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Design and Fabrication of Solar Desalination Unit

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Abstract: Basic need of human is water. The need for fresh water consumption is vast including domestic and industrial purposes. 97% of earth's water is seawater and the remaining 3% is fresh water where 2% is glaciers and available drinking water is 1%. Desalination is a process of removing salt from sea water. Distillation is a process where the water is heated to convert it into water vapours. The vapours are collected and condensed to obtain distilled water separating the components, minerals, solid substances present in water. The various test performed are pH, Turbidity, Total dissolved solids and salinity. In this study, solar heater is used along with Solar Still to enhance the process. The water gets heated by the heat trapped by Solar Heater and then fed to the Solar still. Since the water achieves an higher temperature in solar heater, the evaporation process becomes faster in Solar still, hence increased efficiency of the system.
Keywords: Distillation, Desalination, Solar heater, Solar still, Salinity.

I. INTRODUCTION

The demand for fresh water has increased as the population around the world keep growing and the fresh water resources are depleting with the current requirement. Water scarcity has become far growing global challenge the reason being the impact of climatic change. As seen in Figure 1, the availability of fresh water is only 3%. Hence it is essential to explore new sources of fresh water. Sea water is found in abundance about 97% of the water resources available on earth. This source can be converted to be used as fresh water.

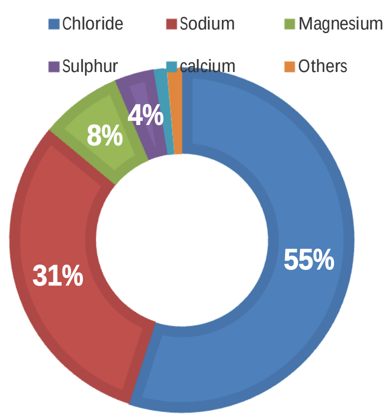

Figure 1: Composition of components present in water

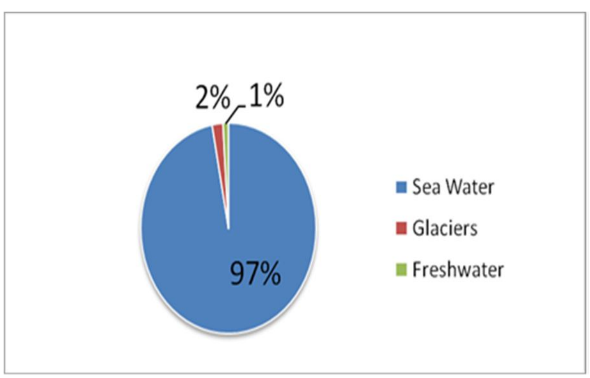

Figure 2: Composition of water on earth

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Heat is source of energy from sun and can be used for desalination by distillation. Heat energy from sun is a free source and renewable source of energy. This energy can be utilised for desalination. In this study distillation process is optimized by using solar heater and solar still. The example for this process can be given by the water cycle occurring in nature like rain where evaporation of water takes place with help of solar energy which in turn returns back to earth in form of rain (fresh water). Solar distillation is an relatively easy and simple treatment of salt water to convert to fresh water. Desalination has been in history in both mythology & practice. Some of the historical appearance of desalination in history back date was the experiments by Aristotle and by ancient Greece. Thomas Jefferson started the earlier stages of desalination. This technology came into force in board ships to avail drinking water in case of emergency.
Other ways of desalination process are as follows:

A. Phase Change Process
1) Multi-stage Flash distillation (MSF)
2) Multi-effect Distillation (MED)
3) Vapour Compression (VC)

B. Thermal Process
1) Reverse Osmosis (RO)
2) Electro dialysis (ED)
3) Solar Desalination(SD)

II. METHODOLOGY

The Solar still basically works on the principle of distillation. Salt water tank & solar heater is connected with pipe. Valve is used to control the flow of water. Water flows from tank to solar heater where the water gets collected in tubular pipes, the solar heater maintains a temperature of 75 to 85 ° C .The water in the pipe gets heated and is further sent to solar still. Pipes are been used to connect solar heater and solar still. Valve is used to control the flow of water. The water then further gets collected in an glass tray placed at the bottom of still. The heated water temperature is about 70 to 80 ° C and wherein the temperature of the still is around 75-85 ° C. The hot water starts evaporating and gets collected at the top of glass in form of water droplets. The maintained slope of angle 25° helps the water droplet to collect down in tunnel. The tunnel is connected to tap and the desalined water is collected in container.
The basic construction of this project is as follows.
1) *Salt Water Tank:* Salt water tank is mounted on a stand where the sea water is collected. The tank is cylindrical in shape.
2) *Solar Heater:* It is an rectangular box made of CR sheet which consist of pipes of steel to heat salt water. An glass is used to trap heat. An rubber beading are placed in between the body and glass for insulation. The heater is mounted on stand. The Solar heater is painted in black to absorb heat.
3) *Solar Still:* Solar still is an CR sheet rectangular box mounted on stand. One side of the still is at slope of 25°. A glass tray is used at bottom of still to collect heated salt water. An glass piece mounted on top of still to trap heat and collect vapours. A water tunnel is installed at the declined side of still to collect the evaporated water. Rubber beadings are being used at upper side of still to provide insulation to the glass. The whole body of still is painted with black to absorb more heat. Outer body of still is covered with plywood to reduce heat dissipation.

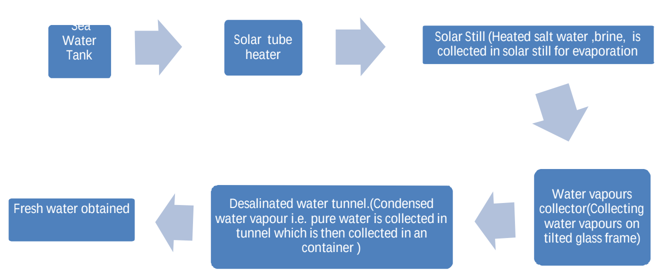

Figure 3: Block Diagram for desalination process

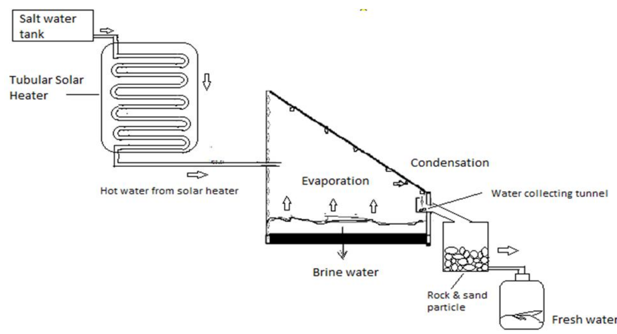

Figure 4: Schematic Diagram of Desalination process

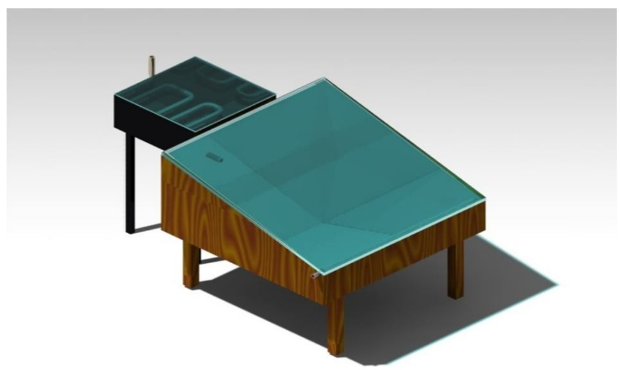

Figure 5: Rendered View

Table I

Sr.No	Particular	Material	Qty	Dimensions	Purpose
1	Solar Still				
1.1	Basin & Side walls	CR sheet	2	1828.8mmx1524mm	For Basin & side walls
1.2	Tray	Glass	1	880mmx570mmx70mm	Tray to cover basin
1.3	Lid	Glass	2	940mmx630mmx5mm	Used as Lid of the still
1.4	Plywood	Wood	2	1828.8mmx1524mm	Installed as outer cover of basin, to reduce heat dissipation
1.5	Angle bar (L shape)	Iron	8	1219.2mm	To hold the corner of still intact & support to stand
1.6	Tunnel	Aluminium	1		To collect evaporated water(distilled water)
2	Solar Heater				
2.1	Basin &Side walls	CR sheet	2	1828.8mmx1524mm	For Basin & side walls of heater
2.2	Lid	Glass	1	940mmx630mmx5mm	Used as Lid of the still
2.3	Pipe	Steel	7	350mmx12.7mm	To store and heat the water
2.4	Elbows	Plastic	14	12.7mm	To connect the pipes
2.5	Water valves	Plastic	2	12.7mm	To control the flow of water
2.6	Angle bar (L shape)	Iron	8		To hold the corner of heater intact & support to stand
3	Water Tank				
3.1	Stand	Square Bar	3	5 feet	To give certain height & support to water tank

1) *Design:* The design and calculation for the fabrication of the project is as follows.

a) The net heat interchange

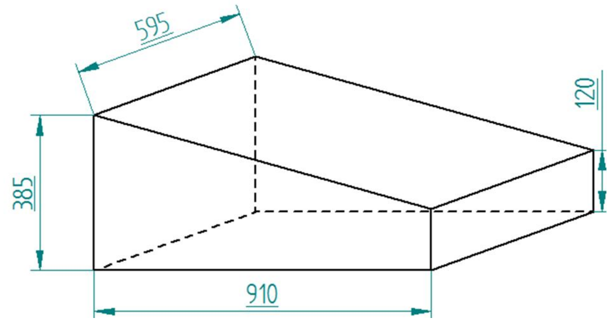

Figure 6: Solar Still

Area of Rectangle=L×B

=91×38.5 =3503.5cm²

Area of triangle= $\frac{1}{2}$ ×b×h

= $\frac{1}{2}$ ×91×26.5

=1205.75cm²

Required area of trapezoidal=3503.5-1205.75

=2297.7cm²

Surface Area=L×B

=91×59.5

=5414.5cm²=0.54m²

From Data Hand Book,

Emissivity of glass, ϵ1=0.92

Emissivity of black surface, ϵ2=0.9 $\frac{\sigma\times(T1^4-T2^4)}{\frac{1-\epsilon 1}{\epsilon 1\times A1}+\frac{1}{A1\times F12}+\frac{1-\epsilon 2}{A2\times\epsilon 2}}$

T1=41□=41+273=314k

T2=89□=82+273=362k

Q12=

Shape Factor, F12

$x=\frac{L}{D}=\frac{0.91}{0.2525}=3.6$

$y=\frac{B}{D}=\frac{0.595}{0.2525}=2.35$

F12=0.46215

$$Q12=\frac{5.67\times10^{\wedge}-8(362^4-314^4)}{\frac{1-0.92}{0.54\times0.92}+\frac{1}{0.54\times0.46215}+\frac{1-0.99}{0.54\times0.99}}$$

Q12=100.91watts

The heat transfer coefficient, h

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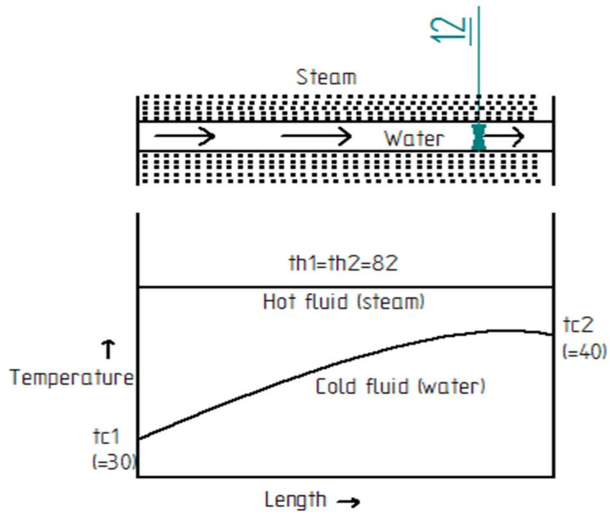

Figure 7: Heat transfer co-efficient

Given, Diameter of pipe=$\frac{1"}{2}$=$\frac{24}{2}$=12mm=12×10^-3m

Ts=$\frac{T1+T2}{2}$=$\frac{25+62}{2}$=36□

T∞=35°C

Tavg=$\frac{36+35}{2}$=35□

Nu=$\frac{hd}{k}$=0.023×(Re)^0.8×(Pr)^0.33 [Equation(17.165)]

Re=$\frac{\rho V d}{\mu}$or$\frac{Vd}{k}$

Here, k=1.24725×10^-6 (Data Hand Book)

Re=$\frac{2\times(12\times10^{-3})}{1.24725\times10\text{^}-6}$

Re=19242.33

Pr=8.52 (Data Hand Book)

Nu=$\frac{hd}{k}$=0.023×(19242.33)^0.8×(8.52)^0.33

Nu=12.47

∴h=$\frac{0.91935}{12\times10^{-3}}$×12.47

h=955.35 $\frac{w}{m^2}$□

The length of the tube, L:
Heat gain by water, $Qw=m\times Cp\times \Delta T$

here, $m=\frac{\pi}{4}\times d^2\times V\times$

$m=\frac{\pi}{4}\times(12\times10^{-3})\times2\times997.5$

$m=0.225\frac{kg}{s}$

$Qw=m\times Cpc\times(t2-t1)$

here, $Cpc=4187\frac{J}{kg°C}$

t1=30□
t2=40□
$Qw=0.225\times4187\times(40-10)$
Qw=9420.75 watts
Q is also given by,Q=UA(LMTD)
$Q=955.35\times\pi\times D\times L\times LMTD$

$\therefore LMTD=\frac{\theta1-\theta2}{\ln\left(\frac{\theta1}{\theta2}\right)}$

where, 1=Thi-Tci
here, Thi=82□
Tci=30□
Tco=40□
1=82-30=52□
2=82-40=42□

$LMTD=\frac{52-42}{\ln\left(\frac{52}{42}\right)}$

LMTD=46.82
$Q=955.35\times\pi\times(12\times10^{-3})\times L\times46.82$
∴Length of the pipe, L=5.58m

Figure 8: Solar Heater

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Figure 9: Solar Still

Figure 10: Solar Desalination Unit

III. RESULT

A. Sea water from karwar shore was collected for the process. The pH level of the seawater was 8, Total dissolved Solids(TDS) was >2400 ppm whereas suitable water for drinking should be <500 ppm. Turbidity of seawater is 0.9 Ntu and suitable water for drinking should range in between 0-5 Ntu. Salinity of seawater is 21.2% whereas suitable for drinking water should be <1 according to BIS – Standard (IS – 10500).The pH of desalinate water found from this experiment is 7.1, TDS (Total Dissolved Solids) is 33 ppm, turbidity is 0, salinity is 0.

B. The mean temperature obtained from solar heater was 75-85°C and the temperature obtained from solar still 70-80°C. Desaline water collected in an hour is 200ml and water collected in 5 hours is 1023ml.

C. The Solar still has total surface of 0.54m^2 which collects 200ml water in 1 hour obtaining the temperature 85° in an hour.

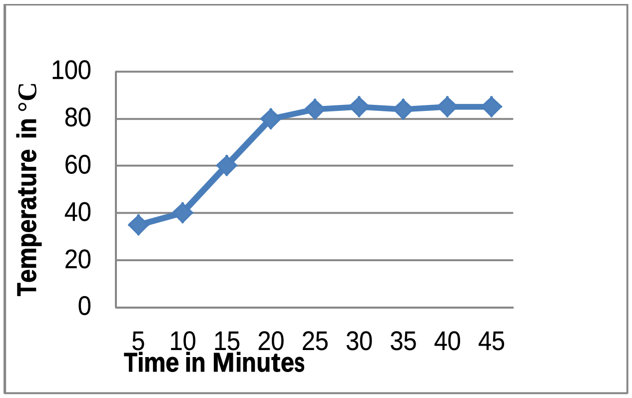

Figure 11: Graph determining rise in temperature in °C with respect to time in minutes.

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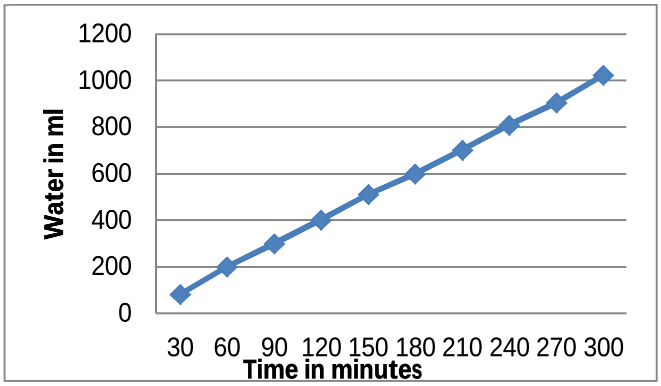

Figure 12: Graph determining desaline water collected in ml with respect to time in minutes.

IV. CONCLUSION

From the experimental results obtained it can be concluded that the average yield of distilled water obtained from solar still with solar water heater system is found to be 1023 ml in 5 Hours. Relatively higher temperature is obtained therefore increasing the efficiency of the process and showing maximum amount of yield. This technology innovation in desalination can direct towards large scale application with advanced research and development. It can also provide solution and increase scope of development in water scarcity areas.

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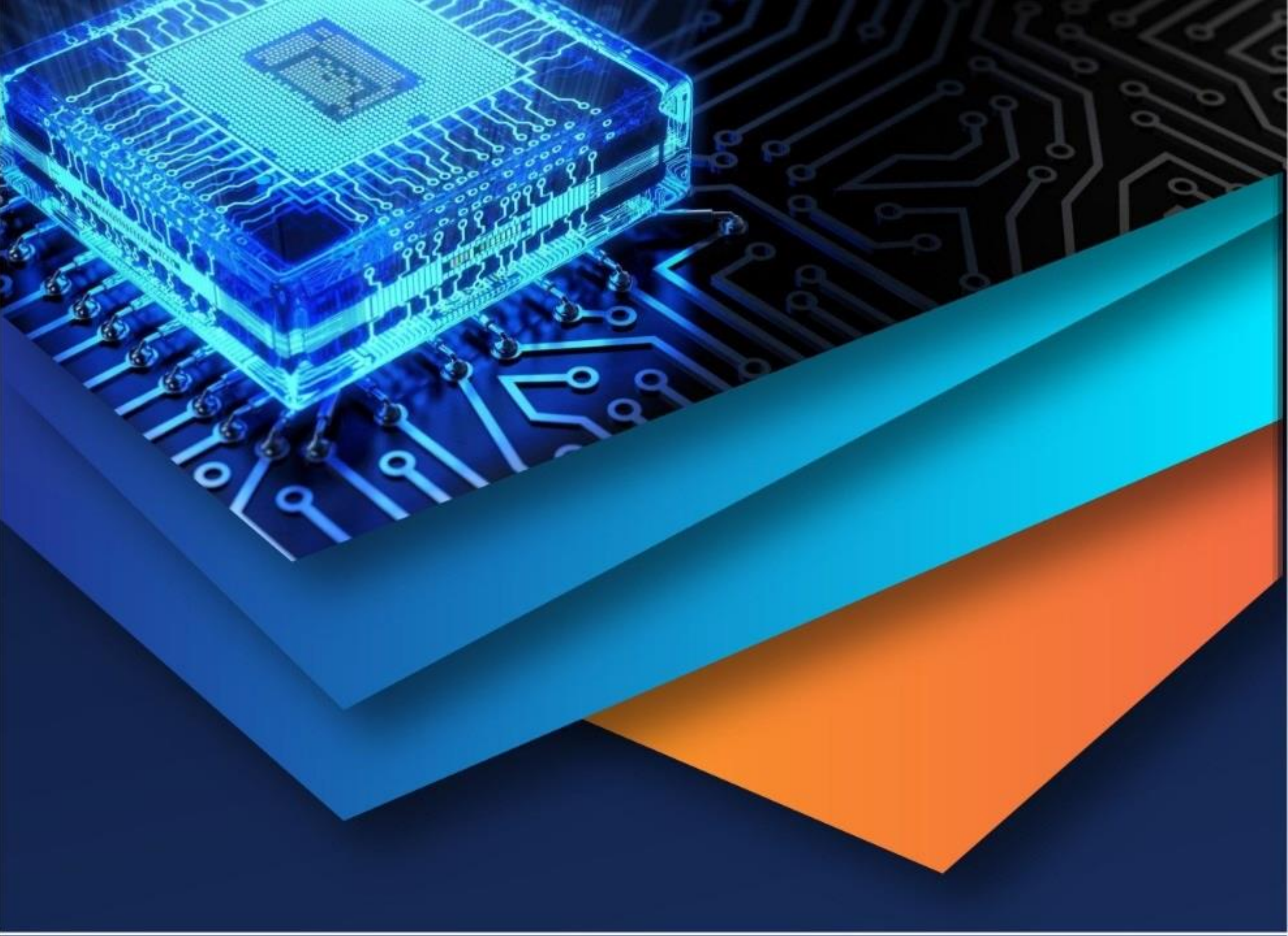

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