STUDY OF SOLAR DISTILLATION PROCESSES FOR THE PRODUCTION OF DRINKING WATER IN ARID ZONES(CASE OF TIMIAOUINE)

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Abstract—Solar distillation in arid area is an alternative to produce fresh water, especially with the availability of solar insolation and the brackish water or poor water quality. As the case of Timiaouine. In this study a solar still with cheap glace was fabricated and experimentally investigated under the climatic condition of Adrar city in the month of August 2017. To improve the solar productivity of still a black polyethylene film and sand were used as absorbers and heat storage materials. The effect of solar intensity, ambient temperature, polyethylene and sand on the solar still productivity were studied. The results show that the daily productivity of still was between 3.84 and 4.48 l/m²day. A maximum of solar intensity obtained at 13:30 p.m. (1210.273 W/m²). The ambient temperature increases with time and reached a maximum value of (40.7 °C) on June 10 at 14:30 and begins to decrease to a value of (39 °C) at 19h. The results show also that water output analysis all parameters have been eliminated completely, Hence, the efficiency of the solar still is approximately 99.91%.

Keywords— Solar still, Glass, Sand, Water quality

1. Introduction

Currently, the demand for freshwater has been growing constantly, with the civilization and socio-economic development of the population, especially in the arid areas of Sahara, and with the scarcity of its natural resources, due to both, to the arid climate and the overexploitation of the underground resources,is becoming a major problem, that threatens the lives of people in these regions. As a result, several techniques have been used, such as the transfer of water to a hundreds of kilometers or the demineralisation. However, these techniques are difficult and expensive,research into the production of drinking water, from other natural resources undrinkable, salty or with poor quality have become of great importance by our country. Over the years, the problem of the availability and supply of energy and water become more acute. Industrial development, population explosion, exorbitant costs and pollution are all factors advocating for the use of renewable energies and in particularly solar energy[1].Solar energy is the most promising application of renewable energy for desalination of brackish water, it is more appropriate for arid and semi-arid regions that offer free energy.

The Algerian territory is a particularly sunny area, especially its Sahara desert, which is considered as the region most exposed to the sun in the world [2]. This territory may benefit from between 2500 and 4000 h of sunshine per year. The City of Adrar enjoys a substantial amount of solar radiation with long sunshine hours, high ambient temperature and high solar radiation intensity (7 kwh/m/day)[3].

Solar energy is abundant, renewable, pollution-free and available on-site. Solar stills are the simplest solar distillation units. They are cheap and need low maintenance but most of them suffer from low productivity and poor efficiency [4].Different designs of solar stills have been developed in many countries to distil water, the best known are those of type greenhouse they are very simple, easy, rustic design, and inexpensive. But the major inconvenience is the low production of drinking water of them (about 2.5 to 3 liters per m² per day) [5].Various researchers around the world have attempted to enhance the productivity of passive solar stills, this improvement can be achieved by a proper modifications in the still design and its operating parameters [4,6]. A solution to this problem, external

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cooling of the glass cover was used to increase the still productivity. Flowing thin film water on the external glass cover has been proposed by several authors[7].For improved the yield of fresh water of solar still, Kumar et al. investigated a novel system by integra[8]. Moreover, Elango et al. [9] presented a new approach to enhance the productivity of the solar still by introducing glass as the basin material. Murugavel et al. [9,10]reviewed different passive methods to enhance the effectiveness of the basin solar still. They reported that the direction and inclination of the transparent cover, cover material, thickness, and temperature are responsible for the performance of the still. Water depth and materials used in the basin also affect the performance of the still.

In the region of Timiaouine where an arid climate prevails, groundwater is a vital resource and sometimes the only source of fresh water available. This region is purely pastoral, characterized by camelin herds and livestock. It constitutes an area of transhumance between the Sahelo-Sudanese zones and the Algerian Sahel. The demand for water in this region is therefore increasingly important and the possibilities for economic development in this region are linked to the development of its water resources [11]. In this area, groundwater pollution by nitrate increases the risk of deterioration in the quality of water resources and creates a health risk for the rural population, which is most often sourced directly from the aquifer[12].

This study presents the assessment of the quality of input and output water, also, the performance of solar still fabricated and tested under the climatic conditions of Adrar,in August 2017, with the main objective is to improve the productivity of solar still by the use of heat storage materials as an absorber.The experiments were conducted to investigate the effect of sand and polyethylene on production of solar still as well as the effect of different environmental and operational parameters on the productivity. Environmental parameters include solar intensity, ambient temperature and the different materials used as an absorber for heat storage and consequently increase the absorption capacity of the basin.

2. materials and methods

2.1.Location and characterization of study area

The study area (Timiaouine township) (Figure 1) is located in the southwestern of Algeria, between longitudes 1° 20′ and 2° 30’ East and latitudes 20° and 22′ North, Near the border with Mali. It stretches over 950 km south-east of Adrar, and 150 km south-east of BordjBadji Mokhtar, 465 km south-west of Tamanrasset and 1820 km south of Algiers. Lies at an elevation of 582 meters (1,909 ft) in the northern part of the Adrar des Ifoghas, a large massif in the Sahara Desert that extends further south to Kidal in Mali. The area is notable for large granite boulders that are found immediately to the west, and further to the north, of the town [11]. It has an area of about 12 553 km². A total population of about 31 451 inhabitants with a growth rate of (0.7). The geomorphology of Timiaouine region is dominated by the outcrops of the granitic rock mass which forms a relief with a great variety of form due to erosion, this variety determines its morphology overall and guides the water system [11].

The climate of study area is a hot desert type (climate classification KöppenBWh), It is extremely hot in summer and moderate in winter, characterized by very low summer precipitation (average of 47.7 mm/year). A large amount of precipitation is collected between the months of July and August, in contrast, the precipitation remains very low or nothing for other months of the year, it also characterized by an annual average temperature of 27.7 ° C.

The geology of this area forms part of the Hoggar geology, it constitutes the western limit of the crystalline massif of Hoggar. The both banks of the TimiaouineWadi are formed by the outcrops of the Precambrian and they are very developed and formed by granite. The sedimentary belt of the intercalary continental maked essentially by sandstone clay levels and lies in an unconformity on the Precambrian basement. Alluvial filling made up of alluvium from the wadi and forming the aquifer of Timiaouine[12].

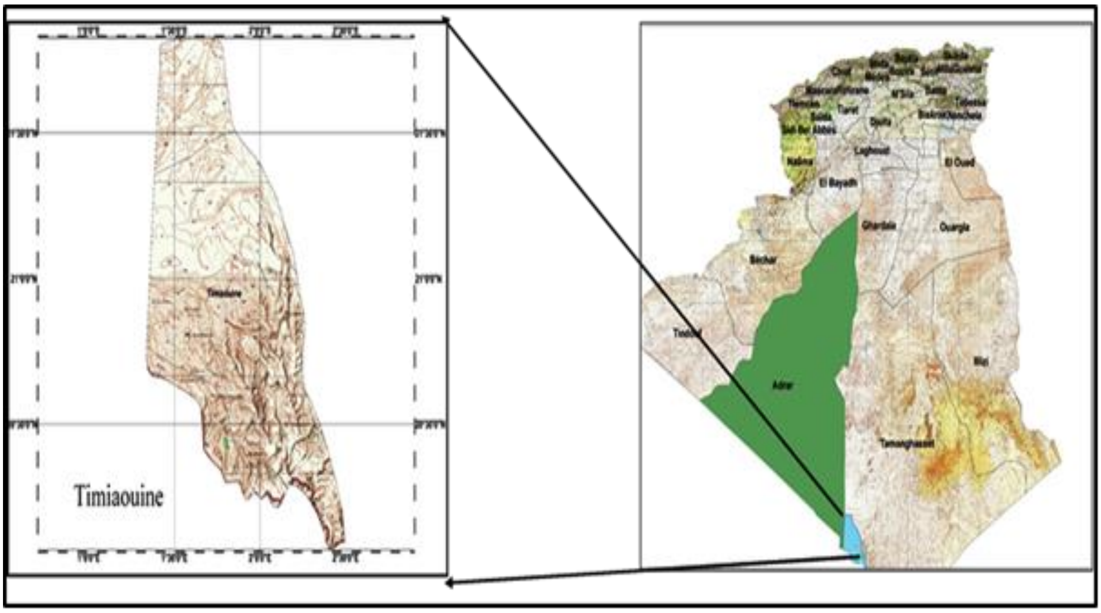

Figure 1 . Geographical location of study area

2.2.Solar still description

The solar still under study is fabricated with cheap 4 mm thick glass. The desalination system consists of a basin painted black inside, with different absorbers, i.e. black polyethylene film and sand to ensure maximum absorption of solar irradiance. The basin area is 0.50 m × 0.50 m (0.25 m²). It is enclosed by a 4 mm thick glass top cover. The side and bottom walls of the basin are covered by an insulation material, such as a 4 cm polystyrene layer, in order to prevent convective heat losses. The assembly reposes in a 16 mm thick wooden box. The entire solar still is kept along the north-south direction in order to take in maximum solar radiation, at 10 ° inclination relative to the horizontal. As shown in the figure below (Figure 2).

Figure 2. Photograph view of the glass solar still under study

The distiller was fed in brackish water by means of a galvanized steel tank of 10 L capacity. The distillate water was collected in the distillate collector at the end of the roof. Silicone was employed to ensure good sealing between the different constituents of the distiller. Figure 3 shows a schematic drawing of the solar still under consideration.

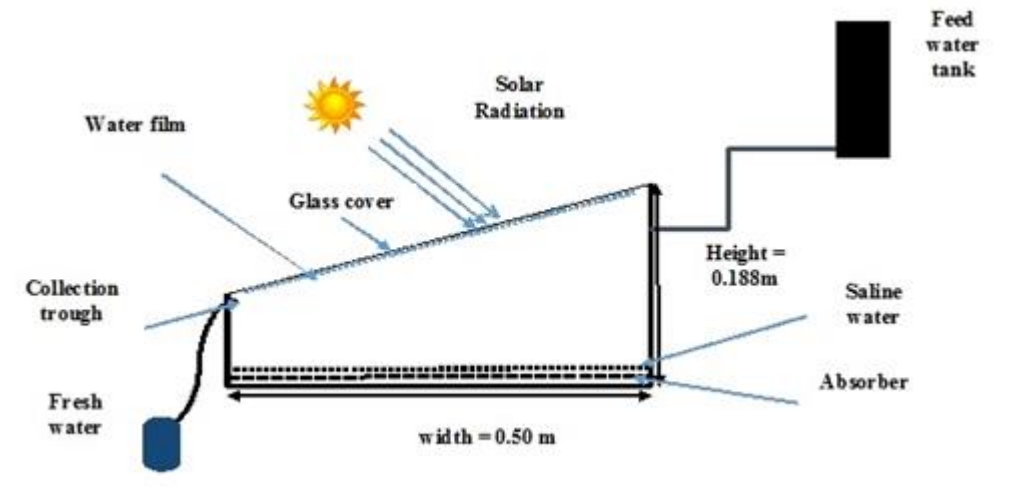

Figure 3. Shema de principe du distillateur solaire

2.3.Experimental setup and procedure

The experiments were conducted between 7:00 a.m. and 7:00 p.m., with a time interval of 30 to 60 minutes (measurement intervals), during the month of June of the year 2017, in Adrar, a city located in southwestern Algeria; its geographical coordinates are 27° 53 North and 0° 16′ West. The temperatures of the main components of the still, namely water and glass cover, were measured by calibrated K-type thermocouples. The K&Z CMP21-type pyranometer was used to measure the global horizontal solar radiation in W/m². The ambient temperature (Ta in °C) was measured with a Campbell CS215 temperature probe. These data were collected from the enerMENA Meteorological Network Station at the Renewable Energy Research Unit in the Saharan Environment (URERMS) in Adrar. A calibrated beaker with graduations ranging from 0 to 1000 mL, with ±10 ml accuracy, was employed for measuring the quantity of fresh water. The water depth in the solar distiller was fixed at 1.5 cm; the conductivity and pH values were measured in situ using a WTW 31.5i conductivity meter and a WTW 31.5i pH meter. The other physicochemical parameters, such as the total dissolved solids (TDS), total hardness (TH), and nitrate (NO_3^-) contents were evaluated at the Laboratory of the National Agency for Hydraulic Resources (ANRH), located in the City of Adrar, according to the standard methods described in the water analysis[13]. The physical and chemical analysis results of groundwater, before and after distillation, are summarized in Table 1.

Tableau 1. Chemical characteristics of saline and distilled water samples

Parameters	Saline water input			Distilled water output		Yield of treatment (%)	WHO drinking-water quality guidelines
	Max	Min	Moy	Max	Min		
pH	8.30	6.10	7.48	7.52	6.8	-	6.5-8.5
EC ms/cm	5.120	0.240	2.210	0.024	0.0074	99.674	2.8
TDS mg/l	170	3230	1334	24	16	99.306	1000
TH mg/l as $CaCO_3$	100	890	450	10	4	98.945	500
NO_3^- mg/l	95	280	193.6	0.8	0.3	99.480	40

3. Results and discussions

The characteristics of the measured solar irradiance versus time are shown in Figure 4. This figure clearly suggests that the solar intensity increases during the morning and reaches a maximum value of 1131.013 W/m² at 01.00 p.m. during the month of June. It also shows that solar irradiation is more intense from 11 a.m. to 3 p.m., whereas it is less intense after 5 p.m. This means that this region has a good solar insolation. The disturbance on the day of June 10 is due to the passage of the cloud.

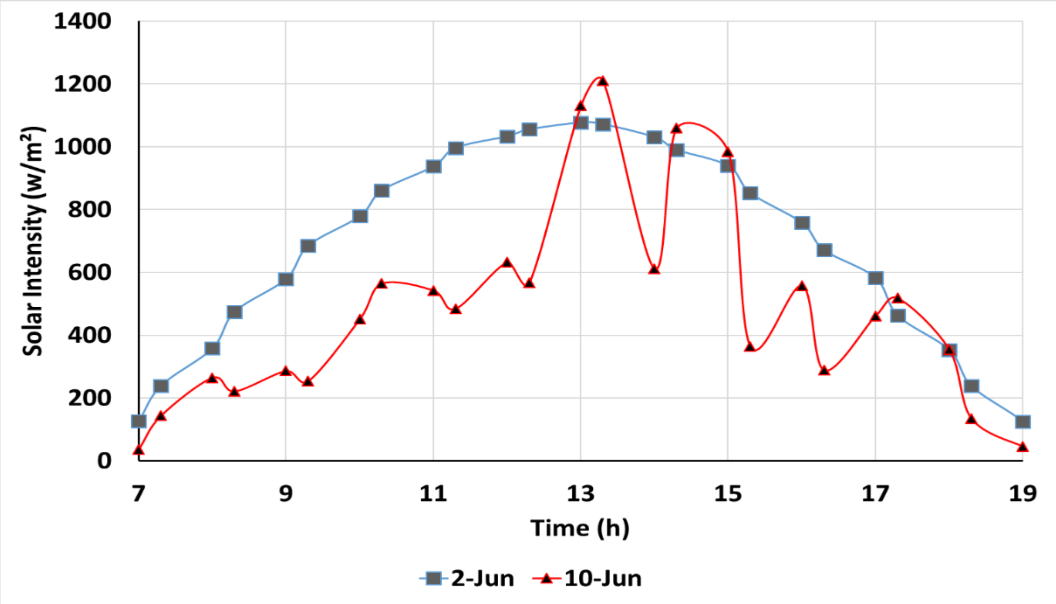

Figure 4. Variation of global solar radiation during the test days

Figure 5 illustrates the variation of the ambient temperature over time. It is clearly seen that the temperatures increase during the morning hours to reach a maximum value of 40.70 °C at 01.30 p.m. The variation of the temperature depends on the variation of the solar irradiation. After 2.00 p.m., the ambient temperature gradually decreases along with the solar energy intensity. It can easily be noticed that the temperature remains high even after 07.00 p.m., which favors condensation even after 20.00 p.m.

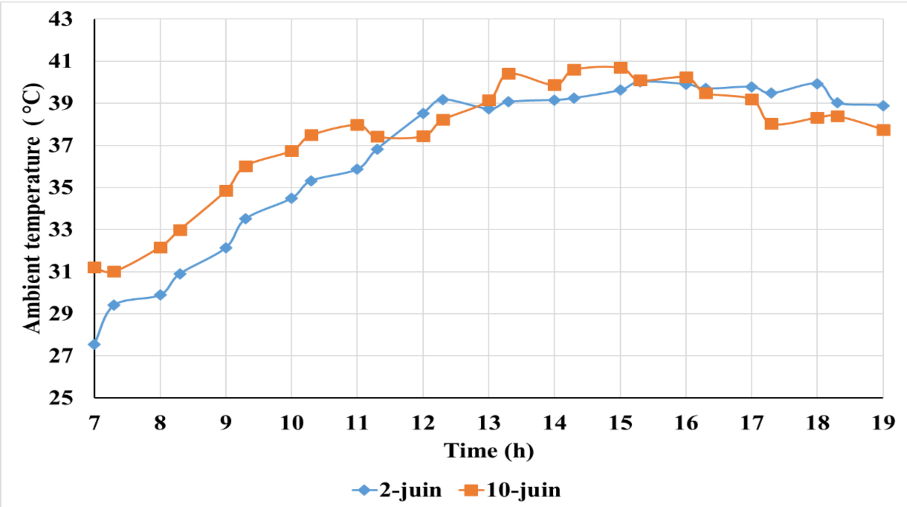

Figure 5Variation of ambient temperature during the test days

Figure 6 depicts the hourly variation of drinking water production when the two absorbers, namely sand and polyethylene, are incorporated into the still. The daily solar still productivity was found equal to 3.84, and 4.48 l/m²/day for sand, and polyethylene, respectively. We also noticed that the water productivity increases from zero in the morning and reaches their maximum values in the evening. This is due to the low temperature of saline water in the morning and water requires a time to warm up. It can also be noted that the productivity of water increases with increasing temperature of saline water. In addition, we can also notice that the productivity of fresh water for the distiller with polyethylene (4.48 l / m²day) is higher than that with sand as absorbent material (3.84 l / m²day). It can be said that polyethylene absorbs better than sand.

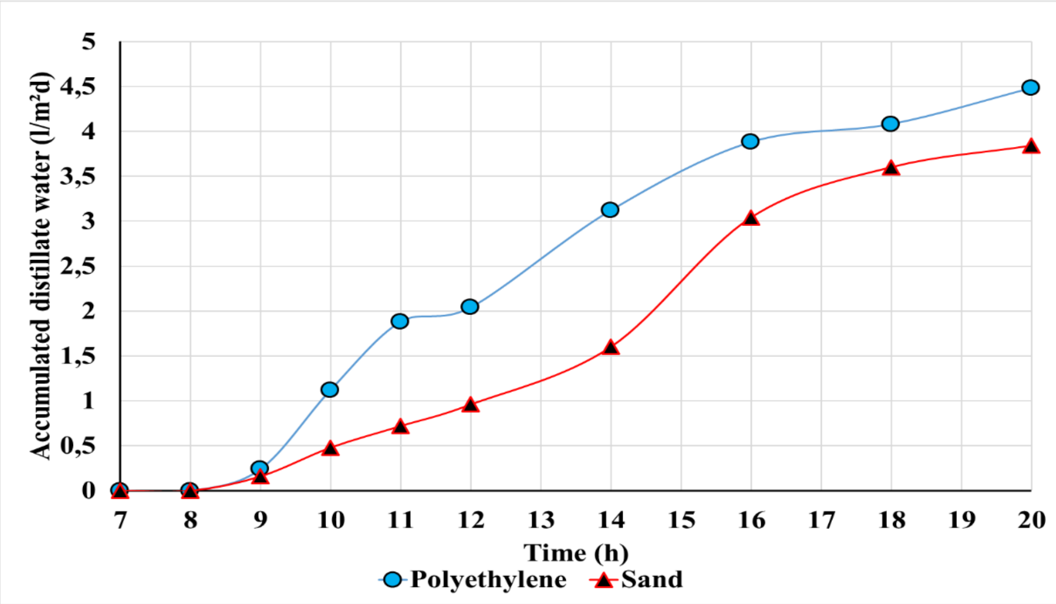

Figure 6. Variation of fresh water productivity for the solar still integrated with different absorbers

The impact on the fresh water production of solar irradiance, is demonstrated by the Figure 7. This figure shows that there is a close relationship between the productivity and solar irradiation with a coefficient of correlation of (R= 0.93), and the two curves have the same pattern. We also observed that the maximum hourly productivity (0.76 l / m²h) corresponds to the maximum irradiation (1131.013 w / m²) at 1 pm.

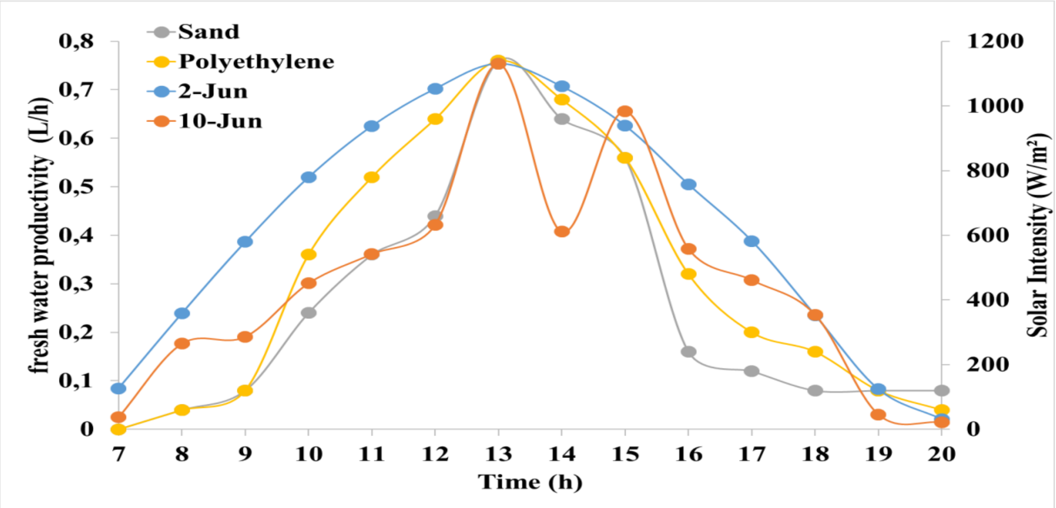

Figure 7. Variation of fresh water productivity and solar intensity

Figure 8 depicts the experimental results of the hourly variation of basin water temperature for different absorbers used in the basin of the solar still. It turned out that polyethylene could attain the highest basin water temperature value (79.9 °C) at 2.00 p.m.; it is followed by sand for which the basin water temperature was found equal to 69.3 °C at 2.00 p.m. This is due to the black color of polyethylene as compared to that of sand.

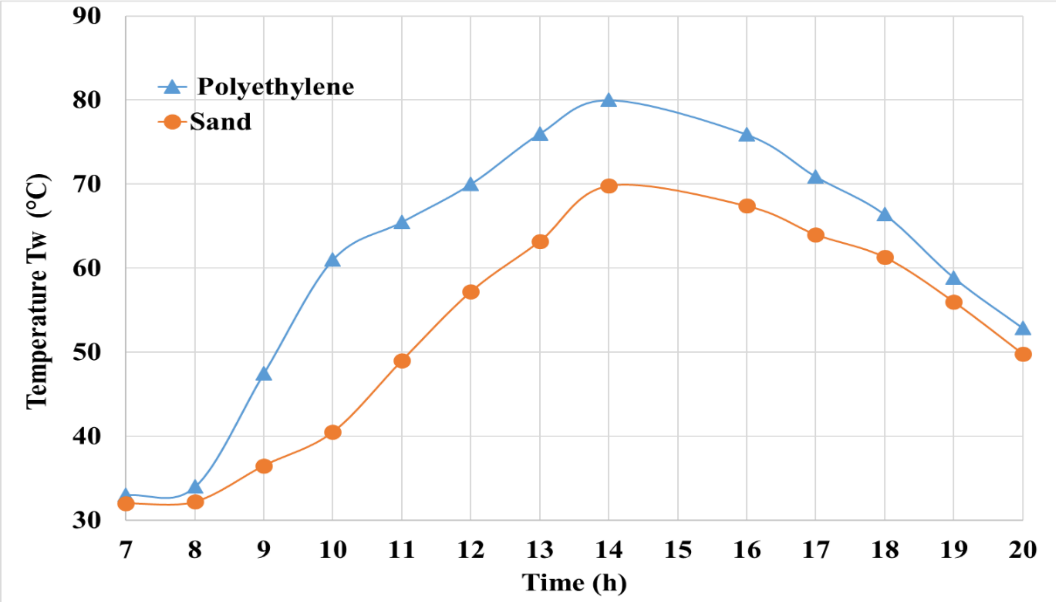

Figure 8. Variation of basin water temperature for various absorbers

Figure 9 shows the evolution of glass temperature with different absorbers used in the solar still basin. It can easily be observed that the cover glass temperature, when using polyethylene, is higher than that recorded with sand. This can certainly be attributed to the radiation reflected towards the glass cover by polyethylene. It is clear from this figure that the difference (Tw-Tg) between the temperature of water and that of glass is important with polyethylene than with sand, which engenders a higher freshwater productivity.

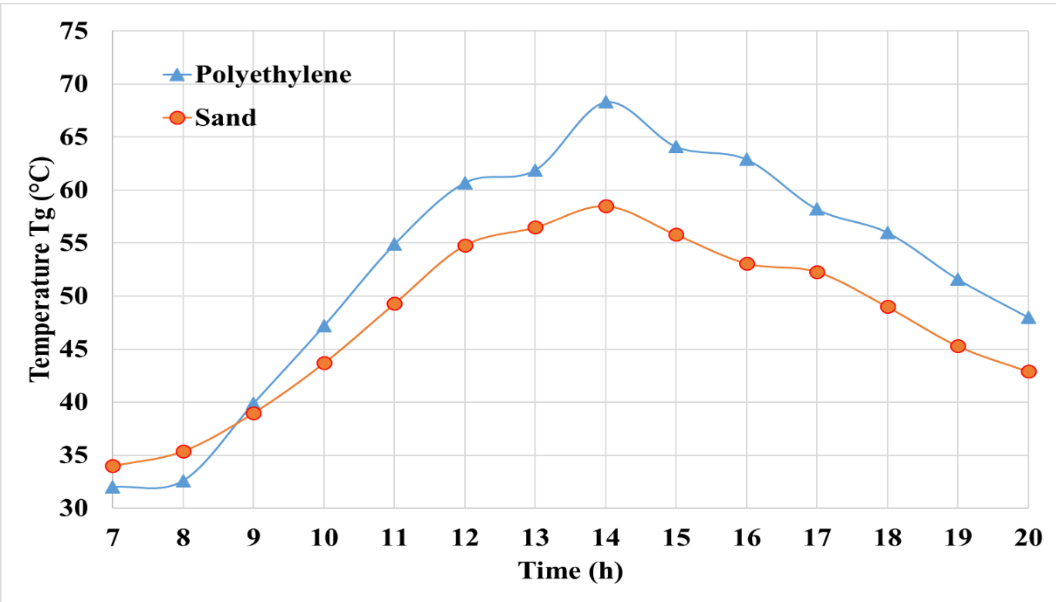

Figure 9. Variation of glass temperature with time

Figure 10 shows the different physicochemical parameters analyzed. As a result of these analysis that the pH of water varied between 6.1 and 8.3, with a mean value of 7.47, most of which can be defined as alkalescent water, the electrical conductivity ranged from 0.24 to 5.12 ms/cm, with mean value of 2.210 ms/cm, TDS in the study area ranges from 170 to 3245 mg/l with an average value of 1334 mg/l, also, the total hardness varies between 100 and 890 mg / l of $CaCO_3$ with an average value of 450 mg / l of $CaCO_3$.Nitrate ranges from 95 to 280 mg / l with an average value of 193.6 mg / l.

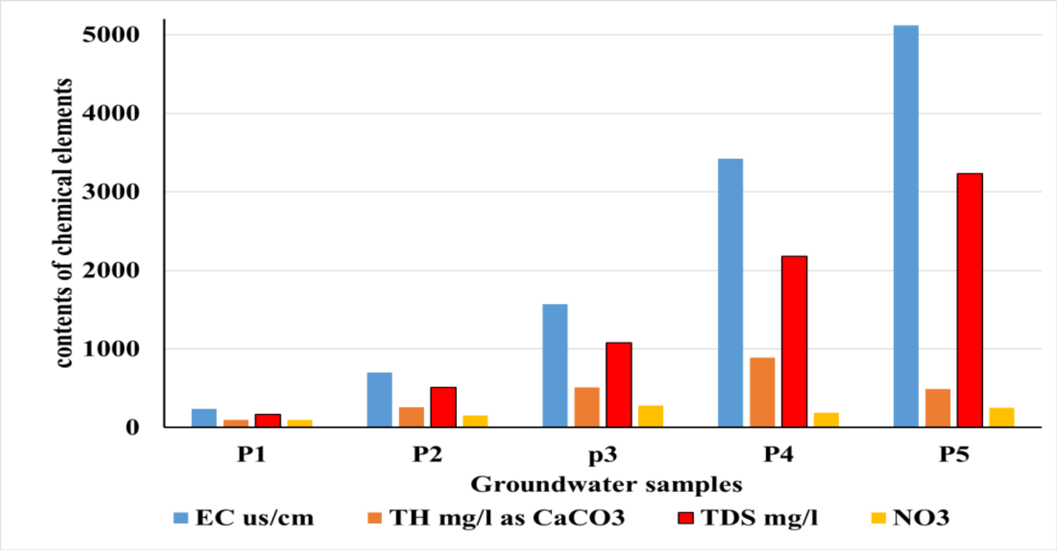

Figure 10. Physicochemical parameters of water input in mg/l and us/cm

Figure 11 shows the physicochemical parameters of distilled water output. From this results, it can be seen that the electrical conductivity is between 7.4 and 24.4 us/cm, the TDS ranges from 16 to 24 mg/l, total hardness ranges from 4 to 10 mg/l as $CaCO_3$, and nitrate ranges from 0.3 to 0.8 mg/l. These findings suggest that the distilled water is safe to drink and complies with the World Health Organization (WHO) standards and guidelines [14].

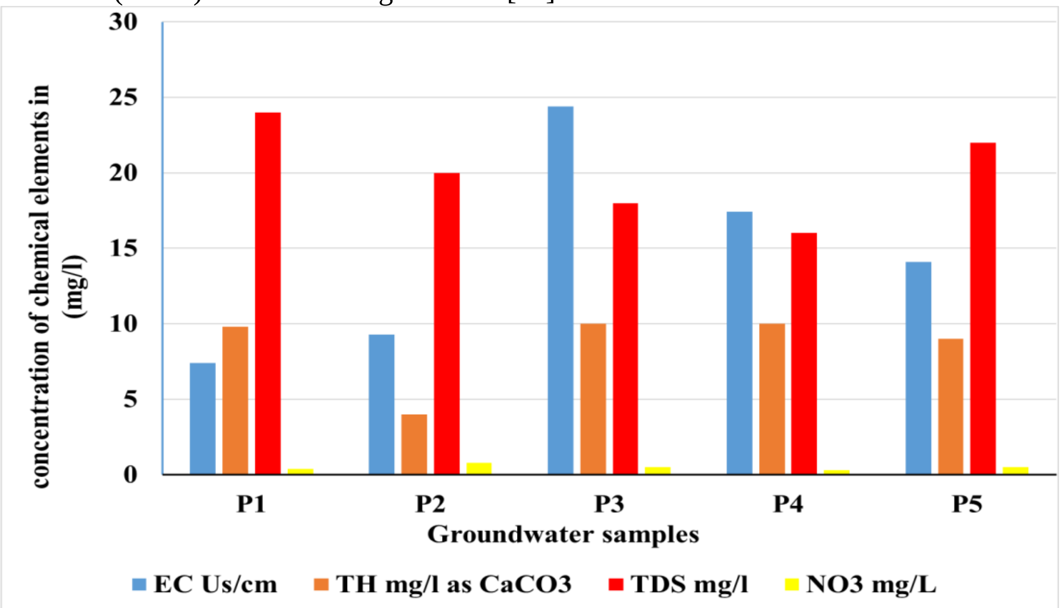

Figure 11. Physicochemical parameters of distilled water output in mg/l and us/cm

4. Conclusion

In this study a new solar still was fabricated with was fabricated with cheap glass and was tested under the climatic conditions of the City of Adrar, different absorbers (polyethylene, sand) were used to increase its productivity of still. The following conclusions were drawn from the results obtained.

Adrar City is an area characterized by a significant solar insolation with a maximum intensity (1210.273W / m²) recorded during the test days.

Solar still productivity varies between 3.84 and 4.48 l / m²day, respectively with sand and polyethylene. The best yield has been obtained with polyethylene. It is also observed that the water analysis of the distilled water is with good quality, and our still has a high distillation performance of the order of 99.91%. Especially for the nitrate.

5. References

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