A comprehensive review on Enhancement heat transfer in solar stills by using external techniques.

Raghvendra Sharma[a*], Deepesh Bhardwaj[b], Shyam Singh Rawat[c], Ajeet Singh Sikarwar[d] , Neelam Baghel[e]

Mechanical Engg. Deptt., Institute of Technology management Gwalior, M.P., 474001, India

Abstract

Water is resuscitative to the life cycle and the provision of drinking water; it can hardly be overcome in the current years. The defiance for human being currently faces of filtered water and the lack of renewable energy. Solar energy is an undesirable way of converting palpable water into fresh water using extraordinary energy sources that are readily obtainable on marl. The main problem with the conventional basin is still that the production is very insignificant. The most notable design parameters that influence productivity are the optimization of solar radiation, evaporation area and water temperature. This paper intentions to give a comprehensive review about that the coalition of appropriate solar stills or improved designs that can favor the solar energy heat gain improves the overall performance of the system. Constructed on the current approach, a perspective conclusion has been made after the rich discussion with the help of distinctive information about the systems.

Keyword: solar still; distillation; heat transfer; solar radiation

1. Introduction

The world population and development of recent industry is increasing with a fast speed throughout the past years. the requests for freshwater and energy are growing quicker than ever. Freshwater is a necessity for different purposes like households use, agricultural use etc. To achieve this demand, necessity of fresh water is essential which is an important inevitability for human being for drinking and to subsist. About 97% of earth water is brackish remaining 2% is acquired by different glaciers and Antarctic region. So, 1% of the total available water is used drinking and all the household purpose [1]. Treatment of brackish water is typically desirable to meet water quality requirements for different beneficial applications. Renewable resources of energy can play the role of an effective alternative to the systems powered by fossil fuels. For being abundant, environmentally friendly, and inexpensive; solar energy is nowadays considered as a promising resource of renewable energy [2]. One of the economical and most energy-efficient traditions to eliminate salinities and other impurities from the brackish water by means of solar energy is by means of solar stills. Solar desalination process doing a very good and optimized process converting for saline and brackish water to unpolluted water. So, Interest for new desalination technology requires to meet the socioeconomic requirements which are increasingly day by day [3]. Complications related to water are abundant. They are so various that in a given nation there is no only solution for meeting the water demands. All substitute water supply solutions are proper use of water, water recycling and upgrading water distribution network to prevent leakage [4]. Solar distillation is analogous to the natural hydrological cycle. It uses a apparatus entitled Solar still where water is spread using solar energy and collected as distillation after steam condensation. The main advantage of this is the use of solar energy rather than electrical energy produced from conventional fuel. This helps in producing drinking water without undignified our environment. Over time, researchers have studied several solar designs to evaluate their concert for climate, operational, and design parameters [5].

2. Working Principle of solar still-

The solar still doohickies use the principles of greenhouse consequence for the evaporation and condensation of water. Numerous designs are possible as was reported in [5]. In a solar still, the radiation from the sun is received, and the received solar radiation provides adequate energy for evaporation of a part of the saline water in the basin. The evaporated water moves, and it is gathered on the top of the basin. Then, the gathered vapor loses its energy and returns to the liquid phase with this variance now, it is not brackish. The interior heat transfer in the still from sink water to condensing cover can take place in three ways mainly by convection, radiation, and evaporation.

3. Heat transfer law used in solar still-

3.1Convective heat transfers

The heat transfer inside the still takes place by free convection. This is because the actions of buoyancy force due to the disparity in density of humid fluid that occurs on account of temperature alteration in the fluid. The heat transfer rate of fluid from the basin water surface to condensing cover can be find by [6]

$Q_c = H_c (T_1\text{-}T_2)$ where- $H_c = 0.884 [(T_1\text{-}T_2) + (P_1\text{-}P_2)(T_1 + 273)/(268.9\times10^3 - P_1)]^{1/3}$.[7]

Radiative heat transfer

For a minor cover inclination and large size of the still, the water surface and cover are considered as parallel surfaces. The radiant heat transfer coefficient from the surface of the water to the cover is given by the following formulation [6].

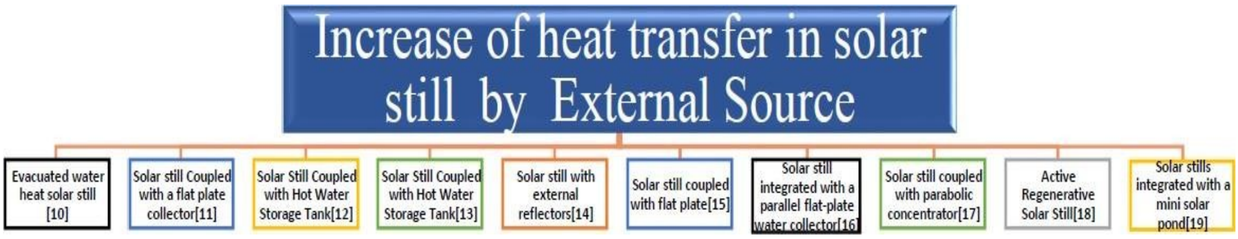
$Q_r = H_r (T_1 – T_2)$ where- $H_r = \varepsilon_{eff}\,\sigma[(T_1 + 273)^2 + (T_2 + 273)^2] [T_1 + T_2 + 546]$.[8]

Evaporative heat transfer-

$Q_e = H_e (T_1\text{-}T_2)$ where- $H_e = 16.273\times10^{-3} H_c (P_1\text{-}P_2)/(T_1\text{-}T_2)$.[9]

The total heat transfer coefficient from the surface of the water inside to the condensing shelter is given by the following equation = $h_c + h_r + h_e$

Studies of heat and mass transfer phenomena, inside the solar still are of great fundamental and practical importance for engineers and scientists of the field. To the best knowledge of the authors of this paper, there are not enough investigations about the different method of heat transfer existing between the saline water free surface and the condensing cover. The aim of the paper is to present a comprehensive investigation concerning on different parameter those are affecting heat transfer in solar still. This will useful for readers and researchers to find the information at a glance in concise manner.



4. Review on Different parameter affecting heat transfer phenomena in solar still.

Table-01. shows a complete summary of design modification for different solar stills.

Table-01. Categorization of different types of solar still.

Authors	Type of Still	Design parameters	Testing place	Result
Z.M. Omara et et al. [10]	The active types solar stills	An Evacuated solar water heater coupled with wick solar still for continuous desalination	Kafrel,sheikh University, Egypt	the water productivity by about 215% as compared to conventional basin still. The daily average efficiency of DLSW was 71.5%.
G.Tiwari et et al. [11]	The active types solar stills	Advancement solar collector and basin area to increase production of an active solar distiller	Delhi, India	the yield improved with increase of number of collectors, as expected, due to more heat transfer from the collector panel into the basin.
V. Belessiotis. [12]	Single-effect solar still of greenhouse type.	A Solar Still Coupled with Hot Water Storage Tank	NCSR, Demokritos	Raising the temperature of the water in the still basin is one of the most efficient ways to greatly increase the productivity of a solar still.
A. E-Bahi [13]	Single Basin Solar Distiller.	A Very low inclined solar power is still connected to the external capacitor	Ankara, Turkey	Increased efficiency by 75%. When operating solar power without a condenser, the yield can be reduced by up to 70% using a condenser.

H.Tanaka [14]	a single slope basin-type solar still	A basin type solar still with external reflectors	Kurume, Japan	The daily water production of a basin type still can be enhanced approximately 70% to 100%.
A. Badran[15]	a conventional-type solar single-stage basin type solar still.	A solar still augmented with a flat-plate collector	Amman, Jordan	An extracted water production was augmentation by 231% in the case of tap water as a feed and by 52%
A. Prasad [16]	a conventional-type solar single-stage basin type solar still.	A solar still integrated with a parallel flat plate solar collector.	Delhi, India	a flat plate collector to achieve distillation of brackish water at high temperature. The water temperature obtained by the proposed system lies well within the temperature range (T~, > 50°C) usually required for high temperature solar distillation.
ZA-Rehim [17]	a conventional-type solar single-stage basin type solar still.	A Single slope still coupled with parabolic concentrator.	Cairo, Egypt	A productivity distilled water is augmented by an average of 18%, due to the changes.
G. Tiwari [18]	a conventional-type solar single-stage basin type solar still	an active regenerative solar still	Delhi, India	Thermal efficiency rises with rise of flow rate due to fast evaporation from the basin water surface at inferior glass temperature.
K. Srithar [19]	a conventional-type solar single-stage basin type solar still	Solar stills integrated with a mini solar pond	Tamil Nadu, India	When using the sponge solar still in combination with small solar pond, the daily production of distilled water increases significantly.

Evacuated water heat solar still-

Z.M. Omara et al. [10]. deal with an evacuated tube solar water heater Shown in Fig.01 was cast-off to heat up the feed water to the wick still in the night, and also, may be used in case of clouding the sun during the daytime. The averaged fed cold and hot water temperatures during day and night-time were 24 °C and 55 °C shown in Fig.02 respectively at corresponding ambient temperature ranged of 15–28 °C. In case of DLSW still, Earlier, there was a 215% increase in the total distillate. When using warm water throughout the day or at night.

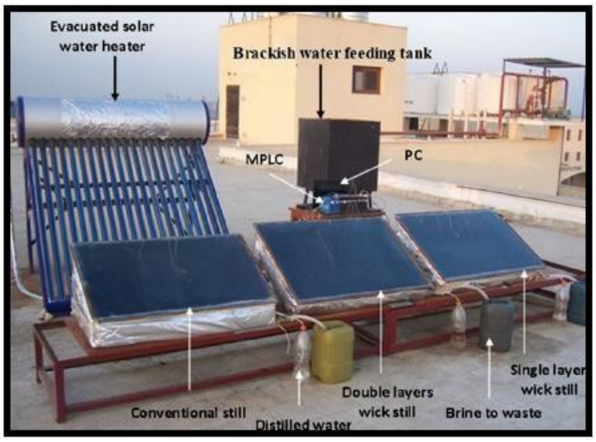


Fig.01- Photograph of Evacuated water heat solar still [10].

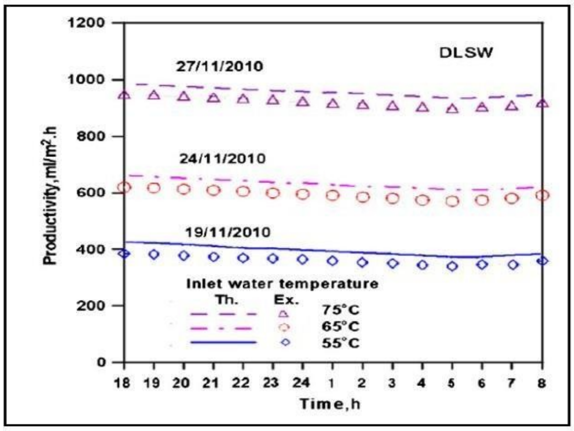


Fig-02. Hourly variation of productivity per m^2 [10].

Solar still Coupled with a flat plate collector-

Tiwari et al. [11] developed a collector/basin area Shown in Fig.03 for a given climatic condition and for given weather conditions and other design parameters. Because the basin has a large storage capacity for water, the water temperature decreases. Therefore, there are reductions in the variation of the internal heat transfer coefficients and the yield the effect of the number of collector areas on the hourly yield is shown in Fig. 4. The yield will increase with make bigger of variety of collectors, as expected, due to extra warmth switch from the collector panel into the basin.

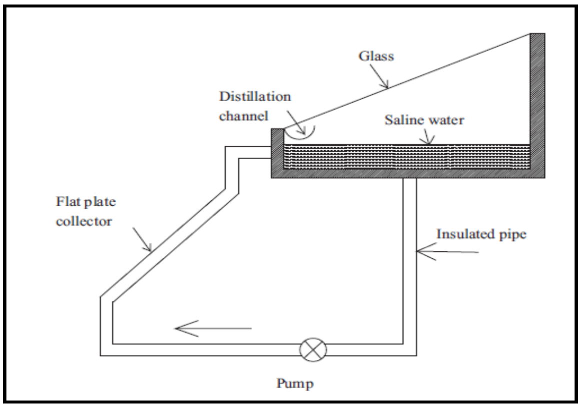


Fig.03- Solar still Coupled with a flat platecollector [11]

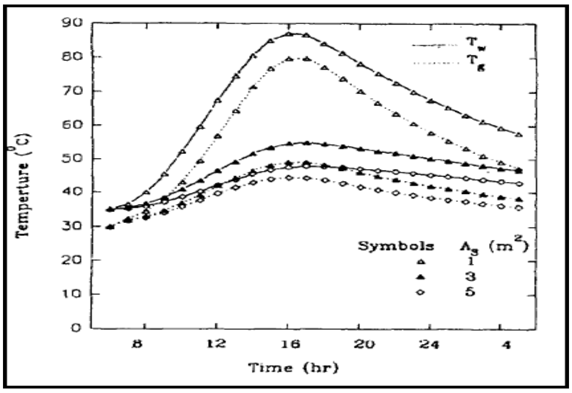


Fig.-04 variation with water and glass temperature [11].

A Solar Still Coupled with Warm Water Storing Tank-

V. Belessitis et al. [12] Make sure that Heat transfer of a hot water tank with a basin, as exposed in the figure. 05 The thermal behaviour of the system is tested by several measuring devices and the temperature of the brine does not change at the temperature level unlike the ambient temperature. Initially, as shown in Figure 06, this design is designed to produce more water when the water temperature is higher, but it makes more sense to change the output of water overnight. Also, during this period, water production was almost continuous. It has also been reported that a solar panel with a hot water tank always changes all solar behaviour, so in a solar connection system, the solar connection always acts as a condenser wave rather than a collection unit. Extract energy, survey data. For distilled water and overnight production, these are related to the sun-absorbed water, and storage tanks are always maintained.

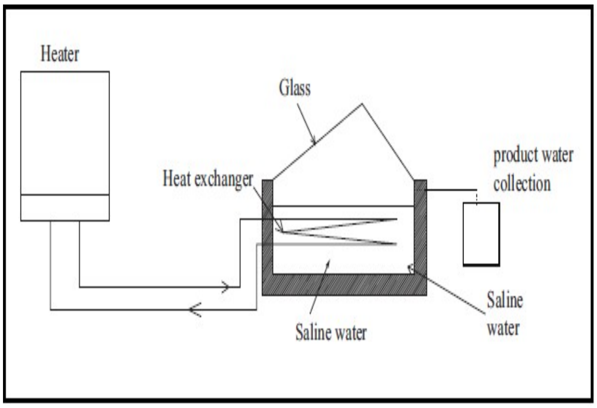


Fig: -05 Solar Still Coupled with Hot Water Storage Tank [12]

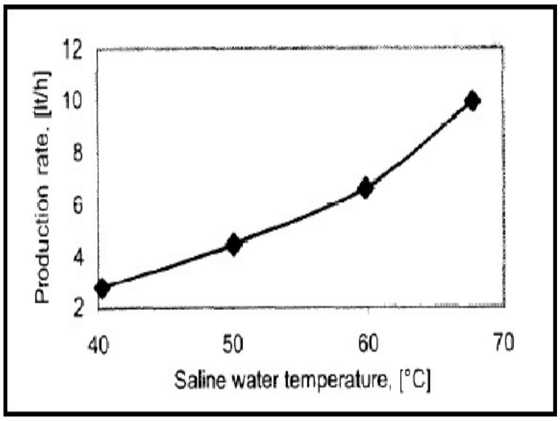


Fig: -06 A Variation of solar still production rate with basin water temperature [12]

A Solar Still Coupled with Hot Water Storage Tank-

Bahi et al. [13] Developed an adapted basin-type solar still with external Condenser Shown in Fig.06. that Purging a fraction of vapor to the combined condenser reduces the pressure inside the evaporator and the creation of vapor droplets on the innermost glass surface, and later the reflection and absorption of the solar radiation are reduced, i.e., more solar energy is transmitted to the water, the glass temperature is also lowered and evaporationis improved Shown in Fig.07. Solar efficiency has always been better at more than 70% and distilled fresh waterwas up to 71 / m^2.d.

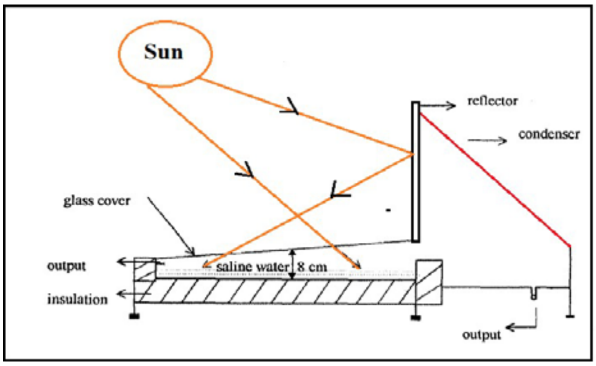


Fig. 07. solar still with, coupled with outside condenser [13]

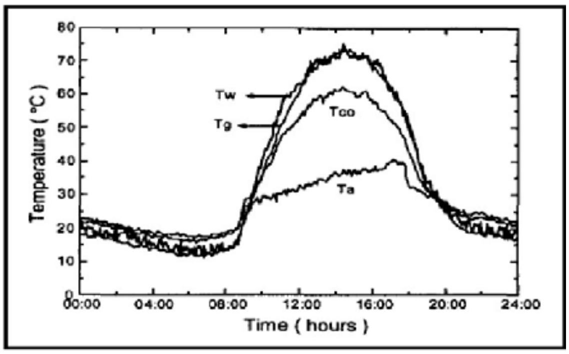


Fig. 08. Various Temperature variation, vs. time [13]

A basin type solar still with external reflectors-

H. Tanaka [14]. was constructed An Active type solar still with exterior reflectors Shown in Fig.09. The external reflection is slightly tilted forward and reflected sunlight shines most effectively on the basin lining as shown in Fig.10. The daily production of water of a basin type can further be reinforced by about 70% to 100%.

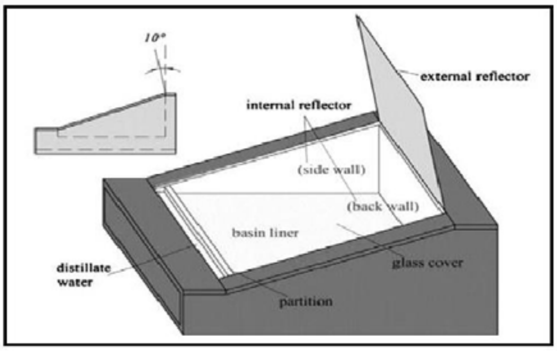


Fig.09-Single slope solar still with external reflector [14].

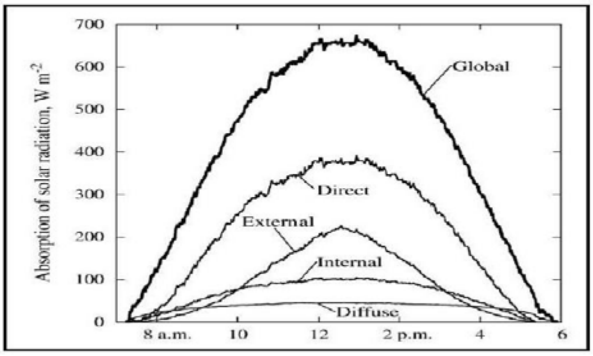


Fig.10-Hourly variations of global solar radiation [14].

Double slope still coupled with flat plate: -

Badran et al. [15] was structured a system that combines a single basin solar type and a classic flat-plate collector were set together shown in Fig.11 Since Aditus is always connected to a locally made pipe accumulator, its leak will be introduced into the standard basin instead of the public storage tank. As shown in Fig. 12, temperature, solar power, and filtered water are measured for several days under different operating conditions. These estimates are made 24 hours a day, always connected to the collector and using tap water and salt water as sources of energy. Pump water production using tap water increased, and the water supply increased by 231% pumped water and 52% salt water.

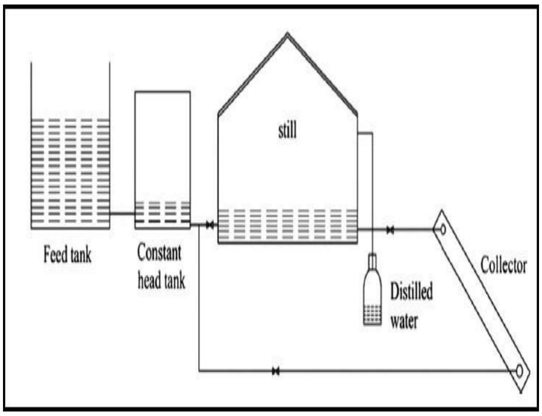


Fig.11-Double slope still coupled with flat plate [15].

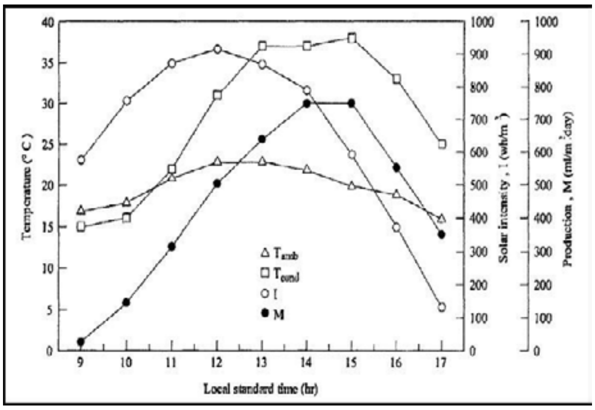
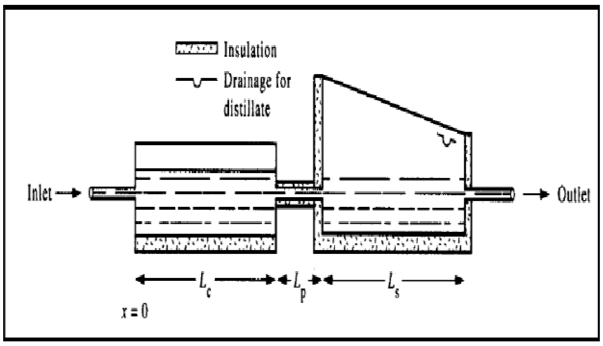


Fig.12- Various parameter and production vs. Time [15]

Solar Still combined with a parallel flat-plate water collector: -

A.Prasad et al. [16] Solar performance analysis with parallel flat solar collectors. Filtration occurs at high temperatures as shown in Fig. 13. The water temperature obtained by the proposed system lies well within the temperature range (T~, > 50°C) usually required for high temperature solar distillation. The water temperature can further be increased by decreasing the water mass/water Shown in Fig.14 depth in the basin of the still. it is envisaged that the proposed system, for high temperature solar distillation, would also be cost effective as compared to that employing a flat plate collector. The explicit analytical expressions are useful for investigating the effects of the still's and collector's parameters on the performance of the system.



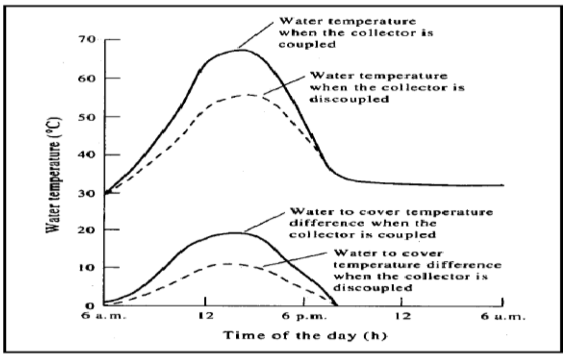
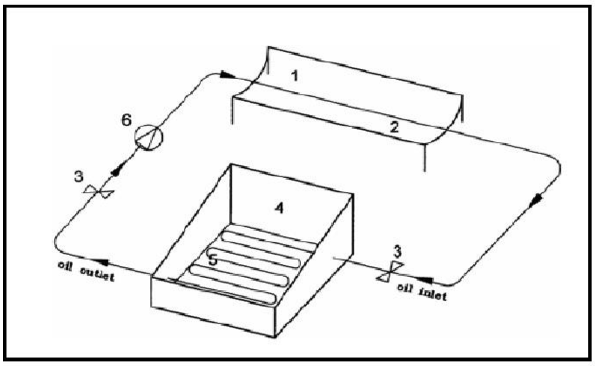


Fig.-13 Diagram of a solar still united with a parallel flat-plate water collector [16]

Fig.-14 Hourly variation of water temperature. and water-to cover temperature difference [16]

A Single slope still coupled with parabolic concentrator.

Zeinab S. Abdel-Rahim et al. [17] was developed a solar parabolic trough with focal conduit and simple heat exchanger Oil Shown in Fig.15 is designated as working fluid. The oil has high thermal properties. The modified unit is used in the sun and night. The proposed photosynthetic desalination system is expressed using the energy balance equations of the various components of the thermal analysis system shown in Fig. 16. You can use the functional similarities of PV desalination systems compatible with traditional PV desalination systems. Determination of financial audit of current firm. Results suggest that this improvement increases freshwater productivity by an average of 18%.



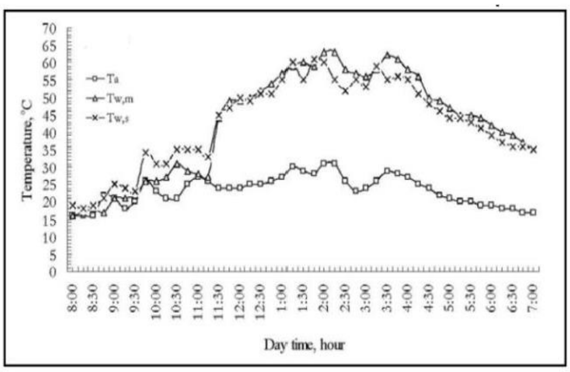


Fig.15.Single still coupled with parabolic concentrator [17]. Fig.16.Variations of ambient temperature and basin water [17]

Active Regenerative Solar Still.

Tiwari et al. [18] consists of a continuous flow of water from the main tank over the glass cover of the solar still Shown in Fig.17. Thus, the glass cover being warm due to latent warmness of condensation from its bottommost is made cool by relatively cold water flowing over it. The hot water leaving the glass cover can be fed to the basin so that the temperature of basin water can be higher up. This method of cooling the glass cover and hence cumulative the rate of evaporation is called 'regeneration'. Their outcomes presented that passive solar regenerative still have innovative efficiency than active ones but in either case with the rise in water flow over the glass cover, the thermal yield was initiate to be enhanced Shown in Fig.18.

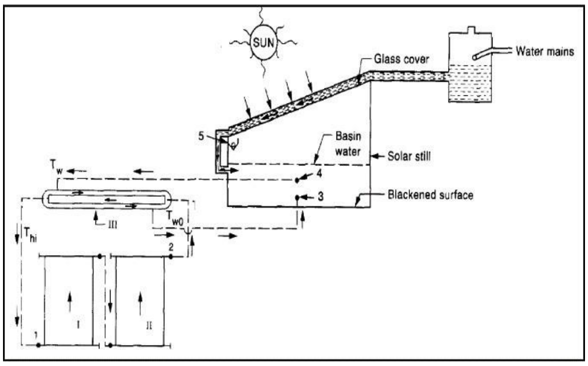


Fig.17- an active regenerative solar still [18].

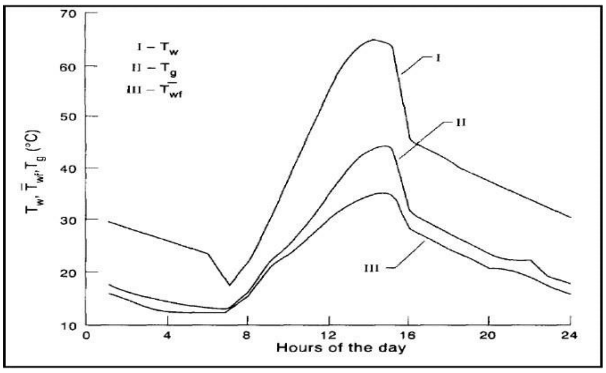


Fig.18-hourly variation of the various temperatures [18].

Solar stills integrated with a mini solar pond-

Sridhar [19] has been established a combination of a solar mini-pond with solar always shown in Fig.19. they often use small solar water pools and integrated sponges to perform many experiments with normal filtered water yields. When the sponge joins the sun with the mini solar pool shown in Fig.20, the steady daily production of filtered water begins to increase significantly. Also, a theoretical investigation is associated with experiments. The results obtained from the theoretical analysis give very good agreement with the experiments. The extreme deviation of the theoretical analysis is a reduced amount of than 10% of the experimental investigation.

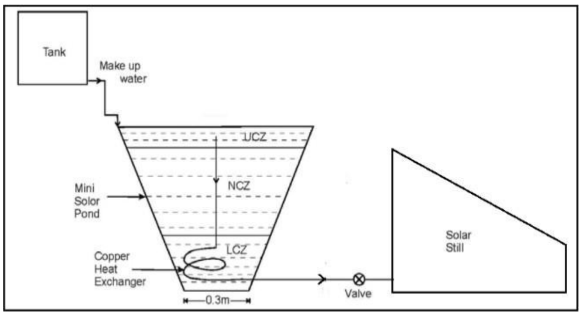


Fig.19 Solar stills integrated with a mini solar pond [19].

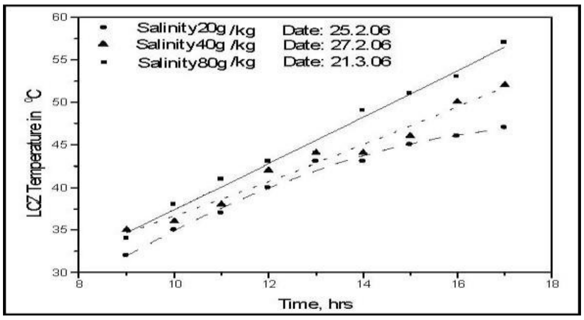


Fig.20.Effect of varying salinity in the pond temperature [19].

Conclusion-

The purpose is to illuminate their improvement of transferred heat energy and Productivity. The productivity of a solar still is directly allied with the amount of solar radiation, the surrounding temperature, water temperature and evaporation area of solar stills. The following conclusions are perceived Based on the above study:

- It was observed that the Evacuated solar water heater and wick solar still had a faster response to incident solar radiation, higher operating temperatures, and higher efficiency than a basin-type solar still. The continuous feeding of hot sailable water, especially overnight, increased water productivity by approximately 215% compared to the conventional still.
- It was detected that water temperatures diminution with a growth of the basin area due to the enormous storage capacity of the water mass in the basin. Therefore, there are reductions in the variation of the internal heat transfer coefficients and the yield the effect of the number of collector areas on the hourly yield. It is clear that the yield increases with increase of numeral of collectors, as predictable, due to additional heat transfer from the collector panel into the basin.

- The inclination of the glass cover was minimized, and the unit responded to solar radiation in less time; the water temperature and evaporation rate were also enhanced. The efficiency of the solar still was improved up to more than 70%, and the distilled fresh water was up to 71/m^2. d.

- The external reflection is slightly tilted forward and the reflected sunlight shines from the most effective position at the end of the basin. A simple alternative to external reflectors can increase the daily production of some types of basins from 70% to 100%.

- a flat plate collector to achieve distillation of brackish water at high temperature. The water temperature obtained by the proposed system lies well within the temperature range (T~, > 50°C) usually required for high temperature solar distillation.

- When the spongysolar is still is also added to a small solar pool, it begins to significantly increase normal daily production of distilled water.

References

[1] Velmurugan.V, Gopalakrishnan.M, Raghu.M, Srithar.R, Single basin solar still with fin for enhancing productivity, Energy Convers. Manage. 49 (2009) 2602–2608.
[2] Alhusseny.A, Al-Zurfi.N, Nasser.A, Al-Fatlawi.A, and Aljanabi.M, "Impact of using a PCM573 metal foam composite on charging/discharging process of bundled-tube LHTES units," Int. J. 574 Heat Mass Transf., vol. 150, p. 119320, 2020.
[3] Belhadj.M.M, Bouguettaia.H, Yacine Marif, Moussa Zerrouki. Numerical study of a double-slope solar still coupled with capillary film condenser in south Algeria. Energy Convers. Manage. 94 (2015) 245–25.
[4] Nisan.S, Benzarti.N, A comprehensive economic evaluation of integrated desalination systems using fossil fuelled and nuclear energies and including their environmental costs, Desalination 229 (2008) 125–146.
[5] Ray.C, Jain.R, drinking water treatment, Focusing on Appropriate Technology and Sustainability, Springer, 2011.
[6] Phadatare.M, Verma.S, Solar Distillation Practice for Water Desalination Systems plastic solar still, Desalination 217 (2007) 267–275.
[7] Dunkle.R, Solar water distillation, the roof still and multiple effect diffusion still, International Development in Heat Transfer, ASME, Proc. International Heat Transfer, Part V, University of Colorado, 1961.
[8] Sharma.V and Mallick.S, Estimation of heat transfer coefficients, upward heat flow and evaporation in a solar still, Trans. ASME (Solar Energy), 113 (1991) 36.
[9] Malik.M, Tiwari.G, Kumar.A and Sodha.M, Solar Distillation, Pergamon Press, UK, 1982.
[10] Omara.M , Eltawil.M , E. ElNashar . A new hybrid desalination system using wicks/solar still and evacuated solar water heater, Desalination 325 (2013) 56–64.
[11] Kumar.S, Tiwari.G. Optimization of collector and basin areas for a higher yield for active solar stills, Desalination 116 (1998) 1-9.
[12] Voropoulos.K, Mathioulakis.E, Belessiotis.V. Experimental investigation of the behaviour of a solar still coupled with hot water storage tank, Desalination 156 (2003) 3 15-322.
[13] Bahi.A, Inan.D, A solar still with minimum inclination, coupled to an outside condenser, Desalination 123 (1999) 79-83.
[14] Tanaka.H, Experimental study of a basin type solar still with internal and external reflectors in winter, Desalination 249 (2009) 130–134.
[15] Badran.A , Hallaq.A , Salman.E , Odat.M. A solar still augmented with a flat-plate collector, Desalination 172 (2005) 227–234.
[16] Yadav.Y and Prasad.A , performance analysis of a high temperature solar distillation system, energyconvers. mgmt. (1995) 365-374,
[17] Zeinab.A, Ashraf.L. Experimental and theoretical study of a solar desalination system located in Cairo, Egypt. Desalination 217 (2007) 52–64.
[18] Tiwari.G, Sinha.G, Parametric studies of active regenerative solar still. Energy Convers Mgmt. 34(3), (1993) 209–218.
[19] Velmurugan.V, Srithar.K, Solar stills integrated with a mini solar pond — analytical simulation and experimental validation, Desalination 216 (2007) 232–241.