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Active solar stills performance and comparison: Overview

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Abstract

Water and energy are the two most important factors for the sustainability of life. Less than 1% of the water is directly usable by society, the largest percentage of which is polluted by intractable industrial development. Solar distillation is a potential solution for producing portable water using a device called a solar distiller, viable in remote areas where solar energy is abundant despite severe freshwater scarcity. Decades of global experience in solar stills research and marketing have laid the comprehensive foundation for the solar stills industry.

In this publication, comparative performance of various designs of active solar stills in terms of design, efficiency, and power output per m2 solar still was performed. The numerical calculations are based on the experimental performance of still images of the sun reported by various researchers. Average annual productivity estimated from different types of solar distillers on 300 sunny days per year. Energy efficiency and production costs based on life cycle cost analysis were also estimated.

Keywords: Active Solar Stills, Annual yield, Energy efficiency, Production cost.

Introduction

Water is the most important resource for every ecosystem on earth. Freshwater availability directly affects socioeconomic development and living standards. In modern times, population growth and industrialization continue to pose freshwater challenges for people in all developed and developing countries around the world. Studies show that about 79% of the water available on earth is salt water, only 1% is fresh water, and the remaining 20% is brackish water. Rough data on the distribution of water on Earth as seawater and freshwater with shares of 96.54% and 2.53% and only 0.36% of him of 2.53% freshwater is directly available to humans [1]. Water is filtered using various thermal techniques such as Multi Stage Flash (MSF), Multi Effect Distillation (MED), Vapor Compression (VC) and membrane techniques such as Microfiltration (MF), Ultrafiltration (UF) and Nanofiltration (NF). desalinate the Reverse osmosis (RO) can be used. Among them, MSF, MED and RO are widely used commercially in the city and rank high.

efficiency. The production capacity of these systems is 5000-20000 L/day. However, these technologies are expensive and rely on conventional energy supplies (fossil fuels and electricity), making them impractical for settlements scattered across Asia and Africa. The continuously rising prices of fossil fuels and the associated greenhouse gas emissions and negative impacts on marine ecosystems make them utterly unsustainable. Moreover, these techniques are not suitable for remote villages, arid regions, and small islands [2]. To meet this demand, solar desalination is one method of producing pure water from brackish or salt water using a device called a solar still. Solar distillers have the advantage of being simple, easy to use, easy to maintain, and do not require conventional energy, but their low and erratic productivity of 2-5 L/m2/day leads to low utilization rates. remains low. Using solar energy for clean water ensures sustainability and can meet the growing demand for fresh water from 15-20L per person/day to 75-100L per day. The first known use of the solar distiller was in 1872 at Las Salinas in the northern desert of Chile to provide drinking water for animals used in nitrate mining. Distillation techniques have been used for his century in land plants and ships. After World War II, the increased demand for fresh water in arid countries accelerated the use of distillation techniques [3]. The freshwater crisis is also being felt in many parts of India. Rural water supply and sanitation are integral components of the overall rural development program in India [4]. As a tropical country, India enjoys an abundance of sunshine, with average daily solar radiation varying between 4.0 and 7.0 kWh/m2 in different parts of the country. In this way we receive about 5000 trillion kWh of solar energy in one year. In India, the first and largest solar distillation plant was installed in 1978 by Bhavnagar of the Central Salt and Marine Chemistry Research Institute (CSMCRI) to supply drinking water to Awanya village and Chachi Lighthouse.

The performance and the daily production of the solar still can be increased by various passive methods such as lowering water capacity in the basin, adding various dyes in the water mass, increasing the absorbtivity by providing various absorbing materials on the basin liner, extracting reflection radiation, reducing heat losses from sides, etc. It could also be improved through active methods of integrating the still with flat-plate collector, heat exchanger, etc. Performance of a single basin solar still coupled with a flat-plate collector show that, the average daily production of distilled water has been found to be 24% higher than for a simple single basin solar still [5]. It has also observed that performance of a solar still integrated with a flat-plate collector with forced circulation mode gives 5–10% higher yield than that of the thermosiphon mode and further 30–35% enhancement in the yield is observed with the proposed system as compared to the conventional system [6]. Cooper [7] found a 60% maximum efficiency for basin-type solar-still for critical water depth. Research over the past few decades have identified major factors like the system thermal inertia, heat recovery and improvised geometric configurations in the solar-still to enhance its productivity. Monthly performances of the passive and active solar stills have been evaluated for different Indian climatic conditions [8]. They inferred that an annual yield depends on water depth, condensing cover inclination and collector area and maximum at 28.35º inclination of condensing cover. Fath et al. [9] have recommended the acceptable cost of the distilled water for potable use in remote areas, if produced from solar stills at $0.03/L (i.e. Rs. 1.20/L). Mukherjee and Tiwari [10] have carried out the economic analysis of three different types of solar stills, namely a 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 reported the minimum cost of distilled water if produced from conventional solar still.

Solar distillation is an attractive alternative to reduce emission of the GHG's with the use of solar energy. The enhancement of the yield from the solar desalination system, in a certain locations, could be attained by a proper modification in the system design. In recent years, various studies (i.e. experimental and theoretical) have been conducted on different configurations of solar stills to enhance the performance and productivity. Sampathkumar et al. [11] presented the detailed review of various designs of active solar stills. In active mode, water in the basin is heated directly as well as indirectly (hot water available from solar collector or industries), and research work reported by various authors in this field.In this paper, 07 various configurations of active solar still are being considered to compare their performance in terms (a) annual yield for the 300 clear sunshine days (b) efficiency and (c) production cost.

Classification of Solar Still

Solar distillation systems are mainly classified into passive solar stills and active solar stills. Many parameters such as tank depth, tank material, wind speed, solar radiation, ambient temperature and tilt angle affect the performance of the distiller. The productivity of any type of solar distiller is determined by the temperature difference between the water in the tank and the inner glass cover. In passive solar distillers, solar radiation is received directly by the pool water and is the sole source of energy to raise the water temperature, resulting in evaporation leading to lower productivity. To overcome the above problems, active processes are implemented by integrating stills with flat plate collectors, heat exchangers, etc. It is used. The combination of solar heat and flat plate collectors is a high temperature distillation process. the sun is still united

Flat plate collectors (FPC) work with either forced or natural circulation. Forced circulation mode uses a pump to supply water. In natural circulation mode, water flows due to the difference in water density. Flat plate collectors give additional heat energy to the solar basin. A pump circulates water from the pool through the flat plate collector to the pool . The active solar distillation is mainly classified as follows [3]:

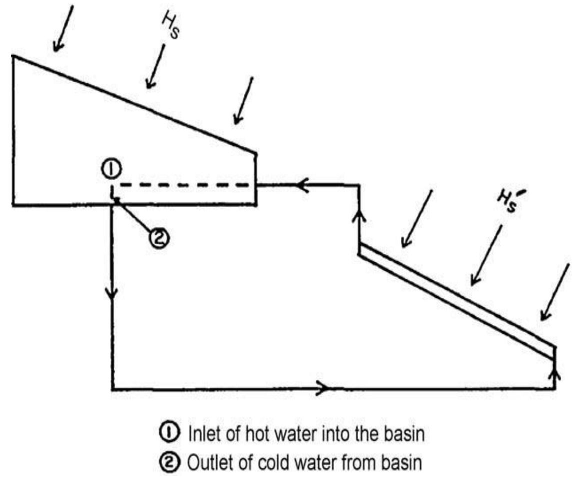
(i) High temperature distillation—Hot water will be fedinto the basin from a solar collector panel.
(ii) Pre-heated water application—Hot water will be fedinto the basin at a constant flow rate.
(iii) Nocturnal production—Hot water will be fed into thebasin once in a day.

Recent research on renewable energy shows a growing interest in vacuum tube solar collectors. Evacuated tube solar collectors have advantages over flat plate collectors for hot water supply. In flat plate concentrators, the sun's rays are perpendicular to the collector only at noon, so some of the sunlight that hits the surface of the collector is always reflected. However, in a vacuum tube collector, due to its cylindrical shape, the sun's rays hit the glass surface almost perpendicularly most of the time. Fig. 1 shows the schematics of various designs of high temperature distillation (active solar stills) under consideration. The specification for each is given in Table-1.

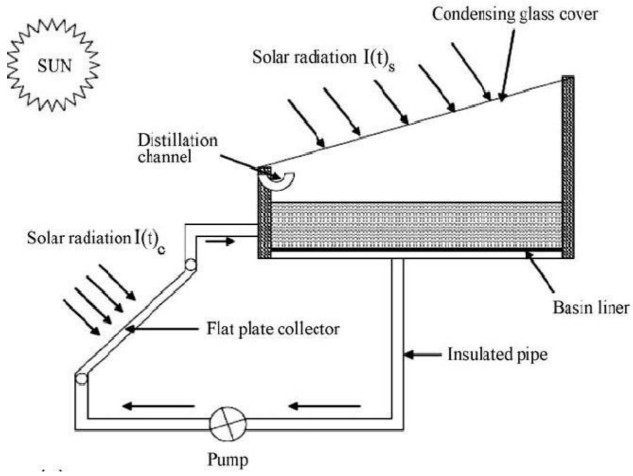
Table 1: Specifications of various designs of solar stills

Reference Authors	**Type of Solar still and denomination used in Figures**	**Specification of solar still**
Badran and Al-Tahaineh [12]	(a) Solar still coupled with flat plate collector (Natural circulation mode)	single basin solar still of area $1m^2$, Collector angle = 35º, Insulation material = Rock wool and thickness = 6 cm
Rai et al. [13]	(b) Solar still coupled with flat plate collector (Forced circulation mode)	FRP single basin solar still of area 1 m^2,Flow rate = 1.15 kg/min, Collector angle = 45º
Sanjay Kumar and Tiwari [14]	(c) Active double effect solar still	FRP single basin solar still of area 1 m^2, Still angle = 15º collector length = 1m Collector angle = 45º Flow rate = 40 ml/min Gap between two glasses = 20 cm
Zeinab S.Abdel-Rehim et al. [15]	(d) Solar still coupled with parabolic concentrator	FRP single basin solar still of area 1 m^2, Collector area = 80 cm long and 0.04cm thickness, Copper pipe length = 2m

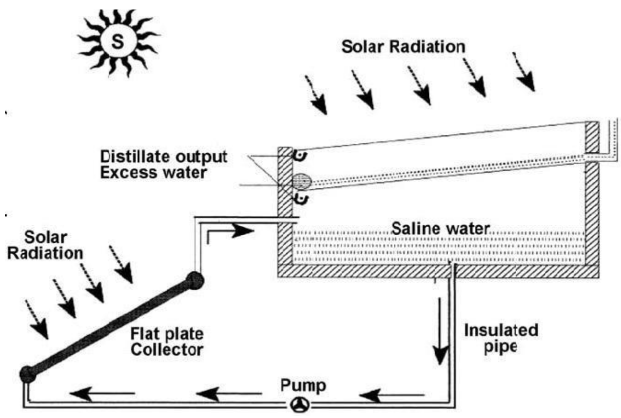
R.V. Singh et al. [16]	(e) Solar still integrated with evacuated tube collector in Natural mode	FRP single basin solar still of area 1 m^2 , Still angle 15º ETC tube ength:1.04m, diameter 0.044 m with line spacing 0.07m and 10 tubes
Shiv Kumar et al. [17]	(f) Solar still integrated with evacuated tube collector in Forced mode	FRP single basin solar still of area 1 m^2 , Still angle = 15º ETC tube length:1.04m, diameter 0.044 m with line spacing 0.07m and 10 tubes
Shiv Kumar and Tiwari [18]	(g) Solar still coupled with hybrid PV/T system	FRP single basin solar still of area 1 m^2,Still angle = 30º Each collector effective area: 2 m^2
T. Arun kumar and others[20]	(h) Solar still- Tubular Solar Still	A concentric tubular CPC solar distillation design with a rectangular absorber and the specifications . The inner and outer circular tubes are spaced with a 5mm gap to allow flowing water and air to cool the outer surface of the inner tube. Rectangular trough with dimensions 2 meters x 0. 03m x 0.025m Designed and spray painted with black paint. Rapid evaporation from the basin lowered the trough water level, leaving a dry spot in the basin. This is circumvented in successive experiments by continuously supplying water to the distiller using a measuring tube. This tube keeps the water level in the pool constant regardless of the evaporation rate. This continuous water supply is maintained by a water storage tank located near the CPC distiller. The outlet of the storage tank is connected to the inlet of the CPC distiller.



(a)



(b)



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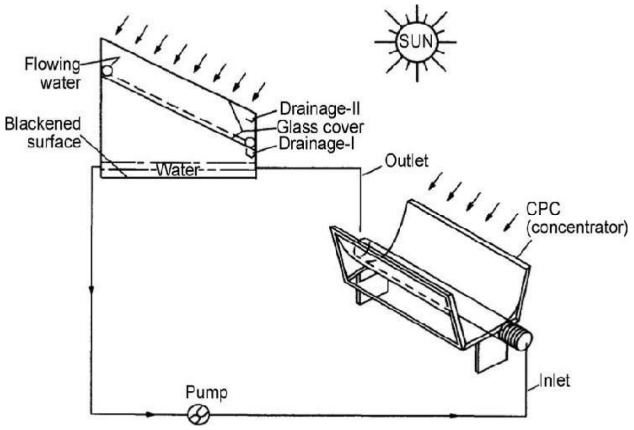

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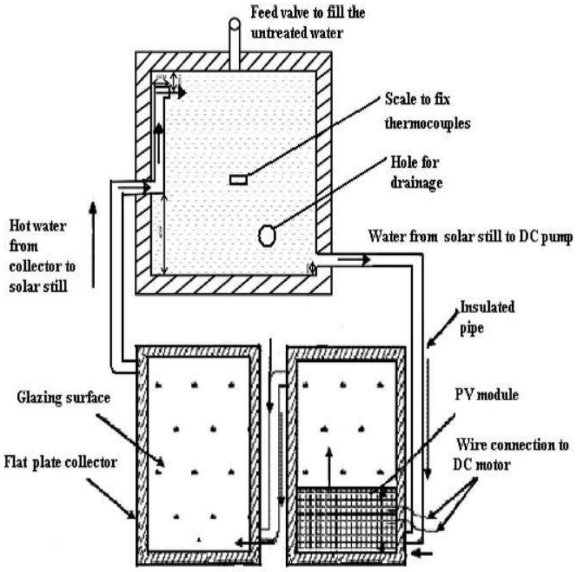
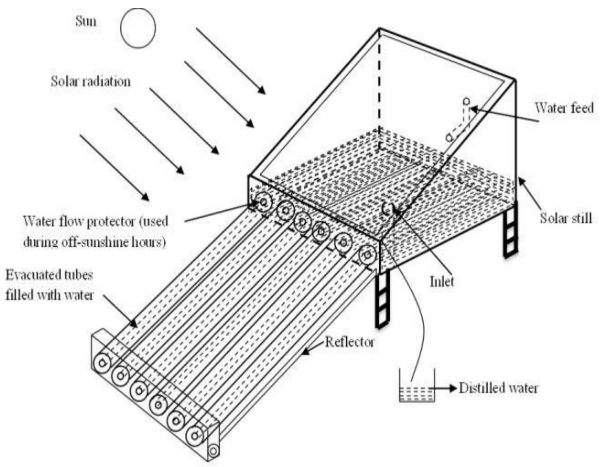


(g)



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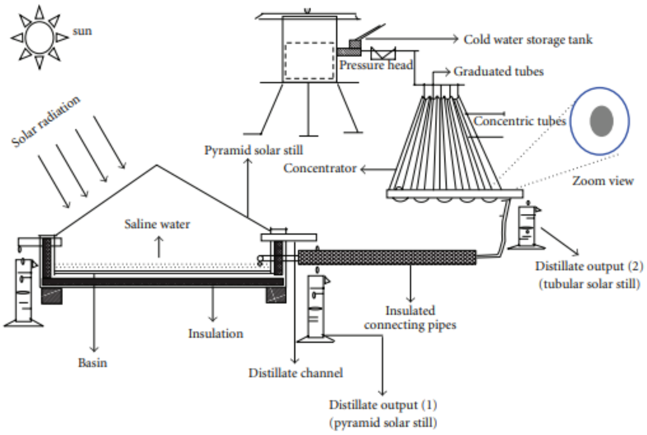
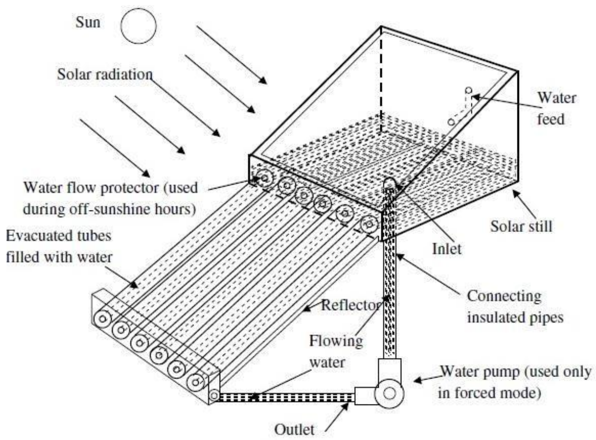


(h)

Figure 1: Schematic of various designs of Solar stills



(f)

Analysis

The theoretical analysis of various design of Solar still under consideration in respect of annual yield, efficiency and production cost are estimated taking annual yield reported for the passive solar still [19] by multiplying the percentage gain reported in respective modified designs, wherever the annual published data are not available. The annual yield is based on taking 300 clear sunshine days into account and with assumption that average radiations fall on the surface are 4.4 kWh/day. The energy efficiency obtained from solar still can be evaluated [3];

$$\eta_{System} = \frac{\text{Annual yield} \times L}{[\,I_s(t)\times A_s + I_c(t)\times A_c\,]\,300 \times 3600} \times 100$$

where L is the latent heat of vaporization (J/kg), A= (A_s+ A_c),total area of collection and I(t) is daily solar radiation (J/m^2)

The economical analysis is based on empirical equations reported [19]. The payback period of the solar still depends on the capital cost, maintenance cost, interest rate and subsidy provided interim of tax rebate. Salvage value of system is assumed to be zero at end of expected life time of 20 years. The present solar still with proper maintenance can function for up to 20 years.

Results and Discussion

The average insolation hitting the surface of the still solar images varied between 4.0 and 7.0 kWh/m2/day and was assumed to be 4.4 kWh/m2/day in the calculations of the various parameters. Annual yields refer to experimental data for passive solar stills reported for climatic conditions in New Delhi (455 kg/year) [18], and the yield enhancement factors calculated by the authors are compared to the given relationship at the specified conditions. was estimated by multiplying by Solar design, still images were considered. The estimated annual yields of the various solar stills considered are shown in Figure 2.

It has been found to be the best solar still among hybrid photovoltaic (PVT) solar stills, with a maximum annual production of 1320.0 kg for the system. but. From an Evacuated Tube Collector (ETC) integrated solar operating in forced mode, the maximum annual energy yield per m2 of solar collector area was determined and found to be 501.0 kg/m2. This is higher than if the ETC integrated solar were still operating in natural mode. mode (i.e. 473.0 kg/m2). This is because effects such as internal recirculation and cold water stagnation in the reservoir are avoided, thus improving heat dissipation in forced mode. The traditional ETC model works in natural mode, but the two water streams move in opposite directions in the pipe, making it unfavorable for heat energy extraction. minimum productivity

618.0 kg was obtained from a solar distiller integrated with a flat plate collector and operated in natural mode.

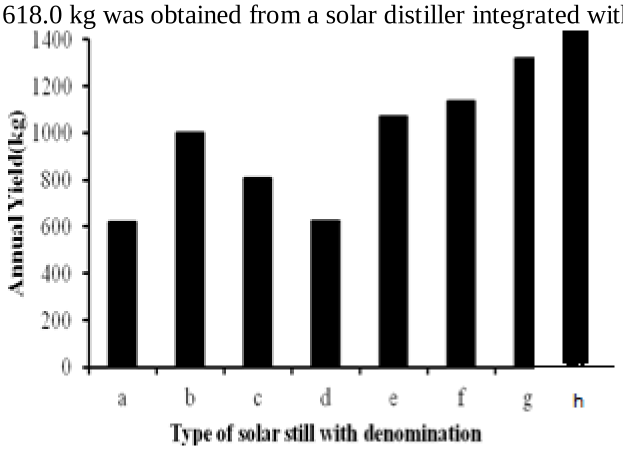


Figure 2: Average annual productivity from various design ofSolar still under reference

Fig. 3 Shows the Energy efficiency, computed for various design of solar still using equation given above. Highest annual efficiency of 26.3% has been found by using Solar still integrated with evacuated tube collector and operates in forced mode. This is due to reduction of thermal losses. The annual efficiency of Hybrid Photovoltaic Thermal (PVT) active solar still has been found to be 13.0%, However, overall energy efficiency has been found to be about 44.0% accounting the electrical conversion efficiency of PV module.

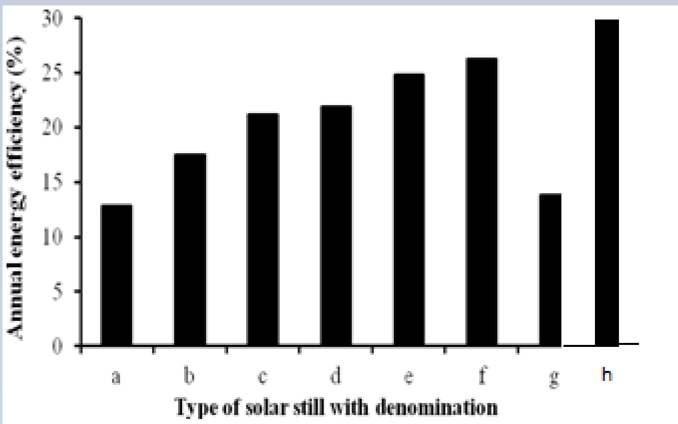


Figure 3: Average annual energy efficiency of various design ofSolar still under reference

Many factors affect the cost of distillate from a solar desalination plant. Capital and operating costs (and thus total cost) are influenced by unit size, location, water supply characteristics, required product water quality, etc. The main economic advantage of solar desalination is that it does not require much infrastructure and is easy to design, install, operate and maintain on site. A better economic return on investment depends on the production costs of distilled water and its applicability. An economic analysis of water desalination plants is given by Fass et al. [9], Tiwari [3] & Kumar and Tiwari [19]. The capital recovery factor (CRF), annual fixed cost (P), reduced capital factor (SFF), annual residual value (S), and average annual productivity (M) are the main calculations used in desalination unit cost analysis. is a parameter. Annual maintenance and operating costs are required for the solar distiller for regular brackish water injection, distilled water collection, cleaning of the glass cover, removal of adhering salt (scaling), etc. The deeper the water, the less often you fill the pool with water. As the system ages, so does maintenance work. Maintenance costs were therefore charged at 10% of the annual cost, or 2% interest over the 20-year useful life of each system. The cost of distilled water per liter (CPL) can be estimated by dividing the annual cost of the system by the annual yield of the solar distiller calculated using Equation [19].

Figure 4 shows the average distilled water cost for different types of solar stills. The results obtained show that the lowest cost of water production is achieved when combining solar with a parabolic concentrator (d), resulting in the lowest Rs. 0.90 per kg for less investment. Maximum production costs were estimated from a solar system with an integrated vacuum tube collector. The cost per kg in forced and natural mode is estimated at Rs. 2.01 and Rs. 1.76 respectively, though these systems are found to be more efficient compared to others. This is due to higher initial cost as well as maintenance cost required in ETC.

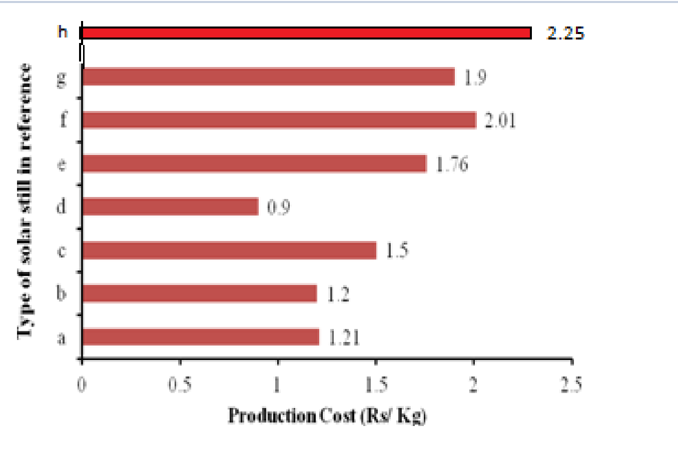


Figure 4: Production cost of distillate from various design ofSolar still under reference

It has been estimated from the Figs. 2 & 4, that that though the comparative annual yield obtained from the solar still integrated with ETC and operates in forced mode (f) is marginally higher (i.e. 6.0%) than that of Solar still integrated with ETC and operates in Natural mode (e), but is not advantageous in respect of production cost.

Conclusions

From the above review and economic analysis of various solar designs still in use today to improve productivity and efficiency, the following conclusions have been drawn.

(a) The maximum annual productivity of a Solar still- Tubular Solar Still is still 1350 kg. However, photovoltaic operation achieves a maximum annual yield of 575 kg/m2 of photovoltaic plant area. It remains active even in forced operation and is built into the tube collector. .

(b) The highest annual efficiency of 28.6% was found using a solar cell integrated into an evacuated tube collector and operated in forced mode.

(c) The highest annual efficiency of 29.3% was measured when the solar cell was integrated into a vacuum tube collector and operated in forced operation.

References

[1] P. Patel, R. Kumar. “Comparative Performance Evaluation of Modified Passive Solar Still Using Sensible Heat Storage Material and Increased Frontal Height”, 3rd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME2016, Procedia Technology, vol. 23, pp. 431 – 438, 2016.

[2] G. Xiao, X. Wang, M. Ni, F. Wang, W. Zhu, Z. Luo , K.Cen. “ A review on solar stills for brine desalination”, Applied Energy , vol. 103, pp. 642–652, 2013.

[3] G.N. Tiwari. “ Solar distillation practice for water desalination systems”, Anamaya Publishers (India), 2008.

[4] D. Singh, D. Pratap, S. maurya, D. P. Maurya. “Hygiene promotion & sanitation through solar distillation for safe drinking water in rural India”, International Journal of ChemTech Research, vol. 3 (1),pp. 51–57, 2011.

[5] S. N. Rai, G. N. Tiwari. “Single basin solar still coupled with flat plate collector”, Energy Conversion and Management, Vol. 23(3) , pp. 145–149, 1983.

[6] Y.P. Yadav. “Analytical performance of a solar still integrated wit a flat plate solar collector: thermosiphon mode”, Energy Conversion and Management, vol. 31(3), pp. 255–263, 1991.

[7] P.I. Cooper, “The maximum efficiency of single-effect solar stills”, Solar Energy, vol. 15, pp. 205-217, 1973.

[8] H.N. Singh, G. N. Tiwari. “Monthly performance of passive and active solar stills for different Indian climatic conditions”, Desalination , vol. 168, pp. 145– 150, 2004.

[9] H.E.S. Fath, M. El-Samanoudy, K. Fahmy, A. Hassabou. “Thermal- economic analysis and comparison between pyramid shaped and single-slope solar still configurations”, Desalination, vol. 159, pp. 69–79, 2003.

[10] K. Mukherjee, G. N. Tiwari. “Economic analysis of various designs of conventional solar stills”, Energy Conversion and Management, vol. 26, pp. 155–157, 1986.

[11] K. Sampathkumar, T.V. Arjunan, P. Pitchandi, P. Senthilkumar, “Active solar distillation—A detailed review”, Renewable and Sustainable Energy Reviews, vol. 14, pp. 1503–1526, 2010.

[12] O.O. Badran, H.A. Al-Tahaineh. “ The effect of coupling a flat plate collector on the solar still productivity”, Desalination, vol. 183, pp. 137–142, 2005.

[13] S.N. Rai, D.K. Dutt, G.N. Tiwari. “Some experimental studies of single basin solar still”, Energy Conversion and Management , vol. 30(2), pp. 149–53, 1990.

[14] S. Kumar, G.N. Tiwari. “Performance evaluation of an active solar distillation system”, Energy, vol. 21(9), pp. 805–818, 1996.

[15] Zeinab S. Abdel Rehim, Ashraf Lasheen. “Experimental and theoretical study of a solar desalination system located in Cairo, Egypt”, Desalination, vol. 217, pp. 52–64, 2007..

[16] R. V. Singh, S. Kumar, M.M. Hasan, M. Emran Khan, G.N. Tiwari. “Performance of a solar still integrated with evacuated tube collector in natural mode”, Desalination, vol. 318, pp. 25–33, 2013.

[17] S. Kumar, A. Dubey, G.N. Tiwari. “A solar still augmented with an evacuated tube collector in forced mode”, Desalination, vol. 347, pp. 15–24, 2014.

[18] S. Kumar, G. N. Tiwari. “Estimation of internal heat transfer coefficients of a hybrid (PV/T) active solar still”, Solar Energy , vol. 83, pp. 1656–1667, 2009.

[19] S. Kumar. “Thermal–economic analysis of a hybrid photovoltaic thermal (PVT) active solar distillationsystem: Role of carbon credit”, Urban Climate, vol.5,pp. 112–124, 2014.

[20] Arunkumar, T., et al. "Experimental study on various solar still designs." International Scholarly Research Notices 2012 (2012).