# Dan Mugisidi - Effect of Iron Sand in Single Basin Solar Still: Experimental Study

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# Effect of Iron Sand in Single Basin Solar Still: Experimental Study

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**Abstract.** The aim of this experiment was to study the effect of iron sand in a single solar still. The study was conducted on an open floor at the Faculty of Engineering, Muhammadiyah University Prof. DR HAMKA in Jakarta, Indonesia between August – September 2018 using two solar stills made of 2 mm stainless steel (420 mm x 305 mm) covered with 3 mm glass with a slope of 30 degrees. Iron sand was taken from Glagah beach, Kulonprogo in Yogyakarta, Indonesia. One solar still contained 20 mm height of iron sand with 15 mm height of water, while the other one contained 20 mm of water without iron sand and was used as a control. The experiment results showed that the efficiency of solar still containing iron sand was 1.5% higher than the control.

## 1. Introduction

The solar still is a simple device for changing water basins in coastal areas with low population densities and is suitable for up to 200 $m^3$/day [1]. Various methods and materials have been used to improve the performance of solar still. Abdel-Rehim used a packed layer composed of glass on the surface of the bottom of the still basin rather than the conventional and rotating shaft solar still, showing that productivity of the packed layer still basin was higher than the other two [2]. Ben Halima created air bubbles inside the solar still to improve evaporation [3], while the tilted-wick placed on the surface of water inside the solar still used by Karaghoulli increased productivity[4]. Valsaraj mounted perforated aluminium on the water surface of the solar still [5] and Da Silva compared the effect of polished, chrome plated, and non-polished aluminium and SUS 304 in terms of performance [6]. Abu Hijleh improved the performance of the solar still with an iron cube due to the higher conductivity [7]. Previously, sand has been used as storage and an absorber since it is cheap and readily available. Velmuragan [8] combined sand with fin to increase solar still productivity, while El-sebaii [9] investigated sand beneath the basin liner. Omara and Kabeel [10]compared black and yellow sand as an absorber in the solar still. The use of sand as an absorber in the solar still can reduce the need for stainless steel, aluminium or iron as an absorber, thereby reducing production costs as sand is cheaper. The present study used iron sand containing 70.3% iron as a porous absorber inside the solar still. To enhance productivity of the solar still, to draw water via capillary action and increase evaporation surface area, the water surface was below the iron sand surface.

## 2. Experimental Set Up

Two single basin solar stills were fabricated using stainless steel plate 2 mm SUS304 and the cover using 3 mm glass. The effective dimensions of the solar still were 40 mm x 30 mm. One solar still was filled with iron sand up to 20 mm and water as high as 15 mm, while the other still only contained water at a height of 20 mm. Iron sand was taken from Glagah beach, Kulonprogo in Yogyakarta, Indonesia. The study was conducted on 19th August 2018, 29th August 2018 and 1st September 2018 starting at 08.00 until 17.00 without put solar radiation condition into account. Temperature was measured using the calibrated thermocouple type K.

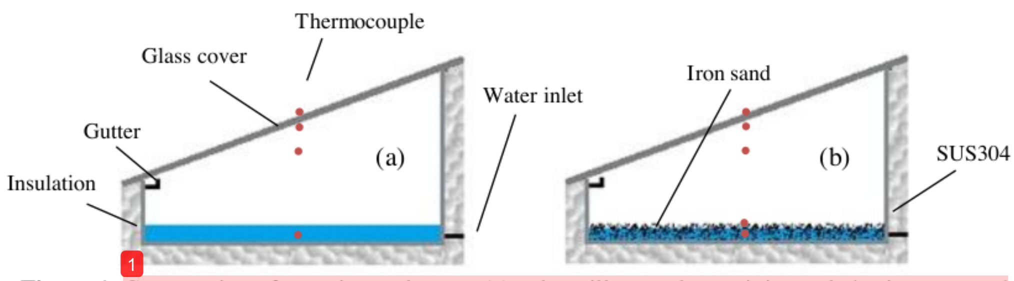


**Figure 1.** Construction of experimental set up (a) solar still control containing only basin water and (b) solar still containing 20 mm iron sand and 15 mm basin water

## 3. Results and Discussion

The study was conducted for three non-sequential days and did not take into account the solar conditions. The solar radiation and ambient temperature on 19th and 29th August as well as 1st September 2018 are shown in **Figures 2–4**.

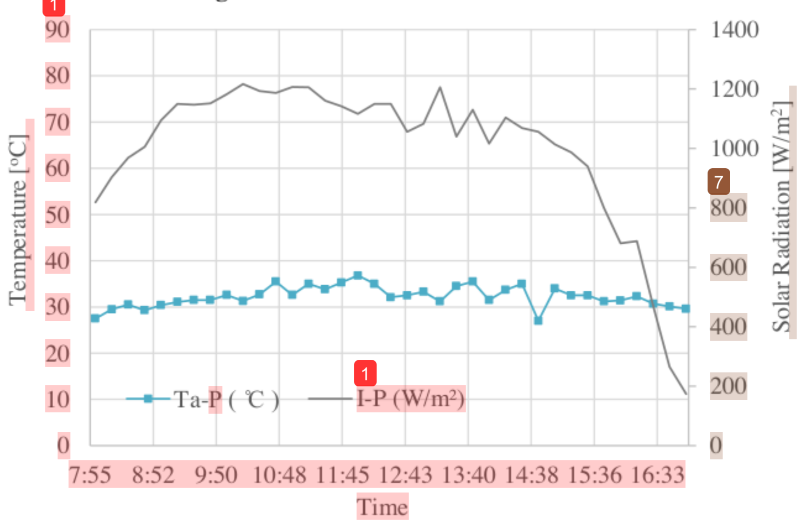


**Figure 2**. Solar radiation and ambient temperature on 19th August 2018

The weather on 19th August 2018 was bright with few clouds and the solar radiation reached above 1200 W/m$^2$, with an average solar radiation of 998.2 W/m$^2$. The average ambient temperature was 32.2°C and the average wind speed was 1.3 m/s with a top speed of 5.9 m/s at 3:15 pm. **Figure 3** shows the solar radiation and ambient temperature on 29th August 2018. There was variation in the solar radiation due to the cloudy conditions, with an average solar radiation of 515 W/m$^2$. The ambient temperature was 32.27°C, slightly higher than that on 19th August 2018, probably due to the lower wind speed of only 0.57 m/s. The solar radiation and ambient temperature on 1st September 2018 is shown in **Figure 4**. The weather on 1st September 2018 was rather cloudy with an average

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solar radiation of 726.4 W/m$^2$. The average ambient temperature was 32.6°C and the wind velocity was 1.12 m/s.

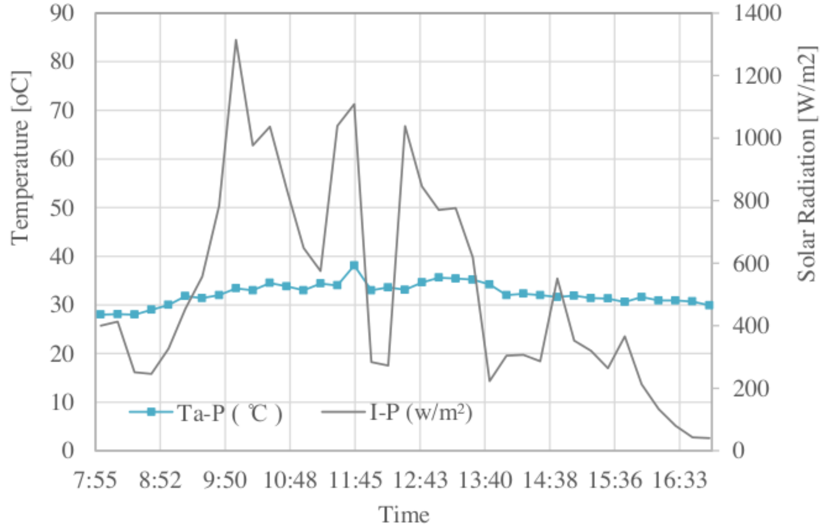


**Figure 3.** Solar radiation and ambient temperature at 29th August 2018

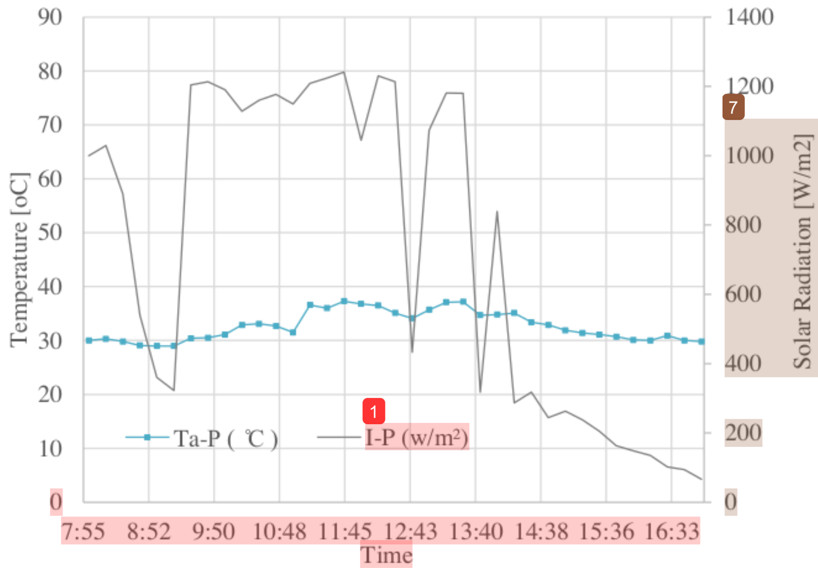


**Figure 4.** Solar radiation and ambient temperature on 1st September 2018

**Figure 5** to **Figure 10** shows the temperature of water, vapour, inner side of cover glass and outer side of cover glass during the experiments. Normally, the temperature of water is higher than the temperature of the inner side of the cover glass, with the temperature difference proportional to the pressure difference on the water surface with partial pressure below the inner side of cover glass. This pressure difference is responsible for the evaporation, thus when the temperature difference between the water and the inside of the cover glass is large, the fresh water yield is higher. On 19th August 2018, the water temperature in the iron and solar still was lower than the inner side of its cover glass,

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so when the water temperature was higher than the inner side temperature of the cover glass, the difference was smaller than the solar still control. Consequently, the fresh water yield in the iron and solar still is lower than the control, as shown in **Figure 11**.

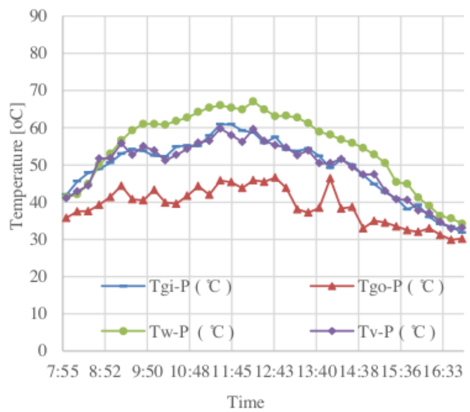


**Figure 5.** Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi) and outer side of cover glass (Tgo) in control solar still on 19th August 2018

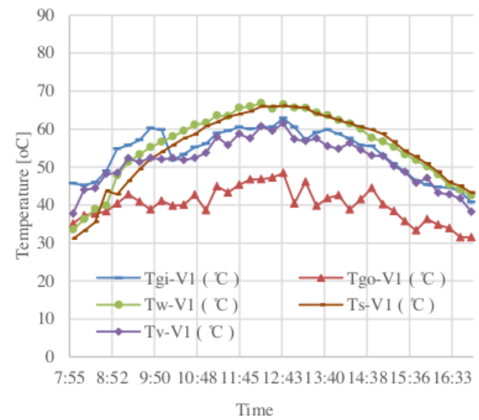


**Figure 6**. Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi), outer side of cover glass (Tgo) and sand (Ts) in iron sand solar still on 19th August 2018

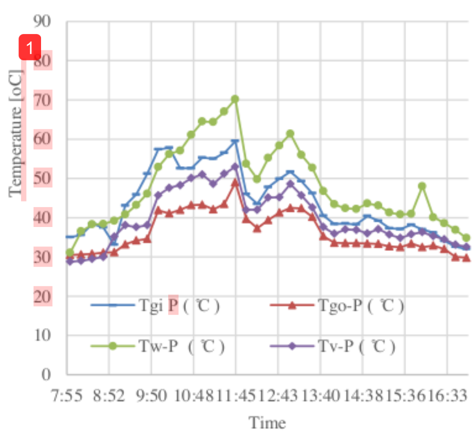


**Figure 7.** Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi), and outer side of cover glass (Tgo) in control solar still on 29th August 2018

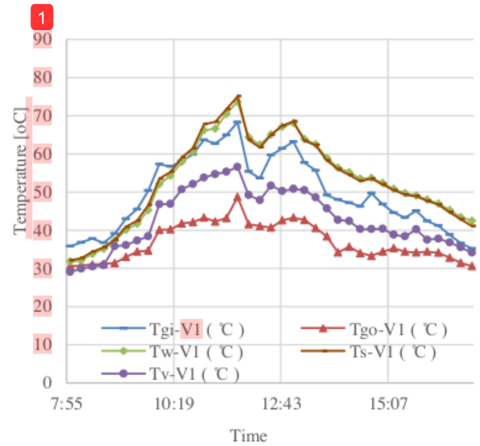


**Figure 8.** Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi), outer side of cover glass (Tgo) and sand (Ts) in iron sand solar still on 29th August 2018

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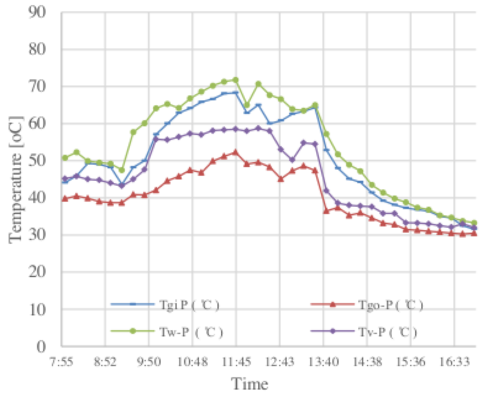



**Figure 9.** Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi) and outer side of cover glass (Tgo) in control solar still on 1st September 2018

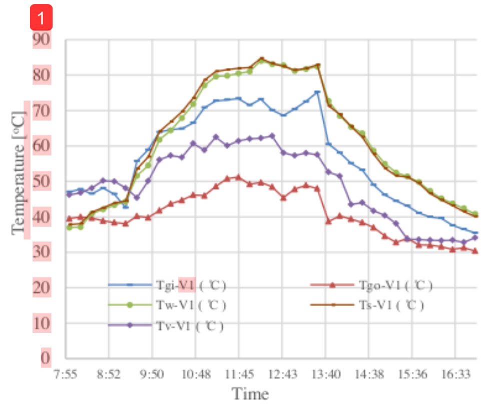
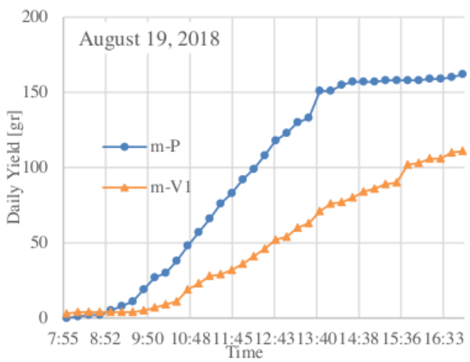
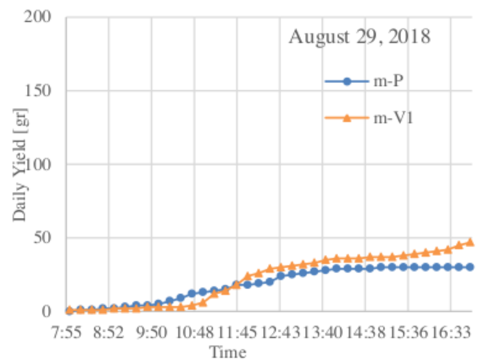



**Figure 10.** Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi), outer side of cover glass (Tgo) and sand (Ts) in iron sand solar still on 1st September 2018




(a)

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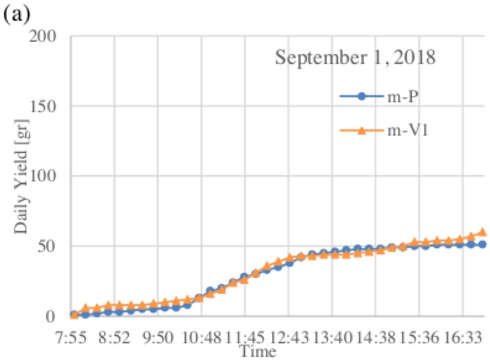


(c)

**Figure 11**. Temperature of basin water (Tw), vapour (Tv), inner side of cover glass (Tgi), outer side of cover glass (Tgo) and sand (Ts) in iron sand solar still on 1st September 2018

The daily yield of solar still control and solar still containing iron sand is shown in **Figure 11.** The solar still containing iron sand generated more fresh water than the solar still control, except on 18th

August 2018, consistent with the previous explanation that the temperature difference in the solar still containing iron sand was smaller than the control, thus the yield was less. The level of water in solar still containing iron sand was lower than the level of the iron sand. Even though the water goes up to the iron sand surface by capillary action, the heat that accumulated on the surface of the iron sand raised the water temperature and transferred directly by radiation and convection to the inner side of the glass, so that the inner side of the glass temperature increased. Therefore, the temperature difference becomes smaller, thus the fresh water yield also becomes smaller.

The efficiency of the solar still is the summation of the daily condensate produced multiplied by the latent heat of evaporation then divided by the summation of the solar radiation over the whole area [8].

$$\eta = \frac{\sum m_{ew} \times h_{fg}}{\sum I(t)_s \times A_s \times 3600}$$

Where $m_{ew}$ is yield in kg, $h_{fg}$ is latent heat of evaporation, $I_{(t)s}$ is average of solar radiation and $A_s$ is the area of the still. This result showed that the efficiency solar still containing iron sand on 19th August 2018 was 46% lower than control, while on 29th August and 1st September 2018, the solar still containing iron sand was 36% and 14.6% higher respectively than the control.

## 4. Conclusion

This study showed that the solar still containing iron sand has 1.5% higher efficiency in lower solar radiation but has lower efficiency at higher solar radiation. It is recommended to increase the water level as high as the iron sand surface level.

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