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RESEARCH ARTICLE

EFFECT OF WIND VELOCITY ON ACTIVE AND PASSIVE SOLAR STILL

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ABSTRACT

The effect of wind velocity on the daily productivity of few active and passive solar stills is studied by computer modeling. Mathematical calculations have been carried out on extreme summer and winter days in New Delhi in order to correlate productivity with velocity for different masses of basin water for the passive stills and various thicknesses or mass flow rates of the flowing brine for the active stills. It is observed that for the active and multi-effect passive stills, productivity increases with the increase of velocity up to a typical velocity beyond which increase in productivity becomes insignificant. However, in all the investigated single effect passive stills, there is a critical depth of basin water beyond which productivity increases as velocity increases until typical velocity. For basin water masses less than the critical mass, productivity is found to decrease with increasing velocity until typical velocity. After typical velocity, the change in productivity is not important in a similar way to that obtained for the active and multi-effect passive stills. The critical depth of basin water for the observed single effect passive stills is found to be 4.5 cm. Moreover, the typical velocity is independent on the still shape and the operation mode (active or passive) but it shows some seasonal dependence. For the investigated stills, typical velocity is found to be 1.5 and 4.5 m/s on extreme winter and summer days, respectively.

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INTRODUCTION

The major problem for the whole world is the availability of pure, clean and healthy water especially in rural areas. Desalination systems with the help of solar energy have been used in many countries to produce fresh water. The working of solar distillation units has been classified into active and passive modes of operation. It is reported that the overall thermal efficiency of a passive distiller is higher than that an active distiller due to the lower operating temperature range (Tiwari, 1992). Several researchers have observed the effects of climatic, and design parameters on the performance of single, double & multi-effect active and passive solar stills (Kumar and Tiwari, 1999; Jubran *et al.*, 2000; Suneja and Tiwari, 1999; Yeh *et al.*, 1999; Sanjay and Tiwari, 1996; Mink *et al.*, 1998). It has been summarized that the productivity of the solar stills increases with the increase of solar radiation and ambient temperature (Garg and Mann, 1976; Elbling *et al.*, 1971). But, it should be pointed out that there are contradictory results about the effect of wind velocity on solar still productivity.

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Garg and Mann (Al-Hinai *et al.*, 2002), Cooper (Elbling *et al.*, 1971), Soliman (Soliman, 1972) and Malik and Tran (Malik MAS and Tran, 1973) have summarized that the increase in wind velocity causes an increase in productivity; while Eibling *et al.* (1971), and Yeh and Chen (Yeh and Chen, 1985; Yeh and Chen, 1985) indicated that an increase in wind velocity causes a decrease in productivity. It has been reported by Morse and Read that the wind velocity has no significant effect on productivity (Morse and Read, 1968). It has been found that the daily productivity of few designs of single and double basin solar stills increases with the increase of wind velocity up to a typical value of velocity (El-Sebaii, 2000). The value of typical velocity is independent on the still shape and the heat capacity of saline, but it shows some season wise dependency. Empirical correlations have been proposed for the daily productivity with velocity for different masses of basin water up to 200 kg. To derive the result, which has been achieved in work for various designs of solar stills under different modes of operations and heat capacity of saline, complete studies have been carried out by computer simulation for different designs of active and passive solar stills (El-Sebaii, 2000). Mathematical calculation have been performed for extreme summer and winter days in New Delhi (Lat. 28.6139391N) with a nominal range of wind velocity from 0 to 10 m/s for different masses (passive stills) or different thicknesses and mass flow rates (active stills) of saline water. It has been found that for the active and multi-effect passive solar stills, the daily productivity increases with the increase of velocity up to the typical velocity for any depth of saline water. Though, for the single effect passive stills, there is a critical depth of saline water beyond which the productivity increases with the increase of velocity up to typical velocity and this behavior is reversed (productivity decreases as velocity increases) for saline water depths less than the critical depth. Besides, the decrease or the increase in productivity occurs up to the same value of velocity, typical velocity, beyond which the productivity becomes almost independent on velocity. The value of velocity is independent on the still configuration mode of operation and the heat capacity of saline but it shows some seasonal dependence.

Nomenclature

P_d	=	Daily Productivity (kg/m^2 day)
P_h	=	Hourly Productivity (kg/m^2 day)
τ_g	=	Transmissivity
ε	=	Emissivity
α_g	=	Absorptivity of glass
χ_g	=	Glass cover Thickness
k	=	Thermal Conductivity (w/m-k)
A_g	=	Surface Area of glass
A_p	=	Surface area of Plate
α_p	=	Absorptivity of plate
ε_w	=	Emissivity of water
c_w	=	Specific heat of water (J/kg k)
Φ	=	Glass cover tilt angle (Degree)
H	=	Heat transfer coefficient

As concluded by cooper (1969 a), the output increases by 11.5% for average wind velocities from 0 to 2.15 m/s, while the increase is only 1.5% for average wind velocities from 2.15 m/s to 8.81 m/s. thus, wind at higher velocities has a lesser influence on the distillation rate. The wind blowing over the glass cover causes faster evaporation from it resulting in a fall in the temperature; thus the yield from the solar still increases for larger water depth in the still. However, for smaller water depth the wind has no effect on the output. Even for larger water depth, wind velocity above a particular value (around 5m/s) has not much effect on the yield. However, as the wind velocity increases, the convective heat loss from the glass cover to ambient increases hence the glass cover temperature decreases which increase the water glass cover temperature difference and hence the overall yield.

The considered stills and mathematical calculations

Different designs of active and passive solar stills have been choose for the current study. The passive systems include, single slope single basin, double slope single basin with and without outer mirrors, single slope double basin and single slope triple basin solar stills. The single slope single basin still with water flowing in the basin is selected as sampling for the active solar stills. Fig. 1 shows Labeled diagrams of the stills under study. The evaporating surfaces of the stills are assumed to have an area of 1.5m^2. The glass cover of basin type solar stills make leaning angles of 10° with respect to the horizontal. The single slope single and multi-effect stills are orientated to face south while the DSSBS, DSSBSMR are oriented to face east–west in order to receive most of the incident solar radiation. Detailed description, thermal analysis and methods of analytical solutions of the energy balance equations for the single and double slope single effect stills can be found in References (Aboul-Enein and El-Sebaii, 1998; El-Sebaii, 1994). However, the double slope single effect still with double slope single basin still with mirror and without mirrors has been presented in (El-Sebaii, 2000). The design and operational parameters of the considered stills are given as follow:

Common parameters

τ_g = 0.92, ε_g= 0.86, α_g = 0.06, χ_g = 0.04 m, k_g = 0.75 (w/m-k), A_g = 1.02 m^2,A_p= 1 m^2, α_p = 0.87ε_w = 0.93, c_w = 4185 (J/kg-k) and $\Phi = 10^{\circ}$

Double Slope Single Basin Still with Mirror and Without Mirror

$\Psi = 100^{\circ}$ (In summer), $\Psi = 50^{\circ}$ (In winter), $A_m = A_g$ = 1.0154 m^2, ρ_m = 0.85 and $s = r$ = 0.508 m

Single Slope Single Basin Still with water flowing in the Basin

Single Slope Double Basin and Single Slope Triple Basin Solar Stills

m_{wu}= 25 kg, m_{wl} = 10-200 kg, $m_{w2} = m_{w3}$ = 25 kg and m_{wl} = 10-200 kg

Heat transfer inside the solar stills occurs by convection, radiation and evaporation from the water surface to the inner surface of the still cover. The heat is then transferred by conduction through the thickness of the still cover. For horizontal solar stills, the various internal heat transfer coefficients are calculated using Dunkle correlations (Dunkle, 1961). However, Dunkle correlations are not valid for vertical channels. Therefore, the internal heat transfer coefficients are calculated using the modified Spalding Õs theory (Spalding, 1963; Kiatsiriroat *et al*., 1986). Further, heat transfer from a still cover to the environment occurs by radiation to the atmosphere and by convection, due to wind, to ambient air. The correlations, which are used for calculating the internal & external heat transfer coefficients, are given in the Appendix 1. The wind heat transfer coefficient (h_w) is calculated using the following Wattmuf *et al*. correlation (Wattmuf *et al*., 1977)

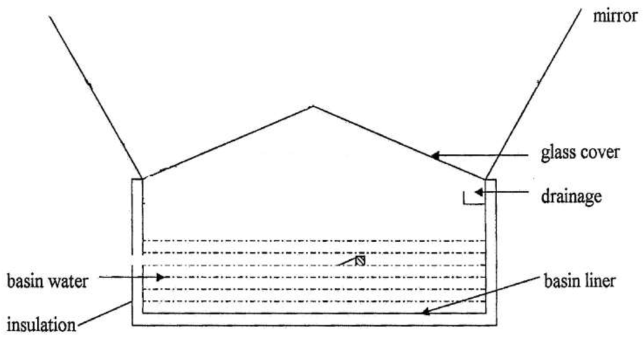
$$h_w = 2.8 + 3V \quad \text{for} \quad V \leq 5 \text{ m/s}$$

$$= 6.15V^{0.8} \text{for} \quad V>5 \text{ m/s} \qquad (1)$$

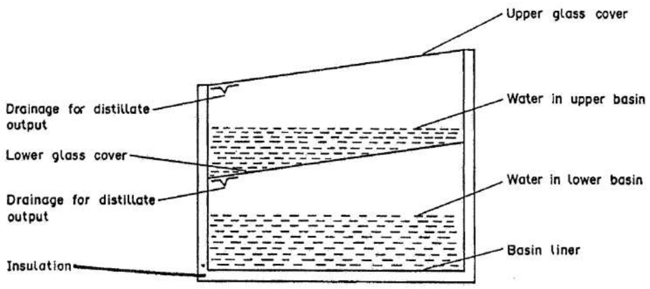
Mathematical calculations have been performed with the help of the computer programs that are developed for the solution of the energy balance equations for the chosen stills. The input parameters to these programs are climatic, design and operational parameters. Fig. 3 shows the regular variations of solar intensities and ambient temperatures on extreme summer (5 June) and winter (26 December) days, which are employed for calculating the total solar radiation, incident on the covers of the various stills and the mirrors of the Double Slope Single

Basin Still with mirror. These calculations are made using another computer program developed by the author using the Liu and Jordan correlations for total solar radiation incident on a leaned surface (Duffie and Beckman, 1991). The timely (hour) productivity of the still is calculated using the following equation:

$$P_{\mathrm{h}} = h_{\mathrm{ewg}}(T_{\mathrm{w}} - T_g) \times \frac{3600}{L} \qquad (2)$$



(a)



(b)

Figure 1. Labeled diagram of (a) Double slope single basin still with mirror (b) Single slope double basin still in (kWh/m^2/day) (http://www.synergyenviron.com/tools/solar_insolation.asp?loc=New+Delhi%2CDelhi%2CIndia)

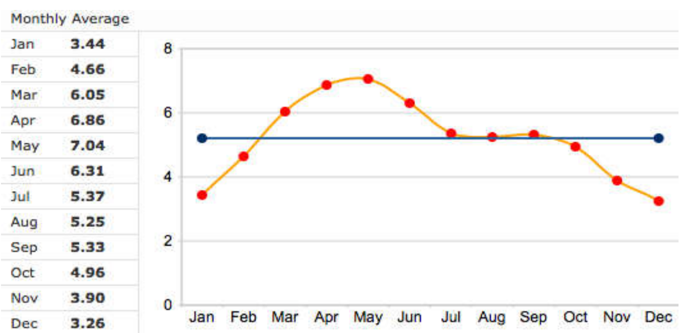


Figure 2. Monthly variations of solar radiation in New Delhi

Where (h_{ewg})is the evaporative heat transfer coefficient, (L) is the latent heat of vaporization of water and (T_w) is the water and (T_g)is glass cover temperatures. The daily productivity (P_d)is calculated as:

$P_d = \sum P_h$(3)

In am going to correlate the daily productivity with the wind velocity for different heat capacities of the saline, mathematical calculations have been carried out for different depth of basin water $m_w$from (1–25 cm) for the passive stills and different mass flow rates min the range 1×10^{-3} to 2×10^{-2} kg/s or different thicknesses of the flowing water changing from 0.6 to 6 cm for the active stills. For double and triple effect stills, calculations are made for different masses of the lower basin water keeping the mass of water in the second and third effects constant at 25 kg.

RESULTS AND DISCUSSION

Mathematical calculations are performed for the stills under study using the same atmospheric conditions of extreme summer and winter days. Here, I will present some examples of the obtained results.

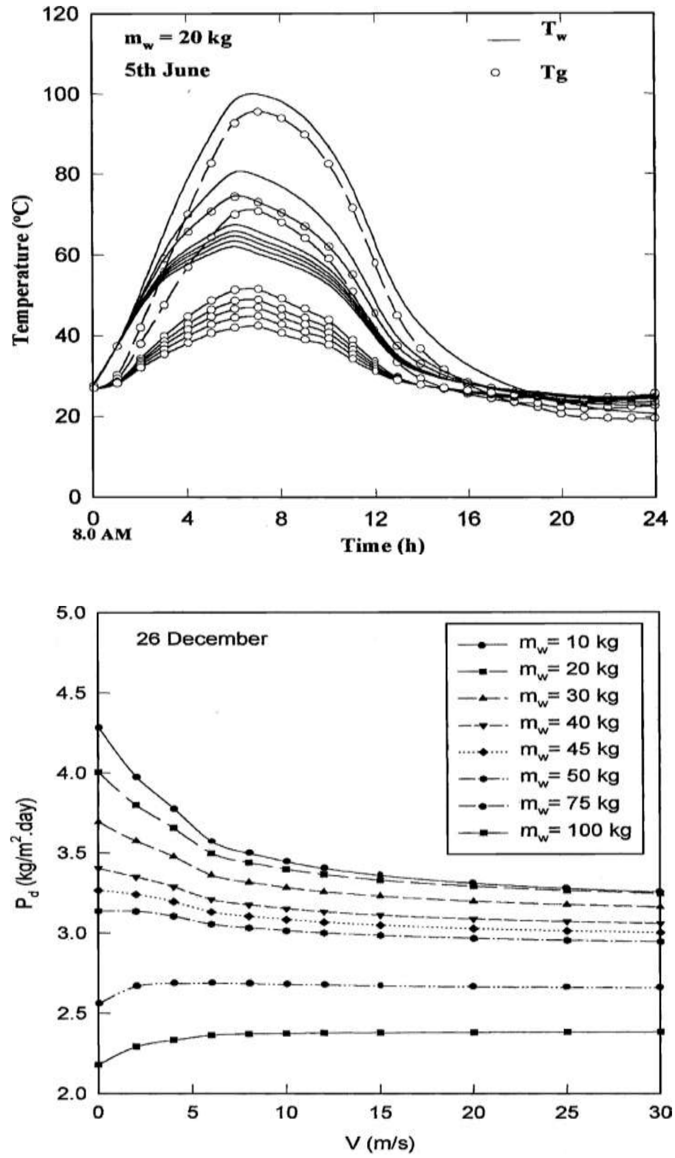


Figure 3. Variation of Temperature V/s Time & Productivity V/s Velocity

Conclusion

On the basis of the results obtained from the various active and passive solar stills, the following conclusions may be drawn: The daily productivity of the active basin type solar stills increase as wind velocity increases up to the typical velocity, possibly because their instant productivities equal zero. So, it is suitable to install such stills in wind area place.

(i) The daily productivity of the multi-effect passive solar stills are found to increase with an increase of velocity until typical velocity may be because the upper basin protects the lower ones against heat losses due to wind especially during the night.
(ii) For the passive single effect basin type stills, it is found that there is a critical depth of basin water beyond which increases as velocity increases up to typical velocity. For shallow depths less than the critical depth, productivity decreases as velocity increases until typical velocity.
(iii) The value of the critical depth for the studied single effect passive stills is found to be 4.5 cm.
(iv) After the typical velocity, the change in productivity becomes irrelevant.
(v) The value of typical velocity is independent on the still shape, mode of operation and the heat capacity of saline, but it shows some cyclic dependence. Typical velocityis found to be 4.5 & 1.5 m/son extreme summer and winter days, respectively.
(vi) The results that have been achieved in the current study may be used to explain the opposingresults, which are reported in the previous studies (9–18,31–33) about the effect of wind velocity on the daily productivity of the solar stills.

Appendix 1

Horizontal stills

The following Dunkle correlations (25) are used for calculating the total internal heat transfer coefficient (h_1)

$$h_1 = h_{rwg} + h_{cwg} + h_{ewg} \quad (1.1)$$

$$h_{rwg} = 0.9\sigma(T_w^2 + T_g^2)(T_w + T_g) \quad (1.2)$$

$$h_{ewg} = 0.884\left((T_w - T_g) + \frac{(Pw-Pg)Tw}{2016-Pw}\right)^{1/3} \quad (1.3)$$

$$h_{ewg} = 9.15 \times 10^{-7}\left(\frac{hcwg(Pw-Pg)L}{Tw-Tg}\right) \quad (1.4)$$

Where h_{rwg}, $h_{cwg}$and $h_{ewg}$are the radiative, convective and evaporative heat transfer coefficients between the water surface and the inner surface of the glass cover. *Pw*and Pgare the partial pressures of saturated vapor at the water and glass cover temperatures, respectively. *L* is the latent heat of vaporization of water. The conductive heat transfer coefficient *Ug* through the thickness of the still cover:

$$Ug = kg/xg \quad (1.5)$$

The total external heat transfer coefficient $h_2$is given by

$$h_2 = h_{rgs} + h_w \quad (1.6)$$

The radiative heat transfer coefficient $h_{rgs}$from the still cover to the sky is given by

$$h_{rgs} = \varepsilon_g\sigma(T_g^2 + T_s^2)(T_g + T_s) \quad (1.7)$$

Where $T_w$is the sky temperature. h_w is calculated using Eq. (1)

Hence, the overall heat transfer coefficient$U_t$through the top of the still can be calculated using the following formula;

$$U_t^{-1} = (h_1)^{-1} + (x_g / k_g) + (h_2^{-1}) \quad (1.8)$$

The external and overall heat transfer coefficients for the west channel can be calculated using Eq. (1.6) - (1.8).

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REFERENCES

Aboul-Enein, S. and El-Sebaii, A.A. 1998. El-Bialy E. Investigation of a single basin solar still with deep basins. *Renewable Energy,* 14:299–305.

Al-Hinai, H., Al-Nassri, M.S. and Jubran, B.A. 2002. Effect of climatic, design and operational parameters on the yield of a simple solar still. *Energy Conversion Management,* 43:1639–50.

Cooper, P.I. 1969. Digital simulation of transient solar still performance. *Solar Energy,* 12:313–31.

Domanski, R. and El-Sebaii, A.A. 1993. Effect of heat capacity of water basin on double-basin solar still performance. Arch Thermodynamic, 14:131–46.

Duffie, J.A. and Beckman, W.A. 1991. Solar engineering of thermal processes. 2nd ed. New York: Wiley.

Dunkle, R.V. 1961. International development in heat transfer. In: ASME Proceedings of International Heat Transfer, Part V, *University of Colorado.,* p. 895.

Elbling, J.A., Talbert, S.G., Lof, G.O.G. 1971. Solar stills for community used digest of technology. *Solar Energy,* 13: 263–76.

El-Sebaii, A.A. 1994. Investigation of thermal performance and heat transfer mechanism of selected solar–thermal conversion systems. PhD thesis, Warsaw University of Technology, Warsaw, Poland.

El-Sebaii, A.A. 1998. Parametric study of a vertical solar still. *Energy Conversion Management,* 39:1303–15.

El-Sebaii, A.A. 2000. Effect of wind speed on some designs of solar stills. *Energy Conversion Management*, 41:523–38.

El-Sebaii, A.A. Thermal performance of a triple-basin solar still. Renewable Energy J (submitted).

Elsherbiny, S.M. and Fath, H.E.S. 1993. Solar distillation under climatic conditions of Egypt. *Renewable Energy*, 3:61–5.

Farid, M. and Hamad, F. 1993. Performance of a single-basin solar still. *Renewable Energy,* 3:75–83.

Garg, H.P. and Mann, H.S. 1976. Effect of climatic, operational and design parameters on the year-round performance of single-sloped and double-sloped solar stills under Indian arid zone conditions. Solar Energy, 18:159–64.

Hollands, K.G.T. 1963. The regeneration of lithium chloride brine in a solar still for use in solar air conditioning. *Solar Energy,* 7:39.

http://www.synergyenviron.com/tools/solar_insolation.asp?loc=New+Delhi%2CDelhi%2CIndia

Jubran, B.A., Ahmed, M.I., Ismail, A.F., Abakar, Y.A. 2000. Numerical modeling of a multi-stage solar still. *Energy Conversion Management,* 41:1107–21.

Kiatsiriroat, T., Bhattacharya, C. and Wibulswas, P. 1986. Prediction of mass transfer rates in solar still. *Energy,* 11:881–6.

Kumar, S. and Tiwari, G.N. 1999. Optimization of daily yield from an active double effect distillation with water flow. *Energy Conversion Management,* 40:703–15.

Malik, M.A.S. and Tran, V. 1973.. A simple mathematical model for predicting the nocturnal out put of a solar still. Solar Energy, 14:371–85.

Minasian, A.N. and Al-Karaghouli, A.A. 1992. Floating vertical solar still for desalination of marsh water. *Renewable Energy,* 2:631–5.

Mink, G., Aboabboud, M.M. and Karmazsin, E. 1998. Air-blown solar still with heat recycling. *Solar Energy,* 62:309–17.

Morse, R.N. and Read, W.R.W. 1968. A rational basis for the engineering development of a solar still. *Solar Energy,* 12:5.

Ozisik, N.M. 1988. Heat transfer. New York: McGraw-Hill; 1988.

Rajvanshi, A.K. 1981. Effect of various dyes on solar distillation. *Solar Energy,* 27:51–65.

Sanjay, K. and Tiwari, G.N. 1996. Performance evaluation of an active solar distillation system. Energy 1996;21:805–8.

Soliman, S.H. 1972. Effect of wind on solar distillation. Solar Energy, 13:403–15.

Spalding, D.B. 1963. Convective mass transfer. London: Edward Arnold; 1963.

Suneja, S. and Tiwari, G.N. 1999. Effect of water depth on the performance of an inverted absorber double basin solar still. Energy Conversion Management 1999;40:1885–97.

Tiwari, G.N. 1992. Recent advances in solar distillation. In: Raj Kamal *et al*., editors. Solar Energy and Energy Conversion. New Delhi: Wiley Eastern,. p. 32–149 (Chapter II).

Tiwari, G.N. and Suneja, S. 1997. In: Solar thermal engineering systems. London: Narosa Publishing House; p. 205.

Wattmuf, J.H., Charters, W.W.S. and Proctor, D. 1977. Solar and wind induced external coefficients for solar collectors. Compless, 2:56.

Yeh, H.M. and Chen, L.C. 1986. The effect of climatic, design and operational parameters on the performance of wick-type solar distiller. *Energy Conversion Management,* 26:175–80.

Yeh, H.M. and Chen, L.C.1 985. Basin type solar distillation with air flow through the still. Energy 1985;10:1237–41.

Yeh, H.M., Ho, C.D. and Hwang, K.J. 1999. Energy and mass balance in open-type multi-effect solar distiller with air flow through the last effect. *Energy,* 24:103–15.

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