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DESIGN, FABRICATION AND PERFORMANCE ENHANCEMENT OF DOUBLE SLOPE SOLAR STILL

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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 seawater is abundant but potable water is not available. Distillation is one of the processes that can be used for water purification. This requires an energy input as heat, electricity 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 portable water using free of cost solar energy. This energy is used directly for evaporating water inside a device usually termed a "*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 a still are used to desalinate seawater, in desert 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 groundwater can be a pleasant, energy- efficient option. Solar Distillation is an attractive alternative because of its simple technology, non requirement of highly skilled labor for maintenance work and low energy consumption. The use of solar thermal energy in seawater desalination applications has so far been restricted to small-scale systems in rural areas. The reason for this has mainly been explained by the relatively low productivity rate compared to the high capital cost. However, the coming shortage in fossil fuel supply and the growing need for fresh water in order to support increasing water and irrigation needs, have motivated further development of water desalination and purification by renewable energies.

KEYWORDS: Water, solar Energy, Distillation, Heat Transfer.

1. INTRODUCTION

There is an urgent need for clean, pure drinking water in many countries. Often, water sources are brackish and/or containing harmful bacteria and therefore cannot be used for drinking. In addition, there are many coastal locations where sea water is abundant but potable water is not available. Pure water is also needed in some industries, hospitals and schools. Solar distillation is one of many processes that can be used for water purification. Solar radiation can be the source of heat energy where brackish or sea water is evaporated and is then condensed as pure water. Due to environmental issues and limited fossil fuel resources, more and more attention is being given to renewable energy sources. In the recent years solar energy has been strongly promoted as a viable energy source. One of the simplest and most direct applications of this energy is the convergence of solar radiation into heat. Solar radiation can be widely used for water heating in hot water systems, swimming pools as well as a supporting energy sources for central heating installations. The energy of the solar radiation is in this case converted to heat with the use of solar panel. Using the sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks. Water is a basic necessity of man along with food and air. Fresh water resources usually available are rivers, lakes and underground water reservoirs. About 71% of the planet is covered in water, yet of all of that *96.5%* of the planet's water is found in oceans, *1.7%* in groundwater,*1.7%* in glaciers and the ice caps and *0.001%* in the air as vapor and clouds, Only

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2.5% of the Earth's water is freshwater and *98.8%* of that water is in ice and groundwater. Less than *1%* of all freshwater is in rivers, lakes and the atmosphere.

2. IDENTIFICATION OF PROBLEM

Solar still technology was first developed in 1872 by Carlos Wilson. In 1920, Kaush used metal concentrators to focus solar energy on brackish water to improve the performance of the still. An efficiency of 50% was achieved, and these results were later confirmed by Pasteur in 1928 (Sodha 1983). In 1930, Abbot used cylindrical parabolic reflectors for focusing solar energy onto tubes containing polluted water. The system worked with an efficiency of 80% (Daniels 1964). Lof, in 1961, investigated the performance of single basin stills with respect to variations in solar radiation, ambient temperature, area of cover, wind velocity, and water depth (Sodha et al. 1983) and his investigations revealed that productivity increased with increased solar radiation and that productivity also increased with increased ambient temperature. Direct variation between solar radiation and the performance of solar stills was later confirmed by Akinsete et al., in 1969 (Sodha et al. 1983). However, Akinsete et al., in their research of 1969, proposed that the effect of energy losses from the still is less significant at higher ambient temperatures. (Cooper 1969) studied the effect of water depth on productivity of solar stills and found out that productivity decreases with increased depth. This is in agreement with Lof's results of 1961. However, there is no mention of optimum depths needed for the still to function most efficiently. Bloemer investigated the effect of angle of inclination of the cover on still productivity in 1965 and found out that the still's performance was the same at inclinations of 10◦ and 45◦ (Alawi 1986). (Salam et al. 1986) reported that productivity of stills is much higher at low angles of inclination and that it decreases with increasing inclination.

(Nijmeh et al.2005), experimentally studied a single basin solar still using various absorbing materials like violet dye, charcoal, potassium permanganate (KMnO4) and potassium dichromate (K2Cr2O7). The best result obtained by violet dye i.e. 29%. (Eman-Bellah 2007) carried out experiments to investigate a method to improve the thermal conductivity of paraffin wax by embedding aluminum powder (80 µm) in it. (Sebaii 2009) et al, studied the performance of solar still with and without the stearic acid as PCM on summer and winter days by computer simulation. Results reveals that after sunset, the stearic acid (PCM) as a heat source for the basin water until sun rise in the early morning hours of the next day. At lower masses of basin water PCM becomes more effective during the winter.

(Tabrizi et al. 2010) studied two cascade solar stills with lat.ent heat thermal energy storage system (LHTESS) and without LHTESS. Both stills had the optimum inclination through the year for Zahedan, Iran.

(Hamadani et al. 2011) used lauric acid as phase change material (PCM) on a solar still and found that distillate productivity at night and on day without PCM was 30% to 35% and with PCM it increased by 127%. (Swetha 2011), used Lauric Acid as a phase change material on his study on a single slope single basin solar still and found 13% increment when it is used with sand as heat reservoir and 36% increment when used with Lauric Acid as PCM.

3. MATERIALS AND METHODS

3.1 Experimental Setup

The schematic view of the experimental set up used is shown in Figure1. The stills designed and fabricated have single basin double slope solar still having basin area (100cm×100cm) with high side wall of 52.77cm and low side wall of 10cm. Galvanized steel sheet having a thickness of 1mm were used or fabrication purpose. To prevent heat loss from the basin to the outside environment, the basin and walls was insulated from outside and bottom by insulating material (Rockwool) of thickness 4 cm. Envelop of basin over the insulating material is supported from outside by wooden sheet having a thickness of 3cm. In the conventional solar still, to increase the absorption of solar energy black coating was done on inner surfaces of bottom and side wall of the basin. The top of basin is covered with 5mm thick glass sheet inclined at nearly 23° with the horizontal. In the modified solar still, to increase absorptive of bottom surface it is painted in black color, while vertical walls with

white paint to increase the reflectivity of the wall. Water sprinkler was used to flow water over the glass surface. Solar still have been sealed by insulating and adhesive tape at the top to prevent vapor leakage from the basin to

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atmosphere. Condensate produced is collected in jar with the help of channel tubes attached at lower side of basin.

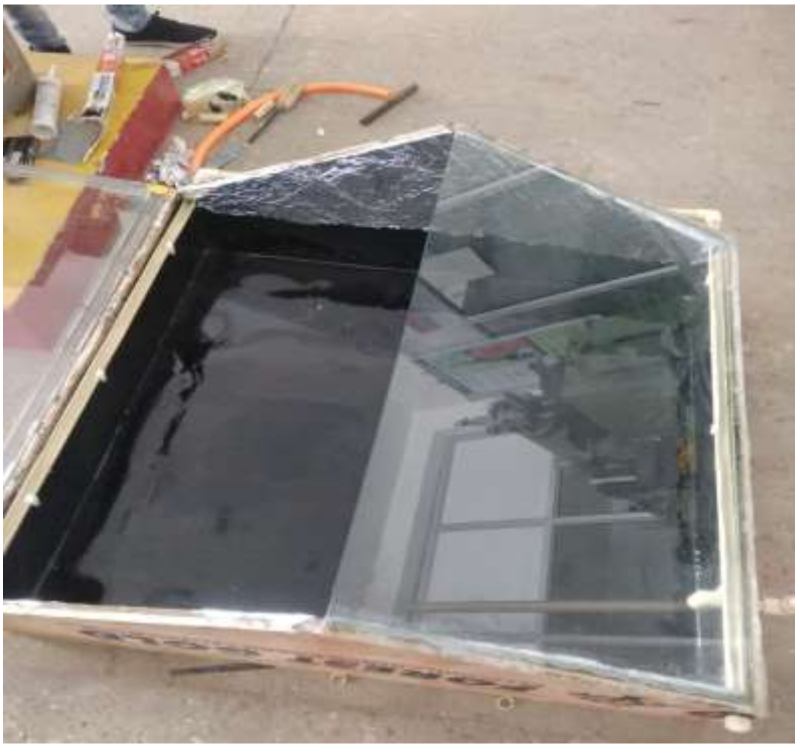

Figure 1: Fabrication of Double slope solar still

3.2 COMPONENT OF SOLAR STILL

Solar still is a simple device which can convert available water or brackish water into portable water by using solar energy. Main components of solar still are:

1. BASIN: It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence, it is necessary that the material has *high absorptive* or *very less reflectivity* and *very less transitivity*. These are the criteria for selecting the basin materials.

2. CONDENSATE CHANNEL: It is the part of the system in which condensed water is collected. Sheet of required dimension is first cut out, and then it is folded by using the folding machine.

3. BLACK LINER: Solar radiation transmitted through transparent cover is absorbed in the black lining. Black bodies are good absorbers. Black paint is used as liner.

4. TRANSPARENT COVER: Glazing glass is used and thickness of 5 mm is selected. The use of glass is because of its inherent property of producing greenhouse effect inside the still. Glass transmits over 90% of incident radiation in the visible range.

5. INSULATION: Rockwool is used as insulator to provide thermal resistance to the heat transfer that takes place from the system to the surrounding.

6. SEALANT: M seal is used as sealant to make the distiller leak proof and air tight. Silicon Glue is used to join Glass to Glass.

7. SUPPLY AND DELIVERY SYSTEM: Five holes are made in the basin, one for supply and four for delivery.

8. TABLE: Ply wood table is used to support whole setup. Ply wood has good surface finish. Base of Ply wood is used because of its good strength.

9. REFLECTOR: *Reflecting Mirror* is used with two sides and is supported by ply wood to prevent its breakage.

10. TEMPERATURE SENSOR: *PT100 Temp Sensor* along with its complimentary components is used. LCD reflecting temperature in °C.

Figure 2: M seal

Figure 3: Silicon Glue

Figure 4: Temperature Glass

4. MODES OF HEAT TRANSFER

Heat transfer describes the exchange of thermal energy, between physical systems depending on the temperature and pressure, by dissipating heat. Systems which are not isolated may decrease in entropy. Most objects emit infrared thermal radiation near room temperature. The fundamental modes of heat transfer are conduction or diffusion, convection, advection and radiation. The exchange of kinetic energy of particles through the boundary between two systems is at a different temperature from another body or its surroundings. Heat transfer changes the internal energy of both systems involved according to the First Law of Thermodynamics. The Second Law of Thermodynamics defines the concept of thermodynamic entropy, by measurable heat transfer.

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The fundamental modes of heat transfer are:-
1-CONDUCTION
2-CONVECTION
3-RADIATION

4.1 Conduction process

Conduction is the process by which heat energy is transmitted through collisions between neighboring molecules. Think of a frying pan set over an open camp stove. The fire's heat causes molecules in the pan to vibrate faster, making it hotter. These vibrating molecules collide with their neighboring molecules, making them also vibrate faster. This process continues until the entire pan has heated up due to the vibrating and colliding molecules.

4.2 Convection process

Convection is the process of moving heat around by putting it into the molecules of a gas or liquid and then moving that hot gas or liquid to a new place where the heat can be released. Convection occurs naturally in our weather systems. If you sit by a large body of water on a sunny summer day you may notice later in the day a breeze coming off the water towards land (on-shore breeze). This is caused when the sun has had time to heat up the land, which in turn heats up the air in contact with it. This hot air expands and rises because it is less dense. As the warm air rises, the cooler air over the water rushes in to replace the warm rising air (the breeze you feel) and the warm air migrates up and over the lake, where it cools and settles down onto the lake.

4.3 Radiation process

Thermal radiation occurs through a vacuum or any transparent medium (solid or fluid). It is the transfer of energy by means of photons in electromagnetic waves governed by the same laws. Earth's radiation balance depends on the incoming and the outgoing thermal radiation, Earth's energy budget. Anthropogenic perturbations in the climate system are responsible for a positive radioactive forcing which reduces the net long wave radiation loss out to Space. Thermal radiation is energy emitted by matter as electromagnetic waves, due to the pool of thermal energy in all matter with a temperature above absolute zero. Thermal radiation propagates without the presence of matter through the vacuum of space. Thermal radiation is a direct result of the random movements of atoms and molecules in matter. Since these atoms and molecules are composed of charged particles (protons and electrons), their movement results in the emission of electromagnetic radiation, which carries energy away from the surface.

5. THERMAL CONDUCTIVITY

Thermal conductivity is ability of material to conduct heat through it. The Thermal conductivity of material depends upon temperature gradient. Thermal conductivity refers to the amount/speed of heat transmitted through a material. Heat transfer occurs at a higher rate across materials of high thermal conductivity than those of low thermal conductivity. Materials of high thermal conductivity are widely used in heat sink applications and materials of low thermal conductivity are used as thermal insulation. Thermal conductivity of materials is temperature dependent. The reciprocal of thermal conductivity is called thermal resistivity. Metals with high thermal conductivity, e.g. copper, exhibit high electrical conductivity. The heat generated in high thermal conductivity materials is rapidly conducted away from the region of the weld. For metallic materials, the electrical and thermal conductivity correlates positively, i.e. materials with high electrical conductivity (low electrical resistance) exhibit high thermal conductivity.

Thermal conductivity depends upon

1. Density of material
2. Pressure and temperature
3. Material structure
4. Moisture content

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6. WORKING OF SOLAR STILL

Solar stills are called stills because they distill, or purify water. A solar still operates on the same principle as rainwater: evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills mimic this natural process.

A solar still has a top cover made of glass, with an interior surface made of a waterproof membrane. This interior surface uses a blackened material to improve absorption of the sun's rays. Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation (short-wave) to pass into the still, which is mostly absorbed by the blackened base.

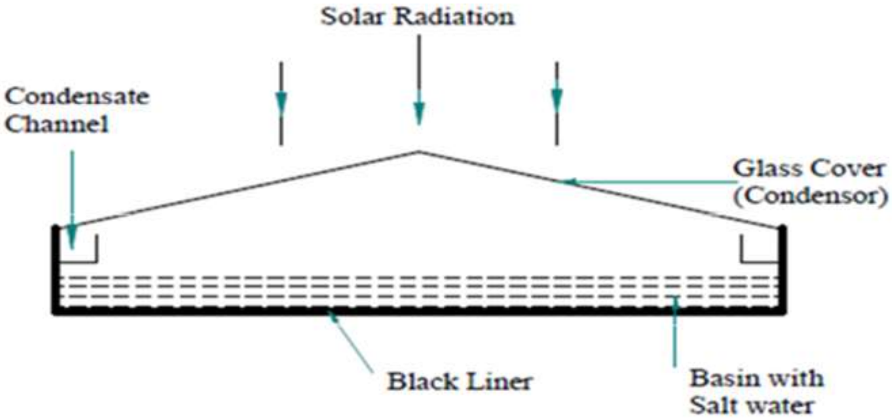

Figure 5: Working principle of solar still

The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The base also radiates energy in the infra-red region (long-wave) which is reflected back into the still by the glass cover, trapping the solar energy inside the still (the "greenhouse" effect). The heated water vapor evaporates from the basin and condenses on the inside of the glass cover.

In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle. There are no moving parts in Solar still and only the sun’s energy is required for operation. The still is filled each morning or evening, and the total water production for the day is collected at that time. The still will continue to produce distillate after sundown until the water temperature cools down. Feed water should be added each day that roughly exceeds the distillate production to provide proper flushing of the basin water and to clean out excess salts left behind during the Evaporation process. The most important elements of the design are the sealing of the base with black

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Figure 6: Experimental Set up of solar still

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6.1 Measuring Instruments

Various measuring instruments were used to determine various parameters of solar still. The measurement of temperatures at various points of the still, such as outer glass surface, inner glass surface, basin water region, vapor region and ambient temperature, have been measured by using k type thermocouple. Thermocouples were attached to digital temperature indicator which indicates different temperatures. The distillate output was measured by jar engraved with marking having capacity of 1,000 ml with least count of 10ml. The intensity of solar radiation was measured on glass cover with the help of solar power meter range 0–2,000W/m^2 with least count 0.1W/m^2.

Figure 7: Measuring Instruments

7. RESULT AND DISCUSSION

Table 1: Temperature readings of various components of conventional solar still

Date: 10/04/2019 **Water Depth: 4 cm**

Time	Inner Air Temp.(T1)	Basin Temp.(T2)	Water Temp.(T3)	Glass Temp.(T4)	Productivity
10:00 AM	51	43	45	47	0
11:00 AM	58	56	57	54	50
12:00 PM	64	65	65	58	200
1:00 PM	71	70	70	60	400
2:00 PM	72	71	70	57	450
3:00 PM	63	68	67	57	400

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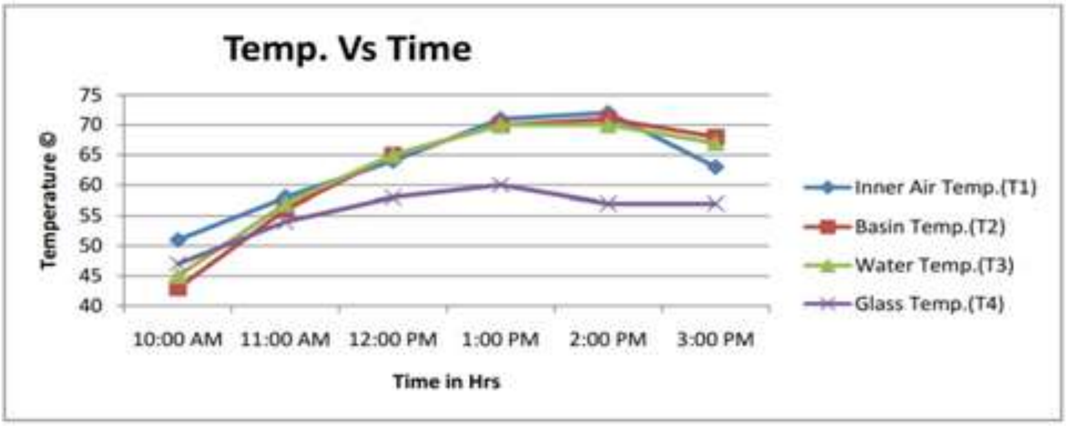

Figure 8: Hourly profile of solar radiation with various temperatures of Conventional solar still

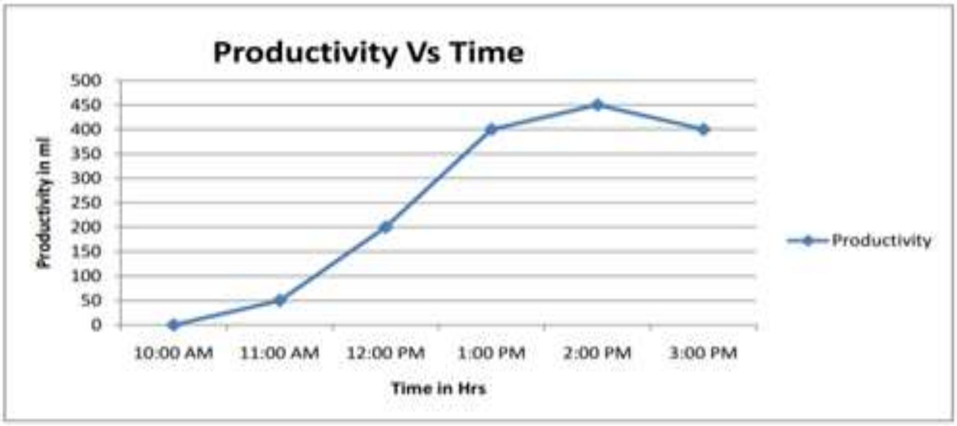

Figure 9: Hourly profile of productivity with Time for conventional solar still

Table 2: Temperature readings of various components of Modified solar still

Date: 18/04/2019 Sponge cubes with 6 cm side Water Depth: 7 cm

Time	Inner air Temp.T_1	Basin Temp.T_2	Water Temp.T_3	Glass Temp.T_4	Ambient Temp.T_5	Productivity (ml)
10:00AM	37	26	26	43	36	0
11:00AM	48	31	31	47	35	35
12:00PM	49	38	51	49	35	85
01:00PM	53	54	44	53	35	160
02:00PM	52	48	48	48	34	310
03:00PM	58	52	51	51	37	510
04:00PM	55	52	52	47	34	655

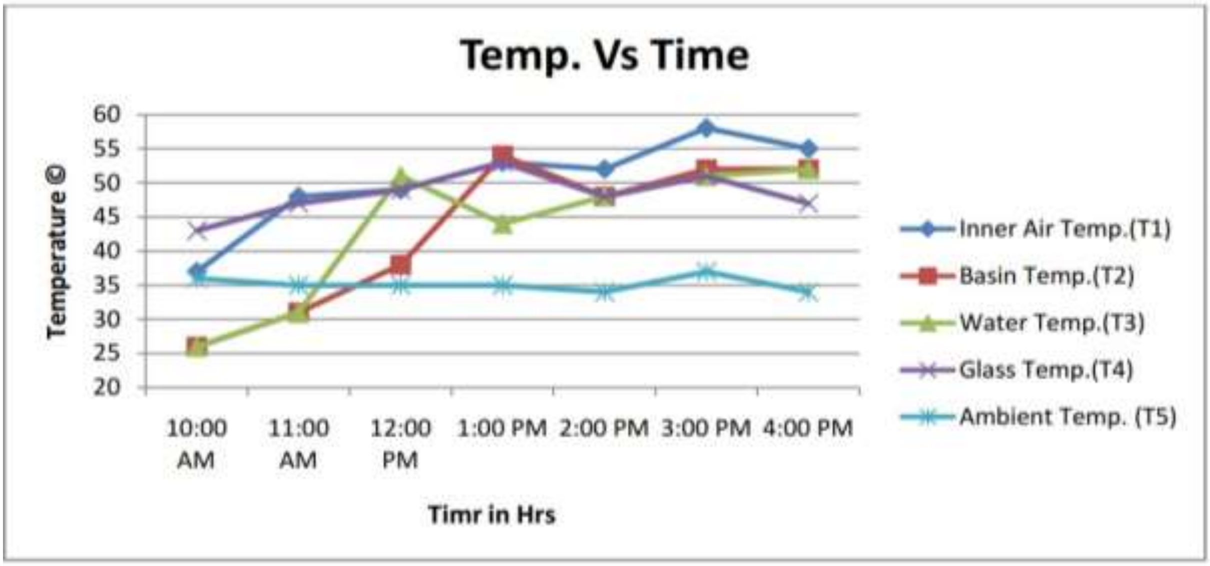

Figure 10: Hourly profile of solar radiation with various temperatures of Modified solar still

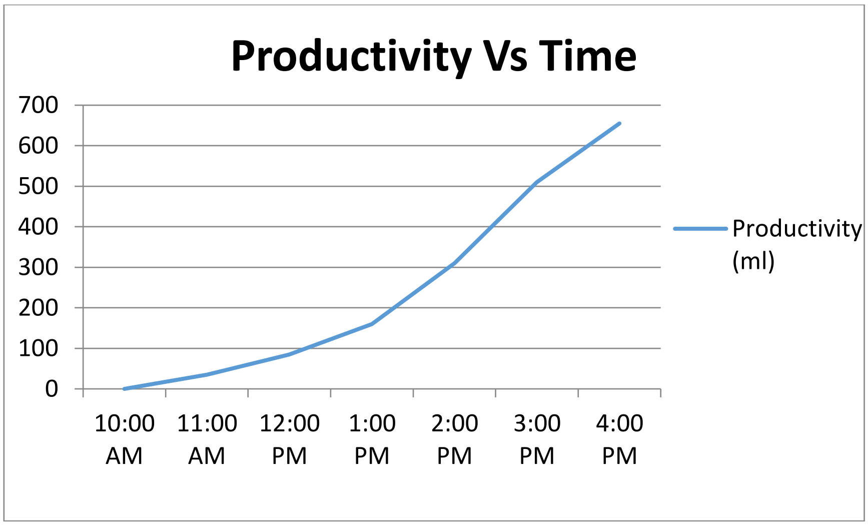

Figure 6: Hourly profile of productivity with Time for modified solar still

8. CONCLUSION

Distillation is a method where water is removed from the contaminations rather than to remove contaminants from the water. Solar energy is a promising source to achieve this. This is due to various advantages involved in solar distillation. The Solar distillation involves zero maintenance cost and no energy costs as it involves only solar energy which is free of cost.

It was found from the experimental analysis that increasing the ambient temperature from 32°C to 47°C will increase the productivity by approx. 12 to 23%, which shows that the system performed more distillation at higher ambient temperatures.

It was observed that when the water depth increases from 4 cm to 7 cm the productivity decreased by 5%.These results show that the water mass (water depth) has an intense effect on the distillate output of the solar still system.

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Solar still productivity also increased by use of sponge cubes which increases the free surfaces of water. The main disadvantage of this solar still is the low productivity or high capital cost per unit output of distillate. This could be improved by a number of actions, e.g. injecting black dye in the seawater, using internal and external mirror, using wick, reducing heat conduction through basin walls and top cover or reusing the latent heat emitted from the condensing vapor on the glass cover. Capital cost can be reduced by using different designs and new materials for construction of solar stills.

It can be concluded that the use of solar water distillation promises to enhance the quality of life and to improve health standards in arid areas near Bhopal.

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REFERENCES

[1] Sodha, M.S., Mathur, S.S. & Malik, M. A.S. *Reviews of Renewable Energy Resources*, vol. 1, Wiley Eastern, New Delhi, India (1983).
[2] Hinnawi, E.E.El, *The environmental impacts of production and use of energy: an assessment prepared by the United Nations Environment Programme*, Tycooly Press for United Nations Environment Programme, Dublin, Ireland (1981).
[3] Daniels, F. *Direct Use of Sun's Energy*, Yale University Press, New Haven, CT, USA (1964).
[4] Cooper, P.I. Digital simulation of transient solar still processes, *Solar Energy*, 12 (1969), 313–331.
[5] Alawi, H., Aljassar, A., Al-Juwayhel, F., Marafie, A., Al-Homoud, A., Ayyash, S. & Kellow, M. *Solar energy prospects in the Arab world*, in 1st Arab International Energy Conference, Pergamon Press, Oxford (1986).
[6] Abdel-Salam, M.S., Helwa, N. H. & Mohamed, M. A. *Effect of cover slope and inside air volume on the performance of solar stills.*, in Solar Energy Prospect in the ArabWorld, H. Alawi, ed., Pergamon Press, Oxford, (1986) 293–297.
[7] Fath H.E.S. Solar thermal energy storage technologies: technical note. *Renew Energy* 14 (1998), 35–40.
[8] Talmatsky, E. & Abraham, K. PCM storage for solar DHW: un unfulfilled promise? *Solar Energy* 82 (2008), 861–869.
[9] Chen, C.R., Sharma, Atul., Tyagi, S.K. & Buddhi, D. Numerical heat transfer studies of PCMs used in box-type solar cookers. *Renew Energy* 33 (2008), 1121–9.
[10] Hussein, H.M.S., El-Ghetany, H.H. & Nada, S.A. Experimental investigation of novel indirect solar cooker with indoor PCM thermal storage and cooking unit. *Energy Convers Manage* 49 (2008), 2237–46.
[11] Atyah, N. & Afif. H. Modeling of greenhouse with PCM energy storage. *Energy Convers Manage* 49 (2008), 3338–42.
[12] Nijmeh, S., Odeh, S. & Akash, B. Experimental and theoretical study of a single-basin solar still in Jordan. *Int. Comm. Heat Mass Transfer* 32 (2005), 565–572.
[13] Eman-Bellah, S., Mettawee, a. & Ghazy, M.R. Thermal conductivity enhancement in a latent heat storage system *Solar Energy* 81 (2007), 839–845.
[14] El-Sebaii, A.A., Al-Ghamdi, A.A., Al-Hazmi, F.S. & Faidah, A.S. Thermal performance of a single basin solar still with PCM as a storage medium, *Appl. Energy* 86 (2009), 1187–1195.
[15] Tabrizi, F.F., Moghaddam, M.D.H. Experimental investigation of weir-type cascade solar still build-in latent heat thermal energy storage system, *Desalination* 260 (2010), 248–253.
[16] Al-Hamadani, A. A. F. & Shukla S. K. Water Distillation Using Solar Energy System with Lauric Acid as Storage Medium, *International Journal of Energy Engineering* 1(1) (2011), 1-8.
[17] Non-Conventional Energy Resources book by *Shaman Saied and D.K Sharma*.