DEVELOPMENT OF A WATER DESALINATOR LOW COST SOLAR HEATING

DESENVOLVIMENTO DE UM DESSALINIZADOR DE ÁGUA DE BAIXO CUSTO COM AQUECIMENTO SOLAR

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Abstract. Approximatelytwo thirdsofthe land surfaceiscoveredwithwater, with 97%salt, theremainder, only1% can be usedfor human consumption.An alternativetotheuseofdrinking waterisdesalinationofsalt waterusing solar energy.Desalinationcan be appliedtosea water(total dissolved solids$\geq$30,000mg.L^{-1}) asthebrackish waterfromwells, (total dissolved solidsbetween500and 30,000mg.L^{-1}). This study investigatedthe effectofoperating variablesanddesignofadesalination unitforbrackish water, lowcost, forfamily use, thatmeetsthe communitiesof the semi-arid areas. The variablesstudiedandwererelatedto climatic conditions: high water level,watersalinityandsolarradiation. The experimentswere performedatalatitudeof9°3' South andlongitude35°35' west, in Maceió,Alagoas.Production was obtainedfrom2.5litres/m^{2}ofdistilled waterper day.

*Keywords:*Desalination. SolarEnergy. Purification.

Resumo. Aproximadamente 2/3 da superfície terrestre está coberto com água, sendo 97% salgada, do restante, apenas 1% pode ser utilizada para consumo humano. Uma alternativa para o uso de água potável é a dessalinização de águas salgadas utilizando energia solar. A dessalinização pode ser aplicada tanto à água do mar (total de sólidos dissolvidos $\geq$ 30,000 mg.L-1), como à água salobra, proveniente de poços, (total de sólidos dissolvidos entre 500 e 30,000 mg.L-1). Neste trabalho foi estudado o efeito das variáveis de operação e de projeto de um dessalinizador para água salobra, de baixo custo, para uso familiar, que atenda comunidades do semi-árido brasileiro. As variáveis estudadas e relacionadas às condições climáticas foram: altura da lâmina d'água, salinidade da água e radiação solar. Os experimentos foram realizados a uma latitude de 9°3' sul e longitude de 35°35' oeste, em Maceió, Alagoas. Foi obtida uma produção de 2,5 litros.m^{-2} de água destilada.dia^{-1}.

Palavras-chave: Dessalinização. Energia Solar. Purificação.

1 INTRODUCTION

The ability to handle salt water, so as to make it fit for consumption, has been sought by mankind for a long time, since more than three quarters of the earth's surface is covered by salt water and this, although it is important for some means of transport and for fishing, contains a high amount of salt which makes the maintenance of human life through its consumption, as well as rural activities (AKILI et al.,2008).According to Soares (2004), factors such as climate, geological features, soil types and distance from the sea will determine the salinity of natural

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waters. Indeed, in arid or semiarid regions is common to salinization of water, due to its own constitution. It is worth noting that the inadequate management of soil can also cause an increase in salinity(MATHIOULAKIS et al., 2007).

Regarding irrigation water, Soares (2004) states that irrigated areas become unproductive due to poor quality of water used. For this type of water, the salinity limits are determined according to the types of crops, soil and climate, and that water containing dissolved salts at concentrations exceeding 2,000 mg.L^{-1} cause significant declines in agricultural production. Water containing dissolved salts concentration equal to or greater than 1,000 mg.L^{-1} are harmful to health and unfit for human consumption (BUROS, 1990; DANTAS, 1998).

With regard to water for industrial use, salinity tolerated depends on the type of product. The water used in the manufacture of textiles, chemicals, paper and food, for example, require low salinity.According Tleimat (1979), thermal desalination processes is one of the oldest, water purification. However, in Brazil, the use of water desalination is still little known, although the Northeast is applied the process of reverse osmosis desalinationbrackish water coming from wells for the supply of small communities.

Bouchekima (2002) highlights the advantages of solar distillation for desalination of water, stressing the fact that this technology uses a clean energy source, free and does not harm the environment. He said the solar distillation seems to be a promising method and an alternative way to the water supply of small communities in remote areas as wilderness (MATHIOULAKIS et al., 2007).

In order to satisfy different audiences, there are several types of solar stills, from the conventional, also called distillers simple effect that can be covered like one or two waters, to more elaborate models which were developed from those with the goal of optimizing and increasing income by reducing costs (QIBLAWEY and BANAT, 2008; EL-GHONEMY, 2012).

The solar distillation is used in hot areas, with the construction of large tanks covered with glass or other transparent material having a surface sunlight passes through the tanks are filled with brackish or salty water of the liquid evaporates, the vapors condense inside the glass, turning it into drinking water, which flows into a collection system, as shown in Figure 1 and thus separate the water from all the salts and impurities (KHAWAJI et al., 2008; ETTOUNEY et al., 2001; AL-KARAGHOULI and ALNASER, 2004[a,b]).According to Esteban et al. (2000) the glass cover of the device is transparent to incoming solar radiation, allowing their passage, but is opaque to infrared radiation emitted by hot water. Fuentes and Roth (1997) show that in solar distillation heat transfer by convection is not desired, the process is useless.
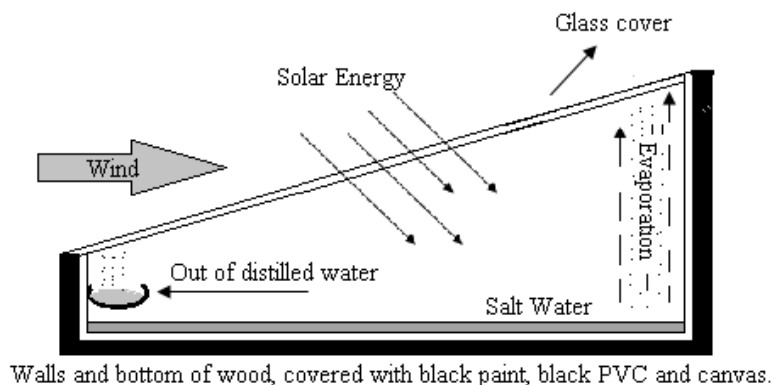

Figure 1. Principle of a desalination unit.

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Al-Hinaietal.(2002)and Cappelletti, (2002) considers thatsolar distillation isapromisingtechnology, particularly inareas of highinsolation anddesert areas, but they arenecessarystudies and researchintended toimprove yieldsand increasethe feasibilityof this technique.This is processcan be applied bothto sea water(totaldissolved solids $\geq$30,000mg.L^{-1}) asthebrackishgroundwater fromwells(totaldissolved solidsbetween 500 and 30,000mg.L^{-1}) (ELTAWIL et al., 2004; KALOGIROU, 2005), which despiteprovidelowersalinitywaterfrom the sea,is still abovethe limitsfor drinkingand domestic use(CONAMA357, 2005).

This paperinter-relates thefollowing variables: temperatureinwater depthandthesteam producedin the external environment, whenthewater depth,the influenceof water salinityin relation todistillationvolume of distilled waterand solar radiation.

2 EXPERIMENTAL

2.1 STUDY AREA

This study of wasconducted in the cityof Maceió, capitalof Alagoas State, northeastern Brazil, with an areaof approximately513.55km2;Situated betweenthe geographical coordinates 9°39'57"latitude and 35°44'07"longitude WGr.The temperaturein the region variesbetween a minimumof 19°Candabsolute maximum of31°C.The study periodoccurredbetween the months ofNovemberto June.During this periodtwodesalination plantswere sized, constructedand operatedsimultaneously in thesolarmonthof highest incidence.

2.2 PARAMETERS EVALUATED

We analyzed the following parameters: height of the water depth(corresponding to10L and20L),salinity(0mg.L-1,800mg.L-1and 1,600mg.L-1), volumeof desalinated water(mL) andsolar radiation(W.m-2).As shownin Table1, thefirstcolumn represents thenumberof the experiment andVi,is theinitial volumeofsolution to bedistilled.(DI)the desalinationwithoutsalt (CI) anddesalination(DII) withsalt concentration(CII).

Table 1. Experimental variables.

Experiment	Period	V_i (L)	C_I (mg.L^{-1})	C_{II} (mg.L^{-1})
1	01/25- 29	10	0	800
2	01/21- 25	10	0	1600
3	03/27- 03	20	0	800
4	03/10- 14	20	0	1600

The dataof temperature, solar radiation andvolume of distilled waterwere obtained froma weather station for 24 hours adayand stored inadataloggerconnected todesalination plants,as
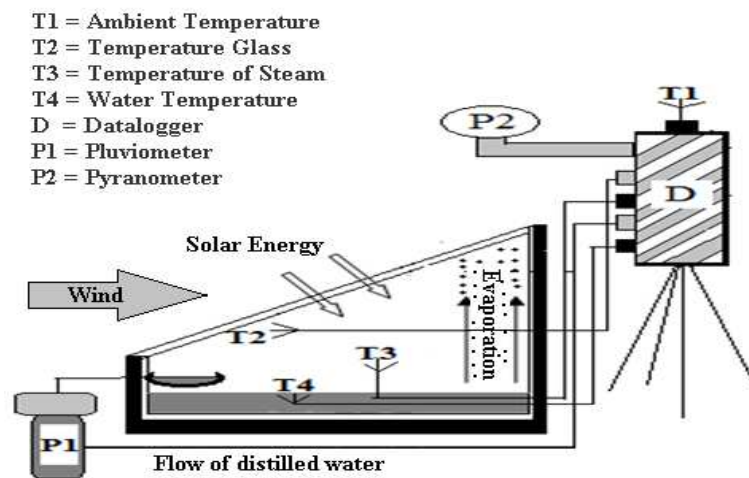
shown in Figure 2.

Figure 2. Schematic of the desalination unit connected to the datalogger.

2.3 EXPERIMENTAL ASSEMBLY

Thedesalination plantswere builtin the Laboratory ofSeparationSystemsandProcess Optimization-LASSOP,Universidade Federal de Alagoas-UFAL, withthe following dimensions:0.5m long; 1.25mwide; heights of 0.1 mand0.4m,corresponding to theside,whichis supportedonthe glass cover,with an area of0.8375m2and a thickness of 0.005 m, formingan angleα=26.6° withthe horizontal.The wallswerelinedandinsulated withPVC andablack canvas, Figure3. These desalination plants of were built from low-cost materials such as wood, PVC, glass and black plastic.

Figure 3. Desalinator built solar.

For theexperiments, thesaline solutionswere producedin the laboratory.Were also conductedother experiments withwatercoming fromwells in the regionof Alagoas.With thephysical-chemical analysisperformedto measuresalinityindesalinated waterthroughadigitalconductivity meter.

3 RESULTS AND DISCUSSION

The experiments were performedat differentoperating conditions: height ofwater depth, solar radiation,salinity, temperatureandwater depthinthe external environment.Thedesalination plantsoperatedsimultaneously, withequal volumes ofwater, butdifferent concentrationsof salts.The equipmentI refer tothatoperated withunsalted waterand equipmentIIrefers tothat operatedwith concentrations of800or 1,600mg.L^{-1} of salt,depending on theexperiment.

As shownin Table2,fourexperiments were performedconsideringtwoinitial heightsof water, correspondingto the volume of10L and20L.In this table, the concentrationsI andIIrefer, respectively, the concentrationsof saltwaterindesalination plantsin operation simultaneously,ie,subject to thesame environmental conditions.VolumeDesal.I andIIrefer to thedaily volumeof distilled waterproduced in eachdesalination.Theyield ofwaterdesalinationusingsaline waterwas calculatedas the ratio ofthe total volume ofdistilledwaterdesalinationandbrackish waterdesalinationtotal volumedistilledwithout salt.

Table 2. Summary of experiments.

Experiment	Initial volumen (L)	Concentration I (mg.L^{-1})	Desal. I volume (L/day)	Concentration II (mg.L^{-1})	Desal. II volume (L.day^{-1})	Relative performance (%)
1	10	0	2.3	800	1.95	85
2	10	0	1.3	1,600	1.00	71
3	20	0	2.3	800	1.50	65
4	20	0	2.6	1,600	1.50	59

*Experiment 1- (Initial volume of 10 Lof water and salt concentration from 0 and 800 mg.L^{-1}).*The Figure 4 show that the distillation desalination I begins before distillation desalination II. Moreover,the peaks ofdistillationare greater thanIto II, characterizing theinfluence,directly,the salt concentrationin the distillation.One canalso observeasimilarroutebetween the curvesof solar radiation andthe volumedistilled forboth devices(with and withoutsalt), showingthe interrelationshipbetween these variables,that is,the higherthe rate ofradiation,the greater thevolume of distilled water.
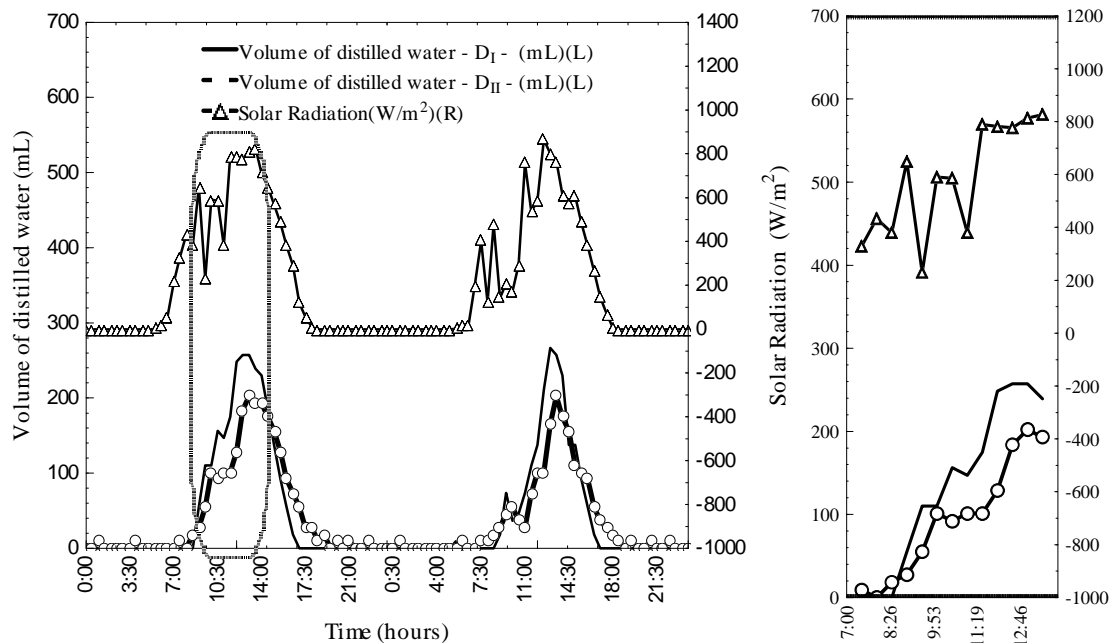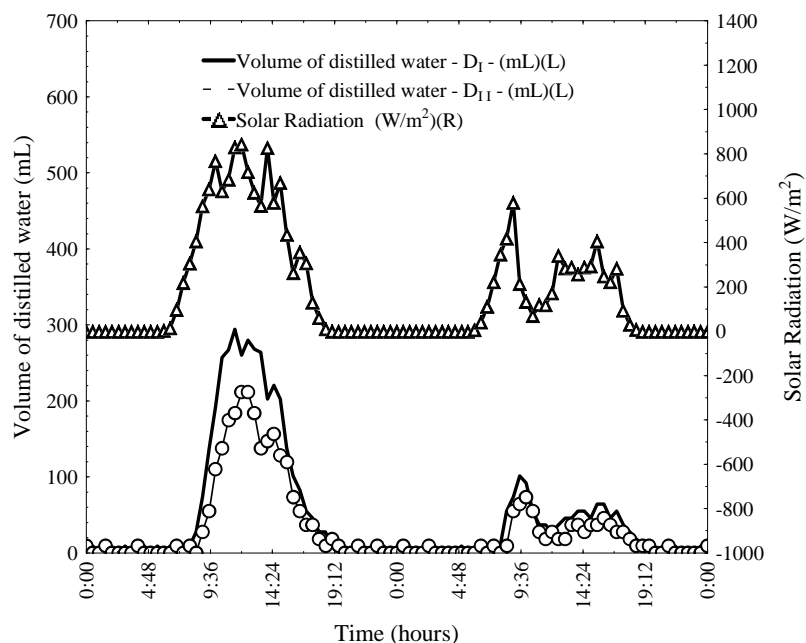
Figure 4. Graph of solar radiation (W.m^{-2}) and the volume of distilled water distillers in I and II, for an initial volume of 10 L of water and salt concentration of 800 mg.L^{-1}.

_Experiment2- (Initial volumeof 10Lof waterandsalt concentration from0 and1,600mg.L^{-1})._TheFigure5, the radiationpeakspresentedonly inthe firstpart of the experiment.Thevolumesofdistilleddesalination plantsexhibited similar behaviorto that of Figure4,that is,desalinator I(no salt)alarger volume ofdistilledwatercompared todesalinationII.

Figure 5. Graph of solar radiation (W.m^{-2}) and the volume of distilled water distillers in I and II, for an initial volume of 10 L of water and salt concentration of 1,600 mg.L^{-1}.

Experiment3- (Initial volumeof 20Lof waterandsalt concentration of0mg.L^{-1} and800mg.L^{-}

[1]).The Figure6showthe dependence ofthe volumedistilledand radiation, peakingarounddistilledvolumeof300mL and200mLfor thedesalinationI (0mg.L^{-1}) andII(800mg.L^{-1}),respectively.Forthe salt concentrationof 800mg.L^{-1} (desalinationII) was obtained fromavolume of distilled water(8.7L), which representsan efficiency of65% over thedesalinatorI,with 0mg.L^{-1} ofNaCl concentrationinwhichwe obtainedavolume of13.6L.Againitwas evidentthat the higherthe rate ofradiation,the greater thevolume of distilled water.
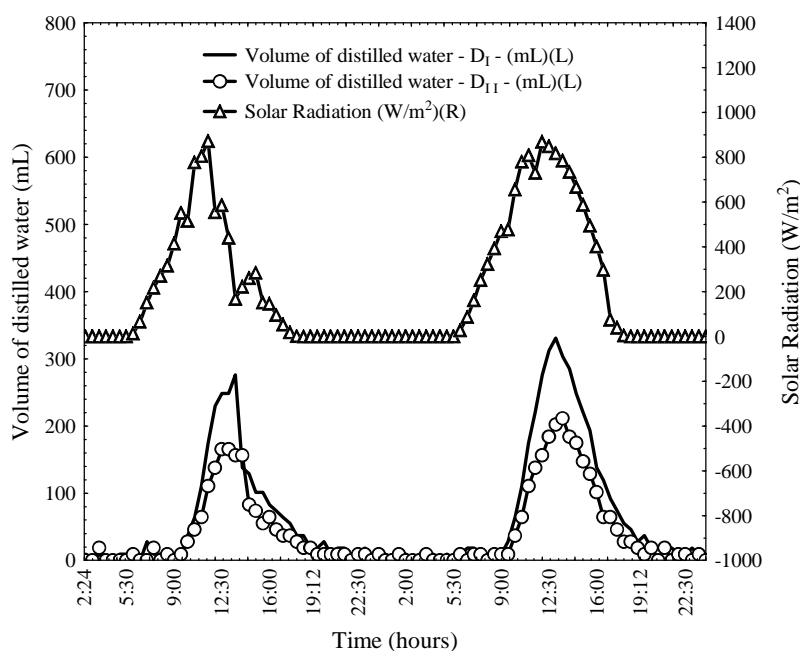

Figure 6. Graph of solar radiation (W.m^{-2}) and the volume of distilled water distillers in I and II, for an initial volume of 20 L of water and salt concentration of 800 mg.L^{-1}.

*Experiment4- (initial volumeof 20Lof waterandsalt concentration of0mg.L^{-1}and 1,600mg.L^{-1}).*The Figure7 shows theinfluence ofsalt concentrationin the volumedistilled.In this experimentthe volume of waterwas 20L, necessitatingagreateramount of energy toheat water, which justifiesagreaterdelayinbeginningthe distillationcompared toExperiments1and 2.
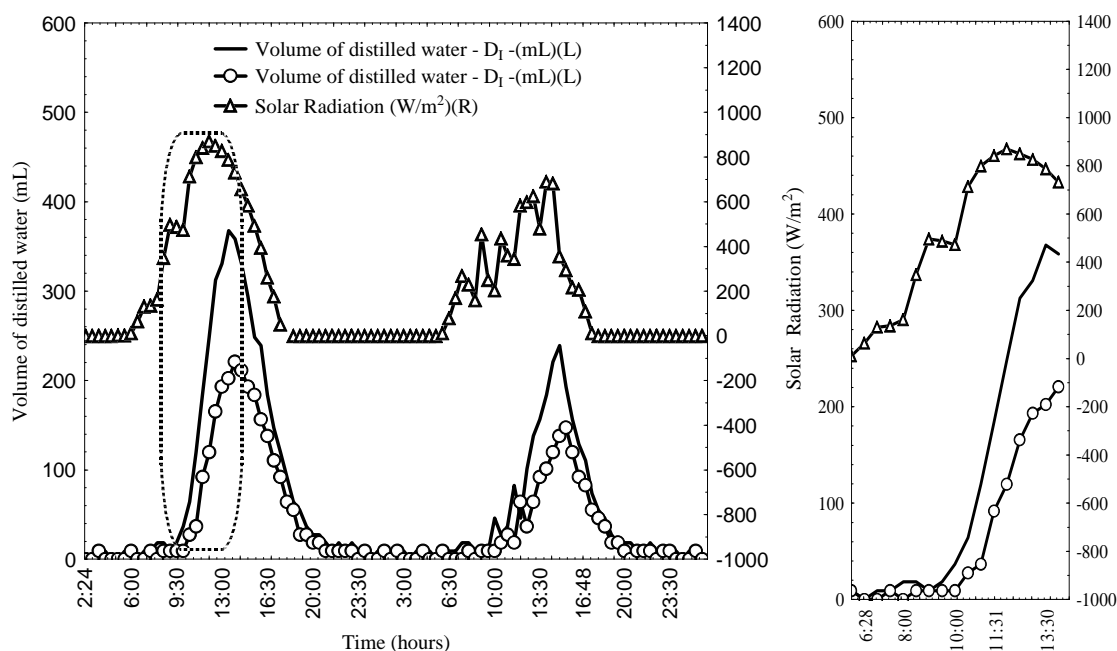
Figure 7. Chart radiation (W.m^{-2}) and the volume of distilled water in distillers I and II for an initial volume of 20 L water and salt concentration of 1,600 mg.L^{-1}.

Figure 8 refers to Experiment 1 and demonstrates both the volume of water produced and the temperature profile of the following: environment, water vapor, water desalination and glass I (D_I). There was concordance between the profiles of the temperature of steam, water and glass and the volume of distillate. There is also the response time between the start of the heating and production of distilled water.
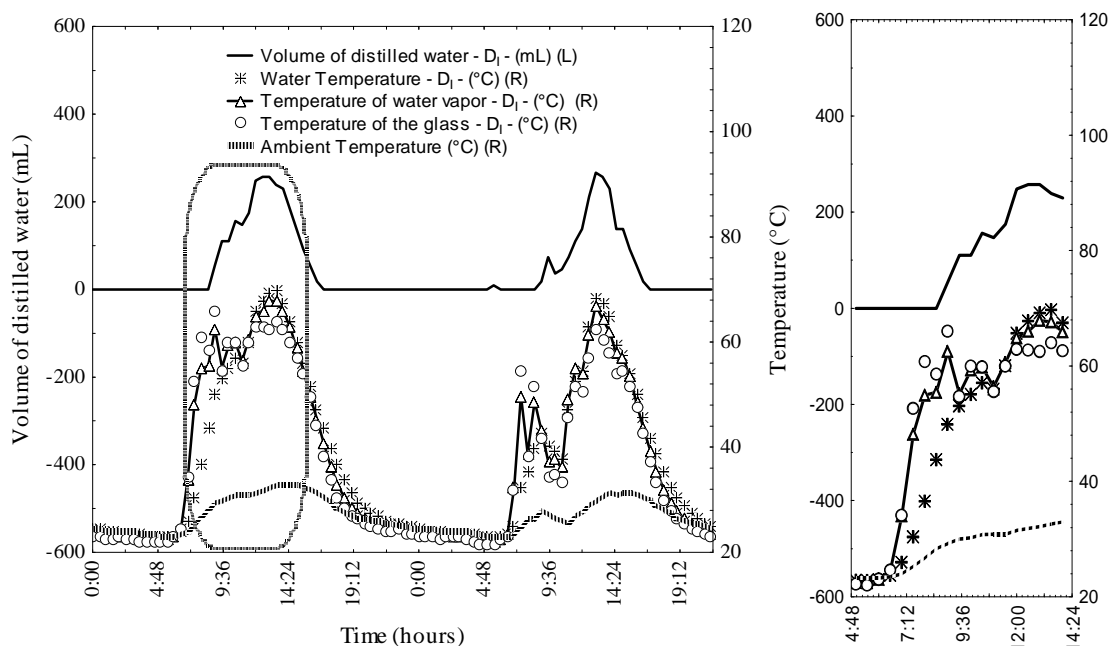

Figure 8. Performance of temperatures within the desalination unit (D_I), for Experiment 1.

In addition toour experiments, experiments were performedwithbrackish waterfromwellsin some regionsof Alagoas, which showedsimilar behaviors.Figure9showsthe visual aspect ofartesianwell waterbefore and afterdesalination.

Figure 9. Comparison between the incoming water (left) and output (right) of the desalinator.

The water produced in desalination plants showed characteristics of drinking water: odorless, tasteless and colorless, and a salt concentration in the range of 200 mg.L^{-1}, below the maximum allowed (500 mg.L^{-1}) by CONAMA Resolution 357, 2005, for waterdrinking.

4 CONCLUSIONS

Regardless of the salinity of the water and the height of the water depth used in the experiments, the profiles of the curves of volume of distilled water by solar radiation show a similar behavior, since the variation of solar irradiation has a daily cycle, witha maximum peak water production in the schedule of noon to one o'clock.After this period, despiste the reduction in the incidence solar desalination unit maintains the temperature, showing a significant production until around 16:00 hours.From this time there is a drop in water production representative, which is gradually reduced.

Moreover, it was observed that the height variation of water depth changed the system performance, with regard to the volume of distilled water, compared with the same system without using water salinity.For a more conclusive, there is need to evaluate the solar incidence for each period of the experiments.Regarding the influence of saline solution, increasing salinity reduced the volume of produced water, which can be explained by the Dühring diagram, Perry and Green (1984).

These desalination plants showed a low initial investment, low maintenance and high reliability.The solar desalination have great ability to solve problems of small scale water treatment in Brazil, provided that the conditions necessary for the choice of this technology to be present, such as a place endowed with high levels of insolation, brackish water and abundant impossibilityphysical or economic to use other energy sources.

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