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Cover Page Footnote

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Performance of a Solar Seawater Distillation with a Triangle Prism Cover and a Fin-Type Absorber

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Abstract

Solar-powered distillation is a seawater distillation method that utilizes solar heat as its main energy source for the purpose producing freshwater and a by-product of the distillation process in the form of salt. This study aims to determine the performance of a solar seawater distillation design with a semi-batch system by combining a fin-type absorber plate and a triangular prism cover. This design is equipped with a reflector and absorber plate, which has a surface area of 0.3969 m^2 with a volume capacity of seawater that can be accommodated in a basin of ±24 liters. It uses a knockdown system on its components for convenience in the process of maintenance and repair. The test results show that the highest freshwater product produced is 0.245 liters and the quality of distilled water meets the standards for consumption. The highest efficiency of solar seawater distillation test results was 8.032% on the third day of testing with an average solar radiation intensity of 805.076 W/m^2. The efficiency of solar distillation of seawater is strongly influenced by the intensity of solar radiation received by the distillation apparatus.

Keywords: fin-type absorber, performance, semi-batch system, solar seawater distillation, triangular prism cover

1. Introduction

The population of Indonesia continues to increase, from 266.79 million people in 2018 with a population growth rate of 1.34% per year during 2010–2017 [1]. Along with this population growth, clean water consumption is increasing, and there is a need for more clean water sources. Limited availability of clean water sources is often found on the coast, and around 15.32% of administrative areas at villages in Indonesia are located in coastal areas [2]. Although rainwater can be used for community needs, it is difficult to obtain during the dry season. Therefore, efforts are needed to ensure the availability of clean water apart from relying on groundwater and rainwater, such as processing seawater into clean water [3, 4].

The method that is often used to process seawater into clean water is desalination. Desalination is the process of distilling clean water or separating salts dissolved in seawater to a level that is safe for community use [5–7]. Current desalination technologies are thermal and membrane-based. Membrane desalination uses a semipermeable membrane to separate the salt content in seawater to obtain freshwater [8, 9]. However, the process is quite expensive as it requires high energy. An alternative desalination method is to utilize solar energy as a heat source, called solar-powered distillation [10]. The advantages of using solar energy include unlimited availability and easy use [11, 12]. In addition, the use of solar energy as a heat source can cut costs when compared to thermal desalination, which uses electricity or fuel [13, 14].

In general, the solar distillation of seawater uses absorber plates with a flat shape due to their simple construction, but the efficiency is still low [15]. One study [16] designed and tested a solar distillation of seawater with a variety of corrugated absorber shapes, resulting in a higher evaporation rate than flat absorbers. Another study [17] tested the fin and wavy absorber shape on the solar distillation of seawater, resulting in higher fin type plate productivity, namely, 41% compared to 21% with a surface area of 1 m^2.

In addition to the shape of the plate, the shape of the solar distillation of the seawater cover may be considered. In general, the material used is transparent glass. In [8], a single slope type solar distillation of seawater that was designed and tested with a surface area of a 1 m^2 reservoir produced a solar distillation of seawater efficiency of 42% with seawater and 37% efficiency using saltwater. Then, [18] conducted a study with a two-type distiller with a sloping glass surface with a reservoir surface area of 0.9 m × 0.7 m with a tilt angle of 30°, resulting in a solar distillation of seawater efficiency of 31.63% with a water depth of 2 cm in the reservoir. Another type is the pyramid-shaped cover and triangular prism designed by [19], where the distilled water produced is 0.5 liters/day for a pyramid shape and 0.9 liters/day for a triangular prism, respectively.

Against this background, further research is needed on the solar distillation of seawater in order to utilize the advantages of each type of solar distillation that already exists. We combine the shape of the absorber plate with a triangular prism cover equipped with a reflector on the side solar distillation of seawater, which functions to increase the solar radiation that enters the distillation room. This solar distillation of seawater is also designed to use a knockdown system on its components to make the maintenance and repair process more convenient. The distilled water quality is compared with the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017 [20].

2. Materials and Methods

Design of solar distillation of seawater. There are three main parts of the solar distillation of seawater: the cover, reservoir, and holder. The cover is an important component of the solar distillation, located at the top, and it functions as a condensation site and a component to minimize heat loss from the absorber plate to the environment. The condensation process changes the water vapor to water droplets and falls, following the slope of the cover, into the water catchment gutter.

The cover material chosen in this study is transparent glass with a thickness of 5 mm because the price is cheaper than other materials such as acrylic, polyethylene, and tempered glass. The choice of glass thickness is based on research conducted by [21], which states that the efficiency of the solar distillation using a cover glass with a thickness of 5 mm is greater than the use of cover glass with a thickness of 3 mm or 8 mm. Transparent glass has a good solar heat transmission capability, which is 86%.

The solar distillation cover is made in the form of a triangular prism with an open and close system that is supported by a wooden frame. The cover is designed with a length of 78 cm, width of 60 cm, and height of 16 cm with a slope of the cover glass of 25°. The selection of the cover glass slope is based on [22], which states that a tilt angle of 25° results in more distilled freshwater than angles of 35° and 55° because the distance between the plates absorber to the cover glass is closer, leading to a faster evaporation process and more distilled water. The cover glass in the form of transparent glass is connected to the storage channel, which is located on the side and the inlet on the back of the cover. The cover is equipped with a storage pipe that functions as a place to collect water from the condensation process. The catchment pipe is made of polyvinyl chloride with a size of ¾ inch, and this part is connected to the outlet. The design of the solar distillation cover is shown in Figure 1(a), while the details of the size of the solar distillation cover are shown in Figure 1(b).

The design of the reservoir is based on the drinking water needs of a family of four. The need for drinking water per day is 2 liters per person, so 8 liters of water are needed to meet the drinking needs of a family. The efficiency of existing distillators reaches 21%–42%. If it is assumed that the designed distillator has an efficiency of 35%, then ±24 liters of seawater are needed as input to produce a freshwater output of 8 liters. The reservoir functions as a container for seawater in the distillation process, containing the absorber plate, inlet, outlet, and cover. The material for the reservoir must have high absorption, low reflectivity, and low conductivity.

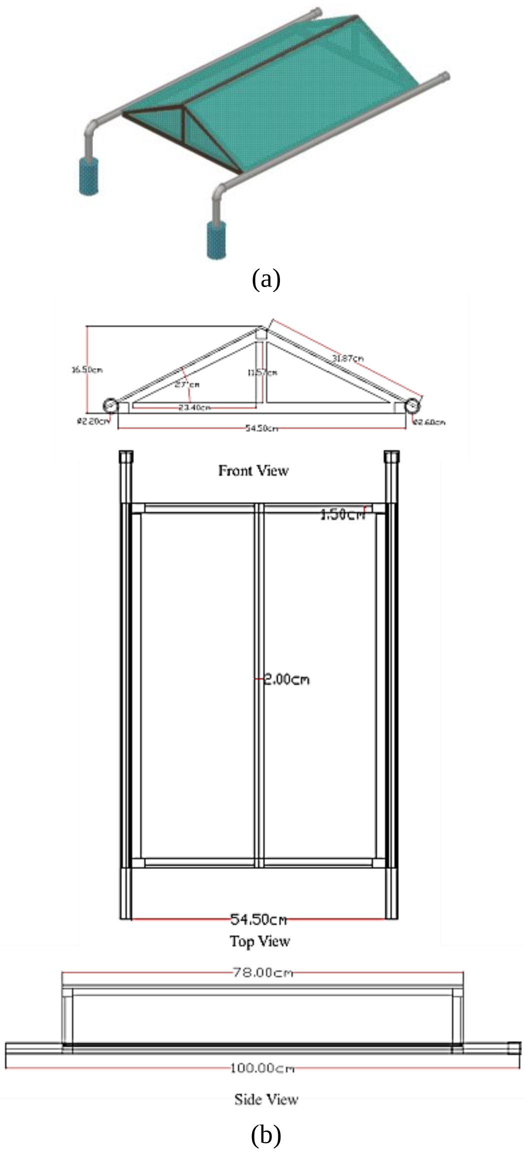


Figure 1. Design of the Cover of Solar Distillation

The absorber plate in this study was designed in the shape of a fin with the aim of expanding the water evaporation section so that it would affect the rate of evaporation. Aluminum with a thickness of 1 mm was chosen as the material because it has high conductivity, can resist corrosion to saltwater, and has a low cost. The size of the reservoir covered by an absorber plate is 73.5 cm long, 54 cm wide and 7 cm high. The determination of these dimensions is based on the assumptions described above that ±24 liters of water is needed as input.

In the reservoir section, there are 7 fin-shaped bulkheads made of aluminum with a thickness of 1 mm and a height of 4 cm fins. The selection of the number of fins, fin thickness, and fin height is based on [9], which states that using 7 fins is more effective than using 14 fins because the shadow area increases with the number of fins so that productivity decreases.

An increase in fin thickness causes a decrease in productivity and efficiency because the amount of absorbed radiation intensity decreases. Furthermore, the use of a higher fin height results in greater productivity and efficiency because the magnitude of the absorbed solar radiation intensity can increase the heat transfer rate of the absorber plate to the seawater beside it such that the water temperature increases and the evaporation process occur.

The absorber plate is coated with silicon or black paint with the aim of increasing heat absorption, and this part is designed to be detachable, making it easier for the maintenance process. The outside of the reservoir is covered. The cover material is wood with a thickness of 2 cm, and the cover dimensions are 78 cm long, 60 wide, and 9 cm high. Wood was chosen because it is an insulating material that can retain heat on the absorber plate. The insulation material has low conductivity.

The distillator is equipped with a reflector connected to the outside of the reservoir. The purpose of using a reflector is to increase the solar radiation that enters the distillation chamber. The reflector used is in the form of a flat mirror that can reflect light at the angle of incidence of light. The design of the reservoir for the distillator is shown in Figure 2(a), while the details of the size of the reservoir for the distillator are shown in Figure 2(b).

The holder functions as a support for the reservoir and the distillator cover. Bayur wood is used as the material because it is relatively low cost and can support good loads. Bayur wood has specifications for strength class II–III and durability class IV [23]. The distillator stand is designed to be 86 cm long, 60 cm wide and 20 cm high. The stand design is shown in Figure 3(a), while the details of the distillator stand sizes are shown in Figure 3(b).

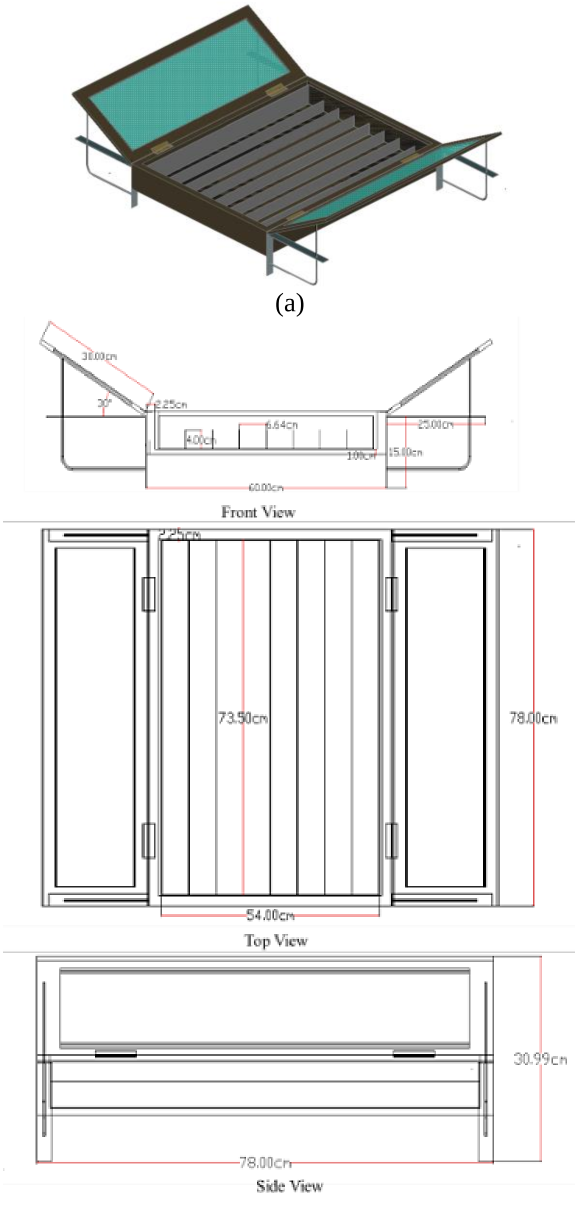


Figure 2. Design of the Reservoir for Solar Distillation

Performance testing of solar distillation. Performance testing was conducted for the function of each component. The performance test was carried out at the parking lot north of the Engineering Building, Politeknik Negeri Jember. The testing process was carried out for three days starting at 8:40 a.m. – 3:00 p.m. West Indonesian Time. At this stage, a sample of 3 liters of seawater was used with a filtering process to remove dirt or particles in the seawater. In the distillator testing, data were collected to calculate the efficiency of the distillator and analyze the quality of distilled water. The results of the performance test were used to calculate the useful energy of the collector, the useful energy of distillation,

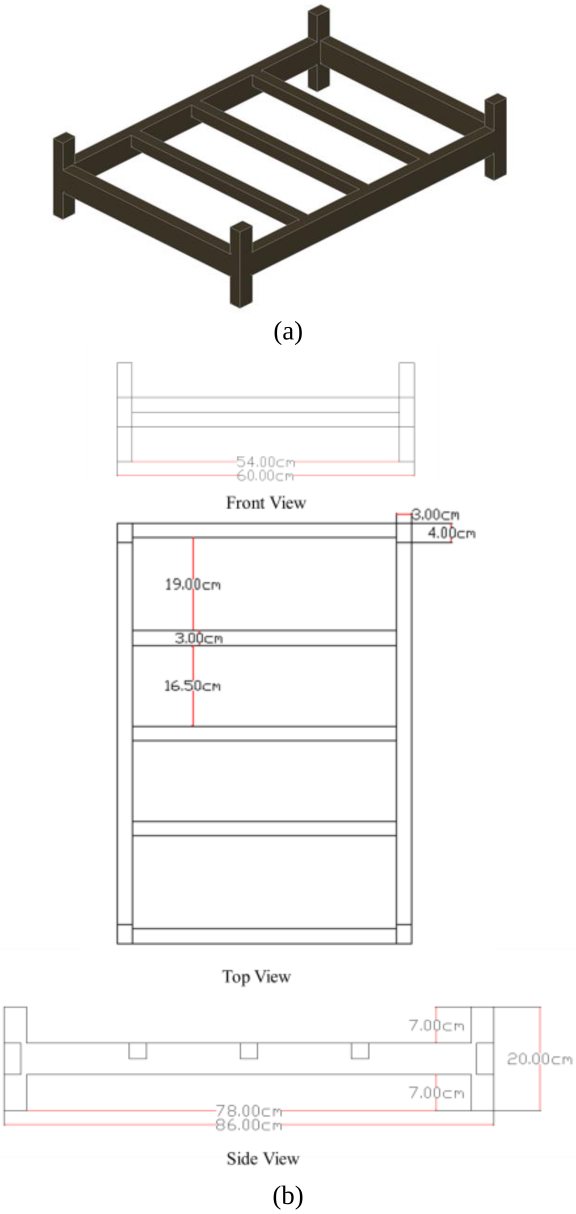


Figure 3. Holder of Solar Distillation

the efficiency of the distillation, and the volume of water produced. The data included solar irradiation, ambient temperature, water temperature in the distillator; cover glass temperature, volume of freshwater produced, and wind speed.

Solar irradiation was measured using a polarimeter with an accuracy ±1W/m^2, wind speed with an anemometer with an accuracy ±0.01 m/s, and the volume of freshwater distilled with a measuring cup with an accuracy ±0.001 liter. For temperature measurement, the data logger Hioki Memory HiLogger LR8401-20 was used. The data logger is an electronic tool that is useful for recording data over a predetermined time and is integrated with the sensors and instruments. The LR8401-20 series data logger logs data at a speed of 10 ms across 30 channels simultaneously. It uses a microprocessor and internal memory that functions as a data recorder through sensors (LR8400E15-85E, 2018). The sensor is a K TP-01 thermocouple probe with a maximum operating temperature of 300 °C (572 ° F) with an accuracy of ±0.4% (Lutron electronic).

Distilled water quality test. The distilled water quality test was carried out with the test limits, namely, physical and chemical parameters [24]. The test was based on the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitation Hygiene Needs, Swimming Pools, Solus per Aqua, and Public Baths as shown in Table 1. The distilled water quality test was carried out using a Total Dissolved Solid (TDS) meter, organoleptic and pH meter [20].

The water quality testing process was carried out by comparing the water from the distillation process with seawater with reference to quality standards with the following test procedures:

a. Physical parameters

Color testing was done using organoleptic tests that use the sense of sight. Total dissolved solids were tested using a TDS meter. Temperature testing was carried out using a thermometer. Taste testing is carried out by organoleptic tests that use the sense of taste. Sufficiently distilled seawater and freshwater samples were used. The odor test was done as an organoleptic test using the sense of smell. Seawater and freshwater samples were used.

Table 1. Physical and Chemical Parameters in Environmental Health Quality Standards and Water Health Requirements for Sanitation Hygiene Needs

Required Parameter	Unit	Quality Standard (maximum value)
1. Physical		
Color	-	Colorless
Total Dissolved Solid	mg/L	1000
Taste	-	Tasteless
Odor	-	Odorless
Salinity	%	-
2. Chemical		
Potential of Hydrogen (pH)	mg/L	6.5 – 8.5

The salinity test (salt content) was carried out using a refractometer. The samples used were seawater and distilled freshwater.

b. Chemical parameters

In accordance with Table 1, for chemical parameters, only a pH test is needed on the distilled water using a pH meter.

Data analysis

a. Useful Energy Collectors

The useful energy of the collector is the heat energy produced by the absorber plate to heat the seawater located above it during the process. The useful energy of the collector can be calculated using Equation (1) [25]:

$$Q_u = Q_{in} - Q_{out}$$
$$Q_u = (\alpha . I_T . A_c . \tau) - (U_L . A_c . (T_p - T_a)) \quad (1)$$

where:
Q_u = collector's useful energy (Watt)
I_T = solar irradiation (W/m^2)
A_c = area of absorber plate (m^2)
α = absorption coefficient of the plate absorber
τ = transmissivity coefficient of cover (glass)
U_L = coefficient of total heat loss ($W/m^2.°C$)
T_p = temperature of the absorber plate (°C)
T_a = environmental temperature (°C)

Not all of the heat transfer processes can be converted into other energy because heat loss occurs. The heat loss in the solar collector occurs at the top, bottom, and sides of the solar collector. In general, the side heat loss of the solar collector is negligible because the contact area of the absorber plate to the side is very small compared to the area of the upper and lower absorber plate. The heat loss coefficient can be calculated using Equation (2) [25]:

$$U_L = U_t + U_b \quad (2)$$

where:
U_L = total heat loss coefficient($W/m^2.°C$)
U_t = upper heat loss coefficient ($W/m^2.°C$)
U_b = lower heat loss coefficient ($W/m^2.°C$)

The upper heat loss coefficient value can be calculated using Eqs. (3) to (7) [25]:

$$\frac{1}{U_t} = \frac{1}{h_{wind} + h_{r-o}} + \frac{t}{k}(\text{glass}) + \frac{1}{h_{r-i} + h_{c-i}} + \frac{t}{k}(\text{water}) \quad (3)$$

where:
t = thickness (m)
k = thermal conductivity($W/m.°C$)
h_{r-i} = inner radiation coefficient
h_{c-i} = inner convection coefficient
h_{wind} = wind convection coefficient
h_{r-o} = coefficient of outer radiation

Radiation coefficient in (h_{r-i})

$$h_{r-i} = \frac{\sigma\,(T_w^4 - T_c^4)}{\left(\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_c} - \right)(T_w - T_c)} \quad (4)$$

where:
σ = Stefan-Boltzmann constant (W/m^2K^4)
ε_w = emissivity of water
ε_c = emissivity of glass
T_w = water temperature (°C)
T_c = glass surface temperature(°C)

Convection coefficient in (h_{c-i})

$$h_{c-i} = 1 - 0{,}0018\,(\overline{T} - 10)\,\frac{1{,}14.\Delta T^{0{,}31}}{L^{0{,}07}} \quad (5)$$

where:
$\overline{T}$ = average temperature (°C)
ΔT = the temperature difference between the absorber plate and the cover glass (°C)
L = water level in the reservoir(m)

Wind convection coefficient (h_{wind})

$$h_{wind} = 5{,}7 + 3{,}8.v \quad (6)$$

where v is the wind speed (m/s)

Outer radiation coefficient (h_{r-o})

$$h_{r-o} = \frac{\varepsilon.\sigma\left(T_c^4 - T_{sky}^4\right)}{T_c - T_{sky}} \quad (7)$$

where T_{sky} is 0.0552 ($T_a^{1,5}$)
T_a = ambient temperature(°C)
T_{sky} = sky temperature (°C)
T_c = glass surface temperature (°C)
ε_c = emissivity of glass

Thermal resistance of the glass: R (glass) $= \frac{t}{k}$

where:
t = thickness of glass(m)
k = thermal conductivity of glass ($W/m.°C$)

Water thermal resistance: R (seawater) $= \frac{t}{k}$

where:
t = sea level in a basin (m)
k = thermal conductivity of seawater($W/m.°C$)

The lower heat loss occurs by conduction from the absorber plate to the lower panel, while the convection, and radiation losses are negligible because their value is smaller than the conduction losses.

The lower heat loss coefficient value can be calculated using Equation (8) [25]:

$$\frac{1}{U_b} = \frac{t}{k}(\text{insulator}) \tag{8}$$

where:

t = thickness of insulation material(m)
k = thermal conductivity of the insulating material (W/m.℃)

b. Useful energy distillation
The useful energy of distillation is the energy needed to evaporate seawater in a reservoir to produce freshwater products in the distillation process. The useful energy of the distillation process can be calculated using Equation (9) [25]:

$$Q_{u-d} = \frac{m_k \times h_{fg}}{t} \tag{9}$$

where:
Q_{u-d} = useful energy distillation(Watt)
m_k = distilled water products per day (kg)
h_{fg} = latent heat of evaporation (kJ/kg)
t = time of testing (s)

c. Efficiency of distillation
The efficiency of the distillation device is the ratio of heat energy to evaporate seawater in a container to produce freshwater products against the amount of solar radiation received by the distillation device through the absorber plate within a certain time. The efficiency of the distillation device can be calculated using Equation (10) [25]:

$$\eta_d = \frac{m_k \times h_{fg}}{A_c \times I_T \times t} \times 100\% \tag{10}$$

where:
η_d = efficiency of distillation(%)

d. Experimental uncertainty analysis
The uncertainty in the experimental result is calculated according to Equation (11) proposed by [27]:

$$W_R = \left[\left(\frac{\partial R}{\partial X_1}W_1\right)^2 + \left(\frac{\partial R}{\partial X_2}W_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial X_n}W_n\right)^2\right]^{1/2} \tag{11}$$

Let W_R be the uncertainty in the result and W_1, W_2,…W_n be the uncertainties in the independent variables. Suppose a set of measurements is made to measure the "n" number of experimental variables. These measurements are then used to calculate some desired result of the experiment (R). If the relationship between the measured parameters and the result is known and the uncertainties of the measurement of each quantity are further known, then the error, or uncertainty in the result W_R is calculated according to Equation (11).

For daily productivity, $m_k = f(h)$ where h is the depth of water in the calibrated flask. Following Equation (11), the total uncertainty for the daily condensate production can be written as Equation (12):

$$W_{m_k} = \left[\left(\frac{\partial m}{\partial h}W_h\right)^2\right]^{1/2} \tag{12}$$

Following Equation (11), the total uncertainty for the daily efficiency can be written as Equation (13):

$$W_{\eta_d} = \left[\left(\frac{\partial \eta_d}{\partial m_{k1}}W_{m_k}\right)^2 + \left(\frac{\partial \eta_d}{\partial I_T}W_{I_T}\right)^2\right]^{1/2} \tag{13}$$

The total uncertainty in determining the hourly productivity and daily efficiency was estimated by Eqs. (12) and (13), respectively.

3. Results and Discussion

Testing of the solar seawater distillator using seawater samples located in the parking lot of the Engineering Building Politeknik Negeri Jember, which was carried out with three repetitions over three days. Based on the results of observations and measurements of research parameters, the environmental temperature, seawater temperature in the basin, water vapor temperature, outer cover glass temperature, and temperature of the absorber plate varied every day depending on the weather and the intensity of solar irradiation received by the distillator.

For instance, the environmental temperature ranged from 26.20–39.55 °C. Environmental temperature directly affects the temperature of the outer cover glass; as a result, when the ambient temperature drops, the cover glass temperature also drops and vice versa. Then, the temperature of the outer cover glass ranged from 30.67–57.30 °C. Environmental temperature affects the temperature of the outer cover glass but does not directly affect seawater temperature because seawater is a good heat store [26]. The seawater temperature does not immediately drop when the ambient temperature drops.

Next, the seawater temperature ranged from 28.90–60.05 °C. The ambient temperature also has no direct effect on the absorber plate temperature. The temperature on the absorber plate has a direct effect on seawater temperature; that is, when the absorber plate temperature drops, the seawater temperature also drops and vice versa. This is because the temperature absorbed by the absorber plate affects the temperature of the seawater in the basin. Finally, the absorber plate temperature ranged from 28.90–58.77 °C.

Analysis of the quantity of distilled water. The quantity of distilled water to time is called the rate of evaporation. With 3 liters of seawater in a distillator basin with a maximum capacity of 24 liters, an average of 0.164 liters of distilled water was produced with an uncertainty of daily productivity ±4.3%. The test was repeated three times in three days in the same time (6 hours, 20 min), from 08:40 a.m. until 3:00 p.m. The first test on July 28, 2020 produced 0.092 liters of water. The second test, carried out on July 29, 2020, produced 0.155 liters of water. The third test, was carried out on July 30, 2020, produced 0.245 liters of water.

The freshwater produced by this distillator is water vapor from seawater that is held by a glass cover, which is then passed through a pipe to the outlet and collected in a freshwater reservoir. The lowest amount of freshwater was measured on the first day and the highest on the third day, meaning that the amount of freshwater produced continued to increase over the three-day period. Figure 4 graphs the quantity of distilled water over the three days.

The quantity of distilled water is influenced by the evaporation process of seawater in the evaporation chamber and the condensation process that occurs on the distillator cover glass. The evaporation process is better if the temperature of the seawater in the evaporation chamber is increasing because the higher the temperature of a liquid, the faster the movement of the molecules in it will result in collisions between molecules, which causes a faster mass transfer process from liquid to gas [26]. The condensation process is influenced by the temperature of the glass covering the evaporating chamber. The steam that is formed changes its phase to a liquid when it hits objects with lower temperatures. The lower the cover glass temperature, the faster the condensation process occurs. Compared with [17], the solar distillation device made has a maximum basin volume of 288 liters. When 50 liters of seawater were used, the average distilled water was 3.08 liters for the conventional type, 3.7 liters for the finned type, and 3.6 liters for the corrugated type.

Solar radiation that hits the distillator is converted into heat energy where the amount of solar radiation affects the volume of freshwater produced. The solar irradiation

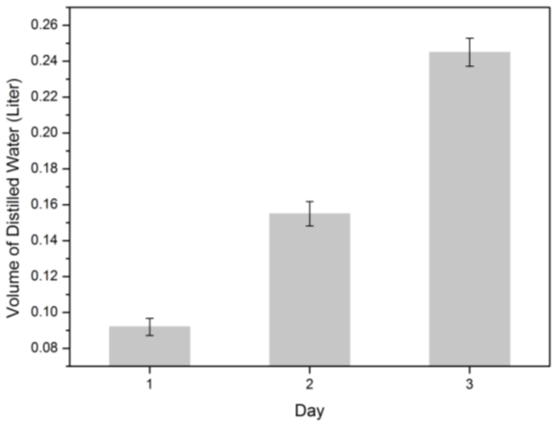


Figure 4. The Quantity of Distilled Water in Three Days

measured during the testing process tended to fluctuate due to weather conditions at the test location. The average solar irradiation for on the first day was 700 W/m^2. It was 660 W/m^2 on the second day and 805 W/m^2 on the third day.

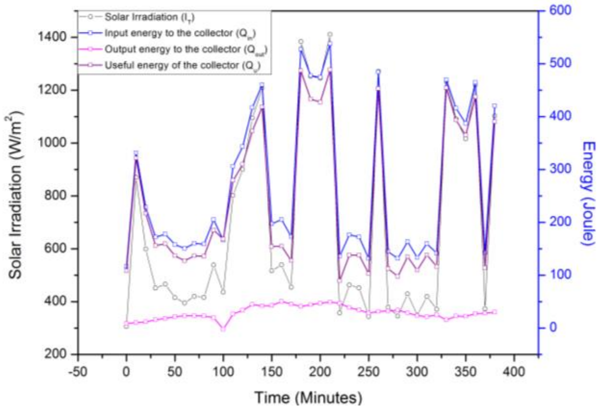
This solar irradiation greatly affected the performance of the distillator. Solar irradiation, which tends to increase during the testing process, causes the temperature in the evaporation chamber to also increase and causes the seawater temperature in the reservoir to increase and undergo the evaporation process. The water vapor then sticks to the cover glass and undergoes condensation.

The obstacles encountered during the testing process included when solar irradiation was initially high and succeeded in increasing the temperature in the evaporation chamber and resulting in the evaporation process; then solar irradiation decreased. The water vapor that sticks to the cover glass cannot undergo condensation, and the water vapor that has successfully undergone condensation becomes water droplets unable to descend through the slope of the glass. When irradiation does not increase for a long time, the water droplets, and steam adhering to the cover glass tend to disappear.

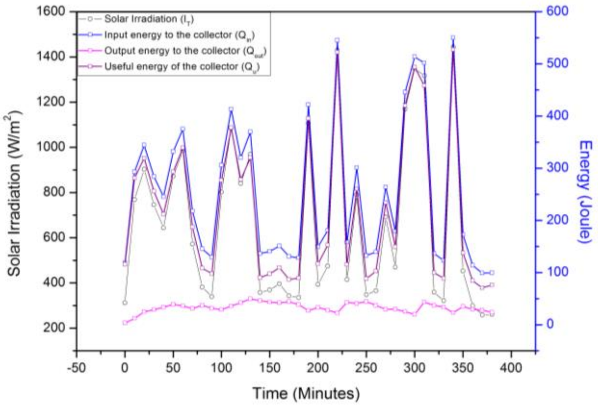
Useful energy analysis of collectors. The useful energy of the collector is the heat energy produced by the absorber plate to heat the seawater located above it during the process. The useful energy of the collector (Q_u) is influenced by the amount of input energy (Q_{in}) and output energy of the collector (Q_{out}). Energy entering the collector (Q_{in}) is the amount of energy that can be absorbed by the absorber plate, which is generated from solar irradiation. The energy entering the collector is influenced by the area of the absorber plate, the absorption of the absorber plate and the intensity of solar radiation. The higher the value of the influencing factors is, the higher the energy entering the collector is. Meanwhile, the energy out of the collector is influenced by the coefficient of total heat loss, the area of the absorber plate, and the difference in temperature of the absorber plate with the environment. The higher the coefficient of total heat loss in the distillation device is, the higher the energy out of the collector is, and this affects the amount of useful energy of the collector in the distillator. Figure 5 shows a graph of the relationship of useful distillation energy, input energy, and output energy to solar irradiation.

Useful energy analysis in the distillation process. The useful energy of distillation is the energy needed for the process of evaporating seawater in a reservoir to produce freshwater products in the distillation process. The highest useful energy of distillation occurred on the third day of distillator testing, which was 25.731 Joule during the one-day testing process. The average useful energy of the distillator in three days of testing was 17.287 Joule with an uncertain value of daily useful energy for the distillator of ±4.6%.

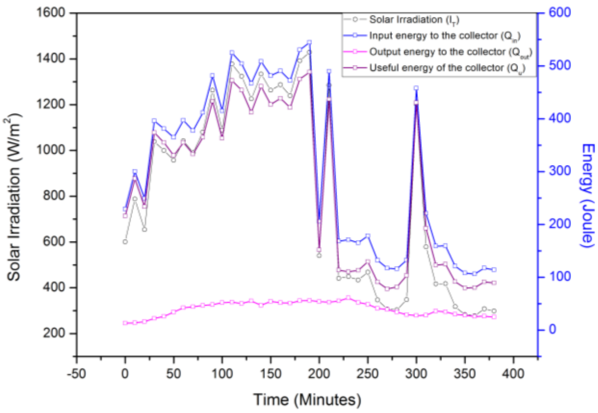
The difference in the value of useful energy for distillation is influenced by the number of freshwater products produced per day, where the freshwater product is water vapor produced from the evaporation process of seawater in a reservoir within the test time span of the distillation device. A graph of the useful energy of distillation is shown in Figure 6.



(a) First day testing: Tuesday, July 28, 2020.



(b) Second day testing: Wednesday, July 29, 2020.



(c) Third day testing: Thursday, July 30, 2020.

Figure 5. The Relationship between Useful Energy of Distillation, Input Energy, Output Energy, and Solar Irradiation

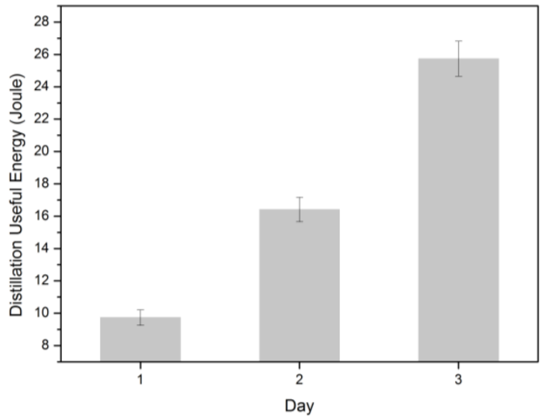


Figure 6. Distillation Useful Energy Comparison

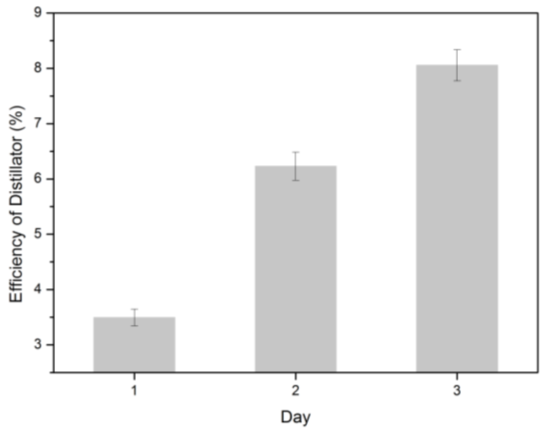


Figure 7. Distillator Efficiency Over Three Days

Distillator efficiency analysis. The efficiency of the distillation device is the ratio of heat energy to evaporate seawater in a container to produce freshwater products against the amount of solar radiation received by the distillation device through the absorber plate within a certain time. A graph of the comparison of distillation efficiency is shown in Figure 7.

Distillator efficiency values tend to increase from the first to the third day of testing. The highest distillator efficiency was on the third day of distillator testing with an efficiency of 8.03% and 0.245 liters of freshwater produced. The distillator average efficiency for the three days was 5.93% with an uncertainty daily efficiency of ±3.9%. The difference in the value of the distillator efficiency in each test is strongly influenced by the intensity of solar radiation received by the distillation device. The higher the intensity of solar radiation received, the higher the rate of evaporation of seawater in the container. This means that freshwater production is also high and has an impact on the efficiency of the distillation device. In [17], the average efficiency of the distillator is 38.3%. This difference in the efficiency value is quite large because the area and volume of the basin are larger and solar irradiation is more stable.

Table 2. Testing the Quality of Distilled Water in Physical and Chemical Parameters

Required Parameter	Unit	Distilled Water
1. Physical		
Color	-	Colorless
Total Dissolved Solid	mg/L	1270
Taste	-	Tasteless
Odor	-	Odorless
Salinity	%	0 %
2. Chemical		
pH	mg/L	7.6

Distilled water quality. Testing the quality of distilled water was carried out by testing physical and chemical parameters. The test was based on the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitation Hygiene Needs, Swimming Pools, Solus per Aqua, and Public Baths. The results of water quality testing are shown in Table 2.

For the parameters tested, the distilled water met the standards for consumption, but a filtering process still needs to be done to reduce the dissolved solids involved in the distilled water.

4. Conclusions

Based on the results of the study and analysis, the following are summarized: a) Solar seawater distillation may be designed by combining the shape of a fin-type absorber plate with a triangular prism cover equipped with a reflector with an absorber plate surface area of 0.3969 m^2 with a volume capacity of seawater that can be accommodated in a container of ±24 liters. b) This distillator uses a knockdown system on its components, which aims to provide convenience in the maintenance and repair process. c) Testing of the solar seawater distillator produces the highest freshwater product of 0.245 liters, and the quality of the distilled water meets the standards for consumption. However, a filtering process still needs to be done to reduce dissolved solids. d) The highest efficiency of the distillator test results was 8.032% on the third day of testing located in the parking lot north of the Engineering Building Politeknik Negeri Jember with an average solar radiation intensity of 805,076 W/m^2.

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