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Indoor tests to investigate the effect of brine depth on the performance of solar still

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Abstract
Many experimental and numerical studies have been done on different configurations of solar stills to optimize the design by examining the effect of climatic, operational and design parameters on its performance. One of the most important of the operational parameters that has received a considerable attention in the literature is the brine depth. This paper reports indoor experimental investigations on the effect of brine depth on the productivity and efficiency of the solar stills at four different brine depths of 1.5, 2, 4 and 5.5 cm. Indoor tests were used by simulating the solar input by proper electric heaters located at the bottom of the still for heating the water contained in the basin of the still. The present study validated the decreasing trend in productivity with the increase of brine depth and showed that the still productivity could be influenced by the brine depth by up to 24%.

Keywords: Desalination; Indoor test; Performance; Solar still; Brine depth.

1. Introduction

Water is one of the most important resources for human life sustainability. Along with the supply of energy, access to fresh water is a fundamental need of all societies. Although water covers approximately 70% of the earth's surface, supplies of potable water are rapidly disappearing. This is because only 0.62% of the available water is in a form that can be traditionally treated for human consumption [1]. As a result, many people do not have access to adequate and inexpensive supplies of potable water. This leads to population concentration around existing water supplies, marginal health conditions, and a generally low standard of living [2]. To overcome this problem there is a need for some sustainable source for the water distillation.

Distillation uses the heat directly in a simple piece of equipment to purify water. The equipment, commonly called a solar still, is a useful device that can be used for the distilling of brackish water for the drinking purposes. It operates using the basic principles of evaporation and condensation. The heat received from solar radiation by the still or from heaters (in the case of the indoor tests) evaporates the water. After evaporation, it leaves all contaminants and microbes behind in the basin. The evaporated and now purified water condenses on the underside of the glass and runs into a condensing trough and then into an enclosed container (Figure 1). In this method, the salts and microbes that were present in the original feed water to solar still are left behind.

Many parameters affect the productivity of such stills which include climatic parameters (such as atmospheric temperature and wind speed), operational parameters (such as using heater for brine heating instead of solar radiation, feed water preheating, cleaning cover and basin, adding soluble dye to the

brine) and design parameters (such as cover materials, thickness and its inclination, thermal insulation and brine depth).
The objective of this work is to investigate the effect of brine depth on the productivity and efficiency of solar still under laboratory conditions.
Table 1 shows a summary of some of the studies cited in the literature that examined the effect of brine depth on productivity. It can be seen from the table that some conflict on the effect of brain depth exists. All investigators apart from [10, 12] concluded that increasing the brine depth cause a reduction in the daily productivity.

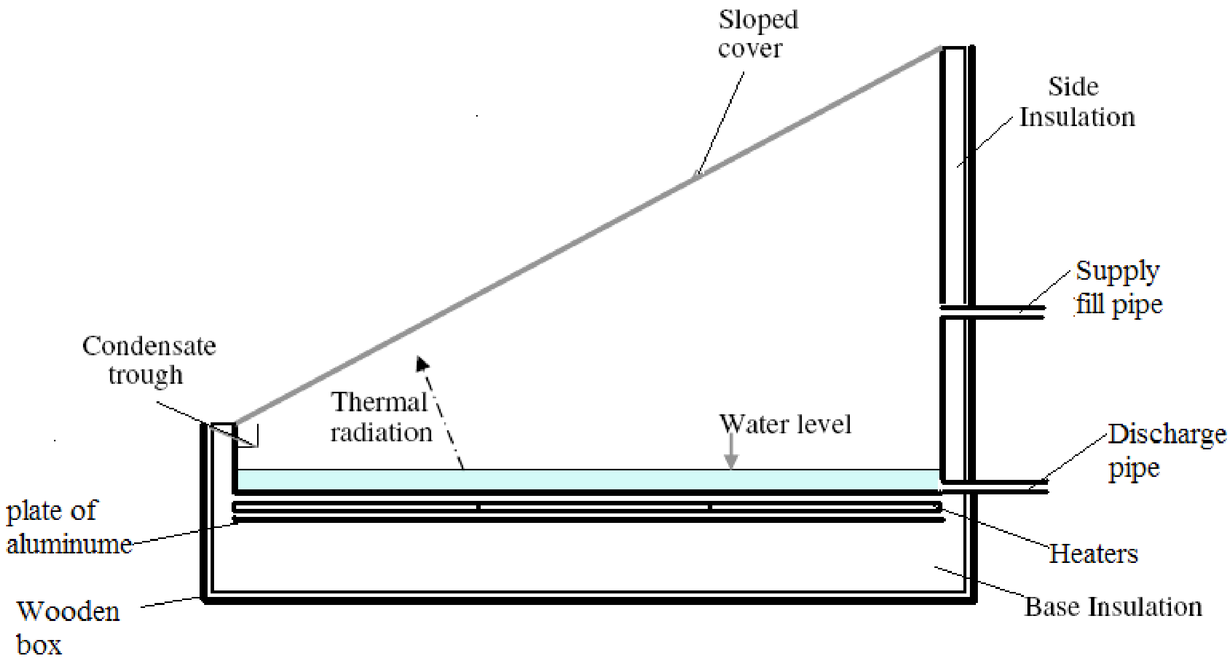

Figure 1. The solar still

2. The experimental setup

The experimental tests were carried out in Baghdad (33.3° N). The still (Figure 2) is manufactured from galvanized iron sheets, 0.8 mm thick with 0.7×0.7 m² base area and 0.555 m height. The condensing surface used is a glass sheet of 4 mm thickness. Silicon rubber sealant is used to insure vapor tightness.
The supply, discharge and distillate output copper pipes were welded to distiller body. Insulation sheet of 5-cm-thick was used on all interior sides of the still. The solar radiation used in outdoor tests was simulated by one kW electrical heaters placed beneath the basin. Three separated heaters were used (Figure 3) in the experimental still arranged appropriately to supply a uniform heat flux to the basin of the still. The dimension of each one of the three heaters is 66×21.5 cm. Each heater is manufactured by twisting a wire with resistance of 2.5 (Ω /m) on a piece of mica with thickness 0.4 mm. The mica has a property of heat conducting and electric insulation. Another pieces of mica where then put below and above the twisted wire. The overall structure was covered with a 1-mm-thick plate of galvanized iron to prevent inflation of the mica as it becomes heated during the operation. The three heaters were connected in series to supply a total current of 4.5 A, a voltage of 220 V and a total power flux of approximately 1000 W/m² to simulate the solar radiation intensity. A variac was used to regulate the input voltage to the heaters. Figure 4 shows a photograph of the constructed still and the instrumentation used.
Thermocouple wires of type K were used to measure the glass, vapor, water and glass temperatures using a digital temperature recorder. The yield, voltage, current and temperatures of the still were measured half hourly in each test from 8:30 am to 1:30 pm. The nocturnal production of the experiments was measured at the next morning. The brine depth studied was in the range 1.5 to 5.5 cm with an input power of 326.16 W.

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Table 1. Summary of the studies cited in the literature on brine depth effect

Author(s)	Conclusion about the Effect Of Brine Depth	Experimental(E) Theoretical(T) Numerical(N)	Outdoor(O) Indoor (I)	Type of Still	Month of Test(s)
Nafey et al. [3]	The numerical results showed that as the brine depth increased, the solar still productivity decreased. The experimental results showed that as the water depth increased from 2 to 7 cm, the output decreased by 14%	E,T&N	O	single sloped solar still	September
Badran and Abu-Khader [4]	As the water depth decreases from 3.5 cm to 2 cm, the productivity increases by 25.7 %	E	O	Single sloped solar still	March and April
Badran [5]	The decrease of the water depth from 3.5 to 2 cm increased the productivity by 26%	E	O	Single sloped solar still	_
Suleiman [6]	The decreased water depth has a significant effect on the increased productivity. The productivity was closely related to the incident solar radiation intensity	E	O	Double sloped solar still	June to February
Toure and Meukam [7]	Maximum total production is obtained at the lowest water depth. increasing the water depth from 5 to 60 mm decreases the total production by 19%	T, E & N	O	Single basin solar still	April
Dimri et. al [8]	The yield decreases with increase of water mass.	E & N	O	Active solar still	December
Younis et. al [9]	The distillation output increased as the water depth decreased, where the maximum distillation output was at 6 cm water depth.	E	O	Single-sloped solar still.	December to August
Elsafty et. al [10]	Increasing water depth has a small effect on the productivity.	T & N	O	Solar still that uses parabolic reflector-tube absorber	_
Tiwari et. al [11]	The yield decreases with the increase of water mass	T	O	Passive and active solar stills with a flat plate collector	_
Fath and Hosny [12]	Increasing saline water mass has little effect on the productivity, reducing the basin mass (heat capacity) improves the productivity by only about 0.5 l.	T	O	Single sloped basin still with enhanced evaporation and a built-in additional condenser	_
Khalifa and Hamood [13]	Increasing the brine depth decreases the productivity, the still productivity could be influenced by the brine depth by up to 48% for brine depth ranging from 1 to 10 cm.	E	O	Single sloped basin type solar still	April and May

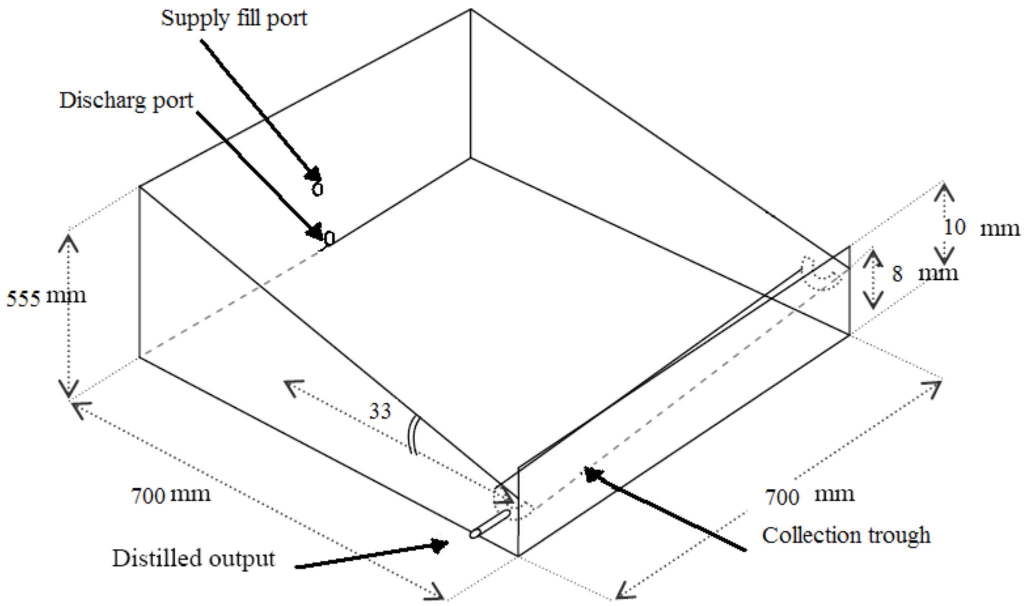

Figure 2. The schematic diagram of the experimental prototype

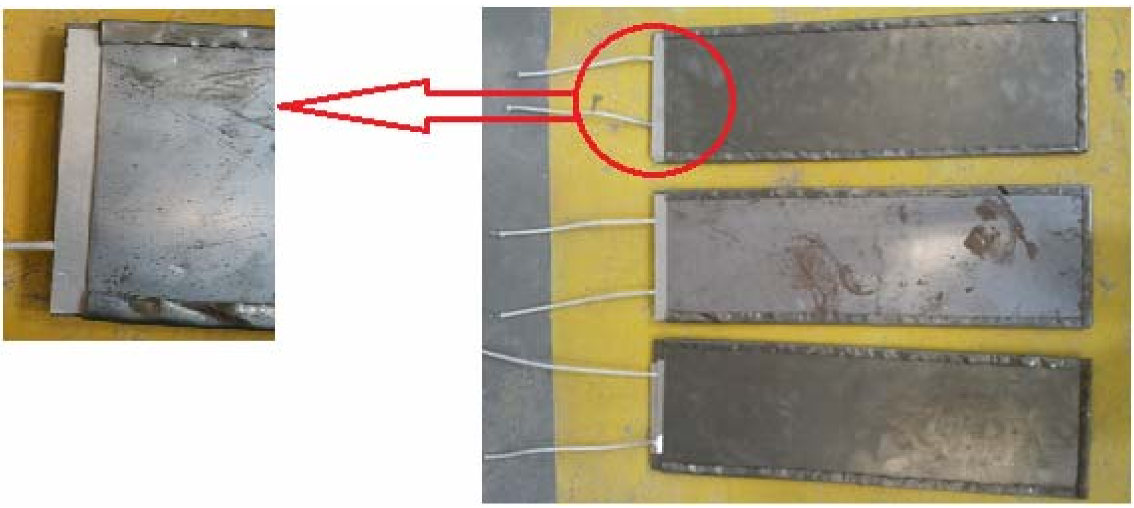

Figure 3. The heaters

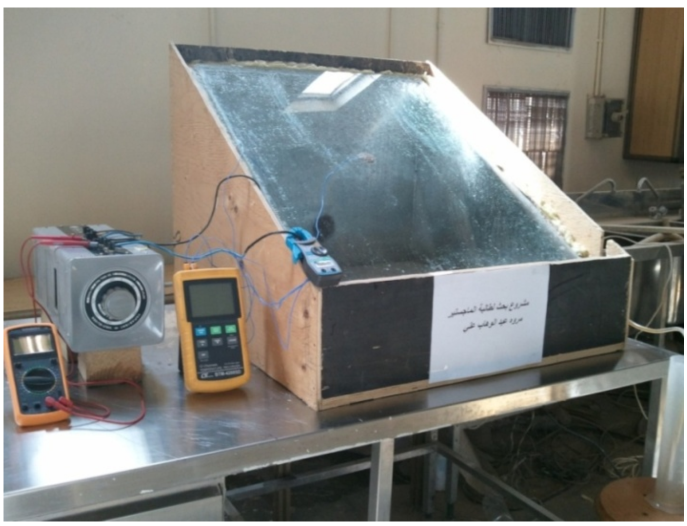

Figure 4. The experimental still

3. Results and discussion

The experimental investigation is performed under the laboratory conditions in January 2012 by using single slope basin type solar still with fixed tilt angle of 33º from horizontal. The experimental results are shown in Figures 5 to 9. Figures 5 to 8 show the half-hourly performance of the solar still with brine depths of 1.5cm, 2cm, 4cm and 5.5cm with an input power of 326.16W. The results indicate that as the water depth increases from 1.5 to 5.5 cm, the output decreases by around 24%. It is observed from the experiments that the still with the lower brine depth starts producing earlier than that of greater thickness, but the productivity diminishes rapidly after turning the heaters off. On the other hand, the still with the higher brine depth has a larger production during the period with no heat input (termed as nocturnal production in the outdoor tests). These values are the initial value of the production line in the figures. This may be due to the large thermal capacity of water, which is directly related to water mass, causing a continuous production after the heaters were turned off. The "nocturnal output" (Figure 9) is increased from 0.653 to1.1736 l/m².day when the water depth was increased from 1.5 to 5.5 cm respectively. Figure 9 shows the values of the distillate (l/m².day) collected for different brine depths and 326.16 W power input to the heaters. It is evident that the productivity decreases with the increase of water depth. It can be concluded that the output of the still is maximum for the lower water depth.

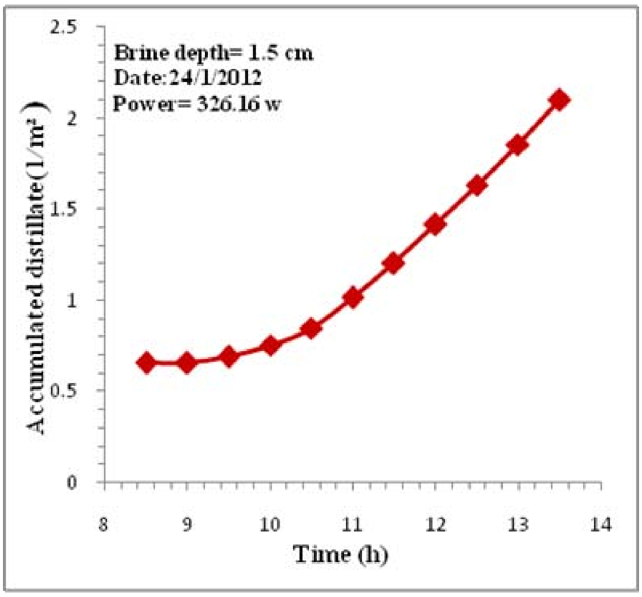

Figure 5. Time variation of accumulated distillate for still with brine depth of 1.5 cm

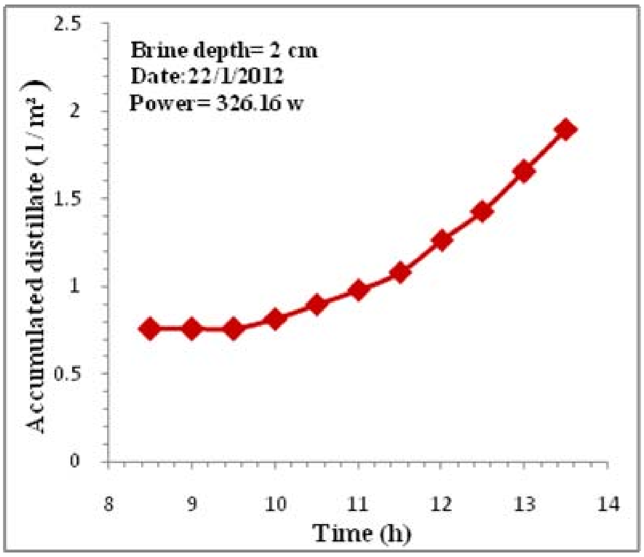

Figure 6. Time variation of accumulated distillate for still with brine depth of 2 cm

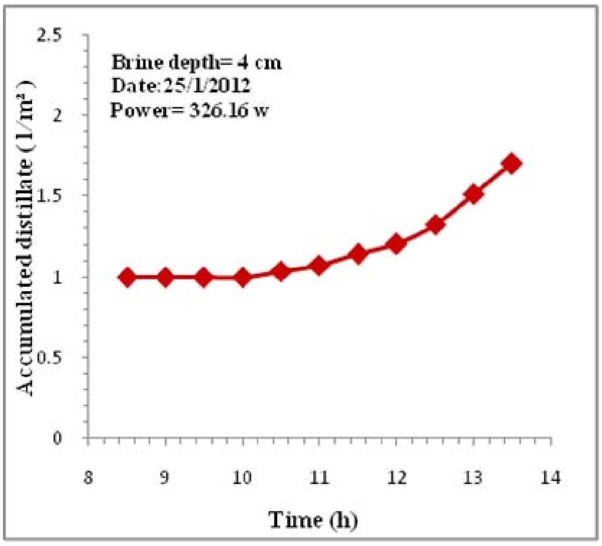

Figure 7. Time variation of accumulated distillate for still with brine depth of 4 cm.

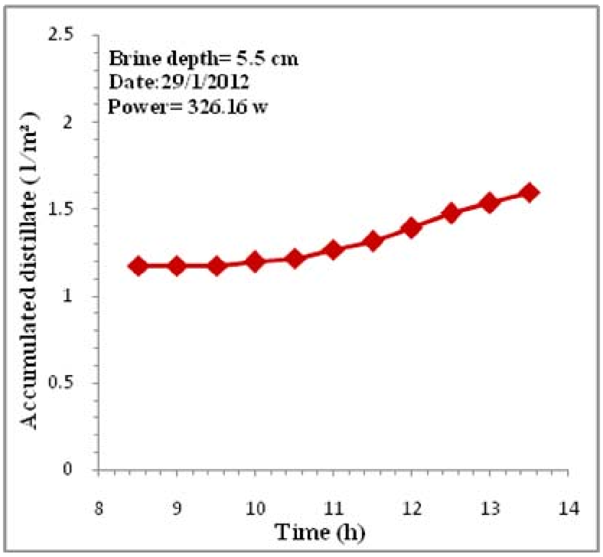

Figure 8. Time variation of accumulated distillate for still with brine depth of 5.5 cm

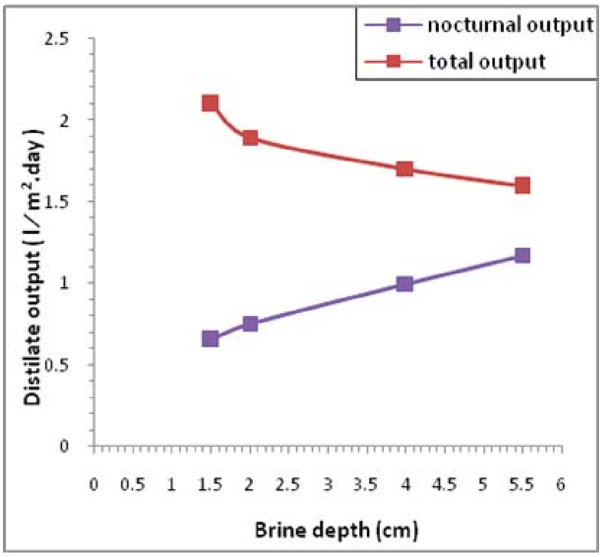

Figure 9. The total and nocturnal output for different brine depths

4. Conclusion

Only few studies were carried out indoor. The present research work investigates the effect of brine depth on the productivity and efficiency of the single-slope basin type solar still using indoor testes by replacing the power input from solar radiation by suitable variable heating system. The indoor tests allow a greater control on the input power and eliminate many factors that may affect the accuracy of the experimental results such as uncontrolled weather conditions. It was verified that increasing the brine depth decreases the productivity of the basin type solar still. The present study showed that the still productivity could be influenced by the brine depth by up to 24% as obtained by the relation,

$$\%change = \frac{Y_H - Y_L}{Y_L} \times 100\%$$

Where Y_H and Y_L are the productivity at the highest and lowest brine depth, respectively) under the laboratory conditions for brine depth ranging from 1.5 to 5.5 cm. As water depth increases, the nocturnal productivity of the still increases. The experimental results showed that the nocturnal productivity of a still operating with 1.5cm brine depth is 31% of the daily productivity while it is 73.5% for the still with 5.5cm brine depth.

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