Materials Science Forum
ISSN: 1662-9752, Vol. 1057, pp 144-151

Submitted: 2021-11-22
Revised: 2022-01-05
Accepted: 2022-01-25
Online: 2022-03-31

Lauric Acid as an Energy Storage Material to Increase Distillation Solar Productivity in Indonesia

Ni Ketut Caturwati[1,2,a*], Imron Rosyadi[1,b], Yusvardi Yusuf[1,c] and Ehsan Tri Saputra[1,d]

[1]Mechanical Engineering Department Universitas Sultan Ageng Tirtayasa

[2]Energy Conversion Laboratory FT-Universitas Sultan Ageng Tirtayasa, Jl. Jend.Sudirman km.3, Cilegon 42435, Indonesia

[a*]n4wati@untirta.ac.id, [b]imron_hrs@yahoo.co.id, [c]yus_unsat@yahoo.com, [d]ehsantrisaputra@gmail.com

Keywords: Energy storage material, PCMs, Solar distillation, Lauric Acid.

Abstract. The use of energy storage materials in a solar distillation system is intended to increase condensate production by making changes in the temperature of the system change slowly, not following fluctuations in the intensity of solar radiation that can change quickly and drastically. One of the effective energy storage systems is the use of Phase Change Materials (PCMs), materials that involve a phase change process in storing and releasing heat, because the latent heat involved in the phase change process has a large enough value under constant temperature conditions so that temperature stability in the system is achieved. The choice of PCM type used in solar distillation is determined by the average temperature that can be reached by the water in the basin, which is strongly influenced by local environmental conditions. This study compares the productivity of the distillate produced by the double slope solar distillation system that uses Lauric Acid as PCM and that does not use PCM. Both studies were conducted at the same time. The optimal amount of LA that must be added to the solar distillation system to get the highest increase in condensate production value is 7.54 kg of Lauric Acid for 64.8 kg of raw water..

Introduction

Water is a very important need for human life, especially clean and healthy fresh water. Scarcity and difficulty in getting clean and suitable fresh water is a problem that has begun to appear in many places on the coast. Most of the water sources obtained are salty water. So to get clean water, it is necessary to process water that is not suitable for consumption into fresh water, clean water and suitable for consumption.

There are several methods that can be used to convert unfit water into clean water, including through the following processes: boiling, filtering, distillation and others. The boiling process will destroy the germs and bacteria present in the raw water, but the impurities are still clearly visible. On the other hand, the filtering process can separate the impurities contained in the raw water but cannot destroy the germs and bacteria present in the filtered water. Meanwhile, in the distillation process, the resulting condensate water will be free from germs, bacteria and other impurities. The process of treating water from seawater, brackish and waste water into fresh water through a distillation system has been widely proposed.[1][2][3][4]

Optimizing the use of solar energy in the water distillation process was developed through a cover glass design as proposed by several previous researchers; single and double slope glass roof designs with various angles of inclination.[5][6][7][8][9][10].

Technology of energy storage material was developed to anticipate weather changes due to fluctuations in the intensity of solar radiation that cannot be controlled. With the use of energy storage materials, the heat change process in the system becomes more stable. In general, the largest capacity of the material to store and release energy occurs during the phase change process. The material will absorb and store the energy it receives by changing the solid phase into a liquid and will release energy when the reverse phase change occurs. Several researchers have shown that the use of energy storage materials in solar distillation systems can not only increase condensate productivity but also reduce productivity.[11][12][13][14][15].

The use of energy storage materials with a phase change temperature higher than the temperature that can be achieved by the system, which depends on environmental conditions, can hamper the productivity of condensate formation. The use of Myristic Acid in solar distillation systems in Indonesia shows a decrease in condensate productivity due to high melting temperatures of Myristic Acid reaching 58 ˚C [13]. While the use of sodium thiosulfate pentahydrate as an energy storage material in solar distillation systems in Indonesia shows a significant increase in the value of condensate productivity.[14]..

The thermodynamic characteristics of PCM materials that can be used in distillation systems include [11]:

1. High enthalpy value.
2. Suitable phase change temperature.
3. High latent heat.
4. High density.
5. High thermal conductivity.

This study examines whether the use of LA as an energy storage material through phase changes can be effective in solar distillation and according to the climate in Indonesia.

Experimental Setup

The research was conducted using the same two solar distillation units where one unit was added with a pipe containing lauric acid in the raw water storage basin, while the other unit did not. Solar distillation units consists:

- Raw water storage basin : 108 cm x 60 cm and height 30 cm. Insulated side walls and bottom
- Cover glass with a thickness of 5 mm is installed with a double slope system and an angle of 45 degrees

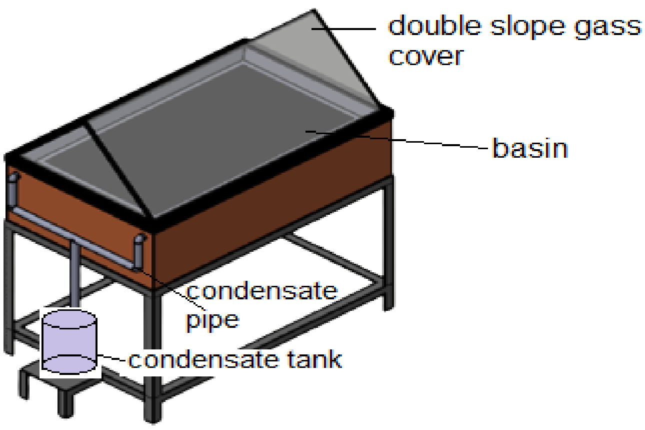


Figure 1. Solar distillation equipment.

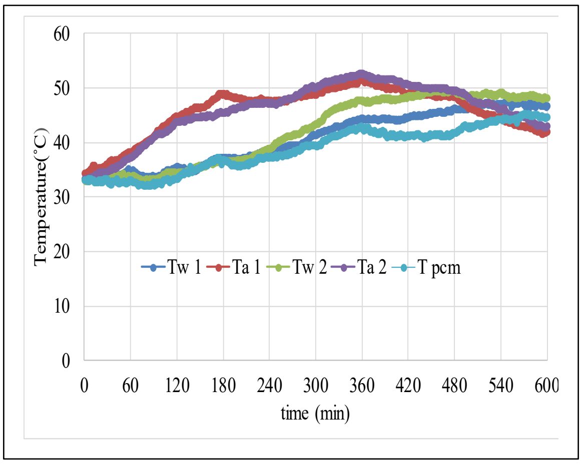
Solar distillation equipment is shown in Figure 1.Some of the measuring tools installed on the test equipment include:

1. Thermocouple connected to Arduino mega 2560 for measure :
   - T_w = Temperature of water in basin
   - T_a = Temperature of air under the cover glass.
   - T_{go} = Temperature of the outer cover glass
   - T_{gi} = Temperature of the inner cover glass
   - $T_\sim$ = Temperature of ambient air
2. Lux meter BH1750 connected to Arduino mega 2560 to measure the intensity of solar radiation.

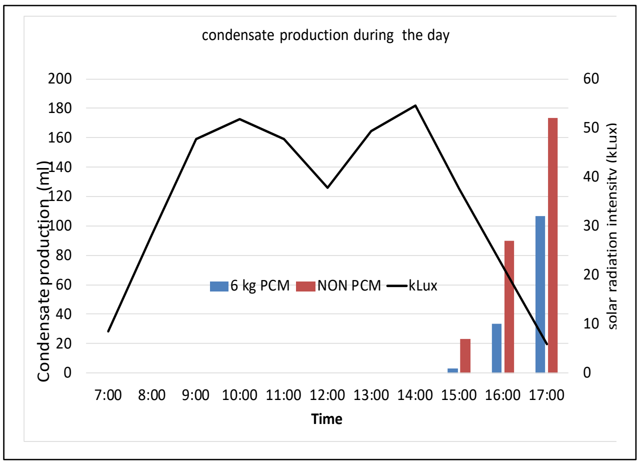
Methodology

The research was conducted simultaneously for a solar distillation system with Lauric Acid as PCM and a solar distillation system without PCM. For the same conditions, observations were carried out 3 times with observation times from 7.00 to 17.00. The amount of Lauric Acid used as PCM varies: 6 kg, 7 kg and 8 kg.

Non PCM testing versus 6 kg PCM testing. The average temperature of the 3 tests is shown in Figure 2 (a). T_{w1} is water temperature in the basin without PCM, T_{a1} is air temperature in solar distillation without PCM, and subscript 2 for system with 6 kg PCM. Figure 2 (b) shows solar radioation intensity and condensate production during the day (from 07.00 until 17.00)



(a)



(b)

Figure 2. (a) Temperature measurement for non PCM (1) and with 6 kg PCM (2)
(b) Average of solar radiation intensity and condensate production during the day.

Condensate production in 24 hours (7.00 to 7.00 the next day) for three times of data collection is shown in Figure 3. Condensate production from solar distillation system with 6 kg Lauric Acid as PCM and without PCM.

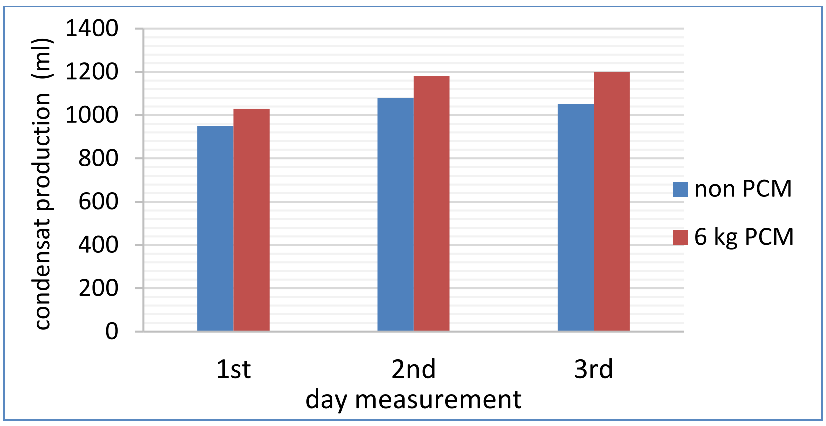
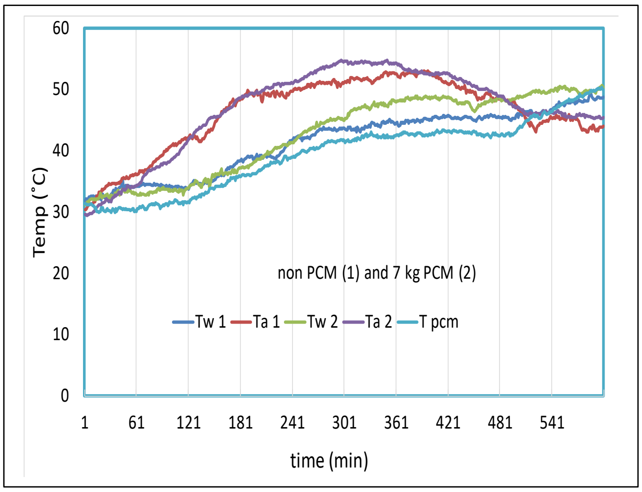
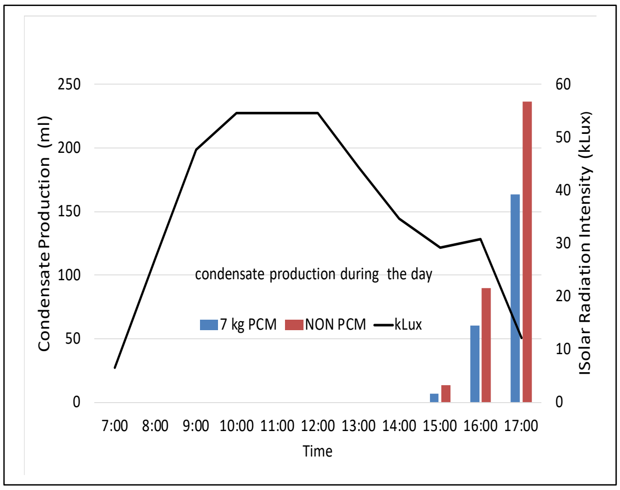


Figure 3. Total condensate production in a day and night
for solar distillation non PCM and 6 kg Lauric Acid as PCM.

Non PCM testing versus 7 kg PCM testing. The average temperature of the 3 tests is shown in Figure 4(a). T_{w1} is water temperature in the basin without PCM, T_{a1} is air temperature in solar distillation without PCM, and subscript 2 for system with 7 kg PCM. Figure 4 (b) shows solar radiation intensity and condensate production during the day (from 07.00 until 17.00)





(a) (b)

Figure 4. (a) Temperature measurement for non PCM (1) and with 7 kg PCM (2)
(b) Average of solar radiation intensity and condensate production during the day.

Condensate production in 24 hours (7.00 to 7.00 the next day) for three times of data collection is shown in Figure 5. Condensate production from solar distillation system with 7 kg Lauric Acid as PCM and without PCM.

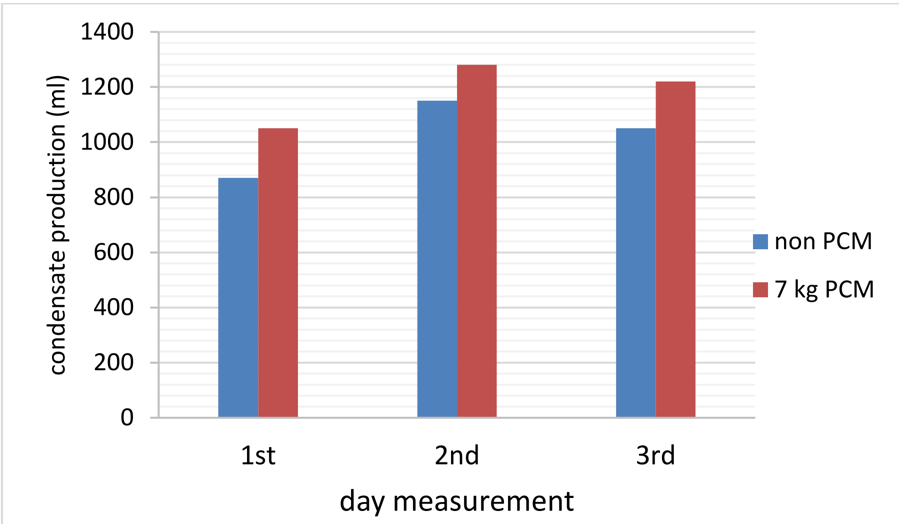
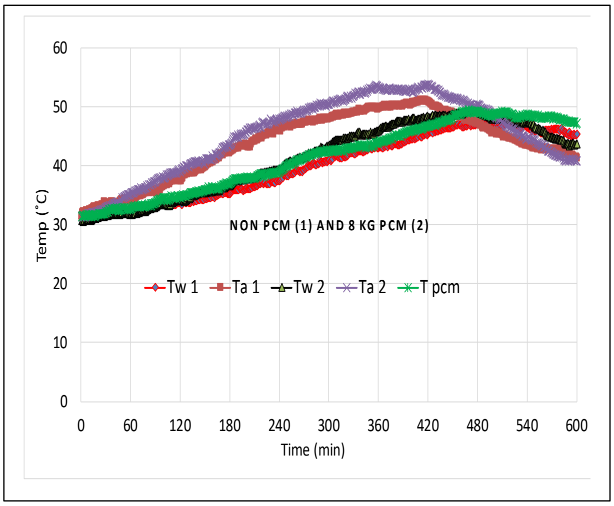
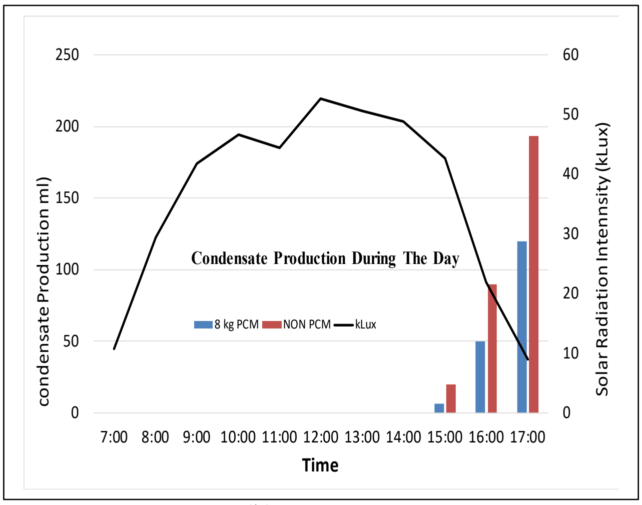


Figure 5. Total condensate production in a day and night
for solar distillation non PCM and 7 kg Lauric Acid as PCM

Non PCM testing versus 8 kg PCM testing. The average temperature of the 3 tests is shown in Figure 6(a). T_{w1} is water temperature in the basin without PCM, T_{a1} is air temperature in solar distillation without PCM, and subscript 2 for system with 8 kg PCM. Figure 6(b) shows solar radiation intensity and condensate production during the day (from 07.00 until 17.00)



(a)



(b)

Figure 6. (a) Temperature measurement for non PCM and with 8 kg PCM
(b) Average of solar radiation intensity and condensate production during the day.

Condensate production in 24 hours (7.00 to 7.00 the next day) for three times of data collection is shown in Figure 7. Condensate production from solar distillation system with 8 kg Lauric Acid as PCM and without PCM.

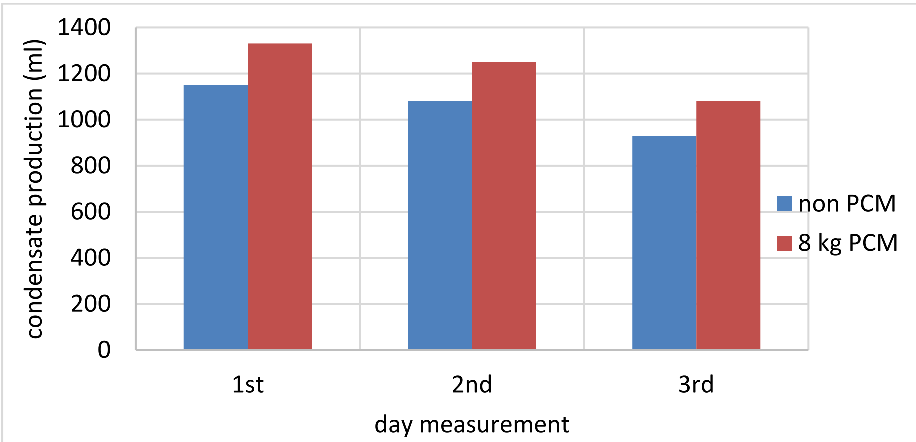


Figure 7. Total condensate production in a day and night
for solar distillation non PCM and 8 kg Lauric Acid as PCM

The results of three tests showed that the use of Lauric Acids (6 kg, 7 kg and 8 kg) as PCM in solar distillation increased the productivity of the condensate produced. Shown in Figure 3; 5 and 7.

Results and Discussions

Generaly, at the beginning of the solar radiation entering the distillation system, the temperature of the water in the basin and the temperature of inside air for the system without PCM has a higher value than the system with the addition of Lauric Acid as PCM ($T_{w1} > T_{w2}$ and $T_{a1} > T_{a2}$). This is because in the system with the addition of PCM, the solar heat received by the system is also used to heat the PCM material. The water temperature in the basin in the system with PCM addition began to look higher than the system without PCM after 11 am, and the difference was increasingly visible when the intensity of solar radiation decreased.

Condensate begins to form on average at 15.00 i.e. when the intensity of solar radiation decreases, this occurs due to the temperature in the distillation system being higher than the ambient temperature. So that the heat transfer, moves from the inside of the system to the outside of the system, which is accompanied by a condensation process on the surface of the inner cover glass.

The amount of condensate produced during the day in the distillation system without the addition of PCM is more than in the distillation system with the addition of PCM. This happens because the heat storage process in the PCM is still ongoing.

The opposite happened at night, the condensate production in the system with the addition of Lauric Acid as PCM was higher than the system without PCM. The total condensate production in 24 hours is shown in Table 1. Which shows the average result of 3 times data collection carried out simultaneously between systems without PCM and with PCM. So that the environmental conditions and solar radiation intensity received by both systems are the same, and a comparison both of them can be done.

Table 1. Total condensate production during the day and night for each of the three trials.

Condition		condensate (ml)				
		1st	2nd	3rd	Avrg	% delta
I	non PCM	950	1080	1050	1026.67	10.71
	6 kg PCM	1030	1180	1200	1136.67	
II	non PCM	870	1150	1050	1023.33	15.64
	7 kg PCM	1050	1280	1220	1183.33	
III	non PCM	1150	1080	930	1053.33	15.82
	8 kg PCM	1330	1250	1080	1220.00	

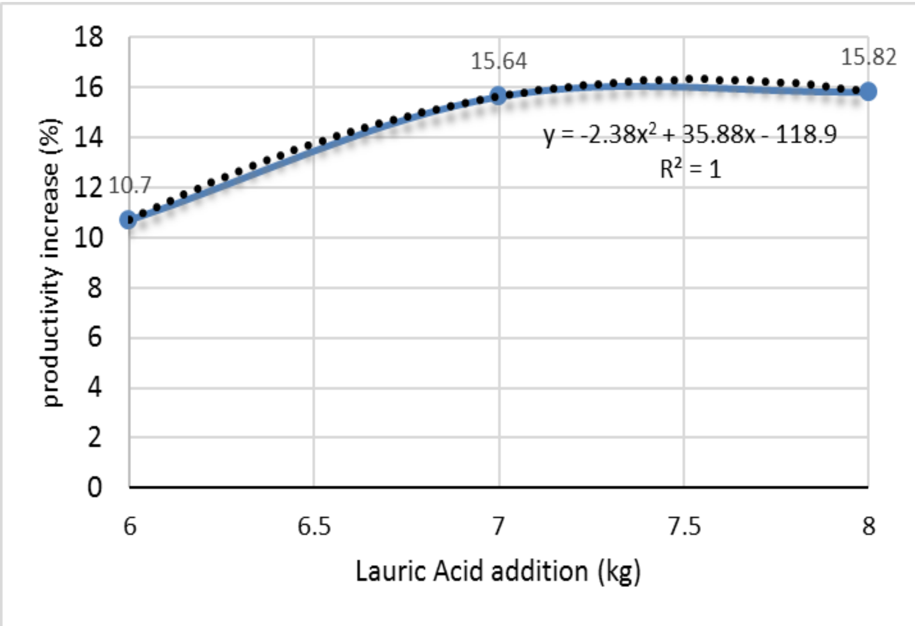


Figure 8. Increased condensate productivity by adding Lauric Acid as PCM to 64.8 kg of water in the basin.

Figure 8 shows the effect of adding Lauric Acid to 64.8 liters of water as PCM into the solar distillation system. The increase in condensate productivity is not directly proportional to the increase in the mass of Lauric Acid added. This shows that the addition of LA as PCM can reach its maximum value, where after the amount of mass is passed, the increase in productivity decreases and can even be lower than without PCM.

The increase in condensate productivity with the addition of Lauric Acid as PCM is expressed in equation (1) below:

$$y = -2.38x^2 + 35.88\, x - 118.9 \quad (1)$$

Where:

y = productivity increase
x = amount of LA added in 64.8 kg of raw water in the basin.

Determination of the optimal value of adding Lauric Acid as PCM in the system is determined by deriving the equation equal to zero.

$$ {}^{dy}/_{dx} = 0 \quad (2) $$

$$ {}^{dy}/_{dx} = -4.76\,x + 35.88 = 0 \quad (3) $$

$$ x_{max} = 7.54 \quad (4) $$

The amount of Lauric Acid that must be added so that the increase in condensate productivity reaches the maximum value is 7.54 kg in 64.8 kg raw water in the basin. In other words, the use of Lauric Acid as PCM in double slope solar distillation has an optimal value at the amount of LA reaching 11.6% of the mass of water in the basin.

Conclusions

The results of weather observations from 07.00 to 17.00 shows that Indonesia has an average solar radiation intensity of 40 klux , an average environmental temperature of 34.5 ˚C and maximum environmental temperature reach 48 ˚C. The installation of a solar distillation system shows that the water temperature in the basin can reach a maximum value of 49 ˚C. This value is higher than the melting temperature of Lauric Acid, so that Lauric Acid can be used very well as an energy storage material with the phase change material method (PCM).

The addition of 8 kg LA or equivalent to 12.3 % of the mass of raw water in the solar distillation system can increase the average condensate production by 15.8%. From this research, the optimal amount of LA that must be added to the solar distillation system to get the highest increase in condensate production value is 7.54 kg of Lauric Acid for 64.8 kg of raw water.

Acknowledgment

The author would like to thank the Faculty of Engineering – Universitas Sultan Ageng Tirtayasa for supporting the implementation of this research.

References

[1] V. Velmurugan, S. P. Kumar, and S. Ragul, "Humidificaton-Dehumidification Desalination System - An Overview," *Ijsrst*, vol. 4, no. 5, pp. 1163–1177, 2018.

[2] F. E. Ahmed, R. Hashaikeh, and N. Hilal, "Solar powered desalination – Technology, energy and future outlook," *Desalination*, vol. 453, no. October 2018, pp. 54–76, 2019, doi: 10.1016/j.desal.2018.12.002.

[3] M. Schorr, *DESALINATION, TRENDS AND TECHNOLOGIES Edited by Michael Schorr*. 2011.

[4] M. C. Garg and H. Joshi, "A Review on PV-RO Process: Solution to Drinking Water Scarcity due to High Salinity in Non-Electrified Rural Areas," *Sep. Sci. Technol.*, vol. 50, no. 8, pp. 1270–1283, 2015, doi: 10.1080/01496395.2014.951725.

[5] A. F. A. Ni Ketut Caturwati, Yusvardi Yusuf, Imron Rosyadi, "COMPARISON OF THE EFFECTIVENESS OF 45˚ AND 60˚ COVER ANGLE ON THE PRODUCTION OF CLEAN WATER ON DOUBLE SLOPE SOLAR DISTILATIONS." 2020.

[6] A. A. Aljubouri, "Design and Manufacturing of Single Sloped Solar Still: Study the Effect of Inclination Angle and Water Depth on Still Performance," *J. Al-Nahrain Univ.*, vol. 20, no. 2, pp. 60–70, 2017, doi: 10.22401/juns.20.2.08.

[7] H. A. Begum, M. A. Yousuf, and K. S. E. Rabbani, “Effect of top cover tilt angle with ground surface on productivity of basin type solar distillation unit,” *Bangladesh J. Med. Phys.*, vol. 10, no. 1, pp. 40–46, 2018, doi: 10.3329/bjmp.v10i1.39149.

[8] R. V. P. Patel and A. Kumar, “Experimental Investigation of Double Slope Solar Still for the Climatic Condition of Sultanpur,” *Int. J. Eng. Technol.*, vol. 9, no. 6, pp. 4019–4033, 2017, doi: 10.21817/ijet/2017/v9i6/170906309.

[9] A. Y. Hashim and W. A. T. Alramdhan, “An attempt to solar still productivity optimization ; solar still shape , glass cover inclination and inner surface area of a single basin solar still , optimization,” *Basrah J. Scienec*, vol. 28, no. 1, pp. 39–48, 2010.

[10] H. N. Panchal and P. K. Shah, “Effect of varying glass cover thickness on performance of solar still: In a winter climate conditions,” *Int. J. Renew. Energy Res.*, vol. 1, no. 4, pp. 212–223, 2011, doi: 10.20508/ijrer.76012.

[11] A. Yadav, M. S. Khalid, P. Saini, and A. Kumar, “Improvement of solar still productivity by using PCM and other enhancement technique- A review,” *Int. J. Eng. Sci. Technol.*, vol. 13, no. 1, pp. 98–104, 2021, doi: 10.4314/ijest.v13i1.15s.

[12] H. Panchal, K. Patel, M. Elkelawy, and H. A. E. Bastawissi, “A use of various phase change materials on the performance of solar still: a review,” *Int. J. Ambient Energy*, vol. 42, no. 13, pp. 1575–1580, 2021, doi: 10.1080/01430750.2019.1594376.

[13] C. N. I. Ketut, Y. Yusvardi, and K. F. Muhamad, “Myristic acid as phase change material (PCM) for increased productivity of solar distillation plant,” *Int. Rev. Appl. Sci. Eng.*, vol. 11, no. 3, pp. 226–231, 2020, doi: 10.1556/1848.2020.00077.

[14] C. N. Ketut, Y. Yusuf, and Z. Arifin, “Productivity of Solar Distillation in Indonesia using Sodium Thiosulfate Penta-hydrate as Thermal Energy Storage,” vol. 2, no. 5, pp. 1–10, 2020.

[15] H. Thakkar and H. Panchal, “Performance Investigation on Solar Still with PCM and Nano-Composites: Experimental Investigation,” *2nd Int. Conf. Multidiscip. Res. Pract.*, vol. III, no. December, pp. 2321–2705, 2015.