Modeling of Solar Water Desalination System for Clean Water Production

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Highlights

- Renewable Energy
- Desalination
- Clean Water

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Abstract: This study investigates the design, construction, and performance evaluation of a double slope solar still as a sustainable solution for desalinating saline water. With water scarcity emerging as an increasingly severe global issue, especially in arid and semi-arid regions, there is a critical need for effective, low-cost desalination technologies that leverage renewable energy sources. The solar still system presented in this research utilizes solar energy to evaporate saline water and subsequently condenses it into potable water, offering an alternative to energy-intensive conventional desalination methods. Through an optimized 45° inclination angle for the still's glass cover, the design maximizes solar absorption, leading to enhanced condensation and water yield by improving the trajectory and rate at which condensed droplets are collected. The still was tested over nine hours of peak sunlight, achieving an average yield of 2.4 liters per day, demonstrating both the system's viability and its operational effectiveness under natural sunlight conditions. Key design elements, including the basin's black liner, the optimal cover inclination, and insulation, were shown to significantly impact evaporation and condensation rates, thereby enhancing the overall efficiency of the desalination process. The findings highlight that double slope solar stills can be an economically feasible, environmentally sustainable solution for providing clean water in resource-limited areas. Furthermore, the study suggests future improvements, such as integrating phase-change materials and reflectors, to increase efficiency even further. This research contributes valuable insights into solar desalination technology, underscoring its potential for application in regions with abundant solar insolation and limited access to fresh water, thus addressing a critical need in global water management.

Keywords: Clean Water; Desalination; Energy; Evaporation

1. Introduction

Particularly in arid and semi-arid areas where access to safe drinking water is scarce, water shortage is becoming a more serious problem. In order to solve this dilemma, creative and sustainable solutions must be developed in light of the growing demand for fresh water and the loss of natural water supplies. A viable solution to this problem is solar desalination, which uses sun energy to turn salty water into potable fresh water. The solar still, particularly the double slope solar still, has attracted a lot of interest among desalination methods because of its affordability, ease of use, and environmental sustainability. [1] A solar still simulates the natural water cycle by working on the principles of evaporation and condensation. The still's water evaporates in the presence of sunlight, removing salts and contaminants, and then condenses on a colder surface to be collected as distilled water. Traditional single slope solar stills have been the subject of much research, but their design limitations limit their efficiency. Double slope solar stills, which increase efficiency by increasing the condensation area and improving thermal performance, are the result of recent developments in the sector. [2] The best design and operating procedures for double slope solar stills to attain maximum efficiency are still up for debate among specialists, despite tremendous advancements in research. To increase the efficiency of solar stills, some researchers support cutting-edge methods including adding exterior reflectors or integrating phase change materials (PCM). Others counter that, especially in areas with low resources, simpler designs could be more accessible and useful. These contrasting viewpoints highlight the necessity of more study to determine the most workable and efficient solutions that can be used broadly. [2] The purpose of this project is to design and build a solar water desalination system using a double slope solar still and assess how well it works in different operating scenarios. Located at a latitude of roughly 33.6844° N, the National University of Technology (NUTECH) in Islamabad served as the site of the experiment. Islamabad is ideally situated for solar energy applications due to its average daily sun insolation of roughly 5.3 kWh/m². This study aims to add to the current discussion on solar desalination technologies by examining both the theoretical and experimental components of this system and provide insightful information that may direct future advancements in the area. It is predicted that the main finding of this study would show that the suggested design is feasible as a sustainable water desalination method, especially in areas with a lot of solar energy.

2. Materials and Methods

A double slope solar still is a simple device that uses sunlight to evaporate water, which then condenses on a clear cover and is collected as distilled water. The main components include:[3]

1. **Basin**: A rectangular container where water is held for evaporation.
2. **Black Liner**: Placed at the bottom of the basin to absorb sunlight and heat the water.
3. **Clear Cover**: A glass or plastic sheet that allows sunlight to enter and traps heat, facilitating condensation.
4. **Insulation**: Material around the basin to minimize heat loss.
5. **Feeding and Blow-Down Pipes**: Used to supply water to the basin and remove brine.
6. **Sealant**: Ensures airtight connections between the cover and basin.

Materials of Construction [4]

- **Basin**: Made from materials like concrete, treated wood, or UV-resistant plastics.
- **Black Liner**: Durable black plastic sheets or black paint to absorb heat.
- **Frame**: Should be sturdy enough to support the cover and withstand weather conditions.
- **Glazing**: Low-iron glass is preferred for its durability, though plastic can be used for flexibility.
- **Insulation**: Waterproof and high thermal resistance materials to reduce heat loss.
- **Sealant**: Non-toxic and easy to apply, ensuring airtightness.

Auxiliary Components

- **Piping and Fittings**: Typically made from PVC or stainless steel, resistant to corrosion and high temperatures.
- **Storage Tanks**: Concrete, plastic, or metallic reservoirs for storing distilled water.

This setup is designed to be straightforward and cost-effective, allowing for easy assembly and maintenance in resource-limited settings.

Dimensions of Still Components:

Volume of Basin = 1.5 ft $\times$1.5 ft $\times$ 0.5 ft (1)

Volume of Basin = 0.4572 m x 0.4572m x 0.1524m (2)

Volume of Basin = 0.031m^3 (3)

Volume of Basin = 31 litres (4)

Glass Inclination Angle = 45^o (5)

Area of glass = 1.06ft x 1.5ft (0.4572 m x0.323088 m)

Area of glass = 0.1477m^2 (6)

The schematic diagram of double slope solar still shown in figure 1 below.

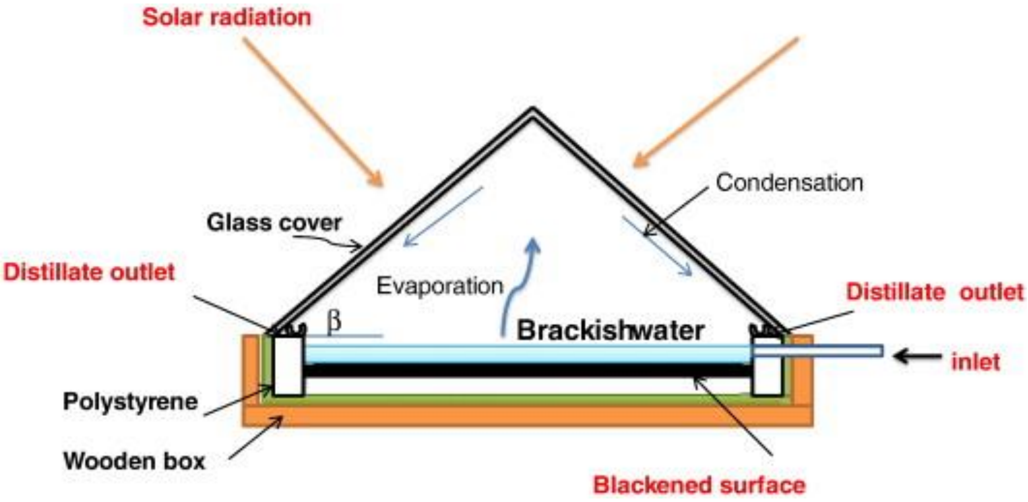

Figure 1. Double slope solar still

Cover Inclination

To ensure efficient water condensation and flow in a double slope solar still, the cover must be tilted at an optimal angle. Unlike solar collectors, which often use an angle close to the region's latitude, solar stills require more specific considerations. The latitude of Islamabad is 33.6844° N, and a common guideline is to set the cover inclination equal to the latitude. This rule of thumb is simple and effective for general solar applications, as it aligns the cover to receive maximum sunlight. However, for our solar still, we explored an alternative approach. By analyzing droplet dynamics using a free body diagram, we determined that the optimal inclination angle for maximum droplet acceleration and therefore improved condensation efficiency is 45 degrees. This angle was chosen based on the need to balance simplicity with enhanced performance, making it well-suited for the specific operational conditions of our solar still. [5]

Free Body Diagram:

The FBD of forces acting on the droplet are shown in the figure 2 below.

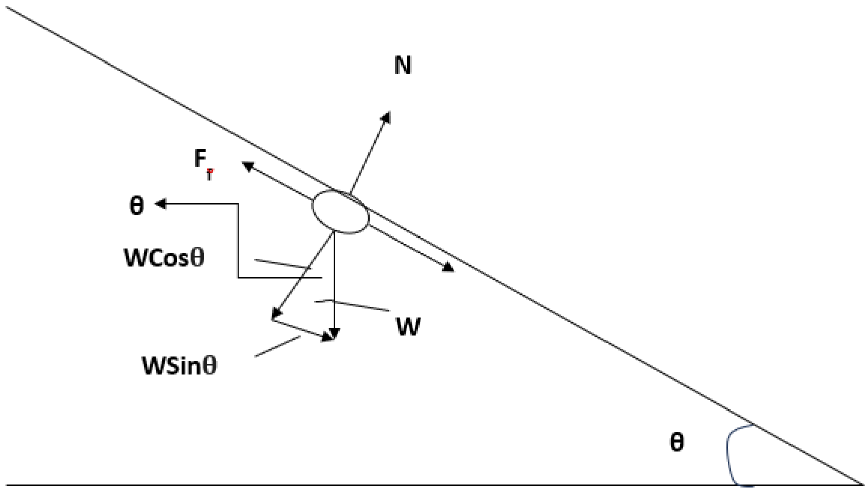

Figure 2. Free body diagram of droplet sliding over a slope

Calculation for inclination angle:

We took the droplet as having the radius of 20mm usually the size of condensed droplet is in the range of 2-20mm. [6]

By using the formula for volume of sphere we get the volume and multiply it with the density of water to get the mass of the droplet. [6]

$$\text{Volume of Sphere} = \frac{4}{3}\pi \boldsymbol{r^3} \quad (7)$$

$$m = \rho V \quad (8)$$

$$= 1000 \times \frac{4}{3}\pi\,(\mathbf{0.020})^3$$

$$= 1000 \times \frac{4}{3}\pi \times (8\times \mathbf{10^{-6}})$$

$$= \frac{4}{3}\pi \times (8\times \mathbf{10^{-3}})$$

$$m = 0.03351 \text{ kg} \quad (9)$$

Now after getting the mass, we will multiply get the normal force acting on the droplet as

$$N - w\,\text{Cos}\Theta = 0 \quad (10)$$

$$N = mg\,\text{Cos}\Theta$$

N = 0.3286 CosΘ

Now we multiply this normal force with the coefficient of friction between glass and water droplet to get the force of friction. For our low iron tempered glass we will have the value of 0.2 as a coefficient of friction between the droplet and the glass. [7]

$\boldsymbol{F_f}$ = μN (11)

$\boldsymbol{F_f}$ = 0.2 × 0.3286 CosΘ

$\boldsymbol{F_f}$ = 0.06572 CosΘ

Now after the force of friction we will use Newton's 2nd law for getting the angle of droplet with the glass.

W sinΘ - $\boldsymbol{F_f}$ = 0 (12)

W sinΘ = $\boldsymbol{F_f}$

$\sin\Theta = \frac{\mathbf{0.6572}\boldsymbol{Cos}\Theta}{\mathbf{0.3286}}$

$\frac{\boldsymbol{sin}\Theta}{\boldsymbol{cos}\Theta} = 0.2$

tanΘ = 0.2

Θ = $\boldsymbol{tan^{-1}}$(0.2)

Θ =11.3° (13)

Hence we have got the angle between glass and the droplet.

W sinΘ – 0.06572 CosΘ = ma (14)

Now we have all the values but not the value of acceleration of the droplet to be put in the above equation of Newton's 2nd law. Hence we will assume that as 5m/$\boldsymbol{s^2}$.Also we can get W by multiplying the mass with the value of g that is 9.81m/$\boldsymbol{s^2}$.**[7-8]**

Hence by assuming,

a = 5m/$\boldsymbol{s^2}$

And after putting the value in the equation of Newton's 2nd law we get,

0.3286 sinΘ – 0.06572 CosΘ = 0.0335×5 (15)

0.3286 sinΘ – 0.06572 CosΘ = 0.1675

sinΘ – 0.2 CosΘ = 0.5

$(\sqrt{\mathbf{1}-\boldsymbol{cos^2}}\Theta)^2 = (\mathbf{0.2\ Cos}\Theta + \mathbf{0.5})^2$

1 - $\boldsymbol{cos^2}$Θ = 0.04 $\boldsymbol{cos^2}$Θ + 0.1 CosΘ + 0.25

1.04$\boldsymbol{cos^2}$ Θ + 0.1cos Θ – 0.75 = 0

$\boldsymbol{cos^2}$ Θ + 0.096 cos Θ – 0.729 = 0 cos $\Theta' = \frac{\mathbf{-0.96} \pm \sqrt{(\mathbf{9.2 \times 10^{-3}}) \times \mathbf{2.916}}}{\mathbf{2}}$

cos $\Theta' = \frac{\mathbf{-0.96} \pm \mathbf{1.71}}{\mathbf{2}}$

cos $\Theta' = \frac{\mathbf{-0.096+1.71}}{\mathbf{2}} = 0.807$

$\Theta' = \boldsymbol{cos^{-1}}(0.807)$

$\Theta' = 36°$ (16)

Hence by this method we have similarly checked different accelerations of the droplet and we got maximum acceleration at 45 degrees. Different accelerations for different inclination angles are provided in the table 1 below.

Table 1. Value of accelerations for different inclination angles

Acceleration(m/s^2)	Angle(°)
0.5	8.6
1	10.1
1.5	14.9
2	19.73
2.5	24.68
3	29.54
4	34.96
4.5	37.81
5	36
5.48	45

Mathematical Modelling:

The balance of energy is key parameter in the solar still for water desalination procees. The energy balance diagram is shown in figure 3 below.

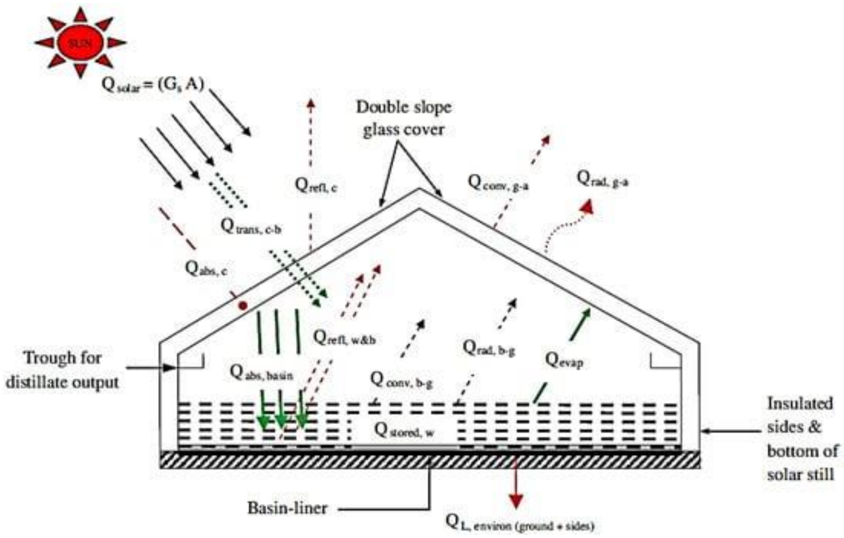

Figure 3. Energy balance diagram of solar still

Glass Cover's Energy balance:

$$GA_g\alpha_g + Q_{conv,b-g} + Q_{rad,b-g} + Q_{evap} = m_g c_{pg}\left(\frac{\Delta T_g}{\Delta t}\right) + Q_{rad,g-a} + Q_{conv,g-a} \quad (17)$$

Saline water's Energy balance:

$$GA_w\alpha_w + Q_{stored,b-w} = m_w c_{pw}\left(\frac{\Delta T_w}{\Delta t}\right) + Q_{conv,b-g} + Q_{rad,b-g} + Q_{evap} + Q_{fw} \quad (18)$$

Basin plate's Energy balance:

$$GA_b\alpha_b = m_b c_{pb}\left(\frac{\Delta T_b}{\Delta t}\right) + Q_{stored,b-w} + Q_L \quad (19)$$

Calculations:

Now Using the Formulas below, we can estimate the productivity of the solar still. Remember that these all are empirical formulas and the results may differ from the actual experimental values.

For finding the hourly yield of a solar still

$$m^{\cdot}_{produced} = h_{evap}\left(T_w - T_g\right) * \frac{3600}{h_{fg}} \quad (20)$$

Now the only unknown parameter in this formula is h_{evap} so we can find its value by using the formula

The evaporative heat transfer coefficient between water and glass can be found by

$$h_{evap,w-g} = \frac{(16.237\times10^{-3})h_{conv,w-g}(p_w - p_g)}{T_w - T_g} \quad (21)$$

Now in this formula there are three unknowns p_w , p_g and $h_{conv,w-g}$. We can find these as respectively.

Vapor pressure at water surface can be found by

pw = $\mathbf{100(0.004516 + 0.0007178tw - 2.649x10 - 6tw^2 + 6.944x10 - 7tw^3)}$ (22)

Vapor pressure on the inner surface of glass cover

pg = $\mathbf{100(0.004516 + 0.0007178tg - 2.649x10 - 6tg^2 + 6.944x10 - 7tg^3)}$ (23)

The Convective heat transfer coefficient between water and glass can be found by

$$h_{conv,w-g} = 0.884\left\{(T_w - T_g) + \frac{(p_w - p_g)(T_w + 273.15)}{(268900 - p_w)}\right\}^{1/3} \quad (24)$$

Now, put the measured values in these formulas

Water temperature = tw = 24 º c

Glass temperature = tg = 14 º c

Now we should have to find Vapor pressure at water surface (pw) and Vapor pressure in the inner surface of glass cover (pg)

pw can be found by

pw = $\mathbf{100\,(0.004516 + 0.0007178tw - 2.649x10 - 6tw^2 + 6.944x10 - 7tw^3)}$

pw = $\mathbf{100\,(0.004516 + 0.0007178(24) - 2.649x10 - 6(24)^2 + 6.944x10 - 7(24)^3)}$

pw = 2.9920 kPa

Now pg can be found by

pg = $\mathbf{100(0.004516 + 0.0007178tg - 2.649x10 - 6tg^2 + 6.944x10 - 7tg^3)}$

pg = $\mathbf{100\,(0.004516 + 0.0007178(14) - 2.649x10 - 6(14)^2 + 6.944x10 - 7(14)^3)}$

pg = 1.5986 kPa (25)

Now we will find convective heat transfer coefficient

The Convective heat transfer coefficient between water and glass can be found by

$$h_{conv,w-g} = 0.884\left\{(T_w - T_g) + \frac{(p_w - p_g)(T_w + 273.15)}{(268900 - p_w)}\right\}^{1/3} \quad (26)$$

$$h_{conv,w-g} = 0.884\left\{(24 - 14) + \frac{(2.9920 - 1.5986)(24 + 273.15)}{(268900 - 2.9920)}\right\}^{1/3} \quad (27)$$

$h_{conv,w-g}$= 1.9046 W/m²K (28)

Now we will find evaporative heat transfer coefficient

The evaporative heat transfer coefficient between water and glass can be found by

$$h_{evap,w-g} = \frac{(16.237\times10^{-3})h_{conv,w-g}(p_w - p_g)}{T_w - T_g} \quad (29)$$

$$\boldsymbol{h_{evap,w-g}} = \frac{(16.237\times10^{-3})h_{conv,w-g}(2.9920-1.5986)}{24-14} \quad (30)$$

$\mathbf{h_{evap,w-g}} =$ 4.288 x 10 $^{-3}$ W/m²K

Now we will find the enthalpy of vaporization h_{fg}

Enthalpy of vaporization h_{fg} can be found by

$h_{fg} = 2501-(2.361\times tw)$

$h_{fg} = 2501-(2.361\times 24)$

h_{fg} = 2444.336 KJ/Kg

Now the hourly yield of a solar still

$$\boldsymbol{m^{\cdot}_{produced}} = \boldsymbol{h_{evap}(T_w - T_g)} * \frac{3600}{h_{fg}} \quad (31)$$

$$\boldsymbol{m^{\cdot}_{produced}} = \boldsymbol{h_{evap}(24 - 14)} * \frac{3600}{2444.336} \quad (32)$$

$$\boldsymbol{m^{\cdot}_{produced}} = 0.0632 \text{ litre} \quad (33)$$

Hence we can predict the productivity of the still for any time or hour of day similarly. Calculating manually is a hectic work so we have made a MATLAB Code (In Appendix) that will ask the user the time from which and to which time the user wants to predict the productivity of solar still. Then the code will ask for temperature of water and glass for each hours and will give the productivity of each hour and also give the productivity of the whole day by adding the productivity of the all the hours.

The productivity showed by the code or theoretically calculated yield in our case is 2.40 liters or kilograms in our case. The maximum yield hours are the peak hours. The phenomenon of evaporation for liquid at high temperature and pressure is described in [9-12].

3. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

3.1. Theoretical Results

As show in table 2, the sum up of all the productivities of the hours give productivity of 2.38 liters.

Table 2. The values of different quantities during hours of the day

Hours (h)	Water Temperature (°C)	Glass Temperature (°C)	Hourly Yield (Litres)
1	24	14	0.06
2	32	28	0.03
3	44	37	0.11
4	53	33	0.52
5	61	47	0.48
6	64	51	0.49

7	56	43	0.37
8	49	42	0.14
9	41	29	0.18

3.2. Experimental Setup:

3.2.1. Hours of Experimentation

Our experimentation was conducted from 9 AM to 5 PM consisting of total 9 hours of experimental observations each day. This time allowed different temperature variations and their impacts on our experiments over this specified part of the day.

3.2.2. Hours of Experimentation

Throughout the day, the temperature varied significantly from minimum to maximum and then drops significantly after the peak hours. The recorded temperatures at each hour is shown in table 3.

Table 3. The recorded temperatures at each hour.

Time	Temperature
9:00 AM	24°C
10:00 AM	30°C
11:00 AM	37°C
12:00 PM	43°C
1:00 PM	45°C
2:00 PM	44°C
3:00 PM	40°C

To determine the average temperature, we summed up these values and divided by the number of readings:

Average Temperature = $\frac{(24+30+37+43+45+44+40+36+34)}{8}$

Average Temperature = 37 °C

Thus, the average temperature during our experimentation period was approximately 37.38°C. This average provides a meaningful indication about the thermal conditions under which the experiment was conducted.

3.2.3. Water Volume and Basin Capacity

We used or poured fifteen liters of water into our solar still for this experiment. The maximum capacity of the utilized basin is 31 liters. We have computed the following to get the proportion of the basin's capacity that is being used:

Percentage of Capacity Used = $\frac{15}{30}$ x 100

Percentage of Capacity Used = 48.39 %.

Consequently, during the experiment, almost 48.39% of the basin's capacity was used. Knowing how much of the basin's volume is utilized for the experiment and making sure we have the capacity to handle the amount of water used are the two reasons this is crucial.

3.3. Experimental Setup:

The average initial evaporation time observed was 57 minutes. We have did testing for three to four days and measured the initial evaporation time for everyday using a stopwatch and we have come to a conclusion that the average evaporation time was 57 minutes During this time, water molecules absorbed enough energy to change from the liquid phase to the gaseous phase. This process occurs as molecules at the surface of the liquid gain sufficient kinetic energy to overcome intermolecular forces, they escape from the surface of the liquid leading to evaporation.

The kinetic energy of water molecules increases as they absorb heat. Once they have enough energy, they break free from the liquid's surface tension and enter the air or atmosphere as vapor. This evaporation is critical in processes such as desalination like we are doing and cooling systems, where the phase change of water plays a vital role in its functioning.

3.4. Velocity of Water Droplet

To calculate the velocity of a droplet, we use the formula s = vt where s is the distance, and t is the time. Given that the distance s is 1.06 feet (which converts to 0.323 meters) and the time t is 4 seconds, the velocity v can be calculated as:

$$s = vt$$

$$v = \frac{s}{t} = \frac{(0.323)}{4}$$

$$v = 0.08075 \text{ m/s}$$

This indicates that the droplet slides from the top to the bottom of the glass plate in 4 seconds at a velocity of 0.08075 m/s.

3.4.1. Volume of Desalinated Water

By the end of the experiment, the total volume of desalinated water collected was 2.07 liters. This indicates the efficiency of the desalination process implemented during the experimental period. The ability to convert a satisfactory portion of the input water to desalinated water demonstrates the effectiveness of the experimental setup and provides valuable data for scaling up the process.

3.5. Experimental Results:

Table 4. The values of different quantities during hours of the day

Hours (h)	Water Temperature (°C)	Glass Temperature (°C)	Hourly Yield (Litres)
1	24	14	0.04
2	32	28	0.03
3	44	37	0.08
4	53	33	0.47
5	61	47	0.41
6	64	51	0.43
7	56	43	0.35
8	49	42	0.11
9	41	29	0.15

From the above 4 table, it was calculated that sum up of all the productivities of the hours gave productivity of 2.07 litres.

4. Discussion

We can see that after we place the solar still in the sunlight, water doesn't immediately start to evaporate. It takes some time according to initial amount of water present in the basin. This water heats up gradually absorbing the heat from sunlight. When this water reaches a high enough temperature, then evaporation starts at a fast pace. We can see the water vapors start accumulating on the glass. The vapors start accumulating and then when enough of their vapors combine, they from a droplet. This droplet due to gravity after sometime starts to slide downwards on the glass until it falls off the edge and into the collection pipes so that it can flow out into the container.

5. Conclusions

The findings from this study reveal that the double slope solar still is a viable solution for desalination, offering a sustainable method to convert saline water into drinkable water by utilizing solar energy. The specific design elements such as the 45-degree inclined glass cover and the blackened basin play a crucial role in enhancing evaporation and condensation rates, ultimately increasing the water yield to an average of 2.4 liters per day. This passive solar desalination system is particularly useful in places without access to conventional energy sources since it offers an inexpensive and low-maintenance substitute for isolated or off-grid areas. Furthermore, the system's reliance on solar energy that is renewable fits in nicely with international initiatives to use eco-friendly technologies to fight water scarcity. Even though the existing design has a lot of potential, efficiency could be further increased with future developments. For example, adding reflectors to increase solar input or using phase-change materials to improve heat retention could increase the system's efficiency.

5.1. Critical Factors Influencing Performance:

5.1.1. Glass Thickness

In a solar still, the glass's thickness has a significant impact on the system's efficiency. The benefit of thicker glass is its ability to hold heat for longer, which can raise the still's internal temperature and quicken the evaporation process. There is a trade-off, though, as too thick glass may block the passage of sunlight, which lowers the energy available for water evaporation. Achieving optimal performance requires striking a balance between solar energy delivery and heat retention.

5.1.2. Coefficient of Friction

The coefficient of friction affects how water droplets flow across the glass surface. The collecting process may be slowed down by a higher coefficient of friction, which indicates more resistance to droplet movement. On the other hand, water droplets can travel more freely and accumulate more easily in the condensation basin when the coefficient of friction is smaller. In this case, the glass surface's smoothness is crucial because smoother surfaces tend to have less friction. However, over time, elements like surface pollution or mineral deposits from evaporated water may cause friction to rise, which could lower the effectiveness of water collecting. The efficiency of the solar still in creating potable water with a significant decrease in salt and other impurities has been confirmed by experimental findings. The system's simplicity, coupled with the low cost of components and minimal maintenance requirements, makes it an attractive option for deployment in remote or off-grid areas where clean water is scarce.

5.2. Influence of Initial Water Volume

Evaporation Rate: One important factor influencing the evaporation rate is the initial volume of water in the basin. A greater initial volume raises the total evaporation rate by increasing the surface area accessible for evaporation, which permits more water to change from liquid to vapor.

5.2.1. Condensation

The condensation process on the inner surface of the glass cover is improved by a higher concentration of water vapor inside the still, which is the result of a bigger initial water volume. This causes more water droplets to accumulate, which raises the total amount of water produced.

5.2.2. Operating Duration

The solar still's operating time before needing to be refilled is also influenced by the starting water volume. In regions where water is limited and replenishment is difficult, a higher initial volume enables the still to continue producing water for a longer amount of time.

5.2.3. Stability of Operation

The stability of the interior environment of the solar still is ensured by maintaining a constant beginning water volume, which is essential for sustaining dependable and effective water production. The evaporation and condensation processes may be hampered by changes in temperature, humidity, and wind brought on by fluctuations in the starting water level.

5.3. Future Enhancements and Opportunities

Even if the solar's current design has shown itself to be beneficial, further optimization can yet be done. Overall performance might be greatly increased by optimizing the system to maximize solar energy absorption, raise evaporation rates, and improve condensation efficiency. Furthermore, the investigation of cutting-edge materials and new technologies may result in desalination systems that are more economical, scalable, and effective.

To sum up, the solar water desalination system provides a sustainable and eco-friendly substitute for traditional desalination techniques. It has the potential to be extremely important in tackling the world's water shortage, giving impoverished areas access to clean drinking water, and supporting larger initiatives for sustainability and environmental preservation with continued research and development.

Nomenclature

G = Incident solar radiation per hour

A_g = Area of the glass

A_w = Area of the water in the basin

A_b = Area of the basin

α_g = Absorptivity of glass cover

α_w = Absorptivity of water

α_b = Absorptivity of basin

$Q_{conv,w-g}$ = Convection heat flow between water and glass

$Q_{rad,w-g}$ = Radiation heat flow between water and glass

$Q_{evap,w-g}$ = Evaporation heat flow between water and glass

$Q_{stored,b-w}$ = Convection heat flow between basin and water

$Q_{rad,g-a}$ = Radiation heat flow between glass and sky

$Q_{conv,g-a}$ = Convection heat flow between glass and sky

Q_{fw} = Heat flow of feed water

Q_{loss} = Heat loss from basin

m_g = Glass mass per unit surface

$\boldsymbol{m_w}$ = Water mass per unit surface

$\boldsymbol{m_b}$ = Basin mass per unit surface

$\boldsymbol{c_{pg}}$ = Specific heat of glass

$\boldsymbol{c_{pw}}$ = Specific heat of water

$\boldsymbol{c_{pb}}$ = Specific heat of basin

$\left(\frac{\Delta T_g}{\Delta t}\right)$ = Change in glass temperature with time

$\left(\frac{\Delta T_w}{\Delta t}\right)$ = Change in water temperature with time

$\left(\frac{\Delta T_b}{\Delta t}\right)$ = Change in basin temperature with time

$\boldsymbol{\dot{m}_{produced}}$ = Water produced in an hour

$\boldsymbol{h_{evap}}$ = Evaporative heat transfer coefficient

$\boldsymbol{T_w}$ = Water temperature

$\boldsymbol{T_g}$ = Glass temperature

$\boldsymbol{h_{fg}}$ = Enthalpy of vaporization

$\boldsymbol{p_w}$ = Vapor pressure at water surface

$\boldsymbol{p_g}$ = Vapor pressure on the inner surface of glass cover

$\boldsymbol{h_{conv,w-g}}$ = convective heat transfer coefficient between water and glass

$\boldsymbol{h_{evap,w-g}}$ = evaporative heat transfer coefficient between water and glass

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