A Performance Analysis and Comparative Study of Single Basin Double Slope Passive Solar Still using Different Materials as Storage Medium

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Abstract— Most of the desalination system works on the electricity, which indirectly consumes high grade or non-conventional energies like coal, gases, fossil fuel and oil. On the extraction of heat energy from these fuels, carbon footprint occurs, which causes induction of greenhouse gases in the atmosphere, ozone layer depletion as well as hazards of health on mankind. It is also responsible to enhance the global warming which is burning topic and major threat to the sustainability of life. The opportunity of harnessing solar energy is most efficient and ecofriendly technique towards the green technology. The solar desalination is one time investment and low temperature process for lifetime pure water production up to 15 to 20 years. In this thesis, various methods of desalination such as direct and indirect have been discussed. On large scale desalination system for production of pure water, indirect methods are adopted. Whereas for small scale and medium scale desalination systems, direct methods are more suitable. The performance and productivity of solar still can be improved by using various locally available materials and by the simple modifications in the design of still. These low cost double slope single basin solar stills can be economically and easily fabricated for meeting daily needs of fresh water. These solar stills are sufficient for the communities live on the island and small households. It can also be used to convert brackish water into pure water for the population residing near river banks. In this project performance analysis of solar still with different storage substances were carried out at different depth of water. The comparison of productivity and thermal efficiency for still having water with jute, aluminum chips, granite, a conventional still and a non-conventional still have done and different graphs were plotted. The analysis and compilation of results have done and concluded that the maximum efficiency and productivity is obtained from jute in comparison to aluminum pieces, granite, saline water in conventional still and saline water in non-conventional still, i.e. 15.69% and 880 respectively. It can be said that "the jute is best storage material among all of them in turn to get maximum efficiency and productivity of single basin double slope passive solar still".

Key words: Solar Still, Aluminum Pieces, Jute, Granite, Storage Medium

I. Introduction

Energy is defined as "the ability to do work". It plays a vital role in the development of any country. As we know, living organism needs energy for their work. The degree of development of the country is measured by the scale of utilizing of energy for human survival. Humans are continuingly doing research to find the alternatives of energy. So, they can increase their comfort level. As a country grows and develops the gross domestic product (GDP) increases and almost proportional to the energy consumption. Human development index (HDI) of India is very low, as compared to other countries. But, it is assumed that it will increase in upcoming years. Energy intensity is defined by the ratio of energy consumption to GDP. This factor is higher for developing countries in comparison to developed countries. "India's energy intensity is 3.7 times of Japan and 1.55 times of USA".

To full fill the demand of energy, people use various sources which can provide the energy effectively and efficiently. But, with increase in population, energy requirement also increases. If we are exploiting the energy resources very soon they gets fully exhausted from the nature, so we need to find the alternatives of non-renewable energy which are also called Renewable source of energy.

Various high and medium technologies have been developed for water purification such as reverse osmosis (RO), multi-stage flash distillation (MSF), multi-effect distillation (MED), vacuum distillation, and vapor compression. But solar distillation is a simple technology which utilizes solar energy (an ample source of non-conventional or renewable energy). It is an economical, effective and environment friendly technology. The most simple and least expensive solar stills are passive solar stills.

Zakaria Haddad, Abla Chaker, Ahmed Rahmani [1] proposed A schematic description of the solar still. It consists mainly of a basin type, single slope solar still in which the VRW is integrated against the rear side of the still. The basin area of the still is 0.36 m2 (0.9 m × 0.4 m) fabricated using 1.0 mm thickness galvanized iron and painted with black spray paint to increase solar ray's absorption. The basin is placed inside a rectangular wooden box of 4 cm thickness and the bottom space between them is filled by 8 cm of glass wool to reduce bottom thermal losses.

Kamel Rabhi, Rached Nciri et al. [2] In this work a modified single-basin single-slope solar still is developed. A pin fins absorber and a condenser are integrated in the modified solar still. A detailed still design and still functioning description is carried out. An experimental comparative performance study is conducted between the conventional still, the still with condenser, the still with pin fins absorber and the still with both condenser and pin fins absorber. A gain of water production in the order of 32.18% is recorded for the still with condenser (using air flow and external condenser) compared to the conventional still. For the case of the still with simple pin fins absorber, the water production gain is only 14.53% compared to the conventional still.

Hitesh Panchal, Indra Mohan [3] The still solar technology has been serving the humanity for a very extended period of time. There have been many modifications since decades to improve the productivity of the same. One of the significant improvements which have been done is the use of fins at the base of the still. Integration of fins in the basin plate of the solar still increases the basin exposure area and thus leads to the higher heat transfer rate and higher evaporation rate. Hence, distillate output of conventional solar still is enhanced. In a series of comparative experiments done before, V. Velumurugan et al. observed that when the wick was used in a single basin solar still, the productivity increased up to 29.6% as compared to the use of sponges which increased the productivity by 15.3%. In the same still, when fins were used, the increment observed was 45.5%.

Basharat Jamil, Naiem Akhtar [4] The present work was carried out at Heat Transfer and Solar Energy Laboratory, Mechanical Engineering Department, Aligarh Muslim University, Aligarh, India (27.89°N, 78.08°E). The actual view of experimental setup i.e. conventional single slope basin type solar still. Galvanized Iron sheet of gauge 22 was used for the construction of solar still. Basin area was kept 1m² with an aspect ratio of 2:1. This is in accordance to the fact that an absorber aspect ratio of 2:1 gives optimal collection of solar energy in the solar still.

Ravishankar Sathyamurthy, P.K.Nagarajan, B.Madhu [5] It is clearly seen that the effect of integrating solar still improves the yield of fresh water from both solar still. A constant gravity feed method was used to cool the cover of tubular solar still and the extracted heat by the water is sent to the basin of pyramidal solar still. The heat extracted from the solar still (Tubular) was utilized for evaporating water from the single basin pyramidal solar still. Experimental results also showed that the flow rate of water for cooling the external cover of the tubular solar still is limited from 10 to 100 ml/min as the extraction of heat from the cover was minimum at increased mass flow rate.

Nisrin Abdelal, Yazan Taamneh [6] In this research, four pyramid-shaped solar still basins were designed and fabricated with the same shape, dimensions and materials but with different absorber plate base materials. The first basin's absorber plate was made of galvanized steel painted in black, the second basin's plate was made of CF/2.5 wt% CNT modified epoxy composite, the third plate was made of CF/5 wt% CNT modified epoxy composite, and the fourth plate was made of CF/2.5 wt% GNP modified epoxy composite. The experiments were carried out in 4 days in September under the outdoors climatic conditions of Irbid city, in Jordan. Brackish water was used in all experiments. Each solar still unit consisted of several parts: a galvanized steel container painted in black and filled with 5 cm thick foam for insulation purposes. A 70 × 70 cm2 galvanized steel plate painted in black was used as the base for the first solar still, whereas the base was composite plate attached to the galvanized steel plate for the remaining three distillers.

M.H. Sellami, T.Belkins, M.L.Aliouar [7] Four identical solar still prototypes were constructed and assembled, one of which was used as a witness unit (i.e. a reference unit without a sponge) while the parameters under investigation were applied to the other three units. The four units operate under recorded meteorological conditions, namely ambient temperature, solar irradiance and wind velocity shows a cross section schematic of the single-slope basin solar still used in these experiments. The solar still support was made of 40 mm thick wood. Its basin (absorber) is a tray (480 × 370 × 30 mm) made of 3 mm thick galvanized metal. The absorbers of both stills were blackened on the surface to ensure maximum absorption of solar irradiance for effective heating of the brackish water. The base of each assembly was further glued with a 30 mm thick polystyrene insulation. The 3 mm thick removable glass cover of the stills was placed such that it makes an angle of 30° with the horizontal which is recommended for the Ouargla region. The glass cover was sealed tightly with silicone sealant to prevent any vapor leakage. Lovedeep Sahota, G.N.Tiwari [8] Body of the still is fabricated with fiber reinforce plastic (FRP) with a top cover of 4 mm thick transparent glass at angle of 30°. The still is kept in east-west direction to retrieve maximum solar radiation. Area of the inner surface of rectangular base of the still is 2×1 m² and it is blackened to absorb maximum solar radiation.

Fraction of solar radiation has been reflected from outer surface of transparent condensing cover and water surface, maximum solar radiation penetrates into the still and absorbed in fluid and blackened inner surface.

P. Vishwanath Kumar, Anil Kumar, OmPrakash, Ajay Kumar Kaviti [9] In the there study, a detailed evaluation of all the solar stills both single and multi-effect type with passive and active configuration is obtainable. The present reading aims at telling the design stipulation and stress the qualities and demerits of a variety of solar stills upon which study has been done till recent past. Also a discussion on prospect scope is given with some recommendations in the field of solar stills enhancement to economically produce sustainable drinkable water.

Ali. F.Muftah, M.A. Alghoul n, Ahmad Fudholi, M.M. Abdul- Majeed, K. Sopian [10]This exertion intends to study the many studies on factors that influence the presentation of solar stills. The consequences showed that the sanitization yield of solar stills are appreciably prejudiced by ambient conditions (e.g. ambient temperature, insolation, wind speed, dust and cloud cover), operating conditions (e.g., depth of water, various dyes, salt deliberation and inlet temperature of water), and design conditions (e.g. diverse passive/active designs of solar stills, incline of the cover, equipment selection, storing supplies, reflectors, insulation, gap distance and sun tracking system). This study proved the fact that decontamination productivity of solar still is seriously prejudiced by climatic, operational, and design parameters.

II. Methodology and Experimental Set Up

The experiment is done in environment condition of BHOPAL city having 77^0 36” E 23^0 16” N in the month of June. This double slope single basin solar still includes the basin area of 1×0.5 m^2 with the two inclined faces having inclination 15^0 each. The experimental setup consists of five components:

A. Solar Still

Fig. 1: Experimental setup of non-conventional double slope solar still.

The placement of solar still is key here, the side with transparent glass section is placed facing South direction while the opaque triangular section must face north. The actual picture of experimental setup is shown in fig below:

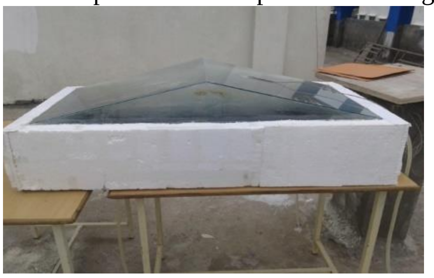

Fig. 2: Non-conventional still with granite pieces and saline water

III. Results and Discussion

Experimentation was carried out during sunny days of 13th, 14th and 15th June between 8:00 am to 8:00 pm.

The experiments were carried out at 1 cm, 2 cm and 3 cm depth of water in 13th, 14th and 15th June respectively at five different solar stills. One is conventional solar still which slope is arranged along length wise and other four stills are modified stills which slope were arranged along width wise.

First day in the case of normal glass cover, the water was collected in majoring jar through outlet valve with 1 cm water level: collecting 630 ml in conventional still, 600 ml in modified still with only saline water, 860 ml in granite, 840 ml in case of aluminum, 880 ml in case of jute.

In the second day, the condensate collected at 2 cm depth of water is 570 ml in case of conventional still, 570 ml in modified still, 820 ml in granite, 815 ml in aluminum still and 840 ml by using jute.

Last day, the experiments were carried out at 3 cm depth of water and the amount of condensate by using different material as: 505 ml through conventional still, 520 ml through modified still, 790 ml by using granite, 790 ml by using aluminum pieces and 825 ml by using jute with saline water.

In all three days, the solar intensity was also measured at time interval of an hour between 8:00 am to 8:00 pm. First day, the maximum solar intensity was 1150 W/m² at 1:00 pm. Second day, the maximum solar intensity was 1157 W/m² at 1:00 pm and the last day maximum solar intensity was measured 1248 W/m² at 1:00.

For measuring the temperature, the k type thermocouple wire with digital display unit was used and these were placed at 4 different point for measuring temperature and another one thermocouple point was arranged to measure the ambient temperature.

Where,

T_1 = Bottom surface temperature with black body
T_2 = Air temperature inside the solar still
T_3 = Inside glass surface temperature
T_4 = Outside glass surface temperature
T_5 = Atmospheric temperature

A. *Latent heat of vaporization of fluid (L)*

$$= 2.4935\times10^{6}[1-(9.4779\times10^{-4}\times(T_2)+1.3132\times10^{-7}\times(T_2^{2})-4.7974\times10^{-9}\times(T_2)^{3})] \text{ ;for } T_2 < 70^{o}C$$

B. *Efficiency (η)*

$$= (M \times L)/(A \times I)$$

Where,

M = yield in Kg/s
L = Latent heat of vaporization in J/Kg
A = Area of base of still in m^2
I = Intensity of radiation in W/m^2

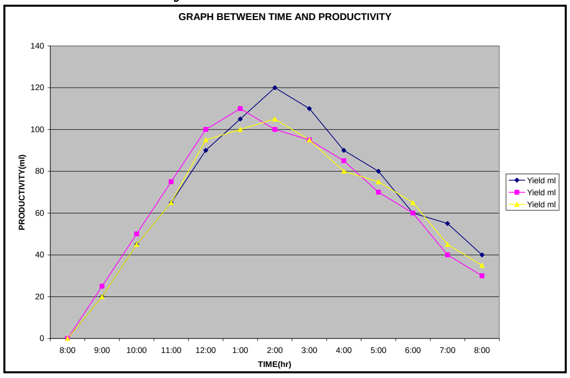

Fig. 3: Overall Productivity with respect to time in jute

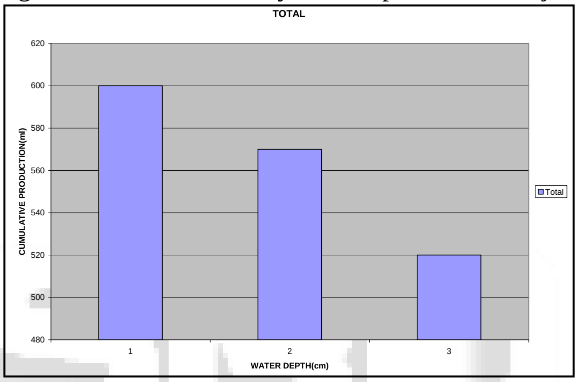

Fig. 4: Cumulative production with respect to depth of water for modified still

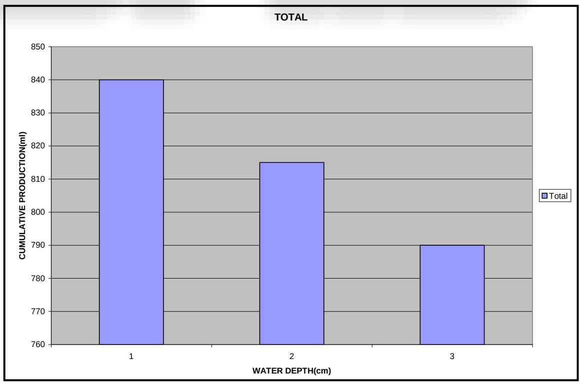

Fig. 5: Cumulative production with respect to depth of water for aluminum

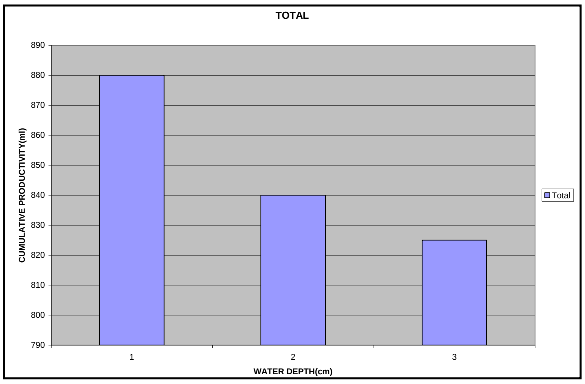

Fig. 6: Cumulative production with respect of water for jute

IV. Conclusion

In this project, 5 double slope single basin passive solar stills are used with different storage materials in three of the still and water is used in two stills i.e. a conventional still and non-conventional. The following observations have been noted during the experiment and by the analysis of results and graphs.

- The maximum yield is obtained from jute with water 880 at 1 cm depth of water, which is 2.3% more that yield obtained by using granite, 4.7% more than the yield obtained from aluminum, 39.68% more than the yield of conventional still with saline water and 46.67 % more than the yield observed from non-conventional still with saline water.
- The maximum efficiencies for each material are observed as, 10.17% by using conventional still with saline water at 1 PM and 1cm, 10.37% using non-conventional still at 2 PM and 1 cm, 15.52% using aluminum pieces at 6 PM and 3cm, 15.58% using granite at 6PM and 3 cm and 15.69% using jute at 6PM and 3 cm depth of water.
- In terms of efficiency, it is observed that the overall maximum efficiency is obtained by using jute is 15.69% which is 0.7% higher than the calculated efficiency of granite, 1.09% more than the efficiency obtained from aluminum pieces with saline water, 54.27% higher than the yield of conventional still using water and 33.9% more than the non-conventional still with saline water.
- So, it can be concluded that the jute is optimized storage material for the production of pure water by using single basin double slope passive solar still.

V. Future Scope

There is always an opportunity to more explore a one technique from one level to other level. The more exploration is required to optimize the existing technique and to make it more efficient. In this project, future opportunities to make it more authentic and optimized are as follows,

- For this project, to get the exact results of the experiment and to validate the experimental results, thermal analysis with help of computational fluid dynamics can be done.
- By taking reference of these readings obtained by using different material, the new materials can also be used and investigated the performance of still.
- In this project, only conventional design of still is used with some storage material. In future, the more comparison can be obtained by using different designs with same materials
- At present, the storage materials are used individually in each still but, for more exploration mix of two or more material can be used to investigate the efficiency and productivity and comparison could be done.

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