EXPERIMENTAL INVESTIGATION AND PERFORMANCE EVALUATION OF SOLAR STILL USING PHASE CHANGE MATERIAL

Hrushikesh Kulkarni[1], Chinmay Kute[2], Chirag Patel[3], Akshay Tavse[4], Prof. Lokesh R. Dhumne[5]

[1,2,3,4] *Students at SRTTC, VIT Kamshet, SPPU, Pune, Maharashtra, India*
[5]*Professor at SRTTC, VIT Kamshet, SPPU, Pune, Maharashtra, India*

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ABSTRACT - *The purpose of this project is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable and depends only on renewable solar energy.*

The motivation for this project is the limited availability of clean water resources and the abundance of impure water available for potential conversion into potable water. In addition, there are many coastal locations where sea water is abundant but potable water is not available. Our project goal is to efficiently produce clean drinkable water from solar energy conversion.

Distillation is one of many processes that can be used for water purification. This requires an energy input as heat and solar radiation can be the source of energy. When solar energy is used for this purpose, it is known as Solar Water Distillation. Solar Distillation is an attractive process to produce potable water using free of cost solar energy. This energy is used directly for evaporating water inside a device usually termed as 'Solar Still'.

Solar stills are used in cases where rain, piped or well water is impractical, such as in remote homes or during power outages. Different versions of still are used to desalinate sea water, in dessert survival kits and for home water purification. For people concerned about the quality of their municipally-supplied drinking water and unhappy with other methods of additional purification available to them, solar distillation of tap water or brackish ground water can be a pleasant, energy efficient option. Solar distillation is an attractive alternative because of its simple technology, non-requirement of highly skilled labour for maintenance work and low energy consumption.

1. INTRODUCTION

The worldwide demand for potable water is continuously growing because of industrial, population and agricultural growth; the result is insufficient supply in many places of the world. A solar still is a valuable device that can be used for purifying brackish water and salt water for drinking water purpose. But the main drawback is solar still is a low productivity device. Heat exchange mechanisms play an important role to enhance the productivity of the solar still systems. The productivity of any solar distillation system is depends on the basin water temperature. The productivity increases with increasing water temperature in the basin.

In this research work, the influence of PCM. The different designs of solar still with PCM are analyzed. Phase change materials and thermal energy storage materials play an important role to enhance the internal energy of the system. Top cover cooling is also one of the methods to induce faster condensation inside the solar still.

1.1 Problem Statement

Lack of potable water mostly in coastal regions where the ground water is also Brackish (salinated).

Despite of large efforts carried out on solar distillation to improve productivity and efficiency, there are some challenges like:

- Lower Yield Rate.
- Time consuming and cannot be used after sunset.

1.2 Objectives

- To design and develop a solar still.

- Improve the productivity.
- Use of PCM to use it after sunset.

2. DESIGN OF SOLAR STILL

2.1Design objectives for an efficient solar still

2.1.1 For high efficiency the solar still should maintain:

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

2.1.2 A high feed water temperature 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.
- Heat losses from the floor and walls are kept low.
- The water is shallow so there is not so much to heat.

2.1.3 A large temperature difference can be achieved if:

- The condensing surface absorbs little or none of the incoming radiation.
- 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.

2.2Design Considerations

Different designs of solar still have emerged. The single effect solar still is a relatively simple device to construct and operate. However, the low productivity of the Solar still triggered the initiatives to look for ways to improve its productivity and efficiency. These may be classified into passive and active methods. Passive methods include the use of dye or charcoal to increase the solar absorbitivity of water, applying good insulation, lowering the water depth in the basin to lower its thermal capacity, ensuring vapor tightness, using black gravel and rubber, using floating perforated black plate, and using reflective side walls. Active methods include the use of solar collector or waste heat to heat the basin water, the use of internal] and external condensers or applying vacuum inside the solar still to enhance the evaporation/condensation processes, and cooling the glass cover to increase the temperature difference between the glass and the water in the basin and hence increases the rate of evaporation.

Single-basin stills have been much studied and their behavior is well understood. The efficiency of solar stills which are well-constructed and maintained is about 50% although typical efficiencies can be 25%. Daily output as a function of solar irradiation is greatest in the early evening when the feed water is still hot but when outside temperatures are falling. At very high air temperatures such as over 45ºC, the plate can become too warm and condensation on it can become problematic, leading to loss of efficiency.

3. EXPERIMENTAL SETUP

3.1 Design of Solar Still

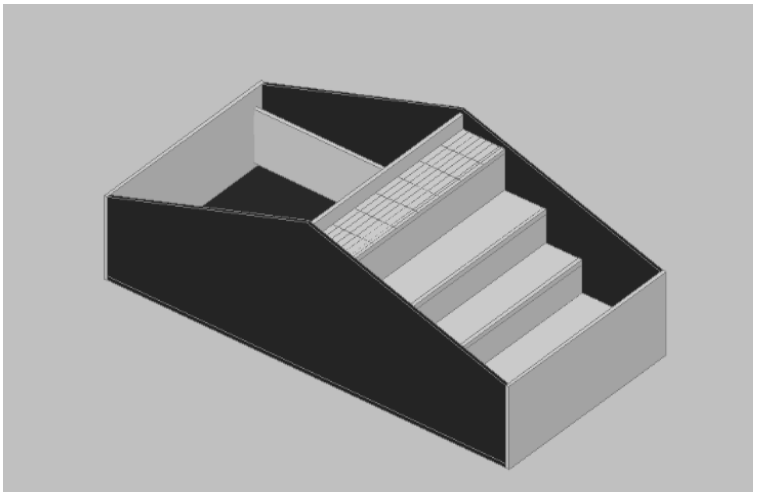


Fig. 8.1.1 Isometric View

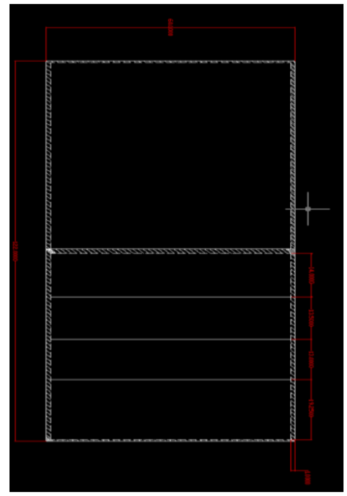
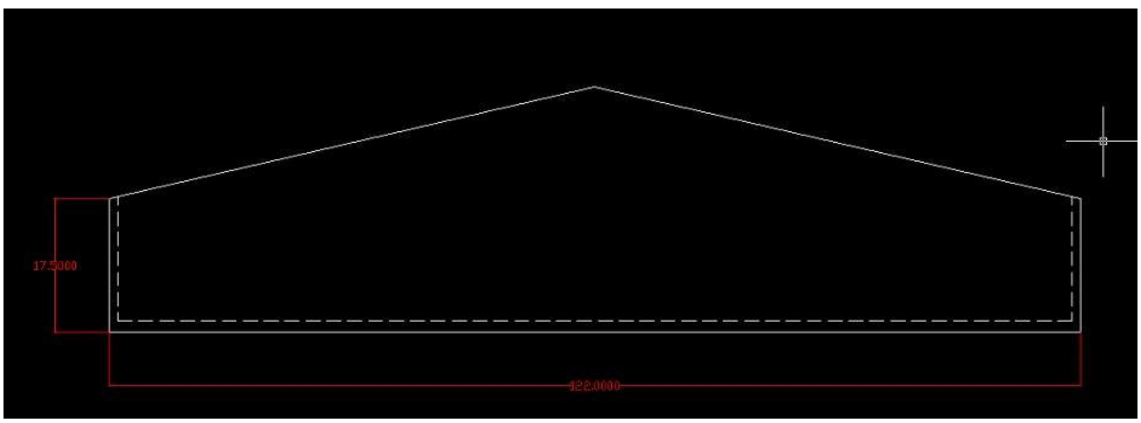


Fig. 8.1.2 Top View



Front View

3.2 Dimensions of Frame

Width	82 cm	
Length	122 cm	
Glass Area	82 cm x 63 cm	
Glass Thickness	6 mm	
Glass Slope	19°	
Connection Pipe	D_i = 1.3 cm	D_o = 1.5 cm
Angle Rod	2 mm	
G.I. Sheet	0.7 mm	
Thermocol Thickness	24 mm	
Wood Thickness	12 mm	

3.2.1 Dimensions of Frame

3.3 Components of Setup

The materials which are used to make the solar still are used in our everyday life and they are found easily near our locality. Materials required for making the solar still are as follows:

i. Wooden Frame.

ii. Thermocol and Aluminium Foil.

iii. Phase Change material.

iv. Galvanized Iron (GI) Sheet and Black Coating.

v. Glass Plate.

3.4 Cost Analysis

Sr. No.	Description	Amount (Rs.)
1	Cost of Wooden Box	1500
2	Cost Of Carpentry Material	400
3	Cost Of Insulating Material	800
4	Cost of G.I. Sheet	400
5	Cost of Paint	300
6	Cost of PCM	800
7	Cost of Pipes & Fittings	1000
8	Cost of Glass Cover	950
9	Cost of Overhead Tank	500
10	Cost of Temperature Sensors	1600
11	Cost of Laboratory Report	1100
Total Cost		9350

3.4.1 Cost Analysis Table

4. PHASE CHANGE MATERIAL

Concept of Phase Change Material (PCM); there are two modes of energy storage:

a) Sensible energy storage.

b) Latent energy storage.

In sensible energy storage system energy is stored as a temperature change in the system i.e. energy is stored as the temperature of the material increases and energy is released as its temperature decreases. While in latent heat storage system, energy as stored due to phase change and no temperature change occurs. Energy is stored as the material changes from solid to liquid or liquid to vapors and energy is given away when it solidify or regain its shape. Paraffin Wax is one of the good examples of phase change material for latent heat storage. Phase Change Materials (PCM) are latent heat storage materials that stores the energy because of the phase change i.e. when a material changes from solid to liquid, or liquid to solid. The temperature remains almost constant when these materials stores and release thermal energy. The heat storage capacity per unit volume of PCMs is much higher as compared to sensible heat storing materials.

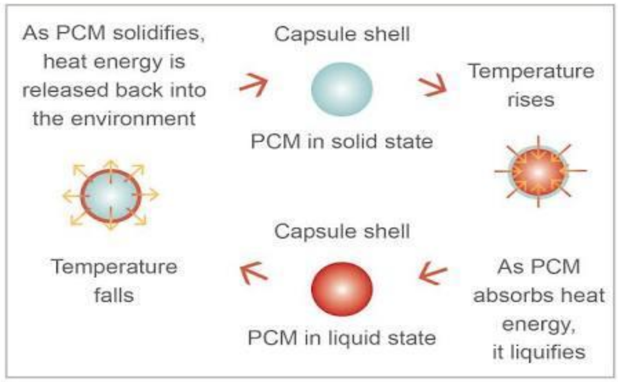


Fig. 4.1 Working of PCM

4.1 Properties of Paraffin Wax

Sr. No.	Parameters	Phase Change Materials
		Paraffin Wax
1	Chemical Formula	$C_{31}H_{64}$
2	Molar Mass	785 gm/mole
3	Appearance	White soft solid
4	Density	900 kg/m3
5	Melting Point (°c)	37
6	Boiling Point (ºc)	322
7	Vapour Pressure (kPa)	0.2
8	Thermal conductivity (W/mk)	0.224
9	Latent Heat of Fusion	251
10	Cost (Rs/Kg)	800

Table No. 4.1.1 Properties of Paraffin Wax

5. EXPERIMENTAL PROCEDURE

Experiment is carried out using following procedure:

- First an observation table is prepared for noting down the readings. The table consists of following columns: Time (in Hr), Atmospheric Temp. (in °C), Basin Water Temp.(BWT) (in °C), PCM Temp. (in °C), Productivity (in ml).
- The experimental hours are from 8 am to 8 pm.
- The solar still is placed where the sunlight is radiant properly making sure that no part of the still is under shadow of external objects during the experimental hours.
- All the clamps are checked to make sure that glass plate is resting properly on still without any gaps.
- The glass plate is cleaned with a dry cloth to remove any dirt or dust accumulated.
- The supply tank placed at a height is filled with saline water and at an appropriate flow rate the saline water is allowed to flow through the pipe into the tank.
- Now at an interval of an hour the readings are taken accordingly.
- The temperatures are measured using the digital thermometers installed in the still and productivity is measured in terms of distilled water collected in ml.

- The excess water is removed from the still through overflow port.
- The above procedure is repeated for at least a month. The calculations are done to obtain efficiency of still.
- Following graphs are plotted from the readings: Atm. Temp. Vs Time, BWT Vs Time, PCM Temp. Vs Time and Productivity Vs Time.
- Final results and conclusions are drawn from the above calculations and graphs.

6. TESTING:-

6.1 Observation Table

SR. NO.	TIME	CONVENTIONAL SLOPE		STEPPED SLOPE	
		PRODUCTIVITY	PCM TEMPERATURE	PRODUCTIVITY	PCM TEMPERATURE
1	8:00 AM	5	15	5	27
2	9:00 AM	15	25	18	30.2
3	10:00 AM	20	35	27	34.6
4	11:00 AM	30	47.8	45	46
5	12:00 PM	35	62.7	87	65.6
6	1:00 PM	90	62.8	104	68
7	2:00 PM	80	64.2	166	75.2
8	3:00 PM	80	58.5	195	71.9
9	4:00 PM	75	60.3	128	64.8
10	5:00 PM	35	50.1	69	55.4
11	6:00 PM	20	40.2	54	49.6
12	7:00 PM	15	35.2	47	43.2
13	8:00 PM	10	27.2	30	35.6

These are the optimum reading hence we have selected and created chart.

6.2 Conventional Slope:-

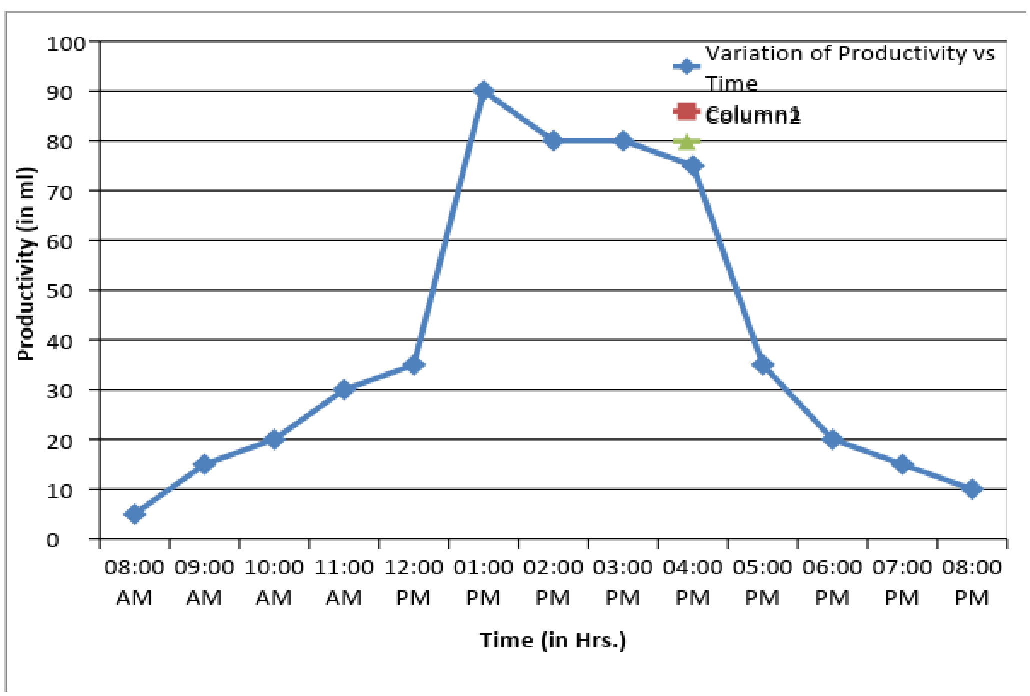


Fig. 6.2 (a) Variation of Productivity vs. Time

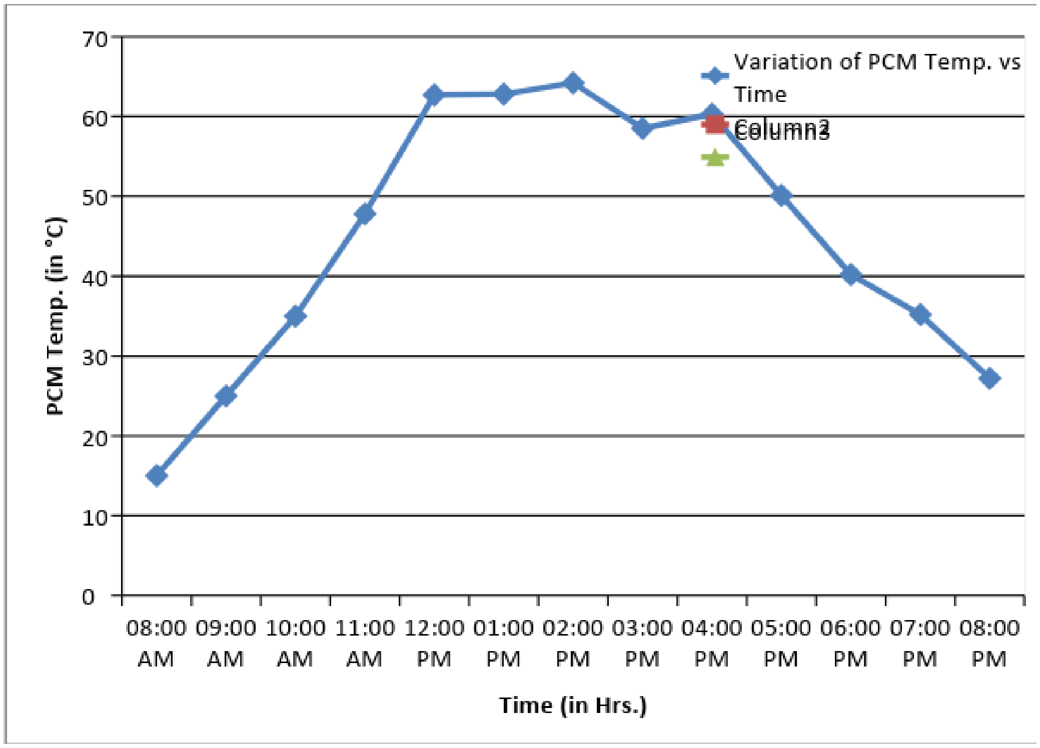


Fig. 6.2 (b) Variation of PCM Temp vs. Time

6.3 Stepped Slope:-

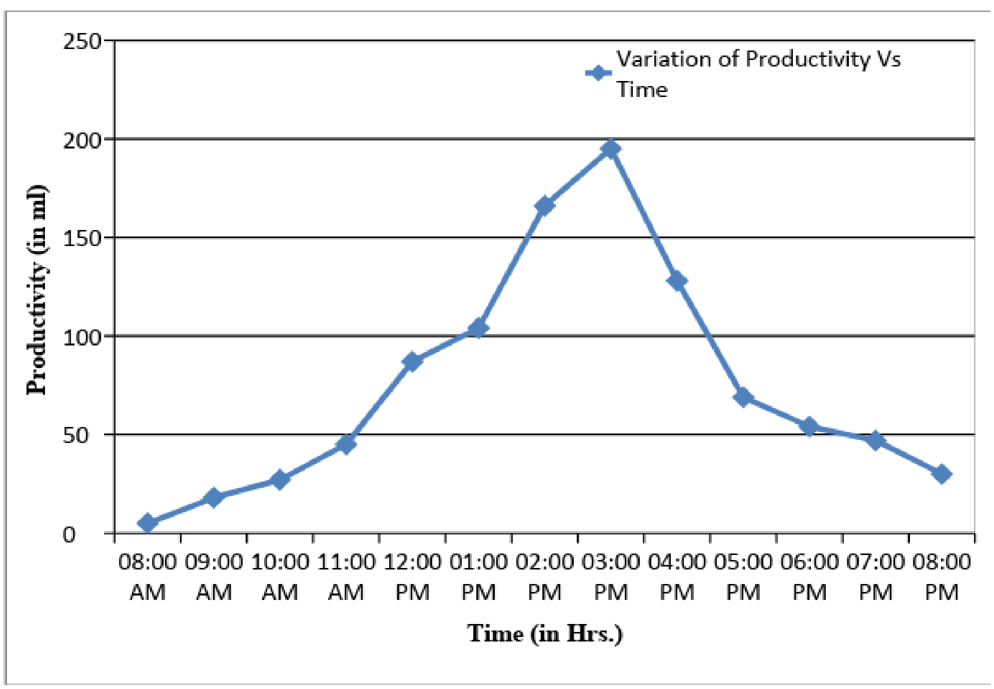


Fig. 6.3(a) Variation of Productivity vs. Time

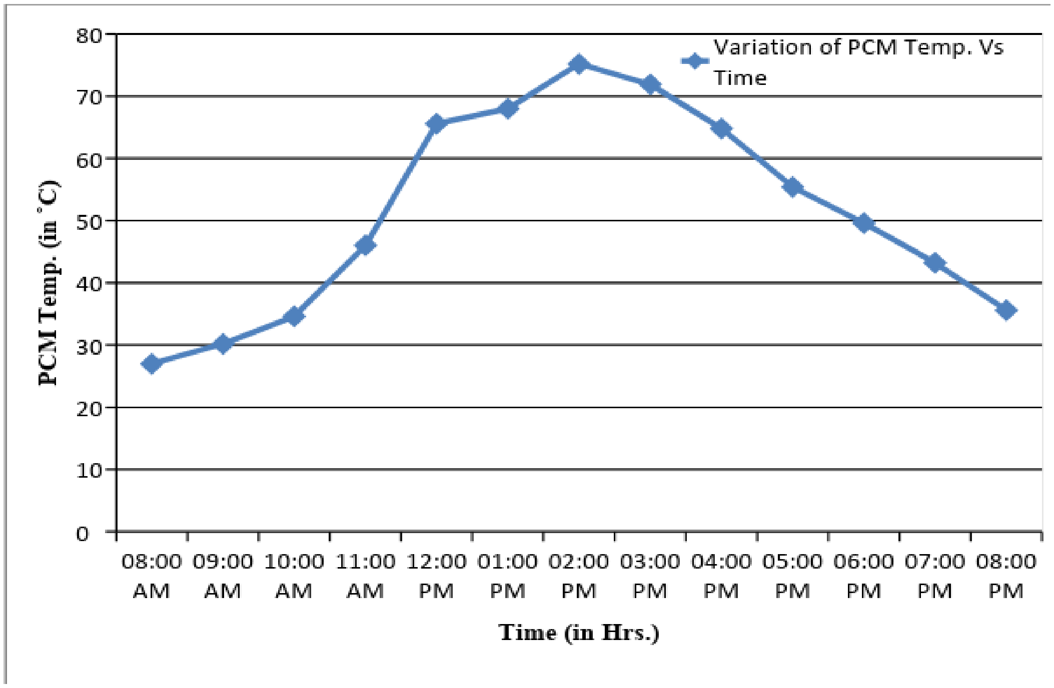


Fig. 6.3 (b) Variation of PCM Temp. Vs Time

7. Results

The comparisons test between Brackish water and Distilled water from —

Bioscience Biotech Laboratories.

Sr. No.	Chemical Test	Brackish Water	Acceptable Limits
1.	pH	8.07	6.5-8.5
2.	TDS	3000 mg/lit	500 mg/lit
3.	Odour	Unagreeable	Agreeable
4.	Chloride	500 mg/lit	250 mg/lit
5.	Calcium	31.20 mg/lit	75 mg/lit
6.	Alkalinity	117.64 mg/lit	200 mg/lit
7.	Total Hardness	400 mg/lit	300 mg/lit

Table 7.1 Result Table (a)

Sr. No.	Chemical Test	Distilled Water	Acceptable Limits
1.	pH	6.95	6.5-8.5
2.	TDS	94 mg/lit	500 mg/lit
3.	Odour	Agreeable	Agreeable
4.	Chloride	21.02 mg/lit	250 mg/lit
5.	Calcium	16.60 mg/lit	75 mg/lit
6.	Alkalinity	24.00 mg/lit	200 mg/lit
7.	Total Hardness	89.82 mg/lit	300 mg/lit

Table 7.2 Result Table (b)

8. CONCLUSION

The Solar still equipped with phase change material (PCM) is to be design and fabricated to improve the daily yield and efficiency of the still. Also the effect of various parameters such as glass cover inclination, flow rate, Material thermal conductivity is to be study. Expected productivity is 5ltr/day. From the test carried out the following conclusions are made the pH test of brackish water is 7.80 and the distilled water is 6.95.

1. The conventional solar still and stepped solar still experimental results are shows the temperature of increase in stepped solar still as compare to the conventional solar still.

2. The conventional solar still and stepped solar still experimental results are shows the distillation rate is higher in stepped solar still as compare to the conventional solar still.

3. Stepped solar still efficiency is better as compare to the conventional solar still.

9. FUTURE SCOPE

Human beings need 1 or 2 litres of water a day to live. The minimum requirement for normal life in developing countries (which includes cooking, cleaning and washing clothes) is 20 litres per day (in the industrialized world 200 to 400 litres per day is typical). Yet some functions can be performed with salty water and a typical requirement for distilled water is 5 litres per person per day. Therefore $2m^2$ of still are needed for each person served.

Solar stills should normally only be considered for removal of dissolved salts from water. If there is a choice between brackish ground water or polluted surface water, it will usually be cheaper to use a slow sand filter or other treatment device. If there is no fresh water then the main alternatives are desalination, transportation and rainwater collection. Unlike other techniques of desalination, solar stills are more attractive, the smaller the required output. The initial capital cost of stills is roughly proportional to capacity, whereas other methods have significant economies of scale. For the individual household, therefore, the solar still is most economic.

For outputs of 1 m^3/day or more, reverse osmosis or electrodialysis should be considered as an alternative to solar stills. Much will depend on the availability and price of electrical power. Solar distillation Practical Action 5 for outputs of 200 m^3/day or more vapour compression or flash evaporation will normally be least cost. The latter technology can have part of its energy requirement met by solar water heaters.

In many parts of the world, fresh water is transported from another region or location by boat, train, truck or pipeline. The cost of water transported by vehicles is typically of the same order of magnitude as that produced by solar stills. A pipeline may be less expensive for very large quantities.

Rainwater collection is an even simpler technique than solar distillation in areas where rain is not scarce, but requires a greater area and usually a larger storage tank.

9.1 Distillation Purification Capabilities

Solar stills have proven to be highly effective in cleaning up water supplies to provide safe drinking water. The effectiveness of distillation for producing safe drinking water is well established and recognized. Most commercial stills and water purification systems require electrical or other fossil-fueled power sources. Solar distillation technology produces the same safe quality drinking water as other distillation technologies; only the energy source is different: **THE SUN**.

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