ICMIEE18-331 Productivity Enhancement of Single Basin Solar Still using Al₂O₃ Nanoparticles

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ABSTRACT

Solar still is one of the prominent and basic sun oriented refining techniques to get fresh water from saline water. This paper investigates the enhancement in productivity of single basin solar still using Al_2O_3 nanoparticles in the base fluid. Nanofluids with high thermal conductivity are perfect heat transfer fluids for gathering thermal energy in solar thermal applications. In this work, the modifications are accomplished into a conventional solar still using nanofluids of varying concentration (0.1% and 0.2%) which ultimately increased the distillate water productivity. The inclusion of nanoparticles on the base fluid have significantly boosted the evaporation and condensation rates as well as the daily yield of the solar still. A maximum increase in productivity of 33.1% is achieved with a 0.2% concentration of Al_2O_3 nanoparticles when added to the base fluid.

Keywords: Solar still, Desalination, Minimum water depth, Al₂O₃ Nanoparticles, Nanofluid.

1. Introduction

For the purification of water various methods are used like filtration, sedimentation, distillation and disinfection. Solar distillation is one of the most popular water purification techniques. The principle of solar distillation is to use solar energy to evaporate saline water, then condense the vapor on a glass surface and collect the condensed fresh water. There are different types of solar stills including pit solar stills, cone solar stills, domo solar stills but the basin still is the most common. Basin stills can be categorized in many forms, however the single slope and double slope solar stills are very popular [1]. With a reasonable investment of capital cost, basin solar still is capable to produce a daily output of several liters of water per square meter of still. And such a still can be designed to operate for as long as 20 years with an efficiency of 30-60% [2].

As the productivity of the single basin solar still is quite low, its popularity is not in the peak. A number of research works have been done to enhance the productivity of the still. In most of the cases, the solar still provided a daily yield of less than 5 L/m² [3]. Complete loss of latent heat of condensation of water vapor is responsible for such a low efficiency. The execution and efficiency relies on numerous parameters like intensity of the solar radiation, wind velocity, temperature distinction between the glass cover plate and saline water, insulation, area of the collector and absorber plate, minimum depth of water, inclination angle and thickness of the glass cover.

2. State of knowledge

Many researchers have experimented the effect of the various factors that result in improved efficiency of the solar still. Omar et al. [4] analyzed the performance and efficiency of a single slope single basin solar still based on solar intensity. They found that with the increase in

solar intensity, performance and efficiency of the solar still increases. The maximum efficiency of solar still is found at noon due to high intensity of solar radiation. Emad Almuhanna [5] also concluded that the rate of daily yield increases with the increase of solar radiation intensity. The basin water depth has a major effect on performance and productivity of the solar still. Distinctive analysts have revealed that the water profundity is contrarily corresponding to the efficiency of the sun based still [6-8]. Tiwari [9] has investigated the impact of the profundity of basin water and revealed that the efficiency of the solar still increments with the diminishing of water depth in the basin. Bilal likewise revealed that the execution of the solar still increments with the decrease in water depth [10]. Many researchers used a number of wick materials for enhancing the productivity of solar stills. Productivity of solar still was improved by about 29% by using sponge as wick material [11]. Among the different wick materials cotton, sponge and jute are most common. Another research work was carried out on stepped solar still by using fins, [12] in which a total of 250 fins were used in 50 trays and 76% improvement in productivity was concluded. An investigation had been done by utilizing aluminum of cuprous and oxides different concentrations [13] and there was extensive enhancement in the everyday yield of the solar still. The impact of cuprous and aluminum oxide nanoparticles in a single basin solar still was investigated and maximum yield was obtained with aluminum oxide nanoparticles Different aluminum oxide nanoparticles [14]. concentrations were added to a double slope solar still and reported that the efficiency increased with the increase in nanoparticles concentration [15]. Another research work had been carried out by using aluminum oxide, cuprous oxide and titanium oxide nanoparticles with different concentrations in the base fluid [16] and a maximum productivity improvement of about 29% was achieved with the 0.25% concentration of aluminum oxide nanoparticles in the base fluid.

3. Statement of the problem

Sun oriented desalination is the way toward changing over the debased salty water into consumable drinking water utilizing solar energy. The sunlight based desalination strategies have been utilized by the humankind for a large number of years. Truth be told, solar stills were the main strategy which was utilized on a little scale to change over debased saline water to consumable water. Be that as it may, the primary disadvantage of the solar desalination is its low profitability. Ordinarily, a sun oriented still can yield $2.5-5 \text{ l/m}^2/\text{day}$ of distillate [17].

Determining a suitable area of absorption and identifying the minimum water depth which leads to the maximum daily yield was the major concern. Then, for the minimum water depth productivity improvement techniques were adopted. For this purpose, Aluminium oxide nanoparticles were added to the base fluid.

The objectives of the research include-

- To determine the productivity of the conventional solar still.
- To determine the productivity of the solar still in addition with nanoparticles in the basin.
- To compare both of the daily yields and finding out the productivity enhancement.

4. System description

The essential standards of solar still are extremely basic yet very compelling. Sun powered refining reproduces the manner in which nature makes rain. A conventional solar still follows two major scientific principles namely evaporation and condensation. At first, the saline water is placed in the basin of the solar still. The solar still is then allowed to sit in the sun in order to absorb the sun's short wave energy. The solar energy heats water up to the point of evaporation. When the water dissipates, water vapor ascends towards the glass cover and leaves anything besides unadulterated water in the bowl underneath. At the point when the water vapor achieves the glass cover, the water gradually consolidates on the glass, causing pure water beads. Various impurities like salts, metals and microbiological organisms can be removed by this process. The output is fresh water which is even cleaner than the purest rain water. The solar still takes into account normal pH buffering and furthermore delivers incredible taste when contrasted with common steam refining.

4.1 Design of the solar still

Designing the model is the preliminary task of each and every research. So, at first the conventional solar still was designed. The solar still basin have a length of 30 inches and a width of 18 inches. The angle of inclination of the glass cover was 12 degree.



Fig.1 3D model of the solar still



Fig.2 2D model of the solar still

4.2 Fabrication of the system

For the fabrication of the system, at first the basin of the solar still was made. It is a container in which the base fluid and the nanoparticles mixtures are provided. The basin was made of galvanized steel of 2mm thickness. The length of the basin was 30 inches and width was 18 inches also having a height of 4 inches. This basin was put into a wooden frame, which is the basic structure of the solar still. The wooden frame was made slightly bigger than the steel basin for the ease of operation. The wooden frame provided space for attaching glass above it. On one side of the frame, a 3/4 inch hole was made for providing saline water into the basin. And on the other side, a PVC pipe was attached to collect the condensed water that flowed down the glass surface. Before putting the steel basin into the wooden frame, the frame was sealed properly using Silicon gum in every corner. Then the glass cover was placed above the frame and the water droplet collection tube was also attached. The tube was sealed at one end and the other end was provided with a water tape. A 3/4 inch elbow joint was placed in the upper side of the frame to supply the saline water into the basin of the solar still.



Fig.3 Fabricated single basin solar still

4.3 Data collection and analysis

After the fabrication of the solar still, the experimental data was taken in shiny days. The required temperatures at different points on the solar still and the amount of fresh water stored were measured carefully. At first, the experimental data were taken for three different water depth (1, 2 and 3 cm). From the output of the solar still it was found that 2 cm was the optimum water depth. This was done for conventional solar still without the addition of nanoparticles. From the daily yield, productivity and efficency of the solar still was calculated.

4.4 Addition of Nanoparticles

In the present study, Aluminium oxide nanoparticles are used because of its high heat transfer co-efficient and availability. The aluminium oxide nanoparticles are added in different concentration ; 0.1% and 0.2% respectively. The nanoparticles are added with the saline water and the daily yield is measured. Aluminium oxide-water nanofluid is prepared by using magnetic steerer machine. For water depth of 2 cm about 4.5 litre saline water and 9 gm nanoparticles are added to the basin, when 0.2% nanoparticle concentration is used.

5. Experimental results

The experimental setup was kept under the sun and data were collected for several days. At first, the experimental data were measured for three different water depths 1cm, 2cm and 3 cm. The daily yield was 402.6 gm, 374.21 gm and 196.50 gm respectively. In spite of the fact that, water depth of 1cm gave the maximum yield, however it come about a few challenges like providing saline water consistently. So, 2cm was considered the optimum level of water depth.



Fig.4 Variation of productivity with water depth

At first, the productivity of the conventional solar still was measured. This was done with 2cm water depth in the basin. The experimental data were taken every hour starting from 9:00 AM to 5:00 PM. The output and the solar intensity were measured throughout the whole day. For the calculation of the still productivity at night, the output was measured the next morning at 8:00 AM. For the conventional solar still, a total of 374.21 gm fresh water was found during day 1.

Then the productivity of the solar still was measured for 0.2% and 0.1% Aluminium oxide nanoparticle concentration and a total of 498.12 gm and 443.50 gm were obtained in the respective days. It was evident that the solar still modified with 0.2% Aluminium oxide nanoparticle provided the maximum output while the conventional solar still the least.

The solar thermal efficiency of the s is given by [17] –

$$\eta_d = \frac{\sum m_d \times h_{fg}}{\sum A_{eff} \times I \times t} \times 100\%$$

Where,

Latent heat of vaporization of water, $h_{fg} = 2230$ KJ/Kg

Net effective area of solar still basin, $A_{eff} = 540 \text{ inch}^2$ = 0.3483864 m²

Time interval, t = 1 hour = 3600 s

✓ Daily efficiency of conventional solar still =

- ✓ Daily efficiency of the modified solar still (0.1 %) = 14.48 %
- ✓ Daily efficiency of the modified solar still (0.2 %) = 16.28 %

 $[\]frac{(0+8+21+46+51+48+40+30+23+107)\times 2230}{0.35\times (615+720+760+860+905+710+480+275+120)\times 3600}\times 100\%$ =12.26 %



Fig.5 Variation of solar intensity throughout Day 1

Fig.5 shows the graphical representational of the variation of solar intensity with time throughout the Day 1. It can be seen that maximum solar intensity was 905 W/m^2 and minimum solar intensity was 120 W/m^2 measured at 1:00 PM and 5:00 PM respectively.





The above figure shows the hourly and accumulated yield of the conventional solar still. The output was zero at 9:00 AM and increased as the day went by. The maximum hourly yield of 51.35 gm was obtained at 1:00 PM. The productivity during the night was measured the next morning at 8:00 AM. From 5:00 PM to 8:00 AM a total yield of 106.95 gm was obtained. The green line shows the accumulated yield of Day 1. A total output of 374.21 gm was found for the conventional solar still.



Fig.7 Variation of hourly output of conventional and modified solar still

Fig.7 shows the graphical representation of the variation of hourly output of conventional and modified solar still. The yellow line shows the hourly yield of the conventional solar still, which is the least among the three. The blue line shows the variation of hourly yield when the solar still was modified with 0.1% Aluminium oxide nanoparticles. The green line is for solar still modified with 0.2% Aluminium oxide nanoparticles, which also gives the maximum yield.



Fig.8 Variation of accumulated yield of conventional and modified solar still

Fig.8 shows the graphical representation of the variation of accumulated yield of conventional and modified solar still. The yellow line shows the accumulated yield of the conventional solar still, which was 374.21 gm. The blue line shows the variation of accumulated yield when the solar still was modified with 0.1% Aluminium oxide nanoparticles. It shows that there is a slight increase in the output when nanoparticles were added and a total of 443.50 gm fresh water was obtained. The green line is for solar still modified with 0.2% Aluminium oxide nanoparticles, which also gives the maximum daily yield of 498.12 gm.

6. Conclusions

A conventional single basin single slope solar was developed. Modification of the solar still was made by the addition of Aluminium oxide nanoparticles to the saline water. A comparative performance analysis of the conventional and modified solar still was made. The following conclusions can be made based on the performance of the solar stills-

- The efficiency of the solar still can be enhanced by the addition of nanoparticles to the base fluid as nanoparticles raise the thermal conductivity, basin water temperature and convective heat transfer coefficient.
- The optimum water depth for conventional and modified solar still is 2 cm.
- The maximum increase in the productivity is achieved with 0.2% concentration of Aluminium oxide nanoparticles (33.1% and 18.52% improvement of the productivity resulted for 0.2% and 0.1% nanopartciles concentration respectively).





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