IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 64-70
www.iosrjournals.org

Single Basin Solar Still Performance with Evacuated Tubes Solar Collector

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Abstract: *In the last few years the demand for fresh water has increased tremendously all over the world. The future demand will be very high and the fresh water resources are getting depleted at a faster rate. We need to depend on the saline water resources for meeting the fresh water demand. One best option is to use solar energy for water distillation. Distillation has long been considered a way of making water drinkable and purifying water in remote location. for ninety seven percent of the earth's mass lies in the oceans, of the remaining 3%,is brackish, 0.5% as fresh water as result many people do not access to adequate and inexpensive supplies of portable water this leads to population concentration around existing water supplies, marginal health condition and generally allow standard of living. Solar distillation could benefit developing countries in several ways. Solar distillation can be a cost effective's means of providing pure water for drinking, cooking, washing and bathing. Solar still operating on sea water can ensure supply of water in draught affected region. In our experiment we uses single basin solar still with evacuated tubes solar collector to convert the saline water into distilled water. As solar energy is plentiful and can be used for converting saline water into distilled water. The pure water can be obtained by distillation in the simplest solar still but here we have focused on the use of evacuated tubes to increase the daily productivity of solar still with less heat losses. Various active methods have been adopted to increase the temperature of the basin so as to increase the productivity of solar still.*

Keywords: *Augmentation, solar still, evacuated tubes.*

I. INTRODUCTION

Water is a precious natural gift and is being polluted by human activities, urbanization and industrialization. The ground water is often over exploited to meet the increasing demand of the people. Less than 1% of earth's water is available for human consumption and more than 1.2 billion people still have no access to safe drinking water. Over 50% of the world population is estimated to be residing in urban areas, and almost 50% of mega cities having population over 10 million are heavily dependent on ground water, especially in the developing countries like India.

Most of the rural people still live in absolute poverty and often lack access to clean drinking water. Nearly half of the population is illiterate, not at all aware of the waterborne diseases affecting their health. Nearly 70% of the infectious diseases in India are waterborne. Indian villages are posed with problem of overexploitation of ground water due to increasing dependence on it as other fresh water resources are dwindling fast. To purify this water and make it portable different methods are utilized such as reverse osmosis, desalination, electro dialysis etc are used.

Distillation process is considered to be one of the most widely adopted techniques for converting sea water. More than 90% of the World wide installed sea water desalination capacity is based on distillation process which can be supplied by solar energy or any other fuel while in reverse osmosis, vapors compression & electro dialysis mechanical or electrical energy is used.

Solar distillation uses the heat of the sun directly in simple piece of equipment to purify water. The equipment, called a solar still, is a man made gadget in which the natural hydrological cycle has been copied in miniature fashion and consists primarily of a shallow basin with a transparent glass cover. The sun heats the water in the basin, causing evaporation. Moisture rises, condenses on the cover and runs down into a collection trough, leaving behind the salts, minerals, and most other impurities, including germs.

Although it can be rather expensive to build a solar still that is both effective and long lasting, it can produce purified water at a reasonable cost if it is built, operated, and maintained properly. This project focuses

mainly on small-scale basin-type solar stills as suppliers of portable water for families and other small users. Of all the solar still designs developed so far, this basin-type continues to be the most economical.
Solar distillation process is carried out both in passive and active modes.
Passive Method: Passive solar still operates in low temperature and the daily productivity is comparatively low.
Active Method: To increase the evaporation rate in an active mode the extra thermal energy is fed into the basin. To increase the productivity of solar still, the various active methods are being carried out by many researchers. Most of the works were based on the flat plate collector and concentrating collector.

II. EXPERIMENTAL SETUP

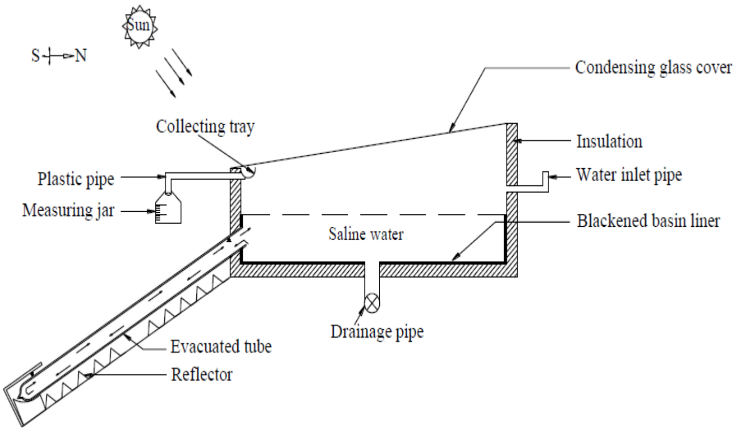

Figure 1: Schematic of experimental setup

The major elements of the experimental setup are single basin solar still and evacuated tubes. The experimental setup used for the study is shown in fig.1. The still is made up of aluminum sheet of 80×80cm^2 areas and the same is also acting as a basin. The inner side of the aluminum plate acts as absorber plate and it is painted with black color for a height of 10 cm at the bottom to absorb higher incident solar radiation. Remaining area in the aluminum plate acts as reflector so as to increase the effect of radiation in the solar still. Another box type outer structure of area 85×85cm^2 was designed and fabricated to hold the still. An insulation of 2cm thickness is provided at the bottom and sides to reduce the heat losses. Cotton wool with the thermal conductivity of 0.018 W/m K is used for this purpose. The water in the basin is condensed by using an ordinary window glass of thickness of 0.4cm and it is fixed at an angle of 12°with respect to horizontal axis. The purified water condensed from the glass is collected by folding aluminum sheet in the lower side of the still in “U” shape. Further the “U” shaped collection tray is connected with rubber pipe to collect the purified in a measuring jar. A silicon rubber sealant is used to hold the glass intact with the still surface and to prevent the vapour leakages from the still. Holes are made in the upper side of the still for the inlet pipe and bottom side for the outlet pipe. The digital thermometers inside the still are fixed by providing two other small holes in sides of the still

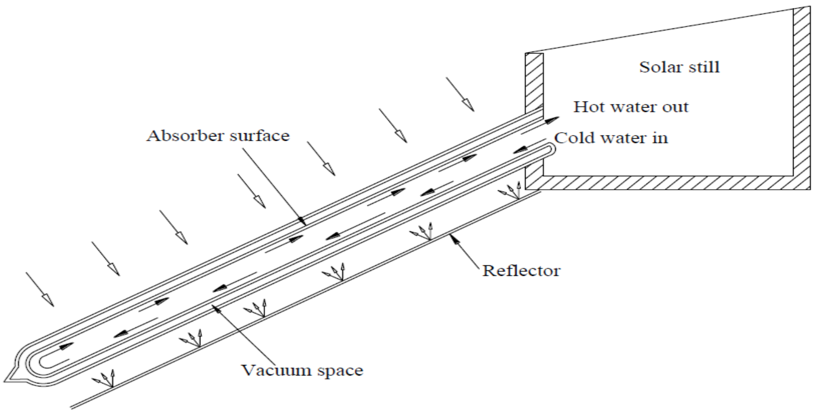

Figure 2: Evacuated Tube Arrangement

The second major part of the experimental setup is the evacuated tubes. Arrangement of evacuated tube in solar still is shown in figure 1. Ten evacuated tubes are coupled by making 6 cm diameter hole in the lower side of the still. The evacuated tubes are placed on a metal frame and it is connected to the still stand at an angle of 45˚ with respect to the horizontal axis. Reflector plate made up of stainless steel is used to increase the reflective radiation falling on evacuated tubes and it is fixed above the metal frame. Water in glass type evacuated tubes with a length of 15 cm, outer diameter of 5.8 cm, inner glass diameter of 4.7 cm and glass thickness of 0.16 cm are used for this study. Rubber gaskets are used to fix the evacuated tubes to the inner side of the basin. The angle of the evacuate tubes is maintained at 45˚ with respect to the horizontal surface so as to receive the maximum solar radiation. The bottom end of the evacuated tube is well supported with sponge materials in a separate metal structure of the frame. The vapour leakage from the still is prevented using silicon sealant. The selective surface absorber in the inner glass receives the solar radiation and it transfers it as heat energy to the water in the tube. The vacuum space in-between the two glasses reduces the heat losses. The water circulation flows naturally through the single ended tubes. Water in the evacuated tubes is heated by the solar radiation and the hot water rises to the still basin due to the density difference. The high temperature water entering the still basin gets mixed up with the low temperature water in the basin. This makes the low temperature water to flow back to the evacuated tubes and this process continues. The pictorial view of the solar still augmented with evacuated tubes is shown in figure 2.

III. EXPERIMENTAL PROCEDURE

The incident solar radiation is transmitted through an angled glass cover to the water in the basin. Thus the basin water gets heated up and evaporates. The evaporated water particles condense in the inside layer of the glass cover. This condensed water flows down the cover due to the slope provided and reaches the channels, where it is collected by the collection jar. At the beginning of the experiment, tap water is filled in the basin up to 5 cm height through the inlet pipe. The experiment is commenced after 24 hours of assembling the glass cover, so as to enable the setup to reach the steady state condition. For each experiment, the glass cover is cleaned in the morning to avoid the dust deposition over the outer layer of the glass. The extensive experiments were conducted on the month of May 2013. The readings were taken from 9AM in the morning till 6PM in the evening at hourly intervals. The variables measured in this experiment are water temperature (Tw), basin temperature (T_b), vapour temperature (T_v), inner glass temperature (T_{gi}), outer glass temperature (T_{go}), evacuated tube inlet temperature (T_{ei}), evacuated tube outlet temperature (T_{eo}), ambient temperature (T_a), and productivity (P). The first set of experiment was started with simple solar still and black gravel is used for productivity enhancement. The second set of experiment was conducted by augmenting the evacuated tubes to the still. The productivity enhancements were compared with the first experimental setup.

IV. RESULTS AND DISCUSSIONS

4.1 Solar Still Alone

Date: 9/05/2013 Time: 9.00 AM to 6.00 PM
On the basis of observation taken, following graphs is drawn:

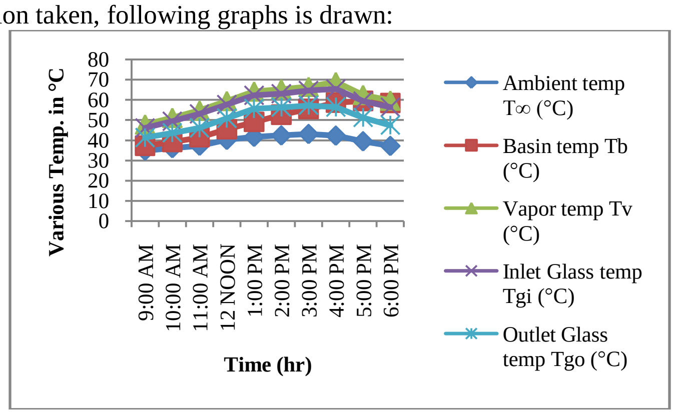

Figure 3: Graph for various temperatures vs. time on day1 in c.

Date: 10/05/2013 Time: 9.00 AM to 6.00 PM
On the basis of observation taken, following graphs is drawn:

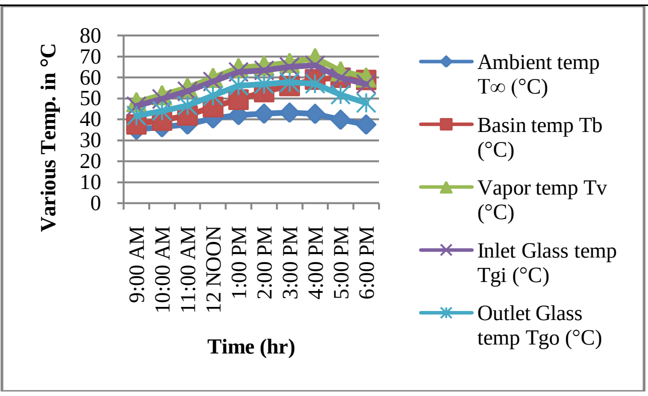

Figure 4: Graph for various temperatures vs. time on day2 in c.

Date: 11/05/2013 Time: 9.00 AM to 6.00 PM

On the basis of observation taken, following graphs is drawn:

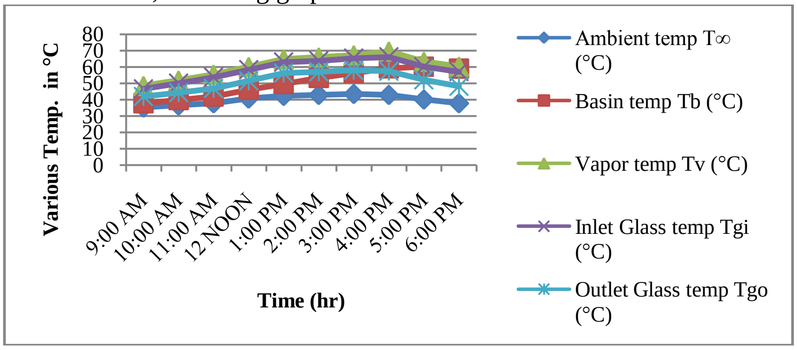

Figure 5: Graph for various temperatures vs. time on day 3 in c.

4.2 Solar Still with Evacuated tubes

Date: 17/05/2013 Time: 9.00 AM to 6.00 PM

On the basis of observation taken, following graphs is drawn:

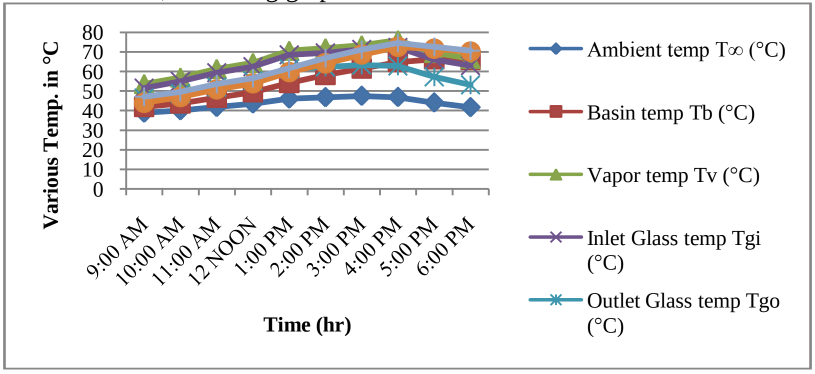

Figure 6: Graph for various temperatures vs. time on day1 in c.

Date: 18/05/2013 Time: 9.00 AM to 6.00 PM

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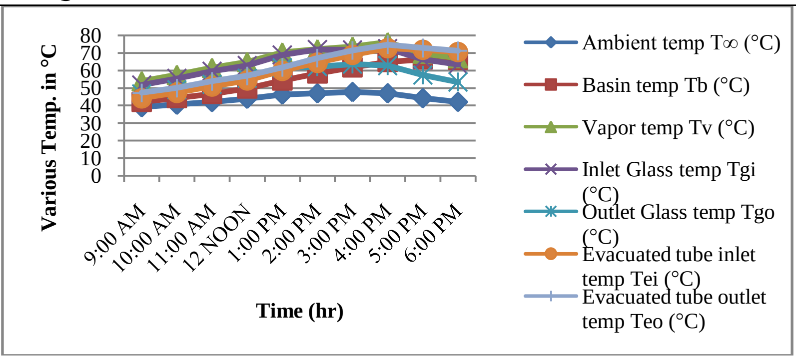

Figure 7: Graph for various temperatures vs. time on day2 in c.

Date: 19/05/2013 Time: 9.00 AM to 6.00 PM
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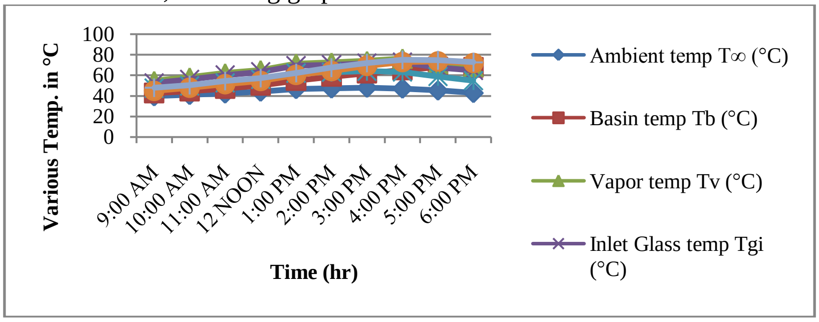

Figure 8: Graph for various temperatures vs. time on day3 in c.

On the basis of observation taken, following graphs is drawn:

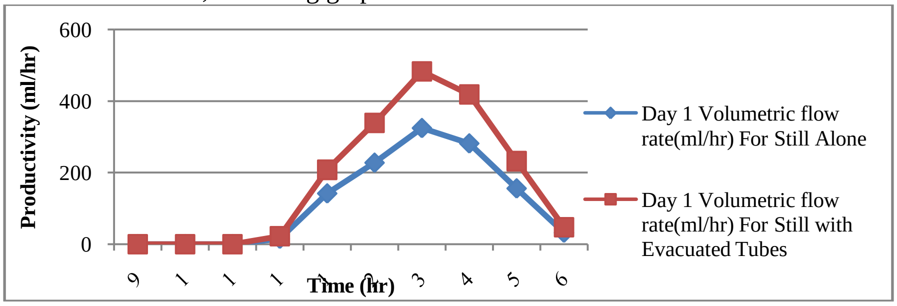

Figure 9: Graph for productivity vs. time on day 1

On the basis of observation taken, following graphs is drawn:

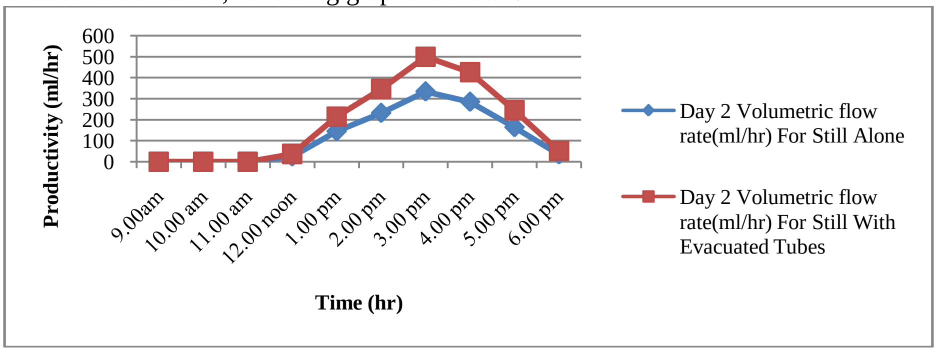

Figure 10: Graph for productivity vs. time on day 2

On the basis of observation taken, following graphs is drawn:

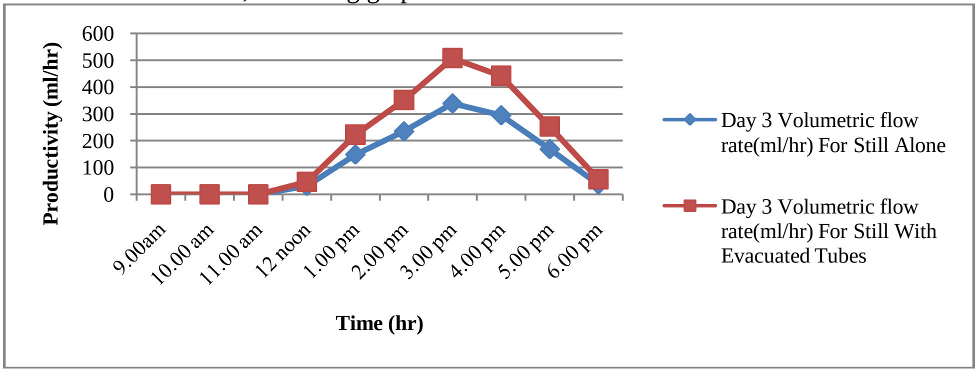

Figure 11: Graph for productivity vs. time on day 3.

The main objective of this work was to improve the performance of ordinary still. The ordinary still was coupled with evacuated tube and tested with outdoor condition.

Experimentation was conducted on solar still with and without evacuated tubes.The following results were obtained.

For day 1 the volumetric flow rate of solar still with evacuated tubes was 48.7 % more than solar still alone. For day 2 the volumetric flow rate of solar still with evacuated tubes was 49.5 % more than solar still alone. For day 3 the volumetric flow rate of solar still with evacuated tubes was 50.2 % more than solar still alone.

In order to increase the productivity of single basin solar still evacuated tubes were directly coupled with the still. Evacuated tubes produced maximum output when compared to other experimental techniques. The performance affecting factors of solar still were studied by recording various parameters.

V. CONCLUSIONS

The various conclusions emerging out of this study are presented below.

1) Solar distillation present a promising alternative for saline water desalination that can partially supported humidity need for fresh water with free energy, simple technology and a clean environment. Producing fresh water by solar distillation can support community living activities, particularly in rural area

2) The orientation of the glass cover depends on the latitude of the place for northern latitude south facing and southern latitude north facing stills are used.

3) The inclination of cover is optimized for rate of condensation of water on the bottom surface of the cover and to collect it without the mass accumulated drops fall back into the basin. Hence it depends on the intensity of solar radiation, rate of evaporation and condensation. Materials used for cover and it's wetting property

4) The glass is most suitable materials for cover, it has the properties such as higher transmittance, wetting property with water have less transmittance loss for solar radiation during condensation, higher thermal conductivity.

5) In this work, the solar still coupled with evacuated tubes was constructed and tested in outdoor conditions.

6) Various experiments were carried out to enhance the productivity of the solar still.

7) The performance of an ordinary still was compared with the still coupled with evacuated tubes. It was found that the daily productivity has increased to 50.2 % by introducing the evacuated tubes.

8) Due to simplicity, low cost, less energy losses and high performance, the evacuated tube were proved to be another option for high temperature distillation when compared to the flat plate collectors.

9) The evacuated tubes were also efficient in the winter season.

10) Annual yield will be more than other active methods like coupling of flat plate collector, parabolic collector etc.

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