



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

Performance Analysis and Evaluation of Solar Still System

Dr. K. Ashok Reddy

Department of Mechanical Engineering,
MLR Institute of Technology, Dundegal (V), Hyderabad, Telangana 500055, INDIA

Abstract: A literature review of solar still with different solar inflations and angles have been presented by various researchers was made available in this paper.

Keywords: solar still, brackish water etc.

I. Introduction

Water is gifted by nature but around 97% of the water in the world is in the ocean, approximately 2% of the water in the world is at present stored as ice in polar region, and 1% is fresh water available in earth for the need of the plants, animals and human life. This water is reducing day by day continuously. And this 1% water is available in rivers, lakes, and underground reservoir. This ground water has also been polluted due to industries, agricultural and population growth during the current year. Polluted water causing Sevier diseases like —water borne diseases. The term —water borne diseases is reserved largely for infections that predominantly are transmitted through contact with or consumption of infected water. And water borne diseases is affecting human health; nearly 70-75% diseases have infected water in India. The world is facing the scarcity of the fresh water. This has become a major problem and global challenge. Therefore, it is required to have a technology for water purification to meet the demand of the water all over the world.

In 1872, Swedish engineer C.Wilson designed the first conventional solar still for supplying fresh water to mining community in Northern Chile. The operation of solar still is similar to natural hydrological cycle that includes two processes, namely evaporation and condensation. A black painted basin filled by brackish water or waste water. Transparent cover is enclosed in a completely air tight area. Transparent cover passes incident solar irradiance and it is absorbed by the basin plate. Consequently basin water gets heated up and evaporates in the saturated conditions inside the still killing all pathogenic bacteria. Water vapors rises towards the cooler inner surface of the cover, where they condense to pure water, due to gravity and run down along the cover bottom surface, getting collected in a collecting tray. The still is easy to fabricate and does not require maintenance and skilled labors. Naga Sarada S et al [1] presented in their technical paper two-thirds of the earth was covered with water and remaining was land, all over the world, access to potable water by the people was narrowing and decreasing day by day. Most of the human diseases are due to polluted or non purified water. Nowadays, each and every country was facing a problem of huge water scarcity because of pollution created by manmade activities. Adequate quality and reliability of drinking water supply was the fundamental need of all people on this earth. Fresh water which was obtained from rivers, lakes and ponds was becoming scarce because of industrialization and population explosion. Water purification using solar energy has become more popular because it was eco-friendly and cost effective. A solar still was commonly used device for water purification and it doesn't require any electricity for distillation of water. Solar distillation was a technology for producing potable water from brackish water or underground water of low quality at low cost. This method can reduce water scarcity problems in the world. In a solar still, water was evaporated using solar energy which was a form of renewable energy and collected as a distillate water after condensation of the vapour. This method can produce distilled water after removal of impurities. Since last three decades, more research work was going on to improve the system performance and efficiency of the solar still and provide a sustainable water purification. A variety of solar distillation devices have been developed with different materials and in different shapes in different locations to improve the efficiency of solar distillation. There was a strong need to improve the single slope solar still performance and increase the production of water distillation. From my literature survey, many researchers, engineers and scientists experimentally studied solar water distillation using Phase Change Materials (PCMs). There is no more work. So, this present paper was focused on performance of solar water

distillation using Phase Change Materials. In this experiment Magnesium Sulfate Heptahydrate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), Sodium Sulphate ($\text{Na}_2\text{S} \cdot 7\text{H}_2\text{O}$) are used as phase change material and Titanium oxide is a nano-material used for energy storage material. Among these energy storage materials Magnesium Sulfate Heptahydrate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) improves the efficiency of solar water distillation.

A.A. El-Sebaei A.A. et al [2] presented in their technical paper transient mathematical models are presented for a single slope-single basin solar still with and without phase change material (PCM) under the basin liner of the still. Analytical expressions for temperatures of the still elements and the PCM have been obtained. The still performance has been investigated by computer simulation. Numerical calculations have been carried out, using stearic acid as a PCM, on typical summer and winter days in Jeddah (lat. $21^\circ 42'$ N, long. $39^\circ 11'$ E), Saudi Arabia. Effect of mass of the PCM (m_{pcm}) on the daylight P_{dl} , overnight P_{on} and daily productivity P_d and efficiency η_d of the still for different masses of basin water m_w has been investigated. It is found that P_{dl} decreases as m_{pcm} increases; but P_{on} and P_d increase significantly with an increase of m_{pcm} due to the increased amount of the heat stored within the PCM. During discharging of the PCM, the convective heat transfer coefficient from the basin liner to basin water is doubled; thus, the evaporative heat transfer coefficient is increased by 27% on using 3.3 cm of stearic acid beneath the basin liner. Therefore, on a summer day, a value of P_d of 9.005 ($\text{kg}/\text{m}^2 \text{ day}$) with a daily efficiency of 85.3% has been obtained compared to 4.998 ($\text{kg}/\text{m}^2 \text{ day}$) when the still is used without the PCM. The PCM is more effective for lower masses of basin water on winter season.

Mohammad Dashtban et al [3] presented in their technical paper a weir-type cascade solar still, integrated with latent heat thermal energy storage system, was designed with the view of enhancing productivity. Use of a heat storage system with 18 kg mass (2 cm thickness) of paraffin wax beneath the absorber plate keeps the operating temperature of the still high enough to produce distilled water during the lack of sunshine, particularly at night. Also, theoretical models were developed for the still with and without PCM, and the calculated results were compared with the experimental data. In addition, the internal convective heat transfer coefficient calculated from the experimental data of the still without PCM was applied for the calculations since the common relation proposed by Dunkle could not follow the still performance. Moreover, important parameters affecting the performance of the still, such as water level on the absorber plate and distance between water and glass surfaces, were theoretically investigated. The performance of the still with and without PCM was also studied on a typical day in Zahedan, Iran. In this regard, the daily productivity was theoretically found to be 6.7 and 5.1 $\text{kg}/\text{m}^2 \text{ day}$, for the still with and without PCM, respectively. The results showed that the productivity of the still with PCM was theoretically 31% higher than that of without PCM. V. Sivakumar [4] presented in their technical paper a technique used to convert brackish or saline water into potable water was called as solar desalination. The demand of consumable water keeps on increasing due to high population density and automation. Solar energy is used for the conversion phenomenon and the device used for desalination was known as a solar still. Active and passive solar stills are the major types of solar stills. Without the utilization of high grade energy (electrical energy), freshwater was derived from the passive solar still. The yield from the solar still (active or passive solar still) depends upon meteorological, and design and operational parameters. By the mercy of nature, meteorological parameters cannot be controlled by human beings. Many researchers framed mathematical expressions, conducted experiments and validated the outcome from the various types of solar stills by varying the design and operating parameters. The methodologies used in the past years to improve the performance of the active and passive solar stills were reviewed in this paper.

N. Rahbar, J.A. Esfahani [5] presented in their technical paper the ability of a 2-D CFD (computational fluid dynamic) simulation in estimating the hourly yield of a single-slope solar still. Moreover, a new equation based on Chilton–Colburn analogy was proposed to estimate the productivity of a solar still. The results are in a good agreement with the results of well known models. However, the accuracy of the CFD analysis in the prediction of Nu number was better than its accuracy in productivity estimation. The results also show that there was an optimum length in which the productivity was maximized. On the other hand, in a fixed length of a solar still, the specific height has an inverse effect on productivity. Moreover, the trend of water productivity was always similar to the trend of convective heat transfer coefficient.

Bhupendra Gupta [6] presented in their technical paper 1% percentage can be used for drinking purpose. The solar water distillation comes out to be a non toxic and promising device which purifies water that uses a renewable solar energy source, Efficiency of the solar water distillation device can be enhanced by increasing evaporation rate that is a combined effect of solar radiation, cover glass temperature, water contamination density, base plate absorptivity and provide additional heat by solar water preheating system. Various investigators uses thermal modeling technique to analyses performance of Solar water distillation device carrying above mentioned factors as basis and shows an optimum value to enhance efficiency. Present paper was a tabulated review of all these governing parameters and modeling equations available for suitable selection.

A.A. El-Sebaei et al [7] presented in their technical paper transient mathematical models are presented for a single

slope-single basin solar still with and without phase change material (PCM) under the basin liner of the still. Analytical expressions for temperatures of the still elements and the PCM have been obtained. The still performance has been investigated by computer simulation. Numerical calculations have been carried out, using stearic acid as a PCM, on typical summer and winter days in Jeddah (lat. 21_ 420 N, long. 39_ 110 E), Saudi Arabia. Effect of mass of the PCM (mpcm) on the daylight Pdl, overnight Pon and daily productivity Pd and efficiency gd of the still for different masses of basin water mw has been investigated. It is found that Pdl decreases as mpcm increases but Pon and Pd increase significantly with an increase of mpcm due to the increased amount of the heat stored within the PCM. During discharging of the PCM, the convective heat transfer coefficient from the basin liner to basin water is doubled; thus, the evaporative heat transfer coefficient is increased by 27% on using 3.3 cm of stearic acid beneath the basin liner. Therefore, on a summer day, a value of Pd of 9.005 (kg/m² day) with a daily efficiency of 85.3% has been obtained compared to 4.998 (kg/m² day) when the still is used without the PCM. The PCM is more effective for lower masses of basin water on winter season.

K. Shanmugasundaram, B. Janarthanan [8] presented in their technical paper to enhance the productivity of the single basin double slope solar still by integrating with shallow solar pond. The performance of the single basin double slope solar still integrated with shallow solar pond has been analyzed theoretically and experimentally. The experiments have been carried out from January to March 2012. The energy balance equations have been written for different temperature elements of the solar still such as glass cover, basin water and still basin. A computer program has been written for analytical solutions of the energy balance equations to evaluate the numerical results of the elements of the still. The productivity and efficiency of the solar still integrated with and without shallow solar pond has been found. It is found that the productivity of the solar still integrated with shallow solar pond is increased compared with the still without integration. The productivity of the solar still integrated with and without shallow solar pond is found to be 5.09 L/m²day and 3.17 L/m²day and the theoretical results are in good agreement with the experimental results.

Shanmugan et al.[9] presented in their technical paper propose a thermal asymmetry model for single slope basin type solar still with sponge liner of different thickness (3 cm, 5 cm, and 10 cm) in the basin. Two different color sponge liners have been used i. e., yellow and black. In the proposed design, a suitable dripping arrangement has been designed and used to pour water drop by drop over the sponge liner instead of sponge liner in stagnant saline water in the basin. The special arrangement overcomes the dryness of the sponge during peak sunny hours. The performance of the system with black color sponge of 3 cm thickness shows better result with an output of 5.3 kg/m² day and the proposed model have used to find the thermal asymmetries during the working hours of the still.

Manchanda and Kumar[10] presented in their technical paper easily accessible type of solar distillation was passive solar still which utilizes freely and abundantly available sun energy for removal of salinity/impurity from saline/brackish water. The main drawback of passive solar still is its lower efficiency and distillation output. Different designs of passive solar stills are fabricated and tested by various researchers to meet water demand economically. Concave wick basin pyramidal-shaped solar still was observed to produce 4.0 l/m²/day average distillate with a cost of 0.065\$/l. Double basin solar still showed an average of 85 % higher yield than single basin still. Stepped type, inclined, tubular, pyramidal, spherical, and hemispherical shapes were considered an efficient designs of passive solar still. Numbers of parameters such as water depth, solar radiation, ambient conditions, condensing cover material, its cooling and direction, internal and external reflectors, sun tracking system, wicks, thermal and energy storage materials were outlined which highly affect the performance of solar still. Water depth of 0.04 m and condensing cover inclination to latitude of the place were observed optimum operational parameters. A distillate output of 4.3 l/m² was collected with cotton gauge top cover cooling to V-type solar still. Increase of 75 % in productivity and 56 % in daily efficiency was observed with internal reflector stepped solar still. An improvement of 380 % was observed in stepwise basin solar still integrated with sun tracking system. Despite large efforts carried out on passive solar distillation, there are some challenges like bulkiness, high initial cost, and optimization of spacing between condensing cover and water surface of inclined still, thermophysical properties of basin material, flow rate, insulation material and its thickness, which need to be improved to make this technique efficient in practical utilization. This review paper mainly presents the results of previous work carried out on the designs, operational and process parameters affecting distillation, cost analysis, further scope of improvement in preceding work along with their limitations. The decade reviews on solar stills based on different context authored by many researchers have also been summarized. Moreover, this review paper will help the researchers to understand the basics of solar still with the need, developments and challenges in passive solar distillation to improve its thermal performance.

Hassan E.S. Fath [11] presented in their technical paper the development of solar stills has demonstrated their application when weather conditions are suitable and the demand is not too large. The problem of the relatively low still productivity and efficiency triggered scientists and engineers to investigate various means of improving the

systems' productivity, reliability and thermal efficiency, in order to reduce water production cost. Ajeet Kumar Rai [12] presented in their technical paper a single slope single basin solar still was designed fabricated, and its performance was tested in the Allahabad climatic conditions. An effort is also made to find the effect of condensing cover material on the performance of solar still. It was found that over the hours of experimental testing that the condensing cover made up of glass gives 64% more distillate than the condensing cover made up of polyvinyl chloride. Cost calculations are also performed to find the payback period of the system.

Marwah AW. Ali et al [13] presented in their technical paper experimental and numerical studies have been done on different configurations of solar stills to optimize the design by examining the effect of climatic, operational and design parameters on its performance. One of the most important of the operational parameters that has received a considerable attention in the literature is the brine depth. This paper reports indoor experimental investigations on the effect of brine depth on the productivity and efficiency of the solar stills at four different brine depths of 1.5, 2, 4 and 5.5 cm. Indoor tests were used by simulating the solar input by proper electric heaters located at the bottom of the still for heating the water contained in the basin of the still. The present study validated the decreasing trend in productivity with the increase of brine depth and showed that the still productivity could be influenced by the brine depth by up to 24%.

Suresh babu.k, S.Chinnathambi, M.Sridharan [14] presented in their technical paper the major source of water in the earth is ocean, which is of high salinity. To desalinate the saline water large amount of energy have to employed, renewable energy like solar energy is utilized it will be a promising source for desalination. The main objective of this research is to utilize the FPC solar water heater effectively for solar still productivity enhancement at an optimal cost. Probably its performance will be one of the best for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable. The experiment is carried out in a typical day in a mild climatic condition at Trichy (10°8050'N, 78°6856' E), Tamilnadu, India. The basin water depth is maintained in 0.02m throughout the study. The performance of the setup is studied theoretically and experimentally. It proves that 77% higher yield when compared to the single basin double slope passive solar still.

Gnanadasan et al [15] presented in their technical paper water was essential to life. The origin and continuation of mankind is based on water. The supply of drinking water is an important problem for the developing countries. Among the non-conventional methods to desalinate brackish water or seawater, is solar distillation. The solar still is the most economical way to accomplish this objective. Tamilnadu lies in the high solar radiation band and the vast solar potential can be utilized to convert saline water to potable water. The sun's energy heats water to the point of evaporation. When water evaporates, water vapour rises leaving the impurities like salts, heavy metals and condensate on the underside of the glass cover. Sunlight has the advantage of zero fuel cost but it requires more space and generally more equipment. Solar distillation has low yield, but safe and pure supplies of water in remote areas. In this context, the design modification of a single basin solar still has been discussed to improve the solar still performance through increasing the production rate of distilled water. The attempts are also made to increase the productivity of water by using different absorbing materials, depths of water, heat storage medium and also by providing low pressure inside the still basin. They greatly improve the rate of evaporation and hence the rate of condensation on the cooler surface. The theoretical results agree well with the experimental ones.

References

- [1]. Naga Sarada Somanchi, Sri Lalitha Swathi Sagi, Thotakura Ashish Kumar, Sai Phanindra Dinesh Kakarlamudi, Ajay Parik Modelling and Analysis of Single Slope Solar Still at Different Water Depth International Conference On Water Resources, Coastal And Ocean Engineering (Icwrcoe'15) Aquatic Procedia 4, 2015, 1477–1482.
- [2]. A.A. El-Sebaei, A.A. Al-Ghamdi, F.S. Al-Hazmi, Adel S. Faidah Thermal performance of a single basin solar still with PCM as a storage medium Applied Energy 86(7-8), 2009, 1187–1195.
- [3]. Mohammad Dashtban, Farshad Farshchi Tabrizi Thermal analysis of a weir-type cascade solar still integrated with PCM storage “, Desalination, 279(1-3), 2011, 415–422.
- [4]. V. Sivakumar, E. Ganapathy Sundaram Improvement techniques of solar still efficiency: A review, Renewable and Sustainable Energy Reviews 28(12), 2013, 246–264.
- [5]. N. Rahbar, J.A. Esfahani Productivity estimation of a single-slope solar still: Theoretical and numerical analysis Energy 49(1), 2013, 289–297.
- [6]. Dr. Bhupendra Gupta, Tonish Kumar Mandraha, Pankaj j Edla, Mohit Pandya Thermal Modeling and Efficiency of Solar Water Distillation: A Review,” American Journal of Engineering Research 2(12), 203-213.
- [7]. A.A. El-Sebaei, A.A. Al-Ghamdi, F.S. Al-Hazmi, Adel S. Faidah Thermal performance of a single basin solar still with PCM as a storage medium Applied Energy 86, 2009, 1187–1195.
- [8]. K. Shanmugasundaram, B. Janarthanan Performance Analysis Of The Single Basin Double Slope Solar Still Integrated With Shallow Solar Pond International Journal of Innovative Research in Science, Engineering and Technology. 2(10), 2013, 5786-5801.
- [9]. Sengottain Shanmugan, Balasundaram Janarthanan and Joseph Chandrasekaran, Thermal Asymmetry Model Of Single Slope Single Basin Solar Still With Sponge Liner Thermal Asymmetry Model Of Single Slope Single Basin, Thermal Science, 2014, 18(2), S439-S450.
- [10]. Manchanda and Kumar A comprehensive decade review and analysis on designs and performance parameters of passive solar still

- Renewables (2015) 2:17, 1-24.
- [11]. Hassan E.S. Fath Development In Simple Solar Stills Renewable Energy Systems And Desalination – Vol. III - Development in Simple Solar Stills - Hassan E.S. Fath Encyclopedia of Desalination and Water Resources (DESWARE) pp-1-9.
 - [12]. Ajeet Kumar Rai, Pratap Singh, Vivek Sachan, Nripendra Bhaskar Design, Fabrication And Testing Of A Modified Single Slope Solar Still International Journal Of Mechanical Engineering And Technology 4(4), 2013, 8-14.
 - [13]. Marwah AW. Ali, Abdul Jabbar N. Khalifa Indoor tests to investigate the effect of brine depth on the performance of solar Still International Journal Of Energy And Environment 4(2), 2013, 211-218.
 - [14]. M.R. Thansekhar and N. Balaji Suresh babu.k, S.Chinnathambi, M.Sridharan Performance Enhancement Study on Single Basin Double Slope Solar Still Using Flat Plate Collector International Journal of Innovative Research in Science, Engineering and Technology 3(3), 2014, 1303-1308.
 - [15]. Moses Koilraj Gnanadason¹, Palanisamy Senthil Kumar, Gopal Sivaraman, Joseph Ebenezer Samuel Daniel Design and Performance Analysis of a Modified Vacuum Single Basin Solar Still Smart Grid and Renewable Energy, 2011, 2, 388-395.