Mathematical and Experimental Analysis of Solar Still Systems Using Q-Dot Glass Evaporator

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Chapter 7

CONCLUSION AND FUTURE SCOPE

7.1 Introduction

Environmental variables have a significant impact on solar still operating performance. High sun intensity and low ambient temperature are the best conditions for solar still performance. Also, Wind velocity was critical in eliminating the latent heat released during condensation. As a result of optimum wind velocity, the rate of condensation improved. Despite increased humidity in the surroundings, solar still increased output. Solar still is powered by solar energy, leaving no carbon footprint.

7.2 Effect of tilt angle

In the first phase of the investigation effect of glass cover tilt angle on solar still, performance in the winter season is analyzed. The rate of production of distillate from SS depends on the climatic conditions such as solar flux intensity, ambient temperature, and wind velocity, on design parameters such as the tilt angle of the glass cover, depth of basin water, and the temperature difference between basin water and inside glass cover because these materials influence the heat transfer coefficient from basin liner to basin water. This investigation is mainly based on experimental analysis, which is why an experimental approach estimated the tilt angle. However, theoretical modeling has been done to apply the results in a widespread domain. It includes the energy balancing over the different components and the effect of QD concentration on solar still performance while assuming solar radiation falls perpendicular to the glass surface. The optimum tilt angle is generally taken as the latitude angle of the location. However, estimating the specific tilt angle experimentally in a specific season is vital to harness the maximum solar radiation without solar tracking, especially in tropical conditions like India, where daylight maximum temperature ranges from 10 °C - 40 °C. Hence, in simulation, tilt angle has not been considered. However, it is worth noting that it can be calculated by incorporating the zenith angle and azimuthal angle of solar radiation to obtain a tilt angle. It will be included in further studies. Conclusive finding of the experiments are as follows,

1. Generally, the tilt angle was set according to the latitude angle of the location, but it gets influenced by the seasons and location. It may be less than, equal to, or greater than the latitude angle of the location.
2. The tilt angle for Model-1 was the latitude angle of location that results in low radiation capture, whereas, Model-2 was fixed at a 30° tilt angle higher than the latitude angle that results in maximum productivity in daylight as well as in the nocturnal time of 925 mL/m^2 and 735 mL/m^2 that makes the overall yield of 1660 mL/m^2 on day-3 in winter season.
3. Model-2 showed first-law and second-law (exergy) efficiencies around 17.25% and 1.1% better than Model-1 of 17.15% and 0.6%. The low efficiency of solar still was due to intermittent heating of brackish water due to cloudy weather and heat loss to the ambient. Whereas, Model-3 showed minimum thermal and exergy efficiency of 7% and 0.3% in the same conditions.
4. The nocturnal yield of solar stills shows good heat retain capacity and the effect of polystyrene coverage on top of solar still. Model-2 gives maximum nocturnal yield of 735 mL/m^2 as compared to 435 mL/m^2 and 275 mL/m^2 for Model-2 and Model-3 respectively.
5. The use of polystyrene coverage on the condenser surface at night was beneficial in the sense to hold the heat inside still.

6. Model- 3 can achieve substantially suitable basin water temperature. However, due to its low tilt angle, it cannot produce high distillate since a low tilt angle causes a less favorable slope for condensed vapor to glide down into the trough collector, which causes a thick layer of condensate and loss of condensate by falling into the basin before reaching to the collector.

7.3 Effect of QD concentration

In the work's second part, the fabrication of SSs and material selection (BPQD) is done to improve the system's performance. Also, a comparative study with and without the coating of novel Pyrex glass-based QD material is done, and the experimental results with fair agreements in the tropical condition validate theoretical results. Moreover, from an economic perspective, this design and material selection benefit the consumers compared to the market price. Two sets of experiments were performed in almost the same working conditions on two solar stills coated with a QD-black paint mixture on the inner portion. In the first set, **0g and 5g by weight** in 500 mL of black paint were mixed and applied. In the second set, **10g and 15g** were thoroughly mixed in 500 mL black paint using a magnetic stirrer at 50 ºC.

1. The experimental and theoretical yield reached up to 991 mL and 1052 mL; 1282 mL and 1282 mL; 2010 mL and 2136 mL; and 2710 mL and 2917 mL with an increase in concentration that yields increases with maximum absolute deviation in yield of 7.63% with a 15g conc.
2. The experimental energy efficiency improves with an increase in concentration as 15.21%, 19.68%, 30.57%, and 41.22%; similarly, experimental exergy efficiency improves to 0.50%, 0.84%, 1.41%, and 2.75% with 0g, 5g, 10g, and 15g QD concentration respectively.

3. The energy efficiency increases to 45.7% with 20g conc. from 41.22% with 15g conc. alone, which is not statistically significant. As a result, saturation can be anticipated at 15 g concentration.
4. Wind velocity positively affects the desalination rate by improving convective heat transfer from the glass surface to the ambient, which helps to cool down the condenser surface. At an average wind velocity of 3 m/s, convective HTC was be 11.8 W/m^2K.
5. Economic analysis highlights the viability of modified SS over conventional SS by low monetary cost and energy cost of distilled water as 1.14 INR/l and 1.72 INR/kWh against 2.62 INR/l and 3.97 INR/kWh with a payback period of 1.98 years against 4.81 years in conventional SS.

7.4 Performance of Prismatic SS with QD and PCM

The third part used novel design and PCM with QD coating to observe the effect. The QD material was used along with PCM to store the solar thermal energy to continue the yield at night. Several experiments have been performed on two distinguished designs of solar still, viz. **conventional SS (CSS)** and **prism type solar still (PSS)**, to measure the consistency and accuracy of solar still. The investigations have been carried out in three phases, viz. **SSs without QD and PCM**, **SSs with PCM only**, **SSs with PCM and QD**, and the conclusions of the experiments are summarized as,

1. Black phosphorus-doped Pyrex glass material has a unique property to absorb a broad length of the solar spectrum and retain that heat for extended periods, boosting the function of PCM.

2. Prism-shaped solar still could not trap as much radiation as CSS, but its heat-retaining capacity gives the advantage of producing a higher yield than CSS. Since CSS was more prone to lose the heat through the glass surface at wind velocity above 4 m/s, however, PSS design helped to hold the heat so that the evaporation process stretched for a more extended period.
3. Wind blow plays crucial role to eject the latent heat from the condenser surface and it also help to maintain appreciable temperature difference glass inner surface and basin water.
4. CSS, without PCM and QD, productivity reached up to 1660 mL/m^2 whereas with PCM reached up to 2360 mL/m^2 and with PCM and QD 3040 mL/m^2 whereas, Prism type (PSS) without PCM and QD, with PCM only, and with PCM and QD yield up to 1830, 2530, 3685 mL/m^2 in a day.
5. With PCM and QD, exergy efficiency has reached up to 2.20% and 1.79% in the case of PSS and CSS. Whereas, utilization efficiency and heating efficiency reached up to 21% and 37.23% for CSS and 27.5% and 49% for PSS.
6. In the nocturnal period, from 17:00 to 22:00, CSS yield was 850 mL/m^2, whereas PSS yield was 990 mL/m^2 with QD and PCM. However, without QD and PCM, these yields fall to 290 mL/m^2 and 130 mL/m^2 in the same period.
7. Economic analysis shows that, monetary and energy cost of distilled water will be INR 1.6/l and 2.48/kWh as compared to 1.9/l and 2.84/kWh with payback period of 2.8 yr. and 3.2 yr. for PSS and CSS respectively.
8. Overall, prismatic solar still has an excellent heat-retaining capacity that PCM can further enhance to supplement the yield in the off-sunshine period. Moreover, BPQD absorbs maximum solar radiation in the sunshine period and increases the evaporation rate.

7.5 Future Scope

1. Like black phosphorus quantum dot material, other QD like carbon QD, graphene, etc., can be investigated with PCM to enhance solar still productivity.
2. From a design perspective, semipermeable membranes can be used to separate the hot water from relatively cooled water inside the basin, encouraging localized heating and increasing the rate of evaporation.
3. MXene and MXene-based two-dimensional composite materials can trap solar radiation for solar desalination with great intent by virtue of their tunable physical and chemical properties.
4. Localized heating could be a solution to enhance the rate of evaporation. For this, dual-axis tracking with a lens has not been investigated with solar desalination.
5. Wind power can be used along with solar energy to assist the heat supply during nocturnal period.
6. Macroencapsulation and microencapsulation PCMs have responded well in many heat storage materials. The prime advantage associated with it is to get a large surface area for heat exchange, and its effective localized heat storage potential can boost the greenhouse effect significantly.
7. Condenser surface (inner glass surface) coating to encourage dropwise condensation can improve the latent heat release of water vapor over the surface as compared to film-wise condensation.