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Experimental study of a solar still two-slope for brine water treatment

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Abstract: Access to fresh water in remote and rural areas is a real challenge. To meet these challenges, the implementation of water treatment techniques must be encouraged. Saline water source, like brine water or seawater can be processed to produce fresh water using solar thermal energy. In this paper, an experimental study of the solar still will be made. The experimental model is located on the site of the center of studies and research on renewable energies (CERER) at Cheikh Anta DIOP University of Dakar. It is a double slope basin type solar still with a surface area of 2.5 m2 and a thickness of 0.15 m. It is covered with transparent glass 98cm long and 51cm wide, inclined at 16° to minimize thermal. Study showed that with a simple solar distiller, it is possible to obtain 5 liters of distilled water.

Keywords: **Still, brine water, distilled water, solar still**

I. INTRODUCTION

Access to fresh water in remote and rural areas is a real challenge, along with high pollution rates in drinking water due to industrial development **[1, 2]**. Generally, potable water scarcity is pervasive problem. The critical need for clean and accessible water is undeniable, playing a vital role not only in maintaining human health, environmental stability and to preserving our planet but also as a key element in overall development **[3, 4]**. To meet these challenges, the implementation of water treatment techniques must be encouraged. Saline water source, like brackish water or seawater can be processed to produce fresh water using different technologies. Different desalination methods have been used to address the growing demands for freshwater. According to **Soufiane Halimi et al. [5]**, significant improvements have been made in the field of desalination. Water desalination is a process for achieving drinkable freshwater from vastly available saline sources. The desalination process during the recent decades has undergone continuous improvement, causing the emergence of various technologies, which can mainly be classified into thermal and membrane methods **[3]**. The decrease in clean water resources with the global population growth highlights solar energy-assisted water production as a sustainable source **[6-8].** Solar energy-assisted distillation provides a sustainable source of clean water by reducing dependence on infrastructure and external resources. Additionally, the increase in the energy lost and appearance of environmental pollution problems have triggered renewed interest in distillation derived from renewable wellhead **[9].** Solar thermal technology, such as solar distillers, offers minimal maintenance and a long operational

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lifespan, making it cost-effective over time **[10]**. Solar distillation system is a promising technology, which collects solar energy to produce pure water by the process of evaporation and condensation in the basin, leaving behind the ions and bacteria **[11]**. Solar distillation is a cost-effective and environmentally conscious method for obtaining safe drinking water in rural areas **([12]**. Various implementation methods for solar water desalination technology are explored now. Enhancing the efficiency of low-cost solar-powered desalination technologies, such as solar stills (SS), is essential for ensuring continuous access to freshwater in remote, water-stressed areas, particularly during cloudy or rainy days when the performance of conventional SS systems is compromised **[13-14]**. Solar still (SS) is a passive desalination method which is known for its simplicity and low productivity **[15]**. Improving the efficiency of basin-type solar stills is crucial for ensuring reliable access to clean water in areas facing water scarcity **[16]**. In this paper, an experimental study of the solar still will be made.

II. SYSTEM DESCRIPTION

II.1. System description and energy balance

The solar still is a passive system. A three (3D) representation of the system is given in **figure 1**.

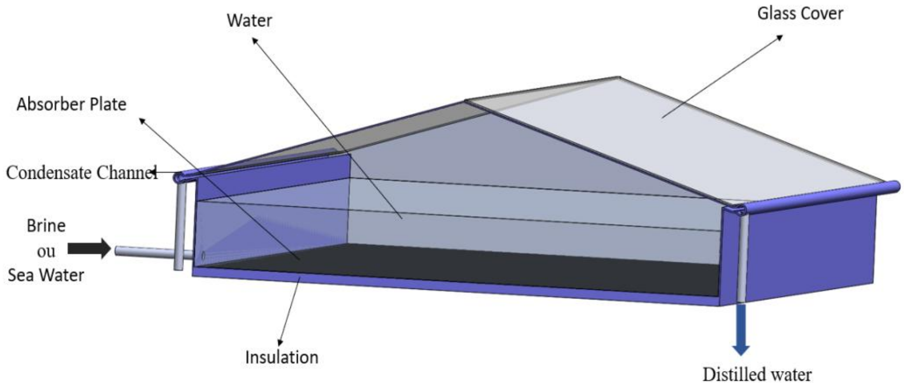

Figure 1. Three (3D) simulation of double-slope solar still

The energy balance of the cover, the saline water and the basin of a distiller has already been carried out by **Rajaseenivasan and Murugavel [17].**

- ✓ Glass cover

The glass cover is assumed to be well cleaned and condensation is only on the cover. The energy balance is given by the equation:

$$a_g A_g I + Q_{c,w-g} + Q_{r,w-g} + Q_{e,w-g} = m_g Cp_g \frac{dT_g}{dt} + Q_{r,g-sky} + Q_{c,g-sky} \qquad (1)$$

- ✓ Basin

The heat balance is written:

$$a_b A_b I = m_b Cp_b \frac{dT_b}{dt} + Q_{c,b-w} + Q_{loss} \qquad (2)$$

- ✓ Water in the basin

It is assumed that the concentration of the brine does not play a role in heat and mass transfers. The heat balance is given by:

$$a_w A_w I + Q_{c,b-w} = m_w Cp_w \frac{dT_w}{dt} + Q_{c,w-g} + Q_{r,w-g} + Q_{e,w-g} \qquad (3)$$

- ✓ The quantity of distillate

The quantity of distillate is given by **El–Sebaii, A.A. et al., [18].**

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$$P_h = 3600\frac{h_{e,w-g}(T_w - T_g)}{h_{fg}} \tag{4}$$

With:
$h_{fg} = 1000(2530{,}3 - 2{,}398T)$

- ✓ Energy efficiency of the system

The energy efficiency of the system for a simple distiller is given by:

$$\eta_{th} = \frac{\dot{m}_{ew}h_{fg}}{a_b.I} \tag{5}$$

II. 2. Experimental system

The experimental model is located on the site of the center of studies and research on renewable energies (CERER) at Cheikh Anta DIOP University of Dakar. As shown in **figure 2**, it is a double slope basin type solar still with a surface area of 2.5 m^2 and a thickness of 0.15 m. It is covered with transparent glass 98cm long and 51cm wide, inclined at 16° to minimize thermal losses, the whole is insulated by a black layer. It has a very simple design and has the advantage of being easy to build and maintain.

Figure 2: Experimental model

III. RESULTS AND DISCUSSIONS

Brine water was used. We demonstrated the performance of the system by measuring the quantity of distilled water in 24 hours. The data of irradiation, temperature inside the distiller, temperature outside the distiller and brine water temperature were measured. After several experiments, the distiller was emptied, cleaned and the tank repainted before it was put into operation again. The experiment still continues with brine water. We carried out the same measurements to see if production will increase.

Fig.3, 4, 5 and **6** show Temperatures inside the still, outside the still, brine water and solar irradiation as a function of time.

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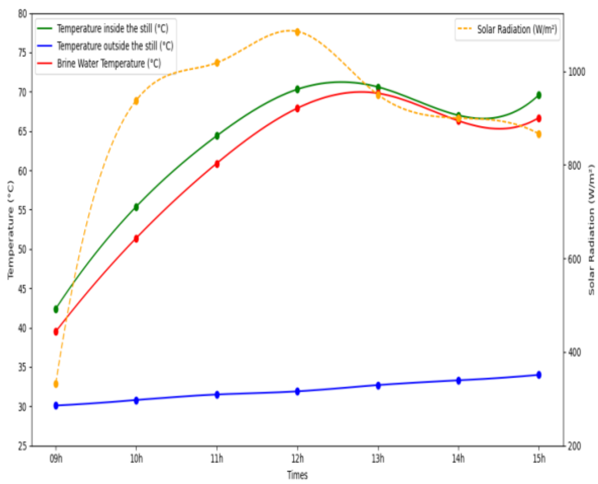

Figure 3: Temperatures inside the still, outside the still, brine water and solar irradiation as a function of time measured on July 29, 2024

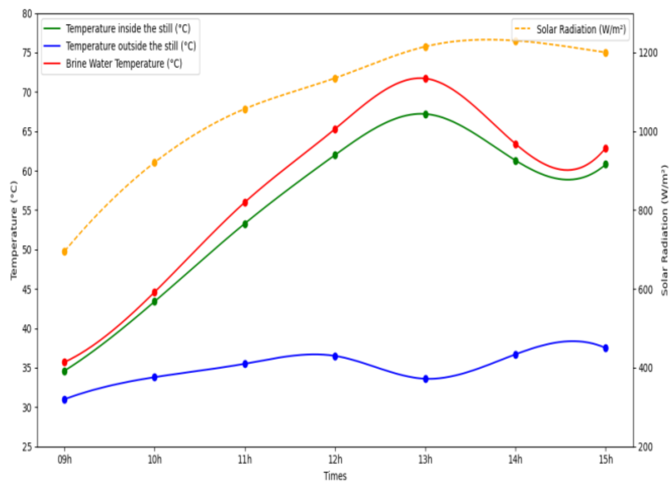

Figure 4: Temperatures inside the distiller, outside the distiller, brine water and solar irradiation as a function of time measured on August 13, 2024

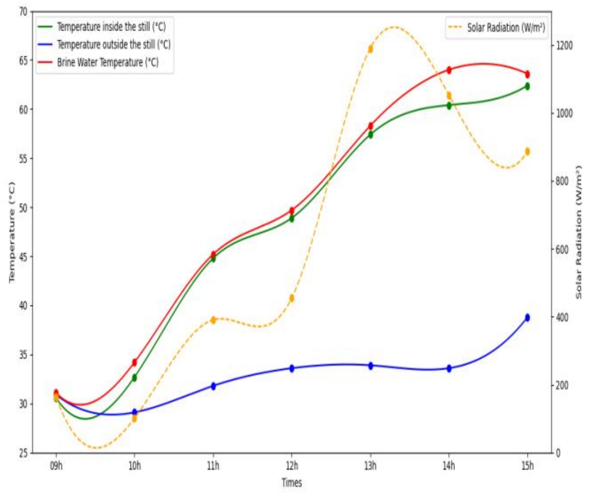

Figure 5: Temperatures inside the distiller, outside the distiller, brine water and solar irradiation as a function of time measured on August 26, 2024

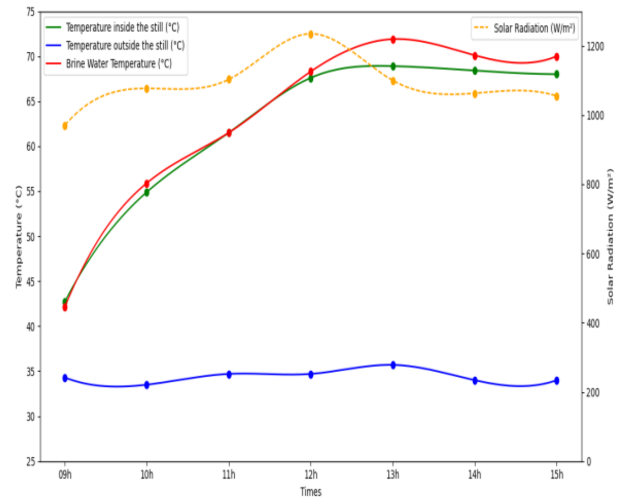

Figure 6: Temperatures inside the distiller, outside the distiller, brine water and solar irradiation as a function of time measured on August 27, 2024

Fig. 3, 4, 5 and 6 show that when the solar irradiation received by the distiller increases, then the inside temperature of the distiller increases. The figures also show an increase in brine water temperature. Thus the brine water evaporates and the condensates are collected in a bottle.
Table 1 gives the volume of brine water distilled after each test.

Table 1: Volume of distilled water for different tests using brine water in the tank

Time (Hours)	29/07/2024	13/08/2024	26/08/2024	27/08/2024
09h	0	0	0	0
10h	0.7892	0.6788	0.7050	0.7838
11h	1.0240	0.7198	0.7634	1.0344
12h	1.5068	0.8315	0.8586	1.5084
13h	2.1550	0,9102	1.0832	2.0902
14h	2.7146	1.2536	1.5727	2.7766
15h	2.9270	1.5496	2.0604	3.0152

The measurements are carried out between August and October, therefore during the rainy season. We noted low volumes for 08/13/2024. This is due to poor solar radiation. The low volumes measured for the

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day of 08/13/2024 are due to a deposit of solid particles on the absorber due to the fact that the distiller remained for a long time without being cleaned

Figure 7 gives the volumes of distilled brine water measured the day after each test.

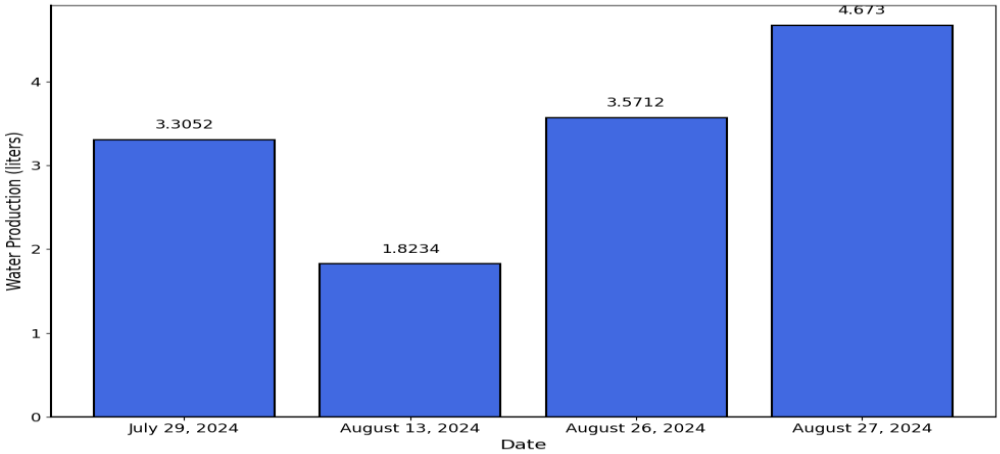

Figure 7: Volume of distilled water measured at 9 a.m. the day after each test using brine water

In Figure 7 we noted large volumes of distilled brine water. This is because during the night, a large amount of water vapor condenses.

IV. CONCLUSION

Access to drinking water is a major problem in rural and urban areas. This is often a source of illness, and therefore a hindrance to development. Therefore, for better living conditions for populations, it is necessary to encourage research in the field of solar distillation. Our study showed that with a simple solar distiller, it is possible to obtain 5 liters of distilled water. We plan to expand the model used with validation under Computation fluid dynamic (CFD). Likewise, it would be important to use sea water instead of brine water.

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