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Performance of Solar Concentrator with and without Mirror Coating Paper

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Abstract

The utilization of solar energy continues to be developed to get the best efficiency. This energy can be used for electricity generation, cooling, and/or drying. One technology that is still under development is the use of solar concentrators. Therefore, our paper aims to measure the performance of the development of a solar collection unit coated with mirror paper. Furthermore, the data is compared with the test data for solar concentrators without mirror paper that was carried out by previous researchers in 2019. The method used in this research is a field experiment. A simple statistical comparison method was carried out on the experimental data. Field testing was conducted after the solar concentrator was coated with mirror paper. The test was carried out for 5 days in full shining sun conditions in Sukabumi Regency, Indonesia. The surface coating of the solar concentrator with mirror paper has not been able to improve the performance of the solar concentrator satisfactorily. Solar concentrators can heat the fluid from its initial average temperature of 19.37 %.

Keywords: Appropriate technology, Energy, Heating, Mirror coating paper, Solar concentrator

Abbreviation

T-amb.	:	The ambient temperature (°C)
T-W1	:	The water temperature in a container (°C)
T-W2	:	The water temperature before passing through the solar concentrator (°C)
T-W3	:	The water temperature after passing through the solar concentrator (°C)
RH-amb.	:	The ambient relative humidity (%)
T-WC-WMP	:	The temperature in water container from solar concentrator with mirror paper (°C)
T-WC-WTMP	:	The temperature in water container from solar concentrator without mirror paper (°C)
SI-WMP	:	The solar intensity from solar concentrator with mirror paper (mV)
SI-WTMP	:	The solar intensity from solar concentrator without mirror paper (mV)
PV	:	Photovoltaics
IoT	:	Internet of things

Introduction

Solar concentrator technology has continued to develop rapidly in recent years. Some of its uses have also almost entered the production phase by the industry for various purposes such as power generation [1-3], cooling [4-6] and/or drying [7-9]. Its use is also not limited to land [1,4,7], but studies have also been carried out underwater [10].

On the one hand, the application of solar concentrator technology has been integrated with PV, as has been done by several researchers [1-3] which convert solar energy into electrical energy. However, its utilization still does not open another point of view, such as the direct use of solar concentrator technology for the daily life of a community. This aims to make solar concentrators an appropriate technology that can be used sustainably in remote areas far from electricity sources. On the other hand, Liang *et al.* [10] have developed the use of underwater solar concentrators to generate electricity through the use of PV. The concept he developed is referring to the use of a solar concentrator in the sea so that it can generate electricity. But unfortunately, the results of this study report that the depth and turbidity of water will affect the PV efficiency.

One of the parameters of solar concentrator application to be an appropriate technology is the ease with which the technology can be adapted and or even replicated by a community so that it can be used sustainably [11,12]. It requires the use of local raw materials in the design so that the technology can be developed. One material that is very easy to find in this research location is mirror paper. This material is thought to be able to reflect sunlight to the point of the solar concentrator pipe so that it can generate heat. Therefore, this paper describes the results of measuring the performance of solar concentrators whose surface is coated with mirror paper. The results of these measurements are then compared with the results of previous studies to provide an overview of the performance of the solar concentrator.

Materials and methods

A prototype of solar concentrator

The solar concentrator used in this study is the result of the development of research by Sitorus *et al.* [13]. This unit consists of 3 main parts, namely the solar concentrator unit, the data logger instrument unit with the sensor and the water container unit and the circulation pump (**Figure 1**). This solar concentrator unit has been integrated with a measurement system based on the internet of things (IoT). Measurement data can be monitored and downloaded via the link ttgotomasi.id/ats/scnsp/gui.php.

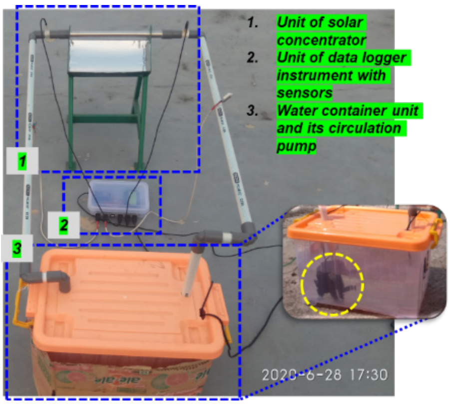


Figure 1 The main parts of a solar concentrator.

The material used to coat the surface of the solar concentrator is mirror paper, as shown in **Figure 2**. The mirror paper is obtained from a local market in the Sukabumi district, Indonesia. The mirror paper is combined with the surface of the solar concentrator by gluing it with paper adhesive glue. The assembly process was attempted so that the mirror paper could still follow the surface pattern of the solar concentrator.

Figure 2 Mirror paper used [14].

Solar concentrator performance testing procedure

The performance test of the solar concentrator was carried out after the surface of the solar concentrator was coated with mirror paper. The experiment was carried out for 5 consecutive days in sunny weather conditions. A data logger measuring instrument has been designed with 3 points for measuring fluid temperature, 1 point for measuring temperature and environment, and 1 point for measuring solar intensity. The temperature sensor used at the fluid measurement point is the DS18B20 digital thermometer type. The temperature and humidity sensor used is the DHT22 digital thermometer. The solar intensity sensor used is the LDR sensor module. The measurement points on the solar concentrator are presented in **Figure 3**. All measurement data are sent via the internet network to the cloud database. This data can be accessed via the http://ttgotomasi.id/ats/scnsp/gui.php.

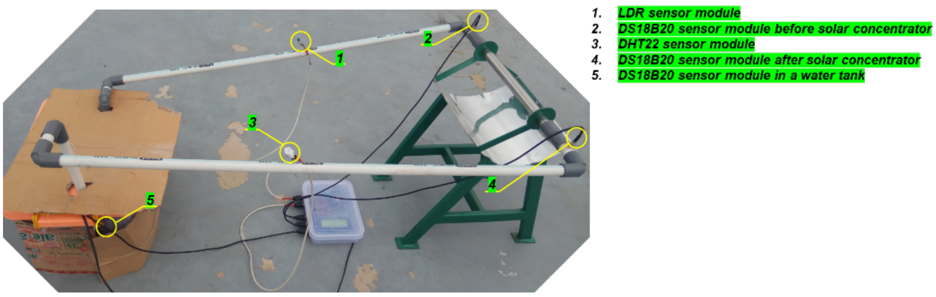


Figure 3 Measuring points in the solar concentrator.

The solar concentrator unit is combined with a fluid container filled with water. This fluid was chosen because it is more stable in storing heat. The amount of fluid used is 0.012 m^3. Furthermore, the fluid is pumped into the solar concentrator and returns to the fluid storage container. This circulation takes place during field testing. The initial measurement of water temperature before testing is carried out every day. Testing was carried out by a field laboratory at Nusa Putra University, Sukabumi, West Java, Indonesia (6°54'17.9"S 106°52'24.1"E) at 576 m above the sea level.

Results and discussion

Performance data of the solar concentrator coated with mirror paper

In the first test, it was found that the average amount of total data that could be recorded was 67.26 % of the 17,198 data that could have been stored. A total of 67.82 % is data that can be recorded on parameters of temperature and humidity of the environment. A total of 67.21 % is data that can be recorded from the measurement point before through the solar concentrator. As much as 66.93 % is data that can be recorded from the measurement point after through the solar concentrator. As many as 66.03 % of data were recorded from the measurement point in the water container. A total of 67.74 % are data recorded from the point of measurement of solar intensity.

The second test results show that the average amount of total data that could be recorded was 59.48 % of the 19,083 data that should have been stored. A total of 58.58 % is data that can be recorded on parameters of temperature and humidity of the environment. As much as 58.57 % is data that can be recorded from the measurement point before through the solar concentrator. As much as 58.57 % is data that can be recorded from the point of measurement after through the solar concentrator. A total of 58.57 % are data recorded from the measurement point in the water container. A total of 64.03 % is data recorded from the point of measurement of solar intensity.

The third test reveals that the average amount of total data that could be recorded was 75.16 % of the 18,900 data that could have been stored. A total of 76.52 % is data that can be recorded on parameters of temperature and humidity of the environment. As much as 76.96 % is data that can be recorded from the measurement point before through the solar concentrator. A total of 76.96 % is data that can be recorded from the measurement point after through the solar concentrator. A total of 67.05 % are data recorded from the measurement point in the water container. A total of 76.97 % are data that are recorded from the point of measurement of solar intensity.

The last two test, it was found that the average number of total data that could be recorded was 62.06 % of the 18,054 data that could have been stored. As much as 62.06 % is data that can be recorded on parameters of temperature and humidity of the environment. As much as 62.06 % is data that can be recorded from the measurement point before through the solar concentrator. As much as 62.06 % is data that can be recorded from the point of measurement after through the solar concentrator. A total of 62.06 % is data recorded from the measurement point in the water container. As much as 62.06 % of the data are recorded from the point of measurement for solar intensity.

The last test reveals that the average number of total data that could be recorded was 57.41 % of the 17,695 data that could have been stored. As much as 57.43 % is data that can be recorded on parameters of temperature and humidity of the environment. As much as 57.42 % is data that can be recorded from the measurement point before through the solar concentrator. As much as 57.42 % is data that can be recorded from the measurement point after through the solar concentrator. A total of 57.32 % were recorded data from the measurement point in the water container. A total of 57.43 % are data recorded from the point of measurement of solar intensity. The summarizes of data obtained during the test is presented in full in **Table 1**.

Table 1 Resuming the amount of data collected during testing.

Testing to	Amount of data recorded at the measurement point				
	T-abm and RH-amb.	T-W1	T-W2	T-W3	SI-WMP
1	11,664	11,356	11.559	11,510	11,649
2	11,179	11,176	11,176	11,176	12,218
3	14,462	12,672	14,545	14,546	14,547
4	11,205	11,204	11,204	11,204	11,205
5	10,162	10,143	10,160	10,160	10,162

Testing on 24 June 2020

The first test of the performance of a solar concentrator coated with mirror paper was on 24 June 2020 from 07:57:33 to 17:30:48 (**Figure 4**). The current local time in this test is GMT+7. The test duration was 9 h, 33 min, 15 s. The initial water temperature of the experiment was 23.62 °C. The highest ambient temperature and relative humidity were 34 °C, 99.90 %. It's happened at 10:51:06 and 17:30:48. The lowest ambient temperature and relative humidity were 24.30 °C, 60.50 %, respectively. It's happened at 17:29:47 and 10:51:56. The average ambient temperature and relative humidity during this test were 28.83 ± 1.78, 87.27 ± 7.57 %. The highest water temperature before and after passing through the solar concentrator was 31.37, 30.62 °C, respectively. It's happened at 14:45:44 and 14:45:49. The lowest water temperature before and after passing through the solar concentrator is 23.38, 23.25 °C, respectively. It's happened at 08:01:13 and 07:57:48. The mean water temperature before and after passing through the solar concentrator pipe was 29.23 ± 1.87, 28.49 ± 1.92 °C, respectively. The highest and lowest water temperature in the container is 30.56, 23.62 °C. It's happened at 14:45:32 and 07:57:58. The average water temperature in the container is 28.49 ± 1.77 °C. The highest and lowest solar intensity on a container was 405, 10 mV, respectively. It's happened at 17:30:40 and 08:06:27. Average solar intensity is 67.12 ± 65.73 mV.

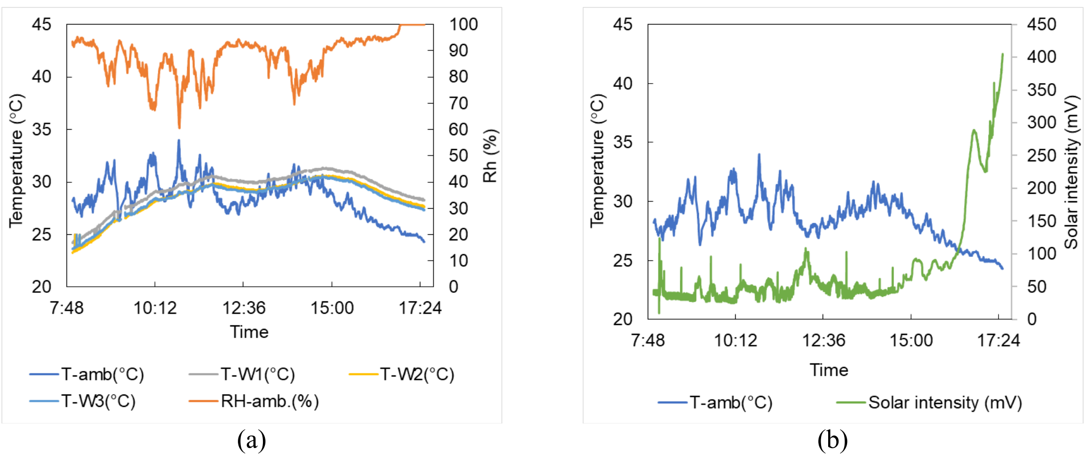


Figure 4 The first test of the performance of a solar concentrator (a) temperature and relative humidity (b) ambient temperature with solar intensity.

Testing on 25 June 2020

The second test of the performance of a solar concentrator coated with mirror paper was on 25 June 2020 from 06:56:04 to 17:32:10 (**Figure 5**). The test duration was 10 h, 36 min, 6 s. The initial water temperature of the experiment was 22.69 °C. The highest ambient temperature and relative humidity were 37.90 °C, 99.90 %, respectively. It's happened at 12:29:29 and 17:32:10. The lowest ambient temperature and relative humidity were 23.30 °C, 42.40 %, respectively. It's happened at 06:57:06 and 12:29:40. The average ambient temperature and relative humidity during this test were 31.22 ± 3.81 °C, 71.20 ± 18.22 %. The highest water temperature before and after passing through the solar concentrator was 34.88, 34.25 °C, respectively. It's happened at 13:41:12 and 12:34:55. The lowest water temperature before and after passing through the solar concentrator is 23.44, 22.56 °C, respectively. It's happened at 07:06:10 and 06:58:33. The mean water temperature before and after passing through the solar concentrator pipe was 29.08 ± 3.75, 28.25 ± 3.83 °C, respectively. The highest and lowest water temperature in the container is 34.19, 22.69 °C. It's happened at 12:53:58 and 07:02:36. The average water temperature in the container is 28.36 ± 3.72 °C. The highest and lowest solar intensity on a container was 428, 24 mV, respectively. It's happened at 17:31:56 and 11:44:24. Average solar intensity is 49.89 ± 52.68 mV.

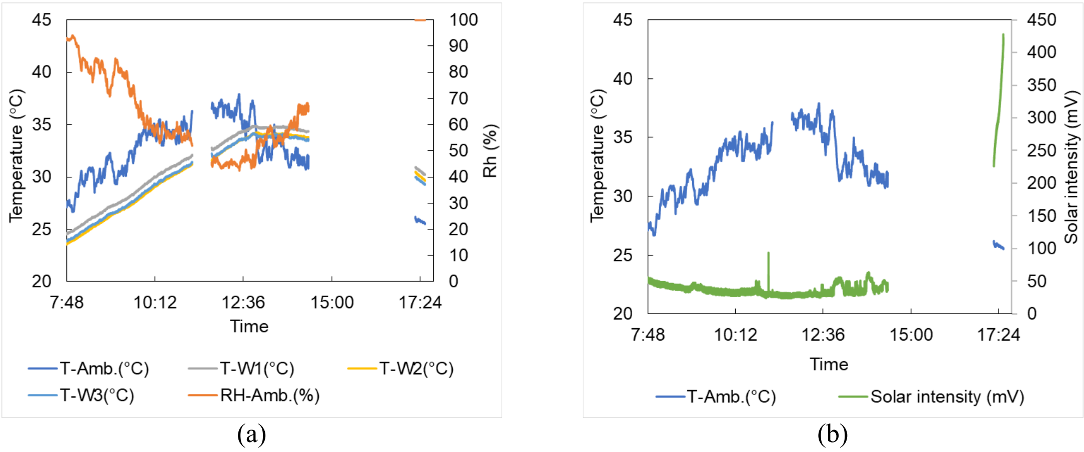


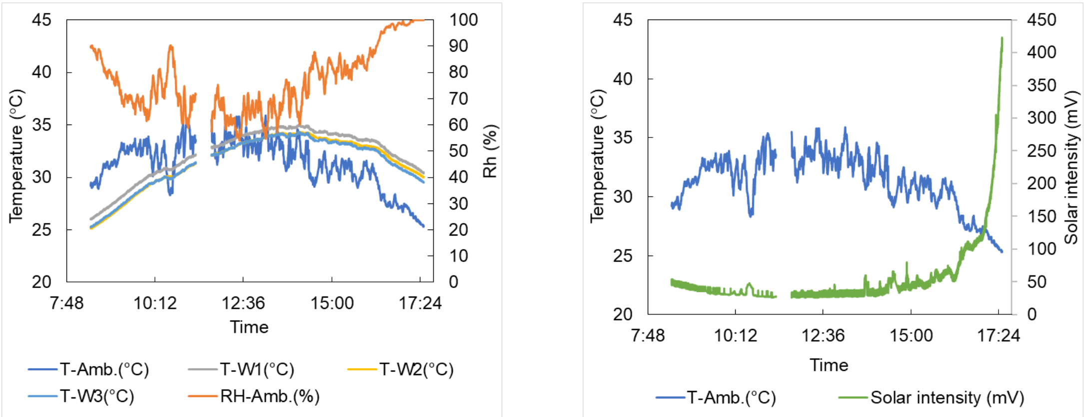
Figure 5 The second test of the performance of a solar concentrator (a) temperature and relative humidity (b) ambient temperature with solar intensity.

Testing on 26 June 2020

The third test of the performance of a solar concentrator coated with mirror paper was on 26 June 2020 from 07:00:01 to 17:30:00 (**Figure 6**). The test duration was 10 h, 29 min, 59 s. The initial water temperature of the experiment was 23.12 °C. The highest ambient temperature and relative humidity were 35.90 °C, 99.90 %, respectively. It's happened at 13:12:23 and 07:12:52. The lowest ambient temperature and relative humidity were 22.40 °C, 54.00 %, respectively. It's happened at 07:00:39 and 12:29:43. The average ambient temperature and relative humidity during this test were 30.57 ± 3.06 °C, 79.05 ± 12.89 %. The highest water temperature before and after passing through the solar concentrator was 35.00, 34.31 °C, respectively. It's happened at 14:08:26 and 14:08:55. The lowest water temperature before and after passing through the solar concentrator is 23.12, 23.12 °C, respectively. It's happened at 07:10:58 and 07:01:07. The mean water temperature before and after passing through the solar concentrator pipe was 30.52 ± 3.93, 29.89 ± 3.82 °C, respectively. The highest and lowest water temperature in the container is 34.31, 24.12 °C. It's happened at 14:12:31 and 07:56:03. The average water temperature in the container is 30.78 ± 3.07 °C. The highest and lowest solar intensity on a container was 423, 26 mV, respectively. It's happened at 17:30:00 and 12:28:19. Average solar intensity is 52.15 ± 37.99 mV.

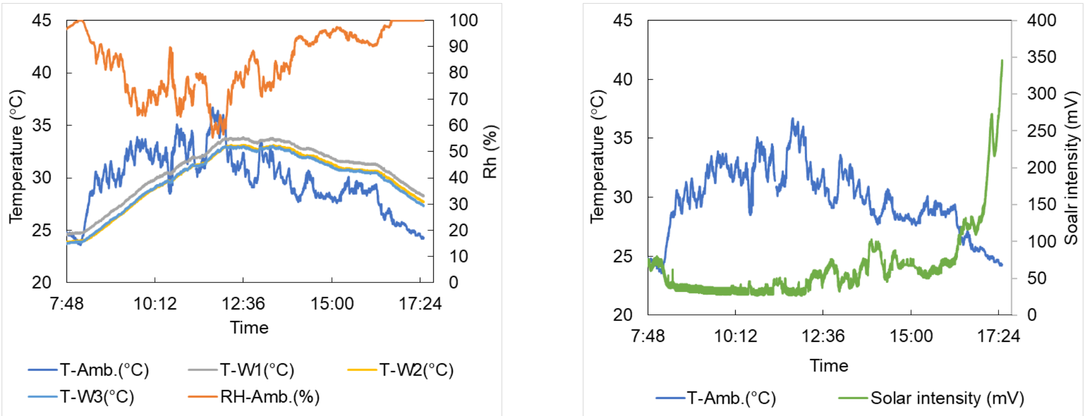
Testing on 27 June 2020

The last two test of the performance of a solar concentrator coated with mirror paper was on 27 June 2020 from 07:28:12 to 17:30:00 (**Figure 7**). The test duration was 10 h, 1 min, 48 s. The initial water temperature of the experiment was 23.56 °C. The highest ambient temperature and relative humidity were 36.70 °C, 99.90 %, respectively. It's happened at 11:46:29 and 08:14:01. The lowest ambient temperature and relative humidity were 23.60 °C, 55.30 %, respectively. It's happened at 08:11:05 and 11:46:15. The average ambient temperature and relative humidity during this test were 29.49 ± 3.24 °C, 84.43 ± 12.41 %. The highest water temperature before and after passing through the solar concentrator was 33.88, 33.13 °C, respectively. It's happened at 12:36:20 and 12:37:02. The lowest water temperature before and after passing through the solar concentrator is 24.37, 23.62 °C, respectively. It's happened at 07:33:08 and 07:29:31. The mean water temperature before and after passing through the solar concentrator pipe was 29.28 ± 3.14, 28.51 ± 3.21 °C, respectively. The highest and lowest water temperature in the container is 33.06, 23.56 °C. It's happened at 13:23:28 and 07:33:31. The average water temperature in the container is 28.47 ± 3.15 °C. The highest and lowest solar intensity on a container was 346, 27 mV, respectively. It's happened at 17:30:00 and 12:01:01. Average solar intensity is 60.58 ± 47.74 mV.



(a) (b)

Figure 6 The third test of the performance of a solar concentrator (a) temperature and relative humidity (b) ambient temperature with solar intensity.



(a) (b)

Figure 7 The last 2 test of the performance of a solar concentrator (a) temperature and relative humidity (b) ambient temperature with solar intensity.

Testing on 28 June 2020

The last one test of the performance of a solar concentrator coated with mirror paper was on 28 June 2020 from 07:40:06 to 17:29:56 (**Figure 8**). The test duration was 9 h, 49 min, 50 s. The initial water temperature of the experiment was 23.75 °C. The highest ambient temperature and relative humidity were 36.20 °C, 99.90 %, respectively. It's happened at 12:21:23 and 07:59:32. The lowest ambient temperature and relative humidity were 24.70 °C, 59.20 %, respectively. It's happened at 07:45:15 and 12:35:20. The average ambient temperature and relative humidity during this test were 30.51 ± 2.38 °C, 84.47 ± 9.36 %. The highest water temperature before and after passing through the solar concentrator was 34.44, 33.69 °C, respectively. It's happened at 13:57:17 and 13:57:47. The lowest water temperature before and after passing through the solar concentrator is 23.75, 22.75 °C, respectively. It's happened at 07:46:29 and

07:46:41. The mean water temperature before and after passing through the solar concentrator pipe was 29.38 ± 3.77, 29.57 ± 3.25 °C, respectively. The highest and lowest water temperature in the container is 33.50, 23.00 °C. It's happened at 13:57:24 and 08:10:28. The average water temperature in the container is 29.57 ± 3.25 °C. The highest and lowest solar intensity on a container is 328, 27 mV. It's happened at 17:26:26 and 12:30:18. Average solar intensity is 55.35 ± 33.01 mV.

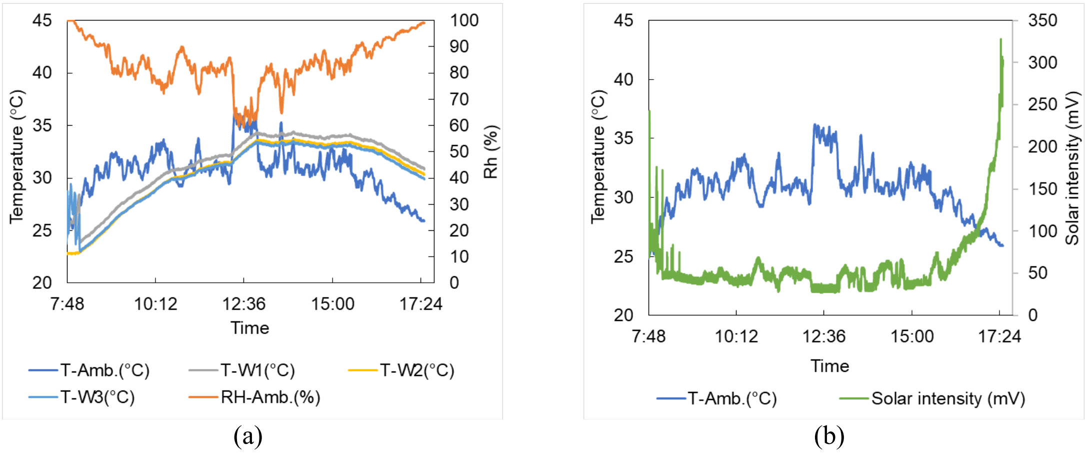


Figure 8 The last of performance of a solar concentrator (a) temperature and relative humidity (b) ambient temperature with solar intensity.

Comparison of performance with and without mirror paper

Overall, the comparison of the performance of the solar concentrator in this paper is compared with the results of the study by Sitorus *et al.* [13] is presented in **Figure 9**. It can be seen that the average solar intensity during the test conducted by Sitorus *et al.* [13] is lower than when tested in this paper. However, the average temperature that can be generated by the solar concentrator is 5.99 % higher than the results of this study. The increase in fluid temperature in this study amounted to 19.37 %. This is presumably because the coating with mirror paper cannot collect solar energy maximally to the surface of the fluid flow pipe.

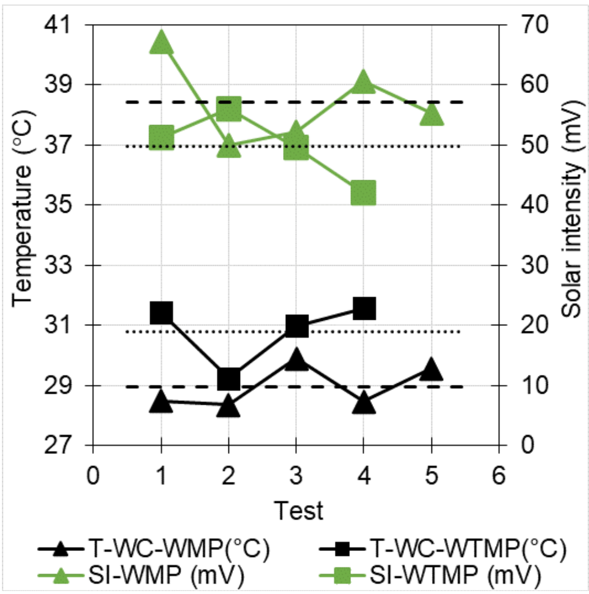


Figure 9 Performance comparison of solar concentrators with and without mirror paper.

Conclusions

Performance measurement of the solar concentrator coated with mirror paper has been carried out. The performance analysis of the solar concentrator has also been compared with that of without mirror paper coating. Mirror paper coating does not provide a satisfactory temperature rise to the heated water container. The difference in temperature of the fluid heated with solar concentrator with and without pine paper is an average of 5.99 %. The increase in fluid temperature from the initial was 19.37 %. Therefore, this paper provides suggestions for researchers and engineers related to the development of solar concentrators to consider the use of mirror paper for solar concentrator surfaces. The future work of this research is to develop and test with a pure mirror coating which is formed according to the surface of the solar concentrator.

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