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Experimental Investigation on a Modified Solar Still with Internal Reflectors

Harimohan Soni[1] and Rajiv Varshney[2]

[1]M. Tech. Scholar, Radharaman Institute of Research and Technology

[2]Associate Professor and Head, Radharaman Institute of Research and Technology

Abstract

Fresh water is one of the primary requirements of human life. Agriculture and industries also require fresh water for their sustenance. Due to population explosion and rapid industrial growth, the demand for fresh water has increased enormously. The purpose of the present work is to evaluate the performance of a modified solar still. In the modified solar still steps are incorporated along with internal reflectors. Experiments are performed on modified solar still and its performance is compared with conventional solar still. It is found that the distillate coming out from modified solar still was maximum at 03:00 pm which is recorded as 25 ml while the distillate coming out from conventional solar still at the same time was 3 ml. The maximum distillate collected from modified solar still is 733% higher than the conventional solar still. The maximum temperature of modified solar still was 32ºC at 3:30 pm.

Keywords - stepped solar still, inclined type solar still, flat basin with reflectors, desalination

1. Introduction

Fresh water is one of the basic requirements of human life. Besides, agriculture and industries also require fresh water for their sustenance. Civilizations haves been dependent on rivers, lakes and underground water reservoirs to fulfill his need of fresh water, an act that is intimately

associated with their evolution. Because of population explosion and rapid industrial growth, the the demand for fresh water has increased enormously. Due to less rainfall in many parts of the world and climate changes, the availability of fresh water is becoming scarce. Moreover, the available resources are getting polluted due to discharge of industrial wastes and sewage in large quantity. About 79 percent of water available on the earth is salty, 20 percent is saline and only 1 percent is fresh. Therefore, conversion of saline water to fresh water through the distillation process using solar energy is a good option for the places where plenty of saline water and sun available [1].

Solar energy can be a major source of power and can be utilized by using thermal and photo voltaic conversion system. The solar radiation received on the surface at noon on a sunny day is about 1kW/m^2. The earth continuously intercepts solar power of 178 billion MW, which is about 10,000 times the demand of the world. Solar still is a device which is used to distillate water using solar radiation. The water containing dissolved impurities such as heavy water and salts and microbiological organism remain in the bottom of the still while the water is vaporizing by solar radiation. This water vapor's condenses upon the inclined glass which is cooled by atmospheric air drops down on the channel at the lower end of glass and gets collected in a collecting jar. The end result is pure distillate water [1].

2. Literature review

For increasing the performance of a solar still various modifications were made in the conventional solar still which are discussed in this literature survey.

Gad modified the conventional solar still by providing glass in the shape of a cone called as conical solar still. This is done to increase the productivity by decreasing the shadow effect and maximizing utility of solar radiation. Also the heat and mass transfer coefficients were evaluated [2]. Somanchi increased the performance of a solar still using phase change materials. Magnesium sulfate heptahydrate ($MgSO_47H_2O$), sodium sulphate (Na_2S7H_2O) were used as phase change material and titanium oxide was a nanomaterial used as energy storage material [3].

Rahbar used CFD modeling and simulation to increase the productivity of solar still. A 2-D CFD simulation was used in computing heat and mass transfer in a tubular solar still [4]. Al-Nimr designed a new solar still introducing porous evaporator, internal condensation and thermos phonic circulation and concentration. A steady state mathematical model of still was proposed and simulated [5].

G.M. Ibrahim constructed and tested modified basin type solar still with air cooled condenser. The system was simulated using a mathematical model and solved numerically using a computer program written in MATLAB code. This model was verified against experimental measurement [6].

Thiago used numerical simulation to study the technical and financial viability of a solar water heating system for a hospital laundry in the city of Recife. After modeling the system's components, some parameters of the systems were optimized such as tilt angle of the collector, water flow rate, area of collectors and the size of the water tank [7]. Park used a multiple effect diffusion hybrid solar still for increasing the productivity of a solar still, with simple sea water feeding device and dual heat sources of solar thermal energy and waste heat [8].

Hansen experimentally investigated a solar still using different wick material as different absorber plate configuration. Different wick materials which were chosen for analysis and water coral fleece material with porosity (69.67%), absorbency (2s), capillary rise (10 mm/h) and heat transfer coefficient (34.21 W/m^2°C) was the most suitable wicking material for higher productive solar still. Performance of the still were compared with different wick materials (wood pulp paper wick, wicking water coral fleece fabric and polystyrene sponge) on the various absorber pate configuration (flat absorber, stepped absorber and stepped absorber with wire mesh) [9].

Omara made modification in conventional solar still was made of stepped solar still through internal reflectors on the steps. A comparison was made between conventional solar still and modified stepped solar still with trays (5 mm depth×120 mm width) to evaluate the performance under the similar atmospheric conditions [10].

3. Materials and Methods

The body of the modified solar still (MSS) is manufactured by GI sheet metal of thickness 1.5 mm. The solar still consists of seven steps also weirs are provided on the side wall of each step to make water to flow from one step to another. Steps were incorporated over the basin with the same material. The bottom of the still and the steps are painted black to increase the absorption of heat from the sun. Two openings are made one at the back and other at the side of the still used for water entry and for the collection of distillate. A toughened transparent glass cover of 4 mm thickness is used to place over the inclined surface of the solar still. The transparent glass cover is made to incline at 29° as per the position of experimental location (i.e. Bhopal, MP, India). Reflector was attached vertically at the inner side of the still to increase the performance

of the still. A channel is provided to collect the condensate from the solar still. Experimental setup is shown in figure 1.

Fig. 1. Experimental setup with instrumentation

The dimensions of modified solar still are as follows:

Basin area =103 cm × 96 cm

Reflector = 60 cm × 40 cm

Steps = 103 cm × 4 cm × 1.5 cm

Firstly, the water is filled in the basin as well as in each step and the basin is closed tightly to provide a leakproff. As soon as the water gets heated due to solar radiation, water gets evaporated and start moving upward both from the basin and steps, comes in contact with the glass sheet and gets cooled with atmospheric air, vapors condense and flow downward on inclined glass sheet and gets collected in the collecting jar through the channel. The condensate collected from the modified solar still is then compare with conventional solar still (CSS).

While performing experiments, the various parameters observed are solar radiation i.e., how much intensity of solar radiation is coming from the sun, since water is filled on each step so temperature of individual steps need to be recorded by using thermocouples i.e., MSS basin, MSS step, MSS glass cover, CSS basin, CSS glass cover, atmospheric temperature. Since water is filled on the steps when water evaporates water vapours formed due to which humidity level is need to recorded in percent i.e., MSS step RH (%), MSS basin RH(%), CSS basin RH(%). Set-up is placed in open atmosphere so air is flowing which comes in contact with glass cover of modified solar still and conventional solar still so air velocity need to recorded i.e., atmospheric velocity(m/s), MSS glass velocity(m/s), CSS glass velocity(m/s) and finally distillate is measured.

4. Results and discussion

When experiments are performed on modified solar still and compared with conventional solar still we find that the distillate coming out from modified solar still is maximum at 03:00 pm as shown in figure 2. which is recorded as 25 ml while the distillate coming out from conventional solar still at the same time is 3 ml. The maximum, distillate collected from modified solar still is

733% higher than the conventional solar still. The temperature of modified solar still is maximum at 3:30 pm as shown in fig. 3.

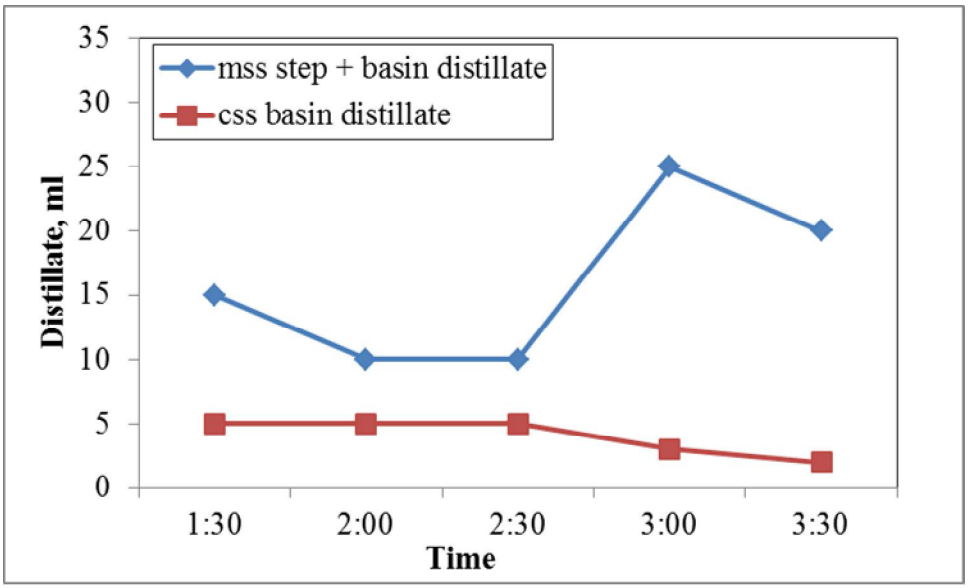

Fig. 2. Variation of distillate w.r.t. time

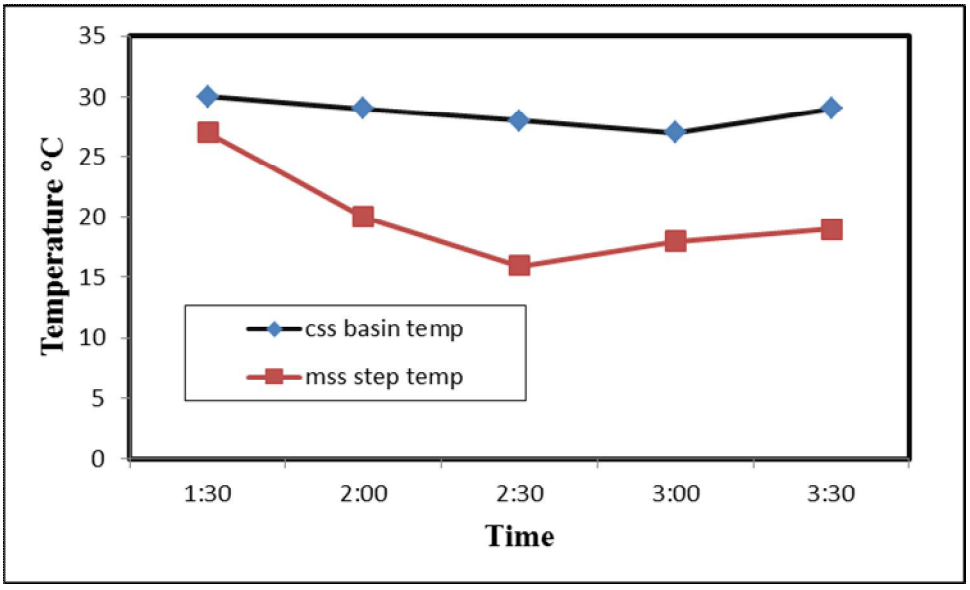

Fig. 3. Variation of temperature w.r.t. time

5. Conclusion

Fresh water is one of the fundamental requirements of human race. Various desalination systems have been designed in the past to get the fresh water. In the present work a solar still is designed with internal reflectors and steps and its performance is evaluated. The performance of this modified solar still is compared with the conventional solar still. It was found that the distillate coming out from modified solar still was maximum at 03:00 pm which is recorded as 25 ml, while the distillate coming out from conventional solar still at the same time was 3 ml. The maximum, distillate collected from modified solar still is 733% higher than the conventional solar still. The temperature of modified solar still was maximum at 3:30 pm. It can be concluded that the present setup can be used for getting the fresh water for the practical purposes in various regions where we have sufficient amout of solar energy available.

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