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Sea Water Distillation Design Using Renewable Energy for Drinking Water

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The increase in drinking water needs in Ternate City is ttriggered by very rapid population growth. Population growth has resulted in the conversion of forests into housing which has resulted in reduced water catchment areas. In the end, several locations experienced a decline in water quality from fresh to brackish. To overcome the decline in the volume and quality of clean water, a plan is being made to distill sea water into fresh water. The method used in this research is the experimental method. Solar desalination is a process where solar energy is utilized to putify the fresh water from saline/brackish water for drinking purposes, in charging of the batteries, research laboratories. Experimental results with a distillation flow area of 325 cm with an average volume of 43.7 ml. Tests with a distillation drain area of 650 cm produced 76.0 ml of fresh water. Experiments with a distillation flow area of 975 cm produced an average of 106.3 ml of fresh water. The effectiveness of distillation occurs at the widest drainage. The price of fresh water per milliliter is IDR 1.41 cheaper than bottled water, namely IDR. 6.66 per milliliter. The results of research on the salinity of salt water to fresh water show that the salinity of salt water is 35 ppt, while the salinity of distilled water is 0, this shows that the result of distillation is fresh water that can be consumed.

Keywords: Saltwater, distillation, renewable energy, freshwater

1. INTRODUCTION

Ternate City is one of the cities in North Maluku Province with a land area of 250.85 km2 (BPS Malut, 2006) whose economic growth is higher than other cities or regencies in North Maluku. The increase in development led to reduced water infiltration so that in some villages well water tends to become brackish or salty. Regarding the supply of freshwater, there are several theories how to purify or desalinate saltwater into freshwater, one of which is by evaporation or distillation. Desalination is a process of extracting freshwater from seawater or brackishwater. Distillation method is widely used because the system is very simple, namely brackish- or seawater is heated and then the fresh steam is taken as a result of purification. The disadvantage of this system is the use of a lot of energy to heat water to obtain evaporation. This research overcomes the weaknesses of this distillation system by utilizing sunlight energy converted into electricity, then converted into heat that can heat the water in the distillation system. The potential use of renewable energy as a clean friendly source of energy to operate small-scale desalination units in remote communities has received increasing attention in recent years. The coupling of renewable energy sources and desalination such as solar, wind and geothermal energy with desalination systems holds great promise for tackling water shortage and is a potential for viable solution of climate change and water scarcity.

An effective integration of these technologies will allow countries to address water shortage problems with a domestic energy source that does not produce air pollution or contribute to the global problem of climate change due to lower conventional energy consumption and lower gas emissions. Meanwhile, the cost of desalination and renewable energy systems are steadily decreasing, while fossil fuel prices are rising and its supplies are depleting. The desalination units powered by renewable energy systems are uniquely suited to provide water and electricity in remote areas where water and electricity infrastructures are currently lacking.

The desalination process by distillation is the separation of freshwater by changing the water phase, while the membrane process is the separation of freshwater from saltwater or brackish water by applying pressure and using a reverse osmosis membrane or by electrodialysis [1], [2]. Distillation is an important method of separation and purification of volatile liquids. The process involves evaporating the liquid by heating, followed by condensing the vapor into a liquid, called distillate [3], [4]. There are various ways of distillation, namely simple distillation, fractional distillation, low pressure distillation, water vapor distillation, and microscale distillation [5], [6]. In practice, the choice of distillation procedure depends on the nature of the liquid to be purified and the nature of the impurities present in it [7], [8], [9].

There are various types of equipment used in the design of seawater distillation into freshwater. Solar panel is a device consisting of several solar cells that are connected and designed to convert the received sunlight energy into electrical energy. Some of the functions of the solar charge controller are (a) regulating the current for charging the battery, avoiding overcharging and overvoltage, (b) regulating the current released/taken from the battery so that the battery is not fully discharged or overload and (c) monitoring battery temperature [10], [11], [12], The specifications of solar charge controller that must be considered are a) direct current (DC) rated voltage 12/24 volts, b) rated DC current, for example 5 ampere, 10 ampere, or more, and c) full charge capacity (charging the battery until the battery is completely full) and low voltage cut (stopping electricity supply to the load because the battery is at the lowest voltage) [13], [14], [15]. A battery is an energy storage device that is charged by DC current coming from a solar panel. In addition to storing DC energy, batteries also functions to convert chemical energy into electricity [16].

2. METHODS

The method used to design the distillation of seawater into freshwater is an experimental method [17]. The research was carried out three times, namely 1) analysis of research potential, 2) distillation prototype demonstration, and 3) technology system. The details about the research roadmap can be seen the following figure [18].

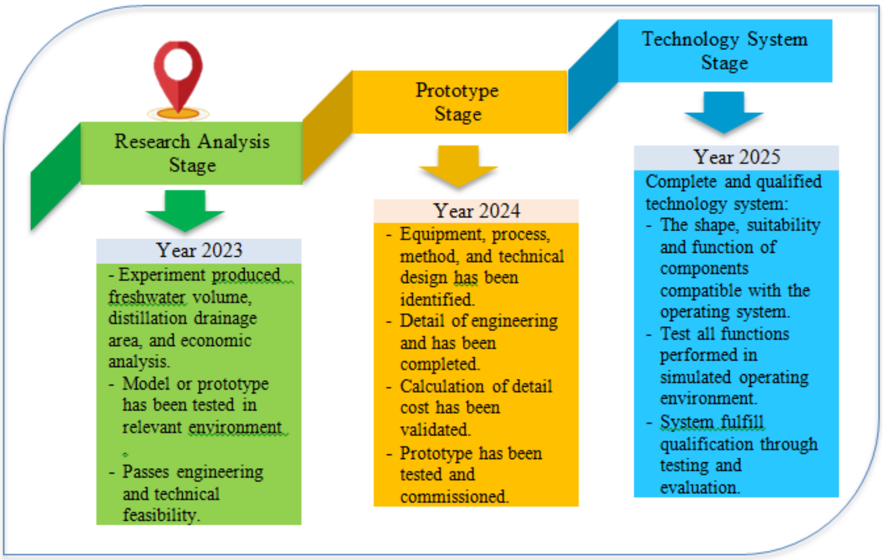

Figure 1. Research roadmap

The research flowchart for the initial stage of the seawter distillation into freshwater can be seen in the following picture.

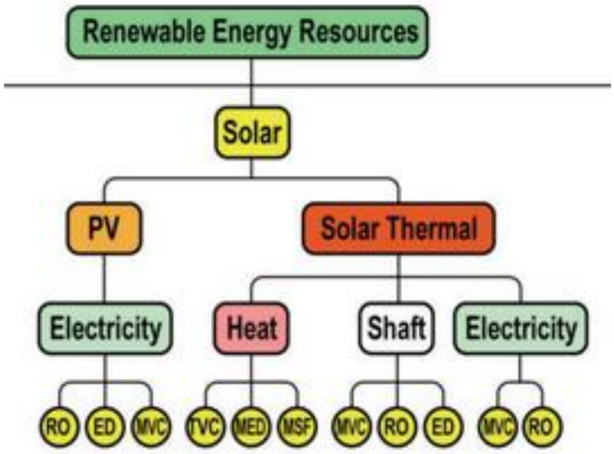

Figure 2. Combination of renewable energy systems with distillation research

Various distillation processes have been developed, some of which are currently under research and development. The most widely applied and commercially proven technologies can be divided into two types:

phase change thermal processes and membrane processes, and, as shown in Figure 2, both encompass a number of different processes. In addition, there are the alternative technologies of freezing and ion exchange which are not widely used. All are operated by either a conventional energy or renewable energy to produce fresh water.

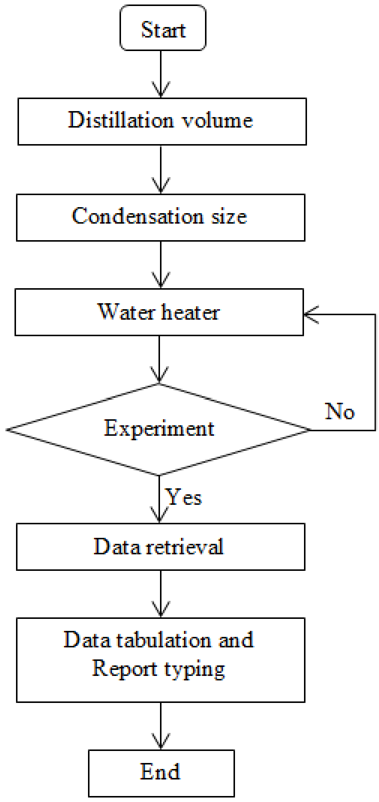

Figure 2. Research flowchart for the analysis stage of distillation of seawater into freshwater

The majority of desalination systems that use a renewable energy source can be divided into three categories: wind, solar [photovoltaics (PVs) or solar collectors] and those that use geothermal energy. These renewable energy sources can be coupled with thermal distillation systems as to produce water. In some cases, these systems are connected with a conventional source of energy (e.g. local electricity grid) in order to minimize the variations in the level of energy production and consequently water production. The experimental stages for distilling seawater into freshwater are as follows.

Stage 1. Measurement of seawater salinity,
Stage 2. Determining seawater volume,
Stage 3. Set water heater power,
Stage 4. Determining the area of the distillation drain,
Stage 5. Heating the distilled water (freshwater volume is recorded when the water boils) for 30 minutes each.
Stage 6. Recording freshwater volume for the first 30 minutes for distillation drain area 320 cm^2.
Stage 7. Recording freshwater volume for the second 30 minutes for distillation drain area 320 cm^2.
Stage 8. Recording freshwater volume for the third 30 minutes for distillation drain area 320 cm^2.
Stage 9. Recording freshwater volume for the first 30 minutes for distillation drain area 650 cm^2.
Stage 10. Recording freshwater volume for the second 30 minutes for distillation drain area 650 cm^2.
Stage 11. Recording freshwater volume for the third 30 minutes for distillation drain area 650 cm^2.
Stage 12. Recording freshwater volume for the first 30 minutes for distillation drain area 975 cm^2.
Stage 13. Recording freshwater volume for the second 30 minutes for distillation drain area 975 cm^2.
Stage 14. Recording freshwater volume for the third 30 minutes for distillation drain area 975 cm^2.
Stage 15. Measure freshwater salinity.
Stage 16. Calculate the effectivity of each distillation drainage size.
Stage 17. Calculate economic value of the distillation freshwater compared to bottled freshwater.

3. RESULTS AND DISCUSSION

Research on the design of seawater distillation into freshwater has been carried out using seawater taken from the coastal area of Fitu Village. Experiments were conducted using three variables: seawater volume (ml), boiling time (minutes), and distillation drainage area (cm^2).

3.1. Experiment of Drainage Area over Freshwater Volume

To obtain the volume of freshwater, experiments were performed by changing the drainage area. For more details about the volume of freshwater produced, see Table 1 below.

Table 1. Experiments of drainage area over freshwater volume

Experiment	Drainage area 325 cm^2	Drainage area 650 cm^2	Drainage area 975 cm^2
Experiment 1	44	77	99
Experiment 2	43	75	110
Experiment 3	44	76	110
Total	131	228	319
Average freshwater volume (ml)	43.7	76.0	106.3

The experiment was performed using 1,500 ml seawater, salinity 35 ppt, boiling time 30 minutes, and each test was carried out three times (total time 90 minutes). The first test with a distillation drain area of 325 cm^2 with an average volume of 43.7 ml. The second test with distillation drain area of 650 cm^2 produces freshwater 76.0 ml. The third experiment of 975 cm^2 distillation drain area produced an average of 106.3 ml of freshwater. The experimental results showed that the effect of distillation drainage area significantly affect the volume of freshwater produced.

The graph of the relationship between the area of distillation drain to the volume of fresh water produced can be seen in the following figure.

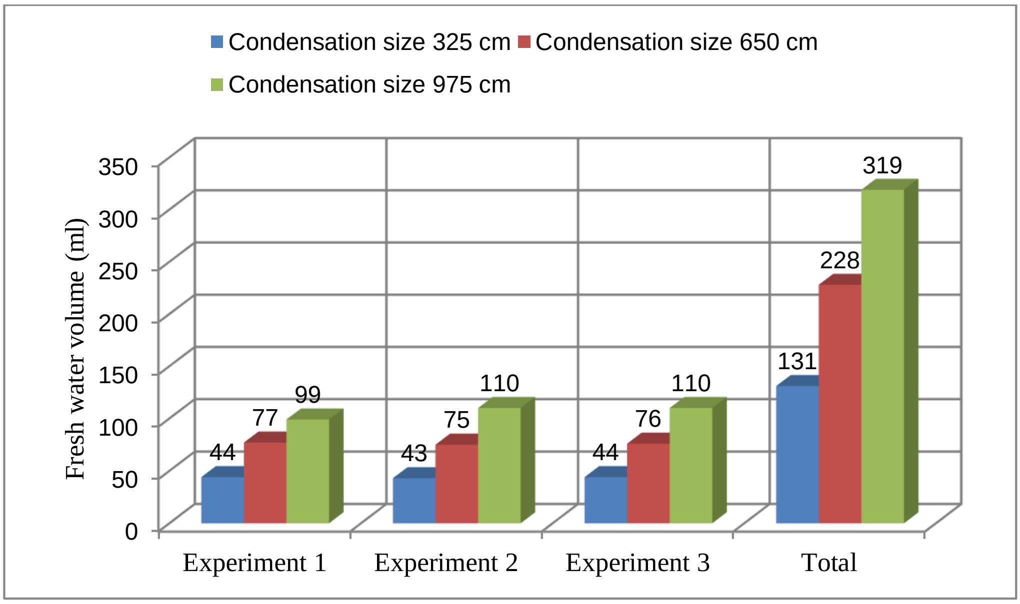

Figure 3. Graph between freshwater produced to distillation drain area

The graph above shows that the volume of fresh water produced is directly proportional to the area of the distillation drain. The distillation drain area of 975 cm^2 or the widest produces a total of 319 ml of fresh water or an average of 106.3 ml.

3.2. Effectivity and Distillation Losses Over Catchment Area

The test results show that the amount of seawater converted into freshwater with the volume of water that evaporates can be calculated using the following formula.

$$ed = s + t \tag{1}$$
$$ld = a - ed \tag{2}$$

where:

a = Seawater volume (ml)
s = Residual seawater volume (ml)
t = Freshwater volume produced (ml)
ed = Distillation effectivity (ml)
ld = Distillation losses (ml)

Area of distillation catchment 325 cm^2
a = 1.500 ml,
s = 950 ml,
t = 131 ml
ed = 950+131 =1081 ml
ld = 1.500 – 1.081 = 419 ml

Area of distillation catchment 650 cm^2
a = 1.500 ml,
s = 950 ml,
t = 228 ml
ed = 950 + 228 =1.178 ml
ld = 322 ml

Area of distillation catchment 975 cm^2
a = 1.500 ml
s = 950 ml
t = 319 ml
ed = 950 + 319 = 1.269
ld = 1.500 – 1.269 =231 ml

The experimental results show that the wider the distillation filter, the higher the volume of freshwater produced.

3.3. Salinity Test Results

Salinity or salt content contained in the distillation results is a variable studied. The results of the salinity testing is shown in Table 2 below.

Table 2. Salinity testing results

Testing	Seawater		Salinity	
Testing 1	35	0	0	0
Testing 2	35	0	0	0
Testing 3	35	0	0	0

Gradual or repeated testing is performed to determine the salt content in seawater with the assumption that evaporation during the first 30 minutes of gram levels is lower than the next 60 minutes and 90 minutes. The salinity of seawater before distilled process is 35 ppt, while the salinity after distilled is 0. This shows that the distilled water is consumable.

3.4. Technical analysis

The electric power of the heater used is 150 watts and operated for 90 minutes or 1.5 hours. It is assumed that the price of electricity per kWH is IDR. 2,000.00. The price details can be seen in Table 3 below.

Table 3. Electricity used in experiment 3

Power (watt)	Duration (jam)	Energy (kWh)	Price per kWh (IDR)	Ditilled water price (IDR)
150	1.5	0.225	2,000.00	450.00

The electrical power of the heater is 150 watts, operated for 1.5 hours, and the total energy consumed is 0.225 kWh. The electrical energy price per kWh is IDR 2,000.00, so the money that must be paid is IDR. 450.

4.5. Economic analysis

The price of mineral water is increasingly expensive, this is due to production and distribution costs. The comparison of prices for mineral water and distilled water can be seen in Table 4 below.

Table 4. Price comparison for mineral water and distilled water

Price of bottled mineral water			**Distilled water price**		
Mineral water (ml)	Price/bottle (IDR)	Price/ml (IDR)	Distilled water (ml)	Price (IDR)	Price/ml (IDR)
600	4,000.00	6.67	319	450.00	1.41

Table 4 above shows the calculation of the production price of distilled water of IDR 1.41 per milliliter, much cheaper than bottled mineral water of IDR 6.67 per milliliter.

4. CONCLUSION

The results of research on the design of saltwater distillation into freshwater showed that the area of distillation drainage significantly affect the volume of freshwater produced. Freshwater salinity is 0 ppt, this indicates that distilled fresh water does not contain salt. Distilled freshwater is much cheaper than bottled freshwater. The use of renewable energies for desalination becomes a reasonable and technically mature alternative to the emerging and stressing energy situation and a sustainable solution for water scarcity. Currently, coupling desalination plants with clean environment-friendly energy resources is a pressing issue due to the dramatic increase in fossil fuel prices and the harmful impacts of burning fossil fuels, such as environmental pollution and climate change

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