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Enhancement of Solar Still Production

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Abstract: In these recent years, the issues about an environment pollution and increasing population is main concerns. The potable or clean water is reducing and being contaminated on a daily basis. Thus, there is some research focused on get a potable water by using a desalination process from a saltwater. Solar still technology is one of the best methods on solving the issues because it is using free solar energy. The computational fluid dynamic CFD model of solar still is one of the best methods on study the improvement of the conventional solar still because it reduces the need of conducting an experiment. The main purpose of this study is to design a solar still that well function and determine the best design of solar still to be function in Malaysia climate. In this study, the performance of the solar still is investigated by using different angle of slope and predicts the performance without any experiment measure, depends on the CFD solar radiation model. In the parameter that have been investigated, the best angle of slope of double slope in Malaysia climate was based on the temperature difference between the glass and the collector. In this study, the results that was generate from the ANSYS Workbench 2020 in climate conditions of Kuala Lumpur, Malaysia (latitude 4.2105° N and longitude 101.9758° E). The results indicated that the 20 degrees angle of slope of double slope solar still were found to be the admirable design to be used in Malaysia climate at water depth of 2cm.

Keywords: CFD ANSYS, Thermal Desalination, Solar Still, Malaysia Climate

1. Introduction

Earth is an aqueous environment where 71 percent of the Earth's surface is water-covered, and 96.5 percent of the water is hold by an ocean. Solar still is a simple solar product that turn the available brackish water into a drinking water. Solar still has been used for hundreds of years and the first exposure is by using a traditional method. The users digging a hole and place a receptacle in the hole in order to collect the condensed water. Small branches are positioned inside the receptacle with one of their ends, and the other ends over the edge of the bowl, forming a funnel to channel the condensed water into the receptacle. Then a cover is placed over that funnel, using smaller branches, leaves, grasses, etc. The completed trap is left overnight, and in the morning, it can absorb moisture from the receptacle. The first recorded use of solar stills was in 1872, when a still in Las Salinas, in the northern

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deserts of Chile, began its three decades of service to supply drinking water to a mining community. The use of solar still is very broad as in domestic and wastewater treatment.

However, the use of solar still in the water climate condition still gives a lot limitation to the users. One of the main limitations of the solar stills are including the solar still have low productivity per unit installation area of daily production compared to another method such as fuel-based desalination technologies. This can be proved by the nature of our life which is solar energy is unavailable after sunset and cloudy weather [1]. In addition, the initial cost to build the solar still is high. The installation of the solar still can be very high if the area of installation area is at high land, large installation area [2].

There are some necessities of the solar still in the daily life which is solar still can be very useful for the military who are required to do a mission on a sea(Abdallah & Badran, 2008). The supply of the clean water that can be drink are very limited, so the solar still area very helpful for the military to stay hydrated and can perform their task completely. The US Navy used the solar still widely during the war which is the solar still is designed to be floating on the seawater when inflated and these things can save their lives.

2. Methodology

A 3-dimensional solar still model as well as simulation analysis of the entire mode is required for the entire project. For the purpose of the presentation, a 3-dimensional model is an effective tool while the simulation and analysis process is chosen as a tool for the verifications of strength. The process of defining element type and choosing a material type and properties are use as the methodology. The modelling of the solar still is built using ANSYS WORKBENCH. The parameters and material properties that using on the solar still is then define. Finally, the results are compute and plotted to see the distribution of the certain variables

2.1 Geometry Creation and Meshing Details

The first step in the CFD analysis of any problem is the creation of the geometric model of the problem domain as per the design specifications. The problem domain considered here is the space confined by the surface of the saltwater in the still basin, side walls, front and back and the transparent cover of the still. A 3D geometry of the double slope type solar still was created by Solidworks 2017, which provided a design model as a design tool to develop the geometric models of the physical problem domain.

The dimension of the solar still in Figure 1 is design with 1x1 meter of solar still. The height of the basin or the collector of the solar still is 424mm. Both element of the double slope solar still is keep constant in this project while the angle of the slope of the solar still is a control variable where the angle of slope of the solar still in this project are 0,10,20,30,40,50 degrees and another design of the solar still is the single slope type of solar still which is called as conventional solar still.

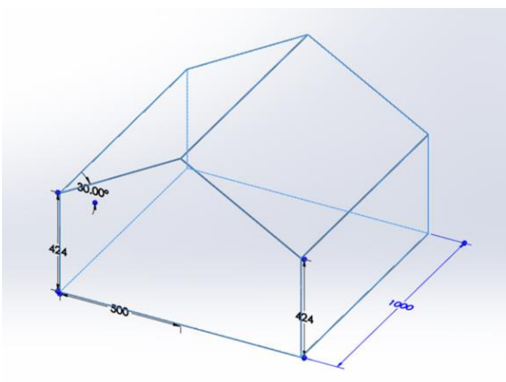

Figure 1: Dimension of the Double Slope Solar Still

There are 7 design of solar still that were simulated. Basically 6 design in this project is model with the double slope type of solar still and another one of the solar still design is model with the single slope type of the solar still model with 30 degrees of slope. The 6 design of the double slope still was simulated with each one of them have different value of angle of slope.

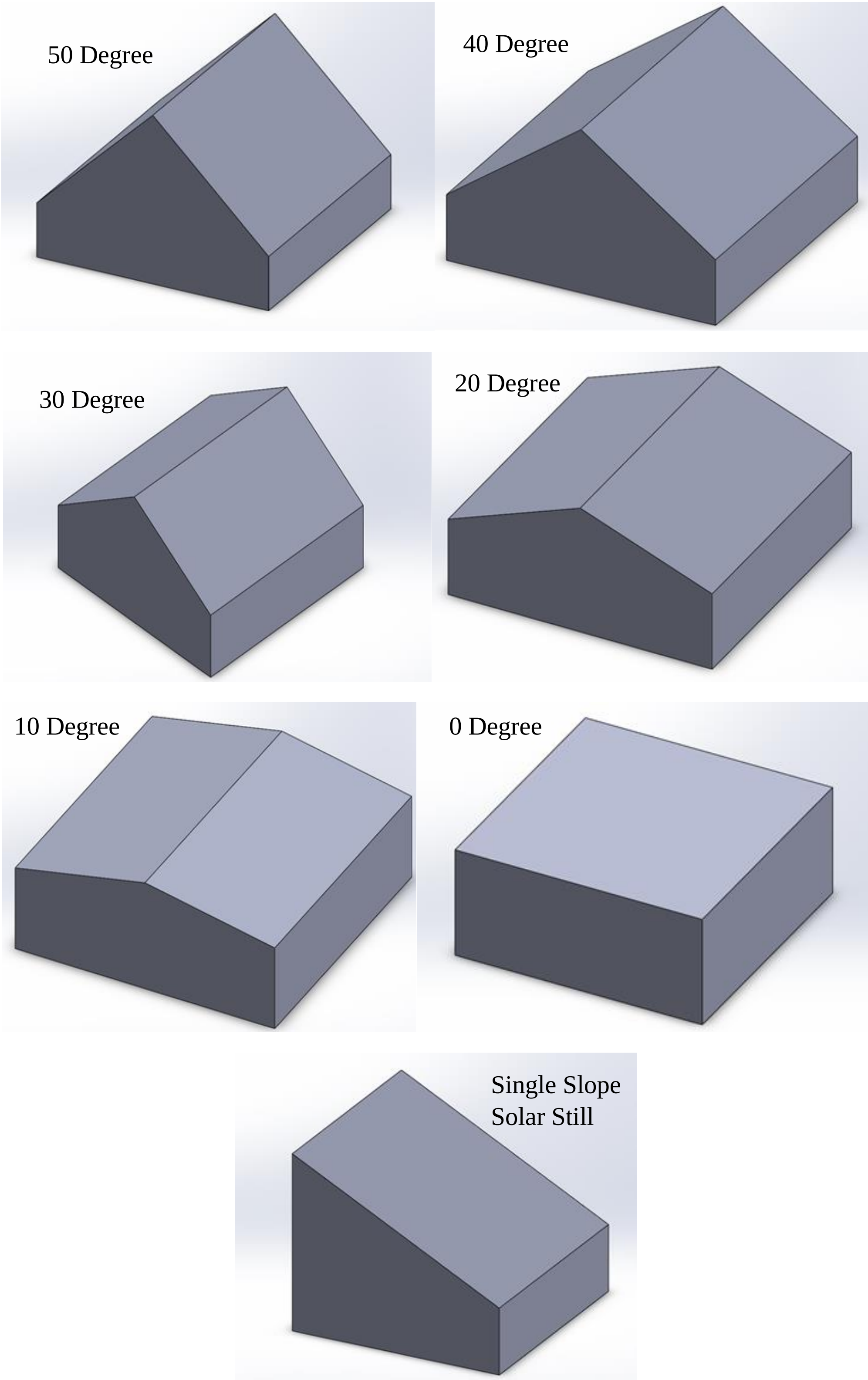

Figure 2: Design of Simulated Solar Stills

ANSYS Workbench CFD meshing technologies provide physics preferences that help to automate the meshing process. For an initial design, a mesh can often be generated in batch with an initial solution run to locate regions of interest. Further refinement can then be made to the mesh to improve the accuracy of the solution. There are physics preferences for structural, fluid, explicit simulations. By setting physics preferences, the software adapts to more logical defaults in the meshing.

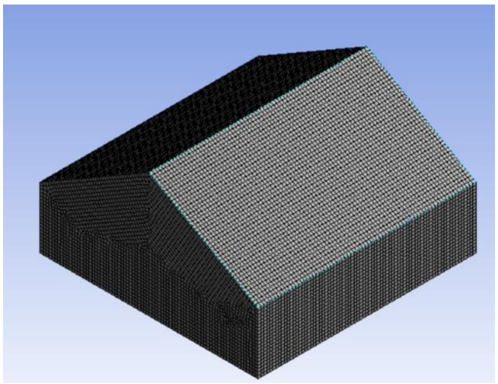

Figure 3: Meshed CFD Domain of Solar Still

Initially the IGES file of the solar still can be imported to the ANSYS. After generating the mesh, it is essential to test the quality of the mesh because it could affect the accuracy of the solution to a great extent. There were several parameters available with ANSYS Workbench for checking the quality of the mesh. Some of the significant parameters were element quality, skewness, aspect ratio, orthogonal quality, etc. In this study, these parameters were checked. A cut cell type method was used which gave the brick type 3D structure as element as shown in Figure 3. The element size 1 cm of the solar still is use. The motive for using such element size was to minimize computational time without compromising the actual results. In the Table 1 show the nodes and elements value and quality after meshing in an ANSYS Workbench 2020.

Table 1: Nodes and Elements in every single solar still design

Angle of Slope (Degree)	Nodes	Elements
0	438643	420000
10	986936	951300
20	1012908	976500
30	1508339	1467900
40	1718833	1675950
50	2022645	1974450
Single Slope	882336	854700

2.2 Assumptions for Simulation

Some assumptions had to be considered in constructing the CFD simulation modelling, as follows:

i. Within the style, there was no thermal energy generation source.

ii. As the ambient wind speed was poor, the impact of wind velocity was ignored, and only free convection was taken into account.

iii. Only form of film condensation occurred in exchange for type of drop condensation

iv. There no leakage occurred in the solar still since the bottom and the side of the solar still basin was insulated hence the solar still is considered as adiabatic.

v. The water level within the basin remained constant and the inlet and outlet saltwater heat flow was negligible.

vi. As the temperature variance was minimal, the fluid properties such as density, thermal conductivity, specific heat and viscosity were used as a piecewise linear temperature profile, while the physical properties of the walls were considered constant.

vii. There was also no gradient of temperatures through the glass cover and the solar water tank.

2.3 Boundary Conditions and Initial Conditions

Incidents of solar insolation are still the most critical factor inside a still. First, due to the absorption and transmissivity of the glass, it is incidental to the glass cover; it is then absorbed by the absorber layer, which raises the water temperature. For simulation purposes the initial water level inside the solar was still assumed to be 2 cm. The fraction of the water and air volume was considered as 0.1 and 0.9, respectively. The initial water temperature and the amount of radiation obtained in every hour for the device used according to the data experimental

Appropriate boundary conditions were defined for solving the continuity and momentum equations at all boundaries. Because of a high number of time phases and machine time constraints, CFD simulation had run time of 10 hours. It was believed that the solar radiation obtained by the basin and the temperatures of water and glass is center on the solar calculator at good weather for 1 hour. On glass, bottom, and surface collection constant temperature boundary conditions were imposed. The experiment was performed from hours 0800 to hours 1700. An average temperature was set as the limiting condition during each 1-hour time period. Solar intensity was dependent upon glass, water, and bottom absorption factor and emissivity. For the overall process heat transfer coefficient of sidewalls was measured and held constant. For the gas phase, a no-slip wall boundary state defined for the liquid phase and free-slip boundary condition was used. The table below show the boundary type and conditions of the project.

Table 2: Boundary Conditions and Boundary Types

Name	Type	Thermal Conditions	Description	Wall Thickness (m)
Glass Wall	Wall	Convection losses (2 w/m^2 .k)	Semi-transparent	0.003
Absorber Wall	Wall	Adiabatic wall (Heat flux = 0)	Opaque	0.0008
Front Wall	Wall	Adiabatic wall (Heat flux = 0)	Opaque	0.05
Back Wall	Wall	Adiabatic wall (Heat flux = 0)	Opaque	0.05
Side Wall (Right)	Wall	Adiabatic wall (Heat flux = 0)	Opaque	0.05
Side Wall (Left)	Wall	Adiabatic wall (Heat flux = 0)	Opaque	0.05

2.4 Validation of the Model

There are variety of studies have been done by previous researchers on analyzing the performance of the solar still by using the ANSYS Workbench software. In order to get a better understanding or better acknowledgement on the expected result on the project, a reference from the previous article or previous research is done. The article that have been used is to compare between theoretical and experimental result. In the Mahmoud El-Sabaey studies, the conventional solar still has been study by using an experimental and CFD modelling to compare the result of the solar still performance. A multi-phase, three-dimensional CFD model was presented for the main purpose of his study, which predicts the performance of the solar still without any experimental measurements, depending on the CFD solar radiation model. Simulated results are compared with experimental water and glass cover temperatures and freshwater yields under the climate conditions of Sheben El-Kom, Egypt (latitude 30.5◦ N and longitude 31.01◦ E) [3]. The parameters and boundary conditions in that studies have been used in this study in order to get an accurate data on the solar still but in this study, the solar radiation data is use in a Malaysia climate and the type of solar still that was simulated is double slope solar still. In the Table 3.4 show the parameter of the researcher used in their paper.

Table 3; Parameter of the Solar Still Used by Mahmoud El-Sabaey Study

	Parameter
Solar Radiation Location	Sheben El-Kom, Egypt (latitude 30.5◦ N and longitude 31.01◦ E)
Type of Solar Still	Single Slope Solar Still
Depth of Water	2 cm
Size of the Solar Still	1 x 1 meter
Glass Wall Thickness	0.003 meter

The conclusion of the study showed that the developed simulating CFD model in the study can be used to predict the performance of the single slope solar still in different solar radiation climate and the developed simulating CFD model also can be used for studying the complex solar still designs.

3. Results and Discussion

Unsteady simulation of the all 6 designs of double slope solar still with different angle of slope and one conventional solar still was carried out with the depth of water in the collector basin 2cm was tested from 0800 to 1700 hours. As the solar radiation was absorbed by the collector basin, the saltwater or brackish water became heated and the evaporation process was occurred. Due to the differences of the temperature in the collector basin and the glass cover, the water condensation was occurred and due to the force of the gravity, the water vapor droplet which attached on the glass cover was slide down to the distillate channel.

In the solar still system, the temperatures of the glass cover, collector basin and the internal mixture of the solar still from the condensation process occurred played a vital role for the water desalination and the performance of the solar still. In general, the production rate of the water distillate by the solar still is depend on the temperature difference between the collector basin and the glass cover.

3.1 Analysis of the Temperature of Glass Cover and Angle of Slope

In the Figure 4 show the graph of the maximum temperature of the solar still in each different time interval for each angle of slope of solar still. The graph shows that the solar still with 30 degrees of slope have the highest value of temperature on the glass cover while the others angle have a temperature between range 300 K to 320 K only. From the figure, it showed that the temperature of the glass cover increased from early morning till noon and decrease slightly as the thermal energy from the sun was disappeared slowly. The result showed a good agreement of simulations result with the experimental result from the Mahmoud El-Sabaey studies. In solar still, after evaporation, whatever vapor was produced, due to its lower density it flows upwards. But due to the coldness of inner glass cover, it gets condensed and converted into water droplets. Due to angle of slope of a solar still, all droplets move downwards and collected in distillate channel to produce fresh water.

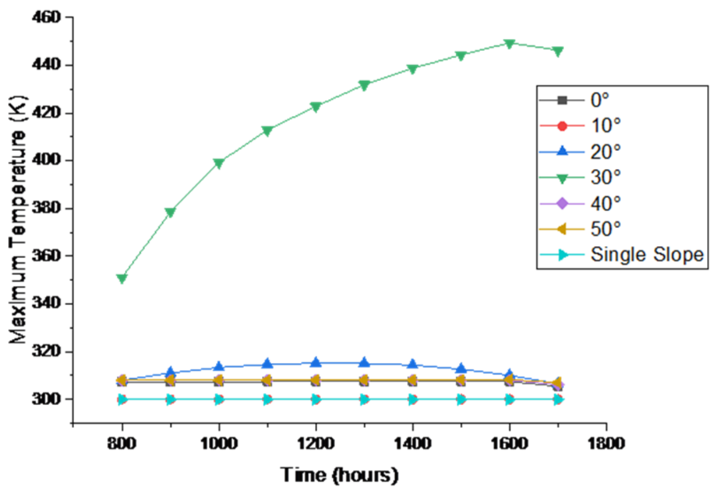

Figure 4: Comparison of each type of solar still of maximum temperature on glass in different time interval

3.2 Analysis of the Temperature of Collector Basin and Angle of Slope

In the Figure 5 shows the graph of the maximum temperature of the collector basin for each solar still with different angle of slope in different time interval. The temperature of the collector basin in the 30 degrees of slope has the highest value of the temperature whereas the others temperature falls below 360 K only. The solar reservoir is still full of water if the amount of water is reduced by solar energy due to evaporation of water, then the float valve operates and supplies the water needed to maintain the pre-determined depth of the water level inside the solar still. In this experiment, a depth of 2 cm is taken from the experiment.

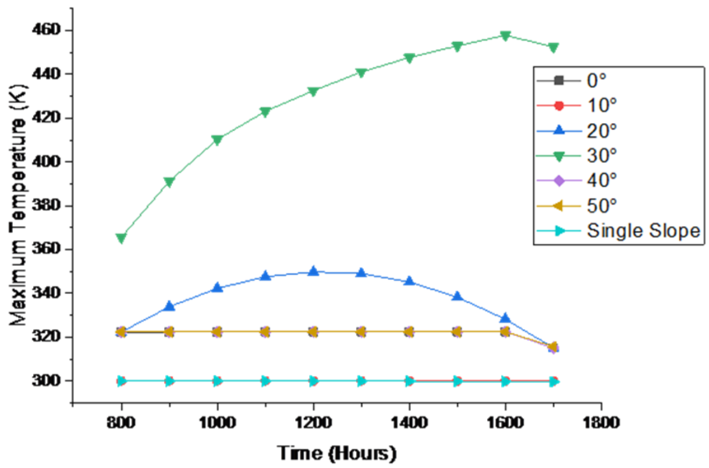

Figure 5: Comparison of each type of solar still of maximum temperature on collector in different time interval

3.3 Analysis of the Temperature of Internal Mixture and Angle of Slope

The Figure 6 show how the temperature of the internal mixture varies in different time interval. On the temperature of the internal mixture, the 30 degrees of slope solar still is maintained to be the highest value of temperature among others solar still. The 30 degrees of solar still internal mixture have the temperature increase drastically from 0800 hours till 1600 hours. As we know, when thermal energy from the sun goes down on the glass cover, then the temperature of the water layer rises, it produces vapour. Measurement of vapour temperature is therefore important. It also increases from morning due to a gradual increase in the availability of the sun, then decreases. These results also provide good agreement on simulation results and experimental results in Mahmoud El-Sabaey studies.

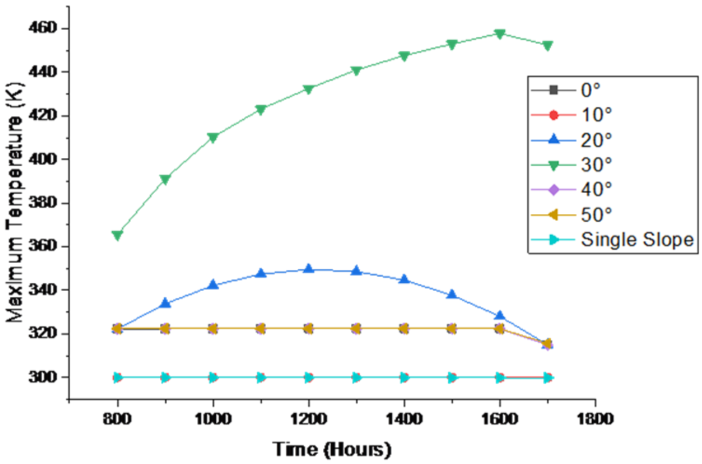

Figure 6: Comparison of each type of solar still of maximum temperature on internal mixture in different time interval

3.4 Analysis of the Velocity of Internal Mixture and Angle of Slope

The Figure 7 shows the velocity of the internal mixture in each degree of angle solar still in each different time interval. In the figure showed that the velocity of each solar still move unevenly or they do not have a pattern for each time interval except for the 0 degree of slope solar still and 30 degree of slope solar still because both type solar still have a constant velocity. Both solar still of velocity line in the figure show that they have an even value in each different time interval.

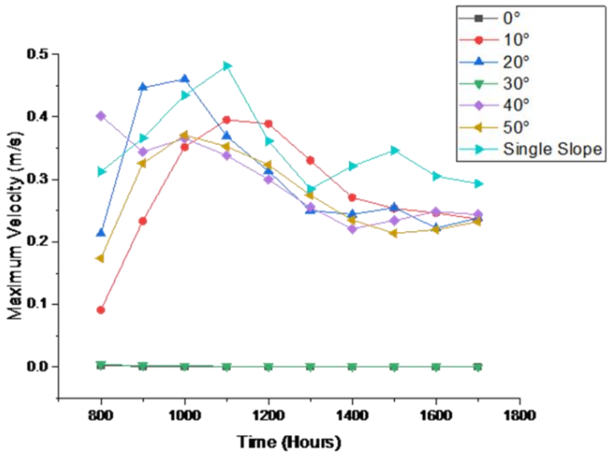

Figure 7: Comparison of each type of solar still of maximum velocity on internal mixture in different time interval

4. Conclusion

The present study focuses on presenting a three-dimensional, multi-phase CFD model for the double slope type of solar still. The model predicted the performance of the double slope solar still with each has different angle of slope with the measurements of the temperature of the glass cover and the collector basin of the solar stills. Outcomes of the study can be concluded as:

i. The double slope solar still performed better than single slope solar still in Malaysia climate.
ii. The 10 degrees slope of double slope solar still and single slope of solar still is not suitable to be used in the Malaysia climate. Both model of the solar still gives the most minimum performance of the solar still based on the temperature contours of the solar still and the temperature difference between the glass and the collector basin of the solar still.
iii. Double slope solar still with 0, 40 and 50 degrees of slope have almost the same performance of solar still.
iv. The 20 degree of angle slope of double slope solar still has the highest performance among all the model of the solar still in this study according to the temperature difference between the glass and the collector in the solar still.
v. The 20 degree of angle slope of double slope type solar still is the most suitable design of solar still to be used in climate of Malaysia in order to overcome the water reducing problems.

As for the recommendations, the investigate of the performance of solar still can be made with install an insulator to the solar still. The insulator can increase the performance of the solar still and a study can be made to investigate the efficiency of the insulator to the solar still. Next, the performance of the solar still can be investigate with different water depth in a solar still. The water depth in a solar still can affect the performance of the solar still. The future study can determine the ideal water depth that can be set in order to investigate the suitable water depth in a solar still in Malaysia climate. Last but not least, the future study can investigate the best material to be use for the collector basin. The material of the collector basin plays a big role in performance of the solar still. This can help future researcher to determine the better solar still performance.

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References

[1] Ansari, O., Asbik, M., Bah, A., Arbaoui, A., & Khmou, A. (2013). Desalination of the brackish water using a passive solar still with a heat energy storage system. Desalination, 324, 10–20.

[2] Ayoub, G. M., & Malaeb, L. (2012). Developments in solar still desalination systems: A critical review. Critical Reviews in Environmental Science and Technology, 42(19), 2078–2112.

[3] S. El-Sebaey, M., Ellman, A., Hegazy, A., & Ghonim, T. (2020). Experimental Analysis and CFD Modeling for Conventional Basin-Type Solar Still. Energies, 13(21), 5734.

[4] Abdallah, S., & Badran, O. O. (2008). Sun tracking system for productivity enhancement of solar still. 220, 669–676.

[5] Lal, R. K., Mishra, S., Dwivedi, J. P., & Dwivedi, H. (2017). ScienceDirect A Comprehensive Study of the Different Parameters of Solar Still. Materials Today: Proceedings, 4(2), 3572–3580.

[6] Khalifa, A. J. N., & Hamood, A. M. (2009). On the verification of the effect of water depth on the performance of basin type solar stills. Solar Energy, 83(8), 1312–1321.

[7] Cavusoglu, A. H., Chen, X., Gentine, P., & Sahin, O. (2017). Potential for natural evaporation as a reliable renewable energy resource. Nature Communications, 8(1).

[8] Biswas, R., Roy, D., Towfiqul Islam, A. R. M., Rahman, M., & Ali, M. (2014). Assessment of drinking water related to arsenic and salinity hazard in Patuakhali district, Bangladesh. International Journal of Advanced Geosciences, 2(2).

[9] Awasthi, A., Kumari, K., & Panchal, H. (2018). Passive solar still: recent advancements in design and related performance. 2515, 235–261.

[10] Anang, Z., Padli, J., Abdul Rashid, N. K., Alipiah, R. M., & Musa, H. (2019). Factors affecting water demand: Macro evidence in Malaysia. Jurnal Ekonomi Malaysia, 53(1), 17–