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Comparative study of renewable energy based stills and electric heater coupled stills for water purification

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ABSTRACT

Water scarcity is the major problem that calls for the development and economy of the country. One of the best and most inexpensive methods to solve those problems were by solar distillation method. The productivity of the still depends upon many parameters. Expect water temperature other parameters cannot be altered. In this work sensible heat storage material; latent heat storage material were used along with biomass boiler and electric heaters to increase the water temperature in the still. An external glass cooling method was used to reduce the losses and increases the condensation rate in the still. Naturally available biomass such as wood was tried in this work as biomass fuel. Experiments are carried out by coupling various still designs such as pyramid, multi-basin and single basin design with biomass boiler and electric heater. The single basin still was operated in solar mode for comparison. Pay back periods are calculated for various stills, the payback periods for biomass augmented stills are low when compared to solar stills and stills coupled with heater. The multi-basin still with electric heater produces more yield than other shapes of design. The percentage of productivity for single basin still was 59% more than single basin solar still,66% more than pyramid still and 72% more in multi-basin still.

Keywords: *Single Basin, Multi-Basin, Pyramid Still, Biomass Boiler, Electric Heater, External Cooling, Solar.*

1. INTRODUCTION

As opposed to the fossil powers, renewable vitality, as the name recommends, exists unendingly and in plenteous amount in the earth. Renewable vitality is prepared to be tackled, in modest, and all the more significantly, it is a clean option to fossil fuels about 16% of worldwide last vitality utilization originates from renewable vitality sources Sunlight based Water Disinfection (SODIS) is a straightforward, earth feasible, ease answer for drinking water treatment at the family unit level for individuals expending microbiologically tainted crude water. Badran [1] has studied the performance of a single slope solar still using different operational parameters experimentally. The study also showed that the daily production of still can be increased by reducing the depth of the water in the basin.Aybar et al. [2] have found that longer flowing water when held on absorber plate leads to an increase in the rate of evaporation. They tested the system with black-cloth wick and black wick. They found that the fresh water generation rate increased two to three times when wicks were used instead of bare plate. Atikol et al.[3] have made an experimental study on an inclined solar water distillation system. Unlike solar systems, the feed water falls down on the solar absorber plate and the system produces fresh water and hot water simultaneously Velmurugan et al. [4] have worked on productivity enhancement of stepped solar still – performance analysis. To improve the productivity, experiments were carried out by integrating small fins in basin plate and adding sponges in the trays. When the fin and sponge type stepped solar was used, the average daily water production had been found to be 80% higher than ordinary single basin solar still.Hiroshi and Yasuhito [5] have proposed a newly designed, compact multiple-effect diffusion-type solar still consisting of a heat-pipe solar collector and a number of vertical parallel partitions in contact with saline-soaked wicks. The productivity of the proposed still is 13% larger than the multiple effect diffusion still coupled with a basin type still. Badran and Tahaneih [6] studied the effect of coupling a flat plate solar collector to increase the productivity. Other parameters like water depth, direction of still and solar radiation were studied.showed that the output of still increased by 36% using a flat plate collector since the saline water fed to the basin becomes preheated in the collector and hence quick evaporation occurs. Ismail [7] has tested with a simple transportable hemispherical solar still and its performance was experimentally evaluated under outdoors of Dhahran climatic conditions. It was found that over the hours of experimental testing through daytime, the daily distilled water output from the still ranged from 2.8 to5.7 l/m^2day. The daily average efficiency of the still reached as high as 33%

with a corresponding conversion ratio near 50%. It was also found that the average efficiency of the still decreased by8% when the saline water depth increased by 50%.

Tripathi and Tiwari [8]inferred that the convective heat transfer coefficient between water and inner condensing cover depends significantly on the water depth of the basin. It is also observed that more productivity was obtained during the off shine hours as compared to day time for higher water depths in a solar still (0.10 and 0.15 m) due to storage effect. Muafag suleiman.K. And Tarawneh [9] conducted the experiment on the impression of water depth on still he also uses a sprinkler for glass cooling to reduce glass cover temperature and improves the productivity of 14% more than conventional still.

2. PROBLEM IDENTIFICATION

Desalination using a solar still is the best source in the semi-arid regions to purify contaminated water. Though the output of the still is low when compared to another process, it is used because it is cost effective and no need for any external source. The water scarcity problems during low radiation periods and night time affect the production of distilled water from the still. Hence efforts are taken to improve productivity and make the solar still suitable for all seasons.

3. EXPERIMENTAL SETUP

The size of the basin was 0.81x 0.82 x 0.75m. The basin is painted black to absorb maximum solar radiation. The side and bottom sides of the stills were insulated with 4mm thick thermocol insulation layer to reduce heat losses in the still. The condensing surface of the still is made of plain glass with 5mm thickness is fixed at 30^0 inclination to the horizontal axis. The pyramid still was built with same area as single-basin still and the height of the still was taken as 0.3m the condensing surface of the still was made of 4 plain glass with 5mm thickness is set at 30^0 inclination (equal to latitude of site) to the horizontal axis having absorptivity of 0.9. A multi basin solar still was fabricated with 1.5mm thick mild steel. The size of the lower basin was 0.81x 0.66 x 0.59m. The lower basin was fitted with 125mm diameter G. I heat exchanger having 6 numbers of turns the upper catchment area was split up into 5 steps having15mm gap between the next measure and height 12cm. The length of the basin is 80cm. The upper and lower basin was separated by a glass cover having a 5mm thickness. A silicon rubber sealant is used to hold the glass intact with the still to prevent the vapor leakage from the still. Collection troughs were provided below the lower edge of the glass cover to collect the condensate. Distillate outlets were provided to drain the water through hoses and to store in jars. Provisions were made to supply raw water, drain the basin water and insert thermocouples.

Fig.1 Experimental setup

3.1 Biomass heater

The biomass heater having 145x133 mm size and height of 0.56m made of galvanized iron was connected as a high temperature source. The biomass is fed in to the furnace area by fuel supply door. The burnt wastes were gathered at the lower end and removed intermittently. The lower end of flame tube is connected up to the heater and the upper end is associated with the fireplace. Heater drum has bay and outlet to hold the feed water from the evaporator. The feed water is supplied by gravity The fumes gasses in the wake of passing through the fire tubes are depleted to the air through stack gave at the upper side of the boiler. The pump was used to flow water again to the evaporator drum at a steady momentum rate of 0.040kg/s.

3.2 ELECTRIC HEATER

An electric heater of the range was immersed in water was used to heat the water in the stills. They are powered by external sources.

3.3 WORKING

The solar-based still comprises of the dark painted basin, which contains saline water, which is incased by a transparent glass spread with hermetically sealed. When solar energy passes through the transparent glass cover and is retained by the water and predominantly by the black area. Because of this, the water in the still is warmed up and dissipates in the wet conditions inside the still. Water vapour rises until they interact with the cooler internal surface of the glass and gather into distilled water, go down along the glass surface and collected in the vessels close-by. In biomass heater the heated water from biomass boiler is supplied to the water in the basin through heat exchanges provided at the bottom of the still through a circulation pump. In case of electric heater the immersion heater is used to heat water in the still.

4. ERROR ANALYSIS

PV sun meter, digital anemometer and mercury thermometers were used to measure global radiation, current of air speed and ambient temperatures respectively. K-type thermocouples with multi-channel digital display unit were used to measure basin, water, glass cover temperatures. The accuracies and error for various measuring instruments are given in Table.1.1

Table 1.1 Error Analysis Table

S. NO.	INSTRUMENT	ACCURACY	RANGE	%ERROR
1	THERMOCOUPLE	±1 ^{0}C	0-100c^0	0.25
2	THERMOMETER	±1^{0}C	0-100c^0	0.25
3	KIPPZONENSOLARIMETER	±1W/m^2	0-5000W/m^2	0.25
4	ANEMOMETER	±0.1m/s	0-15m/s	10
5	COLLECTION TANK	±10ml	0-1000ml	10
6	MEASURING JAR	±10ml	0-500ml	10
7	ELECTRIC HEATERS	±1W	0=1500w	10

5. RESULTS AND DISCUSSIONS

5.1 Effect of water depths on productivity

The effect of water for 2cm depth in the single basin still, pyramid still and multi-basin stills were analyzed with a biomass boiler and the productivity is shown in Fig 2 It is evident that as the water depth is minimum, The productivity will be more. This is due to be the heat capacity of the water in the basin, The productivity for multi-basin still with the boiler is more due to a larger area of basin and area of water will be more it was 59% more than single-basin still and 27% higher than pyramid still. The productivity of pyramid still will be 43% more than single-basin still because of the more condensing area pyramid still the productivity is higher than single-basin still.

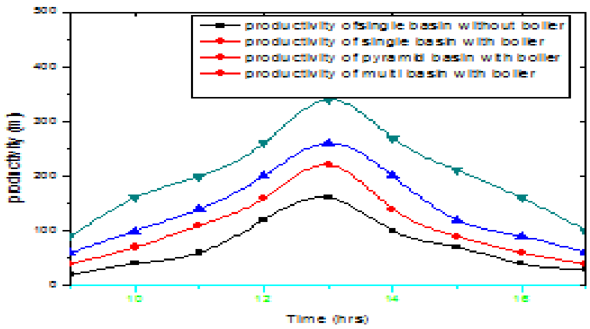


Fig.2 Effect of water depth for various stills

4.2 Effect of solid sensible heat storage materials on productivity

Sensible materials stores more amount of heat energy in addition to the basin absorption. These materials help to increases the water temperature. The Fig 3 shows the productivity of sensible material with time material like copper pieces were placed inside the still with 2 cm water depths and tested along with biomass boiler. The productivity of pyramid basin still was 58% and multi-basin still was 68% more than single-basin still. The productivity of single basin with the boiler is 44%.

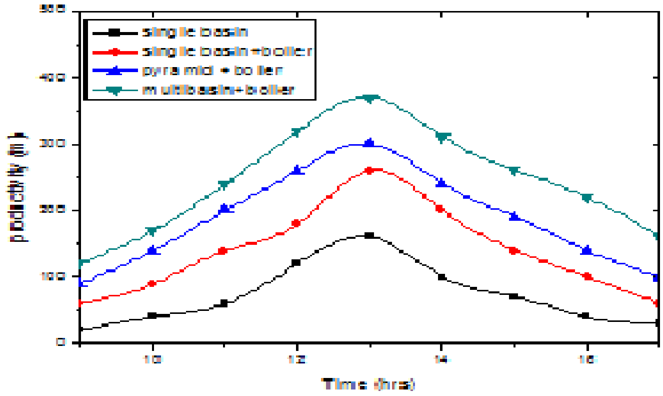


Fig.3 Effect of sensible materials

5.2. Effect of latent heat storage materials on productivity

Latent heat storage material was introduced inside the billets and placed inside the still and tested along with biomass boiler. The commonly used latent heat material is paraffin wax The Fig.4 shows the productivity of various stills with latent heat storage materials. The productivity is higher for multi-basin still 58% and lower productivity is 33% for single basin still when compared with single basin solar still.

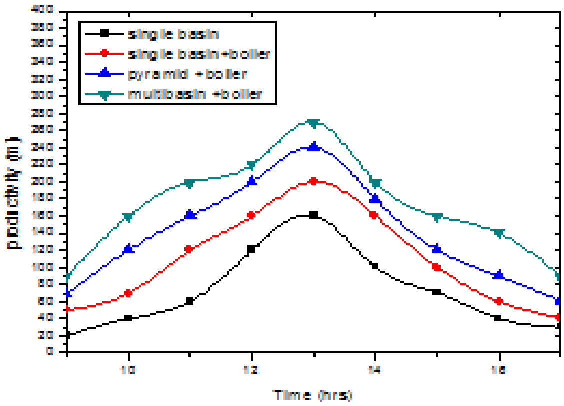


Fig.4 Effect of latent heat materials

5.3. Effect of the water heater on productivity

The electric water heater is used to heat water instead of a biomass boiler in the still. Various stills were operated along with the electric heater. Power for the heater is taken from electric current. The single basin still in solar mode is operated in parallel with other stills. The percentage of productivity for single basin still was 59% more than single basin solar still, 66% more than pyramid still and 72% more in multi-basin still. Because of uniform heating, the productivity is more than the solar mode. The productivity of stills with electric heaters are more than biomass boilers because of losses through the heat exchangers and heat content depends on the calorific value of the fuel. The fig.5 shows the effects of the water heater.

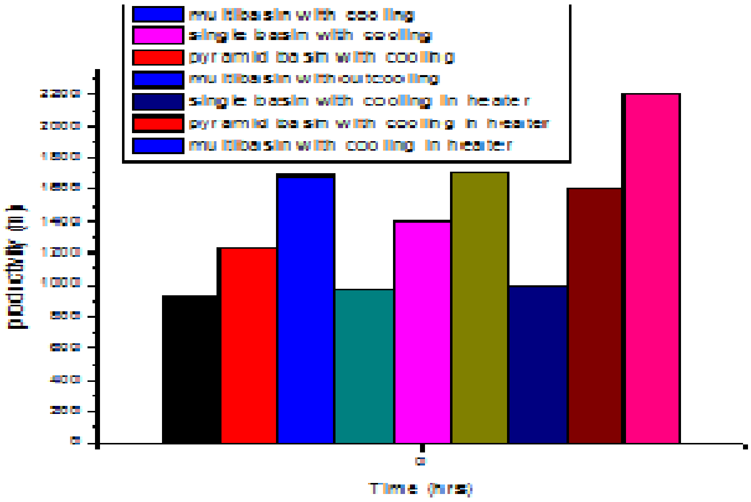


Fig.5 Effect of cooling

5.4. Effect of external cooling on productivity

External cooling of glass cover by both fan and sprinklers were used to reduce the losses inside the still and increases the condensation rate in the still The cooling increases the output of 20% in single basin still , 32% in pyramid still and 40% in multi-basin still for biomass heaters and 25% in single basin,37% in pyramid still and 43% in multi-basin still. Fig 6 explains the effects.

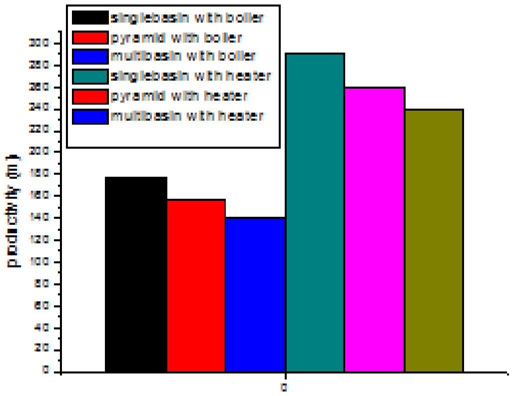
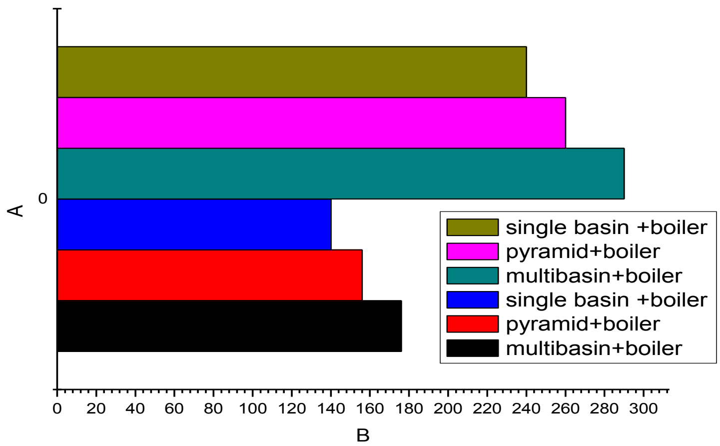


Fig.6 productivity with boiker and heater

6. ECONOMIC ANALYSIS

Fig 7 shows the payback period for various still designs with a biomass boiler and electric heater. The results showed that the biomass boiler produces low payback period than the electric heaters. The operating and maintenance cost of electric heaters were more than biomass boilers.



7. CONCLUSIONS

The focus of this research was to enhance the performance of different types of solar stills by augmenting biomass heat source and electric heaters through the experimental investigations. The influence of various water depths, sensible, latent heat, external cooling surfaces is also analyzed.

The study includes

- The productivity for multi-basin still with the boiler in 2cm water depth was more due to a larger area of basin and area of water will be more it was 59% more than single-basin still and 27% higher than pyramid still. The productivity of pyramid still will be 43% more than single-basin still because of the more condensing area pyramid still the productivity is higher than single-basin still.
- The productivity of pyramid basin still was 58% and multi-basin still was 68% more than single-basin still. The productivity of single basin with the boiler is 44%.for copper as sensible material.
- The productivity is higher for multi-basin still 58% and lower productivity is 33% for single basin still when compared with single basin solar still by using paraffin wax as latent heat material.
- The percentage of productivity for single basin still was 59% more than single basin solar still,66% more than pyramid still and 72% more in multi-basin still in the electric heater as a heat source. Because of uniform heating, the productivity is more than the solar mode.
- The cooling increases the output of 20% in single basin still, 32% in pyramid still and 40% in multi-basin still for biomass heaters and 25% in a single basin,37% in pyramid still and 43% in multi-basin still.
- The operating and maintenance cost of electric heaters were more than biomass boilers.

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