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PERFORMANCE COMPARISION OF MULTI SLOPE SOLAR STILL WITH DOUBLE SLOPE STILL

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ABSTRACT
The growing scarcity of fresh water source is driving the implementation of desalination on an increasingly large scale. The idea of using renewable energy source is fundamentally attractive and many studies have been conducted in this area. Solar distillation is one of the promising effect that uses solar radiation effectively to produce fresh water.
Since there are various methods of solar distillation depending upon various factors, the number of slopes of glazing cover is one of the key factor. This paper presents a theoretical and experimental work performed on a double slope and multi sloped (four) solar still. In this work, additional slopes is incorporated with conventional double slope still to analyze the performance. Double and four sloped solar stills are fabricated with the area of 1.4 m2 and would be tested under same operating parameters and same climatic conditions. In these experiments the fresh water productivity is 3.9 liters for multi sloped still with 29.5% efficiency while for double slope the productivity is 3.1 litres with efficiency of 25.08%. The results indicates that the productivity and efficiency of fresh water will increase for more slopes up to certain limit.

INTRODUCTION
Water and energy are two inseparable commodities which continue to influence the growth of the human civilization. In global, 71% of the earth's surface is water. Of this, nearly 97% of water resources found on the earth's surface are stored in the oceans and seas and it is salty [8]. Only 3% of the total water resources are fresh water. The major amount of fresh water is found frozen in the form of ice sheets and glaciers. The rivers and lakes have only 0.3% of the world's fresh water. The expansion of population and development of industries also leads to damaging the available source of fresh water.

As a result, many people do not have access to adequate and inexpensive supplies of potable water. This leads to population concentration around existing water supplies, marginal health conditions, and a generally low standard of living.

Solar distillation uses the heat of the sun directly in a simple piece of equipment to purify water. The equipment, commonly called a solar still, consists primarily of a shallow basin with a transparent glass cover. The sun heats the water in the basin, causing evaporation. Moisture rises, condenses on the cover and runs down into a collection trough, leaving behind the salts, minerals and most other impurities, including germs [9].

Although it can be rather expensive to build a solar still that is both effective and long-lasting, it can produce purified water at a reasonable cost if it is built, operated and maintained properly.

The construction of reverse osmosis (RO) or conventional desalination plants utilizing fossil fuel sources to the supply fresh water may not be practical in many remote areas. This may be due to one or more of the following reasons: they require qualified technical staff for both maintenance and operation; conventional desalination plants are economic only for very large scale applications, viz., high capacity plants; they both require high fixed capital investment; the availability of a reliable power source to operate the plant.

As the performance of solar still is based on various parameters, this research was aimed at comparing two stills that were fabricated in a similar way differing only in the number of slopes of glass cover. They were installed at the same place, facing north, so that they were subjected to same climatic conditions.

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DESALINATION TECHNOLOGIES

Desalination is by definition a process removing minerals and salts from saline water to produce freshwater, that can be used for human use or irrigation. It's applied to seawater and brackish water with different performances criteria.

It's normally considered that salinity below 500 ppm is suitable as drinking water. Basically, a complete desalination process includes 3-4 steps with, first pumping water (from sea, estuaries or saline aquifers), pre-treatment of pumped water (filtration, chemical addition) desalination process and last, a post treatment if necessary (in some case, adding few minerals).
Desalination process have received great attention as an alternative solution for fresh water production. Desalination is one of the methods which is suitable for potable water. The demand for reliable and autonomously operating desalination systems is increasing continuously. These systems are meant for a basic need of drinking water and fresh water supply [10].

2.1 SOLAR DISTILLATION

Solar distillation seems to be a promising method and alternative way for supplying fresh water. Several solar still designs have been proposed and many of them have found significant applications throughout the world. Solar desalination systems have low operating and maintenance costs and require large installation areas and high initial investments. [9]

2.1.1 Principle of Solar Desalination

A basin of solar still has a thin layer of water, a transparent glass cover that covers the basin and channel for collecting the distillate water from solar still as shown in figure 1.4 The glass transmits the sun rays through it and saline water in the basin or solar still is heated by solar radiation which passes through the glass cover and absorbed by the bottom of the solar still. In a solar still, the temperature difference between the water and glass cover is the driving force of the pure water yield. It influences the rate of evaporation from the surface of the water within the basin flowing towards Condensing cover. Vapour flows upwards from the hot water and condense. This condensate water is collected through a channel. [14]

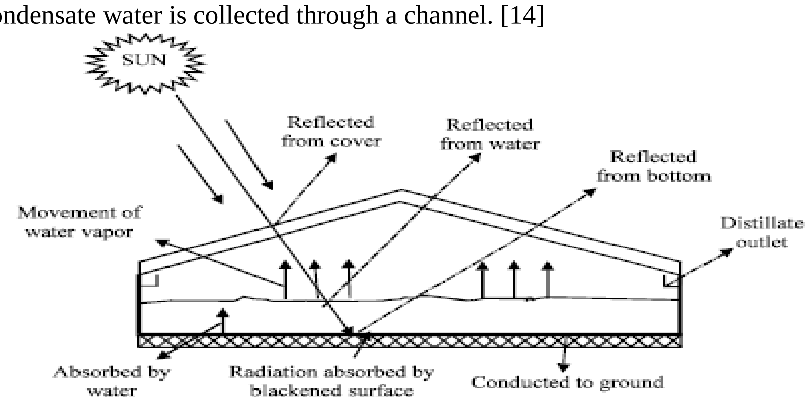

Figure 1.4 solar still principle [14]

2.2 EFFECT OF SLOPE ON SOLAR STILL

One of the factor that contributes to the productivity of solar still is the number of slopes that can be used in the glass cover. The conventional number of slopes used are moreover single or double in the basin type stills.

Hence this project introduce a concept of multi slope (4 slope) solar still shown in figure 4.1 and analyze the outcome with comparison to the conventional double slope solar still. The two models are made with the use of same materials and same dimensions as in table 4.1 to keep in a same location to undergo the experimental process with similar climatic conditions. The comparison mostly done between the productivity of the still for similar factors and conditions that the experiment is being carried out.

EXPERIMENTAL SETUPS

3.1 Experimental Setup of Double Slope Solar Still

The experimental setup of double slope solar still is shown in fig 2 and fig 3.

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Fig 2: Double Slope Solar Still

Fig 3: Vapour Condensation on glass cover

3.2 Experimental Setup of Multi (4) Slope Solar Still

The experimental setup of multi (4) slope solar still is shown in fig 4 and fig 5

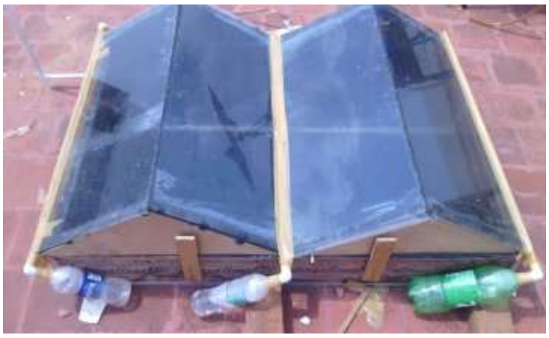

Fig 4: Multi (4) sloped solar still

Fig 5: Collection of water droplets

THEORECTICAL CALCULATION

Location: Tirunelveli
Latitude: 8°44' N
Longitude: 77°42' E
Day ,n= April 20
Declination §=23.45 sin [$\frac{360}{365}$(284+n)] (4.1)
Average solar radiation on still =5.9 Kwh/m^2-day

4.1 Modes of Heat Transfer in Solar Still

4.1.1 Internal Heat Transfer

The heat exchange between water surface and glass cover inner surface of the solar still is known as internal heat transfer. There are three modes, namely convection, radiation and evaporation processes, by which the internal heat transfer process within the solar still is governed. These three modes of internal heat transfer process are described as follows:

Convection heat transfer

Convection heat transfer process is complicated in nature by the fact that it involves fluid motion as well as heat conduction. The convection heat transfer strongly depends on fluid properties and geometry and roughness of solid surface involved. In a solar still, the convection heat transfer takes place between basin water and glass cover inner surface across humid air due to temperature difference between them.

The convective heat transfer rate inside the solar still can be expressed in terms of water temperature (Tw) and glass cover inner surface temperature (Tgi) by the following relation:

$$q_{c,w-g_i} = h_{c,w-g_i}(T_W\text{-}T_{gi}) \qquad (4.5)$$

In the above expression, $h_{c,w-g_i}$ is the convective heat transfer coefficient between water mass and glass cover inner surface and can be calculated as follows:

$$h_{c,w-g_i} = 0.884\text{x } [(T_W\text{-}T_g) + \frac{(P_{W}-P_{g_i})(T_W+273.15)}{268.9X10^3-P_W}]^{1/3} \qquad (4.6)$$

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The saturation vapour pressures at water temperature and glass cover inner surface temperature are evaluated by the following expressions:

$$P_w = \exp\left[25.317 - \left(\frac{5144}{T_W + 273}\right)\right] \quad (4.7)$$

$$P_{g_i} = \exp\left[25.317 - \left(\frac{5144}{T_{g_i} + 273}\right)\right] \quad (4.8)$$

Radiation heat transfer

$$q_{r,w-g_i} = 0.96\ \sigma\ (T_w^4 - T_{g_i}^4) \quad (4.9)$$

Evaporation heat transfer

$$q_{e,w-g_i} = h_{e,w-g_i}(T_W - T_{gi}) \quad (4.10)$$

In the above expression, $h_{e,w-g_i}$ is called as evaporative heat transfer coefficient between water mass and glass cover inner surface and determined by,

$$h_{e,w-g_i} = 16.273\text{x}10^{-3}\text{x}\left[\frac{P_W - P_{g_i}}{T_W - T_{gi}}\right] \quad (4.11)$$

The total internal heat transfer rate is the summation of convective, radiative, and evaporative heat transfer rates between water mass and glass cover inner surface which is given as,

$$q_{t,w-g_i} = q_{c,w-g_i} + q_{r,w-g_i} + q_{e,w-g_i} \quad (4.12)$$

4.1.2 External Heat Transfer

The convection heat loss from glass cover outer surface of the solar still to the atmosphere is given by,

$$q_{c,g_o-a} = h_{c,g_o-a}(T_{g_o} - T_a) \quad (4.13)$$

The convective heat transfer coefficient h_{c,g_o-a} is expressed in terms of wind velocity(v) as follows:

$$h_{c,g_o-a} = 2.8 + (3.0\text{xv}) \quad (4.14)$$

The radiation heat loss from glass cover outer surface of the solar still to the surroundings is given by,

$$q_{r,g_o-a} = h_{r,g_o-a}(T_{g_o} - T_a) \quad (4.15)$$

The radiative heat transfer coefficient between glass cover outer surface and the surrounding is given as,

$$h_{r,g_o-a} = \mathcal{E}_g \sigma \left[\frac{(T_{g_i}+273)^4 - (T_{g_i}+273)^4}{(T_g - T_s)}\right] \quad (4.16)$$

Where $T_s = T_a - 6$

The total top heat loss is the summation of convective and radiative heat losses which is given as,

$$q_{t,g_o-a} = q_{c,g_o-a} + q_{r,g_o-a} \quad (4.17)$$

4.1.3 Heat Transfer from Basin to Water

The rate of convective heat transfer between basin liner and the water mass is given by,

$$q_{c,b-w} = h_w(T_b - T_w) \quad (4.18)$$

4.2 Balanced Equation

ON GLASS COVER:

$$\alpha_g I_t + q_{t,w-g_i} = (q_{c,g_o-a} + q_{r,g_o-a}) m_g c_{p_g} \frac{dT_g}{dt} \quad (4.19)$$

ON BASIN WATER:

$$\alpha_w I_t \tau + q_{c,b-w} = (q_{c,w-g_i} + q_{r,w-g_i} + q_{e,w-g_i}) + m_w c_{p_w} \quad (4.20)$$

RESULTS AND DISCUSSIONS

The various results obtained in the experimental process which are carried out on basin area of 1.3 m^2 with a water depth of 15mm and in north-south orientation is as follows

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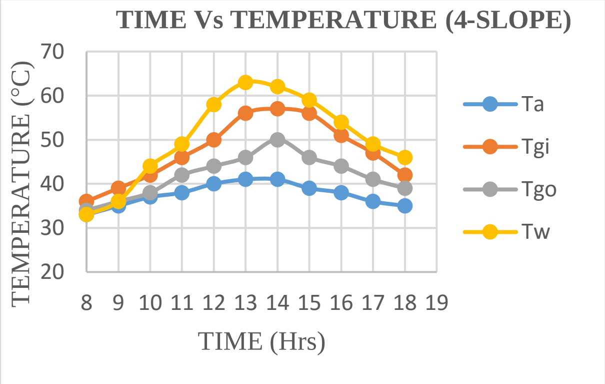

Fig 6: Variation of Temperature with Time (2 slope)

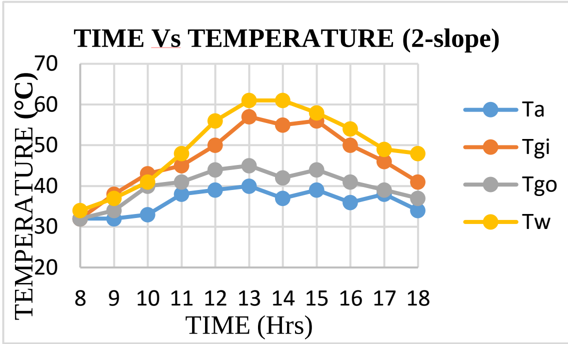

Fig 7: Variation of Temperature with Time (4 slope)

The fresh water productivity of double and multi slope stills are given in fig 8 on hourly basis.

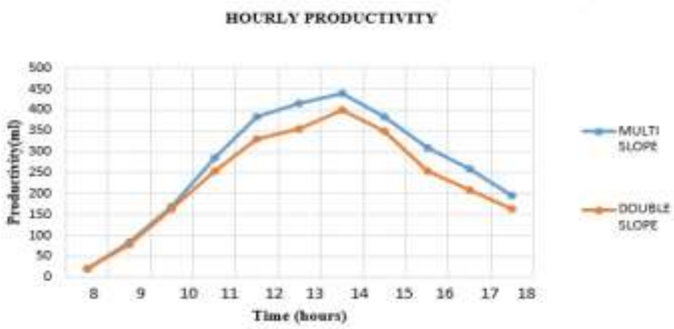

Fig 8: Productivity of Double Slope Vs Multi Slope

Productivity Comparision:
From the fig 9, it is noted that the fresh water productivity of multi slope still is higher than that of the double slope one for the same operating conditions. The total productivity obtained in double slope still is 3.3 litres whereas in multi sloped still it is about 3.9 litres.

Fig 9: Comparision of Productivity of Double and Multi Sloped Stills.

CONCLUSIONS

1. The solar still is designed and fabricated with double slope and multi (4) slope
2. The double and multi sloped still is experimented with a basin area of $1.4m^2$ and in north-south orientation.
3. The maximum productivity was obtained for multi slope still which is 3.9 litres where the double sloped still productivity is 3.3 litres.
4. The overall efficiency is higher for multi sloped still (29.5%) where the double slope still is (25.08 %)

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