PERFORMANCE ENHANCEMENT of SOLAR STILL: A REVIEW

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Abstract: This work represents an overview of solar still and their classification along with a review of relevant studies conducted in the several years over solar still. In this paper we discuss about a technique used to convert brackish or saline water into potable water is 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 is known as a solar still. The solar intensity, wind speed and environment temperature cannot be controlled as they are weather-related factors.

Solar radiation denotes the most vital factor of still output. Investigation modification of solar still based on condensing plate, absorbing materials and energy storing materials such as gravel, black rubber, packed layer and charcoal materials. Also investigation of solar still using integrated technique and different design parameter such as flat plate collectors, evacuated heat tube, steeped solar still, pyramid solar still, tubular solar still, multi basin solar still and also using internal and external condenser, reflectors to increase performance of solar still.

Keywords: Basin, Condensation, Cover Plate, Evaporation and Solar still modification.

1. INTRODUCTION

The necessity of clean drinkable water is the most basic need for any of the living being present on the world. It is said that a human being can live without food for six days, but it will be difficult for him or her to survive for more than 50 hours lacking of water. The same is the case with other living beings present on the earth besides humans. This water need requires to be fulfilled only by the people present on the land for the sake of each other and above all for self and for the generations to come and can be considered as an act of survival by one and all using the already provided massive natural resources. The rate of heat energy is transferred by three mode radiation mode, convection mode and evaporation mode. The evaporated water is condensed on interior surface of condensing plate after liberating the latent heat of enthalpy to the condensing surface. Cover plate put on small slope almost its equal to latitude of present solar still system geographical location to enhance rate of incident solar radiation, condensate soft water flows by gravity into the collection troughs at the lower edge of the condensing cover plate.

The condensing cover plate is at sufficient inclination such that surface tension of the condensate fluid causes to flows only into the collection vessel and not to drop back into the bottom basin. Finally the condensed purified water is dripped into the vessel. The collected water is taken out of the still unit for a drinking. The process of a solar distillation is directed by two simple heat transfer methods namely interior and exterior heat transfer modes. The interior heat transfer occurs inside the solar still system and the exterior heat transfer take place between the solar still system wall, condensing plate and the surrounding air. The mainly difference between the interior and the exterior heat transfer rate is that, inside the solar still convective heat transfer rate take place simultaneously with evaporative mass transfer rate while in outside heat transfer rate no such mass transfer occurs.

2. LITERATURE REVIEW

Many number of parameter affecting output of solar distillation system such as solar radiation, air velocity, atmospheric temperature, area of bottom basin and deepness of water from condensing plate, inlet water temperature, condensing cover inclination, temperature gradient between --water and cover plate etc. Solar radiation, wind speed, atmospheric temperatures are the uncontrollable parameter as they are metrological factors. The other parameters can be varied to improve the performance of solar distillation. Sun ray intensity is the most significant factor to impact on solar still output. Nafey have studied the outcome of the solar still with day hour. It show that minor variation of productivity to increase 3% with temperature increase to 5°C. [1]

Researcher analyzed the effect of collected dust with respect to solar thermal systems productivity. The research was performed in Boston, Massachusetts, and the outcomes indicated that a usual of 1% loss of solar ray incident was due the condensing cover being enclosed in dust, with a slope of cover plate is 30°. [2]

In present status of solar still system that many investigator work on still system to enhance yield by using different experiment such as investigation on cover plate, investigation on different absorbing and energy storage materials and investigation on using different technique and design parameter. Fig. 1 show solar still modification

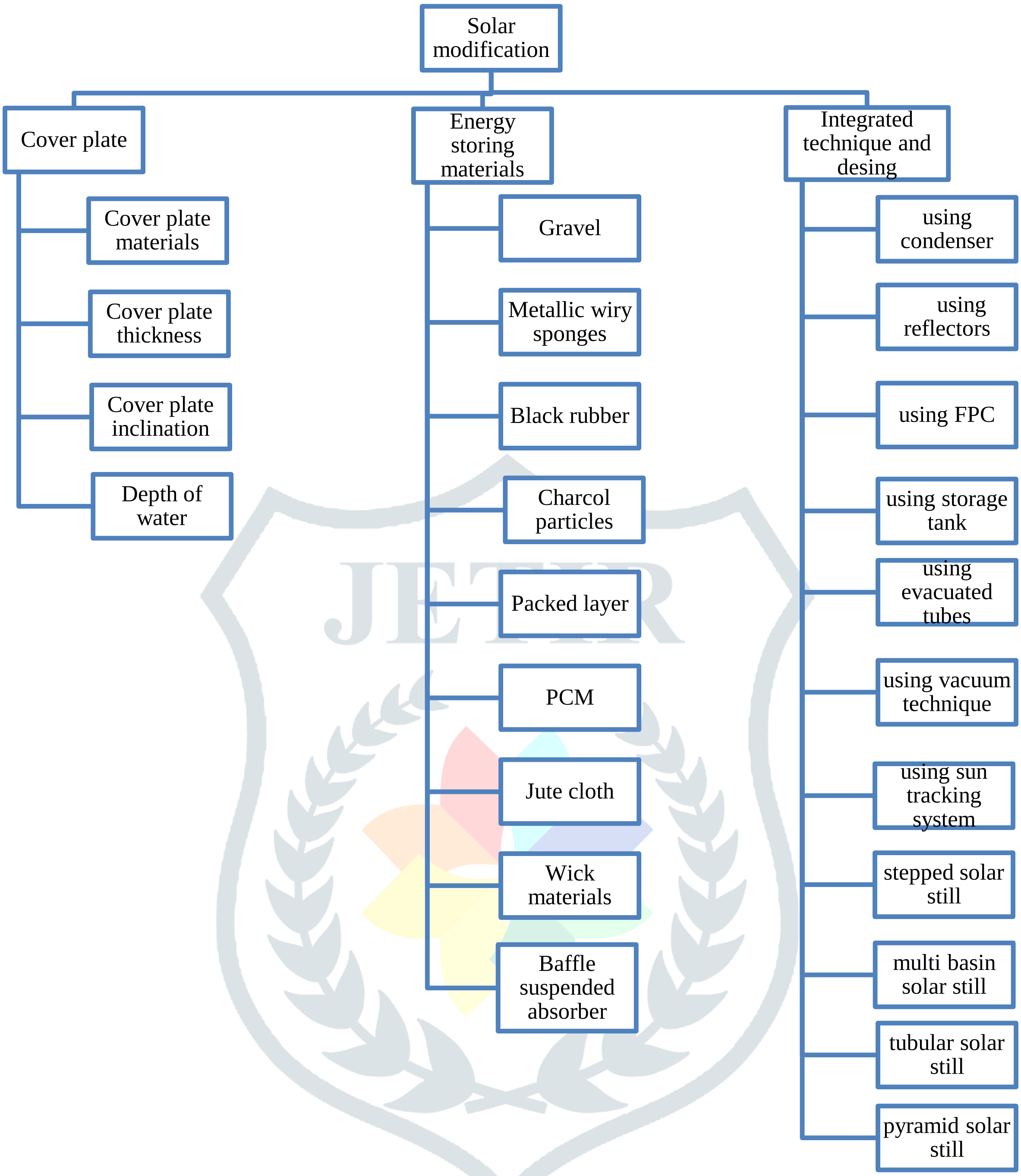

Fig. 1: Solar Still Modification

3. INVESTIGATION ON SOLAR STILL COVER PLATE

3.1 Cover Plate Materials

Dimri study effect of different condensing cover material on daily yield is shown in Fig. 2 It is experimental show that the performance is maximum in the case of copper cover plate due to fast relief of heat available to it. It is due to the great value of thermal conductivity of copper. [3]

3.2 Cover Plate Thickness

H.N. Panchal an effort has been made to discover the effect of altered thicknesses glass cover on single-slope single sink solar still in winter time climatic. Results represents relation between Time and Distillate output by using thickness of glass as a variable. It shows that, 4 mm glass cover plate thickness increases distillate yield compared with 8 mm as well as 12 mm glass cover thickness inside the solar still. [4]

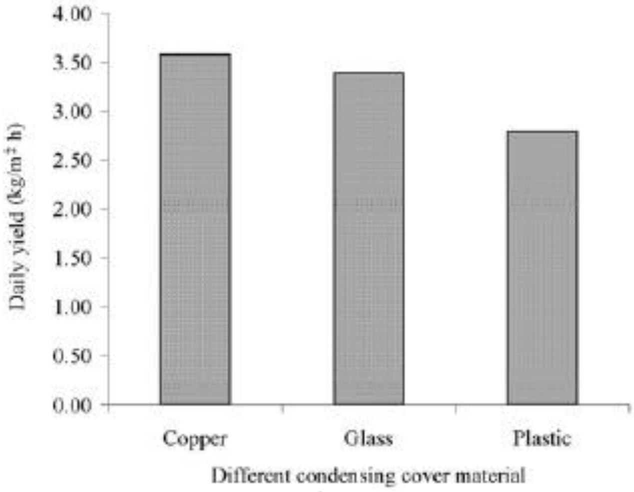

Fig. 2: Effect of condensing cover material on the performance of an active solar still.

3.3 Cover Plate Inclination

Edeoja experiment of the Effect of Slant of Condensing Inclination on the performance of five single basin solar distillation with varying slope angle of inclination of the condensing plate. The same system single basin area of 0.24 m^2 were considered and 4°, 10°, 13° and 15° were selected arbitrarily. The outcomes point to that the optimum angle of inclination for simple single basin solar stills system for Makurdi location is more than 15° as shown by the characteristic liner lines for the water volume/efficiency against condensing plate inclination show in Fig. 3 [5]

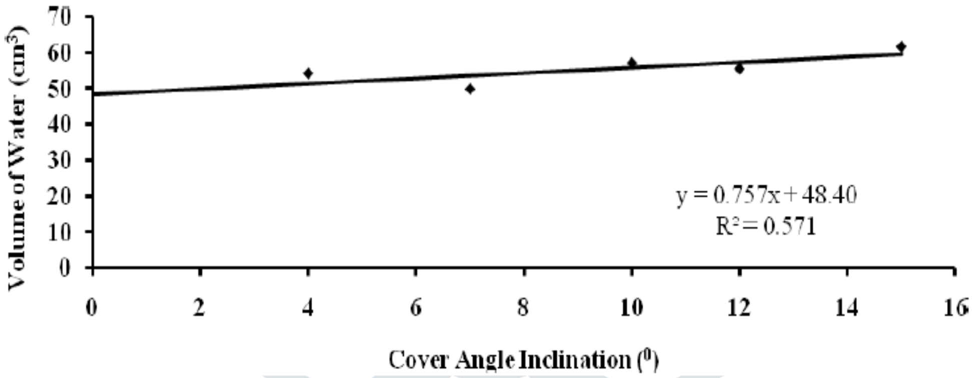

Fig. 3: variation of overall mean volume of water with mean cover angle

Tiwari and Tiwari have start an investigation for three dissimilar condensing cover plate inclination that is 15°, 30°, & 45° for an inactive solar still system through the year of perfect clear atmosphere day-to-day over 24hr under local climatic condition of New Delhi and determine that 15°is the optimum inclination angle. [6]

3.4 Depth of Water

One of the most significant design factors that affect the performance of solar still system is water depth from cover plate. Researcher observe the effect of water distance from cover plate is 2cm & 3.5cm on a single slant single basin solar distillation system. Experiment were done on 1st April 2004 and end result display that productivity of 25.7 % increase by decreasing water distance from 3.5cm to 2cm. Fig. 4 indicate the hourly distillate yield with time for changed water depth from cover plate. [7]

4. INVESTIGATION ON ENERGY STORING AND ABSORBING MATERIALS

Using appropriate energy storing materials and absorbing materials leads to increasing the water upper surface in solar distillation system. Sponge cubes, gravel, wick soil, phase change materials (PCM) are considered as good storing materials for solar still basin.

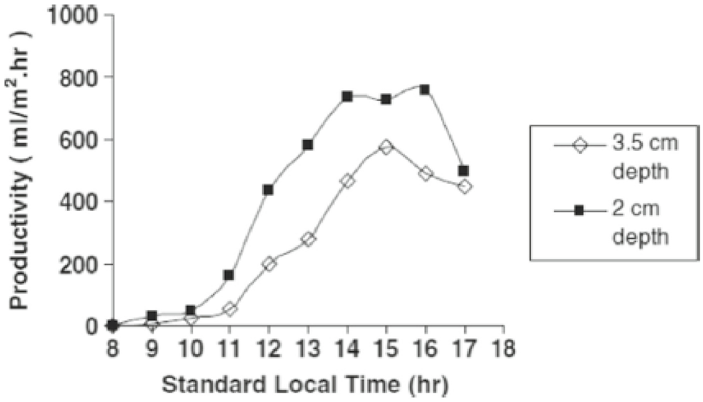

Fig. 4: Hourly distillate output vs. time

Nafey experiment on the effect of black gravel on the yield of the single slope solar still system. The solar still system with gravel is as shown in Fig. 5 Using black gravel of 20–30mm diameter size increases the output by 19% at the location condition of 20 l/m^2 brine volume and 15° glass cover plate inclination. [8]

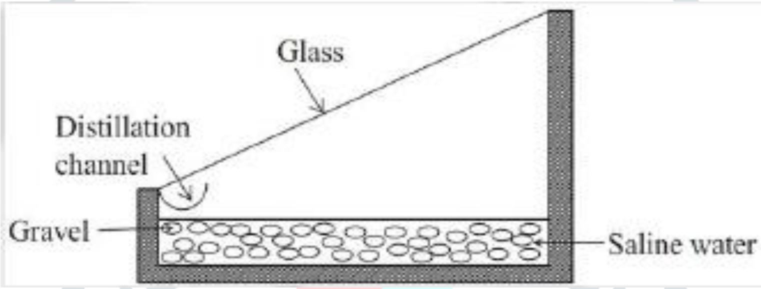

Fig. 5: Solar still with gravel

Salah Abdallah unlike natures of energy absorbing materials like metallic wiry sponges materials (coated and uncoated) and black volcanic rocks materials are used to investigate their influence on the performance of solar stills system as shown in Fig. 6 [9]. Instead, the complete normal gain in the collected purified water taking into the consideration the overnight distilled water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges materials and black rocks materials, respectively.

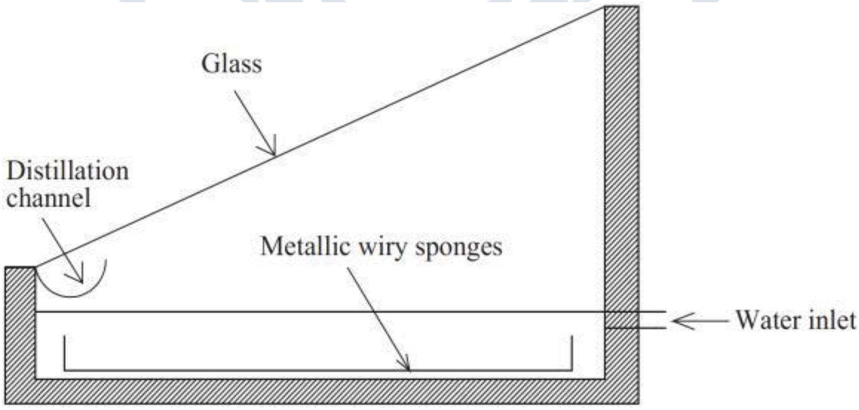

Fig. 6 Solar still with metallic wiry sponges Salah

El-Sebaii single basin single slope solar still system with baffle absorber plate (SBSSSSBA) was fabricated and investigation system shown in fig. 7. Addition a suspended plate within the solar still basin water of a conventional single basin still system declines the preheating time necessary for evaporating the solar still basin water. At time of overnight, the lower layer water supporter acts as a heat energy source for the upper water layer; therefore, evaporation of solar still basin water is continuous even after sundown which increases productivity of solar still system. [10]

Naim fabricated non-conventional single basin solar distillation system with coarse charcoal particles as the absorber medium and studied causes such as range of charcoal particle, saline water flow rate and glass cover plate inclination. A glass plate (0.003 m thick) is complete to cover the entire surface of the plastic box which is 0.03 m directly above the charcoal bed. [11]

Zeinab & Ashraf experimentally studied the conventional solar distillation system with the packed layer that was fixed at the bottom of the solar still basin to improve the efficiency of the solar still.

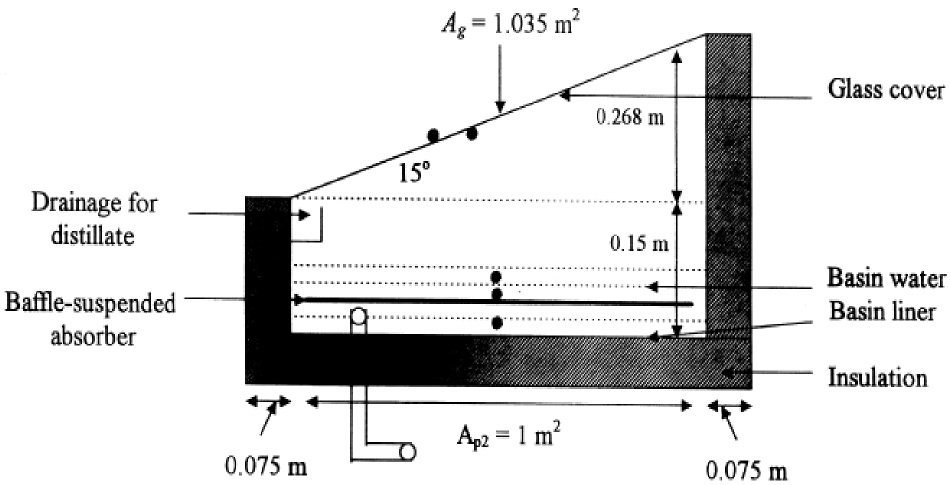

Fig. 7: A Schematic diagram of the constructed SBSSBA.

The efficiency of the changed solar still system using packed layer in solar still basin thermal energy storage system was increased by 5% in May, 6% in June, and 7.5% in July at local climate condition. [12]

Naim boosted the output purified water of the single slope solar still system by the usage of an energy Storing medium (ESM). Experiment time the solar still assembly itself the ESM is placed in solar still tray. The output was improved from 203 ml/m^{2}h to 256 ml/m^{2}h when the duration of the practical experiment was extended to 2 h in the evening period. And the usage of 500 ml purified water as the energy storage material the productivity reached a level of 299 ml/m^{2}h. [13]

Sakthivel improve experimental setup of the regenerative solar still with jute cloth shown in Fig. 8, as an energy storing medium. The latent heat energy released from the condensing cover plate is applied for the evaporation of basin water from the jute cloth. From now, the solar still hourly productivity improve and hotness of the solar still bottom of the glass cover plate gets decreased than in the situation of conventional still. [14]

M. Kalidasa experimental improve the yield of single basin type paired slope solar still system with dissimilar wick medium like light black cotton material, light jute material, sponge sheet materials, coir mat and unwanted cotton pieces. From the dissimilar basin wick materials, light black cotton cloth was the best in effect which yielded greater production per day. [15]

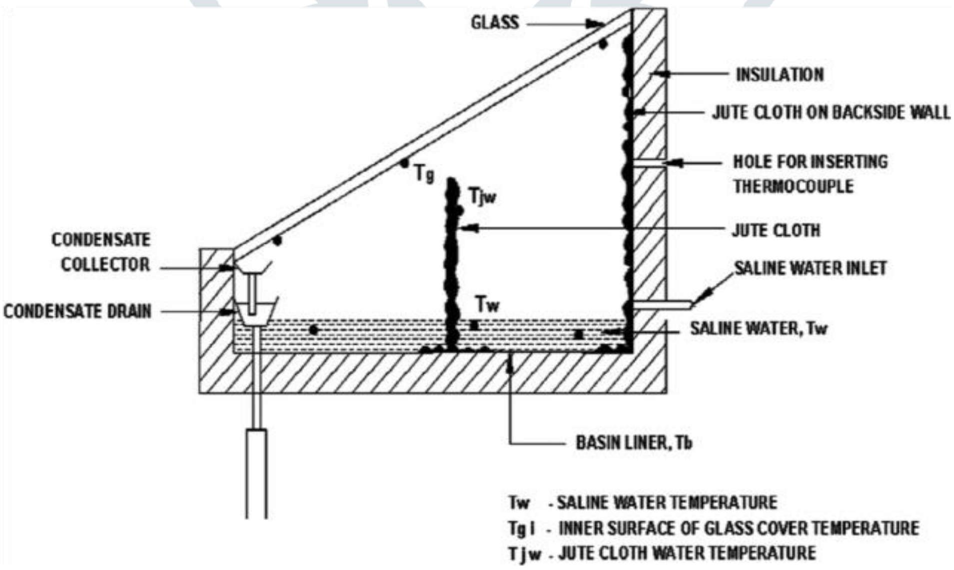

Fig. 8: Schematic diagram of a single slope solar still with vertical jute cloth

Sahoo investigation studies on solar distillation system with a still basin area is 0.73 m^2 was used to succeed a fluoride drop of 92–96% as paralleled to the natural samples. In the major three types, the still basin water volume is various as 10, 15, 20 ml and the effectiveness are 7.28%, 7.78 % and 8.1% correspondingly. [16]

5. INVESTIGATION ON DESIGN PARAMETER AND INTEGRATED TECHNIQUE

5.1 Using Internal and External Condenser

Husham studies and investigation has pointed on discovering approaches. Comparison between collected yields of the three solar distillation warmer period. Consequently, three undistinguishable solar stills were fabricated and assembled with the glass covers plate attached on the upper side stills at an inclination angle of 20° to the horizontal plane, with an effective basin size of 1 m^2. The purified water was accumulated either through the condensers or by running downhearted the inclined glass cover into a distilled water holder. [17]

5.2 Using External and Internal Reflectors

The reflectors, either exterior or interior, are a well and low-priced adjustment to improve the solar radiation focused to the solar still basin liner or the water surface as well as the purification efficiency of the solar still system. Hiroshi Tanaka use exterior reflector was tilted marginally frontward to make the mirrored sun radiation more incident on the still basin liner of the still excellently. The everyday yield of a single basin sort still can be improved about 70% to 100% with an exact simple improvement using interior and exterior reflectors. A schematic diagram and a quick shot of an outside investigation apparatus are shown in Fig. 9. [18]

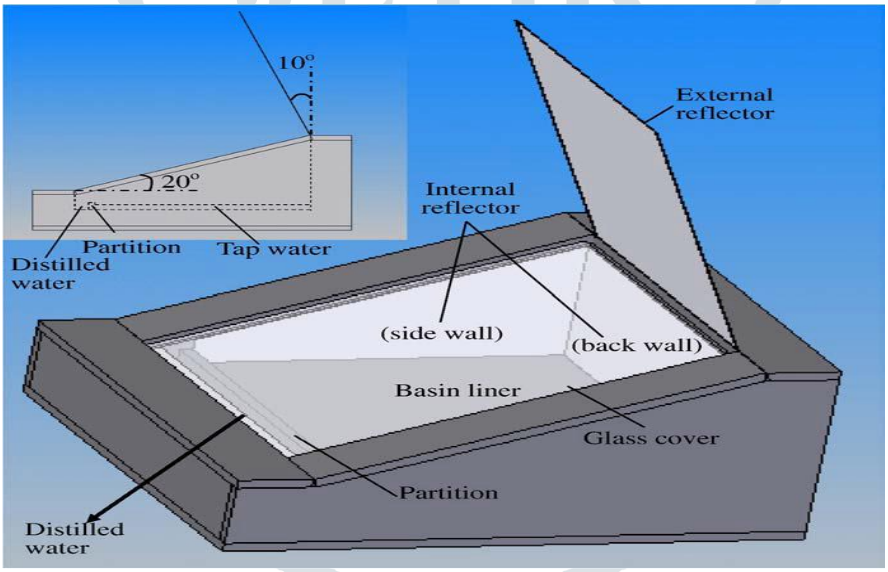

Fig. 9 A basin solar still with reflectors

Salah Abdallah improve experimental setup to increase performance of the single slope still system by increasing the productivity rate of disinfected water. The setting of interior mirrors reflector prepared an increase yield up to 30% in the thermal act of the solar still system. [19]

5.3 Using Flat Plate Collector

In the present technique, an attempt has been made to improve the purified water output of a single slope single basin still system by link it with a flat plate collector, as advised by investigator. The water is spread between the still and flat plate collector with the support of a small pump.

S. N. Raii and g. N. Tiwari increase the performance of the single basin single slope solar still by means of heat up the brackish water using a combined flat plate collector arrangement. The still outputs of water distillate per unit area per day with absorptance of water and insulation thickness are shown in Fig. 10. [20]

T. Rajaseenivasan et al., experiment research on conventional single slant single basin still system and a single slant flat plate collector basin still (FPCB still) are manufacturing with the similar basin area size of 1 m^2.

The residual area of 0.35 m^2 in the FPCB still system is used for flat plate collector arrangement. Fig. 11 graph results show compares the day–night output of both solar stills with dissimilar adjustments in the still basin. It results shows a significant enhancement in the hours of daytime productivity rate for the FPCB still. Extreme distillate output gained at daytime for conventional and FPCB solar stills with jute cloth materials and black gravel materials in the still basin are 3.02 and 4.90 kg/m^2 respectively. [21]

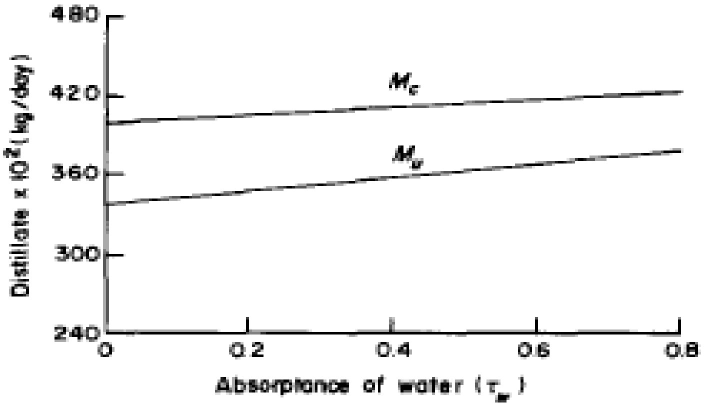

Fig. 10: Variation of total daily distillate per unit area of basin

The net evaporation surface areas of conventional and FPCB solar stills are 1 m^2 and 0.65 m^2 respectively.

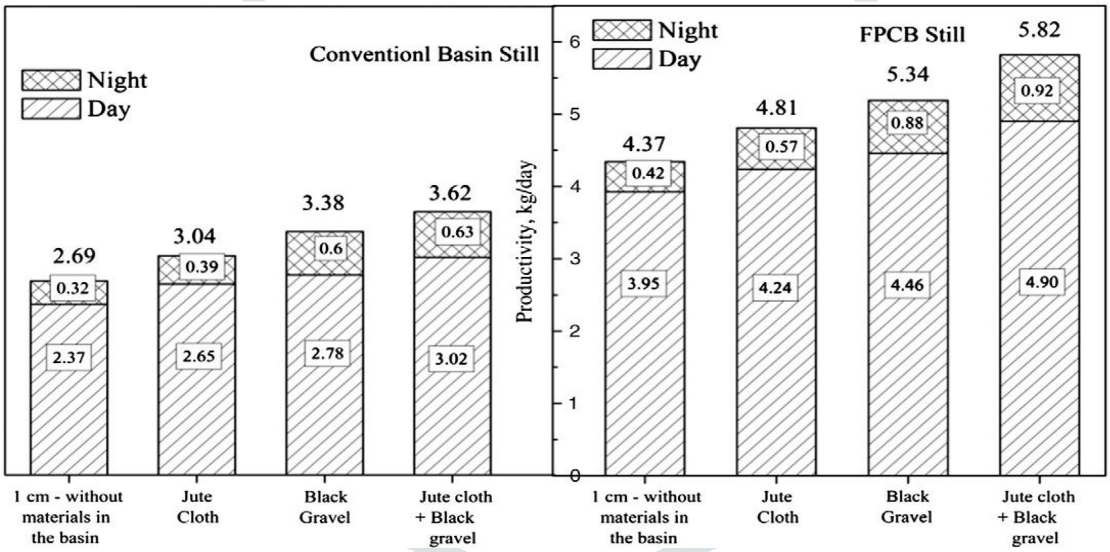

Fig. 11: Variation in distillate production rate with various modifications in basin and FPCB still

5.4 Using Evacuated Heat Tube

On the source of many literature study, a single slope active solar still system is selected for advance improvement and performance investigation which is subjected to be combined with evacuated glass tube (EGT) solar collector for hot water feeding in to the basin of solar still.

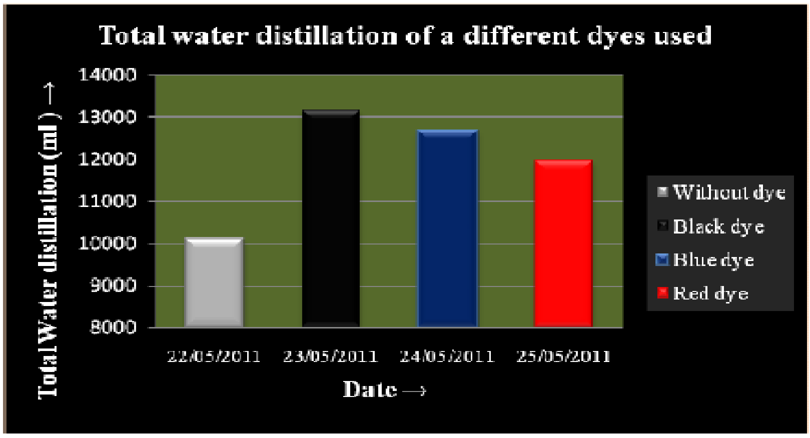

Fig. 12: Total water distillation using different dyes

P. M. Meena et al., developed technologically advanced single slope solar still. Size of solar still basin area is 1 m^2 is projected to be tried with dissimilar surface coatings medium, yield variation with different sensible heat storage medium as black, blue and red dye used inside the contaminate water. Fig. 12 graphically plotted by using recorded data of investigation on non-conventional still and it results shows that total water purification capability improved in case of black color with respect to pure water without any type of dye is 30.38% and also if using blue and red type dye 25.48% and 18.40% correspondingly. [22]. Hitesh N Panchal study experimentally is carried out to identify the influence of coupling an evacuated Heat Pipe Collector (EHPC) on the single slope solar still. The graphically results of coupling a solar still with an evacuated heat pipe collector is shown in fig. 13. [23]

5.5 Tubular Solar Still

Amimul Ahsan enhancement performance of solar still system by using new designed Tubular Solar Still (TSS) shown in fig. 14 made of low-priced, light-weight and locally acquisitioned materials was effectively designed for real use, particularly in there mote or beach areas of under-developed and developing nations to produce purified water from brackish water using solar thermal energy.

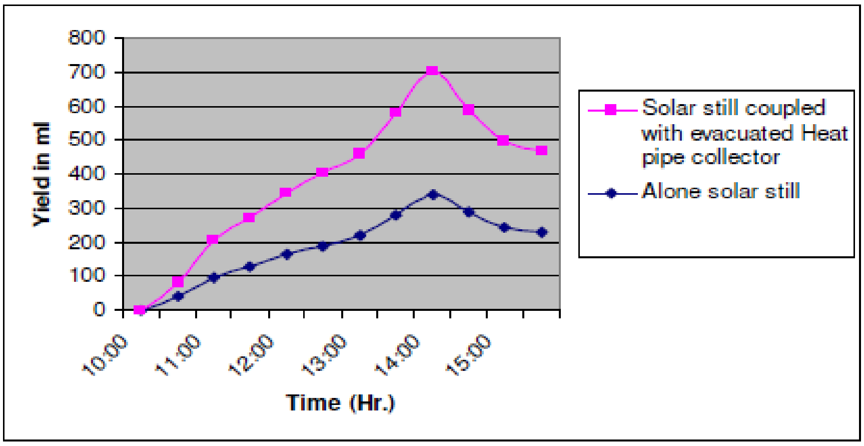

Fig. 13: Comparison of yield between alone solar still and coupled solar still

The new TSS be made of a holder trough, a frame and a tubular type cover. Therefore, the weight load and price of the new TSS were reduced by about 61% and 92% of the old solar still, correspondingly. [24]

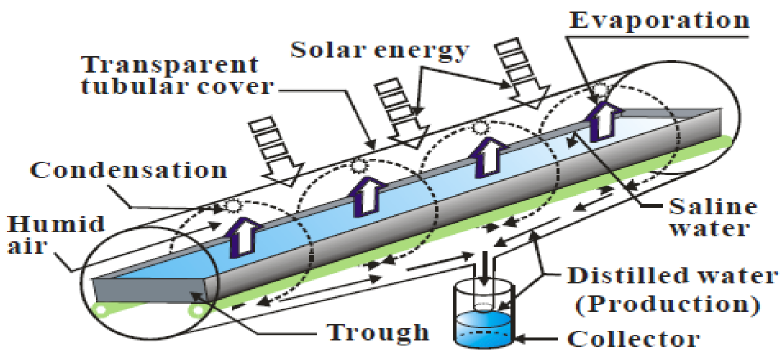

Fig. 14: Schematic diagram of Tubular Solar Still (TSS)

5.6 Integration of Storage Tank

Newly technique of a water storage tank with a conventional solar still system leads to higher purified water output and performance due to higher still basin water hotness level.

Voropoulos studied on performance of a conventional type single basin solar still fixed with hot water type storage tank by keeping the tank water temperature non-variation at different levels shown in Fig. 15 Solar Distillation system for a number of days by keeping the tank water temperature at different water levels, such as 70°C, 60°C, 50°C and 40°C. The investigational work was carried out in day hour as well as in night hour. [25]

5.7 Pyramid Solar Still

Pyramid type of solar still system is one in which top condensing cover is in the shape of pyramid. There were mostly two type shapes of condensing covers plate and basin. Generally available in pyramid solar still system:

a) Triangular shape pyramid solar still system.

b) Square shape pyramid solar still system.

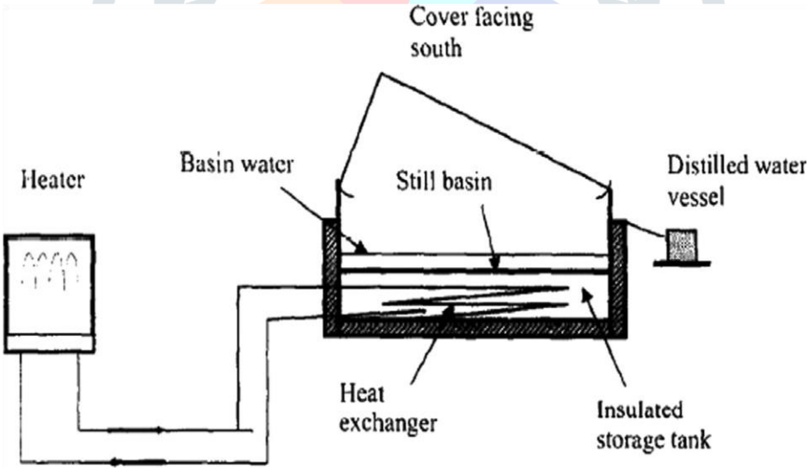

Fig. 15: Schematic diagram of the solar still–storage tank distillation system

Hamdan and researcher have carried out an investigational and theoretical studies comparison for the performance of multiple basin solar still. The size of basin area of 0.96 m × 0.96 m × 0.15 m was kept equal for the all three prototypes of solar still system. By result data show that, researcher found the distillate system yield from triple basin solar still was 24% and 5.8% higher than that of single basin still and double basin still correspondingly. They have gotten that maximum daily productivity of triple basin still, double basin still and single slope single basin solar still system was 44%, 42% and 32% respectively. [26]

Researcher have work on a comparative systematic study for the pyramid shaped solar still system and single slope single basin solar still system for the measured recorded data of total radiation for local condition of the Aswan city (south of Egypt) (φ = 24°). The journalists have analysed that the everyday average annually incident solar radiation and absorbed solar ray-radiation for the pyramid still system were 4% more but also has a 1% higher everyday average twelve-month incident solar ray intensity loss. By practically model study, they have observed a yearly average everyday performance is 30% for the pyramid solar still system and 33% for single slope single basin solar still system. [27]

Kabeel has designed a solar still system with pyramid type formed top condensing cover as shown in Fig. 16. From a financial study on conventional solar still system is 28% more costly than the concave pyramid shape type solar still system for the average yield 2 l/day. As a result, the newly structure solar still is also advantageous from the financial side. [28]

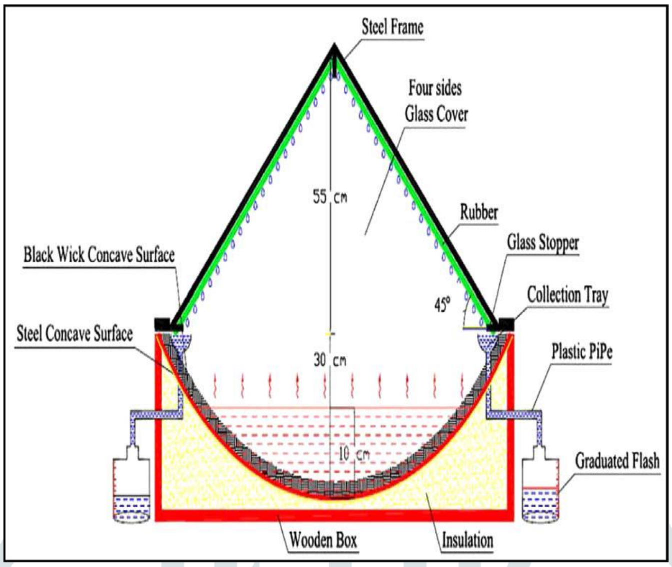

Fig. 16: Pyramid shaped concave wick solar still

6. CONCLUSION

Solar still is the simplest device to get drinkable/fresh purified water from impure water using solar energy as fuel. The basin type single slope solar still can be classified as a conventional solar still system. There are many different designs of solar still system available in market. But now a day researchers have improved design the conventional single slope solar still system to found a better performance at remote area where clean water scarcity, such type of solar still as multi-basin still, multi-slope pyramid solar still systems, and coupled with solar flat plate collector and evacuated glass heat tube (EGHT) to increase the water temperature in solar still basin. Particularly, solar stills look like the best selection to achieve fresh drinkable water goal in desert type remote areas usage.

This paper also highlights on the factors which influence the yield of solar stills system. The most important factors include environment, different design parameter, and operational parameters as local weather condition at particular location. Many investigators have studied the effect of solar radiation on still output, and their outcomes show that solar still output increases with increasing incident solar ray intensity. The influence of wind speeds is slight on yield and efficiency of solar still system. The productivity of the solar still was determined to be directly correlated to total solar ray intensity, ambient air temperature and wind speed at particular geographical area. A lower glass angle generates higher output. The transmitted radiation is partially absorbed by the water mass and partially reflected by the water mass. The transmitted solar ray further reaches the darkened surface where it is generally absorbed. The thermal energy heat the basin liner is then transferred to the water mass in the bottom basin and the left of the energy is gone in environment by conduction through the insulated bottommost and edges of the distiller system.

Rate of heat transfer by convection mode of energy by the bottom basin liner, the water mass in the basin start heated and the temperature of the bulk water mass is higher than the condensing cover temperature at top of still system, there occurs interior heat transfer from the water upper surface to the condensing cover. The various heat storage materials like jute cloth, sponge cube and black cotton cloth materials and fins type heat absorber materials improvement to the distillate output. The yield significantly increased in tandem with an increase of mass of the phase change materials, due to its latent heat storage capabilities. Researcher was also construed a sun-tracking system trumps a fixed system in terms of still productivity.

Experimentally results show, the productivity of the solar still is inversely related to water depths from cover plate, different thickness of cover plate, gap distance between water surface and condensing cover increasing water absorptivity by using dyes which increasing initial water temperatures. The addition designed of a passive condenser to the solar still increases the total yield to almost 70%. Furthermore, integrating solar collector increases yield by 36%. Adding reflectors, whether interior or exterior, is rather useful as it improve the solar ray intensity onto the still basin liner.

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