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# Desalination of effluent waste using biomass heat in pyramid still

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**Abstract**
In this work a pyramid solar still is, used to produce distilled water from industrial effluent using biomass heat source, solar energy. Since industrial waste is utilized as feed primary treatment is given to filter the waste. The concept of integrating the single basin still with biomass heat source is introduced in this research study. At the bottom surface of the basin, heat exchanger is laid at the bottom end. The heat exchanger is connected to the biomass boiler increases the water temperature in the still. A conventional still is also tested with the modified still for comparison. Different solid heat storage materials, Latent heat storage materials are introduced in the shape of small billets to increase productivity. Glass cover cooling is performed by using manual sprinkler at regular interval of fourth dimension. Biomass are tried in this workplace. Chemical analysis shows the reduction of 99% of salts and 100% TDS and 100% increase in COD, BOD levels in the distilled water. Experiments were conducted in biomass modes. Pyramid still produces more output than conventional still.

**Keywords:** effluent, primary treatment, biomass boiler**,** solid, sensible heat storage materials, latent heat storage

## 1. Introduction

The growth of population and human, agricultural and industrial activities increases the need of pure water. The supply of drinkable water is an important problem in the growing nations. In India the storage reservoirs are minimum. Here drinking water scarcity is present in many parts of the country. 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 as waste water and contributed to natural bodies of water. Industrial waste either join the stream or other natural water directly 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. Senthilirajan *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 Tav akkoli Hashjin, and Ahamed banker [18] Fabricated and tested a standalone 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] investegaed a stepped still with continuous circulation and found that the productivity is increased in the modified still by 20% when compared to conventional still. The day and night efficiency of 5%,3.5% was increased for sea and salt water. Karel Ghyselbrecht, Marie Huygebaert, Bart Vander Bruggen, RobBallet, Bouewijn Meesschaert, Luc Pinoy [20] treated industrial waste using electrodialysis bipolar membrane method this method removes 60% of chloride salt from the water. Jianquan Luo, Yinhua Wan [21] treated industrials wastes in their work by using nano filtration methods. NF270 membrane was used to treat the water. This method removes the salts and increases the PH to drinking standards. Since the feed is an effluent it needs proper treatment before it is supplied to the still. Hence in this work pretreatment are given to the feed to remove the impurities, chemicals and salts In order to fulfill the above gap biomass heat source was used to increase the water temperature in the 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, 3cm, and 4cm were 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 yellow sponges, coconut wastes, bricks 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 using RSM. So far no other work was performed by treating effluent using biomass heat source and validate using RSM.

## 2. Experimental set up

The industrial effluent is used as feed it needs handling. The experimental setup consists of four tanks layers connected in series and split up by fine mesh. each tank is in size. A single basin solar still was fabricated with 1.4mm thick mild steel. The size of the basin was 0.75x 0.60 x 0.5m. The lower basin was fitted with 13mm 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 cut heat losses in the still. The condensing surface of the blade is made of plain glass with 3mm thickness is set at $30^0$ inclination to the horizontal axis. A silicone 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 ice 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 120mm outer diameter and shell thickness10mm and height 450mm made of cast iron was used as a high temperature source. The boiler is fired tube type internally fired with locally available biomass materials. The lower part of the boiler is called the furnace where biomass is eaten into the furnace through the fuel input door. The burnt ashes are gathered at the lower end and removed periodically. The lower end of fire tube is joined to the furnace and the upper end is tied to the chimney. Boiler drum has inlet and outlet to hold the feed water from the kettle. The feed water is furnished to the boiler drum by gravity from the input feed water supply tank which is located above the elevation of the boiler. The boiler is supplied with biomass and fired manually. The inlet end of the heat exchanger is connected to the boiler vent pipe and outlet end was connected to the circulation pump to circulate water again to the boiler drum. Experiments were conducted at University college, Ramanathapuram, Tamil Nadu, India during the months of June- July 2019. The interpretations were read from morning 9am to 5pm and 6pm to 12hrs for every one hour interval for solar and biomass modes. 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. Fig.1 shows the internal view of test setup. Table.1 shows the error analysis of various measuring instruments used.

**Table 1**

| S. NO | Instrument | Accuracy | %Error |
|---|---|---|---|
| 1 | Thermocouple | $\pm 1C^0$ | 0.25 |
| 2 | Thermometer | $\pm 1C^0$ | 0.25 |
| 3 | Kippzonensolarimeter | $\pm 1W/m^2$ | 0.25 |
| 4 | Anemometer | ±0.1m/s | 10 |
| 5 | Collection Tank | ±10ml | 10 |
| 6 | Measuring Jar | ±10ml | 10 |

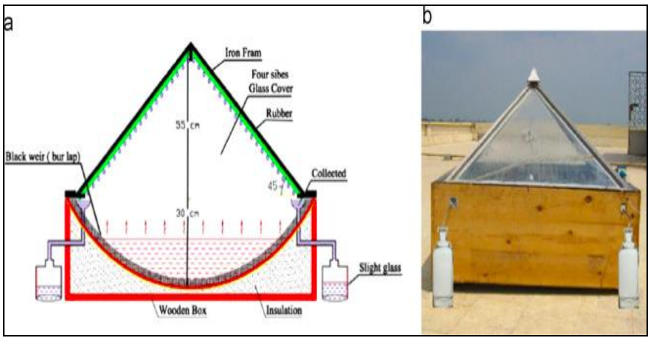


**Fig 1:** Photographic view of Experimental setup

### Water treatment methods

The diverse methods are adopted for purifying the industrial wasteland. The process includes screening, sedimentation, filtration, disinfection, softening etc

### Screening

This process removes very large size particles from the waste. It consists of fine and large size screens to separate fine and large molecules from the effluent.

**Filtration**
This is the operation of drawing the water through the bed of such granular materials is known as filtration. Filtration removes color, odor, turbidity of waste water. Some of the common filter materials include sand, crushed rocks, charcoal layer.

**Disinfection**
The waste water coming from the sand of gravel, filter contains harmful disease producing bacteria in it.

**Water softening**
The reduction of stiffness of water is called damping. Hardness produces scaling problems in various equipments and tubes. Addition of lime removes the calcium and magnesium salts from the water and reduces stiffness.

**Misscellaneous treatment**
Treatment with activated carbon. This is a specially treated carbon, which provides the property of absorbing gases, liquids, fine solids it also takes out odors. The activated carbon is largely applied in powder form added to water before filtration. This procedure cuts down the chlorine requirement. Gets rid of organic matter and color. Its overdose is not harmful. Fig.1 shows the treatment

## 3. Working
Industrial effluent requires treatment before it is admitted into the solar still. There are two cases of treatments needed for waste water they are main and secondary treatments. The primary treatment consists of four tanks connected in series. Each layer is having a mesh which permits the feed to the next layer by gravity. The first layer is filled with a rocks to remove large contaminants from the feed. Afterward that the feed is allowed into the next layer filled with sand the sand layer removes fine and coarse impurities from the feed. The tertiary level is filled with activated carbon to remove color and scent from the feed. The fourth level is filled with caustic soda to get rid of salt from the battlefield. Before moving to secondary treatment chlorine is added to feed it kills the bacteria's and germs from the feed. The secondary treatment consists of passing feed through primary and secondary filters, which slays all the minute particles from feedings and changes the odors and color. At once the feed is admitted into the still. Solar still is 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. While running, the burnt gas gives out the heat to the water in the outer barrel. Therefore, the water gets boiled. 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 ice screen. 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 and the biomass boiler is cut away from the steel. Before beginning the experiments the glass top was cleaned by using cotton cloths.Fig.2 indicates the color changes occurs in the process and

**Fig 2:** color change after primary and desalination

## 4. Modifications
**1. Modes of operations**
Several forms of biomass fuel such as wood chips, wood, palm wastes are applied in the boiler and their operation are found out.

**2. Glass cover cooling**
Glass cover cooling increases the compression process. Hence various cooling methods such as manual spraying of water along the screen at regular interval of time is proving to reduce glass temperature.

**3. Sensible heat storage**
Several types of sensible heat storage materials such as granite pieces, cast-iron pieces and aluminum pieces were trying to increase the water inlet temperature.

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

## 5. Results and discussions
### 5.1. Effect of sensible heat storage materials on productivity in solar mode
Some 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.3 shows the productivity of various solid sensible heat storing materials with time various materials such as cast-iron, Aluminum, Granite pieces are placed inside the still with 2 cm water depth and tested. The productivity of aluminum pieces are 48%more than conventional still The other materials such as granite, cast-iron produces 34%, 45% more productivity than conventional still when operated under solar mode.The productivity is taken for average solar radiation of 500-800 W/m$^2$ during various days of test trails.

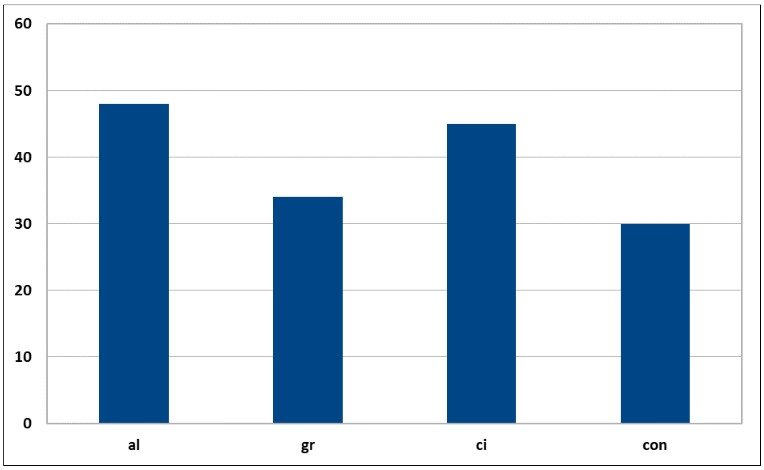


**Fig 3:** Effect of sensible materials

### 5.2 Effect of evaporative surfaces on productivity

Due to capillary action sponges, bricks and coconut coir absorbs more water. Thus, exposure area is increased. Addition of these materials in the still raises the water by capillary action which leads to increase the evaporation rate in the still. As shown in Fig.8 Productivity is increased by about 38 % for coconut coir, 49% for sponges and 26 % for bricks than conventional still operated in solar mode. The readings plotted on the Fig.4 is taken for the average wind velocity of 1.8- 2.5m/s on various days of test trails.

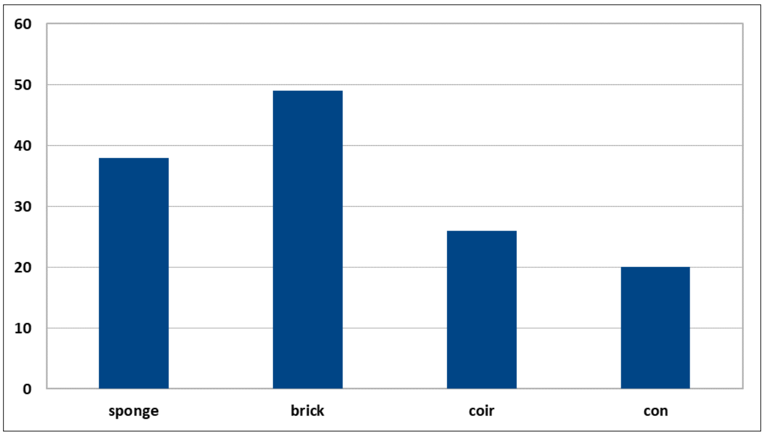


**Fig 4:** Effect of Evoporative materials

### 5.3 Effect of Latent heat storage materials

The Fig.5 shows the productivity of the various latent heat storage materials in solar mode. Various liquid materials such iodine and ethylene glycol 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 glycol is 30% higher than conventional still. Similarly, the productivity of iodine was 18% higher than the conventional still.

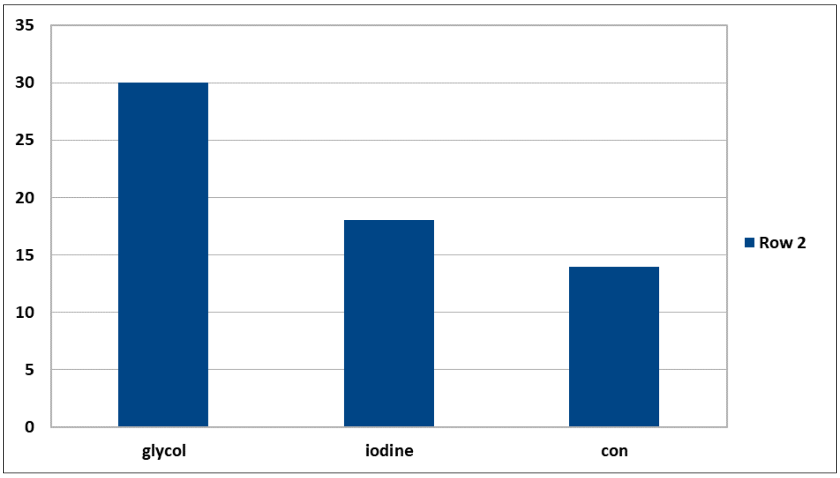


**Fig 5:** Effect of latent heat materials

## 6. Chemical analysis

The chemical analysis of the test feed initially contains higher calcium, chloride, dissolved solids with low COD, BOD levels. After the pretreatment the calcium levels are reduced to 27% and chloride levels are reduced to 30% and the sodium levels are reduced by 36%.The COD and BOD levels are improved by 17% and 7%.The total dissolved solids are reduced to 29% as shown in Fig.11 (a-c).The % reduction of chemicals in the final disilled water is 99% reduction of sodium chloride and 96% reduction of calcium and100% increase in COD, BOD, TDS.

## 7. Conclusion

An experimental work has been conducted to predict the productivity of a single 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.

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

Use of solid sensible heat storage materials in the still improves productivity by 63% than conventional still.

Evoporative surface increases productivity of 38 % for coconut coir, 48% for sponges and 25 % for bricks than conventional still.

The used of evaporative surfaces increases the area of exposure and still productivity by 58% Lower water depth in the still increases the productivity in the still.

Manual glass cover cooling in the still reduces the glass cover temperature and increases the condensation process in the still. COD, BOD, TDS in water are good.

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