PERFORMANCE EVALUATION OF SOLAR STILL WITH AND WITHOUT NANOFLUID

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ABSTRACT

The provision of fresh water is becoming an increasingly important issue in many areas of the world. Clean water is a basic human necessity, and without water life will be impossible. The rapid international developments, the industrial growth, agriculture and population explosion all over the world have resulted in a large escalation of demand for fresh water. The solar still is the most economical way to accomplish this objective. When water evaporates, water vapour rises leaving the impurities like salts, heavy metals and condensate on the underside of the glass cover. Solar distillation has low yield, but safe and pure supplies of water in remote areas. The attempts are made to increase the productivity of solar still by using nanofluids and also by black paint coating inside the still basin. Heat transfer enhancement in solar still is one of the key issues of energy saving and compact designs. Recently, as an innovative material, nanosized particles have been used in suspension in solar still water. The fluids with nanosized solid particles suspended in them are called “nanofluids”. The suspended metallic or nonmetallic nanoparticles change the transport properties, heat transfer characteristics and evaporative properties of the base fluid, The aim of this paper is to analyze and compare the enhanced performance of a solar still using nanofluids with the conventional water. They greatly improve the rate of evaporation and hence the increase in efficiency.

Keywords: Solar Still; Nanofluid; Nanoparticles; Productivity

1. INTRODUCTION

Water is the basic need for human life and we know that without water life cannot exist in this world. We also know that 73% of earth surface is covered with water bodies, even after than there is shortage of water for basic needs for living beings. The main reason for shortage of water is that 0.95% of water on earth surface is saline, 0.027% percent of water is in the form of glacier and 0.013% of water is available for use. We can find useful water in the form of ponds and rivers and lakes and also below the earth surface. This useful water is used by every living being according to their needs. Due to the regular increase in population and pollutions of various forms, water scarcity is becoming an internal agenda. Due to the scarcity of water there are various method are adopted to make the waste water pure and reuse. Solar distillation is the one process to purify the waste water for reuse.

The solar still in which base fluid is at rest and the distillation process is carried with solar radiation is known as passive type solar still [1]. In the passive type solar still there is no need of pumps and motors for distillation. Due to its low maintenance and simple in construction it is widely used at high heat intensity areas [6].

2. EXPERIMENTAL SETUP

Two solar still were fabricated with the Tin Sheet and insulated from sides and bottom to reduce the heat from the water [2]. The dimension are given in the table 1 with the figure 1.

<table>
<thead>
<tr>
<th>Table 1. Dimension of Sola Still</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
</tr>
<tr>
<td>Inner</td>
</tr>
<tr>
<td>Outer</td>
</tr>
</tbody>
</table>

Figure 1. Solar Still

Two RTDs (PT-100) have been used for the measurement of temperature, Solar Radiometer (LM-100) with a resolution 1 W/m² was used for measurement of solar radiation at the still plane [17]. A TDS meter (TDS-3) was used to measure the total dissolved solids in the input water and output water generated by the solar still. The thickness of the tin sheet
was 2 mm as shown in Figure 2. The absorbing plate is painted with black colour so it will be better to absorb the maximum amount of solar radiation falling on them and convert it into the heat [3].

The top of the basin is covered with transparent 5 mm window glass inclined by nearly 30° angles with the horizontal, which was integral part of the design by desining the heights front and top, the aperture area of the glass was 0.43 m² having dimensions 0.77 m and 0.55 m [7]. The experiment were conducted at Jaipur (latitude 26.90° N). The spacing between the glass cover and the water surface was 21.59 cm to 39.87 cm at front and back side respectively. The design of the glass cover does not affect the rate at which the distillate water runs down its inner surface to the collection trough. Consequently, a glass-to-water distance increases, heat loss due to convection become greater, causing the still efficiency to drop.

Figure 2. Complete Setup of Solar Still

A condensate channel runs along the lower edges of the glass cover which collects the distillate and carries it outside the still. The entire assembly is placed on a stand structure made up of cast iron [10]. The outlet is connected to a storage container through a pipe. Provision is made to change water in the still.

The experiment was carried out with water depth of 2 cm. During the experiment the solar radiation at the still plane, ambient temperature and water temperature and portable water generated were also measured at an time interval of 30 minutes from 10 AM to 4 PM [11]. A cross section pipe of diameter 6 cm of length 1 meter is used to carry down the pure condenses water from the solar stills to the collecting container which is provided outside the solar still. Eventually the output of the solar still is increased by hour by hour in the mid period of 12:00 a.m. to 3:00 p.m.

In this study effect of water depth and salt concentration without using nanofluids inside the solar still are mea. From about 3:00 p.m., water temperature start decreasing due to the decreasing of solar radiation. It can be noted that the basin temperature gets closer to the water temperature because of the continuous contact between them which leads to heat equilibrium.

As the glass temperature is much lower than the vapour temperature, it causes condensation of vapour on the glass. Increase in the solar intensity in the early morning until it reaches the maximum at around 12:00 to 2:00 p.m. [13], and then decreases in the late afternoon. The solar intensity has an important effect on the solar still productivity. As the solar intensity increases, the productivity increases due to the increase in heat gain for water vaporization inside the still.

The productivity rate varies as time passes from the early morning until late afternoon. In the morning, the temperature of water is low; therefore it needs high energy to change its phase from saturated liquid to saturated vapour phase. The results show that temperature and required heat are inversely proportional. In the early afternoon the temperature of water reaches the maximum so it needs less heat to vaporization and vice versa in the late afternoon.

3. MAKING OF NANOFLUID

Nanoparticles alumina powder (Al₂O₃) is insoluble in water. So 2- way method is used to dissolve the Nanoparticles in the base fluid i.e water [19]. First we take 4 liters of water as base fluid and we add Nanoparticles Al₂O₃ and Sodium Dodecyle Benzene Sulphonate (SDBS) as the dispersant. Alumina and SDBS are mixed in the ratio of 10:2. After that magnetic stirring and vibrator are used to suspend the Nanoparticles for 1 hour [20]. Finally we will get the nanofluid.
4. RESULTS AND DISCUSSION

The experiment was conducted in the passive type solar still. The solar still was designed to collect the distilled water from the waste water and normal water. The experiment was conducted with and without nanofluid.

4.1 RESULTS WITH NORMAL WATER AND NANOFLUID

The solar still was fabricated and the experiment was conducted in normal impure water and nanofluid. The observation and reading was done from 10:00 AM to 4:00 PM. The solar still was insulated with the insulating material thermacoal and covered with tin sheet to prevent heat loss. This increases the evaporation of water by 20%. The black painting was done inside the box with also increases the evaporation by up to 5 %.

When the experiment was conducted and the observation of the distilled normal water and the distilled nanofluid was observed, its state that the nanofluid increases the thermal efficiency of the experiment by 5% and the distillation process was faster as compared to normal water. The figure16 and figure17 shows the comparison between the average increases in distillation and water temperatures of normal water and nanofluid.

![Fig5. Comparison of still water temp with and without nanofluid in solar still on date 12 June 2015](image1)

![Fig6. Comparison of still water temp with and without nanofluid in solar still on date 13 June 2015](image2)
Fig 7. Comparison of still water temp with and without nanofluid in solar still on date 15 June 2015

Fig 8. Comparison of still water temp with and without nanofluid in solar still on date 16 June 2015

Fig 9. Comparison of still water temp with and without nanofluid in solar still on date 17 June 2015
**Fig 10.** Comparison of still water temp with and without nanofluid in solar still on date 18 June 2015

**Fig 11.** Comparison of still water temp with and without nanofluid in solar still on date 19 June 2015

**Fig 12.** Comparison of still water temp with and without nanofluid in solar still on date 20 June 2015
**Fig 13.** Comparison of still water temp with and without nanofluid in solar still on date 22 June 2015

**Fig 14.** Comparison of still water temp with and without nanofluid in solar still on date 23 June 2015

**Fig 15.** Comparison of still water temp with and without nanofluid in solar still on date 24 June 2015
4.2 THERMAL ANALYSIS

The experiment was conducted in the solar still with and without nanofluid and the various observations and reading were concluded. The observation and reading in the result shows the increase in the thermal conductivity of the water when Al₂O₃-water nanofluid was used [22].

The overall efficiency of the solar still is calculated by:

\[ \eta = \frac{\sum_{i=1}^{n} m_{w} h_{fg}}{\sum A_{s} I} \]

where:
- \( m_{w} \) is the summation of hourly condensate production of distilled water in KJ/s,
- \( A_{s} \) is the area of the solar still in m²,
- \( I \) is the solar radiation with time in W/m²,
- \( h_{fg} \) is the latent heat of vaporization in KJ/s.

The overall efficiency of the nanofluid is 59% and normal water is 54%.

4.3 HEAT LOSS

Adiabatic is the process in which there is no transfer of heat and mass. Hence if the system is adiabatic then there is no transfer of heat and mass between the system and surrounding. But through the practical point of view no system can be adiabatic [4]; hence there is loss of heat.
and mass in the solar still box during the experiment. The amount of heat loss can be calculated by the various means:

- The heat energy used in water evaporation

\[ Q = mL \]

\( Q = \) amount of heat in KJ  
\( m = \) mass of water litre  
\( L = \) Latent heat of evaporation in KJ

The avg. amount of heat loss is 826 KJ.

- The heat used in heating the water in solar still

\[ Q = mC_p T \]

\( Q = \) amount of heat in KJ  
\( m = \) mass of water litre  
\( C_p = \) Specific heat of evaporation in KJ/kg K  
\( T = \) Temperature difference from final to initial

The average amount of heat used to heat the water is 580 KJ.

- The heat loss from the sides of the solar still

\[ Q = UAT \]

\( Q = \) amount of heat in KJ  
\( U = \) overall heat transfer coefficient in W/m²K  
\( A = \) overall area of a solar still in m²  
\( T = \) Temperature difference from final to initial

The overall heat loss from the sides of the solar still is 483.84 KJ.

- The heat loss from the glass

\[ Q = UAT \]

\( Q = \) amount of heat in KJ  
\( U = \) overall heat transfer coefficient in W/m²K  
\( A = \) overall area of a solar still in m²  
\( T = \) Temperature difference from final to initial

The overall heat loss of from the glass is 962.97 KJ.

The total heat loss is the summation of all the heat losses.

\[ Q_{\text{total}} = \text{heat loss in evaporation} + \text{heat loss in solar still} + \text{heat loss in glass} + \text{heat loss in water heating} \]

\[ Q_{\text{total}} = \text{amount of total heat loss in KJ} \]

The total heat loss in the experiment is 2,852.81 KJ.

4.4 ECONOMIC ANALYSIS

The payback period of the solar still setup depends on overall cost of fabrication, maintenance cost, operating cost and cost of feed water [12].

The overall fabrication cost is Rs. 12,350.

The maintenance cost, operating cost and cost of feed water are negligible.

The overall cost of the project = Rs. 12,350 ($205).

Cost of water produced per day = Daily yield × Cost of water per liter = 0.36 × Rs. 1 = 0.36 paisa.

4.5 COST ESTIMATION

The overall cost of the experiment was Rs12, 350. The description of the products is stated below:

Table 2. Cost Estimation (Capital Expenditure)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Capital Expenditure</th>
<th>Amount (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tin Sheet</td>
<td>1500</td>
</tr>
<tr>
<td>2.</td>
<td>Stand</td>
<td>1500</td>
</tr>
<tr>
<td>3.</td>
<td>Glass</td>
<td>550</td>
</tr>
<tr>
<td>4.</td>
<td>Fabrication Charges</td>
<td>1200</td>
</tr>
<tr>
<td>5.</td>
<td>Collecting Tank</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>4,950</td>
</tr>
</tbody>
</table>

Table 3. Cost Estimation (Running Expenditure)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Running Expenditure</th>
<th>Amount (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Thermocoal</td>
<td>200</td>
</tr>
<tr>
<td>2.</td>
<td>Nanofluid</td>
<td>5700</td>
</tr>
<tr>
<td>3.</td>
<td>Overhead Charges</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>7,400</td>
</tr>
</tbody>
</table>

5. CONCLUSION

The experiment was conducted with and without nanofluid. The desired conclusion was that the experiment conducted with the help of nanofluid increases the thermal conductivity of the water up to 20% and the distillation process was also 20% faster as compared to experiment conducted with the normal water [15]. Even insulating the solar still box with the thermocoal and aluminum sheet also increases the evaporation process carried out under the solar still box. The black painting inside the solar still box also increases the efficiency by 5%. When the overall efficiency of the solar still was calculated between the normal water and nanofluid their was 5% increment in the nanofluid efficiency as compares to normal water.

REFERENCES


