. 183, no 1‑ 3, p. 113–126, 2005.
[5] Observatoire du Sahel et Sahra (OSS), Système Aquifère Du Sahara Septentrional (Algérie, Tunisie, Lybie): Gestion Commune d'un Bassin Transfrontalier, vol. I. Tunisie: OSS, 2008.
[6] Observatoire du Sahel et Sahra (OSS), Système Aquifère du Sahara Septentrional : Hydrogéologie, volume II. Tunisie : OSS, 2003.
[7] K. Rabhi, R. Nciri, F. Nasri, C. Ali, et H. B. Bacha, « Experimental performance analysis of a modified single-basin single-slope solar still with pin fins absorber and condenser », Desalination, vol. 416, p. 86–93, 2017.
[8] Y. Taamneh et M. M. Taamneh, « Performance of pyramid-shaped solar still: Experimental study », Desalination, vol. 291, p. 65–68, 2012.
[9] A. D. Jone et A. B. William, Solar Engineering of Thermal Processes, 4th Edition. Canada: John Wiley & Sons, Inc., Hoboken, New Jersey, 2013.
[10] A. A. M. Sayigh, World Renewable Energy Congress VI: Renewables: The Energy for the 21st Century. Elsevier Science, 2000.
[11] Benatiallah D, Bouchouicha K, Benatiallah A, Harrouz A, Nasri B. Forecasting of Solar Radiation using an Empirical Model. Algerian Journal of Renewable Energy and Sustainable Development, 2019, 1(2),212-219. https://doi.org/10.46657/ajresd.2019.1.2.11.
[12] D. Benatiallah, A. Benatiallah, K. Bouchouicha, M. Hamouda, et B. Nasri, « An empirical model for estimating solar radiation in the Algerian Sahara », AIP Conf. Proc., vol. 1968, no 1, p. 030031 1‑ 10, mai 2018.
[13] K. Voropoulos, E. Mathioulakis, et V. Belessiotis, « A hybrid solar desalination and water heating system », Desalination, vol. 164, no 2, p. 189–195, 2004.
[14] A. Ahsan, M. Imteaz, U. A. Thomas, M. Azmi, A. Rahman, et N. N. Daud, « Parameters affecting the performance of a low cost solar still », Appl. Energy, vol. 114, p. 924–930, 2014.
[15] M. Al-harahsheh, M. Abu-Arabi, H. Mousa, et Z. Alzghoul, « Solar desalination using solar still enhanced by external solar collector and PCM », Appl. Therm. Eng., vol. 128, p. 1030–1040, 2018.
[16] B. Nasri, A. Benatiallah, S. Kalloum, et D. Benatiallah, « Improvement of Glass Solar Still Performance Using Locally Available Materials in the Southern Region of Algeria », Groundw. Sustain. Dev., p. 100213, 2019.
[17] P. N. Kumar et al., « Experimental investigation on the effect of water mass in triangular pyramid solar still integrated to inclined solar still », Groundw. Sustain. Dev., vol. 5, p. 229–234, 2017.
[18] T. Elango et K. K. Murugavel, « The effect of the water depth on the productivity for single and double basin double slope glass solar stills », Desalination, vol. 359, p. 82–91, 2015.
[19] R. S. Hansen et K. K. Murugavel, « Enhancement of integrated solar still using different new absorber configurations: An experimental approach », Desalination, vol. 422, p. 59–67, 2017.
[20] V. Velmurugan, M. Gopalakrishnan, R. Raghu, et K. Srithar, « Single basin solar still with fin for enhancing productivity », Energy Convers. Manag., vol. 49, no 10, p. 2602–2608, 2008.
[21] M. H. Sellami, T. Belkis, M. L. Aliouar, S. D. Meddour, H. Bouguettaia, et K. Loudiyi, « Improvement of solar still performance by covering absorber with blackened layers of sponge », Groundw. Sustain. Dev., vol. 5, p. 111–117, 2017.
[22] H. S. Deshmukh et S. B. Thombre, « Solar distillation with single basin solar still using sensible heat storage materials », Desalination, vol. 410, p. 91‑ 98, mai 2017.
[23] M. S. Yousef et H. Hassan, « An experimental work on the performance of single slope solar still incorporated with latent heat storage system in hot climate conditions », J. Clean. Prod., vol. 209, p. 1396‑ 1410, févr. 2019.
[24] A. E. Kabeel, M. Abdelgaied, et A. Eisa, « Effect of graphite mass concentrations in a mixture of graphite nanoparticles and paraffin wax as hybrid storage materials on performances of solar still », Renew. Energy, vol. 132, p. 119‑ 128, 2019.
[25] A. E. Kabeel, S. A. El-Agouz, R. Sathyamurthy, et T. Arunkumar, « Augmenting the productivity of solar still using jute cloth knitted with sand heat energy storage », Desalination, vol. 443, p. 122‑ 129, 2018.
[26] T. Arunkumar, D. Denkenberger, A. Ahsan, et R. Jayaprakash, « The augmentation of distillate yield by using concentrator coupled solar still with phase change material », Desalination, vol. 314, p. 189‑ 192, 2013.
[27] M. H. Sellami et al., « Effect of absorber coating on the performance of a solar still in the region of Ouargla (Algeria) », Desalination Water Treat., vol. 51, no 34‑ 36, p. 6490–6497, 2013.

[28] Minstre des Ressources en Eau MRE, Décret exécutif N°A14-96 du 2 Joumada El Oula 1435 correspondant au 4 mars 2014 modifiant et complétant le décret exécutif N°A 11-125 du 17. Rabie Ethani 1432 correspondant au 22 mars. 2011 relatif à la qualité de l'eau de consommation humaine, vol. N°13. 2014, p. 14‑17.
[29] World Health Organisation (WHO), Guidelines for Drinking-water Quality, 4th ed. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland: World Health Organization, 2011.
[30] N. Rahbar et J. A. Esfahani, « Experimental study of a novel portable solar still by utilizing the heatpipe and thermoelectric module », Desalination, vol. 284, p. 55–61, 2012.
[31] S. Rashidi, J. Abolfazli Esfahani, et N. Rahbar, « Partitioning of solar still for performance recovery: Experimental and numerical investigations with cost analysis », Sol. Energy, vol. 153, p. 41‑50, 2017.
[32] S. W. Sharshir et al., « Enhancing the solar still performance using nanofluids and glass cover cooling: Experimental study », Appl. Therm. Eng., vol. 113, p. 684‑693, 2017.
[33] M. A. Ouar, M. H. Sellami, S. E. Meddour, R. Touahir, S. Guemari, et K. Loudiyi, « Experimental yield analysis of groundwater solar desalination system using absorbent materials », Groundw. Sustain. Dev., vol. 5, p. 261–267, 2017.
[34] T. Rajaseenivasan, A. P. Tinnokesh, G. R. Kumar, et K. Srithar, « Glass basin solar still with integrated preheated water supply – Theoretical and experimental investigation », Desalination, vol. 398, p. 214‑221, nov. 2016.

How to cite this paper:

Nasri B, Benatiallah D, Kalloum S, Benatiallah A. Amelioration of the Performance of Glass Solar Still Using Different Absorbers in Adrar. Algerian Journal of Renewable Energy and Sustainable Development, 2020, 2(2),137-150. https://doi.org/10.46657/ajresd.2020.2.2.6