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A REVIEW ON DESALINATION OF WATER USING SINGLE SLOPE PASSIVE SOLAR STILL

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ABSTRACT

This article reviews single slope solar still and recent studies on the solar still systems for utilized for desalination process. The review includes basic principles of solar distillation and different modifications (optimization) suggested for improvement in distiller yield. General mathematical modeling methodology of solar stills. The efficiency and performance of the single slope solar still are also given.

INTRODUCTION

Availability of fresh, clean water is still challenging to the many parts of the world. Distillation is one of the many processes available for obtaining fresh water from salty, brackish or contaminated water. Sunlight has an advantage of the zero fuel cost but requires large space area for the power generation. Despite a common belief, it is not necessary to boil water to distil it. Simply elevating its temperature below the boiling point adequately increases the evaporation rate. In fact, although vigorous boiling accelerates the distillation process, it can also force unwanted residue into the distillate defeating purification. Furthermore, to boil water with sunlight requires a more costly apparatus than the distiller units which operates at below boiling temperature. Generally, bulky and costly setups are required to generate high temperature. For people concerned with the quality of their municipally supplied drinking water and unhappy with other methods of purification available to them. In recent years, various studies (i.e. experimental and theoretical) have conducted on different configurations of solar stills to enhance the performance and productivity. Sampath Kumar and his associates were reported a detailed review of various designs of active solar distillation [1]. In active mode, water in the basin was heated directly or indirectly (hot water available from solar collector or industries) for climatic conditions such as solar radiation, wind velocity, and ambient temperature has a direct effect on productivity. Although the initial water temperature and insulation thickness have direct effects, but the cover angle has an inverse effect in summer and direct effect in winter. A mathematical model to predict the effect of climatic condition and design parameters on the performance of a solar still were reported [2]. Better efficiency was obtained at the maximum temperature difference between water and glass cover [3]. Tiwari *et al.* [4] reported a comparative performance of three different designs of single basin solar stills. The better yield obtained using a single-slope, solar still made of fiber reinforcement plastic (FRP) than the double slope in winter, but in summer, the reverse results appeared. Al-Hayek and Badran [5] observed that using mirrors in asymmetric greenhouse type solar still, yield was recorded 20% higher than that of the symmetric greenhouse types. Mishra and Tiwari [6] reported the effect of coal powder and blackened metal chip on the single basin passive solar still were blanked metal chip containing in basin area of conventional solar still gives higher yield as compared to the still containing coal powder with the same height of 2.5*cm*. Mutasher *et al.* [7]

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reports the enhancement in clean water productivity by using a combination of sun tracking system with solar still. Esfahani *et al.* [8] used thermoelectric technology to improve the productivity of solar stills. In addition to experimental researchers, there are many studies, which use mathematical modeling to estimate the productivity of solar stills.

Experimental study of a solar still with sponge cubes in basin reported by Bassam *et al.* [9]. The basin water depth has a significant effect on the productivity of the basin. Investigations show that the water depth is inversely proportional to the productivity of still [10–12] Variation of the convective heat transfer coefficient and thermal modeling of solar stills have studied by many authors where the water depth parameter was incorporated as a major parameter that affects the still performance. The effect of using black rubber and black gravel for augmenting the productivity of the solar still is performed [10,11,13–15], these studies shows that black rubber, black gravel and floating perforated black aluminum plate in the solar still increases the solar still productivity by 20%, 19%, and 15%, respectively. Some authors worked on improving the performance of solar desalination systems by using modifications in the solar desalination systems [16]. The effect of water depth on heat and mass transfer in a passive solar still in summer climatic conditions has been studied [10]. In order to improve the performance of conventional solar stills, several other designs have been developed and proposed with their significance, such as the double-basin type [9,17], multi-basin type [18,19], a wick basin type [20] and a multi-wick single slope solar still [21]. Integration of solar still in a multi-source and the multi-use environmental type was also studied [22]. The external reflector was inclined slightly forward to make the reflected sun rays hit the basin liner of the still effectively and daily productivity of a basin type still can be increased about 70% to 100% with a very simple modification using internal and external reflectors [23]. The experimental results and the theoretical predictions are in good agreement, especially on clear days [24]. The water collection area was improved by connecting the stepped trays of 12 numbers, Different water depths of 2 *cm*, 3 *cm*, 4 *cm* were used in the conventional basin while a constant 2 *cm* water depth was maintained in the stepped tray type basin and Maximum productivity of 1.468 kg/m^2 was recorded for 2 *cm* water depth and lowest production of 1.150 $kg/m^2$is obtained for 4 *cm* water depth [25]. Sponges are added to improve the capillary action [9]. For 2 *cm* water depth with wick and sponge combination, the maximum output of 1.305 $kg/m^2$was obtained [26]. The lowest productivity was recorded for 4 *cm* water depth with sponge's combination (1.280 kg/m^2). Packing materials such as wooden chips, sand, coal, coconut coir, were added in the inclined flat plate collector to increase the area of exposure [27]. Different packing material analyzed, rock, sponge and wick combination gain the maximum productivity of 1.745 $kg/m^2$and lowest productivity is for sand and wick combination (1.200 kg/m^2) [28]. The daily efficiency of various combinations was calculated for the coconut coir and wick combination produced 16.36%, nearly 3% increase in efficiency when compared to be conventional still [29]. A theoretical analysis was also performed and compared with experimental results, At maximum deviation of less than 10% between theoretical and experimental analysis was obtained [29]. A theoretical analysis of a tilted wick solar still with an external flat plate reflector which was able to incline in forwards as well as backward according to the seasons [30,31]. The analyses of observed data that the variation of the mean temperature of the earth was explained by the variation of short-wave radiation, arriving at the surface of the Earth [32]. In connection with this, the influence of long-term changes of radiation, caused by variations of atmospheric transparency on the thermal regime reported [33]. A comparison between fixed and the sun tracked solar stills showed that the use of sun tracking increased the productivity for around 22%, due to the increase of overall efficiency by 2%, It was concluded that the sun tracking was more effective than the system and it was capable of enhancing the productivity [34].

Basic principle of a solar still

The basic principle of distillation is simple and it replicates the way of nature made rain. Sun energy increases the temperature of water, which causes the increase in the surface evaporation rate, results in formation of water vapors and condensate at the inner cover of glass as a cool surface. This process removes heavier metals, salts as well as microbiological organisms from water and provides the purest form of water as rainwater.

Principles of solar still

Increasing the area of water in contact with the air to enhance the rate of water evaporation, which can lead to the higher yield of the solar still. Basin area of the still painted with the black color to maximize the coefficient of absorption of the basin. Evaporated water vapors are trapped with the help glass cover, which should be several degrees at a lower temperature than the water. Water from solar still should be quite pure. The slow process of distillation allows a pure form of water to evaporate from the surface and condensate at the lower surface of the inner glass surface. A careful design, constructional material, and operation of a solar still will give pure water free from the harmful materials and cancer-causing substance, colorless, odorless and unfortunately tasteless also, so it has recommended that to add a small quantity of salt for the test to the distilled water obtained from the still. Various energy transfer within the single slope solar still shown in Fig.1[35].

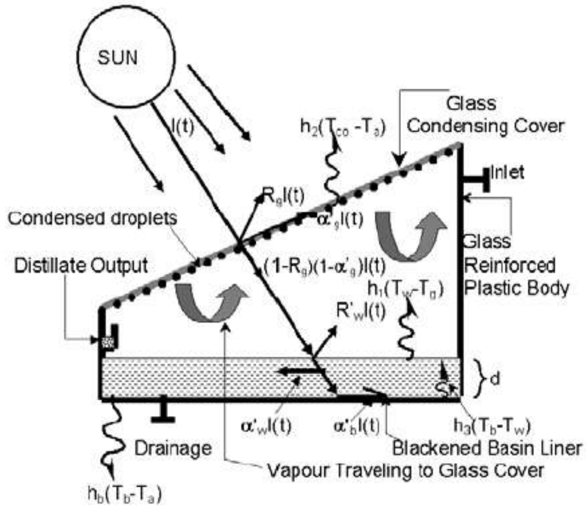

Fig. 1. Cross-sectional view of schematic arrangement and various energy transfers [35]

Heat Transfer within Solar Still

There are three modes possible for heat transfer from water surface to condensing cover these are radiative, convective and evaporative heat transfer.

Radiative heat transfer coefficient

The rate of radiative heat transfer ($\dot{q}_{rw}$) from water surface to the condensing cover can be obtained as [36];

$$\dot{q}_{rw} = \varepsilon\sigma\left[T_1^4 - T_2^4\right] \qquad (1)$$

where, $T_1 = (T_w + 273)K$, $T_2 = (T_g + 273)K,$

Eq. 1 can be rewritten as $\dot{q}_{rw} = h_{rw}(T_1 - T_2)$ (2)

$$\text{where, } h_{rw} = \varepsilon\sigma\left\{\frac{(T_w + 273)^4 - (T_g + 273)^4}{T_w - T_g}\right\} \qquad (3)$$

$\varepsilon = \left[\frac{1}{\varepsilon_w} + \frac{1}{\varepsilon_g} - 1\right]^{-1}$ and $\sigma = 5.67 \times 10^{-8} W / m^2 K^4$

radiative heat transfer coefficient can be calculated.

Convective heat transfer coefficient

The convective heat transfer coefficient (h_{cw}) can be obtain from

$$h_{cw} = 0.884\left\{(T_w - T_g) + \frac{(P_w - P_g)\times(T_w + 273)}{\left(2.689\times10^5 - P_w\right)}\right\}^{\frac{1}{3}} \qquad (4)$$

The volume of P_w and P_g (for the range of temperature 10°C to 90°C) can be obtained at water and inner condensing cover temperature from the relation considering P_w and P_g as a function of temperature.

$$P(T) = \exp\left[25.317 - \frac{5144}{T + 273}\right] \qquad (5)$$

The rate of convective heat loss $\dot{q}_{cw}$ in $\left(W / m^2\right)$ from water surface to the inner condensing cover can be obtained.

$$\dot{q}_{cw} = h_{cw}(T_w - T_g) \qquad (6)$$

Evaporative heat transfer coefficient

The rate of evaporative heat loss $\dot{q}_{ew}$ from water to inner condensing cover is given by

$$\dot{q}_{ew} = 0.0166 \times h_{cw} \times \left(P_{\text{w}} - P_{\text{g}}\right) \qquad (7)$$

Eq.7 may be rearranged as ,

$$\dot{q}_{\text{ew}} = h_{\text{ew}}(T_{\text{w}} - T_{\text{g}}) \qquad (8)$$

$$\text{or } h_{\text{ew}} = \frac{\dot{q}_{\text{ew}}}{\left(T_{\text{w}} - T_{\text{g}}\right)} \qquad (9)$$

and this evaporative heat transfer coefficient can be rearranged as,

$$h_{\text{ew}} = 0.016 \times h_{\text{cw}} \times \left[\frac{P_{\text{w}} - P_{\text{g}}}{T_{\text{w}} - T_{\text{g}}}\right] \qquad (10)$$

Using Eqs. 1, 2 and 3 total heat transfer coefficient h_1 can be written as,

$$h_1 = h_{rw} + h_{cw} + h_{ew} \qquad (11)$$

The rate of heat transfer from water surface to the inner condensing cover one can obtained as,

$$\dot{q} = h_1\left(T_w - T_g\right) \qquad (12)$$

Theoretical Amount of Condensate

The yield in *Kg* can be calculated as

$$M_{ew} = \frac{\dot{q}_{ew} \times A_t \times \Delta t}{L} \qquad (13)$$

where

$$L = 3.1615 \times 10^6\left[1 - 7.6160 \times 10^{-4} T_w\right]$$

for temperature higher then $70^\circ C$, and

$$L = 2.4935\times10^6\left[1 - 9.4779\times10^{-4}T_w + 1.3132\times10^{-7}T_w^2 - 4.7974\times10^{-9}T_w^3\right]$$

for operating temperature less than $70^\circ C$ [36–38]. A_t is basin area of distiller unit , Δt = time interval of the experiment.

Fraction of Heat Transfer

The fraction of heat transfer due to the radiation, convection, and radiation can be evaluated as

$$F_{rw} = \frac{\dot{q}_{rw}}{\dot{q}};\ F_{cw} = \frac{\dot{q}_{cw}}{\dot{q}};\ F_{ew} = \frac{\dot{q}_{ew}}{\dot{q}} \qquad (14)$$

Optimization of cover surface

The glass cover surface receives the radiation from the sun and transmits it to the solar still basin linear. In addition, it receives heat from the basin and transfer to the atmosphere. During these processes, it also allows the vapor to condense and collect in the tray. Hence, It should be efficient to allow energy flow in both the direction for the efficient operation of the solar still.

Direction and inclination of the cover

For a glass material at a lower angle to the incident of sun rays, higher transmittance, and lower reflection was observed [15,29,39,40]. The direction of inclination of the cover depending on the latitude of the location for a lower latitude places double slope distiller unit facing north and south direction was suggested [29,41]. Since for lower latitude regions the sun rays are near to normal inclination on south facing still cover for a part of the year and for the remaining part sun rays are close normal on north facing cover [42]. The cover with an inclination equal to latitude angle will receive the incident close to normal though out the year. However, the inclination of cover will also help to collect the condensate water using collecting tray at the bottom. If the inclination is less, there is a possibility for drops to fall into the basin before it reaches the tray. The condensate mass accumulates when it slides down along the bottom surface of the cover. The surface tension causes for equalization of the weight condensate water trickles during sliding on inner wall of the glass cover. The rate of accumulation of condensate mass depends on the rate of evaporation, condensation, and rate of evaporation are depends on the intensity of incident solar radiation. Hence, the angle of inclination was also optimized with an average variation of solar azimuth angle as per the site. 10° to 50° inclination was provided to a solar still covers the surface and their findings were reported [35,43].

Cover thickness and material

The overall heat transfer of cover plate increases with a decrease in thickness and increase in thermal conductivity and experimental results show that a solar still with glass cover plate with 3 *mm* thickness gives 16.5*%* more production as compared with the distiller unit has glass cover of 6*mm* glass thickness [44]. Glass is the preferred material for cover plate, as it has a higher solar transmittance for various angles of incidence and long service life [15,38,45,46]. The wet surface of the inner glass is allowing film condensation, which results in a reduction of transmittance loss. The other cheap transparent plastic materials do not possess the above-required qualities [47,48].

Cover temperature

The lowering cover temperature of the still will help to increase its productivity. As the temperature difference between glass and basin water increases, which causes to increases the natural circulation of air mass inside still as it will allow increasing both convective and evaporative heat transfer between basin water to cover [49–52]. The cooler inner glass surface will enhance the rate of condensation [53]. The glass cover temperature was reduced by a film of cooling water continuously flowing over the glass [54,55] or intermittent flow of cooling water on the cover [54,56,57]. The cooling water gains latent heat of condensation, this heat regenerated by passing water into a basin. Inverted absorber triple effect solar still as shown in Fig. 2 [58,59]. The wind velocity was also affected the cover temperature. At higher wind velocity, convective heat transfer from basin cover to atmosphere was increases due to the enhancement in convective heat transfer coefficient of cover and atmosphere, which also causes to increases the condensation and evaporation rate and productivity of the still [60,61].

Increasing the condensing area

In a simple conventional single slope solar still, its inner condensing glass cover is only area available for condensation, which has small temperature gradient across the surface due to small thickness, which causes reduction in the rate of condensation. This makes the solar still inefficient and reduces its overall performance. The condensation rate of single basin solar still increased by providing an additional area for condensation. Cover was inclined with an angle equal to the latitude of experimental location to receive the sun rays close to normal and the distance between glass cover and basin water was kept minimum so that maximum volume of air with vapor purges into the condenser area [62]. A mirror was also be used to reflect the solar rays falling on the backside of the condenser on to the glass cover [63]. A solar still has fabricated and tested by condensing the water vapour in inbuilt condenser, which gives higher efficiency from 30% to 70% as compare to the conventional solar still [64].

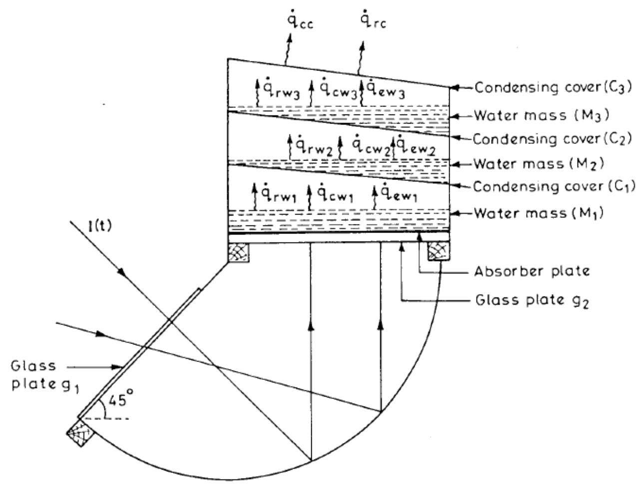

Fig. 2. Schematic diagram of an inverted absorber triple effect solar still [58]

Optimizing the basin

The function of the basin is to receive the entire radiation passing into the still through the cover with minimum reflectance loss and conduction loss to the surroundings. It has to store the energy when it is available in excess and to release the energy when demand was increases and availability was decreases. The evaporation rate of water depends on the natural convection circulation of air mass within the solar still, which is function of temperature difference between the water at basin and the inner glass surface of condensing cover. This temperature difference is the driving force for the circulation of humid air or water vapor, evaporation rate of water depends on area of exposure on basin water and air mass in circulation within the still [65–67].

Basin with different depth of water

The depth of the basin water is give significant effect on the productivity of the solar stills. Investigations shows depth is inversely proportion to its productivity [68–74]. A comparative experimental study for different water depth in single slope solar still was carried out by Tiwar and Tiwari [75] and authors are reported that the higher depth will gives lower yield in daylight hours where as it was higher in case of over-night.

As water depth enhance the volumetric heat capacity of the still basin, it reduces the water temperature for given solar radiation input. However, the temperature and the production rate are uniform and could not affected by sudden variation in incident radiation due to cloud passing for a short time period. The heat stored in the water mass was release during the absence of sunshine and production continuous even during night [10]. For a shallow basin, still the volumetric heat storage capacity of water is less, which causes high temperature. Hence, it must increase the evaporation rate and productivity of the still, but any change in solar radiation will have immediate effect on water temperature and rate of production. Nocturnal production was recorded very less for shallow basin still [76].

Increasing the radiation absorption of the basin

Around 11% of radiation received by the still basin has reflected back to the atmosphere without using it. This loss can be minimize, if the absorption coefficient of the still basin and water is increased. Various techniques have adopted to enhance the absorption capacity of the basin. For increasing the coefficient of absorption of basin water dye has added in it [77]. Water-containing dye have been poured in basin area of solar still; the solar radiation absorbed by the upper layer will increases its surface temperature, which in turn increases the evaporation rate. Different dye with different materials and concentration are having different effects on productivity of different depth water. Black napthylamine dye at 172.5 *ppm* give higher rate of production about 29% compared with red and dark green dye. The effect of dye is more on deep basin still than shallow water basin still in production. Different types of absorbing materials used in the basin along with water to enhance the absorption of the still basin [78]. Researchers for enhancing the production rate of distiller units report rubber mate, charcoal, dye, black metal chips, and some other absorptive materials. Basin lined with coal placed in basin area to enhance the absorption capacity of the basin [6,79–81].

Modifications to increase the radiation received at the basin

Several moderations for enhancing the productivity of solar still were suggested by the researchers, such as the use of sponge, metal chip, coal powder, a greenhouse, an external condenser, subtracting reflectors, flat plate solar collector, effect of dye, sand are suggested for the enhancing the productivity of solar still. Even though the glass cover inclination was optimum to receive the sunrays, the back plate and side plates of the basin receive rays, a part of sunrays. This effect reduces the amount of radiation available in the basin water for heating. Side mirrors was used to reflect sunrays fall on the side plate to the basin area by distiller unit. Experimental results shows that the rate of production is increased by 22% for winter seasons and 86.2% for summer seasons for stills with reflecting mirrors on the vertical walls compared with conventional still [82].

Modifications for increasing the basin surface area

Whenever exposed area of basin water is high, the air mass subjected to natural convection within the solar still will take more amounts of water particles. The water particles wets the surface of the materials available in the basin and exposed to the larger area and ready for diffusion. Different absorbing materials like rubber, gravel and charcoal can be used to improve the absorption, heat capacity and also the evaporation area, to enhance the yield of solar still [14,80,83–86]. The yield of a single basin solar still with different size sponge cubes placed in the basin area was examine experimentally, which gives increase in distillate output by 18% to 27% as compared to the conventional identical still without sponge cubes under the same geographical conditions [87]. The experimental study of solar still with floating-wick shows that its productivity was higher than the common tilted-wick and conventional types of solar stills [88].

Different methods used to increase the surface temperature

As the rate of evaporation, will increases with the basin water temperature of distiller unit. So that the increase the temperature of water contained by still in its basin, higher energy is, need to supply. Heating the top surface of the water alone require less amount of heat and also this results in grater temperature for top surface water. Surface heating technique was used to separates top surface water with remaining water of the deep basin still by using a perforated black floating plate. The separating plate receives the radiation and a part was used to heat the top layer of water and increase its temperature to enhance the productivity of distiller unit. Remaining part of the heat is stored in the water basin and released later during low solar intensity periods. The material used, thickness of the layer are the influencing parameters which affect the productivity of distiller unit. Black painted aluminum sheet with was placed in still containing 2 *cm* of the water thick layer in its basin area, due to this productivity of unit was improved by 28% [89]. Floating perforated black aluminum plate in the solar still increases its productivity by 15% for 3 *cm* water layer and 40% in case of 6 *cm* water layer [14,89,90]. The effect of thermal conductivity of the suspended absorber on the daily productivity of the still was investigated experimentally using stainless steel, glass, aluminum, copper, and mica plates as suspended absorbers was also reported [91]. The experimental results obtain from modified distiller units were compared with the results obtained from conventional solar still. The result of the daily productivity of the still with mica plate was found to be 42% higher than that of a conventional solar still [92].

Different coupling with the solar still

Many researchers report the performance of the coupled solar stills and methods used to evaluate and compared with the conventional solar still in same meteorological conditions. Various results show that the distillate output of the present still approximately 62% higher than that of the conventional solar still. Productivity of conventional solar still is improved sue to the coupling with the solar collector, hot water tank, external reflector, internal condenser or greenhouse.

Solar still coupled with reflectors

Various arrangements for the reflectors, which were used, to enhance energy input to the stepped still and influence of internal and external (top and bottom) reflectors on the performance of the stepped solar still were investigated and reported by many researchers [93–96]. A comparison between modified stepped solar still and conventional solar still have carried out to evaluate performance under the same climate conditions for different distiller units [93,97–100]. A basin type single slope solar still with internal and external reflectors was constructed and examined in outdoor conditions during winter in Kurume, Japan. The external reflector was inclined slightly forward in a such way so that the reflected sunrays hit the basin liner of the solar still effectively and its daily was improved around 70% to 100% with a very simple moderation by deploying internal and external reflectors [101–106]. An analytical and experimental end result for the determination of most favorable position of flat plate solar reflectors during shining hours over a period one-year was also reported by Tanaka [30]. Both mathematical calculation and experimental results point toward that optimal angle position of the bottom reflector is the lowest (5°) for month of December and the highest (38°) for month of June when collector was fixed at β = 45° position [30].

Solar still coupled with sun tracking and reflectors

A sun tracking system have deployed for enhancing the solar still productivity. Computerized Sun tracking devices were use to rotate solar still with the movement of the sun. A evaluation of fixed and sun tracked solar stills shows that the use of sun tracking increased the yield around 22%, due to the raise of overall efficiency by 2%, which conclude that the sun tracking was more useful than fixed system and it is competent for enhancing the production of the distiller unit [7,107]. Temperature variation of the basin water for both fixed and still with tracking shown in Fig.3 reported by Abdallah [108].

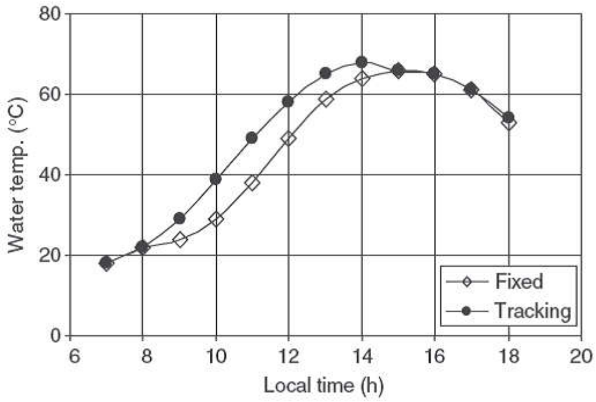

Fig. 3. Temperature variation of the water basin for both fixed still and still with tracking system [108]

Two-axis tracking were buildup to control the direction of the solar collector and system was also tested in for different weather conditions. The reported results shows that there was a considerable enhancement in the thermal efficiency of the active solar still with sun-tracking (38.55%) as compared to passive solar still (22.70%). It has recorded that the efficiency of a system was even higher as compared to active the non-sun-tracking solar stills (34.70%) [7]. It gives credence to solar collector with Sun-tracking can improve the performance of a basin type solar still. In addition, there was a small increase in case of active solar still in comparison of sun tracking and no sun tracking active solar stills [109].

Solar Still coupled with the phase change material

Energy storage systems popularly known as a phage change materials (PCM) used for enhancement of the productivity of the solar stills such systems could be sensible or latent heat systems. Such thermal energy storage systems have many advantages over sensible heat storage and it enhance energy storage capacity of solar still per unit volume and almost constant temperature for charging and discharging distiller units with the help of PCM [110,111]. Recently, many research contributory papers appeared pertaining to the use of PCM as energy storage media integrated with the solar thermal energy systems [112–116]. The study of a transient performance of a steeped solar still with built-in thermal energy storage for heating and humidification of agricultural green house was presented. They have also evaluated the effect of thickness of paraffin wax which was used as a PCM and mass flow rate of air on the performance of solar distiller unit [117]. Their result indicates that decreasing the airflow rate has a significant influence on the still yield, while the greenhouse heat load experiences a decrease. A total productivity of the solar still was recorded about 4.6 L/m^2 with an efficiency of 57% transient theoretical model for a single slope single solar still with and without phase change material (PCM) under the basin liner of the still. Numerical calculations using stearic acid as a PCM material on typical summer and winter days [118].

Productivity enhancement: To increase, the productivity of solar stills were the focus of intensive research. Some studies add heat absorbers such as gravel [84,119–121], sponge cubes [26,122], rubber [13,78,79,117,123], glass balls [77], charcoal [80,124–126], oating absorber aluminum sheets [127,128], dyes and inks [105,129–131], wicks [29,122,132–134], vacuum technologies [135–137], and thermoelectric technology [138]. Excess solar energy storage, using surrounding energy of ground [36,86,139], and computerized sun tracking devices [7,108,140–142] have also been reported. Theoretical performance and experimental investigation of a conventional solar still, fin type solar still and fin type solar pond integrated with fin type solar still were analyzed and reported. Fin type mini solar pond integrated with conventional solar still was boost the production rate by 47%, fin type single basin solar still were increases production rate of conventional distiller unit by 45.5% and fin type mini solar pond integrated with fin type single basin solar still have increased its production by 50% [143]. The test results of a 14-effect unit connected with vacuum-tube solar collector (absorber area 1.08 m^2) given highest daily pure water production is 40.6 kg d ^{1}. The measured highest productivity based on the area of glass cover, absorber material, and evaporating surface was 34.7, 40.6, and 7.96 kg m ^{2} d ^{1}, respectively, The measured solar distillation efficiency was recorded 2.0–3.5 [144]. A new design having additional condensing cover have study of its performance was carryout throughout the year. Due to extra condensing surface, higher yield have observed as compared to conventional single slope still. It has found that water depth, shading on condensing surface or material of extra condensing surface plays significant roles in the distillate output of solar distiller unit. The yield of such distiller unit was recorded approximately 3.015 kg/m2/day on a particular day, which was about 25% more than that of a conventional solar still running in parallel under the same climatic conditions [145].

Conclusion

From this review on single basin, passive solar still, the different methods and modifications used to improve the productivity listed as follows:

- Location, solar radiation intensity, atmospheric temperature, glass cover material and its thickness, basin water depth, inclination of glass cover, heat capacity of still and wind velocity are parameters which affect the performance and efficiency of the still. Basin water depth will be affecting the main parameter for the still.
- The productivity of the solar still decreases with an increasing the depth of water in daylight.
- Rubber sheet can be used to improve absorption, storage and evaporation effect.
- The productivity of the wire-type still is approximately 20% higher.
- The sun tracking is more effective than fixed type system.
- The cover with inclination equal to latitude angle will receive the sunrays close to normal throughout the year.
- The still productivity can increase with decreasing the thickness of glass cover and increasing the temperature difference between water basin and inner wall of the glass cover.
- The distilled water output of the solar still integrated with the greenhouse type was higher than that of the ordinary single basin solar still.
- The daily production of still can be greatly enhanced using sponge cube, metal chip, sand covered with black coal powder.
- The external reflector can increase the distillate productivity, inclined reflectors are better as compared to a vertical reflector.
- Efficiency of concave solar still reaches about 45%.
- Mica sheet as suspended absorber is better surface heating material.
- For lower sun radiation intensity place use of the shallow basin still was suggested.
- Use of PCM is more effective for the lower masses of basin water for the winter season.

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