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IMPROVEMENT IN WORKING OF SINGLE SLOPE SOLAR STILL USING SPECIAL MODIFICATIONS

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ABSTRACT

The availability of drinking water is reducing day by day, whereas the requirement of drinking water is increasing rapidly. Although more than two thirds of earth has been covered with water, only about 0.014% of global water can be used directly for human and industrial purpose. So, the accessibility to drinking water is the one of the main problems of human being in arid remote area all over the world. Solar stills can solve part of this problem in the areas where solar energy is available plenty. Basin type solar stills are simple in design, cheap, have low technologies and it is an important advantage, pollution free. Hence, no high maintenance expenses are required although solar stills have low productivity; they are being a sustainable water production method. Solar still continue to attract wide research attention that is targeted to improve their yield. Many experimental and theoretical studies are being carried out to improve the performance of solar stills.

Key words: Water, solar, pollution

INTRODUCTION

As the population is increasing, fresh water resources are under heavy pressure. A very small fraction, about 3 percent of the available water resources is available as fresh water. Drinking water shortage is expected to become one of the biggest problems for humanity. Many developing countries like India have given topmost priority to fresh water supply in their rural development plans. The timely availability of drinking water in right quantity and quality at the right place is severe in many under-developed and developing countries. At many places the water available is too saline, or, not potable due to the presence of toxic chemicals like arsenic and fluoride beyond permissible limits. The problem is very severe in many rural areas. About 28 percent out of the total 0.575 million villages in India were identified as problem villages. Many villages have scarcity of drinking water.

PRINCIPLE

In a simple solar still, solar radiation passes through the glass cover. This solar energy is almost entirely absorbed by the black cover on the basin while it is partially absorbed in the thin saline water layer. Thus, saline water and basin are heated by the solar energy. The heat is convected from the black surface into the saline water and the temperature of the saline water increase. Vaporization takes place at the interface, saline water surface and air inside of the solar still, at the interface temperature t_i. Interfacial area, saline water surface is semi permeable. A plane is called semi permeable when the mass flux of one component is zero. Such a plane is, for instance, the surface of water, which evaporates into an adjoining air steam.

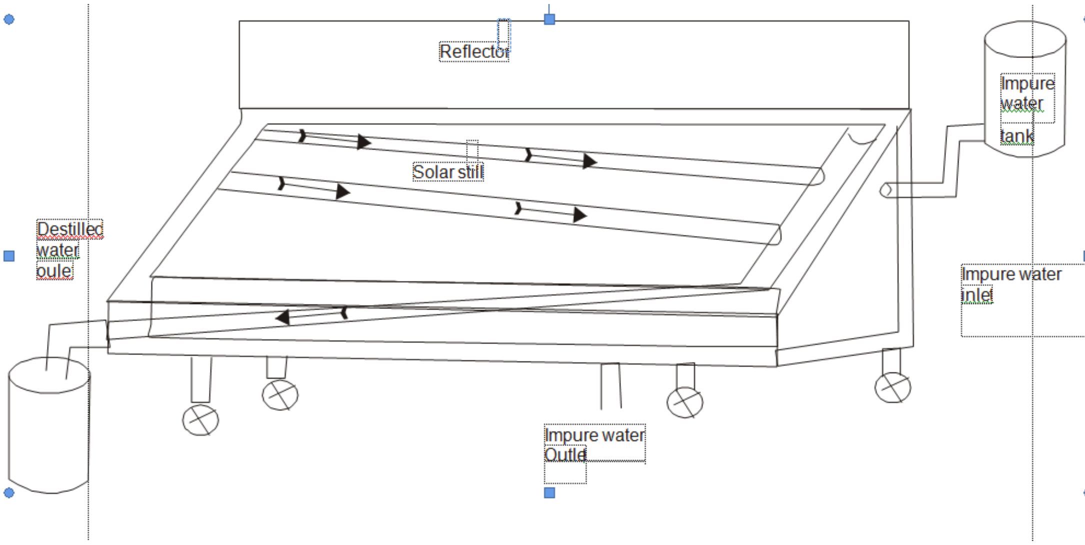

Figure 1 : Schematic view of solar still

Thus, at the interface, the saturated air at the temperature, t_i, is transported by diffusion due to the partial pressure difference and convection due to the natural convection of the humid air from the interface into the air inside of the solar still with the temperature t_r. In steady state or quasi-steady state conditions, the air inside of the solar still is also saturated at the temperature, t_r. Therefore, the humid saturated air inside of the solar still will condense at the glass cover, which has a lower temperature, t_g than the air temperature inside solar still, t_r. Heat of condensation heats the glass cover. The glass cover exchanges heat with surrounding and air inside the still by convection and radiation. The condensate flows down, collecting along the glass cover and then in a channel at the end of the glass cover on the south side of the still. Finally, it is collected in a storage bottle outside of still. The schematic view of the solar still is shown in Fig. 1. In order to calculate the daily produced condensed water and efficiency, energy balance method has been applied by making the following assumptions:

- The whole system is in a quasi-steady state condition.
- Heat loss by radiation from the circumferential area is negligible.
- At the base of the still, temperatures of the walls equal to the water temperature, and the water temperature is the average of the interface temperature, t_i and the bottom temperature, t_b
- The wind speed is assumed to be constant during the experiment.

The performance of a solar still is generally expressed as the quantity of water evaporated by unit area of the basin in one day, i.e. cubic meters or liters of water per square meter of the basin area per day. This performance of solar still can be predicted by deploying the energy and mass balance equations on the various components of the still. The whole system is in a quasi-steady state condition and the temperatures are assumed not to change in one hour interval of time. The energy balance equations for the whole still glass cover, saline water interface and black plate at the bottom has also been done.

METHODOLOGY

Solar distillation is one of the available methods for water distillation and sunlight is one of several forms of heat energy that can be used to power that process. The idea behind a solar still is very simple: saline water inside a black painted basin enclosed in a completely air tight area formed by a transparent cover is heated up and evaporated due to incident solar irradiance that passes though the transparent cover. Consequently water vapour is directed upward and condenses in pure water as it comes in contact with the cooler inside surface of the cover. The energy that the water absorbs contributes to the temperature rise of the water, which leads to evaporation. Evaporation is a process that occurs when the water molecules on the surface of the water obtain enough kinetic energy to change from the liquid to vapour state. The evaporated molecules add to the water vapour between the

glass and the water and create a large temperature difference. This difference in temperature affects the temperature of the water vapour that is inside the still between the glass and the water, which creates natural convection.
A higher temperature difference encourages more convection. The warm water vapour will tend to rise towards the cooler glass cover. When the water vapour comes in contact with the glass, it will condense because the water molecules will lose the kinetic energy needed to be in the vapour state. Since the glass is angled, gravity will cause the condensed water to flow down towards the collection trough.

Despite the advantage of solar stills, their most important drawback is low water productivity or performance in comparison with other thermal desalination methods and to high land requirement. This happens since productivity rate of solar stills depends on the available solar radiation. For this, research activities nowadays move in the direction towards increasing performance and output of solar stills by using several techniques. These are all targeted on the concept of increasing the difference between saline water temperature and glass cover temperature. The view of the solar still and its technical specifications can be seen in Fig. 1 and Table 1 respectively.

Table: 1 Technical Specifications Of Single Slope Taper Solar Still

Length	6ft
Width	3ft
Cover inclination	15 °
Glass cover area	1.65m^2
Absorber plate area	1.59 m^2
Glass Thickness	5mm
Water depth	2cm

Figure: 1 View of single slope solar stil

The general equation to describe heat transfer is an energy balance, which basically says that the summation of the heat input must equal the summation of the heat output. This is based on the law of the conservation of energy which says that heat can neither be created nor be destroyed. This energy balance can be written for the entire still or on a smaller scale for the heat transfer of the glass cover or the water in the basin. In order to be able to calculate the daily produced distilled water from solar still, we apply the energy balance method:

For calculation of Flux I_T on tilted surface at any instant

$$I_T = I_b r_b + I_d r_d + I_g r_r \quad (1.1)$$

Where

$$r_b = \frac{\sin\delta.\sin(\phi-\beta)+\cos\delta.\cos\omega.\cos(\phi-\beta)}{\sin\phi.\sin\delta+\cos\phi.\cos\delta.\cos\omega} \quad (1.2)$$

For the tilted surface facing due south ($\gamma = 0$)

$$r_d = \frac{1+\cos\beta}{2} \quad (1.3)$$

And

$$r_r = \frac{\rho(1-\cos\beta)}{2} \quad (1.4)$$

δ In degrees is given by the following relation

$$\delta = 23.45\sin\left[\frac{360(284+n')}{365}\right] \quad (1.5)$$

For calculation of I_g

Taking Isc = 1.367 kW/m^2

$$H_o = \frac{24\times I_{sc}\times 3600}{\Pi}\left[1+0.033\cos\frac{360n'}{365}\right]\left(\omega_s\sin\phi.\sin\delta+\cos\phi.\cos\delta.\sin\omega_s\right) \quad (1.6)$$

[in kJ/m^2-day]

$$\therefore \quad \frac{\overline{H_g}}{\overline{H_o}} = \left[a+b\left(\frac{S}{S_{max}}\right)\right] \quad (1.7)$$

$$S_{max} = \frac{2}{15}\omega_s \quad (1.8)$$

$$\omega_s = \cos^{-1}\{\tan(\phi-\beta).\tan\delta\} \quad (1.9)$$

ω_s = Sunrise hour angle

Constants a and b in equation are taken from weather data given by Modi and Sukhatme (1979). We have assumed that the values of a = 0.25 and b = 0.57 for New Delhi are valid for Moradabad.

$$\frac{\overline{H_d}}{\overline{H_g}} = 1.411-1.696\left[\frac{\overline{H_g}}{\overline{H_o}}\right] \quad (1.10)$$

The hourly extraterrestrial radiation on a horizontal surface (I_o) is obtained by calculating the instantaneous value at the mid point of time intervals and multiplying by 3600 s i.e

$$I_o = I_{sc}\times 3600\left[1+0.033\cos\frac{360n'}{365}\right]\left(\sin\phi.\sin\delta+\cos\phi.\cos\delta.\cos\omega\right) \text{ [kJ/m}^2\text{-h]} \quad (1.11)$$

The relationship for diurnal variation of the monthly average hourly global radiation at a location is given by

$$\frac{\overline{I_g}}{\overline{H_g}} = \frac{\overline{I_o}}{\overline{H_o}}(a_1+b_1\cos\omega) \quad (1.12)$$

Where

$$\{a_1 = 0.409 + 0.5016\sin(\omega_s - 60^\circ)\}$$
$$\{b_1 = .6609 - .4767\sin(\omega_s - 60^\circ)\} \quad (1.13)$$

For estimating the monthly average hourly diffuse radiation

$$\frac{\overline{I_d}}{\overline{\overline{H_d}}} = \frac{\overline{I_o}}{\overline{\overline{H_o}}} \quad (1.14)$$

$$\therefore \quad I_b = I_g - I_d \quad (1.15)$$

The solar still as shown in Fig. 1 is built with galvanized iron sheet. The bottom and sides of the box are well insulated by thermocol insulation material 1 cm thick. The thickness of the glass cover is 5 mm. A G.I. channel is placed under the lower side of the glass cover to collect the condensed water. The channel is ended with a small plastic pipe in order to drain the fresh water into an external vessel. The glass is mounted at an angle of 15 degree in order to ensure that the condensate will run down the glass in the condensate-collecting channel. The absorbing plate is also made of G.I in the dimensions of 6ft×3ft. The absorbing plate of the solar still has 1.65 m^2 meter square area and it is painted with black paint. Three holes are also drilled to the solar still, one of which is for saline water inlet, the second one for condensed water outlet and the third one for drainage. J type (Iron - constantan) thermocouples have been fitted at different places of the still before fixing the glass cover. They are used to record the temperatures such as outside glass cover for, inside moist air temperature, ambient temperature, bottom temperature and saline water interface.

CONCLUSION

It is evident that with different modifications incorporated in the Solar still there is continuous enhancement in the solar still distillate output and the instantaneous efficiency. It is found to be minimum for the still without insulation and maximum for solar still with insulation having black dye and fan. Temperature variations show that maximum temperature is from 12 noon- 1pm and then decreases continuously.

REFERENCES

1. A.A.Al-Karaghouli and W.E.Alnaser, Performance of single & double solar stills, J. Appli. Energy, 78 (2016) 347-354
2. Abdel-Rehim ZS, Lasheen A. Impoving the performance of the solar desalination systems. Renew Energy 2005; 30:1955-71.
3. Ayav Ilker Pinar, Atagunduz Gurbuz, (2014). Theoretical and experimental investigations on solar distillation of IZTECH campus Area Sea water, Desalination, 208, p.169-180.
4. A. Hanson,W. Zachritz,K. Stevns, L. Mimbela, R. Polka and L.Cisneros, Distillate water quality of a single –basin solar still: Laboratory and field studies, Sol. Energy,76 (2018) 635-645.
5. AL-Hayek and O.O Badran, The effect of using different designs of solar stills on water distillation, Desalination, 150 (2016) 230-250.
6. B.A Akash,M.S.Mohsen,O .Osta and Y. Elayan, Experimental evolution of a single-basin solar still using different absorbing materials, Renewable Energy,14 (1-4) (2005) 307-310..
7. Colin N, Margaret N, Helen D, Jennifer S.Fluoride in UK rivers. Sci Total Environ 2016; 314-316; 209-31.
8. Cooper PI. The maximum efficiency of single-effect solar stills. Sol Energy 2014; 15:205-17.
9. Farid M, Hamad F. Performance of a single-basin solar still. Renew Energy 2016; 3:75-83.
10. Gleick,P.H (1996), BasicWater Requirment for Human Activities: Meeting Basic Needs, International Water , Vol. 21,No. 2, pp.83-91.
11. Howe Everette D.(2016),Marcel Dekker, Inc; ISBN: 0-8247-6200-2, Fundamentals in Water Deasalination.
12. Y. Nakatake, Theoretical analysis of a basin type solar still with internal and external reflectors, Desalination, 186 (2006) 280-299.
13. J.A. Duffie and W.A Beckman. Solar engineering of thermal Processes,
14. 2nd ed. New York, Wiley, 191.
15. K.Voropoulos, E. Mathioulakis and V. Belessiotis, Analytical simulation of energy behavior of solar stills and experimental validation, Desalination, 153 (2017) 87-94.