Enhancing the performance of solar still with solar pond

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ABSTRACT

A single slope solar still with the basin area of 60 cm x 80 cm and slope of 11^0 was fabricated and tested in Pondicherry. The inner wall is coated with black paint in order to improve the heat transfer rate. The bottom and side losses of the still are considerably reduced, due to the porous material beneath the basin liner. Effect of solar pond coupled with the still are experimentally investigated on a clear, low radiation and high radiation and found that clear day has the maximum productivity. A model economic analysis calculation for single basin solar still coupled with pond is also done and the results are reported in this paper.

KEY WORDS: Solar Still, Solar Pond, Basin Liner, Porous Material, Productivity.

1. INTRODUCTION

Solar still is the oldest water purification technology in the world. It employs construction materials, viz, plastic, glass and wood etc and sunlight which is a renewable energy making it cheaper and affordable to everybody. Solar still integrated with mini solar pond, floating porous absorbers, extended porous fins, flate plate collector, phase change material, porous material effluent using fin type, fin plate, sponges, pebbles, black rubber, sand, wick, depth of water, latent heat storage material, sensible heat storage material, heat reservoir, concentrator internal and external reflectors, cascaded system, concave wick evaporation surface, and reciprocating spray feeding and separately or their combination, can enhance the productivity of the solar still. The optimum value of salinity in the mini solar pond is 80 g/kg of water, still with sponge and integrated with mini solar pond has the productivity 4.65 liters. The optimum values of the flowing water thickness and the mass flow rate for this typical configuration of the shallow solar pond-active solar still were obtained as 0.03 m and 0.0009 kg/s.

A solar still was integrated to the shallow solar pond mainly to increase the nocturnal productivity and under the closed mode of operation shallow solar pond enhance the productivity and efficiency of the still all year round. The mini solar pond was used for preheating raw water (Industrial effluent) in solar still system; highest productivity of 100% was obtained when the fin type stepped solar still was integrated with pebble and sponge. The payback period of the overall system was 417 days. To improve the performance of the still, a mini solar pond, stepped solar still and a single basin solar still are connected in series and industrial effluent water is used as feed to the set up. For improvement in the wick type single basin solar still is integrated by baffle plate, pebble, fins, wicks and sponges are. The fin type solar still integrated with fin type mini solar pond has decreased the preheating time of the feed water, which in turn enhances the productivity over 24 hr. The mini pond increases temperature up to 54 °C in the lower convective zone after only 20 days of operation.

The nano fluid pond has the higher solar absorption characteristics and better solar energy (thermal) storage capacity compared to the conventional solar pond. The daily efficiencies of the pond operates under the closed and open cycle modes is 59% and 33%, respectively. In the low temperature, salt-gradient solar ponds has the higher performance by storing large amount of heat. The solar pond incorporated with the porous media increases the overall thermal storage capacity and LCZ temperature of solar pond.

The step wise basin in the solar still enhances condensation by reducing the space between the basin and glass cover. The solar still coupled with various basin materials decrease the preheating time. Objective of the work is to enhance the productivity in cloudy days of the solar still by integrating with a mini solar pond. The schematic diagram of the experimental set up is shown in the Fig.1.

2. EXPERIMENTAL SET UP

The schematic diagram of the experimental set up is shown in the Fig.1. Experimental set up consist of a storage tank with a membrane, a solar pond with heat exchanger, a single slope single basin solar still, and a collection tank. Membrane is semi permeable removes the dust, bacterial content and micro organisms from the raw water. From the storage tank the raw water flows through the flexible hoses and a valve (v_1) controls the mass flow rate to the pond. Further the solar pond reduces the salt content of the raw water and makes the raw water to flows through the flexible hoses and a valve (v_2) controls the mass flow rate to the single slope single basin solar still. The single slope single basin solar still was kept in the North–South facing direction, with the inclination of 11°, which is the latitude of Pondicherry. For a cover material the lower angle of incidence of sun rays that causes the transmittance is higher and the reflectance is lower. The inclination and direction of the cover depend on the latitude of the location. Solar stills are based on the principle of the “hot box”, solar radiation pass through a roof-shaped transparent cover (glass cover thickness 5mm) and then fall on the basin material (galvanized iron thickness 3 mm) contain raw water and heat the water, thereby causing it to evaporate. Formation of water droplets occur inner side of the transparent cover, a collection tray was fixed in the inside surface of the glass cover to facilitate the deflection of the condensate return into the collection channel. The gliding water from the channel was transferred into the collection tank through the flexible hoses. The distillate output from the still was measured, using a collection tank.

Figure.1. Photographic representation of Integration of Solar Still and Solar Pond

Measurement of parameters calculation

Thermocouple: The temperatures of the basin, glass, ambient, and water were recorded with the help of K-type thermocouples. The accuracy of the the K-type thermocouples = ±0.1°C. Least experimental value = 20°C. Paramount possible error = 0.1/20 =0.005. % error for K-type thermocouples used in the experiment = 0.5%.

Solarimeter: The solarimeter is used to measure the solar intensity. The accuracy of the solarimeter = ±1 W/m^2, Least experimental value = 40 W/m^2. Paramount possible error = 1/40 =0.025. % error for solarimeter used in the experiment = 0.5%.

Anemometer: The velocity of ambient air was measured with an anemometer. The accuracy of the anemometer = ±0.1 m/s. Least experimental value = 1 m/s. Paramount possible error = 0.1/1 =0.1. % error for anemometer used in the experiment = 10%.

Collection tank: The collection tank is used to measure the productivity. The accuracy of the collection tank = ±10 ml. Least experimental value = 100 ml. Paramount possible error = 10/100 =0.1. % error for collection tank used in the experiment = 10%.

3. RESULT AND DISCUSSION

The single slope single basin solar still with the reflecting mirror productivity is proposed in this section.

Solar still with the semi permeable membrane: Solar still with the semi permeable membrane is shown in Fig.1. The semi permeable membrane prevent the contaminants, algae, bacteria, viruses, protozoa, fungi, waste, dust particles, salt concentration and micro organism from the raw water, it enters into the mini solar pond. Salt accumulation in solar still is mainly reduced.

Conventional solar still: An experimental investigation was carried out on single-slope solar still without the mini solar pond, with minimum saline water depth of 1.8 cm in basin on clear day (05/03/2016). The bottom and side losses of the still are considerably reduced, due to the porous material beneath the basin liner. The maximum productivity occurred between the hours of 11.30 A.M and 02:30 P.M shown in the Fig.2, with the average solar radiation of 600 W/m^2.The water temperature ranged between 48°C and to 54°C. The ambient temperature for all the experiments was in the range of 25-30°C with the average wind speed of 1 m/s. Productivity of the conventional solar still from 08.30A.M to 08.30 P.M is 1.955 kg/m^2 day as shown in Fig.2.

Single-slope solar still with the mini solar pond and semi permeable membrane on clear day: The mini solar pond is enough for sunlight to reach their bottom and which is a truncated conical shape. The solar pond made up of a galvanized iron sheet (thickness 3 mm) with the cross sectional area of the pond at the top and bottom are 1 m^2 and 0.06 m^2 respectively. The top of the mini solar pond is covered by transparent material (5-mm thick glass). The raw water from a semi permeable membrane was used as a fluid flowing through the heat exchanger (copper has length 9 m and diameter of 0.01 m) to extract the heat from the pond under the open cycle continuous flow heating mode. Solar still basin material integrated with the mini solar pond is examined with minimum saline water depth of 1.5 cm in basin on the clear day (08/03/2016). The maximum productivity occurred between the hours of 11.30 A.M and 02:30 P.M with the average solar radiation of 600 W/m^2. The water temperature ranged between 69°C and 57°C. The higher variations in the water and the glass temperature increase the productivity. The ambient temperature for all the experiments was in the range of 25-35°C with the average wind speed of 1 m/s. The productivity of solar still basin material integrated with the mini solar pond in clear day is 2.544 kg/m^{2}day as shown in Fig.2.

Single-slope solar still with the mini solar pond and semi permeable membrane on partially cloudy day: Similar to section 3 an experimental investigation is carried out on single-slope solar still with the mini solar pond and semi permeable membrane on partially cloudy day (11/03/2016) and it has the productivity of 1.654 kg/m^2.

Single-slope solar still with the mini solar pond and semi permeable membrane on cloudy day: Similar to section 3 an experimental investigation on single-slope solar still with the mini solar pond and semi permeable membrane on cloudy day (14/03/2016) has productivity 1.518 kg/m^2 day shown in Fig.2.

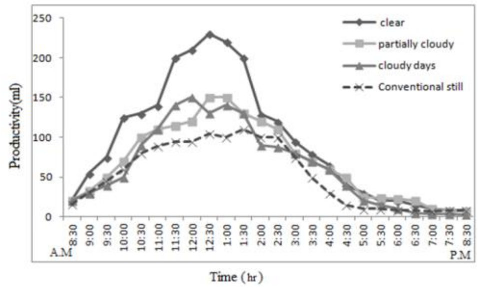

Figure.2. Variation of time with productivity

Economic analysis:

Fabrication cost = (Cost for the membrane + Cost for the mini solar pond + solar still) =5000.

Maintenance cost= Rs. 1/day.

Operating cost: Productivity of the solar still = 2.24 l/m^2/day. Cost of water produced= Cost of water per litre × productivity= 10×2.24=Rs. 22.4.

Cost of mineral per litre=Rs. 0.3. Cost of minerals for 22.4 =Rs. 6.72.

Net earnings=Cost of water produced-Maintenance cost-Cost of minerals=Rs.22.4-1-6.72=Rs.15.68

Payback period=Investment/Net earning = 3500/15.68= 223 days.

4. CONCLUSION

- Semi permeable membrane and a solar pond enhance the productivity of a single slope single basin solar still with reflecting mirror. The payback period of the overall experimental setup was 200 days. By the combination of semi permeable membrane and mini solar pond reduce salt accumulation in solar still. Solar pond coupled with the still are experimentally investigated on a clear, partially cloudy and cloudy days and found that clear day has the maximum productivity.
- The mini solar pond produces the preheating water and increase the productivity of the solar still compared to the conventional solar still.

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