Desalting Goundwater Using Two Vertical Solar Stills in the Desert of Algeria

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Abstract

In arid zones of Algeria lacking in pure water and endowed with an important solar potential, solar distillation represents a good solution for desalting water, man has depend on underground water reservoirs for fresh water requirements, but the use of water, from such sources is not always possible, on account of the presence of salt. Fresh water, which is becoming scarce because of population explosion. The Algerian territory is particularly sunny area especially in its Saharan part. The desert of Algeria is among the most exposed regions in the world, territory may benefit from between 2500 to 4000 hours of sunshine per year. Remote and arid regions depend on underground water for drinking. Unfortunately, underground water is not always considered to be fresh drinking water. The paper deal with the experimentation of two vertical solar stills tested under desert climatic conditions of Algeria desert for desalting brackish water of a well. Experimentations are carried out on the experimental test platform of the Renewable Energy Research Unity in Sahara environment at Adrar, Algeria.

Keywords: Solar Energy, Groundwater, Vertical Solar Still, Desert

Introduction

Arid and semi-arid zones constitute approximately 40% of the earth's land area and they are in general, characterised by high levels of solar radiation and shortages of fresh water. Such regions often possess reservoirs of either brackish or saline water that may be used for both drinking and irrigation after suitable treatment. The Algerian territory is particularly sunny area especially in its Saharan part. The desert of Algeria is among the most exposed regions in the world, territory may benefit from between 2500 to 4000 hours of sunshine per year [1]. Remote and arid regions depend on underground water for drinking. Unfortunately, underground water is not always considered to be fresh drinking water.

An extensive review of various types of solar stills was done by Malick et al. [2], this review was updated by Tiwari [3]. Authors are investigated performance of direct vertical solar still [4]; modifications were made on this direct solar still by providing a condenser in the back of the device, and vertical flat solar collector in the front, the flow thin layer of the water trickle on the back of the absorber plate of a solar collector [5,6]. Design of vertical still was based on the method of inverted water trickle; this method was developed for use in flat plate collectors [7] and solar distillation [8] by Badran et al. The aim of this work has been to use two vertical solar stills for desalting ground water of a well located in remote area, under desert climatic conditions of Algeria. The solar stills should be simple, hardy and easy to maintain and repair by every skilled village artisan with limited technical means. An experimental investigation was carried out on two vertical solar stills: one is an indirect vertical still and the other is direct and indirect vertical solar still.

Methodology

The experimental work was carried out on different days of winter and summer of the year 2006 and December 2005, at the experimental field of the Renewable Energy Research Unity in Sahara Environment at Adrar, Algeria. Adrar (latitude 27° 53’ N, longitude 0° 17’ W and 364 m elevation from sea level). The measured parameters during the course of the experiments are: solar radiation on vertical and horizontal plane, ambient temperature around vertical solar still, and different water temperatures at different points of evaporation and condensation, glass cover temperature, the hourly distillate water produced by each still. Thermocouples of K type have been used to measure temperatures. Distilled water has been measured by a graduated tube test. Solar radiations on vertical and horizontal plane were measured with a pyranometer kipp and Zonen, CM11.

Figure 1 indirect solar still

Figure 2 direct and indirect vertical solar still

Thermocouples and pyranometer were connected to a Fluke data logger. All measured parameters were recorded every one minute and continuously over 24 hours. The measured parameters mentioned above have been evaluated and plotted on hourly basis.

Experiments on two vertical solar stills were done to know the feasibility of this kind of solar still to operate in arid zones. The two solar stills under experimental investigation are shown respectively in figure 1, for the indirect solar still and in figure 2, for direct and indirect solar still.

Results and Discussions

For the indirect vertical solar still, Temperatures T2 and T3 respectively were temperatures of brackish water at the inlet and outlet of solar collector, T4 temperature of the evaporator, T5 temperature of galvanised sheet forward the evaporator, T6 temperature of the galvanised sheet forward the condensing plate, temperature T7 of the condensing plate and T1 ambient temperature. Figures 3 and 4 show the variation of hourly ambient temperature and solar irradiance for 26, 31 December 2005 and 1 January 2006, the higher values of the ambient temperature vary from 9.05 to 21.76°C, and were registered on 26 December and Lowest values were registered on 31 December; these values vary from 6.19 to 19.24°C.

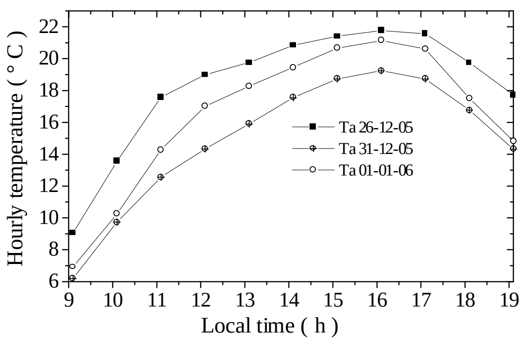


Fig. 3 Hourly ambient temperature

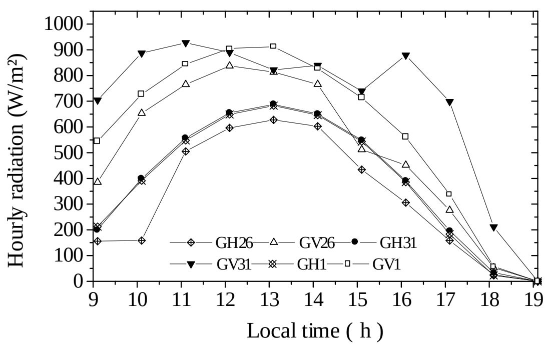


Fig. 4 Hourly solar radiation intensity

Figure 4 shows the variation of horizontal solar radiation GH, and vertical solar radiation GV, for 26 and 31 December respectively, and 1 January. Maximums values registered for vertical planes are those of 31 December before 12:00, and from 15:00 to sunset, solar still was oriented toward the sun, solar radiation was not less than 600 W/m², before 12:00 lowest values of vertical solar radiation intensity are registered on 26 December.

Figure 5 and 6 show respectively, the variation of hourly temperature difference T3-T2 for solar collector. We distinguish two intervals: before 15:00, the highest values were registered for 1 January and after 15:00 the highest values are registered for 31 December, on 31 December the solar still continually oriented.

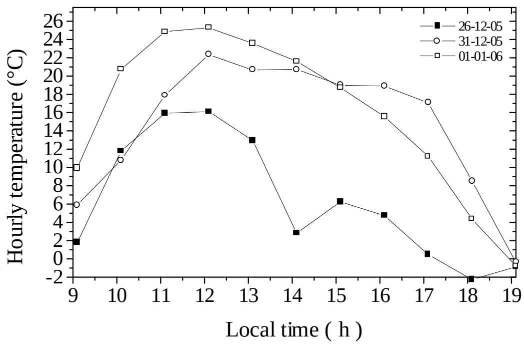


Fig. 5 Hourly T3 -T4 vs.time

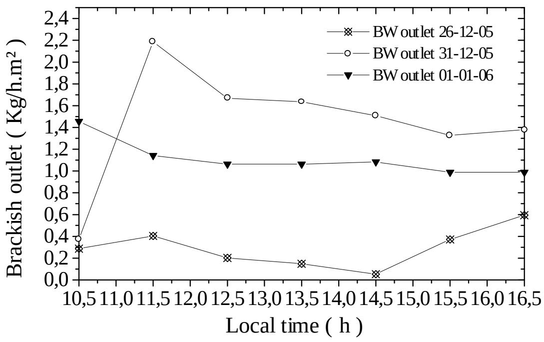


Fig. 6 Brackish water outlet flow rate

Hourly experimental data for an intermittent orientation on 31 December are given in tab.1 and hourly experimental data for south orientation on 1 January are given in tab.2.

Tab.1 Hourly experimental data for intermittent orientation

TIME (H)	T1(°C)	T2(°C)	T3(°C)	T4(°C)	T7(°C)	GH (W/M²)	GV (W/M²)	MD* (KG/H.M²)	MS** (KG/H.M²)
8:30-9:30	6.2	8.64	14.54	28.81	9.63	201.03	704.12	0.0000000	0.403397
9:30-10:30	9.73	14.53	25.33	48.56	21.3	398.45	886.81	0.0920598	0.371549
10:30-11:30	12.56	16.54	34.46	56.46	26.18	556.37	927.27	0.1611047	2.186836
11:30-12:30	14.33	18.41	40.75	55.12	27.93	655.15	889.57	0.1611047	1.666667
12:30-13:30	15.9	20.65	41.31	54.27	29.87	687.26	821.38	0.1611047	1.634820
13:30-14:30	17.55	21.9	42.64	55.78	31.33	650.73	839.15	0.1495972	1.507431
14:30-15:30	18.73	23.39	42.39	55.03	31.87	548.81	739.64	0.1495972	1.326964
15:30-16:30	19.24	23.95	42.85	57.91	32.23	391.28	879.01	0.1611047	1.380042
16:30-17:30	18.72	23.18	40.25	55.36	30.44	197.16	698.75	0.1611047	1.273885
17:30-18:30	16.77	20.45	28.98	37.36	22.47	33.45	211.52	0.0805523	1.305732
18:30-19:30	14.31	17.26	16.88	18.63	14.23	0	0	0.0460299	0.000000

* distilled water flow rate ** outlet brackish water flow rate

The highest value of brackish water flow rate was registered for 31 December, except for the beginning, brackish water outlet flow is equal of that 26 December and the steadly values are those of 1 January, and are almost constant from 11:30 to 16:00, the lowest value of brackish water outlet flow are of 31 December.

Tab.2 Hourly experimental data for south orientation

TIME (H)	T1(°C)	T2(°C)	T3(°C)	T4(°C)	T7(°C)	GH (W/M²)	GV (W/M²)	MD* (KG/H.M²)	MS** (KG/H.M²)
08:30-09:30	6.92	9	18.96	24.74	9.14	212.78	544.1	0.0000000	1.486199
09:30-10:30	10.25	11.75	32.49	40.83	19.78	391.09	726.68	0.0867410	1.454352
10:30-11:30	14.29	15.52	40.38	50.60	28.64	547.75	843.54	0.1486989	1.141189
11:30-12:30	17.01	18.83	44.11	54.86	32.74	648.65	904.88	0.1858736	1.061571
12:30-13:30	18.27	21.66	45.25	56.01	34.09	682.63	911.34	0.1858736	1.061571
13:30-14:30	19.46	24.01	45.62	55.93	35.42	646.01	827.13	0.1858736	1.082803
14:30-15:30	20.66	25.68	44.4	54.48	35.56	543.78	713.99	0.1610904	0.987261
15:30-16:30	21.13	26.78	42.35	51.12	34.2	385.64	561.48	0.1363073	0.987261
16:30-17:30	20.61	25.85	37.08	44.45	29.84	183.46	337.65	0.1115242	0.987261
17:30-18:30	17.52	20.74	25.09	28.59	20.17	22.39	57.79	0.0619578	0.987261
18:30-19:30	14.82	17.38	16.61	17.44	14.3	0	0	0	0.000000

* distilled water flow rate ** outlet brackish water flow rate

Fig.7 shows the hourly temperture difference T4-T7 versus local time. Still yield depend on this temperture, highest value 34.33°C was registred on 26 December, that expalin the highest efficiency obtained in this day.

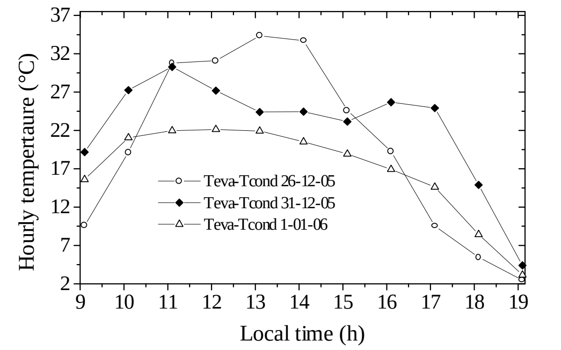


Fig. 7 Hourly difference temperature vs.time

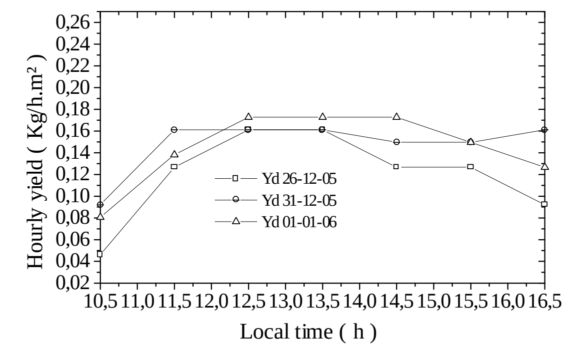


Fig. 8 Hourly yield vs.time

The indirect vertical solar still productivity after a certain period is the accumulated distilled water collected during this period. Figure 8 shows hourly yield versus time.The hourly yield of a solar still, is the summation of the productivities over period of experimentation from 10:30 to 16:30. The daily yield is the summation of the productivities over period of 24 hours is expressed as follows:

$$M_d = \sum_{j=1}^{24} m_{dj} \quad (1)$$

M_d daily yield in Kg/m^2.day $m_{dj=h}$

The hourly efficiency η is the energy used for evaporation to that received by the vertical solar still, it expressed as follow:

$$\eta = \frac{M_h (H_{fg})}{I_h . A} \quad (2)$$

M_h hourly yield in (Kg/h.m²), H_{fg} latent heat of evaporation (KJ/Kg), I_h solar radiation intensity received on the vertical surface of solar collector (W/m²) and A solar collector area in m².

According to Holman [9], H_{fg} can be expressed in the term of T4, T4 is measured in °C. Figure 9 shows the hourly efficiency of indirect solar still versus time.

$$H_{fg} = 2501 - 2.16 T_4 \quad (3)$$

The hourly efficiency of indirect vertical solar still for this three winter day are almost the same from 11:30 to 13:30. For the day of 26 December, is registred the higher value of hourly still efficiency occurred at 57.8% at 15:30. For this three days the hourly efficiency vary from 16.87 to 57.85%.

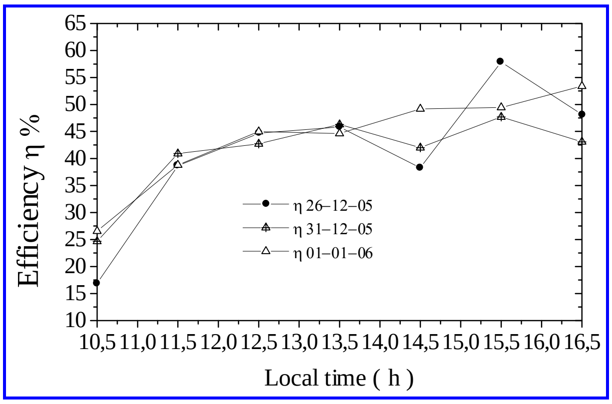
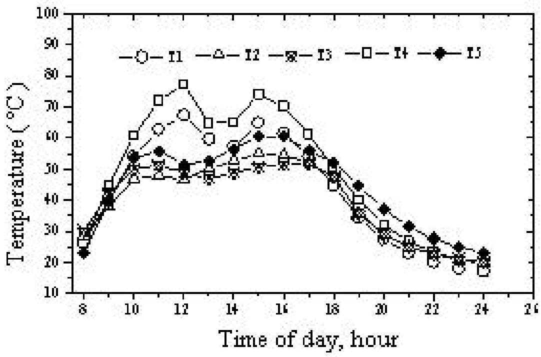


Fig. 9 Hourly efficiency vs.time

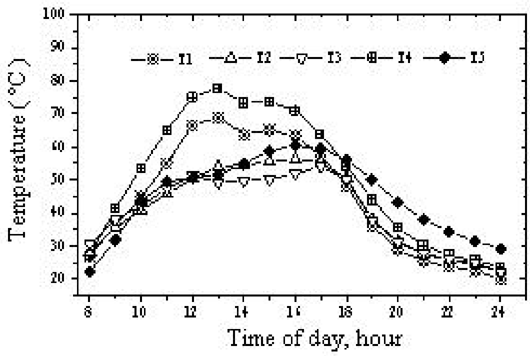
Tests are carried out on the direct and indirect vertical solar still, from April to July. The solar still under test was shown in figure 10. The front side of solar still oreinted due south was a solar collector. T1, T2, T3 cover glasses temperature respectively, inclined, west and east. T4 et T5 are respectively water temperature

Figure 10 Direct and indirect vertical solar still under test

Figure 11, shows the variation of cover glasses temperature and water of upper and lower basin respectively (a) and (b) for 3 and 4 April. Values of cover glass at solar noon for west side and east side for these days are respectively 50.43°C and 51.24°C and 46.45°C 48.85°C, there are no high difference because solar was oriented toward due south and the sun is in zenith.



(a)



(b)

Figure 11 variations of temperatures versus time

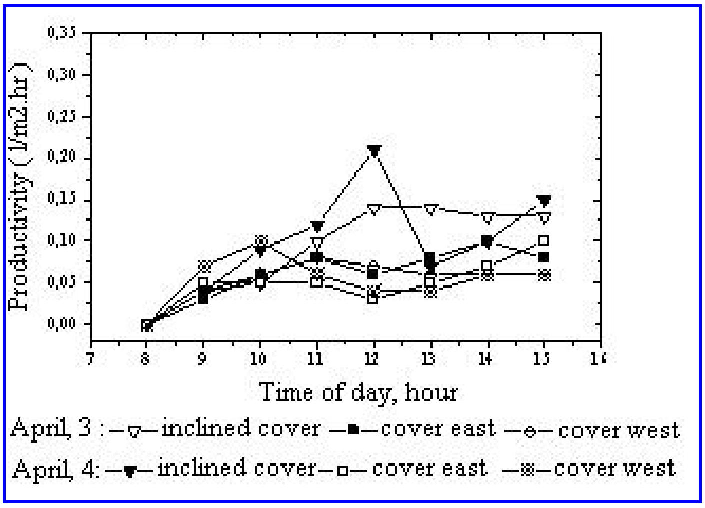


Figure 12 measured productivity of the vertical solar still

Figure 12, shows the measured productivity of solar still, the production rates of distillate water were function of solar radiation and orientation. Distilled water produced on inclined glass cover respectively, 3 and 4 April were 1.06 and 1.09 l/m².day, distilled water produced by east and west glass cover for same days are respectively 1.48 and 1.19 l/m².day. The total daily yield of distilled water produced by new vertical still for these days was respectively 2.54 and 2.26 l/m².

Conclusions

Two solar stills were fully fabricated and tested at the experimental field of the Renewable Energy Research Unity in Sahara Environment at Adrar, Algeria. For the tests investigated on indirect vertical solar still, temperatures levels achieved under arid climatic conditions in winter are acceptable. The best value of brackish water outlet flow rate is 1.0615 Kg/hm²; we find a difficult to maintain constant flow. The maximum value of evaporation temperature obtained is 73.26°C for an ambient temperature ranging from 9.05 to 21.76°C.

Based on the experimental results, the following observations were found:

- Maintenance of two vertical solar stills is not significant
- For getting more distilled water production a number of units can be used
- The water quality produced by solar stills is high because the evaporation method is used, it can be used for drinking, industry and laboratories
- Energy of solar stills is supplied from solar energy, for that they can be used in isolated area of Algerian Sahara zones
- For the direct and indirect vertical solar still, the productivity of the lower basin is higher than of the of the upper basin

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