Study of Solar Still and Ways of Improving its Productivity

Ranbir Kalita[#1], Parimal Bakul Barua[*2], Deva Kanta Rabha[#3], Joyshree Konwar[#4], Kaushik Kalita[#5], Smriti Das[#6], Vivek Gogoi[#7]
*[#1]PhD Scholar, [*2]Professor, [#3]Assistant Professor, [#4,5,6,7]B.E. Final Year Student*
Department of Mechanical Engineering
Jorhat Engineering College, Jorhat – 785 007 (Assam), India

Abstract

Solar Energy is the most abundant source of energy among all non-exhaustible renewable energy sources. In this paper, a brief study on solar still, its history and a brief literature review is presented based on the researches of recent time.

Keywords - *Solar Energy, Renewable source of energy, Solar still, Desalination, Distillation.*

I. INTRODUCTION

Solar stills are mainly used for desalination of saline water or for purification of brackish water. It is a well known fact that drinking pure water is a must to live a healthy life. Also for irrigation and farming, using saline water is not a good choice. Though, water is the most abundant source on earth, yet 97-98 percent of this source is present as either saline water in the oceans or as icebergs in the arctic regions; and only around 3 percent is available as usable water, present in rivers and as underground water. Salt concentration in potable water should not be more than 500 ppm [6]. But this value is much higher in the naturally available saline water.

Ceramic filters can remove solid impurities present in water. But they are not able to produce germ free water. Also, ceramic filters are exhaustible.

Filtrate from ceramic filters can be made germ free by boiling it for at least 20 minutes. This requires burning of fossil fuels or wood. Hence, regular or long term use of this process is not an environment friendly option.

Distillation is an option where the raw water can be converted directly into potable water. Here, heat energy is supplied to evaporate the water, and then the vapour is condensed to obtain the potable distillate. But to supply this heat energy, again fuel has to be burnt.

Reverse osmosis filters are an alternative to produce pure drinking water, but to run these filters electrical energy is required. This poses a problem for remote areas which do not have regular access to grid electricity supply or no supply at all.

Looking into these facts, utilization of solar energy can be considered as the best option since it doesn't create any pollution; hence, environment friendly and also abundantly available. Thus, this paper discusses about how this solar energy can be utilized in a solar still to carry out the distillation process and produce potable water from saline or brackish water.

II. WORKING PRINCIPLE OF SOLAR STILL

Solar stills work on the principle of natural hydrological cycle. Fig. 1 shows the basic structure of a solar still.

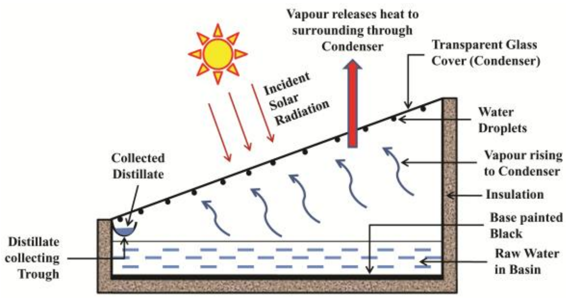

Fig. 1: Basic solar still

The incident solar radiation passes through the transparent glass cover, falls on the water surface in the basin and gets absorbed there. To improve the absorptivity of this incident radiation, the inside of the basin is painted black.

Due to absorption of solar radiation, the water gets heated up and starts to evaporate. The water in the vapour form leaves all the impurities behind in the basin and rises upward to touch the inner surface of the transparent glass cover. Since the outer surface of this glass cover is in contact with ambient air, hence it is cooler than the inside surface and exchange of heat takes place through it. The water vapour touching the glass cover releases their heat and condenses to form tiny water droplets. Here, the glass cover is acting as a condenser. As the glass cover is inclined at some angle to the horizontal, the water droplets trickles down to the lowest edge and falls on a collection trough provided at the lowest edge of the glass cover. Then through an output pipe connected to the collection trough, distillate can be collected.

The process of heat transfer in a solar still can be broadly classified into two categories [1]: Internal heat transfer and External heat transfer. The internal heat transfer is responsible for transportation of water vapour to the inner surface condensing cover. There are three modes available for this [3], viz. convection, radiation and evaporation. The external heat transfer takes place through the condensing cover and is responsible for condensation of the water vapour.

This may take place via conduction, convection and radiation [3].

Solar stills can be Active solar stills or Passive solar stills. If no external power source is applied to accelerate the heat transfer process and the fluid flow takes place solely due to the convection current, then the still would be called as a Passive still; otherwise, an Active solar still. For example, if the water is pre-heated externally and then fed into the still using an electric pump, then such stills would be called as an Active still. Here, the electric pump is acting as an external power source circulating the raw water in and out of the basin.

III. HISTORY OF SOLAR STILLS

Utility of solar energy is known to mankind since long back. Earlier designs of distillation units using solar energy were not efficient and mainly aimed at extracting the salt from the saline water. Documented use of solar stills to produce potable water can be found in the 16th century [4].

As found in the literature survey done by Ghandour and Shalabi [5], the first largest solar still was constructed in the year 1872 at Las Salinas in Northern Chile to supply drinking water to a mining community [4].

Until World War-II, solar distillation technique was given very little interest. It was only during World War-II, when researchers discovered the potential of this technique. A lot of research was done on solar stills during this period. Around 2,00,000 inflatable plastic solar stills were manufactured and kept in the life-crafts for US Navy to produce potable water from saline sea water during the time of war [4].

IV. LITERATURE REVIEW

Sethi and Dwivedi [1] tried to find out the effect of different water depths in the basin on the internal heat transfer coefficients. They used a double-slope active solar still coupled with a flat plate collector under forced circulation mode. To evaluate the values of internal heat transfer coefficients, the authors used the thermal models developed by Dunkle and Kumar & Tiwari. Based on the obtained results, they found significant dependence of convective heat transfer coefficient between water surface and inner surface of condensing cover on the water depth in the basin. The authors also concluded that the values of convective and evaporative heat transfer coefficients calculated by using Kumar & Tiwari’s model are more accurate and realistic than that obtained by using Dunkle’s model.

Yusuf and Cengiz [2] studied the effect of extended surfaces on the productivity and efficiency of a conventional still. They used black painted table-tennis balls of 40 mm diameter as the extended surfaces, placed on the water surface in the basin. Experimentations were performed under two situations: once, when the balls are stationary and second, when the balls are put into motion by using an external pump. The quantity of balls was also varied from 200-400-600 in both the situations. The obtained results when compared to an identical still without extending surfaces (reference still), it was seen that, when the balls are stationary, productivity and efficiency of the still decreases with increasing number of extended surfaces (balls). But, the case is opposite when the balls are put into motion. Productivity and efficiency of the still increases with increasing number of extended surfaces (balls). Hence, the authors concluded that using moving extended surfaces increases the efficiency of a conventional still.

Kumar and Kaviti [3] fabricated a single-basin double-slope passive solar still, and tested it for different water depths. For the same depth of water in the basin, the tests are conducted under two situations: first without adding coal in the water basin and next coal is added in the basin up to that same depth as water absorbing material. Both the tests are conducted for three consecutive sunny days. Experimental results showed a decrease in yield of distillate with increase in water depth in the basin. Also, for the same water depth, when coal is used as the water absorbing material; yield was found to increase by 20%.

Shrestha *et. al.* [4] studied the solar thermal energy utilization in a greenhouse and found that only 48-50% of the incident energy is utilized by the plants and the remaining 50% is wasted as it has to be expelled out by using artificial cooling system to maintain proper atmospheric conditions inside the greenhouse. Looking into this fact, they tried to utilize this excess thermal energy for distillation of water using a solar still. To evaluate the performance of such a greenhouse integrated solar still under the atmospheric conditions of Gangetic Bengal, the authors used the thermal model developed by Srivastava *et. al.* (2000). Runge-Kutta method was used to solve the single-order differential equations and MATLAB codes were also developed for computational purpose. After experimentation, maximum distillate was obtained during the month of April and significant high yield was observed during the other summer months.

Ghandour and Shalabi [5] designed a small-scale tilt-type solar still in which a mesh sheet was welded to the black painted galvanised cascade steel sheet acting as base. The authors investigated the effect of intensity of solar radiation, type of mesh material used, ambient temperature, wind speed, cooling water flow rate over the outer surface of condensing glass cover, and feed rate of saline water into the basin on the productivity of the still. Results of the experimentation showed that productivity increases with increase in intensity of solar radiation and it was found to be 17% higher than that of a conventional still where mesh material is not used. Corresponding optimum feed rate of saline water was 0.5 litre/second and cooling water flow rate was 0.1 litre/second with air gap being reduced to 40 mm from 200 mm. With 0.1 litre/second flow rate of cooling water, 13% higher productivity was obtained as compared to natural cooling; and with 0.5 litre/second feed rate of saline water highest daily productivity was obtained. Also 35.8% increment in daily productivity was observed (from 5.2 to 8.1 litre/m^2.day) when the air gap was reduced from 200 mm to 40 mm.

Rajesh *et. al.* [6] studied the effect of coupling a Fresnel lens to a conventional solar still on its productivity and efficiency. The Fresnel lens was used to preheat the water kept in a separate heating tank. Then this preheated water was fed to the conventional distillation unit through connecting pipes and normal distillation process was carried out. After successful experimentation, the authors observed that, the use of Fresnel lens as a solar radiation concentrating device to pre-heat the water gave a maximum yield of 30.8 litres with an efficiency of 55%.

Saikia *et. al.* [7] fabricated a solar still suitable for the Jorhat region (26.74^{o}N, 94.22^{o}E) of Assam, India. The design was based on "Eliodomestico" solar water still design, with some modifications incorporated into it to increase the output. Raw water samples collected from deep tube well and local water treatment plant (chemical treatment) were used as feed water to the distillation unit. The raw water samples and obtained distillate from the fabricated distillation unit were tested in Public Health Engineering Laboratory, Jorhat. The test results revealed that, the obtained distillate contains low contents of iron (within permissible limit), no turbidity, and zero fluoride and arsenic. Hence, the authors concluded that the obtained distillate is of potable nature and safe for drinking.

Optimum tilt angle of 41^o was used as the tests were conducted mainly during the months of winter season – February, March and April of the year 2015. This can be calculated by using the relation:

Optimum tilt angle = Latitude (+/-) 15^o.

Here, 15^o is to be added to the latitude of the place if the design is to be tested during the winter months; and subtract 15^o if the design is to be tested during the summer months.

During the experimentation, maximum distillate was obtained on 24th April, 2015; corresponding ambient temperature was 36^{o}C. Average yield for those three months was 400-410 ml/m^2 per day.

V. CONCLUSION

Among all the renewable sources of energy, solar energy is the most abundantly available source of energy. Many researchers worldwide are working to find the best possible and efficient way to harvest this energy. The thermal energy received from Sun bears a great potential for being utilized in water purification through the process of distillation. But the main drawback of using solar energy is that it is not continuous and intermittent in nature. Also, during the night time or during rainy or cloudy days, harnessing the Sun's thermal energy becomes impossible or difficult. Hence, complete reliance on solar energy for water purification may not be a good idea. But it should be used as an additional alternative to reduce pollution and fossil fuel depletion.

As compared to the other states of India, like Gujarat or Rajasthan, intensity of incident solar radiation is not that much strong in Assam. Probably because of this reason, very less work has been done under the climatic conditions of Assam or North-Eastern states to utilize the thermal energy received from the Sun. This provides a scope for future research works to be carried out regarding performance evaluation of solar thermal energy utilizing devices and their improvements to suit the climatic conditions of Assam and other North-Eastern states.

ACKNOWLEDGMENT

We are thankful to the TEQIP-III cell of Jorhat Engineering College, Jorhat – 785 007 (Assam), India for the funding and kind co-operation received time-to-time.

REFERENCES

[1] K. Sethi and V. K. Dwivedi, "Evaluation of internal heat transfer coefficient of Double Slope Active Solar Still under Forced Circulation Mode", International Journal of Engineering Research & Technology (IJERT), Volume 1, Issue 8, pp. 1-5, October 2012, ISSN: 2278-0181.

[2] Yusuf Bilgiç and Cengiz Yıldız, "The Effect of Extended Surfaces on the Heat and Mass Transfer in the Solar Distillation Systems", International Journal of Engineering Trends and Technology (IJETT), Volume 22, Number 3, pp. 129-137, April 2015, ISSN: 2231-5381.

[3] Lakhan Kumar and Dr. Ajay Kumar Kaviti, "An Experimental Study on Single Basin Double Slope Passive Solar Still With Different Water Depths", International Research Journal of Engineering & Applied Sciences (IRJEAS), Volume 4, Issue 1, pp. 1-6, January-March 2016, ISSN: 2322-0821 (O), ISSN: 2394-9910(P).

[4] Shristhi Shrestha, Sarad Shrestha and Pradip Bawari, "Performance Evaluation of a Solar Still Integrated with a Greenhouse", International Journal of Engineering Trends and Technology (IJETT), Volume 33, Number 3, pp. 151-158, March 2016, ISSN: 2231-5381.

[5] Atef Ghandour and Khaled Shalabi, "Improving Productivity of Solar Energy Distillation Still For Sea Water", International Journal of Engineering Research & Technology (IJERT), Volume 5, Issue 09, pp. 498-502, September 2016, ISSN: 2278-0181.

[6] Rajesh V R, Harikrishnan K, Chaithanya K K and Subi Salim, "Performance Evaluation of a Solar Desalination System Integrated with a Fresnel Lens Concentrator", International Journal of Renewable Energy Research, Volume 6, Number 1, pp. 250-253, 2016.

[7] Arunabh Saikia, Nirman Jyoti Bhuyan, Tushar Pratim Sarma, Md. Piyar Uddin, Dhrupad Sarma and Dr. Parimal Bakul Barua, "Design, Fabrication and Performance Evaluation of Solar Water Still", International Journal of Engineering Research (IJERT), Volume 7, Issue 9, pp. 152-157, September 2018, ISSN: 2278-0181.

[8] A.J.Sangster, "Engineering a Sustainable and Economically Active Future without Fossil Fuels", International Journal of Engineering Trends and Technology (IJETT) , Volume 17, Number 8, pp. 373-380, November 2014, ISSN: 2231-5381.