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Editors • M. Seenivasan, K. Pattabiraman and A. Vadivel

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Effect of Wick Color on Solar Still Performance with Cylindrical Absorber

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Abstract. Water is a basic necessity for many lives. Water has a vital role in the human body. There are still areas where it is still challenging to get clean water. Contaminated water is hazardous, so it is not suitable for human health and other lives. One of the ways to convert contaminated water into clean water is by distillation of solar water. Solar distillation is Renewable Energy, which is an alternative to getting clean water. Basin type distillation is the most straightforward distillation tool with low efficiency. The low efficiency is due to the slow evaporation process. The research was conducted using a basin type solar distillation device, which has the lowest efficiency than the cloth absorber type. The research was conducted in an outdoor experiment with direct solar radiation intensity. The variations used in this study are variations in the type of absorber, and variations in the mass of water collected in the distillation basin. Absorber area at distillation is 0.4466 m^2. In the conventional type distillation device (Cd) with a water mass variation of 6 kg, the highest distillation yield was 2.08 L/m^2 per day with 31.1% efficiency. In the modified distillation of white cloth (Mdw) with 11 kg water mass variation, the highest distillation yield was 0.90 L/m^2 per day with 17.55% efficiency. In the distillation type modified black tissue (Mdb) with 11 kg water mass variation, the distillation result is 1.77 L/m^2 per day with an efficiency value of 27.5%.

INTRODUCTION

Clean water is a basic necessity for many lives. The demand for clean water is increasing as the human and industrial population increases. Increased are human populations and industry, resulting in an imbalance of water supply with water demand [1]. Geographical conditions make differences in water quality and quantity. Pollutants can cause a decrease in water quality. Contaminated water sources are hazardous to life. Contaminated water can cause death by diarrhea [2].

One way to treat contaminated water into clean water is water distillation. Water distillation is the evaporation of water using heat energy to be condensed. The moving water molecules on the surface of the water evaporate to gas [3]. The heat in the distillation uses solar thermal energy. Solar energy is an alternative energy source that can be used to replace fossil energy. Solar energy that used to purify water is called solar still [4]. Indonesia is located on the equator with abundant sources of solar energy. Indonesia has an average solar radiation intensity of about 4.8 kWh/m^2 [5].

The most commonly used distillations are basin types and fabric types. Basin type distillation has the most straightforward construction, but the efficiency value is lower than that of the fabric type [6]. The purpose of this study was to obtain optimal efficiency in the distillation of modified basin absorber types. The surface area, thickness, base material, surface shape, and color of the absorber significantly affect the evaporation of the distillation [7]. Thermal insulation, steam leakage, and climatic conditions such as wind speed, ambient temperature, and solar radiation significantly affect the distillation [8]. The distillation device is varied by providing 12 legged cylinders in the basin and varying the capillary fabric. Other studies have conducted variations in the absorber using a grooved absorber with

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34.7% efficiency and a fin absorber with an efficiency of 38.3% [9]. The distillation yield can be improved by optimizing evaporation and condensation [10].

RESEARCH METHODOLOGY

The research was conducted an outdoor experiment. The study was conducted for 8 hours, from 8 am till 4 pm. This study uses two configurations of basin type distillation devices. FIGURE 1 shows a distillation apparatus with a basic form (Cd), and FIGURE 2 shows a modified distillation apparatus using a cloth cylinder (Md).

FIGURE 1. Conventional Distillation Model (Cd)

FIGURE 2. Modified Distillation Model (Md)

Experiment Setup

The water reservoir is made of a multiplex with a thickness of 2.5 cm. Distillation basin measuring is 58 cm x 77 cm. The basin is painted black with the inner walls of the basin covered with aluminum foil insulation. The cover of the basin uses glass measuring 66 cm x 84 cm. The thickness of the glass used is 3 mm. The glass is installed with a slope of 15˚. The cylinder used in the Md model is a cylinder with legs. The average height of the feet on the cylinder is 3 cm. The cylinder is made of aluminum with a diameter of 6 cm and a length of 55 cm. The number of cylinders used by the Md model is 12 (FIGURE 2).

The variations in this study consisted of variations in water mass and variations in the type of absorber. The variations in the mass of water used were 6 kg, 8 kg, and 11 kg. Md models use capillary fabrics. The capillary cloth used is tissue. The tissue used is white tissue (Mdw) and black tissue (Mdb). The tissue covers the cylinder until it touches the bottom of the basin. The cylinder base is installed, not in contact with the water surface (FIGURE 3).

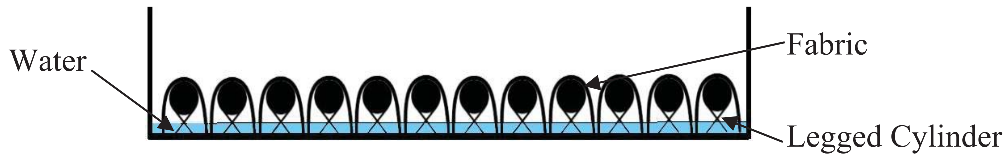


FIGURE 3. Md model cylinder arrangement

Experiment Test

Data collection is carried out every 10 seconds using sensors. The data obtained were then average per hour. The variables measured were glass surface temperature (Tc), absorber temperature (Tw), ambient temperature (Td), amount of incoming solar energy (G), etape, and volume of distilled water (v). The etape value is obtained by the principle of water pressure based on distilled water height using a level sensor. The measured variables were viewed on a laptop using Arduino microcontroller software. The efficiency of the distillation device is obtained using equation (1) below:

$$\eta = \frac{m_g h_{fg}}{A_d \int_0^t G\, dt} \tag{1}$$

where m_g is the mass of distilled water (kg), h_{fg} is the latent heat of water (J/kg), A_d is the area of distillation absorber (m^2), and G of solar thermal energy ($watts/m^2$).

RESULTS AND DISCUSSIONS

The results of the study are shown in FIGURE 4 to FIGURE 7. FIGURE 4 shows the distillation results of the Cd and Mdw models. Variation of water mass 6 kg produces the most distilled water. Cd with a water mass of 6 kg produces the most distilled water, namely 2.08 L/m^2 per day. The Mdw model at a water mass of 6 kg produces distilled water as much as 2.04 L/m^2 per day. The yield of distilled water model Cd at 8 kg water mass decreased 12.9% from the water mass of 6 kg. The yield of distilled water in the Mdw model at 8 kg water mass decreased 16.5% from the mass of 6 kg water.

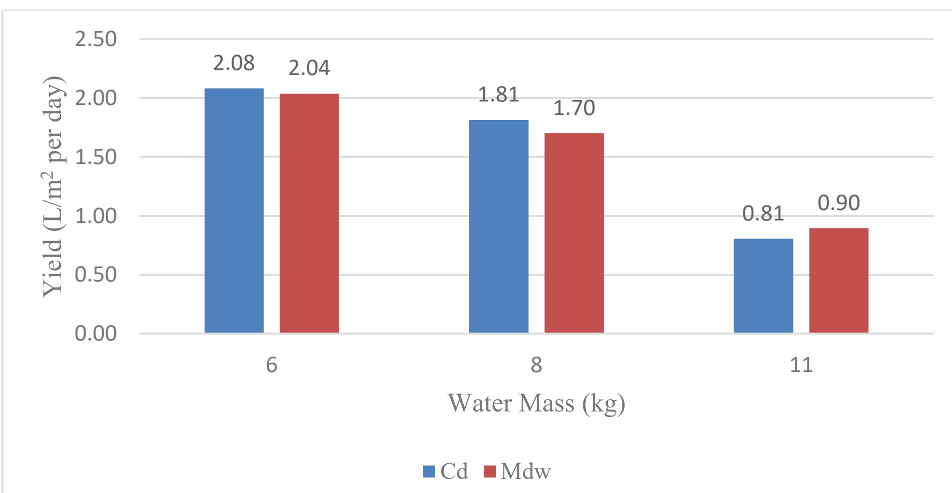


FIGURE 4. The Results of Distilled Water in Cd and Mdw Models

FIGURE 5 shows the distillation results of the Cd and Mdb models. Variations in the mass of water 11 kg had the greatest distilled. The Mdb model, with a water mass of 11 kg produces the most distilled water at 1.77 L/m^2 per day. The most distillation results for the Cd model are 1.46 L/m^2 per day at 11 kg water mass variations. The yield of distilled water model Cd at 8 kg water mass increased 52.1% from the water mass of 6 kg. The yield of distilled water in the Mdb model at 8 kg water mass increased 83.3% from the mass of 6 kg water.

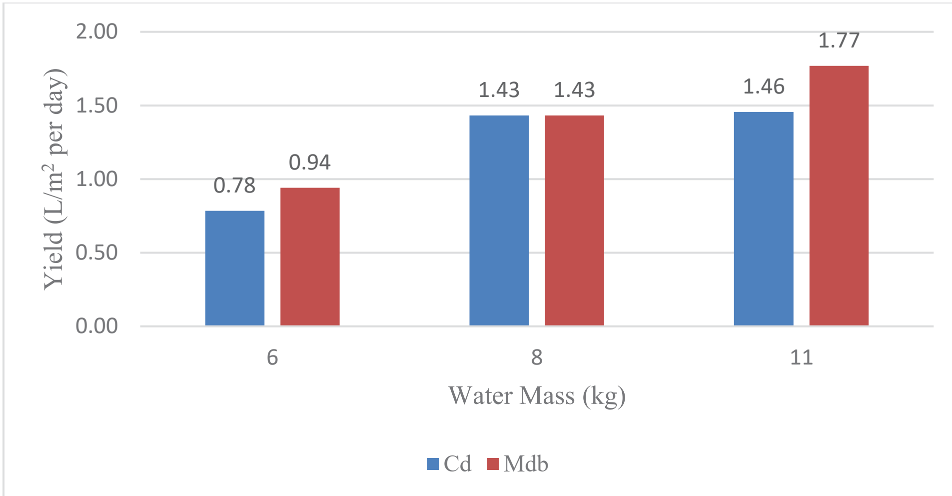
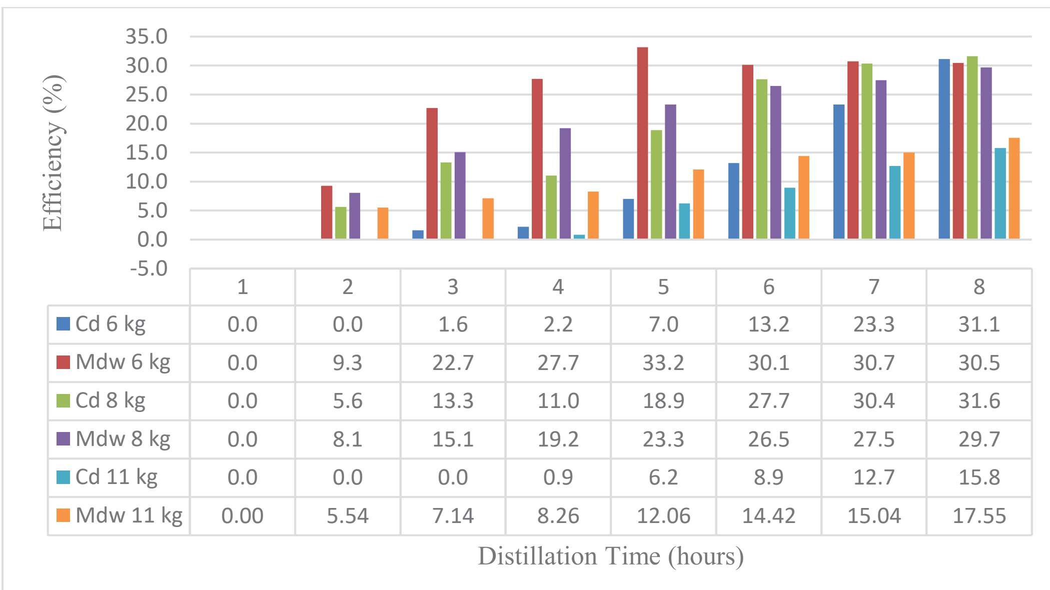


FIGURE 5. The Results of Distilled Water in Cd and Mdb Models

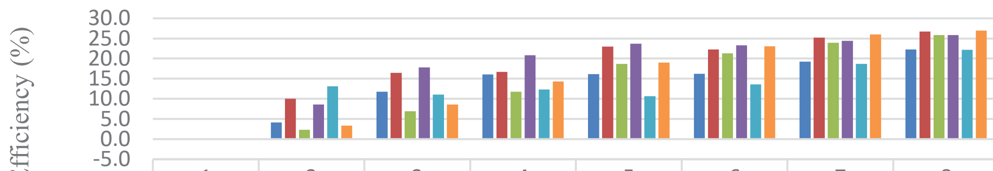
FIGURE 6 is a comparison of the efficiency of Cd and Mdw for eight hours. Efficiency per hour always increases, although the Mdw model at 6 kg water mass decreases slightly at the 6th hour. The highest efficiency is found in Cd with an air mass of 8 kg at 35.8%. Whereas for Mdw, the highest efficiency was found in the 6 kg mass variation is 30.9%. From the comparison of Mdw efficiency, it can be concluded that the greater the mass of water, the lower the efficiency value.



	1	2	3	4	5	6	7	8
Cd 6 kg	0.0	0.0	1.6	2.2	7.0	13.2	23.3	31.1
Mdw 6 kg	0.0	9.3	22.7	27.7	33.2	30.1	30.7	30.5
Cd 8 kg	0.0	5.6	13.3	11.0	18.9	27.7	30.4	31.6
Mdw 8 kg	0.0	8.1	15.1	19.2	23.3	26.5	27.5	29.7
Cd 11 kg	0.0	0.0	0.0	0.9	6.2	8.9	12.7	15.8
Mdw 11 kg	0.00	5.54	7.14	8.26	12.06	14.42	15.04	17.55

FIGURE 6. Efficiency Comparison of Cd and Mdw Models

FIGURE 7 is a comparison of the efficiency of Cd and Mdb for eight hours. The Mdb model has the highest efficiency of 27.5% at 11 kg of water mass variation. The highest efficiency model of Cd found in water 8 kg mass variation is 25.1%. From the comparison of Mdb efficiency, it can be concluded that the greater the mass of water, the greater value of the efficiency.



	1	2	3	4	5	6	7	8
Cd 6 kg	0.0	4.1	11.8	16.1	16.2	16.2	19.2	22.2
Mdb 6 kg	0.0	10.0	16.4	16.7	23.0	22.2	25.2	26.7
Cd 8 kg	0.0	2.3	6.9	11.8	18.7	21.3	23.9	25.8
Mdb 8 kg	0.0	8.6	17.8	20.8	23.7	23.3	24.4	25.8
Cd 11 kg	0.0	13.1	11.0	12.3	10.7	13.6	18.7	22.2
Mdb 11 kg	0.0	3.4	8.6	14.3	19.0	23.1	26.0	27.0

Distillation Time (hours)

FIGURE 7. Efficiency Comparison of Cd and Mdb Models

The evaporation process depends on the absorber temperature, glass temperature, and air humidity. The higher the absorber temperature, the easier it is for the water to evaporate. The lower the glass temperature, the easier it is for the water to condense. From FIGURE 5 and FIGURE 6, it can be seen that Cd has the highest efficiency value at 8 kg water mass. For the Mdw model, the highest efficiency value occurs at 6 kg of water mass. For the Mdb model, the highest efficiency value occurs at 11 kg of water mass. The distilled water results in the Cd model at 11 kg mass variation were smaller than the Mdw and Mdb models. The smaller yield is because the heat in the water travels longer, making it more difficult for the water to be evaporated. The efficiency value of the Mdb model at the eighth hour is always more significant than the Cd model. The greater the efficiency value is proportional to the distillation result. It is giving black color to the fabric results in increased emissivity of the fabric. This increased emissivity leads to better distillation yields and performance.

CONCLUSIONS

Based on the experimental and theoretical analysis of the Cd and Md distillation models, it can be concluded as follows:

- The application of black color on the fabric resulted in the distillation result in the Md model being more significant than the Cd model.
- The yield of distilled water model Cd at 8 kg water mass decreased by 12.9% from 6 kg water.
- The yield of distilled water in the Mdw model at 8 kg water mass decreased by 16.5% from 6 kg water.
- The yield of distilled water in the Mdb model at 8 kg water mass increased 83.3% from the mass of 6 kg water
- The Cd model's highest efficiency value is 33.2%, with a water mass variation of 6 kg and occurs at the fifth hour.
- The highest efficiency value of the Mdw model is 30.7%, with a water mass variation of 6 kg and occurs at the sixth hour.
- The highest efficiency value of the Mdb model is 27.0%, with a water mass variation of 11 kg and occurs at the eighth hour.

This research can be developed using cylinders with different diameters, using different cylinder/tube shapes (cross-sections other than circles, for example, squares or triangles), and using fabrics/tissue with a different thickness/capillary properties.

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