Experimental Investigation and Performance Improvement of Modified Solar Still

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Abstract- *Solar still is a very simple solar device used for converting available brackish water into distilled water. Solar distillation uses the heat of the 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 through, leaving behind the salts, minerals, and most other impurities, including germs. In our project the main objective is to increase productivity of water by increasing the condensation rate by using vibrator and increase heat by helical copper wire.*

Keywords- Heat brackish water, distilled water, shallow basin, condenses, condensation rate

I. INTRODUCTION

Ninety seven percent of the earth's water lies in its oceans. Of the remaining 3 percent, 5/6 is brackish, leaving a mere 0.5 percent as fresh water. As a result, many people do not have access to adequate and inexpensive supplies of portable water. This leads to population concentration around existing water supplies, marginal health conditions and a generally low standard of living. There is an important need for clean, pure drinking water in many developing countries. Often water sources are brackish (i.e. contain dissolved salts) and contain harmful bacteria and therefore cannot be used for drinking. In addition, there are many coastal locations where seawater is abundant but potable water is not available. Pure water is also useful for batteries and in a hospital or schools. Distillation is a one of many processes that can be used for water purification. In this process, water is evaporated, thus separating water vapor from dissolved matter, which is condenses as pure water. Solar water distillation is a solar technology with a very long history and installations were built over 2000 years ago, although to produce salt rather than drinking water. Documented use of solar still began in the sixteenth community century. An early large-scale solar still was built in 1872 to supply a mining community in Chile with drinking water. Mass production occurred for the first time during the Second World War then 200,000 inflatable plastic stills were made to be kept in life-crafts for the US Navy. Solar distillation uses the heat of the directly in a simple piece of equipment to purify water. The equipment, commonly called a solar still, consist 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 through, leaving behind the salts, minerals, and most other impurities, including germs. Although it can be rather expensive to build a solar still that is both effective and long-lasting, it can be produce purified water at a reasonable cost if it is built, operated, and maintained properly.

A. SOLAR STILL OPERATION

The main future of operation is the same for all solar stills. The incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface in contact with the water to be distilled. The vapor condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air, and runs down into a gutter from where it is fed into the storage tank.

B. NEEDS SERVED BY SOLAR DISTILLATION

- Solar distillation could benefit developing countries in several ways:
- Solar distillation can be a cost effective means of providing clean water for drinking, cooking and other basic human needs
- It can improve health standards by removing impurities from questionable water supplies.
- It can help extend the usage of existing fresh water in location where the quality or quantity of supply is deteriorating. Where sea water is available, it can reduce a developing countries dependence of rain fall.
- Solar still operating on a sea or brackish water can ensure supplies of water during a time of drought.
- Solar distillation generally uses less energy to purify water than other methods.
- It can foster cottage industries, animal husbandry, or hydroponics for food production in areas where such activities are now limited by inadequate supplies of pure

water. Fishing could become important on desert seacoast where no drinking water is available for fisherman.

- Solar still permits settlement in sparsely-populated locations, thus relieving population pressures in urban areas.

II. LITERATURE REVIEW

A. 2.1 ENERGY REQUIREMENT FOR WATER DISTILLATION

The energy required to evaporate water is the latent heat of vaporization of water. This has a value of 2260 kilojoules per kilogram (KJ/kg). This means that to produce 1 liter (i.e. 1kg since the density of water is 1kg/liter) of pure water by distilling brackish water requires a heat input of 2260Kj. This does not allow for the efficiency of the heating method, which will be less than 100%, or for any recovery of latent heat is rejected when the water vapor is condensed. It should be noted that, although 260Kj/kg is required to evaporate water to pump a kg of air through 20m heads requires only 0.2Kj/kg. Distillation is therefore normally considered only where there is no local source of fresh water that can be easily pumped or lifted.

B. 2.2 DESIGN OBJECTIVES FOR AN EFFICIENT SOLAR STLL

For high efficiency the solar still should maintain:

- A high feed (uninstalled) water temperature.
- A large temperature difference between feed water and condensing surface.
- Low vapor leakage.

A high feed water temperature can be achieved if:

- Heat loss from the floor and walls are kept low.
- The water is shallow so there is not so much to heat.
- A high proportion of incoming radiation is absorbed by the feed water as heat. Hence low absorption glazing and a good radiation absorbing surface are required

A large temperature difference can be achieved if:

- A high proportion of incoming radiation is absorbed by the feed water as heat. Hence low absorption glazing and a good radiation absorbing surface are required.
- Condensing water dissipates heat which must be removed rapidly from the condensing surface by, for example, a second flow of water or air, or by condensing at night.

The cost of pure water produced depends on:

- The cost of making still
- The cost of the land
- Operating cost
- Cost of the feed water
- The discount rate adopted
- The amount of water produced.

TABLE-1 GLOBAL SOLAR RADIATION VALUES IN TIRUNELVELI REGION

MONTH	GLOBAL SOLAR RADIATION EXPOSURE MJM^{-2} DAY^{-1}
January	17.62
February	21.07
March	23.45
April	22.54
May	20.59
June	19.00
July	18.73
August	19.41
September	16.41
October	14.39
November	14.96
December	19.34

III. PRECONSTRUCTIONAL CONSIDERATIONS

A. SIZE

The relationship between the size of a solar still and its capacity depends upon its design and efficiency. The area/capacity is approximately 10 to 1 if the unit is glass covered and well insulated. For example, a 114 liter (30 gallons) per day still will require 300 sq ft under optimum condition. On cloudy or rainy days, production days, production stops so it is necessary to build a solar device to anticipate this handicap. Therefore, it is best to provide for a good storage facility to hold the water produced. But our still is quite small; it is designed so that water collected can be drained into bottles

B. SITE SELECTION

The still requires unobstructed sunlight from early morning to late afternoon. It should be placed so that the length of the still runs from east to west. The south facing glass should face due south as such as much as possible. The still should be kept level

C. OTHER CONSIDERATIONS

The quality of water produced can be greatly affected by the storage facility and the collection method just to name two factors. Many prefer to boil water which sits in a catchment of some kind before using it as drinking water. On the other hand, if the still is kept clean and the distillate is drained into clean bottles for storage, the water will remain clean.

D. DISADVANTAGES OF PLASTIC FILMS:

There are two commonly used covers for the solar still for condensation purpose. They are

- Transparent plastic films
- Glass cover

Because of the following problems, glass-covered stills appear to be more reliable:

- Plastic films become brittle and deteriorate from the sun's ultraviolet radiation.
- As a result, depending upon quality of the plastic, they may have to be replaced every three to six months.
- Condensing water usually form droplets on the surface of the plastic film. These droplets reflect a portion of the solar energy to the sky and they often drip back into the basin
- Plastic film is easily damaged by heavy rains, wind and wildlife

For high efficiency the solar still should:

- Maintain a high feed water temperature
- Maintain low vapor leakage
- Retain same temperature throughout the day
- Avoid heat loss through floors and walls
- Not have high dept

IV. CONSTRUCTION

The various components present in the improved solar still are

A. SOLAR GLASS

Solar glasses are generally used in order to increase the condensation inside the still. This is because in a solar glass the incoming solar radiation is absorbed and it does not allow the radiation to go out from the solar still which is not possible in the ordinary glasses. In our project the solar glasses used are of the dimensions as follows:

- Two glasses of dimensions 100x100 cm for the aperture
- Two triangular glasses of dimensions 100cm base and 30cm height
- dimensions 100cm base and 30cm height

These glasses are joined together with the help of a special sealant magnum bond which is specially used to join glasses together.

B. WATER STORAGE TRAY

The saline water is usually stored in the water storage tray which is generally made of sheet metal. The dimensions of the tray are 100x100x10cm. The height should be as minimum as possible so that the condensation will be faster and more rapidly.

C. RECIEVER PLATE

The water that is condensed must be collected with the help of the receiver plate. The receiver is attached to the glasses so that the water can be directly collected. The receiver is placed in an inclined position so that the condensing water can easily flow through the plate and get accumulated at one end which can be collected using special arrangements. The dimensions of the receiver plate are 96cm height and 2 cm width.

D. TABLE SETUP

The entire apparatus is placed over a table in order to hold it firmly. The dimensions of the table are 1.2x 1.2 m area.

E. OUTLET TUBES

The outlet tubes are sued to transfer the water from the receiver plate into the bottle kept outside the apparatus. The dimensions of the outlet tube are 8mm in diameter and about 75cm in length.

F. COLLECTOR SETUP

The collector setup that is used to collect the pure water is generally a bottle which is connected to the receiver plate by means of the outlet tubes. Care should be taken that there is no leakage between the collector bottle and the receiver plate so that all the water gets collected in the bottle.

G. VIBRATOR SETUP

It is composed of dc motor with eccentric weight fixed to the tray. The motor speed is 600 rpm, so the frequency of the vibration is 25 Hz. and the maximum exiting force is about 29 Newton. The vibration is directed mainly to the vertical direction by using unidirectional elastic supports (rubber constrained layer) underneath the four columns which are carrying the system. The power consumed by the vibrator is with 12v battery.

H. HELICAL COPPER WIRE SETUP

Helical copper wires are stretched over the basin bottom. The coil mean diameter is 25 mm and the wire diameter is 1.5 mm, they are blackened as the basin bottom. The average depth of the brine water in the basin is 60 mm, and the total average water mass is about 100 kg.

V. EXPERIMENTAL SETUP

The saline water is supplied to the solar still from the saline water storage tank. Once the trays are filled close the pipeline. When the solar radiations fall on the glass, water evaporates and condenses in the glass. The condensed water is collector in the receiver setup. In the receiver setup, the sheet metal bent to V-shape is attached in the inclined position to inside of the glasses. Then, after finishing a day cycle, fresh water will be allowed inside the tray, early morning.

A. SIMPLE STILL

Simple solar still in a still, without any accessories added to the setup. The setup is an ordinary setup, in which the water is heated only by the tray that comes through the inclined and the side glasses. The setup is completely sealed, so that heat produced by the rays may be trapped inside to get effective condensation.

B. STILL WITH VIBRATOR

Here the setup is exactly similar to the above one, except there is a vibrator attached to the tray. This vibrator is used for every 30 minutes after evaporation and condensation. This will increase the efficiency of the solar still comparatively.

C. STILL WITH VIBRATOR AND HELICAL COPER WIRE

In this setup in addition with vibrator a series of helical copper wires are ties longitudinally in the iron rods welded in square shape. This setup is kept inside the tray and this will increase the efficiency of the solar still comparatively.

VI. DESIGN OF SOLAR STILL GLASS

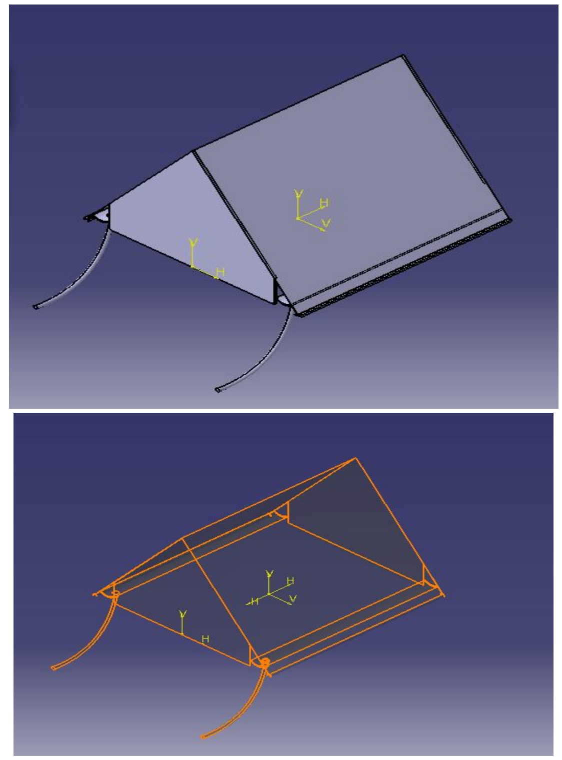

Figure-1 Isometric view

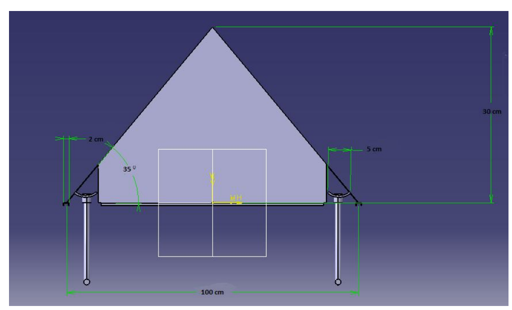

Figure-2 Front view

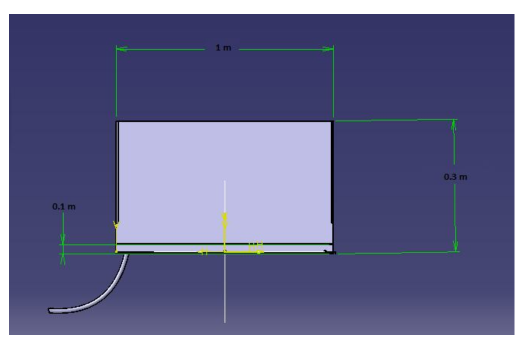

Figure-3 Side view

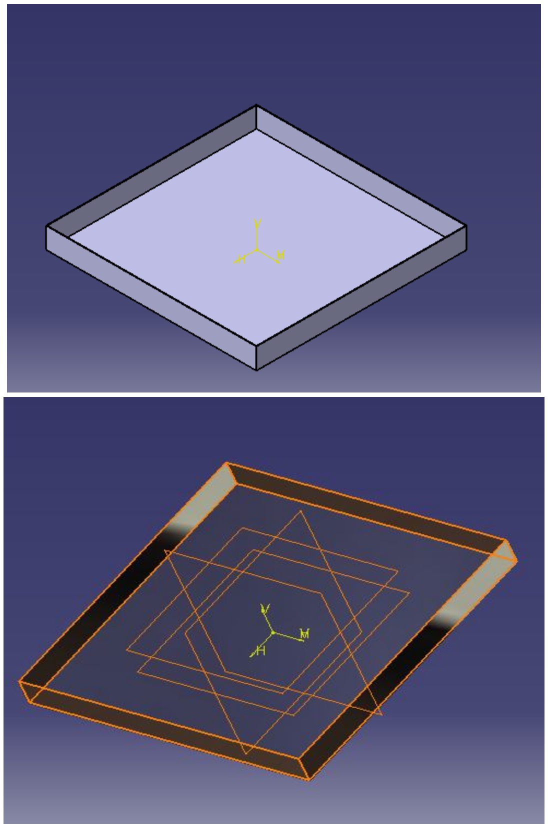

Figure-4 Tray Isometric View

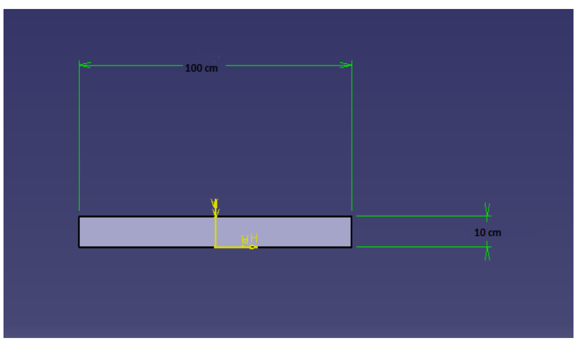

Figure-5 Front view

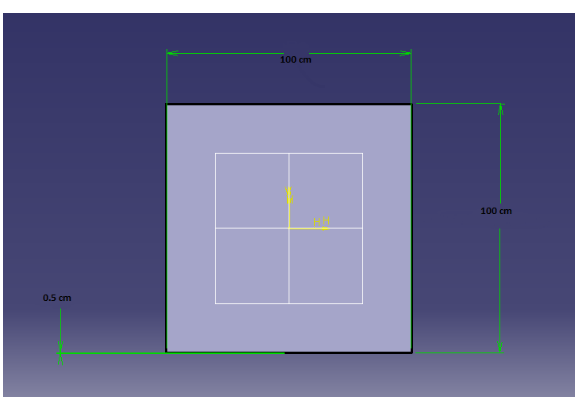

Figure-6 Top view

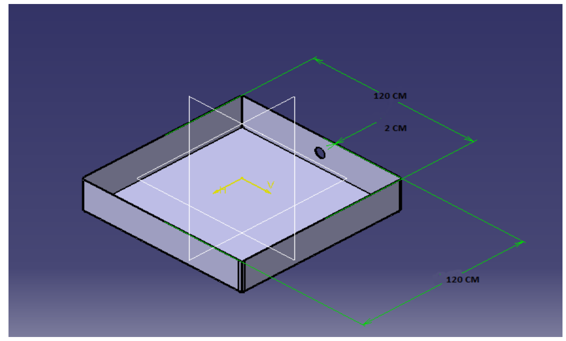

Figure-7 Plywood

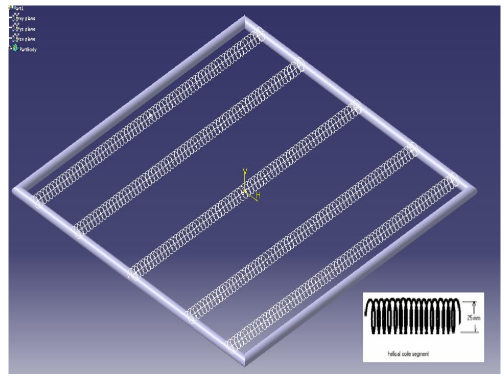

Figure-8 Helical copper wire setup

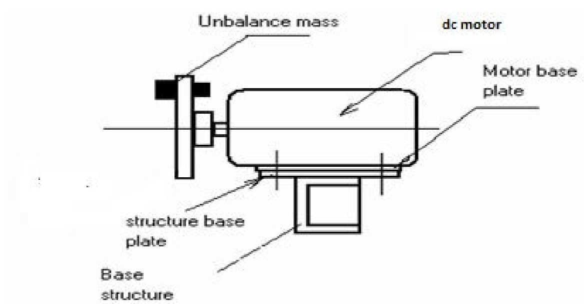

Figure-9 Vibrant

VII.OBSERVATION

After the experimental setup is made the readings are taken at different stages of experiment. The quantity of water condensed, water temperature, chamber temperature and also the atmospheric temperature is noted for all the three setups and the readings are tabulated.

A. SIMPLE SOLAR STILL:

TABLE-2
DATE: 17/3/2014

TIME	WATER TEMPERATURE °C	WATER QUANTITY ml
10:00 AM	50	60
11:00AM	54	70
12:00 AM	59	110
01:00 PM	63	160
02:00 PM	65	130
03:00 PM	66	100
04:00 PM	65	90
05:00 PM	63	70
06:00 PM	59	60
Total		850

Atmospheric temperature = 36^0c

B. SOLAR STILL WITH VIBRATOR

TABLE-3
DATE: 18/3/2014

TIME	WATER TEMPERATURE °C	WATER QUANTITY ml
10:00 AM	50	90
11:00AM	55	100
12:00 AM	58	130
01:00 PM	64	150
02:00 PM	66	160
03:00 PM	68	150
04:00 PM	67	130
05:00 PM	65	100
06:00 PM	62	90
Total		1100

Atmospheric temperature = 36^0c

C. SOLAR STILL WITH VIBRATOR AND HELICAL COPPER COIL

TABLE-4
DATE: 19/3/2014

TIME	WATER TEMPERATURE °C	WATER QUANTITY ml
10:00 AM	52	130
11:00AM	56	150
12:00 AM	60	160
01:00 PM	65	170
02:00 PM	70	170
03:00 PM	71	170
04:00 PM	71	160
05:00 PM	69	150
06:00 PM	66	140
Total		1400

Atmospheric temperature = 34^0c

VIII. GRAPH

A. SIMPLE SOLAR STILL

DATE: 17/3/2014

Total volume of water collected for the day =850 ml/day
From the quantity collected the efficiency is calculated using the formulae

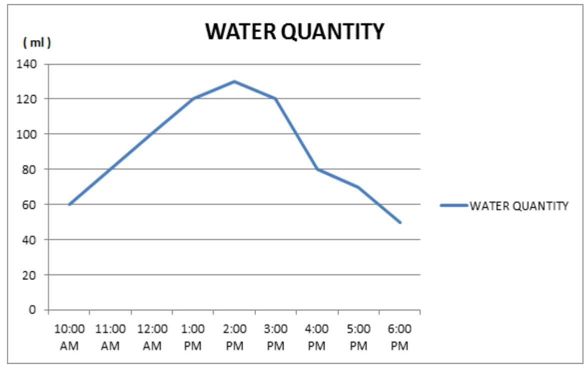

Figure-10

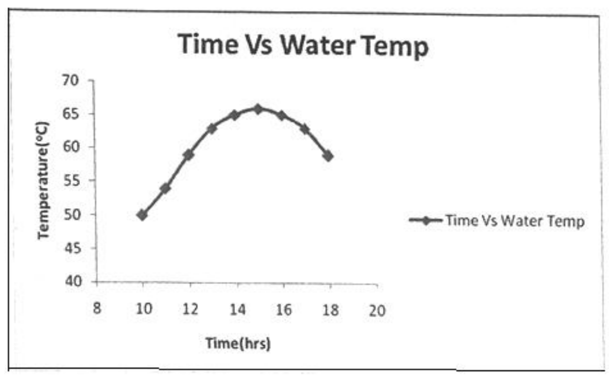

Figure-11

B. SOLAR STILL WITH VIBRATOR

DATE: 18/3/2014

Total volume of water collected for the day = 1100ml/day

From the quantity collected the efficiency is calculated using the formulae

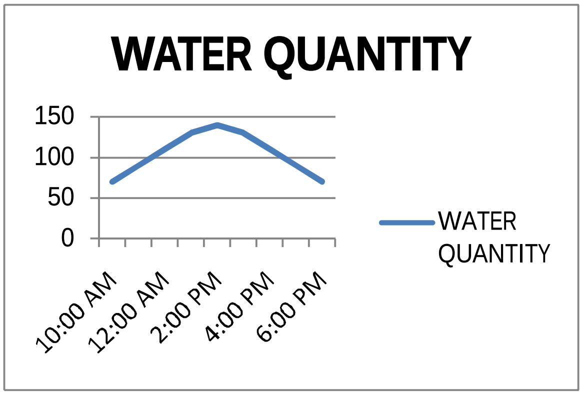

Figure-12 Water quantity

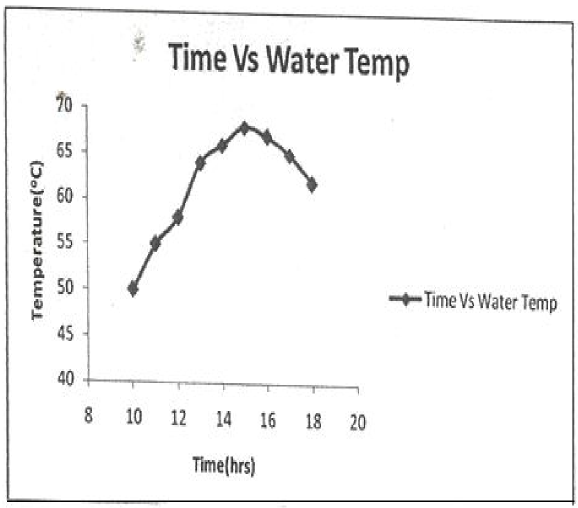

Figure-13 Time Vs Temp

C. SOLAR STILL WITH VIBRATOR AND HELICAL COPPER WIRE

DATE: 19/3/2014

Total volume of water collected for the day =1400 ml/day

From the quantity collected the efficiency is calculated using the formulae

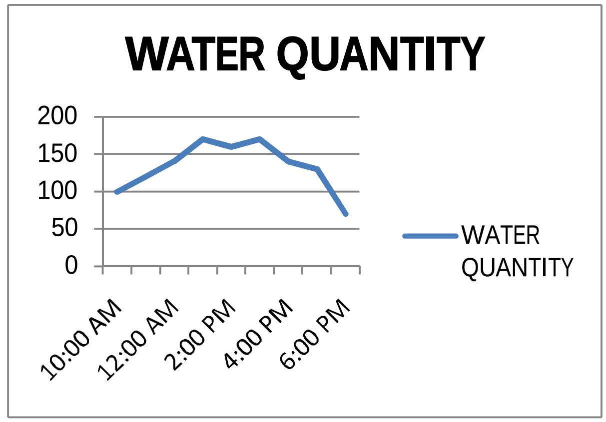

Figure-14 Water quantity

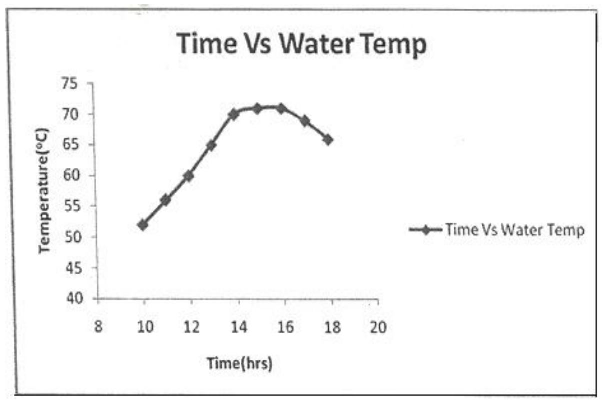

Figure-15 Time Vs Water Temp

D. PRODUCTIVITY COMPARISON

From the quantity of water collected from various stages of experiment the highest quantity taken and readings are plotted

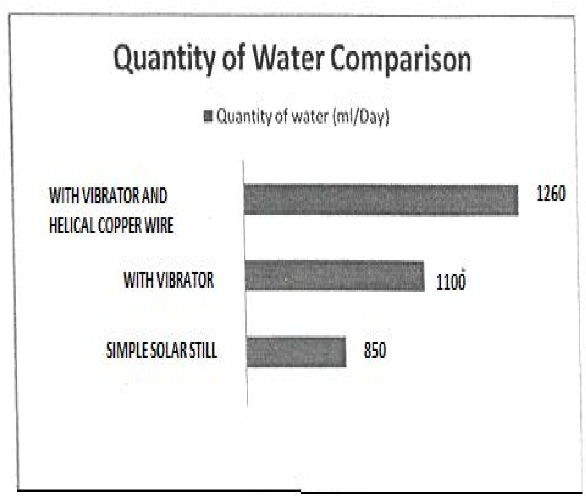

Figure-15 Quantity of water comparison

IX. CALCULATION

A. ESTIMATED OUTPUT OF INPUT SOLAR STILL

The intensity of solar energy falling on the still is the single most important parameter affecting production. The distilled water output (Me in kg/m2) is the amount of energy utilized in vaporizing water in the still (Q e in J/m2) over the latent heat of vaporization of water (L in kJ/kg). Solar still efficiency (n) is the amount of energy utilized in vaporizing water in the still over the amount of incident solar energy on the still (Q t in kJ/m2).

These can be expressed as:

Solar still production: **M e = Q e / L**

Vaporizing water in the still **Q e = M e * L**

Solar still efficiency: **η = Q e / Q t**

Latent heat of vaporization of water **L =2260 kJ/kg**

Amount of incident solar energy on the still 1 m^2 **Q t = 23000 kJ/m2**

X. OUTPUT

- Simple solar still M e = 0.850 liter

Q e = 0.850 * 2260 = 1921
η = 1921/23000=0.086 =8%

- With vibration M e =1.100 liter

Q e = 1.100 * 2260 = 2486
η = 2486/23000=0.10 =10%

- With vibrator and helical copper wire =1.4 liter

Q e = 1.4 * 2260 = 2712
η = 2711/23000=0.13 =13.7%

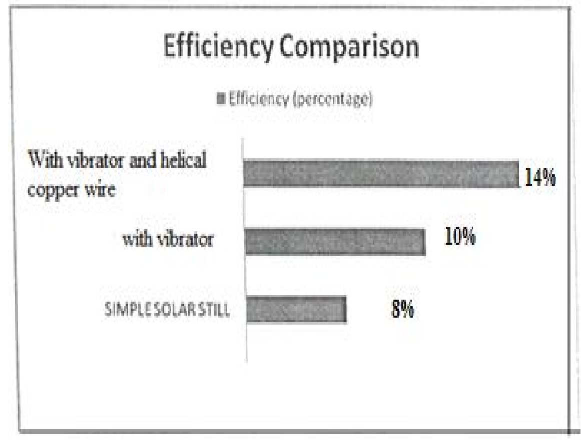

Figure-16 Efficiency comparison

XI. RESULTS AND DISCUSSION

A. ECONOMIC COST AND ANALYS

The payback period of the experimental setup depends on overall cost of fabrication, maintenance cost, operating cost and cost of feed water. The overall fabrication cost is RS 8,500.

The maintenance cost and the cost of feed water is negligible.

- Overall cost to be considered=Rs8,500
- Cost per liter of distilled water =Rs10
- Average productivity of improved solar still=1.22l/day
- Cost of water produced per day=Rs20.2
- Payback period is 297 days.

B. APPLICATION

The energy from the sun used to distill water is free. But the cost of building a still makes cost of distilled water rather high at least for large scale used such as agriculture and flushing away waste in industries and homes consequently the solar still is used principally to purify water for drinking and for some business, industries, and laboratory and green-house applications. It also appears able to purify polluted water

C. ADVANTAGES

- Low cost.
- No electric power is required quality of water is pure.
- No skilled labor required.
- Can be manufactured easily.

XII.CONCLUSION

The performance characteristic of simple basin still, still with steel balls, Combination of lenses and steel balls type still are analyzed in terms of efficiency. Production of water is increased by 63 ml/day when steel balls and lenses are integrated simple solar still .the result shows that the addition of steel balls and lenses makes good use of solar energy available and retain the heat effectively inside the still than simple solar still. Maximum production occurs when both these effects are combined. Theoretical as well as experimental analysis is made. The salinity of water has been reduced and it is testified that it can be used as distilled water effectively. Economic analysis is also made the payback period of the setup is 297 days.

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