Solar Interfacial Technology and its Effect on Clean Water Evaporation from Contaminated Water Sources

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Introduction

Solar thermal energy has been used as a method of evaporation for centuries[1]. However the process can be slow, and the output is often significantly lower than the energy input. Other methods of obtaining clean water include membrane technology, which requires pumping water through a thin, porous membrane[2]. This technique is good at purifying water, however it requires copious amounts of energy, and can be tedious. In recent years, the development of Solar Interfacial technology has attracted mass amounts of attention, by researchers around the world[2] This technology utilizes the air-liquid interface, in order to contain thermal energy where evaporation is taking place[2]. This has the potential to exponentially speed up evaporation rate.

Purpose

- Determine how beneficial using solar interfacial technology is to the solar-thermal evaporation process
- Discover how light intensity affects the solar-thermal evaporation process

Methods and Materials

Parts of Evaporation System

Solar absorber

- Cotton cloth coated multiple times in a carbon and sodium alginate solution
- Submerged in a calcium carbonate solution for 48 hours to lock in carbon molecules, and maintain black colour, for best solar absorption

Insulator

- Made of porous styrofoam
- Limits heat loss, while allowing water vapour to evaporate through

Material

- Porous cotton material, to allow water to flow through it, up the container.

Transparent Container

- Contains the bulk of the system while holding it in place, as well as storing the waste water

Waste water

As for the mixture inside the container, it contains various substances including organic pollutants and heavy metal ions

Assembly

- Insulator is cut into a circular shape, with a wide hole at the center
- 6x2 cm pieces of cloth material are cut. These are then fitted inside the hole in the insulator.
- Once the insulator is fit into the jar, the material will dip into the slurry that sits at the bottom of the container, to conduct the water upwards
- The photothermal material/absorber is cut into 5x5 cm circles, and placed atop the system

Fig. 1 LED light, Can be adjusted to different intensities

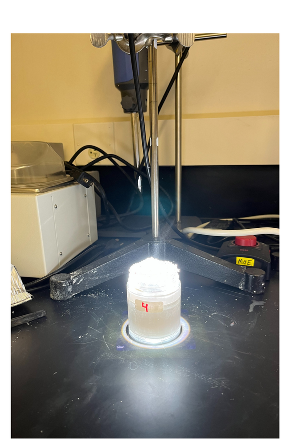


Fig. 2 Entire Solar evaporator system under LED lamp

Fig. 3 Mass reading of solar evaporator system

Readings

After placing the assembled systems under the LED light, we leave them for the following hour. After the hour has passed, a mass reading is taken of each sample, using a balance scale. Once the appropriate data has been collected, we return the samples to the LED lights. We repeat this process every subsequent hour, to get as conclusive data as possible. After multiple hours of data collection, results from each of the samples are compared and contrasted. They are charted and then graphed, to look for indicators and characteristics of the best system.

Results

Mass loss was measured every hour a reading was taken. Since the system is unchanging between readings, the only mass loss can come from evaporation.

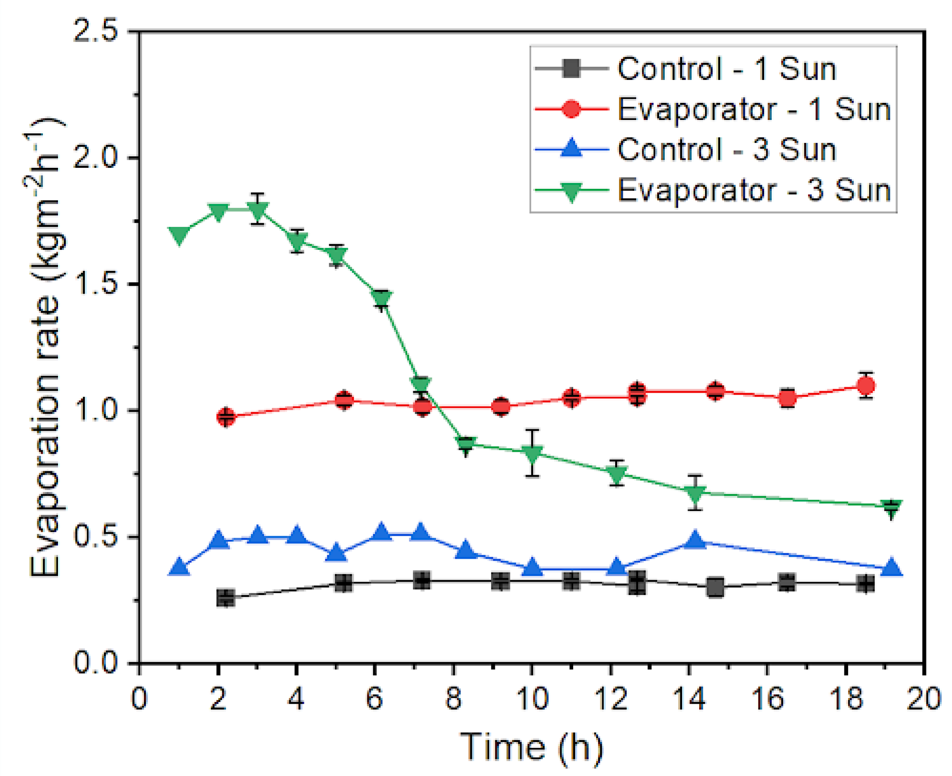
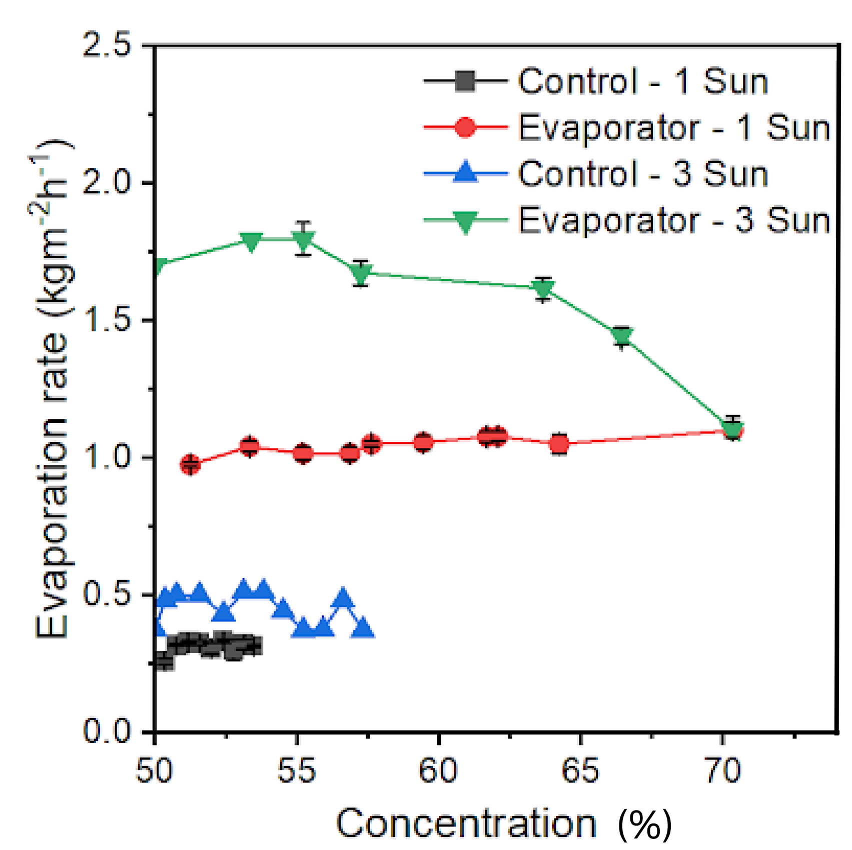


Fig. 4 Evaporation rate of both control and evaporator samples under 1 and 3 sun intensities, as a function of time

Control samples, with no evaporation structures, were measured alongside the solar interfacial systems. Each was measured for multiple hours, under 1 sun (1 kW/m2) and 3 sun (3 kW/m2). Consistent, but lower evaporation rate is noted among control samples. Evaporator under 1 sun evaporator is higher, but still consistent. Evaporator under 3 sun experiences initial high evaporation ,with steep drop at around hour 6



Concentration for all systems started the same, in terms of waste substances and clean water concentration. As evaporation took place, clean water concentration went down (through evaporation), and pollutant concentration rose. Although this result is observed in all systems, it is most prominently observed in the structures with evaporators, as the most clean water left their systems. The greater the evaporation rate observed, the greater the concentration of waste substances when evaporation ceased

Fig. 5 Evaporation Rate of clean water in both control and evaporator samples, as a function of concentration

Thermal Images of Sample under 1 Sun

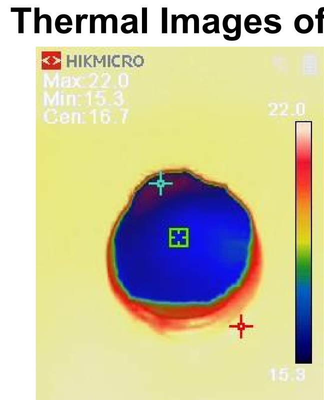


Fig. 6 1 kW/m2, 0 Minutes

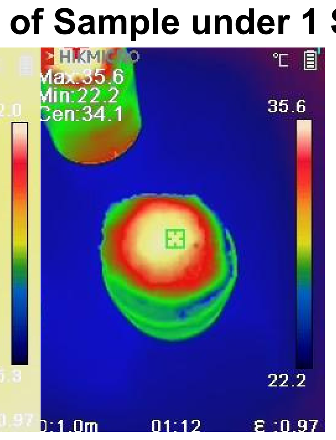


Fig.7 1 kW/m2, 5 Minutes

Thermal Images of Sample under 3 Sun

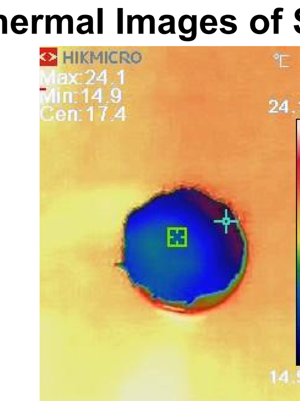


Fig.8 3 kW/m2, 0 minutes

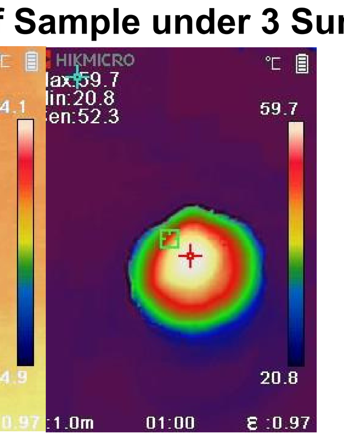


Fig.9 3 kW/m2, 5 minutes

After using thermal imaging to compare the top face of the evaporator system, a great temperature change is observed, after the sample has had time to sit under the LED. Under 1 kW/m2, the sample rises roughly 20°, while under 3 kW/m2, it rises over twice that

Conclusions

From the repeated experiments, multiple conclusions can be drawn:

From Figure 4

- the evaporator systems are nearly 4 times more effective, than the controls when it comes to clean water evaporation.
- In both the control, and evaporator pairs, the samples placed under 3 sun, achieved a higher evaporation rate, than their 1 sun counterpart. This is due to the increase in thermal energy, that comes with an increase in light energy
- The sample equipped with the evaporator, and placed under 3 sun was the best out of all fours samples, performing with an extremely high evaporation rate at start, despite dipping around the 6 hour mark
- The drop in evaporation rate of the 3 sun evaporator sample, is likely due to the concentration of the sample. Because this structure was performing at such high rates, the concentration of clean water in the structure dropped quickly. Therefore, there was less water in the overall system, and thus evaporation rate was reduced

From Figure 5

- Both systems with an evaporator were more efficient when it came to percentage of water evaporated in the system. This is evident in that when evaporation stopped in each system, the ones with photothermal material had an exponentially higher polluntant value, as a large amount of water had left the system through evaporation

From Figures 6-9

- Intensity of solar energy, and therefore thermal energy has a direct impact on evaporation rate. From studying the previous graphs, it is evident that the greater the light intensity the greater the evaporation rate. In these figures, the temperature rises sharply once placed under the solar light, proving the solar- thermal conversion. Because evaporation increased with an increase in light, a conclusion can be drawn that this is due to the temperature change, as the photothermal material converts the light to heat

In conclusion, the evaporation systems did increase evaporation rate of clean water, by roughly four times. Additionally, the presence of greater solar radiation, also aided in the increased water evaporation. These repeated experiments proved, that the coupling of an evaporation system, with high solar intensity, made for the fastest, and most efficient evaporator system

References

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2) Yaoxin Zhang, Ting Xiong, Dilip Krishna Nandakumar, Swee Ching Tan. (2020), Structure Architecting for Salt-Rejecting Solar Interfacial Desalination to Achieve High-Performance Evaporation With In Situ Energy Generation, Advanced Science, 7, 1903478

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