The comparative analysis of solar desalination with cooling glass

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Abstract. Fresh water plays a role and is responsible for life. The need for fresh water continues to increase due to its use in various fields of life, such as agriculture, industry and population. To prevent water shortages, it is very important to show the gap between the demand and supply of drinking water by developing water purification technology. Solar power / solar energy (renewable energy sources) in the form of distillation is one of the most promising, simple, and economical technologies for the purification of salt and brackish water. double slope passive system with the addition of water-cooled glass outside with water diluted by a solar-powered DC pump from photovoltaics with no outer glass cooler.

1. Introduction

Over time, fresh water is increasingly needed by humans in everyday life, from the need for drinking water to other needs such as cooking, washing, bathing, and so on and due to an increase in the standard of living. So with that, the production of clean water must also be balanced so that water needs can be fulfilled, because according to the United Stations Organization that in 2025, an estimated 1800 million people in the world will experience a scarcity of clean water (UN Water) [1]. At present the source of clean water that can be obtained from springs, rivers, lakes, oceans, but the water source is now mostly contaminated with chemicals and toxic to humans such as air pollution that causes rainwater to mix with industrial smoke substances and vehicle emission [2] [3].

This problem can be overcome by using sea water, as we know that sea water is very abundant because 2/3 of Indonesia's territory is ocean or 71% of the earth's surface. So with that sea water supply certainly will not run out. However, sea water cannot be used directly because it has a high salt content which is around 3% [4]. So that sea water can be used, it needs to be converted into fresh water first, this process is known as desalination [5].

In this research, we will be discussed the comparison of efficiency and production of fresh water from the two seawater desalination devices, namely desalination with cooling glass on the outside and without cooling glass [6].

2. Solution method

2.1. Sample preparation

Sea water obtained from The Coast of Bali Lestari, Serdang Regency, North Sumatera, Indonesia with a salt content of around 3%, is taken as the main ingredient in this experiment.
2.2. Experimental set-up
The passive solar system with double slop desalination system that is assembled consists of an evaporator, glass cover, outer glass cooling water pipe, pump, sea water tank, drain a pipe from the tank to the evaporator and a pipe for condensation results. The testing process can be done by filling a water tank using sea water as much as 19 liters. Seawater that has been filled in the water tank, is channeled to the evaporator by opening the water tap until the water level in the evaporator reaches 2 cm. this height can be seen from the ruler contained in the evaporator [7].

In the evaporator there are 5 thermocouples, each of which serves to measure the temperature of sea water, the inner and outer west glass, the inner and outer east glass, while to measure and record air temperature, wind speed, radiation intensity and air humidity sensors used in the HOBO Micro Station Data Logger are installed adjacent to the evaporator. Data read by the thermocouple and sensor from the HOBO Micro Station Data Logger is connected to a laptop that has previously been calibrated and adjusted in its programming language.

Sea water that experiences condensation in the evaporator will evaporate and condensate water will stick to the glass and will then flow into the reservoir. for the first device, the outer glass is cooled using cold water which is designed in such a way that the pump power to drain water comes from photovoltaic / solar power and for the second device without drainage of cooling water on the outer glass

![Experimental Setup](image)

**Figure 1.** Experimental Setup.

2.3. Thermal modelling
Natural convection occurs in moist air in the tub because of the temperature difference between the surface of the water and the inner surface of the glass cover. The convective heat transfer coefficient is given as follows:

\[
h_{cwE} = 0.884 \left( \frac{(T_w - T_{gwE}) + (P_w - P_{gw})(T_w + 273)}{2.689 \times 10^{5} - P_w} \right)^{\frac{1}{3}} \]

(1)

\[
h_{cwE} = 0.884 \left( \frac{(T_w - T_{gw})(T_w + 273)}{2.689 \times 10^{5} - P_w} \right)^{\frac{1}{3}}
\]

(2)
Where $h_{cwgE}$ [W/m$^2$ °C] is convection heat transfer coefficient of east side glass cover, $h_{cwgW}$ [W/m$^2$ °C] is convection heat transfer coefficient of west side glass cover, $T_w$ [°C], $T_{gIE}$ [°C], $T_{g IW}$ [°C] are water temperature in basin, east side inner glass temperature, west side inner glass temperature respectively. $P_w$ [N/m$^2$], $P_{gIE}$ [N/m$^2$], $P_{g IW}$ [N/m$^2$] are water saturated partial pressure, east side glass saturated partial pressure, west side glass saturated partial pressure respectively which can be found by the equations below

$$P_w = \exp\left[25.317 - \left(\frac{5144}{273 + T_w}\right)\right]$$ (3)

$$P_{gIE} = \exp\left[25.317 - \left(\frac{5144}{273 + T_{gIE}}\right)\right]$$ (4)

$$P_{g IW} = \exp\left[25.317 - \left(\frac{5144}{273 + T_{g IW}}\right)\right]$$ (5)

Double slope solar still performance depends on the evaporative and convective heat transfer coefficient. Evaporative heat transfer coefficient as follows

$$h_{ewgE} = 0.016273 h_{ewgE} \frac{P_w - P_{gIE}}{T_w - T_{gIE}}$$ (6)

$$h_{ewgW} = 0.016273 h_{ewgW} \frac{P_w - P_{g IW}}{T_w - T_{g IW}}$$ (7)

Where $h_{ewgE}$ [W/m$^2$ °C] is evaporation heat transfer coefficient of east side glass cover, $h_{ewgW}$ [W/m$^2$ °C] is evaporation heat transfer coefficient of west side glass cover.

Efficiency of DSSS is the ratio of the amount of heat energy used to get a certain amount of distilled water to solar energy that occurs within a certain time interval. The efficiency of the system can be found using the following equation.

$$\eta_{theoretical} = \frac{m_{dE} \times h_{fg}}{\Sigma I(t) A_b t} \times 100\%$$ (8)

$$\eta_{actual} = \frac{m_{dA} \times h_{fg}}{\Sigma I(t) A_b t} \times 100\%$$ (9)

Where $m_{dE}$ [kg] and $m_{dA}$ [kg] are theoretical distillation output mass and actual distillation output mass respectively. $\Sigma I$ [W/m$^2$] is total solar radiation within a certain time interval. Where $h_{fg}$ [J/kg] is latent heat of vaporization can be found with the following equation

$$h_{fg} = 3044205.5 - 1679.1109 T_w - 1.14258 T_w^2$$ (10)

The theoretical output of the double slope solar still per 30 minutes can be obtained as follows

$$m_{ewE} = \frac{h_{ewgE}(T_w-T_{gIE}) A_b 1800}{h_{fg}}$$ (11)

$$m_{ewW} = \frac{h_{ewgW}(T_w-T_{g IW}) A_b 1800}{h_{fg}}$$ (12)

$$m_{dt} = m_{ewE} + m_{ewW}$$ (13)
Where \( m_{w,d} \) [kg] \( m_{w,W} \) [kg] are theoretical distillation output mass on east side and theoretical distillation output mass on west side respectively.

3. Result and discussion

The results below were obtained in the experimental process on 29th of June 2019 from 8 AM to 6 PM at Medan City, North Sumatera, Indonesia with geographic coordinate 3°34’ North and 98°40’ East. The graph below will show a graph of the temperature to time comparison of the two devices.

![Graph showing temperature comparison](image)

**Figure 2.** Variation of temperature with time (a) Desalination without cooling, (b) desalination with glass cooling.

From figure 2, the highest and lowest temperatures of the water in the basin are 56.47°C and 26.37°C respectively at 1.30 PM and 8 AM. The highest and lowest temperatures of the east side outer glass are 43.48°C and 26.95°C at 2.30 PM and 8 AM. The highest and lowest temperatures of the east side inner glass are 46.71°C and 26.35°C at 2 PM and 8 AM. The highest and lowest temperatures of the west side outer glass are 45.85°C and 23.97°C respectively at 2 PM and 8 AM. The highest and lowest temperatures of the west side inner glass are 47.67°C and 24.30°C respectively at 2 PM and 8 AM.
The highest and lowest temperatures of the cooling water are 38.53°C and 24.35°C. While the highest and lowest temperatures of the environment are 35.42°C and 28.35°C at 1.20 PM and 8 AM.

From figure 3 showed that the solar radiation starts at 194.4 W/m² at 8 AM and ends at 23.1 W/m² at 6 PM. The maximum solar radiation measured is 616.9 W/m² at 11.35 AM and total solar radiation during this experimental is 212424.9 W/m².

From figure 4, the highest and lowest theoretical distillation volume of double slope solar still with cooling outer glass are 884,130 ml and 8.77 ml at 1.30 PM and 6 PM. The theoretical distillation volume ends with 134 ml at 6 PM. While, the highest actual distillation volume are 540 ml at 1.30 PM. At 8 AM to 8.30 AM there are no actual distillation volume obtained. Meanwhile at 6 PM the actual distillation volume produced is 100 ml. The total theoretical distillation volume produced was 7.57 liters while the actual total distillation obtained was 4.36 liters and then the highest and lowest theoretical distillation volume of double slope solar still without cooling outer glass are 520.24 ml and 7.66 ml at 13.30 PM and 08.00 AM. At 18:00 WIB theoretically the resulting volume was 136.62 ml. While the highest and lowest actual distillation volume in tool 1 are 310 ml and 5 ml at 13.30 PM and 09.00 AM. At 08.00 AM to 08.30 AM no distillation volume is produced on 2nd device. While at 18.00 WIB the actual distillation volume produced is 125 ml. The total theoretical distillation volume on 2nd produced was 4,216 liters while the actual total distillation volume on 2nd obtained was 2,895 liters.

4. Conclusion
With the amount of solar radiation which is 212424.9 W/m² absorbed by the system on 27th of June 2019, in the first device with cooling outer glass total theoretical distillation volume produced was 7.57 liters and the actual total distillation obtained was 4.36 liters. In which, the theoretical efficiency of the system obtained is 90.88% and the actual efficiency of the system is 52.32% meanwhile the
second device without cooling outer glass total theoretical distillation volume produced was 4,216 liters and the actual total distillation obtained was 2,895 liters. In which, the theoretical efficiency of the system obtained is 50.49\% and the actual efficiency of the system is 34.5\%.

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