

Desalination of Single, Double Slope Still using Biomass and Solar Energy

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Abstract- In this work a single basin, double basin solar still is, used to produce distilled water using biomass heat source, solar energy. The concept of integrating the single basin and double basin with biomass heat source is introduced in this research study. The heat source is connected to still increases the water temperature and also increases the productivity in the still. A conventional still is also tested with the modified still for comparison. Different solid heat storage material, Latent heat storage material are introduced in the shape of small billets to increase productivity. Glass cover cooling is performed by using manual sprinkler at regular interval adds fourth dimension. Experiments are conducted in biomass modes and solar modes. Biomass mode produces more output than solar mode in double basin still.

Keywords – Biomass boiler, solid, sensible heat storage materials, latent heat storage, water depths. Biomass, double basin, single basin

I. INTRODUCTION

The growth of population and human, agricultural and industrial activities needs pure water. In India the storage reservoirs are minimum. Huge amount of water is required for different industrial processes, only a fraction of the same is incorporated in their products and lost by evaporation the rest finds its way into the watercourses. Many attentions are given in India on treatment of waste water. Many attempts have been made to improve the efficiency of the stills. Ashokkumar and Tiwari [1] investigated the use of hot water in double slope heat exchanger and found that the use of hot water increases production during off sunshine hours. Voropolulos et.al [2] experimentally investigated the hybrid still coupled with solar collectors the results showed that the productivity is doubled by coupling. Badran and Tahaneih [3] found that the output of still was increased by 36% by using a flat plate collector. Velmurugan and Srithar [4] fabricated the solar still with pretreatment arrangement. This arrangement reduces the color and purity of effluent. The addition of sensible material increases the production. Senthilrajan et.al,[5] analyses Multibasin still with biomass heat sources and done analytical validation using response surface methodology. Senthilrajan et.al [6] integrated a pyramid still with single basin still using common biomass heat source with various sensible materials the results shows that the productivity of combined still was maximum in biomass mode than conventional and solar modes. Badran [7] 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. [8] found that length of an 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. Murugavel et al. [9] fabricated a basin type double slope solar still with mild steel plate and tested with minimum mass of water. Different wick materials like light cotton cloth, sponge sheet, coir mate and waste cotton pieces were used in the basin. Still with aluminium rectangular fin arranged in different configurations and covered with different wicks were also tested. Fath and Hosny [10] analysed the thermal performance of a single sloped basin still with an inherent built in condenser to improve condensation rate. Atikol et al. [11] studied the inclined solar water distillation system and tested with three variants, base plate, black cloth, and wick. Nakatake [12] made a study to increase the distillate productivity by an inclined the flat plate external reflector on a tilted wick solar still. Zeinah et al. [13] used the oil heat exchanger to preheat the saline water inside the solar still and got 18% increase in productivity. Hiroshi and Yasuhito [14] have 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. Tarawneh [15] has studied about the effect of water depth in the basin on the water productivity. The performance characteristics showed that the water productivity is closely related to the incident solar radiation intensity. Boubekri and Chaker [16] studied the effect of the speed wind, the mass flow rate and the water depth in the basin. The results showed that productivity of the still is maximum for a flow rate of 0.0009 kg/s and 0.0015 kg/s and also the wind speed increases the temperature difference between glass and water. Economic analysis was performed by using various equation used in Kandapal and Garg [17] and calculated payback periods. Shiva Gorjian, Bharath Ghobadian, Teymour Tavakkoli Hashjin, and Ahamed banker [18] fabricated and tested a stand alone point focus parabolic solar still. The saline water is preheated before send in to the still by the point focus parabolic collector. The daily productivity of 5.12Kg was reported in their work. S. A. El-Agouz [19] investigated a stepped still with continuous circulation and found that the productivity is increased in the modified still by 20% when compared to conventional still.

In this work the performance of the single basin solar still is investigated. The lower portion of the basin fitted with a heat exchanger and coupled with a biomass boiler. The biomass boiler acts as a heat source to supply continuous heat into the basin. Sensible and latent heat storage materials are used in the lower and upper basins to increase water temperature. Various water depths of 2cm was analyzed. Various combinations of sensible, latent heat, evaporation materials, and latent heat materials are used in the form of billets in the still to increase productivity. Glass cover cooling is provided with the help of manual sprinkler at regular interval of time to increase the condensation rate. To increase evaporative area sponges, are used along with sensible and latent heat storage materials. The performances of still with biomass boiler are compared with the performances of conventional still.

II. EXPERIMENTAL SET UP

A single basin, double basin solar still was fabricated with 1.5mm thick mild steel. The size of the basin were 1x 1.4 x 0.5m and 1.5x1.8x0.75m. The lower basin of both the stills were fitted with 12mm diameter G. I heat exchanger having 8 numbers of turns. The basin is painted black to absorb maximum solar radiation. The position and bottom positions of the stills were insulated with 3mm thick thermocouple insulation layer (0.015W/m-K thermal conductivity) to reduce heat losses. The condensing surface is made of plain glass with 3mm thickness is set at 30° inclination to the horizontal axis. A rubber sealant is applied to keep the glass intact with the steel to prevent the vapor leakage from the still. Collection troughs were provided at a lower place the lower borders of the 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, run out the basin water and insert thermocouples. The biomass boiler having 150mm outer diameter and shell thickness 18 mm and height 750mm made of cast iron was used as a high temperature source. The boiler is internally fired with locally available biomass materials. The feed water to the boiler drum by gravity from the input feed water supply tank which is located above the elevation of the boiler. Safety valves and pressure gauges are present in the boiler.

III. WORKING

Solar stills were supplied with 2cm depth of water through the inlet pipe in the still. Biomass boiler was filled with feed water supplied from the inlet supply tank. Biomass having 1kg of mass are fed inside the furnace through the fuel supply door and ignited manually. Water in the drum gets heated the burnt gas passes through the inner side of the fire tube and exhausted to the atmosphere through the chimney. The boiled water is distributed inside the solar still through the heat exchangers and the circulation pump. The water inside the solar still absorbs heat from the heat exchangers and evaporated into vapors reaches the bottom surface of the cover. The top surface of the basin was cooled externally the vapor condenses and collected in the condensate collection channel as distilled water. A collection flask collects the distilled water. Water circulation and the burning process in the boiler continuous through circulation pump at constant speed. In the solar mode the still is exposed to solar radiation only Fig.1 indicates the experimental setup.

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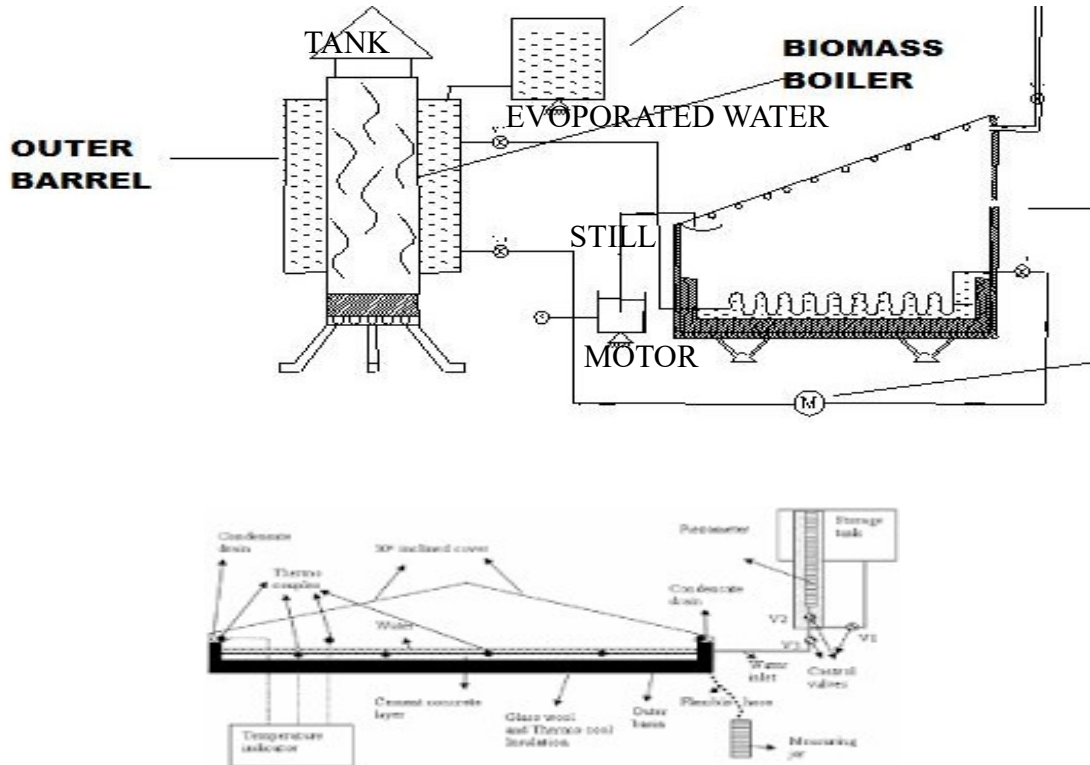


Fig.1 Experimental setup

Experiments were conducted at University college, Ramanathapuram, Tamil Nadu, India during the months of June- July 2019. The interpretations were read from morning 10 am to 5pm. 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 was used to measure basin, water, glass cover temperatures.

IV. MODIFICATIONS

i. Modes of operations

Several forms of biomass fuel such as wood and palm wastes are applied in the biomass boiler as fuels. The still was operated without biomass boiler and with biomass boiler. The conventional still also run in series with the modified biomass still for comparison.

ii. Glass cover cooling

Glass cover cooling increases the compression process. Hence cooling methods such as manual spraying of water at regular interval of time on the glass cover reduce glass temperature.

iii. Sensible heat storage

sensible heat storage material such as rock stones, were trying to increase the water inlet temperature.

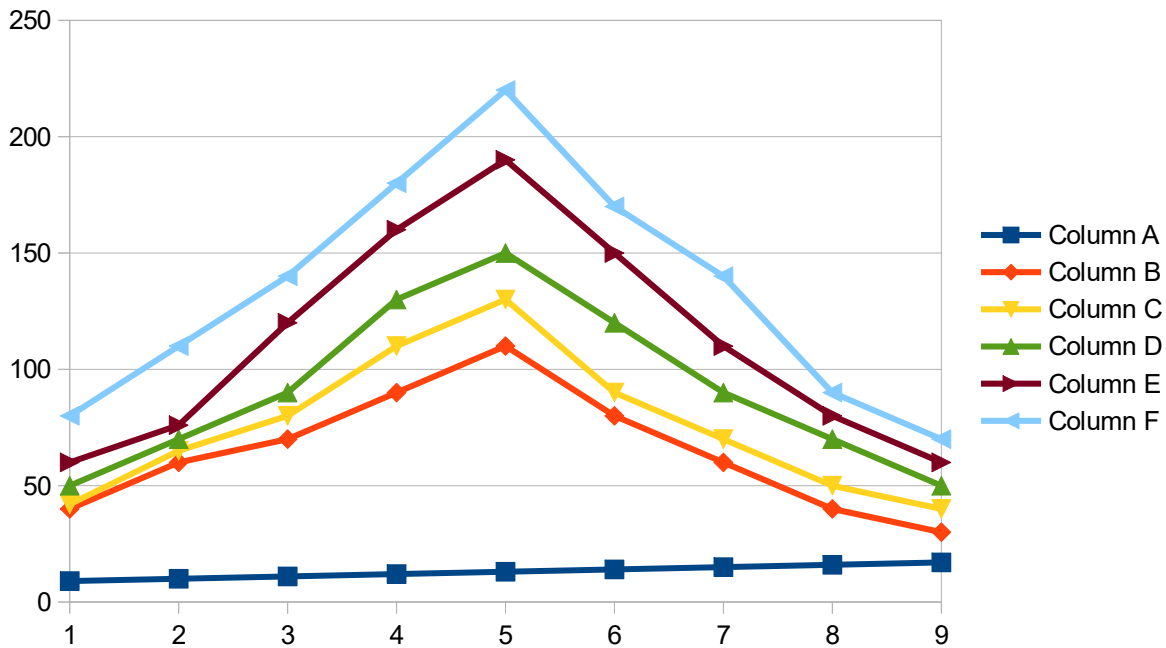
iv. Evaporative area

To increase exposure area coconut coir, were introduced in the watershed.. All the exposure materials are of area 0.5x0.5m placed 20% in the water surface.

V. RESULTS AND DISCUSSIONS

5.1. Effect of sensible heat storage materials on productivity

Sensible materials can store more amount of heat energy and increases the heat capacity of the basin in addition to increasing the basin absorption. These materials absorb energy during heating periods and released energy slowly during cooling. The Fig.2 shows the productivity of various solid sensible heat storing materials with time various material such as pebble pieces are placed inside the still with 2 cm water depth and tested in both biomass and solar mode. The productivity of rock stones pieces are 48% more than conventional still (790ml/hr) and 54% more in biomass mode in double slope still and in single slope still it was 36% more than conventional and 40% more than conventional still. The productivity is taken for average solar radiation of 500-900 W/m² during various days of test trails

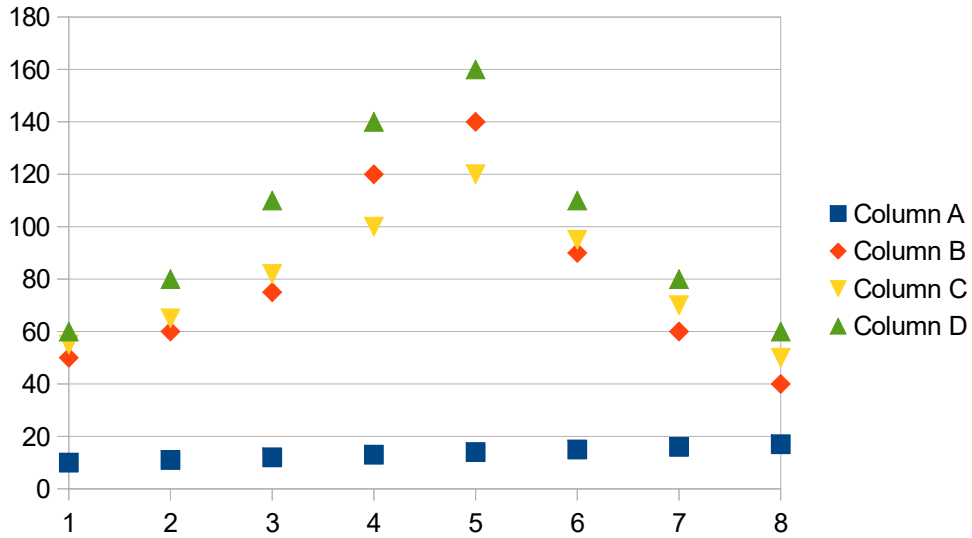


column A, B, C- still with stone solar mode D,E,F still with stones in biomass mode

Fig.2 Productivity of sensible heat materials

5.2 Effect of evaporative surfaces on productivity

Due to capillary action coconut coir, absorbs more water. Thus exposure area is increased which leads to increase the evaporation rate in the still. As shown in Fig.8 Productivity is increased by about 44 % for coir than conventional still and 55% in biomass mode. The readings plotted on the Fig.3 is taken for the average wind velocity of 1.9- 2.9m/s on various days of test trails.

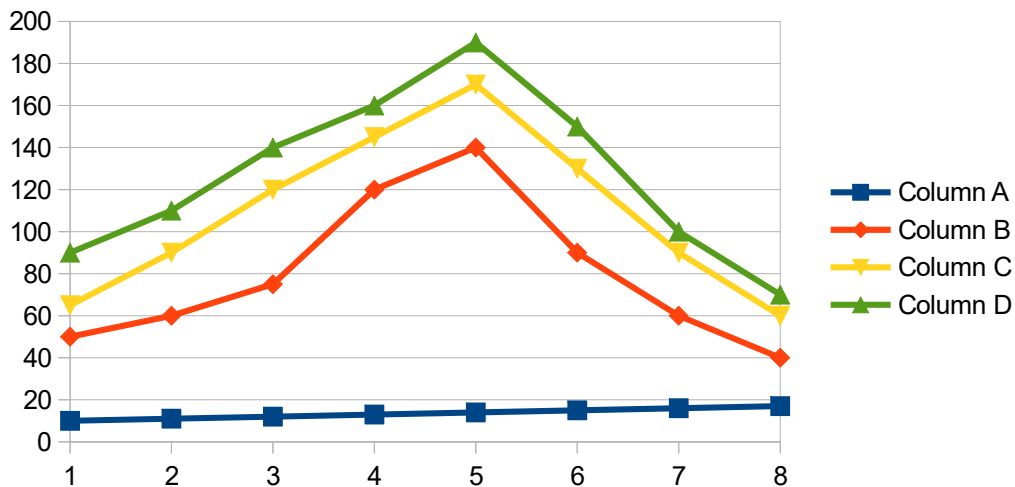


column A-Hours, B-conventional C- still with sponges solar mode D-stillwith sponges in biomass mode

Fig.3 Productivity of Evaporative materials

5.3 Effect of Latent heat storage materials

The Fig.4 shows the productivity of the various latent heat storage materials in solar mode. Various soild materials such wax are packed inside the billet and introduced into the still. The latent heat materials having a property of changing their phase from liquid to vapors during charging periods and from vapors to liquid phase again during discharging periods. During the charging periods it absorbs energy and releases during discharging. The productivity of wax is 40% higher than conventional still. Similarly the productivity was 58% higher than the conventional still in biomass mode.



column A-Hours, B-conventional C- still with wax solar mode D-still with wax in biomass mode

Fig.4 Productivity of latent heat materials

5.4 *Temperature reduction using cooling water*

The amount of water produced from the solar still depends upon the parameters such as wind velocity, relative humidity, and ambient temperatures. If the wind velocity is higher it cools the glass cover quickly than at lower velocities. Lower ambient temperature also cools the glass quickly. Lower relative humidity results in decreasing the sky temperature and increases the cooling process. In this work water is forced by the pump and sprays as a jet on the glass cover and reduces the glass cover temperature, which increases the condensation process. The Fig.5 shows the temperature of glass before and after cooling. It was concluded that the glass cooling reduces the temperature and improves the productivity in the still. The conventional still produces least output. The double basin still produces more output in biomass mode than all the combinations.

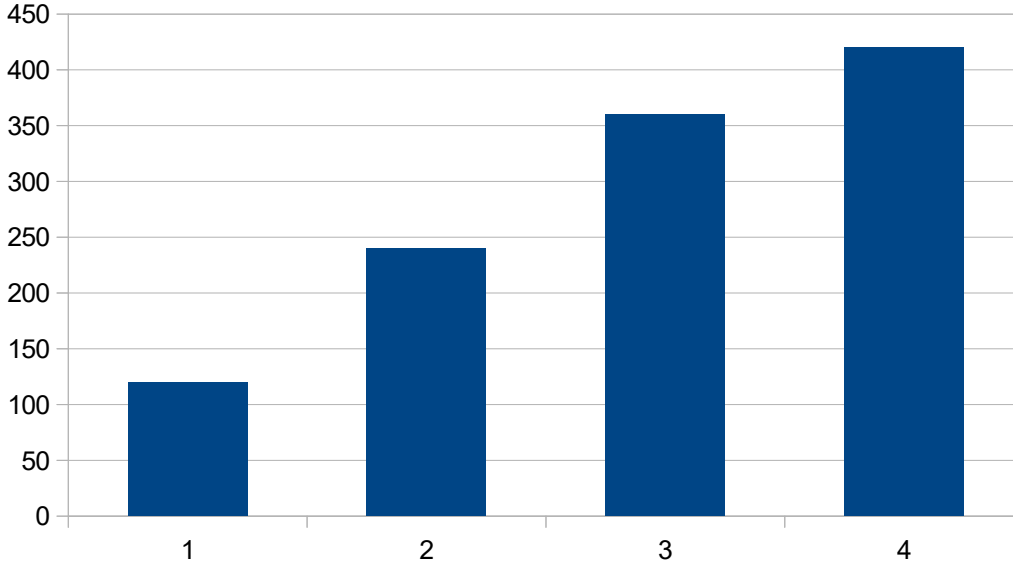


Fig.5 Productivity on glass cover cooling

VI. CONCLUSIONS

An experimental work has been conducted to predict the productivity of a single slope, double slope solar still coupled with biomass boiler using different solid, liquid sensible heat storage mediums and various evaporative materials.

Based on the experimental results the following conclusions are made

An increase in the still productivity was observed with the increase in the energy supplied by the biomass boiler.

The productivity of the still coupled with biomass boiler does not depend on solar radiation.

Changes in solar radiation do not affect production. Solar still behaves as condensing unit.

Water production is made constant if continuous burning inside the boiler. Biomass is Eco friendly.

The yield can be increased in proportion to increase in inlet water temperature.

Use of sensible, latent heat storage materials in the still improves productivity by 73% than conventional still.

Evaporative surfaces, cover cooling increases productivity

double basin still because of more area of contact produces more output than single basin still in all modes.

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