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Energy Efficient Stepped Basin Type Solar Still

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Abstract- Energy efficient stepped basin type solar still is used to enhance the productivity of solar still. The efficiency of flat basin type solar still is low which is known as conventional solar still. In order to increase the efficiency of solar still we use stepped basin by replacing the flat basin. It is found that the efficiency of stepped basin type solar still is higher than the conventional solar still because of its large absorbing area or basin area. The number of step in basin is five. The tray of galvanized iron sheet with minimum depth is mounted on each steps of basin. In addition we also introduced internal reflector. The effect of installing a reflecting mirror on vertical side of the steps of stepped still also help to enhance the productivity of solar still. This project mainly focus on maximizing the production of distilled water by emphasizing the three important factors; decrease in depth of water, increase in exposure area and temperature of saline water.

Keywords- *Steps, tray of galvanized sheet, internal reflector mirror*

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Chapter 1: Introduction

The solar distillation process is a conventional process which is used for many years the function of this process is to distillate the water with the using of solar radiation and it purify the contaminated water this is widely used in rural areas where there are no availability of pure water it also removes salinity from water and make it drinkable. It works on of solar radiation when solar rays strikes on distillator then lower black surface will absorb all radiation and water particle which is in contact with that surface will evaporate and it will clinged to inclined glass surface and as time passed this water particle will condensed on that surface and whatever salt and other contaminated particle will remain at base and pure water can be collected at bottom inclined surface with use of gravity.

1.1 Present Useful Water Scenario

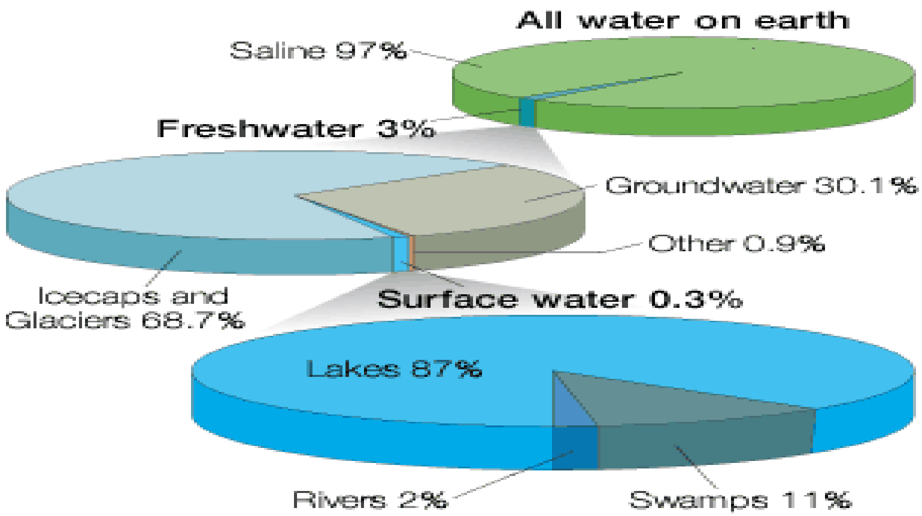


FIGURE 1 : 1.1 DISTRIBUTION OF WATER ON EARTH

"Water is life". It is a unique natural resource among all sources available on earth. No life form can be sustained without water on the planet. It is essential for all the important activities like food production, industries like energy, production and manufacturing. It plays an important role in economic development and the general well being of the country. United Nations stated that water is a social and cultural good, not merely an economic commodity. Chemically water is a compound of oxygen and hydrogen with highly distinctive physical and chemical properties. It has chemical formula: H_2O.Out of all the water available on the Earth, 97 % of water is saline and is in oceans, 3% of water is freshwater available in rivers, streams and glaciers. There is enough freshwater available on the planet for current population of the world but it is distributed unevenly. Following graph shows the Earth's water distribution.

1.2 Indian Scenario

1.2.1 Surface water resources

Water resources including rivers, lakes or fresh water wetlands are known as surface water resources. Precipitation is the natural recharging source for the surface water resources and it also maintain the hydrological cycle. Rivers are the major source of water in India. The utilizable annual surface water in rivers of the country is 690 km^3. Human activities like artificial dams, reservoirs are also included in the same category and have capacity to increase utilization of the water.

1.2.2 Groundwater resources

Water sources like subsurface water or water within aquifers are known as ground water resources.Ground water resource recharge from the precipitation mostly in the monsoon season India. Canal irrigation and other form of irrigation systems also contribute to the recharging of the ground water. The annual potential of natural groundwater recharge from rainfall in India is about 342.43 km^3, which is 8.56% of total annual rainfall of the country. The annual potential groundwater recharge augmentation from canal irrigation system is about 89.46 km^3 .(Rakesh Kumar, R. D. Singh and K. D. Sharma).

1.2.3 Water Availability and Quality in India

Water is available only for a few hours in most Indian cities and the quality is also not up to the mark.Water woes are also because of insufficient or low pressure and erratic supplies.The rural population suffers from low water quality but the urban and semi- urban areas are most prone to water shortage.The water quality should be safe and sound at the microbiological level and mere continuous supply is not enough. Another aspect is the water wastage in terms of leakages and illegal connections.

Chapter 2: Experimental studies

2.1 Component of Solar Still

1. Stepped Basin with tray
2. Transparent Cover
3. Insulator
4. Still Box
5. Saline Water Tank
6. Collection Trough

7. Stand
8. Distilled water collecting vessel

2.1.1 Detail Discription of Component of Solar Still

1. **Stepped Basin with tray**

It is the part of solar still in which the water to be distilled is kept. It is therefore essential that it must it must absorb solar energy. Hence it is necessary that the material have high absorptivity or very less reflectivity and very less transmissibility. These are the criteria for selecting the basin material. In this project we use galvanized steel sheet for stepped basin. There are five stepped on basin. On each stepped of basin one tray is mounted with 5mm depth which contain the saline water to be distilled. The surface of stepped basin and tray is coated with black die in order to absorb the solar radiation. Fig. 1.1 shows the view of tray.

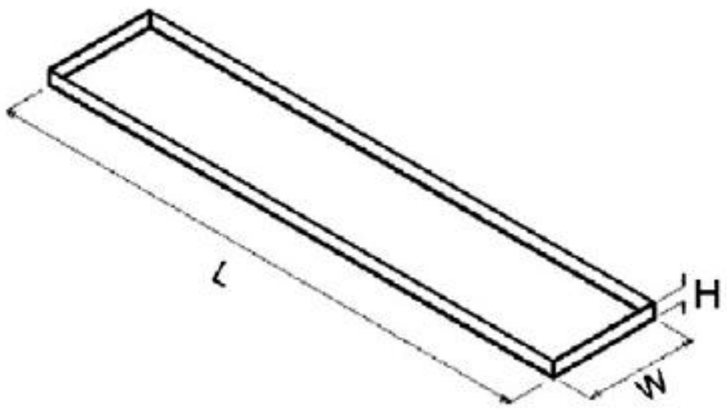


Fig 1.1 View of tray [2]

2. **Transparent Glass Cover**

Transparent glass cover is the most critical component of solar still. It is mounted above stepped basin. It must be able to transmit a lot of solar radiation. The transparent glass cover should be strong enough to resist high winds, rain, hail and small earth movement. Moreover, it must be "wet table". Wettability allows the condensing vapor to form as sheet of water on underside of transparent glass cover rather than as water droplet. If water does form a droplet, it will reduce the performance of the still.

Tampered glass is the best choice as transparent glass cover material in term of wettability and its capability to withstand high temperature. It is also three to four time stronger than ordinary window Glass. One disadvantage of tempered glass is its high cost. Ordinary window glass is the next best choice. So we use ordinary window glass as transparent glass cover which has low cost than tampered glass cover.

The thickness of glass cover is 3.5mm and glass cover is inclined at 72.63^0horizontally, which is equal to Latitude of Gandhinagar [23.22^0 N][11]. Gandhinagar is situated at 23.22^0North Latitude and 72.63^0 East Longitude. So as to maximize amount of solar radiation.

3. Insulation

Insulation used to retard the flow of heat from solar still, increased the still performance. Insulation is placed under the still basin. Since this is a large area susceptible to heat lose. In this project we use saw dust as insulation. Saw dust is easily available as well as it include low cost.

4. Still Box

Still box generally provides rigidness to the still. But technically it provides thermal resistance to the heat transfer that takes place from the system to the surrounding. So still box has a material having low value of thermal conductivity and should be rigid enough to sustain its own weight and weight of the transparent glass cover.

We use the plywood for still box of thickness 15mm and size (1030*670mm).

5. Saline Water Storage Tank

Saline water storage tank perform the function of storing the saline water to be distilled. A valve is provided with storage tank to control the flow of water from tank to the solar still through pipe according to requirements. Saline water storage tank is placed on stand. The height of stand is greater than the height of solar still in order to provide facility of the automatically flow of water from saline water storage tank to the solar still.

6. Collection Through

The collection through is located at the base of tilted glass cover. It serves to collect the condensed water and carry it to storage. It should be as small as possible to avoid shading of basin. Stainless steel is the material of choice, although it is expensive. Common varieties such as 316 are acceptable. Other metal require protective coating to prevent corrosion. Copper and brass should not be used because they should create a health hazard.

7. Mirror

Mirror is act as internal reflector in stepped basin type solar still. The mirror is added on the vertical side of steps of stepped basin. To reflect the solar rays falling on side wall of the steps of stepped basin reflecting mirror are fixed on vertical side of steps of stepped basin .the effect of installing a reflecting mirror on the vertical side of steps of stepped basin can increases the productivity of solar still. Fig. 1.2 shows the mirror is added on the vertical side of steps of stepped basin.

8. Distilled Water Collecting Vessel

Vapor condensed inside the glass cover is first fall on collection trough in the form of droplet. This distilled water is then supply to distilled water collecting vessel through the pipe. The pipe is connected between the collection trough and distilled water collecting vessel. The distilled water is storage in side this vessel.

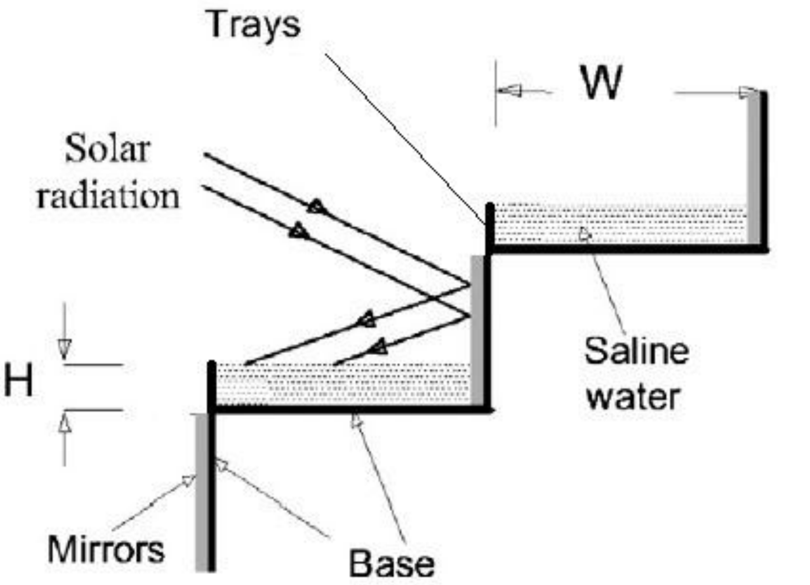


Fig.1.2 Trays and mirrors on the steps of the modified stepped still. [4]

2.2 Experimental Set Up

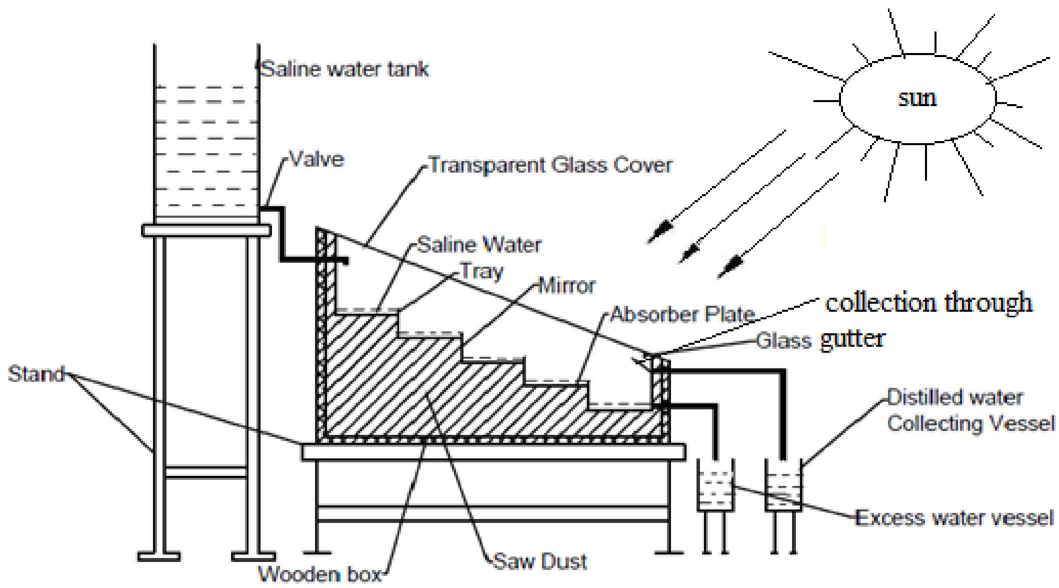


Fig 1.3 SCHEMATIC DIAGRAM OF STEPPED BASIN TYPE SOLAR STILL

The experimental set up of stepped basin type solar still is shown in figure. It is consist of saline water storage tank and stepped basin type solar still mounted on stand as shown in figure. The basin in the still is looking like a stepped type of structure. The absorber plate is made up of galvanized iron sheet of 1mm thickness. The absorber plate is made of 5 steps figure shows the step with tray on horizontal side and mirror on the vertical side of step. The stepped type structure of the absorber plate is coated with black dye because it is an established fact that black dye is the best solar radiation absorbing material. The absorber plate is placed inside a wooden box. The space between the wooden box and stepped type absorber plate is filled with sawdust to avoid the heat loss from the bottom and sides of the solar still. The glass cover of solar still is made up of 3.5mm thick simple window glass. The saline water is supplied to the solar still from the saline water storage tank through polyvinyl chloride (PVC) hose pipe. The trays of absorber plate are filled with saline water one after another starting from the top and excess water comes out from the excess water channel provided at the side of still.

When solar radiation falls on the glass cover, it is absorbed by the black absorber plate. Also solar radiation fall on the vertical side of steps are reflected to the absorber plate due mirror are attached on the vertical side of steps. Due to this, the water contained in tray at depth of 5mm begins to heat up. When the saline water absorbs maximum solar radiation equal to specific heat capacity of its mass, it is saturated and evaporation of water is takes place. The water vapour formed due to evaporation of water are rises and it come in contact with the glass cover. Then the water vapor is condensed at the inside of glass cover, as its temperature is low. The glass cover is sealed with a rubber gasket to ensure the vapor is not lost to the atmosphere. The condensed water trickles down to the distillate collection through provided at the bottom and is collected into a distillate water vessel by using a hose pipe which is mounted at the side of the solar still.

When the evaporation of water in the tray takes place the saline water level in the tray of solar still decreased to compensate the loss of water, at regular intervals the makeup water is added to the tray of solar still from the storage tank.

2.3 Objectives

- ❖ To increase the surface area of solar still per unit mass.
- ❖ To compare the output of stepped solar still with conventional solar still.

2.4 Methodology

In this project our main objectives is to increases the efficiency of single basin type solar still. The Productivity of a Solar Still Depend on Exposure area, saline water depth & Temperature of the Saline Water, Glass Cover Thickness, and The Design of the Present Work Is such that the all above factors are accomplished. In this work basin is made with five stepped on each step the tray is mounted of fixed depth and fixed width. The main objective is to improve the efficiency of solar still by ensuring

- ❖ To a high feed water temperature
- ❖ To increasing the absorbing area of incident solar radiation.
- ❖ To low vapor leakage
- ❖ To maintaining Minimum depth of the saline water in stepped basin type solar still.
- ❖ To install an internal reflector (mirror) at the vertical side of step.
- ❖ To increasing the evaporation rate.

2.5 Factors Affecting the Efficiency of Solar Still

- Solar intensity ambient temperature
- Wind velocity
- Water-glass temperature difference
- Depth of water
- Temperature of inlet water
- Glass cover thickness
- Glass cover angle
- Absorber plate

2.6 Material Used and Dimension

2.6.1 Material Used

1. Material used for wooden box : Plywood
2. Insulation material : Thermocol
3. Transparent cover material : Glass (simple window glass)
4. Material used for stepped basin and tray : Galvanized steels sheet

2.6.2 Dimensions

2.6.2.1 Dimension of Wooden Box

1. Width of wooden box : 1030 mm
2. Length of wooden box : 1170 mm
3. Thickness of wooden box : 15 mm
4. High side wall height : 360 mm
5. Low side wall height : 80 mm
6. Area of box : 1.20 m^2

2.6.2.2 Dimension of Stepped Basin

1. Width of step : 200 mm
2. Height of step : 75 mm
3. Length of step : 1170 mm
4. No of step : 5
5. Thickness of basin : 1 mm

2.6.2.3 Dimension of Glass Cover

1. Width of glass : 1070 mm
2. Length of glass : 1170 mm
3. Thickness of glass : 3.5 mm
4. Angle of inclination of glass cover : Latitude of Gandhinagar [23.22^0 N]

   Gandhinagar is situated at 23.22^0 North Latitude and 72.63^0 East Longitude.

2.6.2.4 Dimension of Tray

1. Depth of tray : 8 mm
2. Width of tray : 200 mm
3. Length of tray : 1170 mm

2.7 Daily Efficiency of Solar Still

The performance rating and efficiency of solar still is determined by plotting the graph of amount of fresh water produced per unit of basin area in one day versus the solar radiation intensity over the same period. Such curves for several still are draw. Efficiency is defined as

$$nd = \frac{\sum m.hfg}{\sum A.Ig}$$

Where ;

hfg : latent heat of evaporation , MJ/kg
m : condensate production , lit./day
A : area , m^2
Ig : average solar radiation , $kWh/m^2/day$

The energy required to evaporate water is called the latent heat of evaporation (hfg) of water
The performance of solar still is generally express as the quantity of water produced by each unit of basin area in a day. This quantity will vary with the design of the solar still, with the intensity of solar radiation and with the atmospheric condition in the surroundings.

2.8 Modification of Solar Still

Figure 1.4 Front view of solar still with steps

Figure 1.5 Side view of solar still with steps

Figure 1.6 Front view of Comparative solar still

Figure 1.7 Side view of Comparative solar still

Chapter 3: Result and Discussion

In this chapter experimental data of solar still with steps and without steps has shown and graphical representation has done

3.1 Observation Table (without steps)

Time	Output (ml)	Solar Radiation (W/m²)	T_{atm} (°C)	T_g (°C)	T_w (°C)	T_b (°C)	H Efficiency (%)
08:00-09:00	0	480	27	28	23	28	0
09:00-10:00	80	630	31	32	29	34	7.14
10:00-11:00	160	760	33	35	34	39	11.84
11:00-12:00	250	804.8	35	38	36	44	17.47
12:00-13:00	300	812.55	38	43	37	46	20.77
13:00-14:00	380	766	36	46	38	49	27.90
14:00-15:00	345	628.5	34	48	39	52	30.88
15:00-16:00	277	530.8	32	47	37	51	29.35
16:00-17:00	245	308.55	31	47	35	50	44.66
17:00-18:00	199	280	28	46	33	48	39.98
TOTAL	**2236**						**Avg:22.99**

Calculation of Efficiency of solar still

η = m x hfg/Ig x A

m= Daily output (lit./day)

hfg= Latent heat of water (MJ/kg)

A= Aperture area of still (m^2)

Ig= Daily global solar radiation ($kWh/m^2/day$)

m = 80ml/hr

=0.080 kg/hr

hfg= 2.43 MJ/kg

A= 1.02×1.17m^2

=1.20m^2

Ig= 630

=0.630 $kWh/m^2/hr$

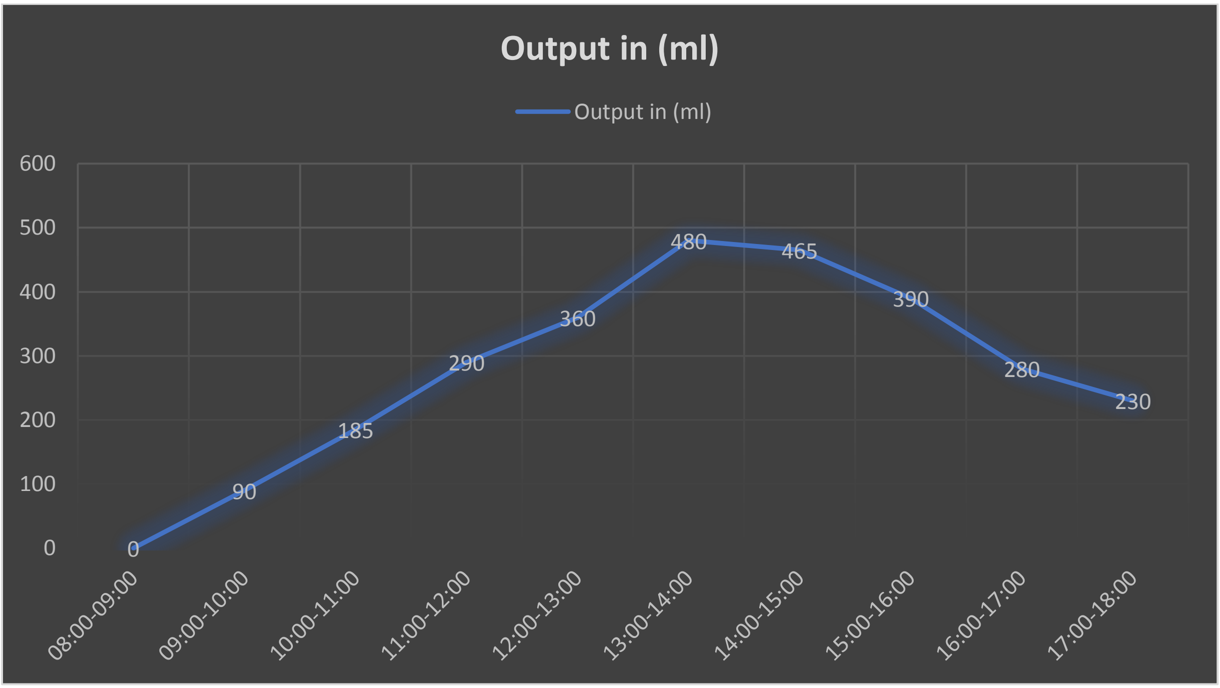
$$\eta = \frac{(0.080)(2.43\times10^6)}{(1.20)(0.630)\times3600\times10^3}$$

=0.07142

=7.14%

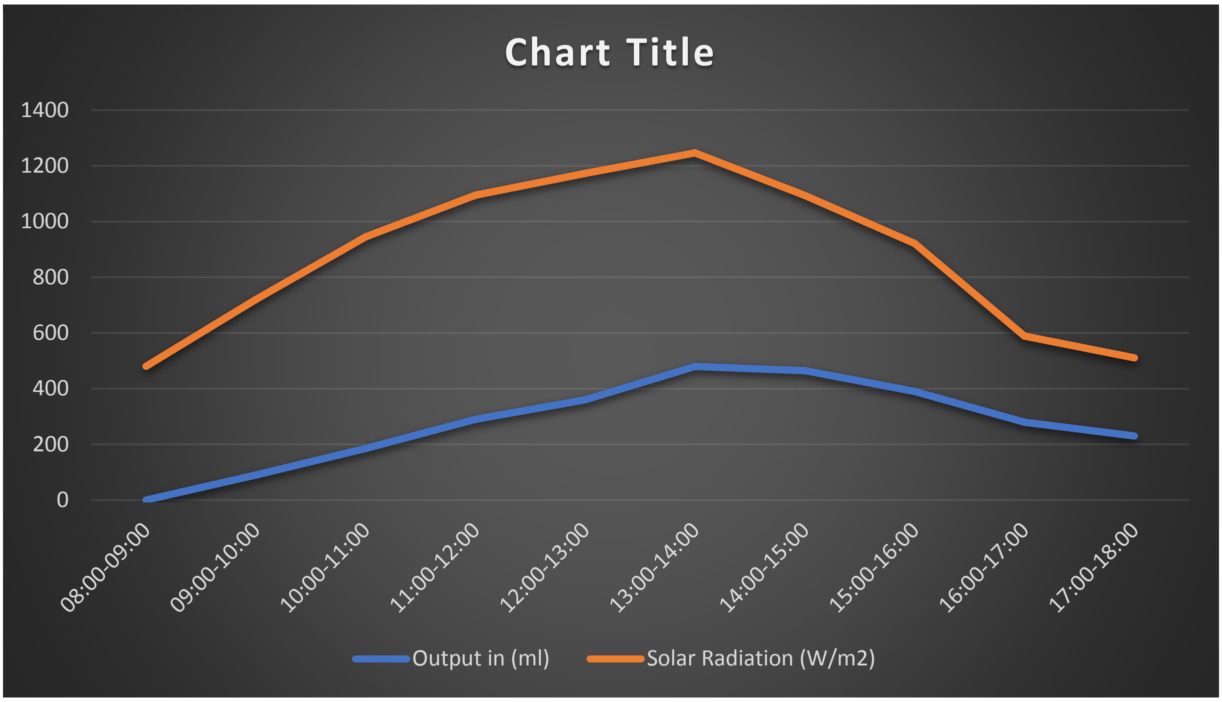
GRAPHICAL REPRESANTATION OF DATA

Graph 1 :- Time Vs Output



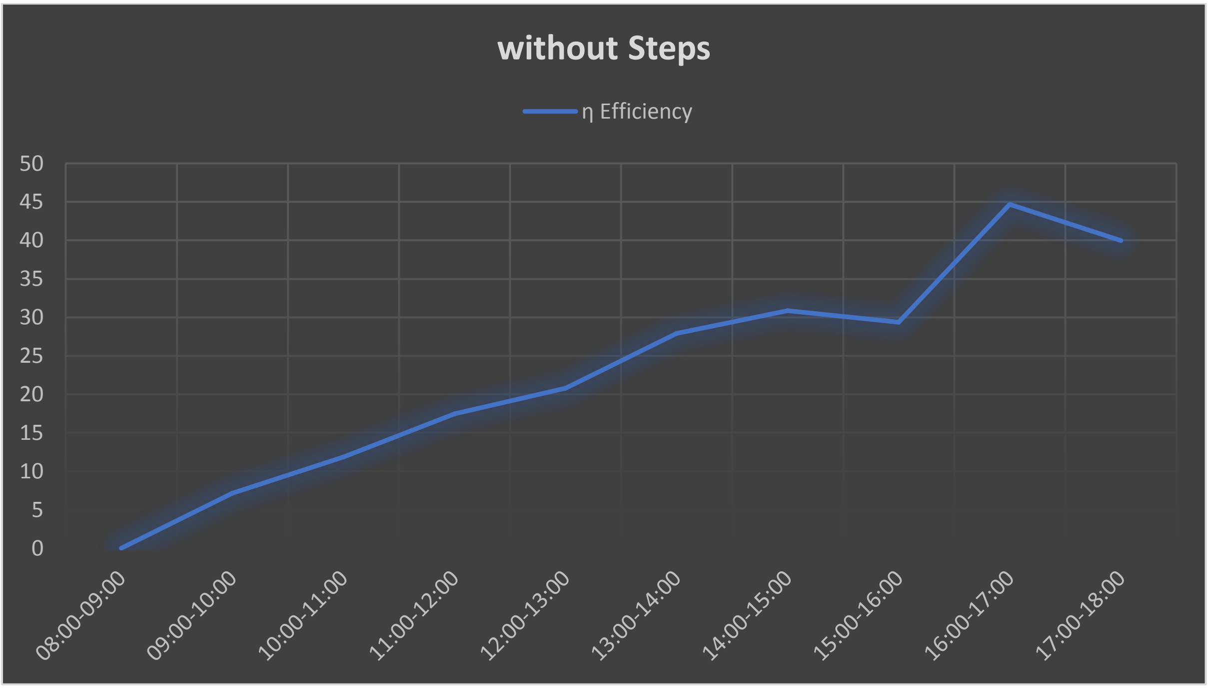
Here as per data the maximum output can be get during 13:00-14:00 time period and output is 480 ml. As time passes the output increases because the intensity of solar radiation is increases.

Graph 2 :- Output Vs Solar insolation



Here the maximum solar radiation can be get during 12.00-13.00 during this time all the radiation will directly impinge on the solar still and maximum radiation is 812.55 W/m^2

Graph 3: Efficiency Vs Time (without Steps)



As shown in graph the Efficiency is varying with time and maximum efficiency is 44.66% during 16.00 to 17.00 during this time the solar radiation is lower but still efficiency is higher because efficiency depends upon (m*hfg/A*Ig) with using this as solar radiation decrease efficiency will increase and efficiency also depends upon without Steps output. Compare to output the rate of decrement of radiation is more.

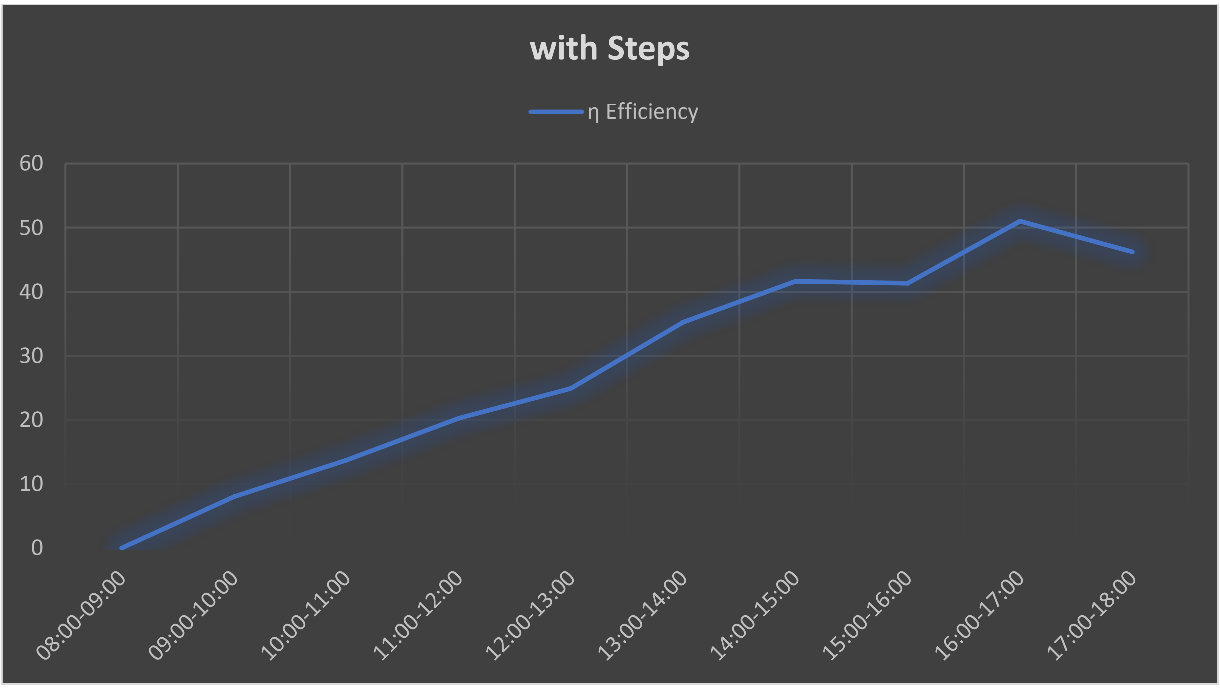
3.2 Observation Table (with steps)

Time	Output (ml)	Solar Radiation (W/m²)	T_{atm} (°C)	T_g (°C)	T_w (°C)	T_b (°C)	η Efficiency (%)
08:00-09:00	0	480	27	28	23	28	0
09:00-10:00	90	630	31	34	29	38	8.04
10:00-11:00	185	760	33	37	34	44	13.69
11:00-12:00	290	804.8	35	39	36	49	20.27
12:00-13:00	360	812.55	38	45	37	52	24.92
13:00-14:00	480	766	36	48	38	58	35.25
14:00-15:00	465	628.5	34	49	39	54	41.62
15:00-16:00	390	530.8	32	51	37	53	41.33
16:00-17:00	280	308.55	31	50	35	52	51.04
17:00-18:00	230	280	28	49	33	51	46.20
TOTAL	**2770**						**Avg:28.24**

3.3 Calculation Table

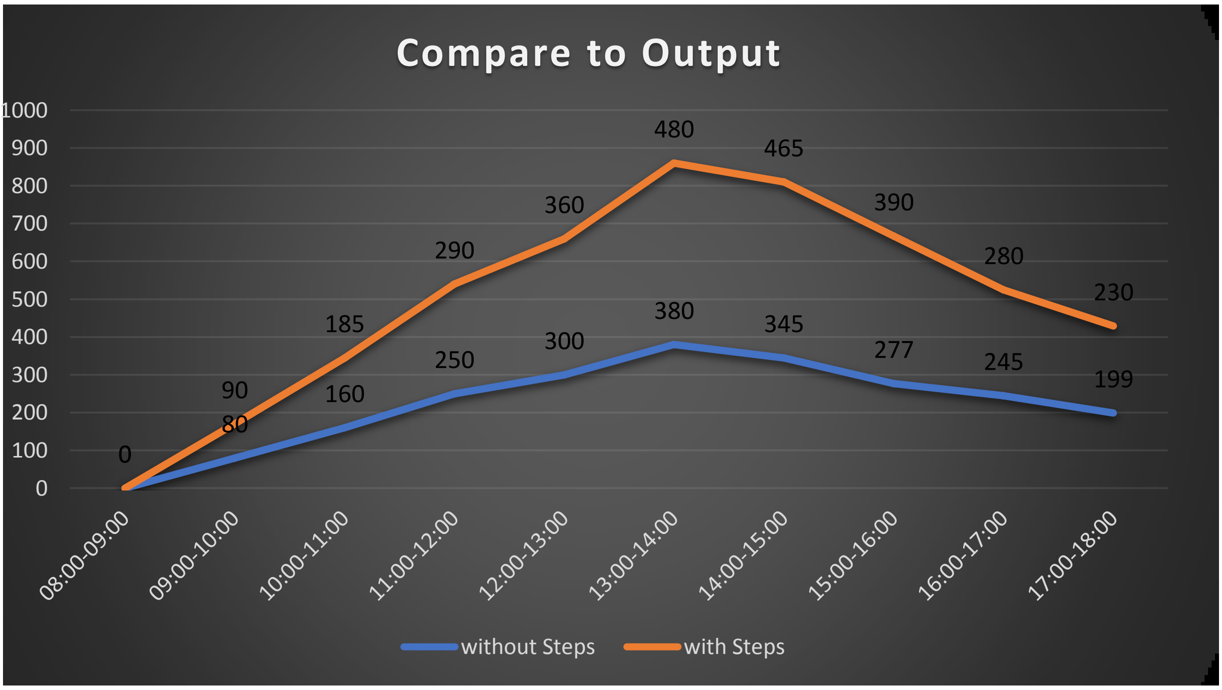
Time	Output without Steps (ml)	Output with Steps (ml)	Solar Radiation (W/m²)	η Efficiency without Steps (%)	η Efficiency with Steps (%)
08:00-09:00	0	0	480	0	0
09:00-10:00	80	90	630	7.14	8.04
10:00-11:00	160	185	760	11.84	13.69
11:00-12:00	250	290	804.8	17.47	20.27
12:00-13:00	300	360	812.55	20.77	24.92
13:00-14:00	380	480	766	27.90	35.25
14:00-15:00	345	465	628.5	30.88	41.62
15:00-16:00	277	390	530.8	29.35	41.33
16:00-17:00	245	280	308.55	44.66	51.04
17:00-18:00	199	230	280	39.98	46.20
TOTAL	**2236**	**2770**		**Avg:22.99**	**Avg:28.24**

Graph 4 :- Efficiency Vs Time (with Steps)



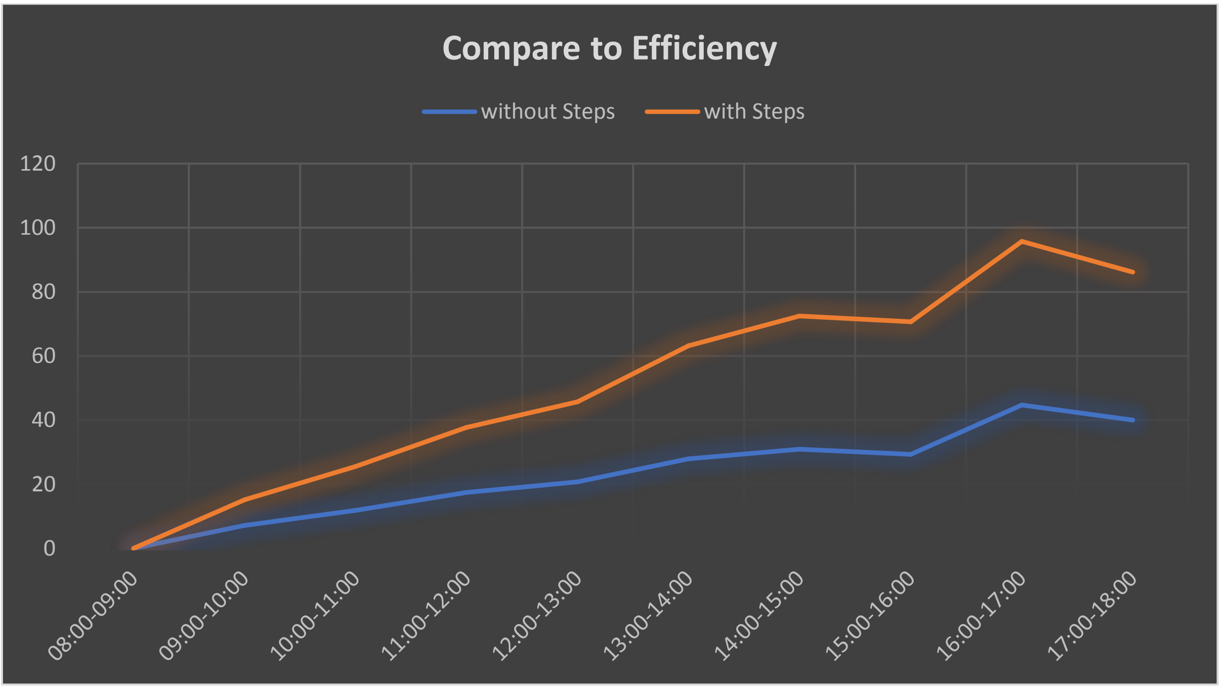
As shown in graph the Efficiency is varying with time and maximum efficiency is 51.04% during 16.00 to 17.00 during this time the solar radiation is lower but still efficiency is higher because efficiency depends upon (m*hfg/A*Ig) with using this as solar radiation decrease efficiency will increase and efficiency also depends upon Steps output. Compare to output the rate of decrement of radiation is more.

Graph 5: Output with Steps Vs without Steps



Here we can see the increase in total output during each time of interval because by including the steps the rate of evaporation is increase and condensate can be get from both of side.

Graph 6: Efficiency with Steps Vs without Steps



Result

(i)Percentage increase in Efficiency

Efficiency of conventional solar still is increased from ηcss=22.99 to ηass=28.24.

%Increase= (ηass-ηcss)/ ηcss *100

= (28.24-22.99)/22.99*100

%Increase =22.84%

ii) Percentage increase in output

Qass=2770 ml ,Qcss=2236 ml

Output of solar still is increased from 2236 ml to 2770 ml.

% Increase= (Qass-Qcss)/Qcss*100

= (2770-2236)/2236*100

% Increase =23.88%

Chapter 4: Advantages

1. Efficiency of step basin type solar still is high as compared to conventional solar still.
2. Maintenance cost is low.
3. The heating source of saline water is solar energy which is available in abundance.
4. Solar energy involved zero cost.
5. It can produce clean & pure drinking water.
6. Heat loss from the bottom & side of the solar still is minimum.
7. Vapor leakage is low.
8. Evaporation rate is high as compared to solar still.
9. No skilled operator is required.
10. Wastage of water will be minimum.

Chapter 5: Disadvantages

1. Solar still required solar energy which is not available at night.
2. Solar still need to be clean regularly every few day.
3. Structure is complicated as compared to conventional solar still.
4. It has additional cost of tray.
5. Productivity is decrease with the time for variety of reasons.

Chapter 7: Conclusion

In this experiment condensed water is getting which is free of salt.
Contaminated particle will be collected at bottom side
Natural pH is claimed
As the solar radiation is increasing the output will increase because rate of evaporation increase with the solar radiation
By designing stepped basin type solar still total distillate can be increased from 2236ml(between 08am to 06pm) to 2770 ml which indicate 23.88% increase in total distillate
And overall thermal efficiency will increase from 20.01% to 21.29% which shows that 22.84% rise in efficiency.

In this project our main objective is to improve the efficiency of single basin type solar still. After studying the various surveys we are able to know more about solar still. After changing the flat basin by stepped basin we expected that the efficiency of solar still will increase by change in various parameters like saline water depth, basin temperature, glass cover thickness, absorber area etc.

Chapter 8: Future scope

1. Implementation of stepped basin instead of flat basin in solar still
2. Assembly of all the component of solar still

3. Make a working model of solar still
4. Increases in efficiency of solar still

References

[1] Prof.Nilamkumar S Patel, Prof.Reepen R Shah, Mr.Nisarg M Patel, Prof.J.K.Shah, Mr.Sharvil B Bhatt

Effect of various parameters on different types of solar still;

ISSN: 2319-8753; Vol. 2, Issue 5, May 2013

[2] A.E. Kabeel, A. Khalil, Z.M. Omara, M.M. Younes,

Theoretical and experimental parametric study of modified stepped solar still,

Desalination 289 (2012) 12–20.

[3] J.S. Gawande* , L.B. Bhuyar

Effect of Climatic Parameters on the Performance of Different Designs of Stepped Type Solar Still;

ISSN: 2279-0535. Volume: 2, Issue: 2

[4] Z.M. Omara, A.E. Kabeel, M.M. Younes

Enhancing the stepped solar still performance using internal reflectors;

Desalination 314 (2013) 67–72

[5] Ajeet Kumar Rai*, Pratap Singh, Vivek Sachan, Nripendra Bhaskar

Design, Fabrication and Testing Of a Modified Single Slope Solar Still;

ISSN 0976 – 6340 (Print)

ISSN 0976 – 6359 (Online)

Volume 4, Issue 4, July - August (2013), pp. 08-14

[6] Jagannath S. Gawande*1, Lalit B. Bhuyar2, Samir J. Deshmukh

Effect of Depth of Water on the Performance of

Stepped Type Solar Still; Aug. 2013, Vol. 3 Iss. 4, PP. 137-143- 137

[7] Alaudeena, K. Johnson b , P. Ganasundar b, A. Syed Abuthahir c,

K. Srithar b,

Study on stepped type basin in a solar still

Engineering Sciences (2014) 26, 176–183

[8] Non conventional Energy Sources by G.D. RAI, KHANNA PUBLISHERS

[9] J.S. Gawande and L.B. Bhuyar

Effect of Climatic Parameters on the Performance of Different Designs of Stepped Type Solar Still

Current Trends in Technology and Science

ISSN: 2279-0535. Volume: 2, Issue: 2

[10] K. Kalidasa Murugavela, Kn.K.S.K. Chockalingama, K. Sritharb*

Progresses in improving the effectiveness of the single basinpassive solar still

Desalination 220 (2008) 677–686