Water Desalination by Solar Distillation in the Southwest of Algeria

N. Laskri, N. Nedjah, D. Daas, and M. Baccouche

***Abstract*—The desalination of brackish water by solar distillation is a widely used operation in arid region, at the scale of a small village or even a family. The combinations of desalination and solar technologies become very economic process especially in arid zones in the southwest of Algeria. It is principally an economic question.**

The objectives of our study are testing the feasibility of solar distillation in desalinating water. The lack of drinking water and the scarcity of its natural resources caused both by the drought and the over exploitation of groundwater is becoming a major problem that threatens the lives of the inhabitants in several sub-Saharan regions.

The drinking water in the south of Algeria is very concentrate on salts. The distilled water after solar distillation gives good removal yield of the global mineralization (99% of total dissolved ions).

***Index Terms*—Solar energy, desalination, brackish water, demineralization.**

I. Introduction

The desalination is a promising new technology that has great potential to reduce the need for conventional power, to use solely renewable energy sources, and to reduce the overall cost of water treatment.

Desalination has been considered to meet growing water demand for Southwest communities close to saline waters, but because such plants are energy and capital intensive, use has been limited by unfavorable financials.

To become economically competitive, or at least less expensive, it is necessary to reduce energy used in desalination [1].

In the extreme south of Algeria, water is needed principally for municipal and agricultural applications.

In the arid zones, desalination is mainly required to control the nape salinity and provide potable water to selected communities that have critical water quality problems. Currently freshwater resources became inadequate or non-sufficient due to the demographic and industrial growth. The shortage of freshwater resources is a major problem in arid regions of the world. More than 97% of the water on the surface of the Earth is salt water and the desalination of this water presents an alternative solution to provide water for drinking and irrigation purposes.

Solar distillation is one of the techniques used to produce freshwater from brackish water and seawater through solar energy [2].

Adrar is an Algerian Saharian city known for its hot and dry climate, where a massive amount of energy is used.

Fig. 1. Geographies' of Adrar (Algeria).

In this city located in the extreme south of Algeria which is an extermely arid zone, water is needed principally for municipal and agricultural applications.

Well the problem is that, in Adrar, there are some regions that face critical issues of water quality, the reason why, desalination is highly required in order to control the nape salinity and provide these regions with potable water.

It is a matter of carrying out artificially and on a small scale what nature does daily and on a large scale and which consists in the absorption of solar radiation by oceans, lakes and rivers, causing evaporation some water.

The vapour produced is transported to cooler regions through the wind. When the steam is cooled, condensation begins to cause precipitation of rain and eventually snow.

Man has reproduced, in a miniaturized model, this natural cycle (Fig. 2).

Several types of solar distillers have been produced, the most widespread ones being those of the greenhouse type; they have the advantage of being simple, easy to make, of rustic design, and inexpensive.

But they have the major disadvantage of a very low production of drinking water (on the order of 2.5 to 3 liters per m ^{2}per day).

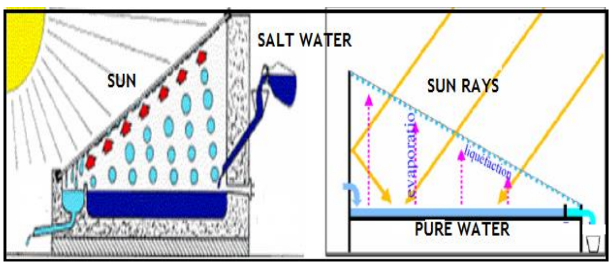

Fig. 2. Principals of solar distillation.

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The authors are with Laboratory of Physical Metallurgy and Property of Materials, University of Badji Mokhtar Annaba, Algeria (corresponding author's phone: 0021367209719; e-mail: n.laskri@epst-annaba.dz, n.nedjah@epst-annaba.dz, d.daas@epst-annaba.dz).

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Solar distillation is a technique that uses solar radiation to heat brackish water in a tank covered by an inclined glass [3].

The salt water in the tank will heat up (the faster the tank is black) and with the increase in temperature some of the water will evaporate and the water vapor will liquefy on the inner surface of the transparent glass.

Eventually, drops of water will form, pour on the surface of the window and fall into the tank at the corner.

II. Materials and Methods

A. Water

The water is collected from several wells of the city of Adrar (southwest of Algeria). The samples were collected in polyethylene bottles and kept in a damp place and in the dark; they were the object of direct measurement of physicochemical parameters and pollution parameters.

The measurement of pH is done directly by reading on a pH-meter to combined electrode. It is a handy pH-meter type HANNA HI 8314.

Measurement of the oxygen consumed in five days by a sample diluted with saturated water into oxygen, sown with the seeds, and then placed in a thermostatic chamber at 20 ℃. The phosphorus measurement is done using the method of ammonium molybdate at 380 nm.

The ions sulphates were determined with nephelometric method by spectrophotometry UV at 420 nm. The measure of the mineralization elements is done like AFNOR French standards collection. The table 1 showed the concentration of the water of the city.

The water is very rich on calcium, magnesium, carbonates and sulphates.

The concentration of minerals in water exceeds Algerian standards norms, especially the case of sulphates and carbonates, not to mention the concentration of calcium, magnesium and potassium.

The results obtained in the table below shows that the water before solar distillation is very rich on calcium, magnesium, carbonates and sulphates.

The concentration of minerals in water exceeds Algerian standards norms, especially the case of sulphates, carbonates, calcium, magnesium and potassium.

The drinking water in the south of Algeria is very concentrate on salts.

TABLE I: Mineralization of the Water before Distillation

global mineralization	results	Algerian' norms
Calcium Ca++ mg/l	382	75-200
Magnes. Mg++ mg/l	206	150
Sodium Na+ mg/l	300	200
Potass. k+ mg/l	34	200-500
Chlorure Cl^- mg/l	480	200-400
Sulfate SO_4^{--} mg/l	1500	400
Bicarbon. HCO_3^- mg/l	180	0,2
Carbonate CO_3^{--} mg/l	20	0,2
Ammonium NH_4^+ mg/l	0,000	0,05-0,5
Nitrite NO_2^- mg/l	0,001	0,1
Nitrate NO_3^- mg/l	95,00	50
O.phosphate PO_4^{3-} mg/l	0,005	0,5
Mat. Ox. mg/l O2	2,10	3,5
Fer mg/l	0,1	0,3

The lack of drinking water and the scarcity of its natural resources, caused both by the drought and the over exploitation of groundwater, is becoming a major problem that threatens the lives of the inhabitants in several sub-Saharan regions.

All this remarks is demonstrated in Table I.

B. Solar Distiller

The experimental system consists essentially of:

Two "hot box" solar distillers of the same nature (fiberglass)

And of the same dimensions (1200 * 960 * 20 mm), the inclination of the lid is 10 ° with respect to the horizontal so as to have the maximum amount of sunshine.

The insulation is provided by

- A layer of polystyrene with a thickness of 5 cm.
- A black Fiberglass container.
- Water blade with a thickness of 5-10 cm
- Tank for water [4]

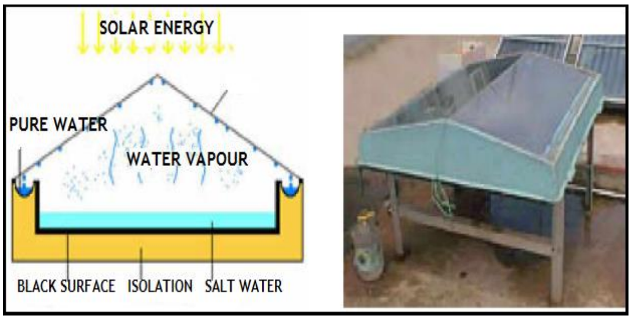

Fig. 3. Experimental device of solar distillation.

The salt water in the tank will heat up (for a faster heat up process tanks are painted in black) and with the increase in temperature some of the water will evaporate , then the vapor will liquefy on the inner surface of the transparent glass. Eventually, drops of water will form, on the surface of the window and fall into the tank at the corner.

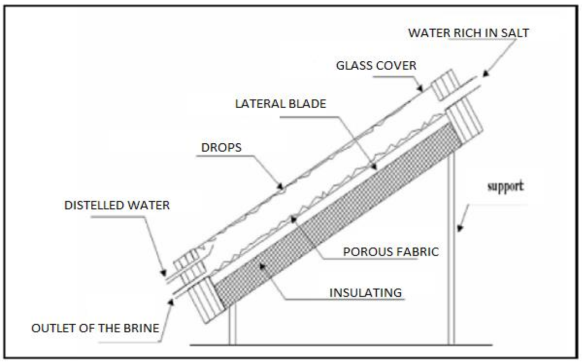

Fig. 4. Solar distillation if the sea water.

III. Results and Discussion

After solar distillation we obtained the results shows all in Table II.

TABLE II: Demineralization of the Water after Distillation

Parameters	BEFORE	AFTER	(%)
pH	7,39	5	32,34
Conductivity ms/cm	4,88	0,02	99,59
Residu sec à 110 °C mg/l	3100	60	98,07
Nitrite NO_2^- mg/l	0,001	0,0005	50
Nitrate NO_3^- mg/l	95	0	100
O.phosphate PO_4^{3-} mg/l	0,005	0	100
Mat. Ox. mg/l O_2	2,1	0	100
Calcium Ca++ mg/l	382	18	95,29
Magnes. Mg++ mg/l	206	6	97,09
Sodium Na + mg/l	300	2	99,33
Potass. k+ mg/l	34	0	100
Chlorure Cl^- mg/l	480	20	95,83
Sulfate SO_4^{--} mg/l	1500	38	97,47
Bicarbon. HCO_3^- mg/l	180	2	98,89
TH °F	178	7	96,07
TAC °F	15	0	100
Minéralisation mg/l	3026	14	99,54
Somme des ions mg/l	3177	84	97,36

From the results shown in Table II, there is a general decrease in water quality parameters. We observe a decrease of the bicarbonate ions of the distilled water because during the phenomena of distillation of the reactions are activated and which are:

The ionization of water:

$$2H_2O = H_3O^+ + OH^-$$

Balance carbon dioxide - carbonic acid:

$$CO_2 + H_2O = H_2CO_3$$

Dissociation of carbonic acid:

$$H_2CO_3 + H_2O = HCO_3^- + H_3O^+$$

Balance bicarbonate-carbonate:

$$HCO_3^- + H_2O = CO_3^{2-} + H_3O^+$$

We observe a decrease in calcium ion because they combine with the carbonic forms and can lead to the precipitation of the calcium carbonate according to the following reaction [5]:

$$CO_3^{2-} + Ca_2^+ = CaCO_3 \downarrow$$

A total absence of TAC in distilled water, which corresponds to the neutralization of all the dissociated carbonic species, is observed and, by continuing the neutralization, the following reaction is obtained:

$$HCO_3^- + H_3O + = H_2CO_3 + H_2O \quad [6].$$

This reaction is favored in the direct direction, which decreases the pH of the medium and reaches a value of 5. The transformation of soluble calcium and magnesium salts into almost insoluble compounds can be explained by the following reactions:

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

$$Ca(HCO_3) + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 + MgCO_3.2H_2O$$

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3$$

$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$$

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$$

These reactions depend, in practice, on the temperature and pH of the water [7].

The majority of mineral elements are removed by solar distillation.

The case of the sodium is very apparent (99%). We obtained a removal rate 98% for the carbonates. It is very satisfactory result and prompts us to apply this process for the desalination of water.

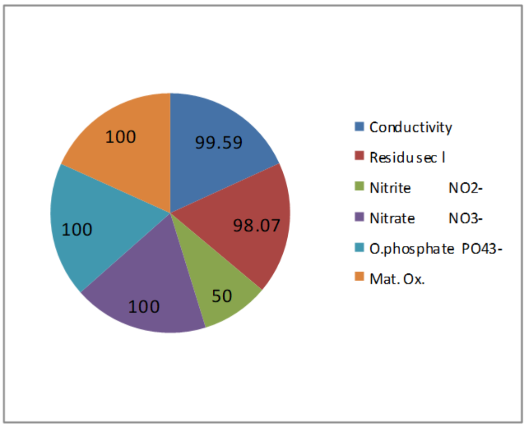

Fig. 5. Removal percent of parameters of pollution after solar distillation.

In the same case we found for the global mineralization a percentage of 97% of purification (see Fig. 6).

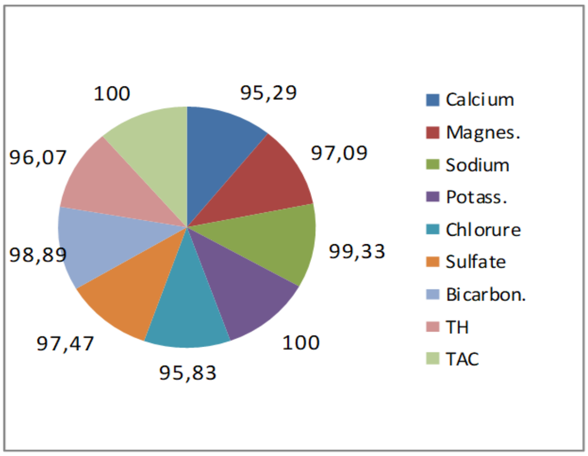

Fig. 6. Mineralization of the water after solar distillation.

IV. CONCLUSION

Le process of treatment of distilled water by solar distiller it gives good yield, because the elimination of soluble salts, minerals and other elements attracts a water of bad quality one obtains water of good quality [8], [9].

The solar distiller of hot box type comprises usable compositions is simple as glass, fiberglass, thermal insulation (polyester).

Generally, distilled water produced and therefore demineralized but contains impurities is back to storage ..., which can be considered mostly as pure water, although this is not the case. A second distillation can then be carried out. To obtain pure water directly, an osmosis unit is used.

Did the use of these waters affect health?

It is very suitable for chemical tests, which it does not disturb. It is not suitable for medical applications.

Homes can be used [10], [11].

Distilled water is therefore an economical way to replace tap water which is hypotonic with respect to blood plasma (less concentrated). One can get the lack of fruit elements. Taking grapes for example brings minerals and sugar [12], [13].

Solar distillers last many years and are an easy, low solution technology for water purification.

The objective of this research work is to select a purification method as well as a renewable energy technology which can be most effectively coupled to supply clean drinking water to a local population at minimal operating costs.

It presents experimental results of desalination of water rich in salt, which is taken directly from the nape in the south of Algeria (Adrar exactly).

This study consists in testing the feasibility of solar distillation,the distance between Adrar and other cities is more than 700 km and that this city is one of the cities that have a high sunshine

Since Adrar is characterized by intense sun lights and high temperature (45° along the whole year) Maximizing the use of renewable energy for sustainable development is highly recommended. The case of the sodium is very apparent (99%).

We obtained a removal rate 98% for the carbonates which is a very satisfactory result and prompts us to apply this process for water desalination.

Though its advantages; distillation presents a number of drawbacks mainly a very low production of drinking water (on the order of 2.5 to 3 liters per m^3 per day).

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Laskri Nabilai was born in Annaba- Algeria, she received her PhD at the Department of Process Engineering in 2016, she holds a magister degree chemical engineering in 2000 at the Department of Process Engineering, University of Annaba- Algeria. From 2003 to 2005, she worked as a researcher in renewable energy center, and then she moved to the university as a lecturer until to 2012. Now she occupies the position of a professor at the (ESTI) college of higher education of industrial technologies -Annaba, Algeria.

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