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Experimental investigation of double basin solar still integrated with solar flat plate collector and solar pond with modified design

M. Muthu Kumar[a,*], S. Rajesh[a], S. Joe Patrick Gnanaraj[b]

[a]*Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, India, emails: mmkumar91@gmail.com (M. Muthu Kumar), s.rajesh@klu.ac.in (S. Rajesh)*
[b]*Department of Mechanical Engineering, St. Mother Theresa Engineering College, Tuticorin, Tamilnadu, India, email: gnanaraj.134@gmail.com*

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ABSTRACT

There has been a practice of converting saltwater into potable water using solar stills for more than a century. Their production is only 2,000–5,000 mL/m²·d, considering all the modifications. The process of production is expensive and inconvenient. The double basin solar stills are the only recommended solution to this problem. In this work, the performance of a double basin solar still with exterior reflectors, lower basin with flat plate collector (FPC) and mini solar pond has been examined and it was executed in Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India (latitude 11.9089° N, longitude 79.7589° E) with 09.00 to 19:00 h on a daily basis for a period of 20 d. Further, it has been examined whether the modifications have an impact on the effectiveness of double basin. Even in double basins, the 100 cm² × 100 cm² upper basins have a 5-step tray inside the lower basins for stability. There is a total of 25 compartments in each tray, having five portions each section. Materials, such as granite, for storing the heat is present in each unit. The yield of distilled water has been increased to 5,650 mL/m²·d, when the external reflectors were installed. The yield has further increased to 6,249 mL/m²·d when the double basin solar still is connected to the FPC and small solar ponds. The overall yield due to the modifications has been increased by 127.5%.

Keywords: Double basin solar still; Solar radiation; Reflector; Solar pond; Stepped absorber plate

1. Introduction

Human life on this planet depends heavily on water availability Also, plants animals need water to survive. But large-scale industrial and agricultural expansion has put a strain on the limited water supplies in the world in recent years. Seawater constitutes the majority of the water on our planet. Glaciers and polar regions have two percentage of the world's water. Around one percentage of the world's water can be used for human purposes. While most of the water is potable, they often include hazardous germs or salty in nature (containing dissolved solids). Because of this, it is not suitable for human consumption. There is an abundance of saltwater in coastal areas but in certain other parts of the world the drinking water is scarce. Desalination provides a solution to this problem upto an extent. This process consists of removing salt and other minerals from water. For human use, desalination is the process of transforming saltwater into freshwater.

Single basin was popular more than a century ago because of its simplicity, ease of use, and inexpensive cost. They do not pollute the environment and are adaptable to the environment. Condensation loss via the glass cover of the still is one of the most severe issues with solitary solar. 2,000–5,000 mL/m²·d can be generated using a simple type of solar still. As a result, the system is quite expensive.

* Corresponding author.

El-Samadony et al. [1] and Velmurugan & Srithar [2] addressed the problems of Temperature, isolation, wind speed, dusty and mist conditions, salt concentration, salty water depth and water temperature differential that are the factors affecting single basin solar still. For a solar still, factors including the amount of accessible surface area, absorber flatness, and glass tilt contribute to the vintage of the distilled product; due to the nature of these characteristics and they cannot be manipulated. The output of the solar still may be improved by adjusting the other variables.

In a single type of solar still, the quantity of distilled water obtained per square foot is relatively low. As a result, it is not suitable for circumstances when the space is limited. Malik and Puri [3] suggested an innovative approach using a double basin solar still, to optimize production per unit area. Sodha et al. [4] made the lower glass cover of a solar still and concealed heat of condensing vapour to hot water, rather than letting it to escape into the atmosphere. An energy-storage chamber in the bottom basin provided a means to produce more distilled water than other design.

Murugavel et al. [5] used several functional heat storage materials including quartzite rock and cement concrete fragments in solar still and concluded that quartzite rock was found to be effective storage medium. Rajaseenivasan et al. [6] examined the impact of water depth in the system. Tarawneh [7] performed small modifications in Rajaseenivasan et al. [6], in which, it was observed that shallow water depth was more effective., increasing the yield to 6.7000 $mL/m^2\cdot d$. Murugavel and Srithar [8] examined the behaviour of the double-slope solar still by utilizing taper constituents, including light cotton garments, sponges, coir mate, and left-over cotton parts. The best yield was obtained by using light black cotton fabric. Velmurugan et al. [9] and Alaian et al. [10] found that the production of stepped solar stills equipped with fins, sponges and both was enhanced by 76%, 60.3%, and 96%, respectively. Kabeel et al. [11] made a comparison of traditional single-slope solar stills and improved solar stills with double slope stills in which it was found that double slope stills performed well than single slope and studied the impact of tray depth and breadth on the solar still's performance. The vertical side of the stepped panel was affected additional wicks. The production of stepped still peaked at a depth and breadth combination of 5 and 120 mm.

El-Agouz [12] and Alaudeen et al. [13] found that productivity increased by 58.4% and compared it with the traditional still having cotton absorber and a storage tank to test the efficiency of modified stepped solar still. Kabeel et al. [11] found that modified stepped stills outperformed traditional solar stills by around 20% on a daily basis when designed with an oblique flat plate collector with a tiered tray-type basin. Due to increased exposure area, wood chips and sand were mixed into the inclined horizontal plate collector. Maximum production was 1745 mL/m^2 for the combination of rock and sponge. El-Samadony et al. [1], theoretically investigated a stepwise solar still with cooling coils. Further, it was found that possibility of water film cooling can boost daily distillate productivity in stepped stills by as much as 8.2% and it is dependent on the specific mix of film cooling variables. Tanaka [14] and Omara et al. [15] examined the rate of radiation heat transmission in the solar still and found that there is a strong correlation between solar still output at solar radiation of 200 W/m^2 with the shape and glass cover oblique angle or the sites latitude angle.

Abdallah et al. [16] used internal and external reflectors to outfit a basin-type solar still and found that productivity raised by 70%–100% during the winter season. Tanaka [17] found that stepped solar stills behave differently from that of traditional stills. Internal and external reflectors in updated stepped solar still make it more than 100 times more efficient than normal solar still. Kabeel and Abdelgaied [18] fitted reflecting mirrors on the classic solar still's interior surfaces. The distilled water output was increased by 380% with the stepwise basin used in conjunction with a sun tracking device. Further, with the stepwise basin being replaced with a flat basin, its performance increased by 180%. Omara et al. [19] explored stepped solar stills with reflectors on the vertical side of the steps and compared with ordinary stills, improved solar stills with and without interior reflectors and found that they offer productivity benefits of between 75% and 57%, respectively with increased efficiency with varying the angle of the outside reflectors from time to time.

Pandey [20] and Rajaseenivasan et al. [21] found that the double basin still is the best option since it can produce 50% more distilled water, when space is at a premium, and further investigated influence of different materials on energy evaporation rates and energy efficiency in solar still with single and double basins, with findings of double and single basin stills achieving extremely high energy efficiency of 2.072% and 1.412% with mild steel. Joe Patrick Gnanaraj and Velmurugan [22] conducted trials, one with and another without insulation on the sides of the still, and found that uninsulated cases had an 8% boost in efficiency, while those with side-insulated cases saw a gain of about 13%. Joe Patrick Gnanaraj et al. [23] linked a double basin solar still with a smooth plate collector using a thermosiphon system and found that it was preferred over the still that relied on forced circulation for high-temperature distillation, especially, if there was no electricity. Panchal and Shah [24] used a heat exchanger to investigate the transient behaviour of double basin solar still. They found that with hot fluid entering the heat exchanger at a temperature of 400°C efficiency increases by 20%–25%. Deshmukh and Kolhe [25] used an experimental solar still with dual slopes and a vacuum tube connection was built and found that distillation output peaked at 11.064 kg/d once the water depth was set to 0.03 m. Panchal and Shah [26] investigated the use of evacuated tubes and a reflector in double basin solar stills and found that production was increased by 50.8%–62% rise in production.

Park et al. [27] found that adding exhausted tubes to a double basin solar still improved its efficiency by 56%, by adding black stone pebbles and an evacuated tube resulting in a 67% boost in performance. Morad et al. [28] found that a micro-solar still was 57% more productive than the typical still in their investigation. Kumar et al. [29] found that production increased by 59% by integrating a tiny solar pond with solar.

Joe Patrick Gnanaraj et al. [30] conducted an experiment at Villianur, Puducherry, India with different combinations in double slope solar still from 08:00 to 17:00 and found that the solar still with reflector plate and mirror performed well with low and high intensities of sunlight and produced 66% distillation between 11:00 and 16:00. Joe Patrick Gnanaraj and Ramachandran [31] made an attempt to optimize distillation by applying Taguchi method with optimization parameters of compartmental basin, basin water depth, size (diameter) of cylindrical wicks and thickness of basin glass cove, and analysed the results with S/N ratio analysis, mean response method, analysis of variance and regression analysis, by which they identified the various optimization parameter levels.

In this work, the performance of a double basin solar still with exterior reflectors, lower basin with flat plate collector (FPC) and mini solar pond has been examined and it was executed in Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India (latitude 11.9089° N, longitude 79.7589° E) with 09.00 to 19:00 on a daily basis for a period of 20 d.

2. Objectives

In this study, it is intended to enhance the performance of double basin single slope double basin solar still by modifying it with solar pond, FPC and external reflector:

- To design solar still with double basin:
  - Solar still with double basin liner design are to be constructed.
- To analyse the thermal performance of double basin single slope solar still.
  - Performance of double basin solar still is to be determined by repeated experiments under different atmospheric conditions, that is, sunny days, cloudy days, windy days, summer days and winter season.
- To evaluate the performance of double basin single slope solar still with different atmospheric condition.
  - Thermal performance of the still is to be studied by recording and analysing various parameters by the variation of water temperature, basin temperature, glass temperature and yield every 1 h.
- To estimate and compare the yield of distilled water from modified solar still with single slope solar still.
- Performance of double basin solar still is modified by adding:
  - Reflector
  - Pond
  - Flat plate collector
  - Combination of all the three.
- To recommend the best performing solar still:
  - Solar still with combination that has best performance of the above four will be commercialised.

3. Experimental set-up

The main aim of this work is to increase the yield of water in desalination using solar still. Fig. 1 shows a typical single-basin solar still. It uses $140\ cm^2 \times 100\ cm^2$ of absorber space on the solar still. The thickness of both conventional and modified solar still is 4 mm. In terms of sidewall height, it ranges from 61 cm for the lower sidewall to 119 cm for the higher sidewall. The entire basin is painted black, by which solar rays can be absorbed. A 1.5 cm space is sustained among the basin and wooden border. Filling the still's gap with sawdust reduces heat loss.

To keep the still safe, a sheet of 4 mm thick transparent glass has been placed over the top of it. The glass is inclined at an angle of 30^0 angle with respect to the horizontal. The bottom of the still is covered with pebbles and black rubber cubes to absorb the quantity of solar radiation to retain heat for a longer period. The distilled water can be drained by using the glass cover. Improvement in terms of yield of water, can be shown, if a desalination system with single-basin solar still is converted into double basin solar still. Experimental setup of modified double basin solar still is shown in it.

In the proposed system the area of upper basin and lower basin solar still area are $1\ m^2 \times 1\ m^2$ and $1.4\ m^2 \times 1\ m^2$, respectively. The depth of the pond is 1 m. It is necessary to raise the absorber surface area of the basin by inserting an angled absorber plate into it. The absorber plate is permanently mounted with an angle of 30°. The lower basin provides an additional 33% of the contact surface area.

There are five steps in the stepped absorber plate. Two side walls of each basin have a set of steps extending from one to the other. All the trays are 19 cm wide and 7 cm depth. Each tray is made up of galvanized iron sheet with a 4 mm. Each step tray has been divided into five sections, and the following alterations have been made to the segments to improve production from the existing systems:

- Work of Joe Patrick Gnanaraj et al. [23], To overcome the absence of sensible heat storage materials in that pebbles at bottom were spread out.
- Work of Joe Patrick Gnanaraj and Ramachandran [32] was deeply analysed. In order to improve the system, a third heat-storage material, black granite gravel was added.
- Works of Esen & Esen [34] and Esen [35] were taken into account. For improving the capillary action and to increase the exposed surface, several sponges were inserted in a single section.

Fig. 1. Experimental set-up of double basin solar still integrated with solar pond.

- Works of Joe Patrick Gnanaraj and Annaamalai [33] was considered. This work shows that increase in solar absorption.

Three stepped trays, on the other hand, allows for more evaporation because of their low depth. Furthermore, suitable storage materials are more efficient in absorbing the heat and extending manufacturing time. 4 mm thick glass covers the upper basin. They are fixed to the horizontal at an angle of 30°. The reverse of the stepped absorber plate is insulated with 30 mm polyurethane foams.

The upper basin and lower basin are installed in a cooperated manner using external reflecting mirrors which are installed two sides of the basin setup. The glass covers of the reflecting mirrors are same and are an inclined angle of 25°. Gnanaraj and Ramachandran [31] performed experiment by taking the reflector angle as 15° for similar methods of experiment.

Similarly, the top glass cover directs extra sunlight into the bottom basin (20 cm^2 × 100 cm^2 extensions on both sides). A pair of adjustable-stand-mounted exterior mirrors are retained on either side of the still. The angles of the mirrors are adjustable and maintained such that the lower basin obtains maximum amount of solar energy. The upper basin is fixed to the flat plate collector to enhance production. Flat plate collectors are connected to metal pipes running over the length of each tray. The flat plate collector can exchange heat with water in the pipe. Gnanaraj and Ramachandran [31] made the lower converting zone (LCZ) of solar pond integrated into the lower basin. Gnanaraj and Ramachandran [32] used dual-wall construction to construct the lower basin's bottom. Dual-walled lower basin allows hot, salty LCZ water to flow into it. As a result, the bottom still of solar pond may receive thermal energy from the LCZ. The upper basin has a slight gap on both the lower and higher sides. Gnanaraj and Ramachandran [31] again applied the same Taguchi method with different parameters of parameter I – sodium chloride concentration level (1.5, 2.5 and 3.5 kg), parameter II – mini solar pond zone (lower converting zone (LCZ), middle converting zone and upper converting zone), parameter III – angle of the reflecting mirror at the bottom of the still (–15°, 0° and 15°) and parameter IV – angle of the mirror fitted in the pond and found that yield was 95.4% higher than conventional one.

4. Experimental methodology

The experiment was conducted in Francis Xavier Engineering college, Tirunelveli, Tamil Nadu, India (latitude 11.9089° N, longitude 79.7589° E). The investigation was conducted with the north-south to maximize the potentiality of the results. All the glasses were wiped to be clean every day before the start of the experiment. The two basins were filled with saline water. Every 2 h, the saline water was replenished to the needed level. Experimentation started at 9 AM and ended at 7 PM and the experiment was conducted over a day. Glass, basin, water temperatures along with ambient temperatures and yield of the water were measured per hour. Analyses and conclusions were generated from the obtained data. The experimental setup and its plan are as shown in Figs. 1 and 2, respectively.

5. Theoretical analysis

Conventional and double basin still can produce a specified volume of potable water every day among the two types of solar stills. Initial temperatures are assumed to be ambient temperature.

5.1. Solar still energy balance calculations

For calculating water mass in basins of the upper and lower regions, as well as upper and lower glass, the following equations are used:

Equation for energy balance for basin (dE_b/dt) taken from [23] and reproduced as Eqs. (1) and (2):

$$\left(\frac{dE_b}{dt}\right) = I(t)A_b\alpha_b - Q_{\text{loss}} - Q_{c,b-w} \tag{1}$$

$$\left(\frac{dE_b}{dt}\right) = \left(mc_p\left[\frac{dT}{dt}\right]\right)_b \tag{2}$$

For upper water mass (dE_{uw}/dt) taken from [23] and reproduced as Eqs. (3) and (4):

$$\left(\frac{dE_{\text{uw}}}{dt}\right) = I(t)\alpha w + Q_{c,b-\text{uw}} - Q_{\text{loss}} - Q_{c,\text{uw}-g} - Q_{r,\text{uw}-g} - Q_{e,\text{uw}-g} \tag{3}$$

$$\left(\frac{dE_{\text{uw}}}{dt}\right) = m_{\text{uw}}c_{p,\text{uw}}\left(\frac{dT_{\text{uw}}}{dt}\right) \tag{4}$$

For lower water mass (dE_{lw}/dt) taken from [23] and reproduced as Eqs. (5) and (6):

$$\left(\frac{dE_{\text{lw}}}{dt}\right) = I(t)\alpha w + Q_{c,b-\text{lw}} - Q_{c,\text{lw}-g} \tag{5}$$

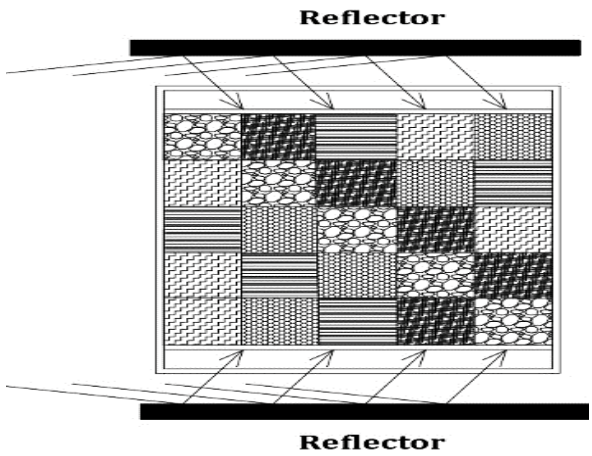

Fig. 2. Top view of experimental set-up.

$$\left(\frac{dE_{\text{lw}}}{dt}\right) = m_{\text{lw}}c_{p,\text{lw}}\left(\frac{dT_{\text{lw}}}{dt}\right) \tag{6}$$

For upper glass cover (dE_{ug}/dt) taken from [23] and reproduced as Eqs. (7) and (8):

$$\left(\frac{dE_{\text{ug}}}{dt}\right) = I(t)\alpha_g + Q_{r,w-\text{ug}} + Q_{c,w-\text{ug}} - Q_{e,w-\text{ug}} - Q_{c,g-\text{sky}} \tag{7}$$

$$\left(\frac{dE_{\text{ug}}}{dt}\right) = m_g c_{p,g}\left(\frac{dT}{dt}\right)_{\text{ug}} \tag{8}$$

For lower glass cover (dE_{lg}/dt) taken from [23] and reproduced as Eqs. (9) and (10):

$$\left(\frac{dE_{\text{lg}}}{dt}\right) = I(t)\alpha_g + Q_{r,w-\text{lg}} + Q_{c,w-\text{lg}} + Q_{e,w-g} \tag{9}$$

$$\left(\frac{dE_{\text{lg}}}{dt}\right) = m_g c_{p,g}\left(\frac{dT}{dt}\right)_{\text{lg}} \tag{10}$$

Following assumptions were made to solve the energy balance equations:

$$\begin{aligned} T_w &= T_w + dT_w \\ T_g &= T_q + dT_g \\ T_b &= T_b + dT_b \end{aligned} \tag{11}$$

The equation for convective heat transfer among the basin and water is reproduced from [23]:

$$Q_{c,b-w} = h_{c,b-w}\left(T_b - \underline{\underline{T_w}}\right)A_b \tag{12}$$

The basin's heat loss to the environment is computed taken from [23]:

$$Q_{\text{Loss}} = U_b\left(T_b - T_a\right)A_b \tag{13}$$

Heat transfer for side loss as in [23]:

$$Q_{\text{loss}} = U_b\left(T_b - T_w\right)A_w \tag{14}$$

U_b = 14 W/m²·K,·U_b = 14 W/m²·K convective mass transfer coefficient [23].

The following formula can be used to determine convective heat transfer among water and glass as taken from [23]:

$$Q_{c,w-g} = h_{s,w-g}\left(T_w - T_g\right)A_w \tag{15}$$

7,128 – 429.12T_w + 9.84$T_w^{\ 2}$

P_w = P_w = saturated pressure at condensing glass surface (N/m²)

$$P_g = 7128 - 429.12T_g + 9.84T_g^2 P_g \tag{16}$$

The following formula can be used to determine radiant heat transfer between water and glass.

$$Q_{r,\,w-g} = \sigma\varepsilon\left(T_w^4 - T_g^4\right)A_w \tag{17}$$

$\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴, Stefan–Boltzman constant

$\varepsilon_{\text{eff}} = (1/\varepsilon_w + 1/\varepsilon_g)^{-1}$

The following formula can be used to determine heat transfer between evaporating water and glass.

$$\begin{aligned} Q_{e,x-g} &= h_{e,w-g}\left(T_w - T_g\right)Ah_{e,w-g} \\ &= \left(15.973\times10^{-3}\right)h_{c,x-g}\left(p_w - p_g\right)/\left(T_w - T_g\right) \end{aligned} \tag{18}$$

Heat transfer by radiation among glass and sky:

$$Q_{\text{teg}-\text{sky}} = \sigma\varepsilon_{\text{eff}}\left(T_g^4 - T_{\text{sky}}^4\right)A_g \tag{19}$$

Where $\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴

$\varepsilon_{\text{eff}} = (1/\varepsilon_{\text{ug}} + 1/\varepsilon_1\ g^{-1})$

$T_{\text{sky}} = T_a - 6_g$

The initial temperatures of Water, basin and glass are considered as ambient temperature. For example, the difference in upper and lower water temperatures (DWT), basin temperature changes (BTC), and upper and lower glass temperature changes (DGT) were measured. And they were substituted in (1) (3) (5) (7) and (9). The MATLAB software was used to solve the equations.

Energy raised by the two basin still = energy raised by heating through sun + energy gained through reflectors + energy gained through pond + energy gained through flat plate collector (FPC).

5.1.1. Total condensation

The whole condensation rate is equated by the formula given below:

$$\left(\frac{dm_c}{dt}\right) = \frac{\left(T_w - T_g\right)h_{e,w-g}}{\left(h_{\text{fg}}\right)} \tag{20}$$

where h_{fg} can be calculated from the following equation [26].

h_{fg} = (573.42 – 4.6623 × $10^{-1}T_w$ + 1.6124 × 10 – 4$T_w^{\ 2}$ – 3.4126 × 10 – 6$T_w^{\ 3}$) × 4.2761

5.1.2. Daily efficiency (%)

The following formula can be used to estimate theoretical daily efficiency:

$$= \frac{\sum\left(m_e h_{\text{fg}}\right)}{\sum A_s l(t)} \tag{21}$$

6. Results and discussion

The experiments were conducted during the period of March to October-2021 at a constant wind velocity of 0.3–0.5 m/s. The rate of ambient temperature is 27°C–37°C. During the experimental days maximum solar radiation was 850 W/m².

6.1. Effect of temperature difference in single basin solar still

Fig. 3 shows the effect of variation of temperature with respect to time in a single basin solar still. The temperature difference in the surrounding environment affects both the water and the glass. Around 14:00 h, the temperature and hence rate of heating had reached its peak and the same has been shown in Fig. 3. Also, the glass temperature reached 55°C. Between 12:00 and 15.15 h, the temperature exceeded 50°C. Due to the temperature difference between water and that of glass, the rate of evaporation increased. The temperature of the water is also affected by the temperature of the glass. The temperature peaked at 75°C around 14:30 h. Between 12:15 and 15:15 h, the temperature reached 70°C. The yield of water was 2,745 mL/m²·d produced from the distillation process. Fig. 3 shows the temperature variations in air, glass, and basin water.

6.2. Effect of temperature difference in double basin solar still

Fig. 4 shows variation of temperature in double basin solar still. At 14:30 h, glass temperature at the top of the basin was 54°C. At 09:00 h, the temperature was 35°C; At 14:30 h, it had risen to a peak value of 54°C and the same has been shown in Fig. 4. The water temperature in the upper basin was 77°C at 14:30 h. The water attained 70°C between the hours of 12.15 and 16:15 h. Between 13.15 and 17:15 h, temperature was 60°C. The temperature variation between the glass and the water were around 21°C, 23°C, 20°C and 25°C with respected to 12.15, 13:15, 14:15 and 15:15 h pm. Fig. 4 shows the variation of temperature in glass cover, basin water and the surrounding environment. In perspective, the upper basin produced 3,044 mL of distilled water every day and lower basin output was 1,289 mL/d and the same has been depicted in Fig. 5.

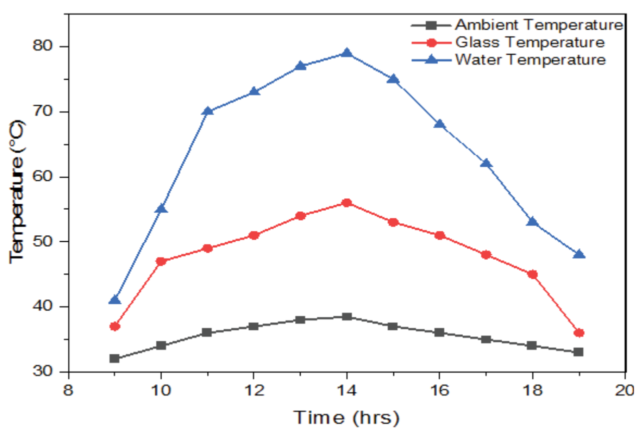

Fig. 3. Effect of temperature variation in conventional still.

The glass of bottom basin reached at a temperature of 52°C by 14.30 h. As a result, the water temperature reached to 70°C at 14:30 h. The bottom basin generated distilled water at a rate of 1,289 mL/m²·d. It was lower than the production of the upper basin. The distribution of temperature difference is shown in Fig. 4.

6.3. Performance of double basins solar still with exterior reflectors

Fig. 6 shows the temperature variation in double basin still with reflectors with higher level of productivity. The higher level of productivity was achieved by installing the reflective surfaces in the top and bottom basins. Further, reflectors were placed outside the basins and were focused towards more sunshine at the top and lower regions. As a result, between 12:15 and 14:30 h, the top basin glass temperature reached 60°C. The water temperature had reached 81°C at 14:30 h. The temperature attained 73°C from 11.30 until 16:30 h. After installing external reflectors, the yield of distilled water in the top basin rise increased from 3,044 to 3,660 mL/m²·d and the same has been shown in Fig. 7.

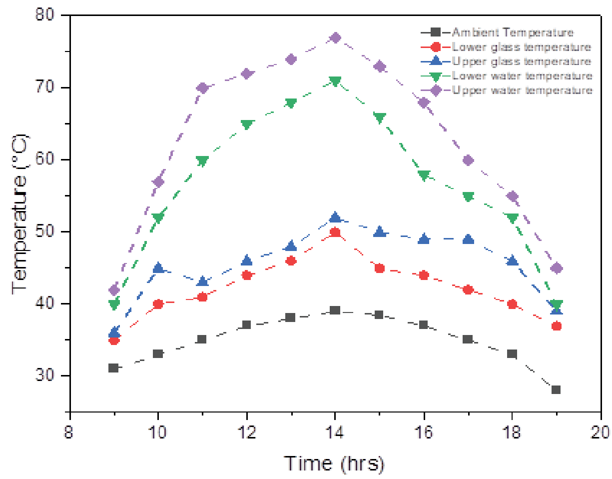

Fig. 4. Temperature difference in double basin still.

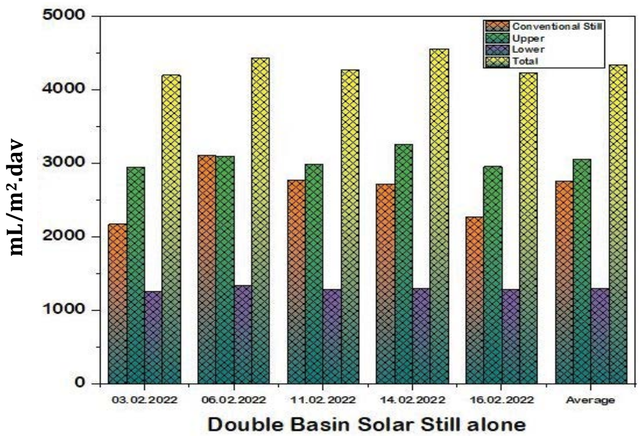

Fig. 5. Yield of double basin solar still alone.

The performance of the lower basin has also been improved. Temperatures in the glass stood at 50°C between 11.15 and 16:15 h. Around 14:30 h temperature of 58°C was recorded. The water temperature in the basin has also increased. A maximum of 75°C was reached around 14:30 h. The temperature had been over 70°C for most of the day. Yield from lower basin was improved from 1,289 to 1,990 mL/m^2·d in the lower basin. The combined distilled water flow from the lower and upper basins was 5,650 mL/m^2·d and the same has been depicted in Fig. 7.

6.4. Effect of modified solar still with reflector, FPC and solar pond

Fig. 8 shows the temperature variation in modified solar still with reflectors, FPC and solar pond. External mirror was placed in single slope double basin solar still. A FPC and mini solar pond was placed in lower still basin. As a result, performance of upper basin and lower basin were improved. The upper cover temperature was maximum 54°C in single slope double basin solar still without any modifications. When the external reflectors were installed, the temperature reached 69°C and reduced to 67°C, when connected to the FPC and solar pond. Water temperatures increased from 77°C to 81°C and 84°C, respectively, in reflector-fitted stills and FPC and mini-solar-pond-linked stills, respectively. The upper basin generated the output of 3712 mL/m^2·d of distilled water asper Fig. 9. Performance of both the upper and lower basins improved. When the reflectors were attached, the temperature reached 58°C and further fixing of solar pond and flat plate collector caused the temperature to reach 66°C.

Similarly, at 14.30 h, the water temperature in the basin varied from 70°C to 75°C and finally attained 80°C. Distilled water collected from bottom basin was at a rate of 2537 mL/m^2·d and the same has been shown in Fig. 9.

6.5. Comparative performance

Fig. 10 shows the comparative performance of different types of basins. From the results, it is seen that only 2,745 mL/m^2·d of potable water per day might be produced by a conventional single basin solar still every day. The flow rate was augmented to 4,332 mL/m^2·d with double basin. When the exterior reflector is connected to another

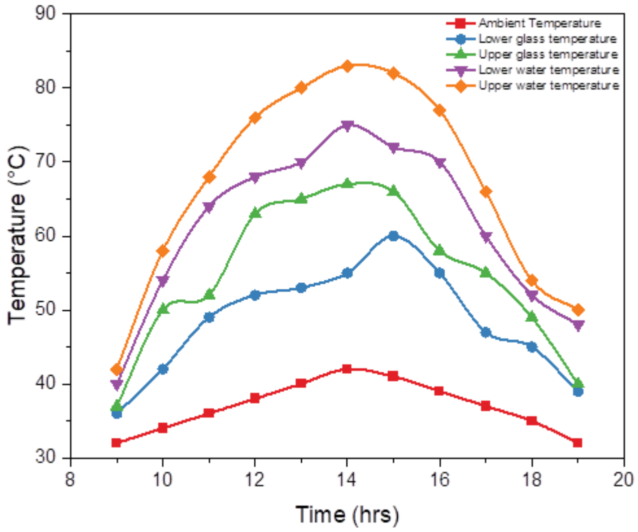

Fig. 6. Temperature variation in double basin still with reflectors.

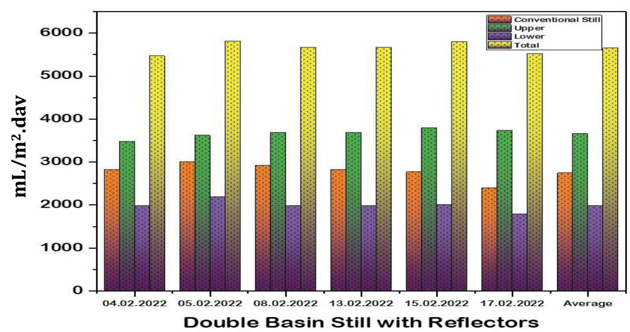

Fig. 7. Yield of double basin solar still with reflector.

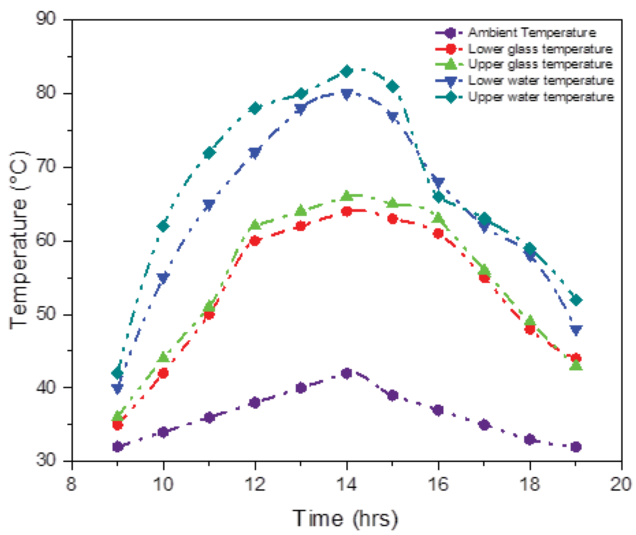

Fig. 8. Temperature variation in double basin still with reflectors, pond and FPC.

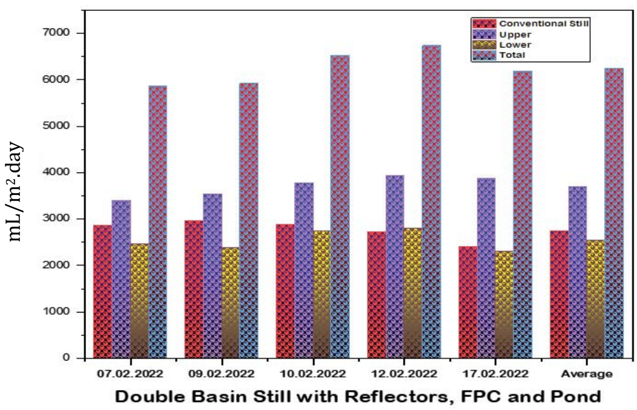

Fig. 9. Yield of double basin solar still with reflector, FPC and pond.

double basin, the production increased to 5,652 mL/m^2·d. The yield rate raised to 6,249 mL/m^2·d after connecting FPC to the top basin and the solar pond to the bottom basin. The double basin solar still outperformed the conventional still with production increased by 57.83%. External reflectors boosted production by 105.8%. When it was placed with FPC and a solar pond, it increased by 127.65%. Further, in double-basin solar stills, the lower basin has always contributed lesser than the upper basin. The upper basin contributed 70.25%, while the lower basin contributed 29.75%. The modifications improved the relative performance of lower still from 29% to 35% using the FPC and the solar pond with the reflectors placed.

6.6. Cumulative performance

Fig. 11 shows the combined performance of the conventional and double basin solar stills. The behaviour of the double basin was improved by the above modifications. The double basin solar still outperforms the conventional solar still in terms of overall performance.

6.7. Effect of yield with respected to modification

The difference in temperature affects the yield of potable water. At 14.30 h, productivity reached its maximum level. Afterwards, it started to decrease gradually as shown in Fig. 12.

6.8. Comparison of experimental and mathematical analysis

Double basin solar stills connected with FPC and reflectors, were used for theoretical and experimental performances. Experimental and theoretical results were quite near to each other, as shown in Fig. 13. A maximum of 15% of the variation has been found.

6.9. Error analysis

Copper thermocouples were used to measure temperatures of glass, water, and basin. The flow rate was calculated with the use of a jar. Solarimeter measurements were used to determine the solar radiation. Table 1 summarises

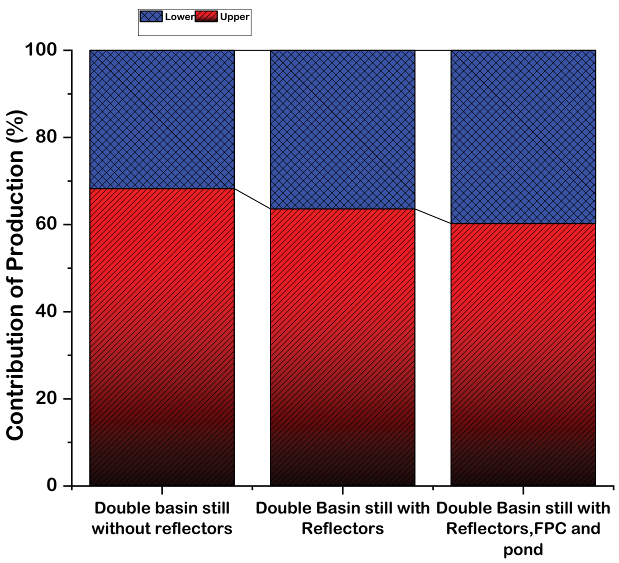

Fig. 10. Contribution of production in different modification.

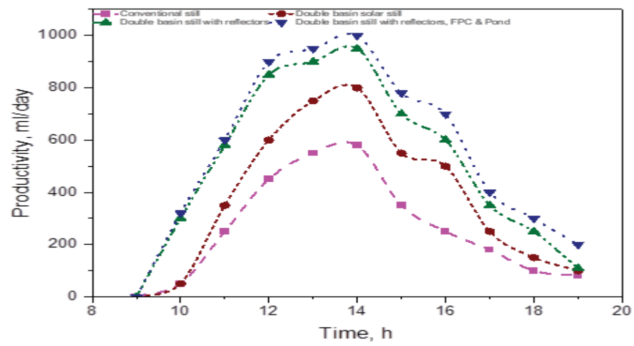

Fig. 12. Variation in productivity.

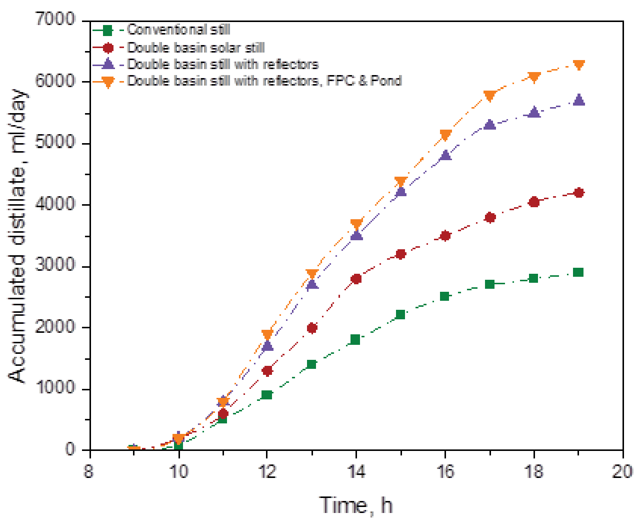

Fig. 11. Cumulative performance.

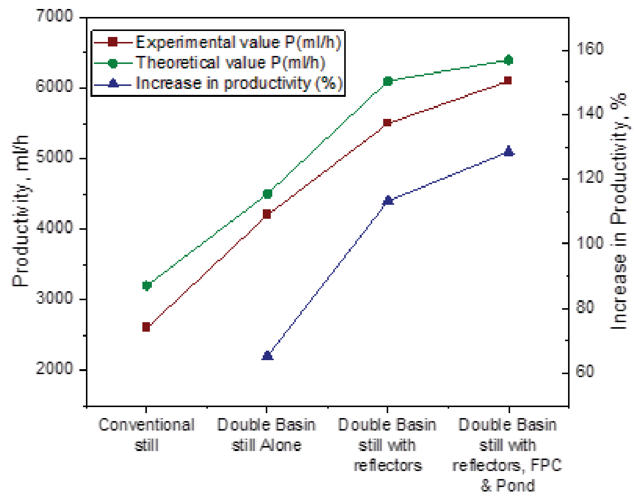

Fig. 13. Comparison of experimental value and theoretical value.

Table 1
Ranges and accuracy

S. No.	Name of the instrument	Accuracy	Reference range	Error (%)
1	Thermometer	±1°C	0°C–800°C	0.2
2	Thermocouple	0.10°C	0°C–80°C	0.10
3	Kipp Zonens olarimeter	±2 W/m^2	0 to 4,500 W/m^2	0.10
4	Measuring jar	2 mL	0–1,500 mL	5
5	Anemometer	±0.1 m/s	0–20 m/s	10

the least counts and ranges of available for the measuring instruments.

7. Conclusion

In this research work a new double basin single slope desalination unit has been designed, fabricated and tested to have more yield of water than the conventional solar still. The maximum yield of conventional solar still was 2,745 mL of portable water per day. However, the yield of modified double basin desalination was 4,300 mL/m^2·d it was achieved by the addition of second basin.

- A few modifications were made in the double basin to increase productivity further. Exterior reflectors were used to direct additional sunlight into the lower and upper basins. Because of this, the amount of distilled water produced each day grew from 4.3 to 5.6 L/m^2·d.
- The FPC and the mini solar pond were connected to the lower basin to increase the yield. The production of double basin improved from 4.3 to 6.2 L/m^2·d, by using exterior reflectors and the FPC and mini solar pond.
- Compared to a single-basin conventional still, the double-basin still produced 57.83% more yield. The usage of external reflectors increased production by 105.88%. FPC and mini solar pond combination increased production by 127.65%.
- In multiple basins with reflectors, the percentage of yield increased to 35.22%. With the FPC and the mini pond were connected to the still, the percentage of yield increased up to 40.6%.
- The theoretical analysis of portable water was 15% higher than experimental value of this research work.
- Finally, as per this experimental result and discussion, the modified double basin solar still is preferable than conventional solar still for portable water production. It has been planned to commercialize the same.

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