

Investigation of Performance of Stone Fin Solar Still Absorber by Water Depth Variations

Nova Risdiyanto Ismail^{1*}, Dadang Hermawan², Purbo Suwandono³, Leo Hutri Wicaksono⁴

^{1,2,3,4} Mechanical Engineering, Universitas Widyagama, Malang, Indonesia

*Corresponding author email: nova@widyagama.ac.id

Received : February 07, 2022

Received in revised form April 30, 2023

Accepted : July 12, 2023

Online : August 8, 2023

Abstract – Passive Solar is still suitable for Indonesia's islands and coastal areas. Various attempts have been made to increase the performance of passive solar stills, including using porous materials, fins absorber models, and making water in the form of a thin layer. This study aims to increase the distillate output and Efficiency of Solar still. This study's method compares stone fin solar stills absorbers using water depth variations of 1 cm, 2 cm, and 3 cm with conventional solar stills at a water depth of 1 cm. The study resulted in the distillate output of stone fin solar still absorber of 3.35 (liter/m².day) higher than the conventional solar stills 2.44 (liter/m².day) at a depth of 1 cm. The highest Efficiency of solar stills using the stone fin solar still absorbers is 58.45% higher than conventional solar stills, 43.60% at a depth of 1 cm. Solar stills with lower water depths resulted in higher distillate output and Efficiency. Solar stills using stone fin absorbent plates produce higher productivity and Efficiency than conventional ones.

Keywords: Solar still, Fins absorbers stone, Distillation output, Efficiency

Introduction

Passive Solar is still a distillation technology using solar energy without additional energy. Therefore, this technology should be applied in coastal and remote areas (Raihananda et al., 2021). Passive Solar's advantages are easy construction, easy operation, and low maintenance costs; it is more economical, environmentally friendly, and does not use additional energy (Rajaseenivasan, Tinnokesh, Kumar, & Srithar, 2016). However, there are also weaknesses of the passive Solar still, such as the transmission of solar radiation to the absorber through seawater, water above the basin reflects solar radiation, slow preheating process, and slow evaporation (Awasthi, Kumari, Panchal, & Sathyamurthy, 2018), and low productivity (Raju & Lalitha Narayana, 2016). Environmental conditions, tool design, and operational methods influence the performance of passive solar stills. (Muftah, Alghoul, Fudholi, Abdul-Majeed, & Sopian, 2014).

Various efforts have been made to improve the design of passive solar stills, especially in solar radiation heat absorbers. Development of solar radiation heat absorbers from the material side that can increase the productivity of solar stills, such as using black pebbles (Hamidi, 2020), using black stone (Abdallah, Abu-Khader, & Badran, 2009), adding quartz sand (Murugavel, Sivakumar, Ahamed, Chockalingam, & Srithar, 2010), using concrete stones (Shanmugan, 2013), using black granite (Madhav, 2011)(Mevada et al., 2022), stone as heat storage (Mohamed, Hegazi, Sultan, & El-Said, 2019), Thus, solar stills with heat-absorbing materials can be applied in the community (Bansal, Singh, Kishore, & Dogra, 2019).

Efforts to increase the absorption of solar radiation heat and increase the productivity of solar stills can be accomplished by making solar radiation heat absorbers in the form of fins (Panchal & Mohan, 2017)(Sathyamurthy et al., 2020)(Mohaisen et al., 2021) (Tuly, Rahman, Sarker, & Beg, 2021). Several studies on Solar still use fin absorbers has been proven to increase the distillate output, for example using pin fins (Rabhi, Nciri, Nasri, Ali, & Ben Bacha, 2017), using mild steel (Jani & Modi, 2019), using inclined fins (Panchal et al., 2020), using hollow-fins (Modi & Jani, 2021), using hollow-fins and wick-segments (Modi, Patel, Patel, Patel, & Patel, 2022), using fins with a length of 2 cm and a distance of 7 cm (El Hadi Attia, Kabeel, Abdelgaied, El-Maghlany, & Bellila, 2021), solar still with PCM and pin fins (Kateshia & Lakhera, 2021), using fins with the

addition of fly ash (Islam *et al.*, 2021), using parabolic fins (Kaviti, Mary, Ram, & Kumari, 2021), using five radial fins (El-Said, Abou Al-Sood, Elsharkawy, & Abdelaziz, 2022), using hollow cylindrical fins filled with phase change materials (Attia *et al.*, 2022), using combination of transparent walls, copper fins, internal and external reflectors (Shmroukh & Ookawara, 2020), using pyramid hollow circular fins and PCM (Kabeel, El-Maghlany, Abdelgaied, & Abdel-Aziz, 2020), adding fins and reflector (Bataineh & Abbas, 2020).

Test the performance of solar stills can be achieved by varying the water depth (Kabeel, Sathyamurthy, *et al.*, 2019). Several studies of solar stills with variations in water depth, including testing pyramid solar stills with a water depth of 1 cm, produce the highest productivity and Efficiency (Muthu Manokar *et al.*, 2020), tested the tubular Solar still with the lowest depth (0.5 cm) and the cover glass coolant flow rate of 2 Liters/hour to obtain the highest productivity and Efficiency (Kabeel, Sharshir, Abdelaziz, Halim, & Swidan, 2019). The lower the water depth, the productivity will increase accordingly (Alwan, Shcheklein, & Ali, 2021).

Passive Solar development is still carried out by identifying operational conditions. Optimization of operational conditions is performed by making the water flow spread evenly and in the form of a thin layer. Several studies to optimize operational conditions and resulting in increased distillate output, including; using cotton cloth (Kalidasa Murugavel, *et al.*, 2008), using *wick* (Aybar *et al.*, 2005), using charcoal cloth (Mahdi *et al.*, 2011), using woolen cloth wick material (Nougriaya, Chopra, Gupta, Baredar, & Parmar, 2021), using square pyramid solar still (SPSS) with woolen fabrics (Saravanan & Murugan, 2020) and using jute cloth (Alawee *et al.*, 2021).

From the description above, to increase the productivity and Efficiency of solar stills, the following can be carried out: 1) using black-colored stone, 2) making solar radiation heat absorbers in the form of fins, 3) using a porous material as a medium for water flow in the form of a thin layer, 4) using materials available in nature and easy to obtain. Thus, the novelty of this research is to make a heat absorber for solar radiation using black-colored stone material that is fin-shaped, porous, and available in nature. Black-colored stones can maximize the reception of solar radiation energy. The fin absorber can expand the solar radiation receiving surface and the evaporation surface. The porous material can be a capillary flow medium to spread water through a thin layer. (Ismail, Soeparman, Widhiyanuriyawan, & Wijayanti, 2018) and hot flow media (Ismail, Soeparman, Widhiyanuriyawan, & Wijayanti, 2019)(Ismail *et al.*, 2019)(43)(Ismail, Soeparman, Widhiyanuriyawan, & Wijayanti, 2020). Materials available in nature can facilitate application and utilization by the community. This study aims to investigate the performance of stone fin-absorbing solar stills with variations in water depth.

Materials and Methods

Experimental setup

Basin of Solar still uses mortar material, a mixture of sand and cement (Table 1). At the same time, the fin-absorbing Solar is still made entirely of stone. The dimensions of the Solar still using stone fin absorbers can be seen in Figure 1. Each Solar still is covered with a 3 mm thick sheet of glass with a slope of 18.40°. The sides and bottom are covered with 5 mm thick glass and 5 cm thick Styrofoam. Seawater flows from the tank through the buoy and into the input pipe. Water will flow from the input pipe according to the basin's flow path. The buoy serves to maintain the stability of the water basin. The outlet pipe is used for the drainage line. The distillation channel is made of aluminum and is installed at the bottom end of the coverslip to drain the water to the reservoir.

Research Variables

This research uses conventional solar stills and fin-absorbing solar stills. The independent variables in this study were water depths of 1 cm, 2 cm, and 3 cm on fin-absorbing solar stills., while the conventional Solar still, as a comparison, uses a water depth of 1 cm. This independent variable is used to see the performance of solar stills with a load of water volume varying through the water level. Variations in water level indicate the volume of water to be distilled; this independent variable following previous studies (Jani and Modi, 2019), (Muthu Manokar *et al.*, 2020), (Alwan, Shcheklein, and Ali, 2021). The dependent variables are water temperature, cover glass temperature, fin/basin absorbent temperature, and distillate output. Data collection from 8.00 a.m. to 3.00 p.m. in 30-minute intervals (Widiharsa, 2008) (Caturwati, Yusuf, Rosyadi, & Almarwan, 2020). At the same time, the controlled variable is where the data collection is located in the Mechanical Engineering Building 1 Universitas Brawijaya -7.9504272 south latitude coordinates and 112.6130977 east longitude coordinates.

Tabel 1. Material specification (Ismail et al., 2020)

Specification	Porosity (%)	Thermal Conductivity (W/m °C)	Mean pores hole radius (mm)	Macro Photo graph
Concrete with River sand aggregate	19.00 - 22.40	0.60 - 0.63	0.047 -0.116	
Natural stone	14.60	0.46	0.189	

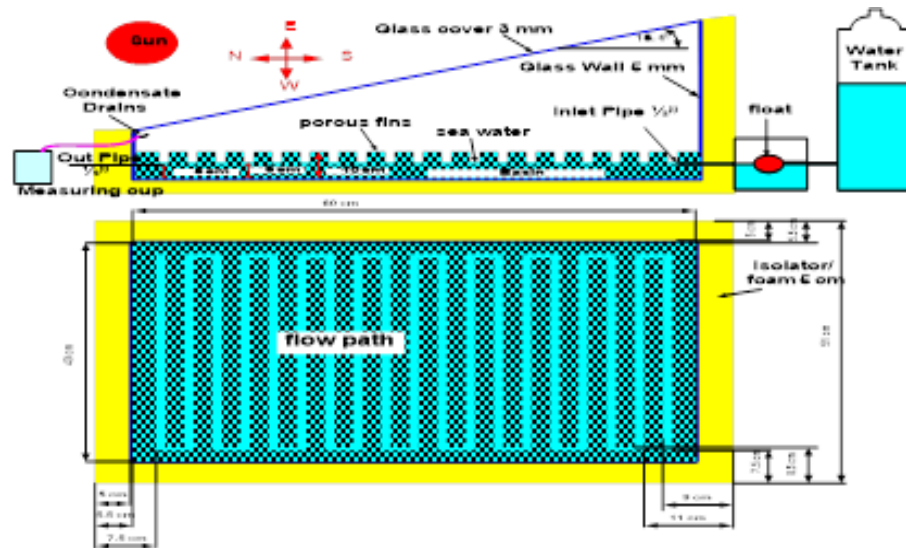
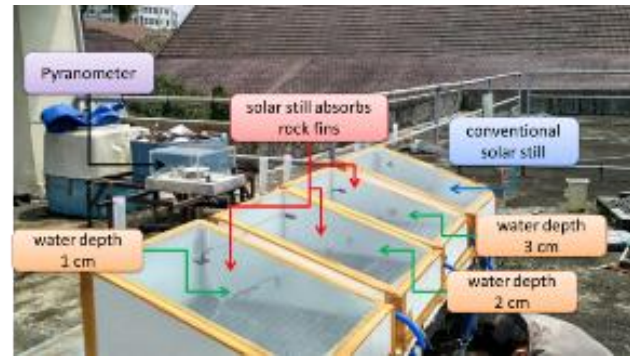


Figure 1. Tool schematic.



(a)



(b)

Figure 2. (a) Absorbing fins of stone material, (b) Testing of Solar still.

Measuring Equipment

Thermocouples, pyranometers, and measuring cups are used to measure the parameters. The percentage of errors, accuracy, and instruments can be seen in Table 2.

Table 2. Measuring Equipment

SI.	No.	Instrument	Accuracy	Range	% Error
	1	Thermocouple	± 0.1 °C	100 – 200 °C	0.25 %
	2	Pyranometer	± 1.0 W/m ²	0 – 1200 W/m ²	1 %
	3	Anemometer	± 0.1 m/s	0 – 25 m/s	5 %
	4	Measuring cup	± 1.0 mL	0 – 200 mL	1 %

Distillate output and Efficiency**a. Distillate output of Solar still**

Distillate output can be calculated using the equation from (El-Sebaey, Ellman, Hegazy, & Panchal, 2022), as follows:

$$m_D = \frac{q_e}{L_{ev}} t \quad (\text{kg/m}^2) \quad (1)$$

where:

- m_D = Mass of condensate water produced (kg/m²)
- q_e = Heat used for evaporation (W/m²)
- L_{ev} = Latent heat of vaporization (J/kg)
- t = Data retrieval time interval (minute)

Water evaporation latent heat uses the equation (Rahbar & Esfahani, 2012):

$$L_{ev} = 3.2615 \times 10^6 [1 - (7.616 \times 10^{-4} \times T_w)] \quad (2)$$

b. Solar Still Efficiency

Solar still efficiency can be defined as the ratio between heat transfer in the distillation apparatus with condensation evaporation to the amount of solar radiation, expressed by the equation from (Saravanan & Murugan, 2020), as follows:

$$\eta_i = \frac{q_e}{G_t} \quad (\%) \quad (3)$$

For the daily Efficiency produced by the Solar still experimentally, (Elsheikh et al., 2021)(Hammad, Shalaby, Kabeel, & Zayed, 2022), as follows:

$$\eta_i = \frac{m_p \cdot L_{ev}}{G_s \cdot A \cdot t} 100\% \quad (4)$$

where:

- η_i = Solar still Efficiency (%)
- $\dot{m}_p$ = Mass flow rate of distillation product per day (kg/day)
- G_t = Total solar radiation (W/m²)
- G_s = Daily total solar radiation (MJ/m²)
- A = basin area (m²)

Results

This study aims to determine the productivity and Efficiency of solar stills. Several parameters are needed to be able to calculate the Efficiency. The main thing measured is the intensity of solar radiation as an energy source, water temperature and absorbent plate temperature to obtain the enthalpy value of evaporation (L_{ev}), condensate water productivity. Ambient temperature to identify environmental conditions during research. In addition, this study also identified the temperature of the cover glass. The temperature of the glass is used to identify the condensation process.

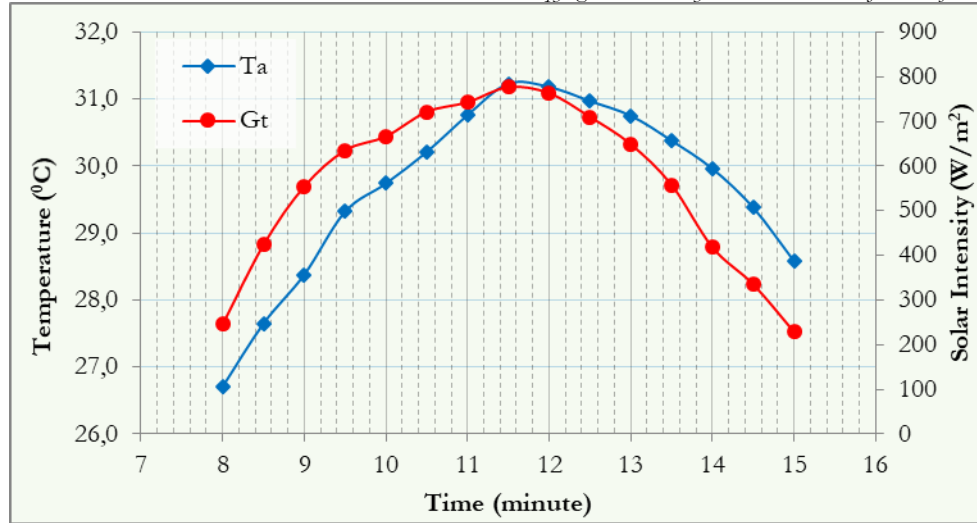


Figure 3. Ambient temperature.

From Figure 3, it can be seen that the ambient temperature follows the pattern of solar radiation. The intensity of solar radiation increases gradually from morning to noon and reaches its peak at 776.74 W/m² at 11.30 a.m. Ambient air temperature reaches its maximum value at 11.30 a.m., but from noon to late afternoon the decline becomes slower, due to the thermal inertia of the ambient air mass.

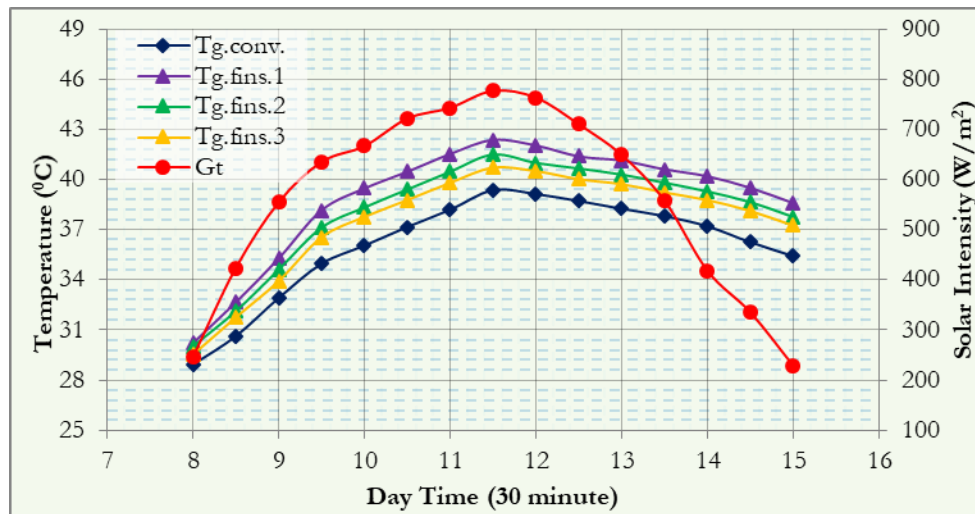


Figure 4. Cover glass temperature.

In Figure 4, it can be seen that the daily average cover glass temperature follows the pattern of solar radiation. The temperature of the cover glass is influenced by the absorption of solar radiation heat of 0.05%, the temperature of the fin absorber, water temperature, ambient temperature, and evaporation (Agrawal, Rana, & Srivastava, 2017)(RPN, Namprakai, & Ampun, 2013). The lowest cover glass temperature is 28.93 °C using conventional Solar still, and the stone fin absorber is 29.52 °C at solar radiation of 245.85 W/m². The highest cover glass temperature is 39.36 °C using conventional Solar still, and the stone fin absorber is 42.36 °C at solar radiation of 776.74 W/m².day.

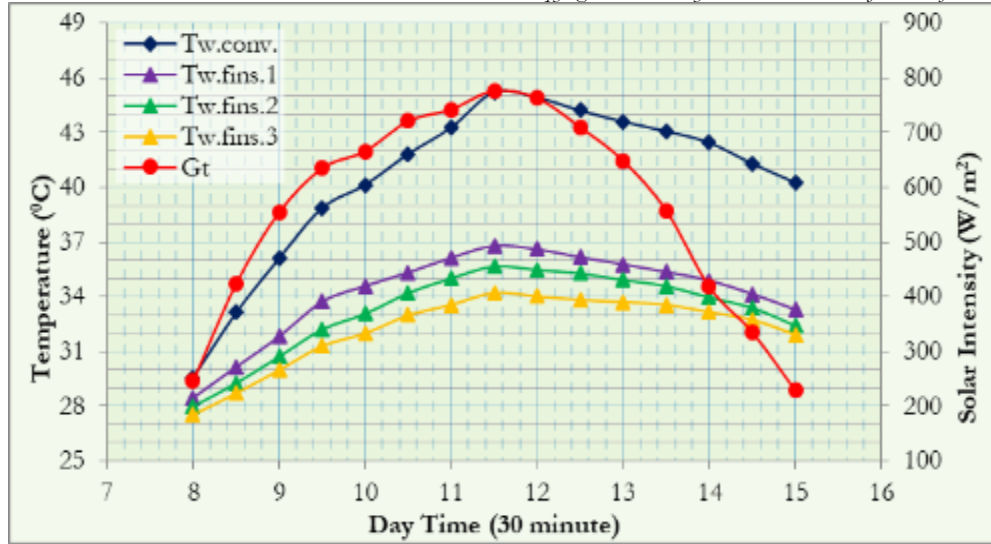


Figure 5. Water temperature.

In Figure 5, it can be seen that the daily average water temperature follows the pattern of solar radiation. The lowest water temperature is 27.53 °C using a stone fin solar still absorber at a water depth of 3 cm and conventional at 29.53 °C with solar radiation of 245.85 W/m². The highest water temperature is 45.23 °C using conventional Solar still, and a stone fin absorber is 36.80 °C at 776.74 W/m² of solar radiation.

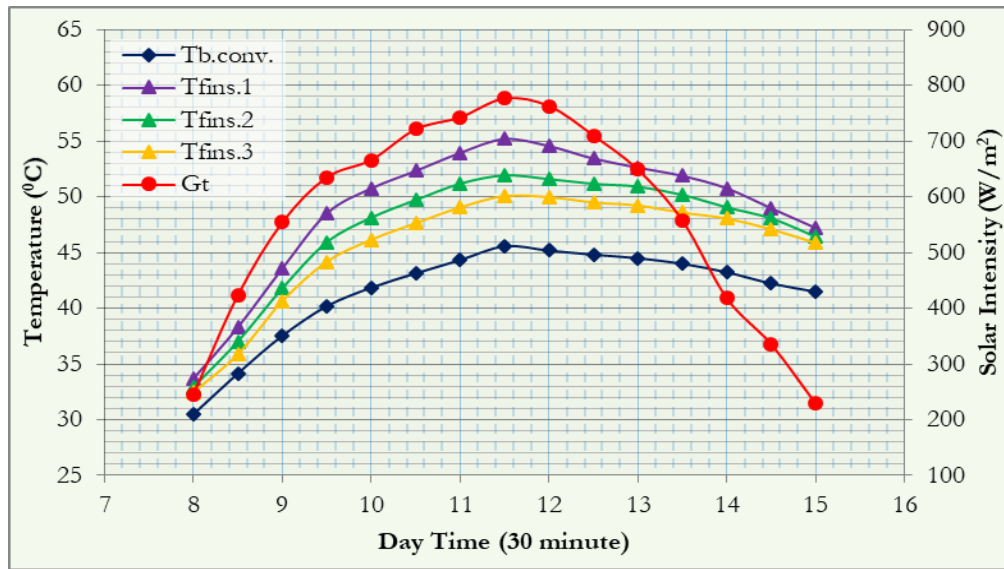


Figure 6. Basin temperature.

In Figure 6, it can be seen that the daily average basin temperature follows the pattern of solar radiation. The lowest fin temperature is 32.48 °C at a depth of 3 cm, the conventional basin temperature is 30.50 °C at a water depth variation of 3 cm, and solar radiation is 245.85 W/m². The highest basin temperature is 45.57 °C using conventional Solar still, the fins stone temperature is 55.56 °C at 1 cm water depth variation, and solar radiation is 776.74 W/m².

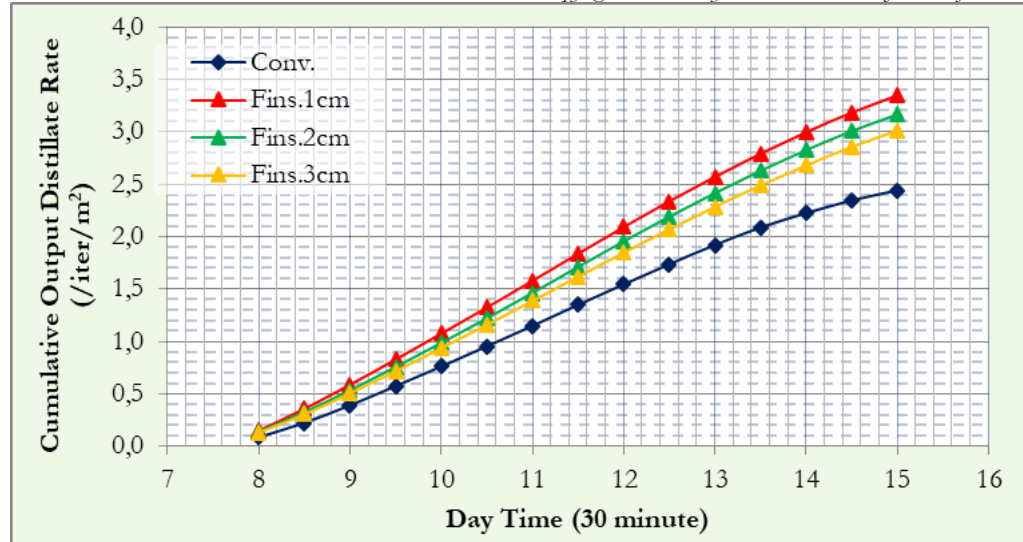


Figure 7. Cumulative Output Distillate.

In Figure 7, it can be seen that the output of the distillate every 30 minutes follows the pattern of solar radiation. The lowest distillate output is 0.13 (liter/m²) using stone fins solar still absorber at a water depth of 3 cm, and conventional 0.09 (liter/m²) solar radiation is 245.85 W/m². The highest distillate output is 0.20 (liter/m²) using conventional Solar still, and a stone fin absorber is 0.26 (liter/m²) at a water depth of 1 cm and solar radiation of 776.74 W/m².

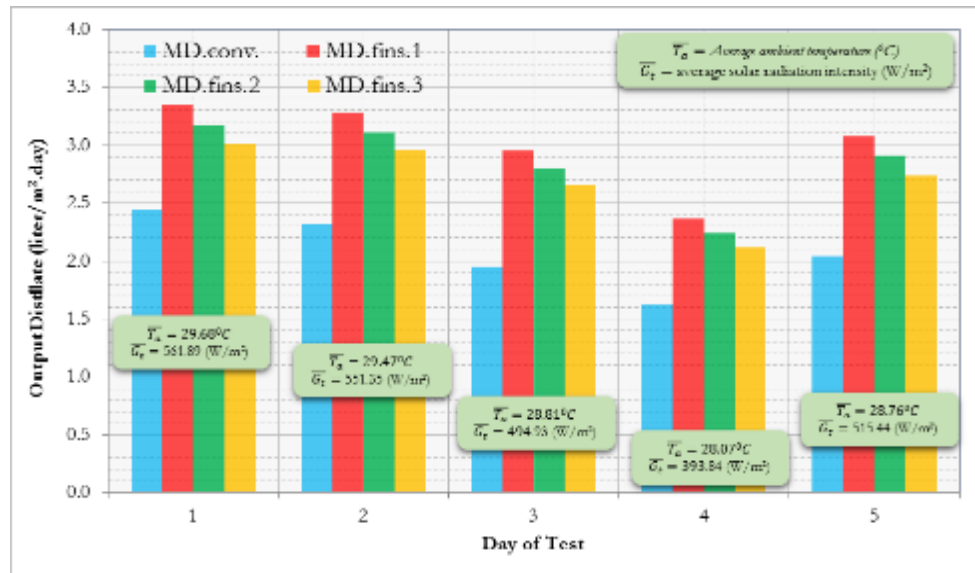


Figure 8. Daily distillate output.

Figure 8 shows the daily distillate output from 8:00 a.m. to 3:00 p.m. for stone fin solar stills absorber at water depths of 1 cm, 2 cm, and 3 cm, while conventional solar stills at a depth of 1 cm for comparison. Figure 8 clearly shows that the output of the distillate depends on solar radiation and solar radiation absorption. From the experimental results, the highest daily distillate output using stone fin absorbers is 3.35 (liter/m².day) at a water depth of 1 cm and an average solar radiation of 561.89 W/m². Meanwhile, the lowest daily distillate output using conventional Solar still is 1.62 (liter/m².day) at a water depth of 1 cm, and the average solar radiation is 393.84 W/m².

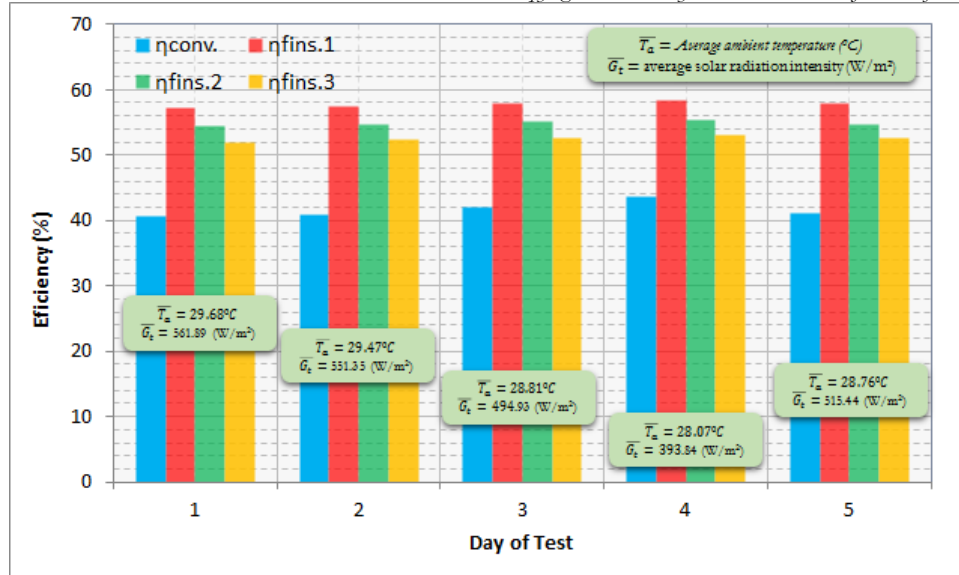


Figure 9. Solar Still Efficiency.

Figure 9 shows the lowest daily Efficiency of 51.91% using stone fin solar stills absorber at a water depth of 3 cm, and conventional solar stills is 40.56% efficiency at a water depth of 1 cm with an average daily solar radiation of 561.89 W/m². The highest Efficiency is 43.60% using conventional solar stills and 58.45% using stone fin absorbers at a water depth of 1 cm with solar radiation of 393.84 W/m².

Discussion

The temperature of the cover glass for stone fins solar still absorbers is higher than conventional at any variation in water depth; this condition is caused by heat transfer by convection, radiation, and evaporation, as well as condensation processes on the cover glass (RPN, Namprakai, & Ampun, 2013) (Agrawal & Rana, 2019). At lower water depths, the cover glass temperature is higher; this condition is more influenced by the area of the fins exposed to solar radiation and the amount of evaporation.

Conventional Solar still water temperature exceeds stone fin absorbers at any water depth variation. The difference in the average water temperature of conventional solar stills with fin absorbers at a depth of 1 cm, 2 cm, and 3 cm is 6.31 °C, 7.33 °C, and 8.32 °C, respectively. This daily average water temperature difference indicates that the stone fin solar stills absorber at various water depths is not exposed to direct solar radiation. The higher the water depth, the more heat is needed to be transferred to increase the temperature of the same water. In addition, the heat received by the fin absorber is used more for evaporation in the fin pores.

The stone fin temperature is higher than conventional at any water depth. This condition is caused by 1) the stone fin absorber being black colored, 2) a wider surface exposed to solar radiation, and 3) direct exposure to solar radiation. The lower water depth causes the capillary flow of water to be more extended, and more heat is utilized for the evaporation process in the fin pores, and some is transferred to the water between the fins. At higher depths, the heat transferred to the water between the fins is greater than at lower depths. This can be seen in Figure 5, where the difference in water temperature from morning to noon is greater than that from noon to evening. Higher water depth will increase the volume of water. The larger the volume of water, the greater sensible heat and not enough for evaporation. This can be seen in Figure 4, where the water temperature between the fins is smaller than the temperature of the cover glass.

The distillate output of stone fins solar still absorber is higher than conventional fins. This is caused by: 1) The heat received by the absorbent surface will be transferred to the fin body, and the water flows by capillary action in the pores in the form of a thin layer, thereby reducing sensible heat and increasing latent heat. 2) The large heat contact area on the porous fins accelerates the evaporation process. In Figure 7 it can be seen that the water depth affects the accumulation of distillate output. The accumulated distillate output increases with decreasing water depth. The depth of the water will affect the amount of water between the fins, the length of the capillary flow path from the surface of the water to the surface of the fin and the difference in height from

the surface of the water to the surface of the fins. Low water depth causes capillary water flow through the pore to the fin surface to be slow and thin, so that the evaporation process on the fin is faster. In addition, at low water depths, heat transfer from the fin surface to the water between the fins is small, so that more heat from the fin surface is focused on heating the water on the fin body.

The Efficiency of stone fin solar still absorber at any depth variation is higher than conventional Solar still. Such conditions are caused by the mechanism of receiving solar radiation, heating water and the evaporation process, which affect the output of the distillate. Stone fin Solar still absorber at a lower depth, resulting in higher Efficiency. This condition is caused by the high distillate output. Solar stills with higher average daily solar radiation, resulting in lower Efficiency. Such conditions are caused by the heat received by the absorbent of solar radiation, some of which is stored by the material. This can be seen from Figure 6, where the temperature of the fin absorber from noon to the afternoon decreases more gently and has a smaller temperature difference. Therefore, it is necessary to do research with a longer duration of up to 24 hours.

Conclusion

From the results of the study, it can be concluded that the daily distillate output of solar stills using stone fin absorbers is 3.35 (liters/m².day) higher than conventional solar stills of 2.44 (liters/m².day) at a depth of 1 cm. The Efficiency of solar stills using stone fin absorbers is 58.45% higher than conventional solar stills of 43.60% at a depth of 1 cm. Solar stills with lower water depths produce higher distillate output and Efficiency. Solar stills using stone fin absorbent plates produce higher productivity and Efficiency than conventional solar stills.

References

- Abdallah, S., Abu-Khader, M. M., & Badran, O. (2009). Effect of various absorbing materials on the thermal performance of solar stills. *Desalination*, 242(1–3), 128–137. <https://doi.org/10.1016/j.desal.2008.03.036>
- Agrawal, A., & Rana, R. S. (2019). Theoretical and experimental performance evaluation of single-slope single-basin Solar still with multiple V-shaped floating wicks. *Heliyon*, 5(4), e01525. <https://doi.org/10.1016/j.heliyon.2019.e01525>
- Agrawal, A., Rana, R. S., & Srivastava, P. K. (2017). Heat transfer coefficients and productivity of a single slope single basin solar still in Indian climatic condition: Experimental and theoretical comparison. *Resource-Efficient Technologies*, 3(4), 466–482. <https://doi.org/10.1016/j.reffit.2017.05.003>
- Alawee, W. H., Essa, F. A., Mohammed, S. A., Dhahad, H. A., Abdullah, A. S., Omara, Z. M., & Gamiel, Y. (2021). Improving the performance of pyramid solar distiller using dangled cords of various wick materials: Novel working mechanism of wick. *Case Studies in Thermal Engineering*, 28(October), 101550. <https://doi.org/10.1016/j.csite.2021.101550>
- Alwan, N. T., Shcheklein, S., & Ali, O. (2021). Investigation of the coefficient of heat transfer and daily cumulative production in a single-slope solar distiller at different water depths. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, 43(21), 2820–2837. <https://doi.org/10.1080/15567036.2020.1842561>
- Attia, M. E. H., Kabeel, A. E., Abdo, A., Abdelgaied, M., Bellila, A., & Abdullah, A. S. (2022). Optimal configurations of hemispherical solar distillers using the higher conductivity extended hollow cylindrical fins filled with latent heat storage materials. *Journal of Energy Storage*, 50(March), 104706. <https://doi.org/10.1016/j.est.2022.104706>
- Awasthi, A., Kumari, K., Panchal, H., & Sathyamurthy, R. (2018). Passive Solar still: recent advancements in design and related performance. *Environmental Technology Reviews*, 7(1), 235–261. <https://doi.org/10.1080/21622515.2018.1499364>
- Aybar, H. Ş., Egelioglu, F., & Atikol, U. (2005). An experimental study on an inclined solar water distillation system. *Desalination*, 180(1–3), 285–289. <https://doi.org/10.1016/j.desal.2005.01.009>
- Bansal, G., Singh, D. B., Kishore, C., & Dogra, V. (2019). Effect of absorbing material on the performance of Solar still: A mini review. *Materials Today: Proceedings*, 26(XXXX), 1884–1887. <https://doi.org/10.1016/j.matpr.2020.02.412>
- Bataineh, K. M., & Abbas, M. A. (2020). Performance analysis of solar still integrated with internal reflectors and fins. *Solar Energy*, 205(February), 22–36. <https://doi.org/10.1016/j.solener.2020.04.059>
- Caturwati, N. K., Yusuf, Y., Rosyadi, I., & Almarwan, A. F. (2020). Comparison of the Effectiveness of 45° and 60° Cover Angle on the Production of Clean Water on Double Slope Solar Distillations. 3(02), 59–69. [https://doi.org/10.25299/rem.2020.vol3\(02\).5176](https://doi.org/10.25299/rem.2020.vol3(02).5176)

- El-Said, E. M. S., Abou Al-Sood, M. M., Elsharkawy, E. A., & Abdelaziz, G. B. (2022). Tubular solar air heater using finned semi-cylindrical absorber plate with swirl flow: Experimental investigation. *Solar Energy*, 236(February), 879–897. <https://doi.org/10.1016/j.solener.2022.03.054>
- El-Sebaey, M. S., Ellman, A., Hegazy, A., & Panchal, H. (2022). Experimental study and mathematical model development for the effect of water depth on water production of a modified basin solar still. *Case Studies in Thermal Engineering*, 33(March), 101925. <https://doi.org/10.1016/j.csite.2022.101925>
- El Hadi Attia, M., Kabeel, A. E., Abdelgaied, M., El-Maghlany, W. M., & Bellila, A. (2021). Comparative study of hemispherical solar distillers iron-fins. *Journal of Cleaner Production*, 292, 126071. <https://doi.org/10.1016/j.jclepro.2021.126071>
- Elsheikh, A. H., Katekar, V. P., Muskens, O. L., Deshmukh, S. S., Elaziz, M. A., & Dabour, S. M. (2021). Utilization of LSTM neural network for water production forecasting of a stepped solar still with a corrugated absorber plate. *Process Safety and Environmental Protection*, 148, 273–282. <https://doi.org/10.1016/j.psep.2020.09.068>
- Hamidi, A. S. S. N. (2020). Pengaruh Pelat Penyerap Terhadap Kinerja Solar Still Di Kota Ngabang. *Rekayasa Mesin*, (January), 85–95.
- Hammad, F. A., Shalaby, S. M., Kabeel, A. E., & Zayed, M. E. (2022). Experimental investigation and thermo-economic performance analysis of a modified solar distiller design with thermal storage material and v-corrugated absorber basin. *Journal of Energy Storage*, 52(PC), 105020. <https://doi.org/10.1016/j.est.2022.105020>
- Islam, A., Sharma, A., & Singh, P. K. (2021). Performance study on customized Solar still by optimum fins for production of distilled water. *Materials Today: Proceedings*, 45(xxxx), 3517–3520. <https://doi.org/10.1016/j.matpr.2020.12.960>
- Ismail, N. R., Soeparman, S., Widhiyanuriyawan, D., & Wijayanti, W. (2018). The Influence of Pores Size and Type of Aggregate on Liquid Mass Transfer in Porous Media. *Journal of Engineering and Applied Sciences*, 13(17), 7171–7178. <https://doi.org/10.3923/jeasci.2018.7171.7178>
- Ismail, N. R., Soeparman, S., Widhiyanuriyawan, D., & Wijayanti, W. (2019). The influence of pores size and type of aggregate on capillary heat and mass transfer in porous. *Journal of Applied Engineering Science*, 17(1), 8–17. <https://doi.org/10.5937/jaes17-18090>
- Ismail, N. R., Soeparman, S., Widhiyanuriyawan, D., & Wijayanti, W. (2020). Temperature Distribution and Evaporation Rate in Porous Media. *Journal of Southwest Jiaotong University*, 55(3), 1–12. <https://doi.org/10.35741/issn.0258-2724.55.3.28>
- Jani, H. K., & Modi, K. V. (2019). Experimental performance evaluation of single basin dual slope solar still with circular and square cross-sectional hollow fins. *Solar Energy*, 179(November 2018), 186–194. <https://doi.org/10.1016/j.solener.2018.12.054>
- Kabeel, A. E., El-Maghlany, W. M., Abdelgaied, M., & Abdel-Aziz, M. M. (2020). Performance enhancement of pyramid-shaped solar stills using hollow circular fins and phase change materials. *Journal of Energy Storage*, 31(June), 101610. <https://doi.org/10.1016/j.est.2020.101610>
- Kabeel, A. E., Sathyamurthy, R., Sharshir, S. W., Muthumanokar, A., Panchal, H., Prakash, N., ... El Kady, M. S. (2019). Effect of water depth on a novel absorber plate of pyramid solar still coated with TiO₂ nano black paint. *Journal of Cleaner Production*, 213, 185–191. <https://doi.org/10.1016/j.jclepro.2018.12.185>
- Kabeel, A. E., Sharshir, S. W., Abdelaziz, G. B., Halim, M. A., & Swidan, A. (2019). Improving performance of tubular Solar still by controlling the water depth and cover cooling. *Journal of Cleaner Production*, 233, 848–856. <https://doi.org/10.1016/j.jclepro.2019.06.104>
- Kalidasa Murugavel, K., Chockalingam, K. K. S. K., & Srithar, K. (2008). An experimental study on single basin double slope simulation solar still with thin layer of water in the basin. *Desalination*, 220(1–3), 687–693. <https://doi.org/10.1016/j.desal.2007.01.063>
- Kateshia, J., & Lakhera, V. J. (2021). Analysis of Solar still integrated with phase change material and pin fins as absorbing material. *Journal of Energy Storage*, 35(October 2020), 102292. <https://doi.org/10.1016/j.est.2021.102292>
- Kaviti, A. K., Mary, B., Ram, A. S., & Kumari, A. A. (2021). Influence of aluminium parabolic fins as energy absorption material in the solar distillation system. *Materials Today: Proceedings*, 44, 2521–2525. <https://doi.org/10.1016/j.matpr.2020.12.603>

- Madhav, J. (2011). Performance of Black Granite Basin Solar Still : A Comparative Study. *Int J Engg Techsci*, 2(2), 161–168.
- Mahdi, J. T., Smith, B. E., & Sharif, A. O. (2011). An experimental wick-type solar still system: Design and construction. *Desalination*, 267(2–3), 233–238. <https://doi.org/10.1016/j.desal.2010.09.032>
- Mevada, D., Panchal, H., Ahmadein, M., Zayed, M. E., Alsaleh, N. A., Djuansjah, J., ... Sadasivuni, K. K. (2022). Investigation and performance analysis of Solar still with energy storage materials: An energy- exergy efficiency analysis. *Case Studies in Thermal Engineering*, 29(July 2021), 101687. <https://doi.org/10.1016/j.csite.2021.101687>
- Modi, K., & Jani, H. (2021). Experimental and theoretical assessment of dual-slope single-basin Solar still with the circular cross-sectional hollow-fins. *Cleaner Engineering and Technology*, 4, 100231. <https://doi.org/10.1016/j.clet.2021.100231>
- Modi, K. V., Patel, U. N., Patel, S. J., Patel, J. N., & Patel, S. R. (2022). Efficacy of partially and fully submerged circular cross-section metal hollow-fins and black cotton cloth wick-segments on a single-basin dual-slope solar still. *Journal of Cleaner Production*, 344(February), 131059. <https://doi.org/10.1016/j.jclepro.2022.131059>
- Mohaisen, H. S., Esfahani, J. A., & Ayani, M. B. (2021). Improvement in the performance and cost of passive solar stills using a finned-wall/built-in condenser: An experimental study. *Renewable Energy*, 168, 170–180. <https://doi.org/10.1016/j.renene.2020.12.056>
- Mohamed, A. F., Hegazi, A. A., Sultan, G. I., & El-Said, E. M. S. (2019). Enhancement of a solar still performance by inclusion the basalt stones as a porous sensible absorber: Experimental study and thermo-economic analysis. *Solar Energy Materials and Solar Cells*, 200(November 2018), 109958. <https://doi.org/10.1016/j.solmat.2019.109958>
- Muftah, A. F., Alghoul, M. A., Fudholi, A., Abdul-Majeed, M. M., & Sopian, K. (2014). Factors affecting basin type Solar still productivity: A detailed review. *Renewable and Sustainable Energy Reviews*, 32, 430–447. <https://doi.org/10.1016/j.rser.2013.12.052>
- Murugavel, K. K., Sivakumar, S., Ahamed, J. R., Chockalingam, K. K. S. K., & Srithar, K. (2010). Single basin double slope solar still with minimum basin depth and energy storing materials. *Applied Energy*, 87(2), 514–523. <https://doi.org/10.1016/j.apenergy.2009.07.023>
- Muthu Manokar, A., Taamneh, Y., Kabeel, A. E., Prince Winston, D., Vijayabalan, P., Balaji, D., ... Mageshbabu, D. (2020). Effect of water depth and insulation on the productivity of an acrylic pyramid solar still – An experimental study. *Groundwater for Sustainable Development*, 10, 100319. <https://doi.org/10.1016/j.gsd.2019.100319>
- Nougriaya, S. K., Chopra, M. K., Gupta, B., Baredar, P., & Parmar, H. (2021). Influence of basin water depth and energy storage materials on productivity of Solar still: A review. *Materials Today: Proceedings*, 44, 1589–1603. <https://doi.org/10.1016/j.matpr.2020.11.796>
- Panchal, H., Mevada, D., Sadasivuni, K. K., Essa, F. A., Shanmugan, S., & Khalid, M. (2020). Experimental and water quality analysis of solar stills with vertical and inclined fins. *Groundwater for Sustainable Development*, 11, 100410. <https://doi.org/10.1016/j.gsd.2020.100410>
- Panchal, H., & Mohan, I. (2017). Various methods applied to Solar still for enhancement of distillate output. *Desalination*, 415(March), 76–89. <https://doi.org/10.1016/j.desal.2017.04.015>
- Rabhi, K., Nciri, R., Nasri, F., Ali, C., & Ben Bacha, H. (2017). Experimental performance analysis of a modified single-basin single-slope solar still with pin fins absorber and condenser. *Desalination*, 416(January), 86–93. <https://doi.org/10.1016/j.desal.2017.04.023>
- Rahbar, N., & Esfahani, J. A. (2012). Estimation of convective heat transfer coefficient in a single-slope solar still: A numerical study. *Desalination and Water Treatment*, 50(1–3), 387–396. <https://doi.org/10.1080/19443994.2012.720442>
- Raihananda, F. A., Philander, E., Lauvandy, A. F., Soelaiman, T. A. F., Budiman, B. A., Juangsa, F. B., & Sambegoro, P. (2021). Low-cost floating solar still for developing countries: Prototyping and heat-mass transfer analysis. *Results in Engineering*, 12, 100300. <https://doi.org/10.1016/j.rineng.2021.100300>
- Rajaseenivasan, T., Tinnokesh, A. P., Kumar, G. R., & Srithar, K. (2016). Glass basin solar still with integrated preheated water supply – Theoretical and experimental investigation. *Desalination*, 398, 214–221. <https://doi.org/10.1016/j.desal.2016.07.041>

- Raju, V. R., & Lalitha Narayana, R. (2016). Effect of flat plate collectors in series on performance of active Solar still for Indian coastal climatic condition. *Journal of King Saud University - Engineering Sciences*, 187(1), 1–8. <https://doi.org/10.1016/j.jksues.2015.12.008>
- RPN, A., Namprakai, P., & Ampun, W. (2013). The thermal performance of an ethanol solar still with fin plate to increase productivity. *Renewable Energy*, 54, 227–234. <https://doi.org/10.1016/j.renene.2012.08.004>
- Saravanan, A., & Murugan, M. (2020). Performance evaluation of square pyramid solar still with various vertical wick materials – An experimental approach. *Thermal Science and Engineering Progress*, 19, 100581. <https://doi.org/10.1016/j.tsep.2020.100581>
- Sathyamurthy, R., Mageshbabu, D., Madhu, B., Muthu Manokar, A., Rajendra Prasad, A., & Sudhakar, M. (2020). Influence of fins on the absorber plate of tubular Solar still- An experimental study. *Materials Today: Proceedings*, 46(xxxx), 3270–3274. <https://doi.org/10.1016/j.matpr.2020.11.355>
- Shanmugan, S. (2013). EXPERIMENTAL ANALYSIS OF A SINGLE SLOPE SINGLE BASIN SOLAR STILL WITH HOT WATER PROVISION. *International Journal of Applied and Natural Sciences (IJANS)*, 3(1), 19–24.
- Shmroukh, A. N., & Ookawara, S. (2020). Evaluation of transparent acrylic stepped Solar still equipped with internal and external reflectors and copper fins. *Thermal Science and Engineering Progress*, 18, 100518. <https://doi.org/10.1016/j.tsep.2020.100518>
- Tuly, S. S., Rahman, M. S., Sarker, M. R. I., & Beg, R. A. (2021). Combined influence of fin, phase change material, wick, and external condenser on the thermal performance of a double slope solar still. *Journal of Cleaner Production*, 287, 125458. <https://doi.org/10.1016/j.jclepro.2020.125458>
- Widiharsa, F. A. (2008). Geometri radiasi matahari di kota malang. *Transmisi*, 4(2), 473–484.