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EVALUATION OF CLEAN WATER PRODUCTIVITY IN DISTILLATION EQUIPMENT WITH ZINC-COATED STEEL BASINS

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Water is a very important component for humans in everyday life. The need for clean water is currently increasing, especially for people living in coastal areas, this is because the water still contains salt and smells. Solar radiation energy is an alternative energy source. However, its use has not been utilized optimally, as science develops, solar energy has become an object of research, and one discovery of the use of solar energy is distilling sea water using solar energy.

Under these conditions, research will be carried out on clean water distillation equipment, to see and analyze the productivity of water produced by clean water distillation equipment that uses zinc-coated steel tanks. The results obtained do not rule out the possibility that this distillation device with a zinc-coated steel tub can be used to reduce the problem of lack of clean water, especially as it is known in coastal areas where solar energy sources are not only abundant but also very abundant, but the availability of clean water is limited. still very minimal. So that existing solar energy sources can be used as an energy source in distillation equipment to produce clean water.

From these results, the productivity of the water produced can be seen that solar radiation has a great influence on increasing the efficiency of the distillation equipment. Then the results of condensate water production and efficiency produced by a tool with a one-sided cover glass are greater than a tool with a double-sided cover glass

Keywords: solar energy, solar radiation, sea water, productivity, efficiency, zinc coated steel, cover glass, clean water

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1. Introduction

Water is a very important component for humans in everyday life. The need for clean water is currently increasing, especially for people living in coastal areas, this is because the water still contains salt and smells. Solar radiation energy is an alternative energy source. For humans who live in tropical areas and are located on the earth's equator, solar radiation energy can be used as an energy source because it is abundant. However, its use has not been utilized optimally, as science develops, solar energy has been used as an object of research, and one discovery of the use of solar energy is distilling sea water using solar energy. With the development of technology, researchers are trying to study the productivity of condensate water in seawater distillation equipment. This can overcome the problem of lack of clean water in coastal areas, so that coastal communities can meet their need for clean water every day. Seawater distillation is a process of purifying seawater from its existing content, namely salt. The process used is a physical separation process between water and salt content by evaporating sea water which is then cooled so that the steam changes form into fresh water.

2. Literature review and problem statement

Indonesia is a country located below the equator, so Indonesia has a tropical climate. What makes regions in Indonesia have a large source of solar energy is solar heat. Apart from that, Indonesia is an archipelagic country, which has many islands and many coastal areas. One of the main problems often experienced by people living in coastal areas is the lack of clean water. This is because much of the clean water available has been mixed with sea water or brackish water, making the water unusable in everyday life. As time progressed, researchers carried out a series of studies to produce tools that could be used to convert salt water or brackish water into clean water that could be used in everyday life, and could even be consumed.

The following are several studies conducted to calculate the productivity of clean water produced by basins made from different materials. The paper [1] carried out an analysis of a distillation tool to increase the efficiency of the tool and minimize costs for making the tool, so the simplest basin type solar power model was created, so that this tool was modified by increasing capillary distillation. Then in the paper [2] was carried out by designing three similar solar power distillation ponds consisting of an insulated metal box with channels, and a pyramid-shaped glass cover installed in the basin at an inclined angle (α=45°), with the average daily output results being found around 9,448 liters/day, analysis was carried out to see the performance of the distillation equipment.

The paper [3] carried out an analysis to develop and improve the performance of a solar powered distillation system, focusing on the phase change materials Potassium Dichromate ($K_2Cr_2O_7$), Magnesium Sulfate Hepta Hydrate ($MgSO_4{\cdot}7H_2O$), and Sodium Acetate (CH_3COONa) which are energy absorbing materials. And in the paper [4] an analysis was carried out to see a comparison of the performance of a dual condensation chamber solar power distillery with a conventional solar power distillery, with the results showing that the exergy efficiency of a distillery with a separate condensation chamber was 60.8 % higher than that of a conventional solar distillery.

In the paper [5] the performance of an inclined solar still with and without baffles was studied, so it was found that the yield of fresh water and water evaporation in the solar still completely depended on the water retention time with the sun's rays, and the yield of the solar still increased by 1.68 times solar still without insulation, the analysis was carried out to obtain the conclusion that the increase in yield from tilted solar stills depends on the contact time of the flowing water with the sunlight and the temperature of the absorber.

The paper [6] was carried out to analyze the temperature difference between the inner and outer glass covers of conventional basin type solar stills and low thermal inertia solar stills obtained by modifying conventional stills, and it was found that for conventional stills, the maximum temperature difference was up to 7.14 % during the day and significant in the morning and evening, then for low thermal inertia, the difference is greater up to 10.2 %. Then in the paper [7] which was a study that used a tilt type solar-powered water distillation tool, this distillation tool was analyzed so that it was found that the tool could produce an average of 0.09 m^3 of water per day.

The paper [8] used a water distillation device with a collector box with an opening area of (1×0.6) m, with the highest water distillation efficiency analysis results of 11.4 % in sunny weather. The aim of the paper [9] is to analyze and obtain portable water from almost all available sources by utilizing solar energy, the incoming solar radiation is focused on a clean water distillation unit to analyze the distilled sample, and the pH of the distilled product is 8.10±1.06, which is within the WHO limit for drinking water.

The paper [10] aims to analyze increasing the efficiency of solar energy water distillation by increasing the efficiency of the water evaporation process through controlling the inlet water flow rate. The research was carried out using experimental methods on the parameters that were varied, namely the water input rate, with the results of the research showing that the production of distilled water using The maximum microcontroller-based water rate controller is 523 % compared to the model without a water rate regulator at a water flow rate of 0.3 liters/hour, with a distillation efficiency of 66 %. And in the paper [11] an analysis was carried out on a water distillation system using a solar collector made from copper plates and colored with black thermal pigment to increase the absorption of sunlight. This tool can produce up to 486 ml of water at an interval of around 30 minutes in sunny weather conditions.

Then in the paper [12–17] an analysis was carried out to determine the effect of the shape of the glass cover on the productivity of the solar still clean water distillation tool, and observations were carried out with two treatments, namely one-sided cover glass and two-sided cover glass, with the results of the research showing that more water was produced. with a one-sided glass cover compared to a two-sided cover, namely the average amount of clean water produced in a day is 1,563.3 ml with a one-sided cover and 1,285 ml with a two-sided glass cover, and a one-sided glass cover has an efficiency of 56.34 % and the double-sided glass cover has an efficiency of 53.86 %.

From a number of studies that have been carried out by researchers and teams as described above, further research is needed on "Productivity of Condensate Water in Distillation Equipment with Zinc-Coated Steel Basins", so that evidence will be obtained regarding the distillation of clean water using solar power (solar still). Based on previous research.

In this research, experimental tests showed weaknesses in the productivity of the distillation equipment. This experimental research can only test and record the results. The results obtained are evaluated by carrying out calculations based on existing formulas. So, if there is low productivity of the distillation equipment then researchers cannot identify the real problem accurately. As is known, the productivity of a distillation device is determined by the amount of clean water produced.

As is known, the productivity of the distillation equipment can be seen from the clean water produced. Supporting factors include the condition of the open land used, where there are no obstacles such as trees or electricity poles. So that sunlight can directly reflect its rays into the distillation apparatus.

By observing the refining equipment, all events in the field can be seen clearly. Every movement, both equipment conditions and weather conditions. So researchers can easily make decisions about what to do, to solve the real problem. For example, if the weather is not good, then data collection is carried out on another day, when the weather is good, to get optimal productivity of the distillation equipment. This research will lead to the distillation of clean water for coastal communities. It is hoped that this tool can be useful for the community in meeting their daily need for clean water.

3. The aim and objectives of the study

The aim of this research is to determine the productivity and efficiency of condensate water produced by a distillation device whose basin is made of zinc-coated steel.

To achieve the set aims, the following objective have been set:

– to find out solar radiation intensity data and basin temperature data in the field;

– to find out data on the production of condensate water produced;

– to determine the efficiency of distillation equipment every day.

4. Materials and methods

4. 1. Object and hypothesis of the study

This research will use an object, namely a clean water distillation device. This tool uses a basin made from zinc-coated steel. By using glass on two sides of the tool. It is possible to see how clean water productivity is produced by a distillation device with a zinc-coated steel basin.

In this research, it is possible to see how the productivity of a distillation device whose basin is made of zinc-coated steel produces clean water. So, the temporary hypothesis adopted is that the distillation apparatus whose basin is made from zinc-coated steel is very good at producing clean water, and that the distillation apparatus whose basin is made from zinc-coated steel is not good at producing clean water. Where the productivity of the tool is assumed to be the result of clean water produced by the tool.

4. 2. Solar still working principle

The operation of *a solar still* is in principle the same as the rainwater process: namely evaporation. Water that comes from the surface of the earth is heated by sunlight and evaporation will occur. This water vapor will gather and multiply, then this collection of water vapor will experience cooling which then the water vapor will turn into water droplets that fall back to the earth's surface in the form of rain water. When the water evaporates, there is a release of the charge contained in the water, where the water vapor will leave all the impurities contained in the water. The working process of this solar still equipment imitates the natural evaporation process as seen in Fig. 1.

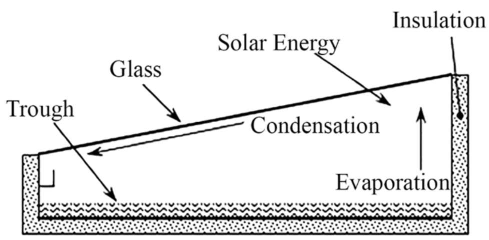

Fig. 1. Solar still type basin scheme

The absorber plate will absorb heat energy from the sun, then heats the seawater in the reservoir. The water vapor from heating will evaporate up and fill the bottom surface of the cover glass. Outside air flowing on the outside of the equipment will cool the cover glass, water vapor will condense which will then turn into water. Condensed water will flow down through the inner surface of the cover glass and then into the holding tank through a channel.

4. 3. Solar still performance

In general, the main parts of a solar still are divided into four parts, namely: cover glass, absorbent plate, insulator, and condensate drains. Solar still sketch as in Fig. 2.

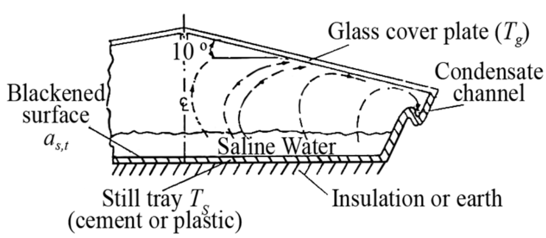

Fig. 2. Solar still sketch

To get optimal efficiency from a solar still, it is necessary to pay attention to:

– cover glass; performance will be affected by the amount of cover glass used, thickness, type of material, treatment of cover glass (coating and etching);

– absorbent plates; The performance will be affected by the material type and the color of the absorber plate;

– isolator; type and thickness will affect the performance of the solar still.

The efficiency of a solar still equipment can be defined as the ratio between heat transfer in the distillation equipment by means of condensation evaporation to the amount of solar radiation received by the solar still. The efficiency of solar still equipment will be influenced by many factors, including; the depth of water in the reservoir, the angle of inclination of the cover glass, the thermal coefficient of the absorber plate and the area of the solar still.

4. 4. Experimental installation

The research was carried out using a direct data collection method on a direct object, namely a solar still type basin with the aim of determining the ability of the equipment to produce clean water against changes in time and intensity of solar radiation. This seawater distillation tool is made with an orientation facing north, this aims to ensure that the surface of the glass cover of the tool is always exposed to sunlight from sunrise to sunset. Then an analysis of the clean water produced is carried out. The research location is in the Mechanical Engineering Parking Lot of the UNSRAT Faculty of Engineering. Fig. 3 shows the object of research is the distillation equipment.

Fig. 3. Distillation equipment

The construction of seawater distillation equipment consists of several parts, namely:

– basin or holding basin made of zinc-coated steel;
– styrofoam;
– cover glass;
– clean water channel;
– dull black type paint.

4. 5. Research procedure

This data collection was carried out from 08.00 to 13.00 with data recording done every 10 minutes. Data collection was carried out on the equipment using a one-sided coverslip. In carrying out this test, data collection is carried out on:

– basin temperature;
– cover glass temperature;
– outside air temperature;
– instantaneous solar radiation;
– wind velocity.

5. Results of the study of the productivity of distillation equipment

5. 1. Research results from collecting data on solar radiation intensity and collecting basin temperature data in the field

Observations were made for six days in July 2023, data was collected from 07.00 to 17.00 with the results obtained varying between the first day and the fifth day. Sun Intensity data during testing can be seen in Fig. 4.

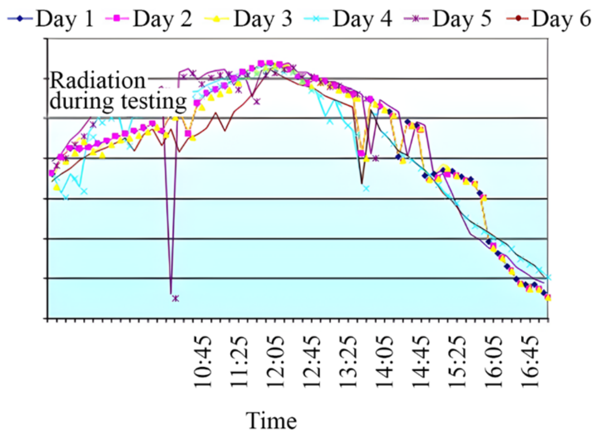

Fig. 4. Solar intensity during the test

Fig. 4 shows that the intensity of solar radiation received when data collection took place starting at 07.00 increased slowly, then reached its peak at 11.25 to 12.25 after that the received solar intensity decreased until 16.05. A significant decrease in solar intensity on day 4 was due to clouds blocking sunlight from reaching the research equipment, at 10.15, the same thing also happened on days 3 and 6.

The following is a graph of the relationship of time to basin temperature for testing at 6 days. It is known that solar energy in the form of heat received by the equipment after passing through the cover glass will be absorbed by the basin which is made of zinc-coated steel. Basin temperature will increase with increasing solar radiation and will decrease with decreasing solar radiation. Increasing the temperature of the basin will cause an increase in the temperature of the water in the basin. As the temperature of the water in the basin increases, the seawater in the basin will evaporate and this water vapor will rise which will then stick to the bottom surface of the cover glass. With the temperature difference between the water vapor that sticks to the bottom surface of the cover glass and the top surface of the cover glass, the water vapor will condense which is hereinafter referred to as the product of an equipment. Basin temperature data on days 1 to 6 can be seen in Fig. 5.

From the graphs in Fig. 5, and observations in the field, a conclusion is drawn:

– the product of an equipment is not only affected by the amount of solar radiation received by the absorber plate, but also by the temperature difference between the water vapor and the cover glass. This temperature difference will occur if there is cooling caused by wind blowing on the top surface of the cover glass. The greater the wind blowing on the top surface of the cover glass, the faster the condensation process will occur, thereby increasing the production of clean water;

– the production of clean water produced by the equipment on the absorbent plate with one-sided cover glass is more than the absorbent plate with double-sided cover glass, this is because the surface area on the one-sided cover glass is larger than the surface area of the two-sided cover glass where on both cover glasses This forms a thin layer caused by the evaporation of seawater trapped at the bottom of the coverslip.

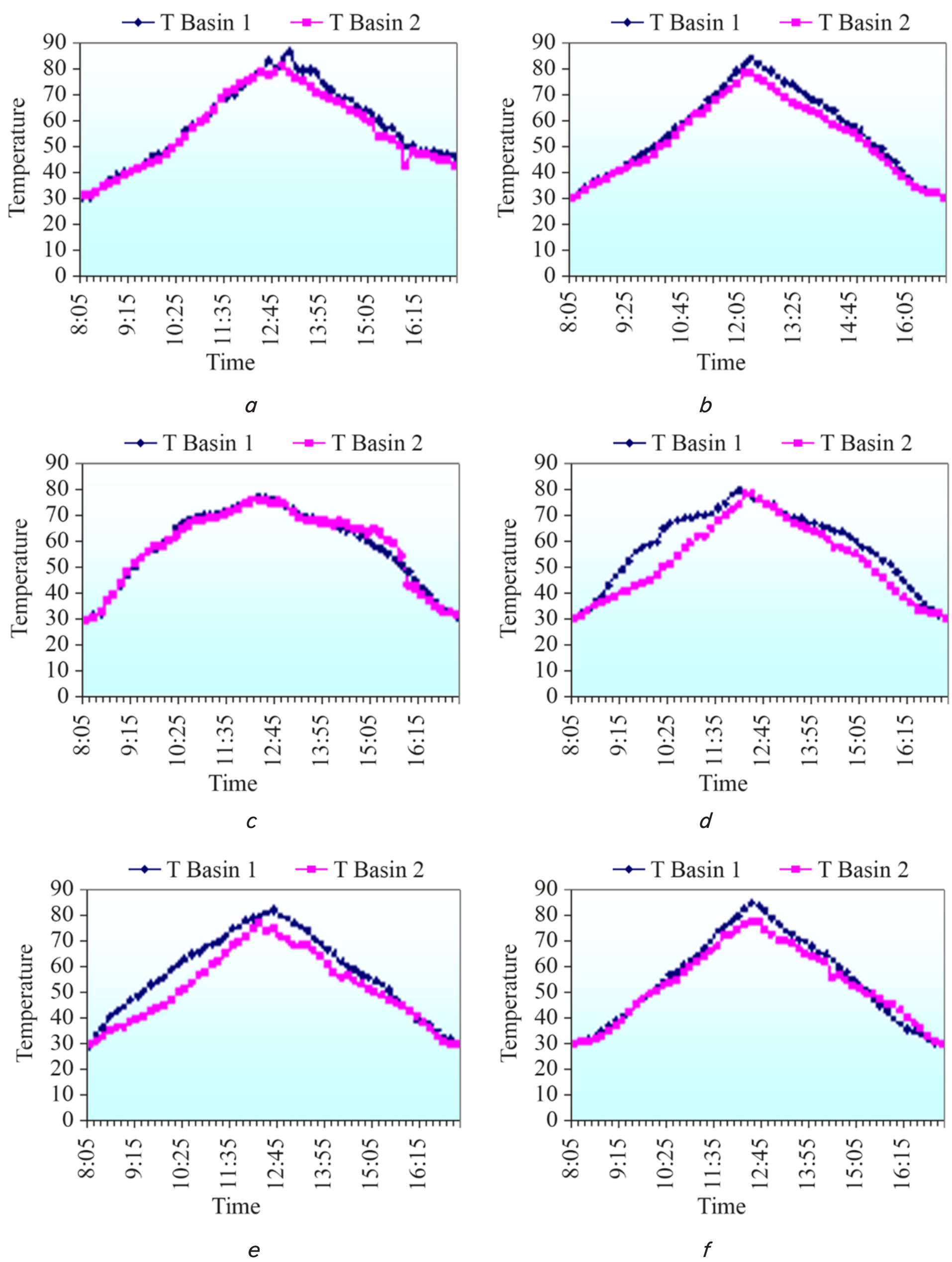

Fig. 5. Relationship between Time and Basin Temperature on: *a* – Day 1; *b* – Day 2; *c* – Day 3; *d* – Day 4; *e* – Day 5; *f* – Day 6

5. 2. Results of data processing, condensate water production

From observations in the field it was found that the production of clean water produced by equipment on absorbent plates with basins made of zinc-coated steel produces quite a lot of clean water, because the heat received by basins made of zinc-coated steel is better. Condensate water production data can be seen in Fig. 6.

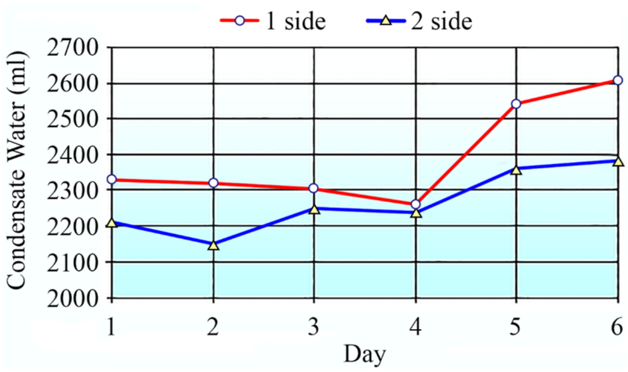

Fig. 6. Graph of condensate water production on testing for 6 Days

In Fig. 6, the average amount of condensate water produced by the one-sided coverslip is 2,393.3 ml/day and the highest amount is produced on the 6th day, which is 2,605 ml, while the two-sided coverslip only produces average condensate water. And average of 2,265 ml/day with the highest production achievement occurring on the 6th day, namely 2380 ml.

5. 3. Results of data processing, equipment daily efficiency

In practice in the field, the daily production of distillation equipment is different every day. This difference is due to the fact that the intensity of solar radiation received by the equipment is not the same, as well as the wind blows which are not the same every day. Thus the daily efficiency of equipment with a single sided cover glass varies. Daily equipment efficiency data can be seen in Fig. 7.

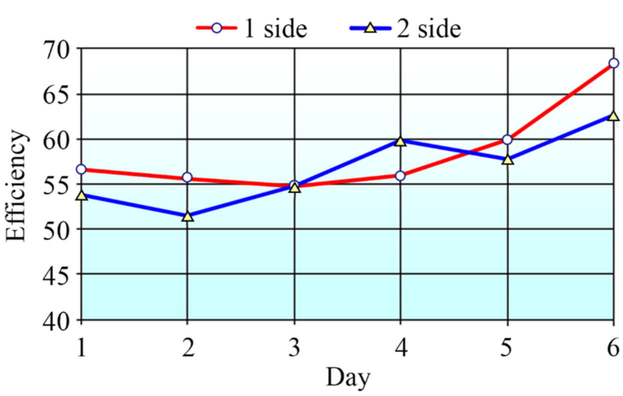

Fig. 7. Graph of daily equipment efficiency on 1 side and 2 sides in testing for 6 days

As shown in Fig. 7, there was an increase in efficiency on day 4 for the double-sided coverslip and a decrease in efficiency for one-sided coverslip, this was because the amount of water produced by the tool with one-sided coverslip decreased on the 4th day. namely 2,260 ml, this is what affects the decrease in the efficiency of the one-sided cover slip.

6. Discussion of the results that influence the productivity and efficiency of distillation equipment in producing clean water

The evaporation process occurs due to an increase in temperature in seawater, this process is due to the intensity of solar radiation absorbed by the basin which will then raise the temperature of the seawater in the basin. The intensity of solar radiation for each time is not the same. Therefore, the intensity of solar radiation will affect the amount of water vapor production in the equipment. The greater the intensity of solar radiation absorbed by the basin indicates the greater the energy received by the absorber plate which is used to evaporate seawater in the basin (Fig. 4).

The intensity of solar radiation for each time is not the same. Increasing the intensity of solar radiation will increase the production of steam in the equipment, thereby increasing the production of condensate water. A momentary or sudden decrease in the intensity of the sun occurs due to the blocking of sunlight from the research equipment by clouds.

The intensity of solar radiation received by the equipment will be absorbed by the basin, an increase in the intensity of solar radiation will be followed by an increase in the temperature of the absorber plate, with an increase in the temperature of the basin, it will cause a heating process in seawater in the basin which causes the formation of water vapor. The greater the intensity of solar radiation received by the basin, the greater the heat energy to raise the temperature of sea water in the basin, the greater the heat energy, the more water vapor will be produced (Fig. 5).

From data processing, it was found that the production of water in the distillation apparatus with a 1-sided cover glass produced an average amount of water 2,393.3 ml/day more than the distillation equipment with a 2-sided cover glass which produced an average amount of water 2,265 ml/day (Fig. 6), this is because the surface area of the cover glass on one side is wider than the cover glass on 2 sides, so that the condensation process that occurs on the cover glass on one side is more because the glass surface receives more solar energy and wind blows, also evidenced by the efficiency obtained from the two tools, namely the highest efficiency produced by a tool with a one-sided cover glass of 68.27 % which is greater than the highest efficiency of a two-sided cover glass which is only 62.50 % (Fig. 7).

Increasing the rate of evaporation can increase the vapor pressure at sea level, thus the pressure difference between the vapor at the surface of the sea water and near the cover glass will be even greater, this causes the heat transfer rate of water vapor from the sea surface to the bottom surface of the cover glass to increase.

The presence of solar radiation absorbed by the glass and water vapor attached to the bottom surface of the cover glass will cause an increase in temperature between the cover glass and the surrounding air. This will result in a natural convection heat transfer process in which heat on the surface of the cover glass will flow into the air around. The existence of a temperature difference between the cover slip and the water vapor that sticks to the bottom surface of the cover slip will cause the condensation process to occur. Due to the condensation process caused by natural cooling on the top surface of the cover glass, the vapor pressure on the bottom surface of the cover glass will decrease. The difference in pressure between the points can cause heat transfer to occur along with the mass transport of the vapor. The process of forced convection will occur due to the wind blowing on the top surface of the cover glass. And there will be a glass cooling process, which will occur a condensation process on the bottom surface of the glass which produces condensate water.

The limitations of this research are shown more in the data collection process, where weather greatly determines solar radiation and temperature in the basin. So that all obstacles can be taken into account by collecting data during the summer, so that the data obtained is more significant. Apart from that, in field conditions, it is better to do it in field conditions that are free of obstacles, such as trees and buildings. With the results of this research, it can be said that this tool can be used to meet the need for clean water in areas that lack clean water, such as in coastal communities. This research can also be developed or carried out again by changing the basin material to test the productivity and efficiency of which tool has higher productivity and efficiency values. So this research can be a benchmark for further research.

7. Conclusions

1. The amount of daily radiation causes an increase in the efficiency of the distillation apparatus. Rising sea water temperatures cause an increase in the rate of evaporation so that steam production in the basin increases.

2. The production of condensate water produced by a tool with a one-sided cover glass averaged 2,393.3 ml/day, more than the tool with a double-sided cover glass which only produced an average of 2,265 ml/day.

3. The efficiency achieved by the basin using a single-sided cover glass is 68 %, greater than using a double-sided cover glass which is only 62 %. The decrease in efficiency is affected by the wasted heat due to leaks in the cover glass connection and the cover glass holder, as well as condensate water leaks in the reservoir channel.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has associated data in a data repository.

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