REVIEW ON THERMAL PERFORMANCE OF SINGLE SLOPE SOLAR STILL WITH COVER COOLING

Ayush Tiwari[1], Prof. Nutan Diwan[2]

[1] *Student ME (Thermal Engineering) ,Government Engineering College Jagdalpur, Chhattisgarh, India*
[2] *Assistant Professor, Mechanical Department, Government Engineering College Jagdalpur, Chhattisgarh, India*

ABSTRACT

Solar distillation represents a most attractive and simple technique among other distillation processes, and it is especially suited to small-scale units at locations where solar energy is considerable. In this solar energy is used to evaporate the water, then this vapour is condensed as pure water. This process removes salts and other impurities to produce fresh water by utilizing the heat from solar energy. Various works have been carried out to improve the distillate productivity of the solar still. This review article explains about the various techniques followed to improve the productivity of the solar still. The review includes basic principle of solar distillation, and also the quality of distilled water. A classification of the solar still systems was made in order to explain the types of solar still systems. In this study, various performance enhancement technologies are discussed.

Keyword : *- Solar distillation, solar still, productivity, review*

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1. INTRODUCTION

Portable water is a human birthright as much a birthright as clean air. However, much of the world's population does not have access to safe drinking water. Hence, new and reasonable way of saving has to be found, using and recycling the water that we have. As people can survive for days, week or month's without food, but cannot live for more than a week without water. The body uses water for digestion, absorption, circulation, transporting nutrients, building tissues, carrying away waste and maintaining body temperature. The average adult consumption about 10 cups of water daily. Adults should drink six to eight cup liquid per day. The world council believes that by 2020 we shall need 17% more water than is available if we are to feed the world. Today, one person in five across the world has no access to safe drinking water. Every day more than 30,000 children die before reaching their fifth birthday, killed either by hunger or by water borne diseases. The first solar distillation device in the world was built in Chile. It had an overall area of 4700m2, consisting of many cells of basic basin solar still [2]. Solar still could play a significant role in where there is an adequate amount of solar energy and a source of brackish water is available. Solar still could produce a considerable amount of fresh water at reasonable cost and which is inexpensive to build and easy to maintain. 95% of the functioning solar stills are of basin type because of its efficient performance and reliability in operation.

2. CLASSIFICATION OF SOLAR STILL

Many research works have been carried out on designs of solar still by various researchers throughout the world. Most of the conventional still developed employs a single basin for meeting water requirements up to 5 l/day. The various designs of domestic solar still developed so far includes single basin single slope, single basin double-slope, Hybrid solar still, hemi-spherical, triangular and pyramid type solar still. The broad classifications of solar still are illustrated in Fig.

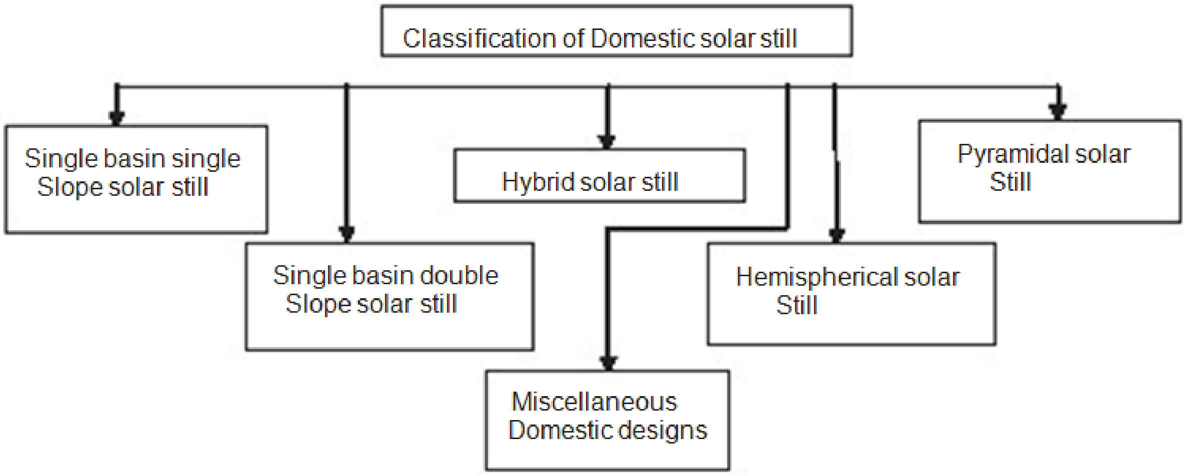

Fig. *Classification of solar still*

Fig. *Single slope solar still*

Fig Double slope solar still

3. BASIC OPERATION

A solar still operates on the same principle as rainwater: evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills mimic this natural process.

A single basin solar still has a top cover made of glass, with an interior surface made of a waterproof membrane. This interior surface uses a blackened material to improve absorption of the sun's rays. Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation (short-wave) to pass into the still, which is mostly absorbed by the blackened base. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The base also radiates energy in the infra-red region (long-wave) which is reflected back into the still by the glass cover, trapping the solar energy inside the still (the "greenhouse" effect). The heated water vapor evaporates from the basin and condenses on the inside of the glass

cover. In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle.
The still is filled each morning or evening, and the total water production for the day is collected at that time. The still will continue to produce distillate after sundown until the water temperature cools down. Feed water should be added each day that roughly exceeds the distillate production to provide proper flushing of the basin water and to clean out excess salts left behind during the evaporation process

4. PERFORMANCE FACTORS OF SOLAR STILL

Solar still should provide as much of distillate as possible per unit area per day. The evaporation rate of the water in the solar still is directly proportional to the exposure area of water in the still, absorber area and temperature of water in the basin. The productivity of the solar still increases with the increase in absorber area. The distillate water production rate can be increased by varying the design of solar still, depth of water, salt concentration, location and different absorbing materials and evaporation techniques. Various parameters affect both efficiency and productivity of the still like climatic parameters such as solar insolation, ambient air temperature, wind speed, atmospheric humidity, sky conditions etc., and design parameters such as thermo physical properties of materials used in its construction, orientation of the still, tilt angle of the cover, spacing between cover and the water surface, insulation of the base, vapour tightness, initial water temperature, water salinity etc. [3]

5. LITERATURE SURVEY

i. **Frick and Sommerfield** [1] introduced a solar still with inclined evaporating cloth (single wick) with negligible thermal capacity which increases the temperature of water thus enhances the rate of evaporation, but the main disadvantage of the still was drying of clothes at times. This problem was later on rectified by

ii. **Sodha et al [2]**, they proposed a new design in which blackened wet jute clothes with their upper edges dipped in saline water, forms the liquid surface and attains high temperature on account of low thermal capacity. They reported an overall thermal efficiency of 34%, moreover they concluded that the cost of solar still is less than half the cost of basin type solar still of same area.

iii. **Tiwari et. al [3]** introduced a modified design with double condensing multiple wick solar still, the condensing glass cover of a simple multiple wick solar still becomes hot on summer days, which reduces distillate output, to increase output a double condensing multiple wick solar still has been proposed.

iv. **Kumar et al. [4]** presented the annual analytical expressions for water and glass temperature for active distillation system. Yield has been obtained in terms of design and climatic parameters. Numerical Computations has been done for Delhi climate. It was observed that for a given parameters, the annual yield is optimum when the collector inclination is 20^0 and the still glass cover inclination is 15^0.

v. **Tripathi et al. [5]** presented computer modeling of passive and active solar stills for different depth of water in the basin of solar still by the concept of solar fraction.

vi. **Tiwari et al. [6]** presented the thermal analysis of passive and active solar distillation system by using the concept of solar fraction inside the solar still with the help of AUTOCAD 2000. Experiments have been conducted for New Delhi climatic conditions (latitude 28°35′N, longitude 77°12′E) during the months of November and December for different water depths in the basin (0.05, 0.1 and 0.15 m) for passive as well as active solar distillation system. Analytical expressions for water and glass cover temperatures and yield have been derived in terms of design and climatic parameters. It was observed that
   (i) The solar fraction plays a very important role at lower values of solar altitude angle;
   (ii) The internal convective heat transfer coefficient decreases with the increase of water depth in the basin due to decrease in water temperature;
   (iii) There is a fair agreement between the experimental observation and theoretical prediction during daytime as compared to that during the night.

vii. **Sodha et al [7]** performed experiment to study the effect of dye on output of solar still, they concluded that the black dye injected in water increases the productivity of solar still by about 48% for 14cm of water depth. They recommend the use of black and violet dye for increasing the production of water in solar still. The productivity increases rapidly with increasing insulation thickness up to 4cm and then slowly in both cases with and without dye

(i) .

viii. **Tiwari and Tiwari [8]** experimentally determined a relation for predicting convective and evaporative heat transfer coefficients for all three condensing covers inclined at 15^0, 30^0 and 45^0under indoor situation. The operating temperature range for the experiment was maintained at steady state from 40^0C to 80^0C, they found that the higher yield was obtained with an increase in temperature for 30^0 slope as compared to 15^0 and 45^0 slopes of condensing cover.

ix. **Tiwari and Tiwari [9]** studied effect of water depths on evaporative mass transfer coefficient for a passive solar still in summer climatic condition. They observed that the nocturnal distillation is significant in the case of higher water depths because of reduced ambient and stored energy.

x. **Abdallah et al [10]** experimented single slope solar still by using different types of absorbing materials like metallic wiry sponge, and black volcanic rocks in four identical single slope solar stills , there result shows that uncoated sponge has the highest water collection during day time followed by black rocks then coated metallic wiry sponge.

xi. **Singh and Tiwari [11]**evaluated the monthly performance of passive and active solar stills for different Indian climatic conditions. Numerical computations were carried out for hourly variations of average insolation at the Chennai, Jodhpur, Kolkata, Mumbai and New Delhi stations. Analytical expressions for water temperature, glass cover temperature and yield as a function of climatic parameters were also derived. On the basis of numerical computations, it was inferred that: (1) the annual yield significantly depends on water depth, inclination of condensing cover and collector as expected for both passive and active solar stills.

xii. **Tiwari and Rao [12]** implemented one of the methods of flowing continuous water over the glass cover to reduce the temperature of glass cover in order to increase the production yield of a solar still.

xiii. **Abu hijleh [13]** theoretically investigated the effectiveness of film cooling of solar still under different operating characteristics, his results indicated that the proper use of the film cooling parameters can increase the still efficiency by 6%.

xiv. **Tiwari and Madhuri [14]** incorporated the flow of waste hot water in the basin of solar still along with the continuous flow of cooled water over glass cover and obtained the enhancement in the production output of solar still.

xv. **Lawrence et al. [15]** validated their mathematical model by incorporating the effects of water flow over the cover of a single slope solar still and the heat capacity of water mass in the basin. They found an increase of 7 and 10% in efficiency of solar still due to continuous flow of water in the cases with and without black dye present in the basin of solar still; moreover there is no change in efficiency of solar still above mass flow rate of 1.5m/s.

xvi. **Abu hijleh and Mousa [16]** extended there earlier work and included evaporation effect of water flowing over glass cover; the effect of water film cooling of the glass cover on the efficiency of a single-basin still has been investigated numerically. They suggested that proper use of the film-cooling parameters may increase the still efficiency by up to 20%. On the other hand, a poor combination of these parameters leads to a significant reduction in efficiency. The presence of the cooling film neutralizes the effect of wind speed on still efficiency. Only a small fraction of the cooling film evaporates as it passes over the glass cover.

xvii. **Ahmed and Alfayalakawi [17],** studied and evaluated the effect of wind speed and use of water sprinkler to cool the glass cover of single slope solar still. Their results indicated that the increase in production rate is between 8% to 31.8%.

xviii. **Badran [18]** studied numerically the effect of introducing a water film cooling on efficiency of a conventional solar still. The result shows that using the appropriate combination of water film parameter still efficiency can be increased by 6%.

6. ECONOMICS OF SOLAR DISTILLATION

Economic analysis is essential to determine the cost of distilled water produced and to determine the payback period of an investment to reduce the risk of project failure. However the cost of solar distillation unit depends on initial investment, rate of interest, annual distillate, and maintenance cost and life time of solar stills. Economic analysis of solar distillation system has been done in past by various researchers.

Mukherjee and Tiwari [19] have carried out the economic analysis of three different types of the solar stills single slope, fiber-reinforced plastic (FRP) still, a double slope FRP solar still and a double slope concrete solar still for Indian climatic conditions. They have concluded the minimum cost of distilled water produced from conventional solar stills.

Delyannis and Delyannis [20] have carried over techno economic analysis of small size of solar distillation plant of capacity $1m^3$/d, they estimated the cost of distilled water as $12\$/m^3$.

Tleimat and Howe [21] have reported that the solar distillation plants of capacity less than 200l/day are more economical than the other type of plants.

Madani and Zaki [22] studied the effect of carbon powder and basin insulation on yield of solar still experimentally. They conducted economic analysis of the proposed design of plant of $50m^3$/d and estimated cost of $\$2.4/m^3$.

7. CONCLUSIONS

Solar stills have proven to be highly effective in cleaning up water supplies to provide safe drinking water. The effectiveness of distillation for producing safe drinking water is well established and recognized. Most commercial stills and water purification systems require electrical or other fossil-fueled power sources. Solar distillation technology produces the same safe quality drinking water as other distillation technologies; only the energy source is different : the sun. Various advances can be made in solar distiller to enhance its efficiency depending upon the requirement. Based on the above findings of various researchers the performance of the solar still can be maximized. This review article will lead to increase the productivity of solar still by implementing various methods proposed in the literatures.

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9. REFERENCES

[1] Frick G, Sommerfield J V., Solar still of inclined evaporating cloth., Solar energy 14, 427, (1973).
[2] M S Sodha, G.N Tiwari, R C Tyagi., Simple multiple wick solar still: analysis and performance, Solar energy 26, 127, (1981).
[3] G.N Tiwari, S.B Sharma M S Sodha. Performance of double condensing multiple wick solar still.Energy conversion management 24, 193-199, (1984).

[4] Sanjeev Kumar, G.N Tiwari, H.N Singh., Annual performance of active distillation system., Desalination 127, 79-88, (2000).

[5] Rajesh Tripathi and G.N Tiwari., Thermal modeling of passive and active solar stills for different depth of water by using the concept of solar fraction., Solar Energy 80, 955-957, (2006).

[6] G.N Tiwari, S.K Shukla, J.P Singh., Computer modeling of passive/ active solar stills by using inner glass temperature., Desalination 154, 171-185, (2003).

[7] M.S. Sodha, A. Kumar, G.N. Tiwari, G.C. Pandey., Effects of dye on the performance of a solar still., Applied Energy 7, 147-162, (1980).

[8] A.K. Tiwari, G.N. Tiwari., Effect of condensing cover's slope on internal heat and mass transfer in distillation: an indoor situation., Desalination 180, 73-88, (2005).

[9] A.K. Tiwari, G.N. Tiwari., Effect of water depths on heat and mass transfer in a passive solar stills in summer condition., Desalination 195, 78-94, (2006).

[10] Salah Abdallah, Mazen M. Abu-Khader, Omar Badran., Effect of various absorbing materials on the thermal performance of solar., Desalination 242, 128-137, (2009).

[11] H.N. Singh, G.N Tiwari., Monthly performance of passive and active solar stills for different Indian climatic conditions., Desalination 168, 145-150, (2004).

[12] G.N. Tiwari, V.S.V. Bapeshwara Rao., Transient performance of a single basin solar still with water folwing over the glass cover., Desalination 49, 231-241, (1984).

[13] Bassam A.K Abu-Hijleh., Enhanced solar still performance using water film cooling of the glass cover., Desalination 107, 235-244 (1996).

[14] G.N. Tiwari, Maduri, H.P. Garg., Effect of water flow over the glass cover of a single basin solar still with an intermittent flow of waste hot water in the basin., Energy Convers. and Management, 25-3, 315-322, (1985).

[15] S.A. Lawrence, S.P. Gupta, G.N. Tiwari., Effect of heat capacity on the performance of solar still with water flow over the glass cover., Energy Convers. and Manag. 30, 277-285, (1990).

[16] Bassam A.K Abu-Hijleh, and Hasan A. Mousa., Water film cooling over the glass cover of solar still including evaporation effects., Energy 22-1, 43-47, (1997).

[17] Ahmed and Alfayalakawi., Productivity enhancement of conventional solar still using water sprinkler and cooling fan., Journal of advanced science and engg. Research 2-3, 168-177, (2012).

[18] Badran O.O., Experimental study of the enhancement parameters of single slope solar still productivity., Desalination 1-3, 136-143, (2009).

[19] R. Mukherjee, GN Tiwari., Economics of various designs of conventional solar stills .Energy conversion and management 26, 155-167, (1986).

[20] Delynnis , Dellynis, ., Economics of solar stills ., Desalination 52, 167-176, (1985).

[21] Tleimat BW, Howe ED. Nocturnal production of solar distillers. Solar Energy 10, 61–6., (1996)

[22] Madani AA, Zaki GM. Yield of stills with porous basins. Applied Energy52:273, , (1995)

[23] G.N Tiwari., Solar Energy Fundamentals, Design Modeling and Applications, Narosa publishing house, New Delhi, (2002).

BIOGRAPHIES

	**Ayush Tiwari** Student M.Tech(Thermal Engineering) Government Engineering College Jagdalpur, Chhattisgarh, India
	**Nutan Diwan** Assistant Professor, Mechanical Department, Government Engineering College Jagdalpur Chhattisgarh, India