Researchers and Reviews on Active Solar Distillation System

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Abstract— Solar distillation is one of the most promising technologies for supplying potable water. Simply due to its lower productivity, it has limited application. Only, when solar distillation is coupled with any mechanical source, then it increased productivity. Such, the device is called active solar still. The present review paper shows researches done on a solar distillation system for increment in distillate output.

Key words: solar still, active solar still

I. INTRODUCTION

Water is essential for the survival of all living things. Three quarters of the earth's surface is covered with water, and through a process called the hydrologic cycle it is distributed to most of the land masses. The hydrologic cycle is simply the evaporation and precipitation of water supplied from the oceans, surface water, and transpiration of plants. The evaporated water condenses into clouds, which are carried away by winds to different locations and eventually released in the form of rain or snow. The hydrologic cycle is continuously repeated and is powered from the solar energy, which causes water evaporation and moving the wind. As the water falls through the atmosphere, it may dissolve gases and accumulate fine particles such as soot and factories emissions. Reaching the ground, the water will pick up organic materials, minerals and clays. Surface water is highly affected by seasonal changes. The water temperature as well as the composition may vary considerably with time over the year. During summer months, bacteria will grow more readily. In cold climate during winter months, the solid contents of surface water are increased due to ice formation. During autumn, decaying of organic matter such as leaves increases the organic matter concentration in the surface water.

Mehsana is located in the North Gujarat region. It is a best place for the research on solar energy. Hence, some researchers have done on solar still. [1-19]. Researches on active solar distillation are listed below:

II. ACTIVE SOLAR DISTILLATION SYSTEM

A. Flat Plate Collector (Natural Circulation Mode)

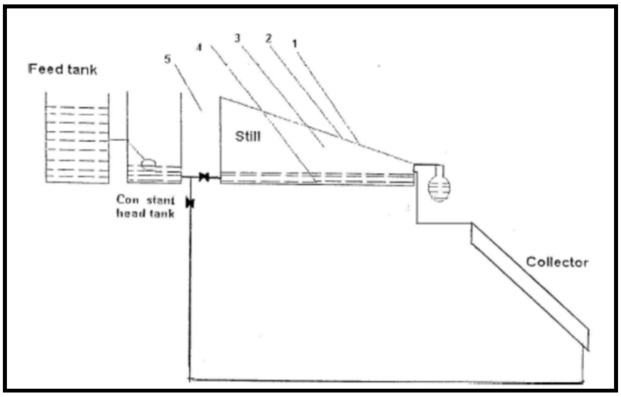

Fig.1 A schematic diagram showing the arrangement of the still-collector systems [20].

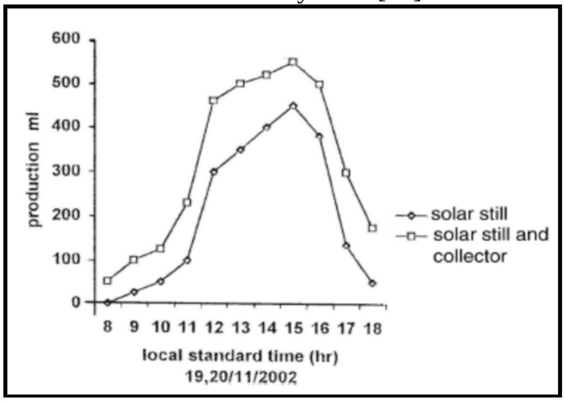

Fig. 2 Comparative variation of still productivity [20]

O.O. Badran et al [20] the effect of coupling with a flat plate solar collector on the productivity of solar stills was carried out. The increase of water depth has decreased the productivity, while the still productivity is found to be proportional to the solar radiation intensity. Comparison of the output between coupled and stand-alone still was studied. It was found that the productivity of the coupled still is found to be 36% higher than the still alone. It can be concluded that, the present still design leads to higher distilled water output due to higher basin water temperature.

B. Flat Plate Collector (Forced Circulation Mode)

S.N Rai et al [22] the daily distillate production of a coupled single basin still is 24% higher than that of an uncoupled one. S. N. Rai et al [23] the water is circulated between the collector and the still by the thermosyphon method. It is clear that the rate is much more in the mode of operation using jute cloth and small dye than without jute cloth. The maximum increase in this case is 35%.The increase in the rate of distillation is 50% more than the thermosyphon mode and 120% of the simple single basin solar still. From the fig 4, it is clear that there is an optimum value of water mass for maximum daily distillate, which is 6.75 kg m^2 for the month of October.

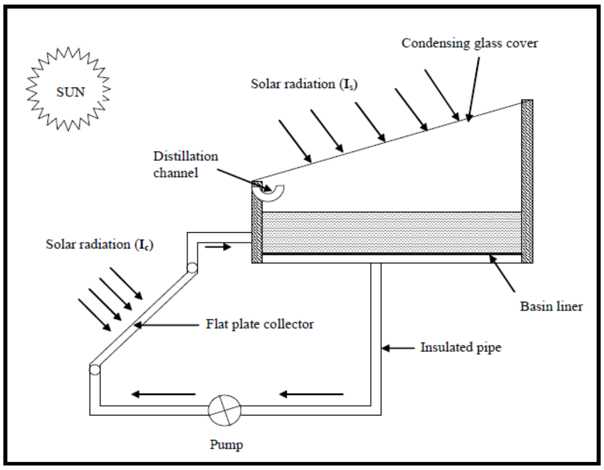

Fig.3 Single basin solar still coupled with flat plate collector [21].

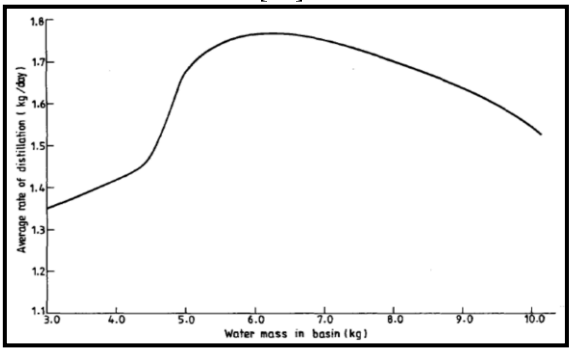

Fig. 4.Variation of rate of distillation with basin water mass [23]

C. Double Effect Solar Still Coupled With Flat Plate Collector

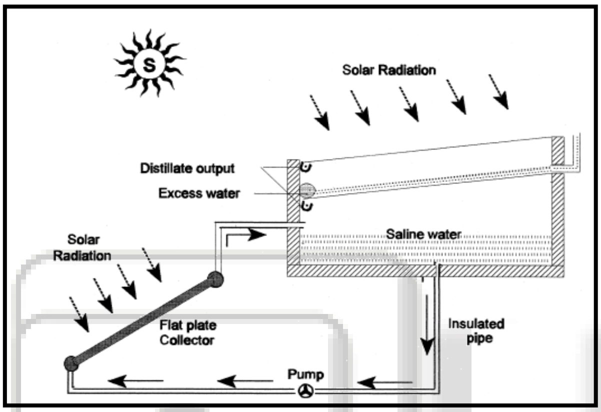

Fig: 5 Double effects solar still coupled with flat plate collector [24].

Sanjeev Kumar et al [24] in this case, the latent heat of condensation is utilized for further distillation by flowing water over the first condensing cover. The effects of collector area, flow rate, basin area, water depth etc. on daily yield have been presented for a typical day of Delhi climate conditions. In Fig.6 indicates a higher yield from the lower basin. The maximum yield of 3.34 kg/m2/h at noon from the lower basin is due to the high water temperature of 95^0C at that time. This hourly yield is only possible in the active mode of operation and hence commercially economical. The yield from the upper basin is much lower in comparison to the lower basin. In fig.7 the storage effect in the basin increases as the water depth increases, and hence, the overall water temperature decreases for a given amount of solar energy. Because of the low operating temperature, the rate of evaporation also decreases, and hence, the daily yield and thermal efficiency decrease.

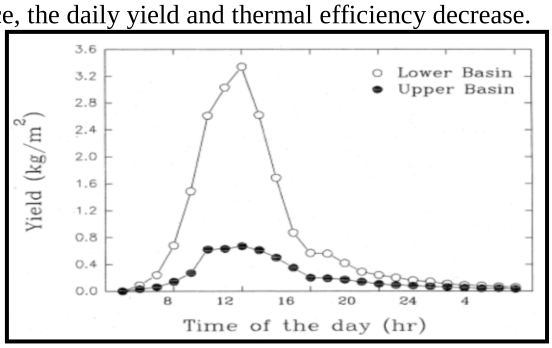

Fig. 6 .Hourly variation of yield in lower basin and upper basin [24]

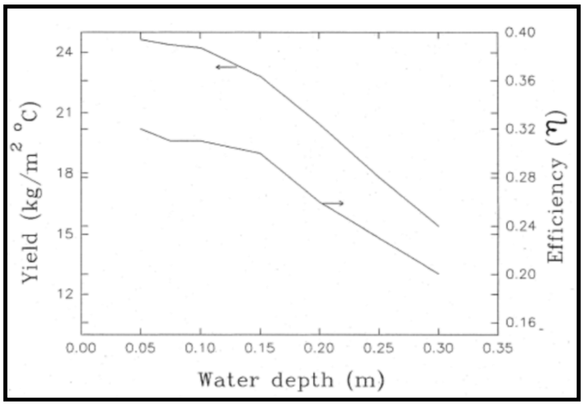

Fig. 7 Variation of daily yield and efficiency vs. lower basin water depth [24]

Sanjeev Kumar et al [25] an average of 7.5 liters of distilled water per day can be obtained in the active mode with the water flow arrangement over glass. In the passive and active modes without arrangements for water flow, average outputs were 2.2 and 3.9 liters of distilled water per day, respectively.

D. Single Basin Solar Still Coupled With Evacuated Tube Collector

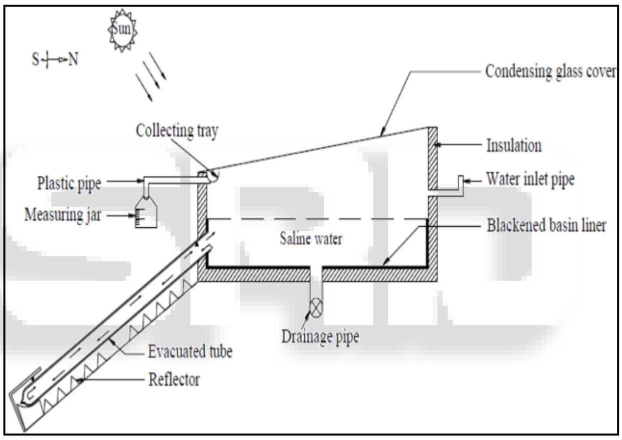

Fig. 8: Single basin solar still coupled with evacuated tube collector [26]

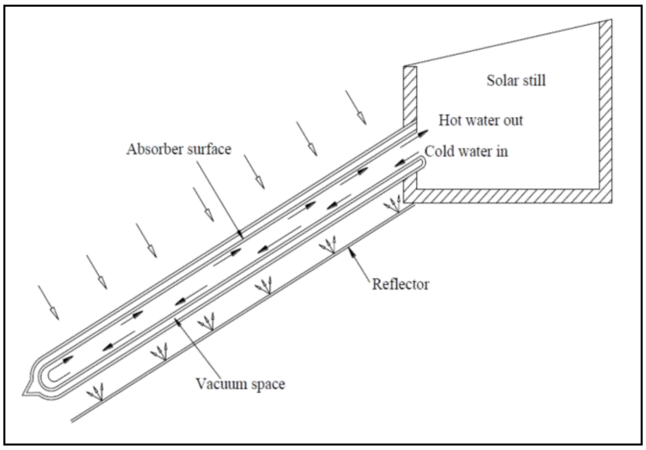

Fig: 9. Evacuated Tube Arrangement [26].

Syed et al [26] presented the performance of an ordinary still was compared with the still coupled with evacuated tubes. It was found that the daily productivity has increased to 50.2 % by coupled with the evacuated tubes. Due to simplicity, low cost, less energy losses and high performance, the evacuated tube used for high temperature distillation when compared to the flat plate collectors. To increase the evaporation rate in an active mode the extra thermal energy is fed into the basin.

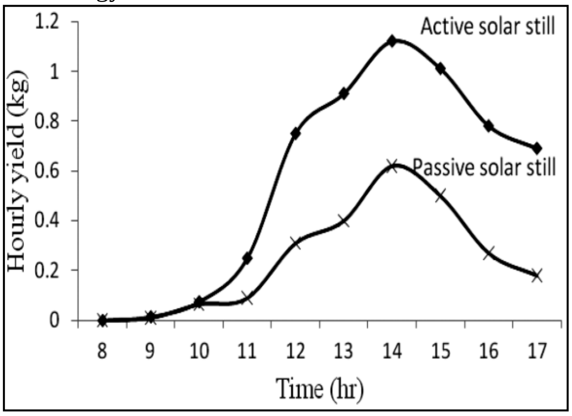

Fig: 10 Hourly variation of yield in an active and a passive solar still [27]

K. Sampathkumar et al [27] concluded that the distilled water yield is increased in an active solar still by 129% during the day time and 83% during night time than compared to a passive solar still. The maximum daily production of 7.03 and 3.225 kg are obtained from active and passive solar stills, respectively, at a water depth of 0.04 m. The active solar still is more efficient than the passive solar still throughout the year. However, the average monthly yield of the active solar still is higher in the winter than the summer.

E. Single Basin Solar Still Coupled With Evacuated Tube Collector in Forced Mode

Shiv Kumar et al [28] present in a single slope solar still with an evacuated tube collector and operates in forced mode. The daily yield has been obtained as 3.47 kg for basin water depth 0.01 m and at mass flow rate of 0.006 kg/s. The optimum daily output has been obtained as 3.9 kg with energy and energy efficiencies as 33.8% and 2.6% respectively during typical summer. The average annual output per unit of solar collector area has been estimated higher than the natural mode. However, the optimum performance has been found to be at mass flow rate of 0.06 kg/s for basin water depth 0.03 m.

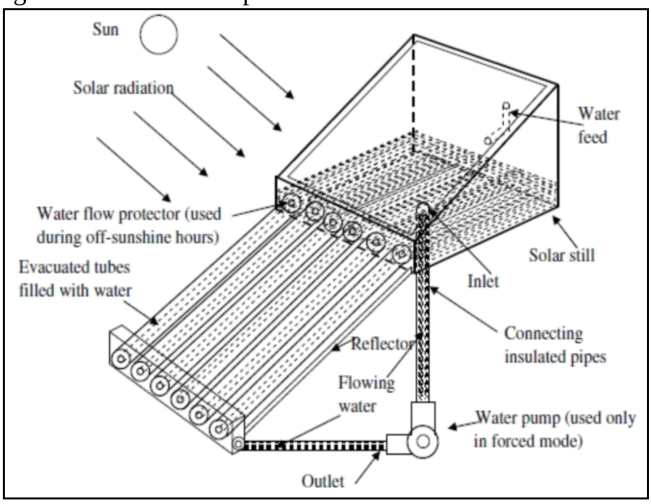

Fig: 11 Schematic diagram of EISS solar still in forced mode [9]

F. Double basin solar still coupled with evacuated tube collector

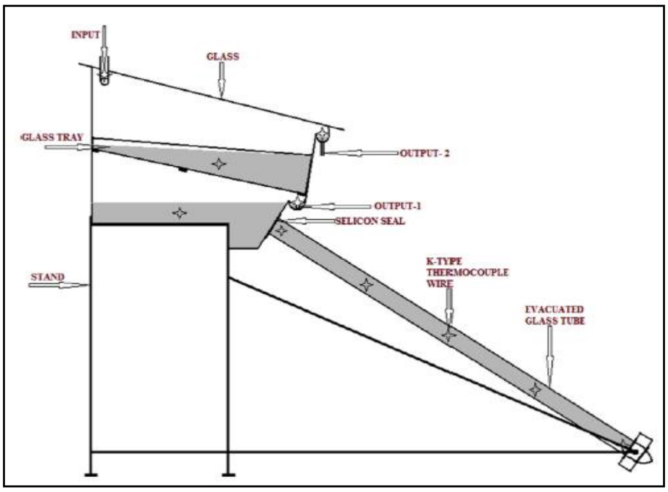

Fig: 12.Experimental set up of solar still coupled with vacuum tubes [29].

Hitesh N Panchal et al [30] in this research work the distillate output of the solar still depends on the depth of water in the lower and upper basin. During daytime, the distillate output of lower depth is higher, but in the case of nocturnal production, a reverse output is obtained. The maximum daily distillate output of 11.064 kg is obtained from the solar still at a depth of 0.03m.Solar still is efficient to obtain the average distillate output of 8 kg. This types of solar still, latent heat of condensation of the lower basin is utilized to heat water of the upper basin and hence the distillate output.

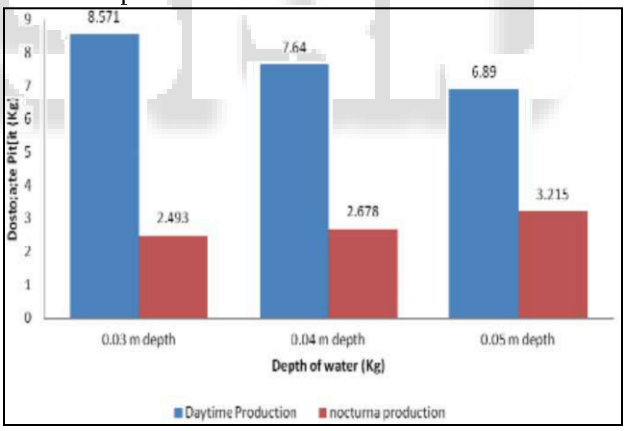

Fig: 13.Day and nocturnal production of the distillate output of the solar still [30].

Hitesh N Panchal et al [30] Figure 13 shows the day and night yields of the present solar still at various depths during 15 May of the experiment. It has been observed that a higher daytime distillate output (during morning 7:00 am to 17:00 pm) was obtained by 0.03m depth followed by 0.04 and 0.05 m, respectively. But during night time (18:00 pm to 06:00 am), the distillate output obtained by 0.05m depth was found more compared with 0.04 and 0.03 m. The reason is an increment in the distillate output during the night is a reverse effect of higher water depth inside the solar still.

G. Pyramid-Shaped Active Solar Still

Ali Kianifar et al [31] presented one of them was equipped with a small fan (active system), to enhance the evaporation rate while the other one was tested in passive condition (no fan). So finally to examine the effects of radiation and water depth on exergy efficiency, experiments in two seasons and two different depths of water in the solar still basin were performed. The cost of fresh water per liter for an active solar system is roughly 8-9% lower in comparison with the passive unit. Using a small fan in a pyramid-shape solar still result in 15-20% increase in daily productivity of fresh water. In summer, the exergy efficiency for active system is higher than passive while in winter the exergy efficiency is nearly the same for both systems. In Fig: 15 show the results for both passive and active systems have lower productive cost in comparison with other solar stills, except the single slope type system.

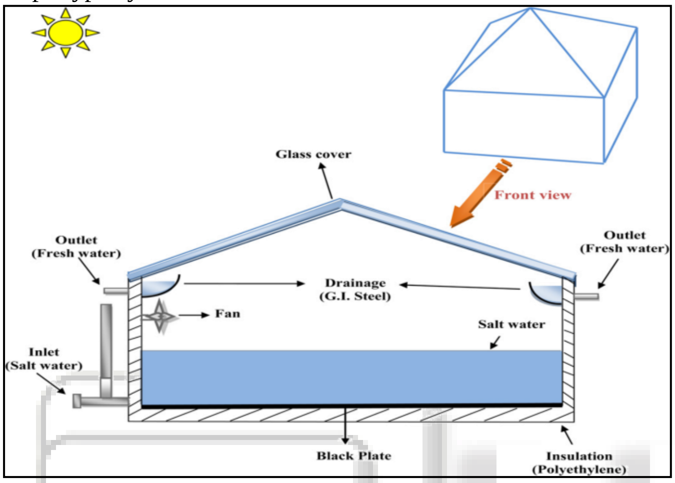

Fig: 14.Schematic of the active solar still [31]

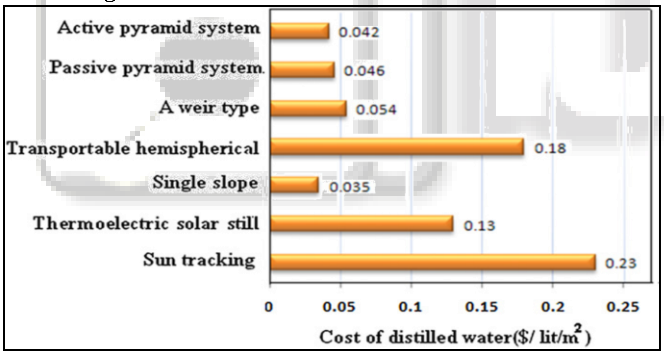

Fig: 15. Comparison between different solar stills and the present work [31]

H. Solar Still Coupled With Parabolic Concentrator

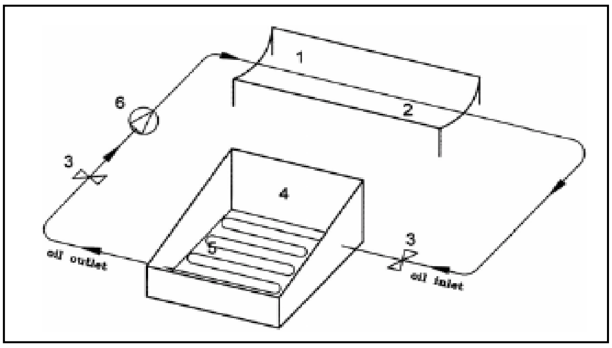

Fig: 16 solar still coupled with parabolic concentrator [13]

Zeinab S. Abdel-Rehim et al [13] the parabolic shaped concentrator or solar collector concentrates the incident solar radiation on large surface and it focuses on to a small absorber or receiver area. The performance of concentrators is much affected by the sun tracking mechanism. The tracking mechanism should move the collectors throughout the day to keep them focused on the sun rays to achieve the higher efficiency. These types of solar collectors reach higher temperature compared to flat plate collectors owing to reduced heat loss area. The fresh water productivity is increased by an average percentage of 18%, according to the modification design. The results show that, as time goes on, all the temperatures increase and begin to decrease after 4.00 pm with respect to the solar radiation, although the temperature values of the modified system are still higher than the conventional one. Fig :17 show that fresh water productivity for modified solar still is higher than conventional still.

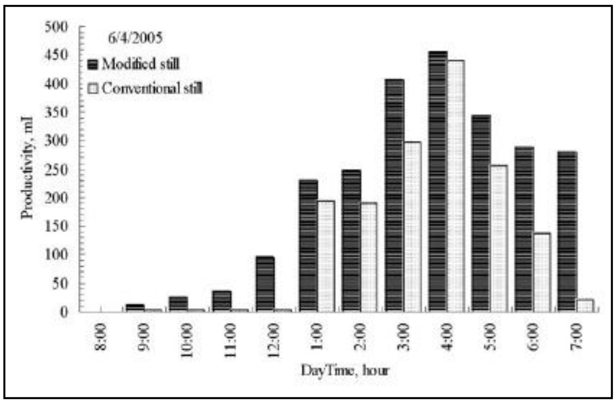

Fig.17. Fresh water productivity for the conventional and modified solar stills [32]

I. Double Effect Solar still coupled with parabolic concentrator

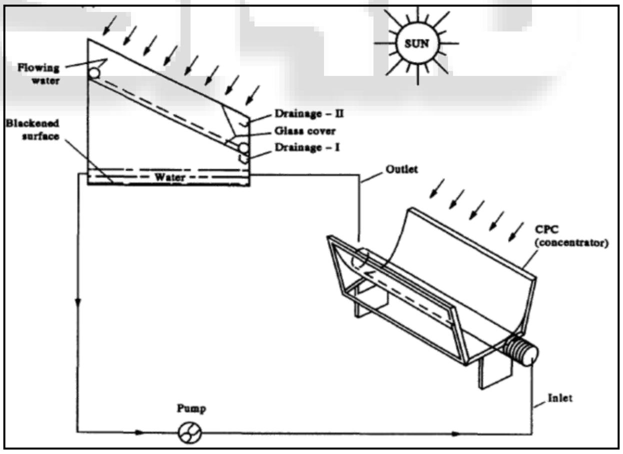

Fig: 18 Double effects solar still coupled with parabolic concentrator [33].

Bhagwan Prasad et al [33] suggested that, (i) the temperature of the water in the lower basin is increased in comparison with single effect distillation due to the reduced upward heat losses. (ii) The hourly output in the lower basin is reduced due to the reduced temperature difference between the water and glass temperatures. However, the overall output is increased due to reutilization of the latent heat of evaporation in the second effect. (iii) The hourly yield from the lower basin increases with increase of flow velocity due to the decrease in the lower glass temperature. It is due to the fact that the lower glass covers temperature decreases due to the fast removal of the latent heat of vaporization. (iv)The evaporative heat transfer coefficient is a strong function of the operating temperature range. The convective and radiative heat transfer coefficient does not vary significantly.

J. Solar Still Coupled With Parallel Flate Plate Collector

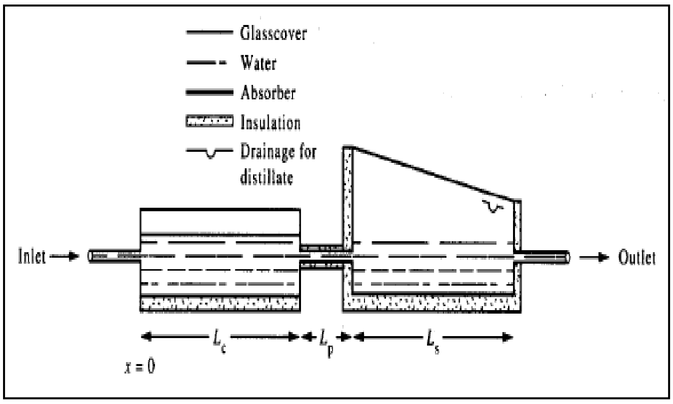

Fig: 19 solar still integrated with a parallel flat plate water collector [34]

Y. P. Yadav et al [35] the collector essentially consists of a parallel flat plate placed over the insulation with an air gap through which the water will flow below the absorber. There is a glass sheet over the absorber and the whole assembly is enclosed in a wooden box. The top of the plate (absorber) is blackened by black board paint before the glass cover is placed over the absorber. The collector outlet is connected to the still by a pipe covered with insulation. The circulation of water between the collector and the still can be made either via a pump (forced circulation system) or by placing the collector over a supporting structure at such a height as to provide adequate head for natural circulation of water (thermosyphon) in the system. The results show that, a significant rise in the distillate output is observed when the still is coupled with the collector and this system can be preferred as cost effective compared to the flat plate collector

K. Double Slope Single Basin Solar Still With Heat Exchanger

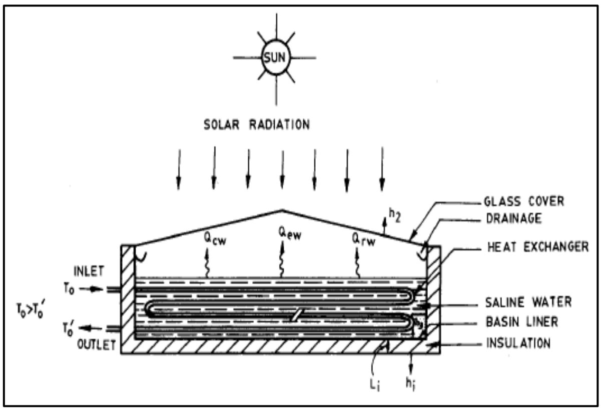

Fig: 20 Double slope single basin solar still with heat exchanger [36]

Ashok Kumar et al [16] presented that solar radiation falling on the glass cover is transmitted through it and the water and is then absorbed by the basin liner. This results in heating the water mass by convection and, thus, in evaporation. Hot water or another fluid flowing through the heat exchanger also transfers energy to the water mass. The authors observed that, the evaporative heat transfer coefficient depends strongly on temperature and advised to use the waste hot water with either higher temperature or during off sunshine hours. Also found that, the efficiency of the system was improved with the inlet temperature of the working fluid.

L. Double Basin Solar Still with Heat Exchanger

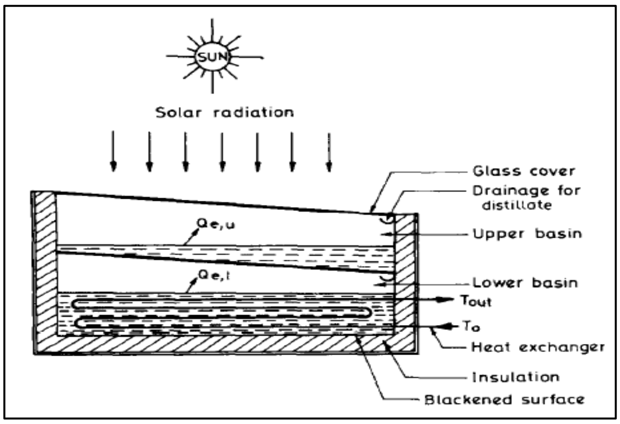

Fig: 21. Double-basin solar still integrated with a heat exchanger [37]

Ashok Kumar et al. [36] presented that the incident solar radiation is absorbed by the blackened surface. A part of this energy is utilized to heat the water of the lower basin while the remainder is lost to the ambient. The fluid passing through the heat exchanger also transfers heat to the lower water mass. Evaporation takes place from the surface of the heated water. The condensing water vapour transfers energy as latent heat of vaporization to the lower glass cover and further heats the upper basin water. The increase in system efficiency with increasing inlet temperature of the heat-exchanger fluid is due to the fact that the efficiency of the system has been calculated on the assumption that the total insolation is absorbed by the blackened surface and constitutes the only input energy.

Y. P. Yadav [37] it is concluded that (i) the efficiency of a double basin solar still coupled to a heat exchanger is significantly less, as compared to that without heat exchanger. (ii) the efficiency of a double basin solar still coupled to a heat exchanger is a strong function of the heat exchanger length and the mass flow rate of the working fluid.(iii) An overall system efficiency should be employed to depict the performance of a double basin solar still coupled to a heat exchanger.

M. Active regenerative solar still

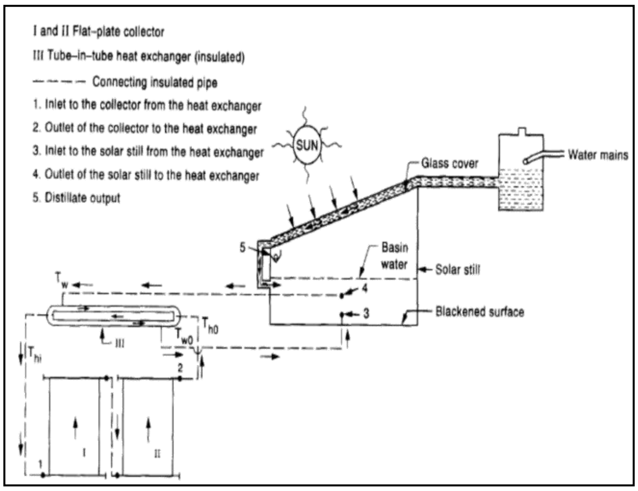

Fig 22: Cross-sectional view of an active regenerative solar still [38]

G. N. Tiwari et al [38] in this system, the water in the basin is heated under an active mode, and the system operates at higher temperature and, hence, higher evaporation. Thus, the glass cover will receive more latent heat of vaporization. In turn, the temperature of the glass cover increases, and the temperature difference between the glass cover and basin water decreases. This causes low vaporization and, thus, low yield. To decrease the glass temperature, cold water is made to flow over the glass cover. Heat is transferred from the glass to the flowing water which, in turn, keeps the temperature difference large. Moreover, if the temperature of the flowing water at the outlet becomes higher than the basin water temperature, then it can be fed to the basin for higher yield. This system is known as a regenerative active solar distillation system. Fig: 23 represent the hourly variation of yield for passive and active solar stills with and without a regenerative effect. It may be concluded that there is an improvement in overall performance of the system due to the regenerative effect. This is because the latent heat of vaporization is utilized for distillation.

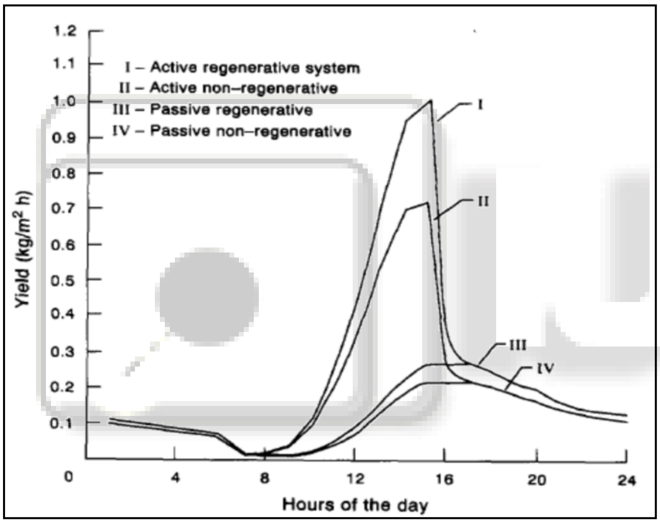

Fig. 23: Hourly variation of the yield [38]

N. Multiple Effect Vertical Solar Still with a Flat Plate Collector

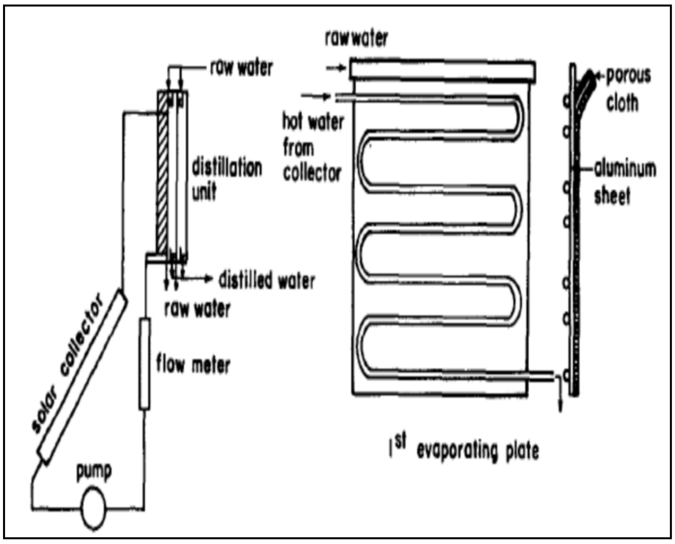

Fig.24. Schematic sketch of the multiple effect still with a fiat plate solar collector [39]

Kiatsiriroat et al. [39] in this system the distillation unit consists of 'n' parallel vertical plates. The first plate is insulated on its front side and the last plate is exposed to ambient. Each plate in the enclosure is covered with wetted cloth on one side. The cloth is extended into a feed through along the upper edge of each plate. Feed water in the through is then drawn onto the plate surface by capillary. Excess water moves down the plate and is conducted out of the still. The last plate is cooled by air or water. Finally conclude that, the distillation output increases slightly when the plate number is over 5, and it increased by about 34% and 15% when the evaporating plate numbers are 1 and 6, respectively.

O. Solar still integrated with a tubular solar energy collector

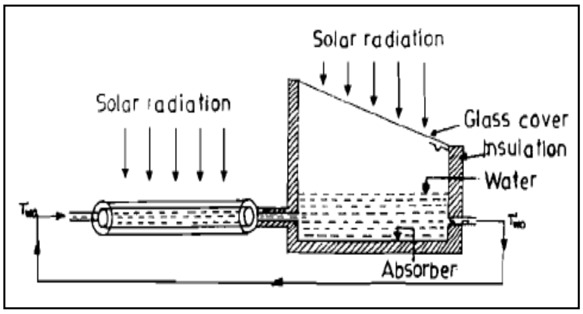

Fig: 25. Schematic diagram of a solar still integrated with a tubular solar energy collector [40].

Y. P. Yadav [40] it is found that the yield and overall efficiency decrease with increased flow velocity. This is also anticipated result. Because as the flow velocity increases, the thermal capacity of water mass being fed into the basin of the solar still is increased. As a result, the water temperature of the solar still decreases reducing there by the rate of evaporation. Finally, it is presented that the daily distillate output increases with increased collector length while decreases with increased flow velocity. The overall efficiency of the system increases with increased collector length and decreases with increased flow velocity.

P. Vertical multiple-effect diffusion-types still coupled with a heat-pipe solar collector

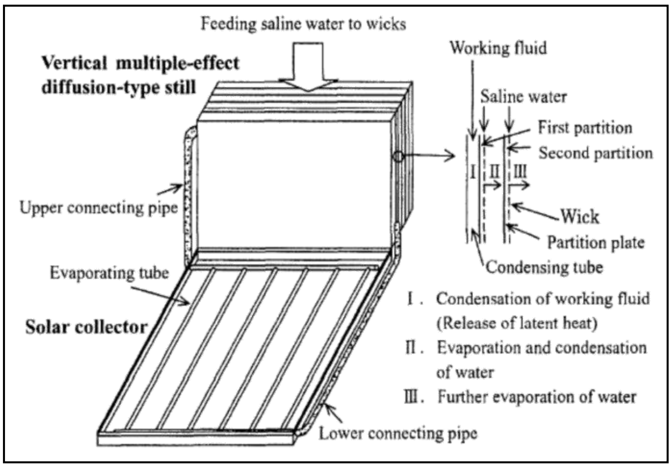

Fig.26. Schematic diagram of vertical multiple-effect diffusion-type still coupled with a heat pipe solar collector [41]

Hiroshi Tanaka et al. [41] concluded that the overall production rates of the multiple effect still were about 93%, which indicates that the heat pipe of the proposed still can transport thermal energy well from the solar collector to the vertical multiple effect diffusion type still In the experimental results, time variations of the temperatures in the still and the distillate production rate on the second partition produced by varying the radiation from the heating lamps to imitate actual solar radiation are in good agreement with the predictions.

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