ANALYSIS OF ASSORTED PARAMETERS INFLUENCING THE PERFORMANCE OF SOLAR DISTILLATION SYSTEMS: A REVIEW

[1] PIYUSH SONI, [2]PAWAN SONI,[3]JANKI SHARAN MISHRA
[1,2,3]STUDENTS, VINDHYA INSTITUTE OF TECHNOLOGY & SCIENCE ,SATNA (M.P),
[1] piyushsoni420786@gmail.com

***Abstract*— water is the most vital element for sustaining life on the earth. There is almost no water left on earth that is safe to drink without purification after 20-25 years from today. This might be a bold statement, but it is unfortunately true. In developing countries, unavailability of safe and unreliable drinking water is a major problem. The world's demand for potable water is increasing at a constant rate with the growth of population and industries. The solar water distillation comes out to be a non toxic, environment friendly and promising device which purifies water that uses a renewable solar energy source. The TS, TDS, TSS, phosphates and chlorides are reduced to zero after the solar distillation. It insures that the distilled water is 'Pure' water. Water desalination using solar energy is suitable for potable water production from brackish and seawater.**

Various attempts have been made by the researchers to purify the saline water using solar stills using solar energy .But the conversion rate of saline water into pure water is very less and the efficiency of the stills were also not up to the mark. The present paper is an attempt to show the effect of various parameters how they affect the performance and efficiency of the solar still.

***Keywords:* Analysis, factors, performance, still, productivity, solar etc.**

I. INTRODUCTION

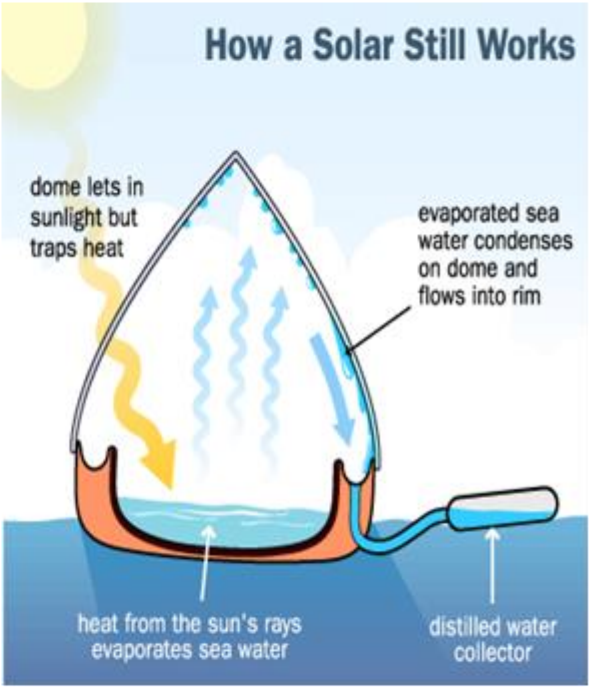
Water is the foremost need for human along with food and air. In today's world availability of fresh water is a prime challenge for people in all developed or developing countries. There will be hardly some water left on Earth which would be safe to drink without purification .The supply of drinking water is a growing problem for most parts of the world. Near about 80 countries, having 40 % of the world population, are suffering from this problem. It is estimated that out of 5, 75, 000 near about 1, 62, 000 Indian villages alone face the problem of saline or contaminated water (Srinivas et al, 2010). The increase in pollution will magnify the problem of water scarcity. This scenario is definitely not sustainable for the future of human being. So, the purification of water is very import. Fortunately there is a solution to these problems. It is a technology that is not only capable of removing a very wide variety of contaminants in just one step, but is simple one i.e. the use of solar energy. Low daily productivity of fresh water with the solar stills triggered scientists to investigate various means of improving stills performance and thermal efficiency to reduce cost of the water purification. The process to produce fresh water for drinking and other useful purpose from the salted and brackish water is called desalination since desalination is followed by evaporation and condensation hence it produces very high quality pure water. The available solar stills for desalination of water is free of cost whose productivity varies from 2Liters/day to 12Liters/day and the efficiency varies from 20% to 80% which depends on the design parameters and hybridization of solar still. The construction of the solar still is very simple which is followed by a transparent glass cover topping the enclosed basin. Solar irradiation incident on inclined glass cover which is further transmitted into basin and absorbed by water as well as bottom blackened surface (basin liner).Due to absorption of solar energy the water gets evaporated and condensed at inner surface of glass cover and is collected in trough at lower end of glass cover. From critical point of view it must be concluded that solar distillation process is most economical and environment friendly, another advantage that the desalination has that it will never run out of its raw material. Due to the reason that the facility is located right next to the ocean and the ocean is so vast. Because of this, desalination is proved to be a drought-proof resource that is constantly able to produce fresh water regardless of the amount of rainfall. The solar distillation performance depends upon the operating and climatic conditions, design of solar still.

A. About the solar energy

The energy radiated by the sun is uniformly distributed in all direction in the form of electromagnetic waves. When this energy is absorbed by body, it increases its temperature. It is a clean, abundantly, inexhaustible and universally available renewable energy [6]. The solar power where sun hits atmosphere is about 1017 watts, and the solar power on earth's surface is 1016 watts. The total requirement of power for all needs of civilization is 1013 watts. Therefore, the power given by sun is about 1000 times more than what we need.

II. THE PRINCIPLES OF SOLAR WATER DESTILLATION

The principle of solar water desalination using solar energy is very simple and yet effective also as distillation replicates the way nature makes rain. The energy obtained from the sun is used to heat up the water to the point of evaporation. And as the water gets evaporated, water vapor rises, condensing on the glass surface for collection. This process is capable of removing impurities, such as salts and heavy metals, and eliminates microbiological organisms. The end result of which is water cleaner than the purest rainwater.



III. THE SOLAR STILL

A. Introduction

The first ever man-manufactured large-scale water desalination system, which dates back to the 19th century, is the solar still. A solar still consists of an airtight insulated basin which is covered with an inclined glass cover. The Solar energy in the form of radiation passes through the transparent glass or plastic cover and is absorbed by saline water in the basin so that water is heated and causes evaporation. The water vapor condenses at the inner side of the glass cover and the liquid flows by gravity into a trough where it is collected. Basins are painted black to increase the solar absorption, and long wavelength radiation cannot pass from the solar still through the glazing. In other words, the greenhouse effect makes the solar still look like a heat trap. A solar still must have flushing to prevent salt precipitation and the flushing frequency depends on the quality of feed water.

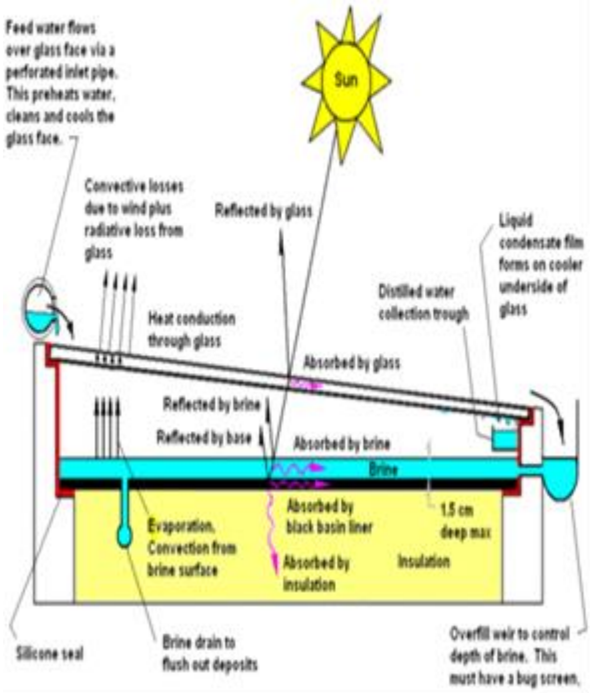
B. Details of Various Parts of the System

1) Still Basin: This is the part of the system in which the water to be distilled is kept. Therefore it is necessary that it must absorb the solar energy. Hence the basic requirement for the basin material is that it must have high absorptivity or very less reflectivity and very less transmissivity. These are the some essential criteria's for the selection of the basin materials. The various kinds of the basin materials that can be used are: 1. Leather sheet, 2.Ge silicon, 3. Mild steel plate, 4. RPF (reinforced plastic) 5. G.I. (galvanized iron).

2) Side Walls: The side walls of the still provide the rigidity to the structure of solar still. But technically the side walls perform the function of providing thermal resistance to the flow of heat from system to surrounding. So it must be able to sustain its own weight, weight of still and the water pressure and in addition to that it must have low value of thermal conductivity. Different materials that can be used are: 1) wood, 2) concrete, 3) thermocol, 4) RPF (reinforced plastic).

3) Top Cover: the part of the solar still which provides a condensing surface to water vapor and transmits the solar energy to the basin is called top cover. So the top cover must have some features which are: 1) Must have high transmittance factor for solar radiation, 2) Non-adsorbent of water,3) Have smooth and clean surface. The Materials that can be used are as: 1) Glass, 2) Polythene.

4) Channel: The condensate which is formed due to condensation slides over the inclined glass cover and falls in the passage, this passage which fetches out the distilled water is known as channel. The materials which can be used are: 1) P.V.C., 2) G.I. 3) RPF



IV. CLASSIFICATION OF SOLAR DISTILLATION SYSTEMS

A. ACTIVE DISTILLATION

A) HIGH TEMPERATURE DISTILLATION
1. Auxiliary heating
2. Collector or concentrator panel heating
3. PV integrated collector

B) NORMMAL TEMPERATURE DISRIBUTION

B. PASSIVE DISTILLATION

A) HIGH TEMPERATURE RANGE i.e. MORE THAN 60 °C
1. Horizontal basin solar still
2. Inclined basin solar still

3. Regenerative effect solar still
4. Spherical condensing solar still
5. Vertical solar still

C. NORMAL TEMPERATURE RANGE i.e. LESS THAN 60 °C

1. Convective solar still
   a. Single slope solar still
   b. Double slope solar still
   c. Symmetrical
   d. Nonsymmetrical
2. Inclined solar still
3. New design of solar still

SOLAR STILL OF ACTIVE TYPE

In this type of solar still, an extra amount thermal energy is from an external source is fed to the water in the basin to create a faster rate of evaporation. A broad classification of the solar stills is depicted above.

SOLAR STILL OF PASSIVE TYPE

In this type of stills the energy needed for the distillation of water is taken only from one source i.e. sun only. The conventional low temperature solar stills, operating at a temperature below 60 °c are single slope and double slope solar still. And of these the former one is more versatile and efficient than the latter one.

Numerical analysis: in this section we will develop the relation between various parameters and show numerically i.e. by the use of formulas how the variation in these parameters affects the performance of the still and how the output i.e. the amount of distillate obtained varies.

1. Calculation of base area: The calculation of base area is based on the amount of distilled water required. With a desired output of 4 liters of water the amount of solar energy needed can be calculated as follows.

The mass of 4 liters of water = volume × density

M = 4×10-3×1000 = 4 kg

The latent heat of vapourisation of water, h =2260 KJ/kg

Hence the solar energy needed = M*h =4×2260 =9040 KJ

Now for calculating the amount of incident solar energy it is required to analyze the data of incident solar energy in a city every month.

For example the average incident solar energy in Mumbai per year is about 6.23 KWh/m2/day

Therefore Q incident = (6.23×1000) ÷24 = 259.583 W/m2

Assuming 8 hours of operation per day Qincident = 259.583×8 = 2076.664 W/m2=2076.664×3.6=7476 KJ

Hence base area required A = Q needed/Q incident =9040/7476= 1.21 m2

2. Determination of variation in productivity: the heat transfer energy balance in and out of the still is evaluated considering the three main components.

a) Glass cover
b) Water in the basin and,
c) Basin itself

A) In the glass cover following phenomenon occurs

a. Absorption
b. Conduction
c. Convection
d. Radiation.

1. Absorption in the glass cover is given by Q abs = Q incident × Ag × αg

Generally the glass covers absorption αg is about 5%

2. Conduction in the glass cover is given by Q conduction = k × Ag× (Tgo – Tgi)/L

So about 95% of the incident energy is conducted through glass cover and reach the water in the basin.

3. Convection through the glass cover is given by Q convection = h ×Ag × (Tgo-Ta). In convection the heat lost to the ambient air is the due to Q abs. Convection occurs only in the presence of wind if there is no wind then no convection either force or free.

4. Radiation from the glass cover occurs to the both side i.e. to atmosphere and to the basin. To both way the radiation is given by Q radiation = ε × б × A × (Tg4-Tamb4) and ε × б × A× (Tg4-Tb4).

B) In the basin following phenomenon occurs

a. Absorption
b. Reflection
c. Losses to the surrounding

1. The basin absorbs as much heat as is transmitted by the glass cover. That is for basin Q abs = Q transmitted by the glass cover which is given by (Q abs)b=(Q con)g

2. Losses to the surrounding are due to conduction mainly.

C) At the water surface the main phenomenon is the evaporation of water. the heat or solar energy which is absorbed by the basin is eventually given back to the water by which the water evaporates.

Now in this section we will show the variation in the performance and output of solar still by varying either the material property or material itself.

1. For the top cover of the still two materials are advised glass and polythene. If we use glass then the energy transmitted to the basin will be equal to the product of glass's transmittance and the incident solar energy.

The transmittance of glass is .8 and of polythene is about .9 i.e. if we use polythene around 12.5% more solar energy would be available. But polythene is not used because of its low life i.e. is get damaged easily.

2. For the basin the materials that can be used are leather, mild steel, GI, silicon etc. for the basin material the main two properties which are of importance value are specific heat and it ability to absorb solar energy. These two properties of these materials are listed below.

MATERIL	SPECIFIC HEAT (J/Kg--K)	ABSORPTIVITY	THERMAL CONDUCTIIVITY
MILD STEEL	510	.85	43
GE SILICON	705	.8	68
GALVANIZED IRON (GI)	449	.64 TO .92	80

Now when mild steel is used as basin material it absorbs 85% of the energy falling in it so for every 1000 J of incident energy it absorbs 850 J and the gain in temperature of the material in per Kg is 1.67 K.

When Ge silicon is used as basin material it absorbs it absorbs 800 J of energy per 1000 J and the rise in temperature per kg of material is 1.135 K.

When GI is used it absorbs 920 J of energy per 1000 J of solar energy and the rise in temperature of per Kg of the material will be 2.05 K.

From above analysis it is clear that the rise in temperature of per Kg of material is higher in the case of GI and is 2.05 K. the rise in temperature is directly related with the evaporation of water because more the rise in temperature of basin material more will be the energy available for evaporation of water.

Another thing to be noted that this is the rise in temperature of per Kg of the material i.e. more be the Kg of the material more the heat is required to gain the required change in temperature hence the material should be light i.e. having low density.

The thermal conductivity of the basin material is a parameter which determines how quickly the heat or solar energy will be conducted through the body. For basin the main function is to absorb heat and then give this heat back to the water thus its thermal conductivity should be low.

3. Side walls are to provide rigidness to structure and technically for providing thermal resistance for flow of heat from system to surrounding. Hence it should have low thermal conductivity. For side walls the various materials that can be used are wood, concrete, thermocol etc. the thermal conductivities of various materials are listed below.

MATERIAL	THERMAL CONDUCTIVIITY (W/M-K)
WOOD	.04 TO .12 (DEPENDS ON MOISTURE CONTENT)
CONCRETE	2.5
THERMOCOL	.033

Concrete is generally not used as side wall material because of its high thermal conductivity. The remaining two are wood and thermocol. The table above suggests that thermocol must be used as side walls because of low thermal conductivity as long as it is able to sustain the weight of still and water in the basin. But if water is to be distilled is in large quantity then wood must be used.

For the same thickness the heat lost from wood is 22.22% is more than the heat lost from thermocol

V. LITERATURE REVIEW

Pinakeen Patel, Rajesh Kumar (ICIAME 2016) has presented a paper showing the comparative study of three still one having large frontal area, one having sensible heat storage material at the basin and the third one is a traditional one. He showed the effect of HSM and variation of frontal area in the performance of the solar still. From his Experiment it is confirmed that Solar Still with Thermal Fluid gives maximum distilled output when minimum difference between Basin Liner Temperature (TBL) and Thermal Oil Temperature (Toil) is above 17^{o}C - 19^{o}C. Based on his experiment he concluded following points

As temperature difference between Basin liner and Inner Glass Surface increases distilled output is increases.

For best distilled output small frontal height between 50-70 mm is Maximum suited.

Pınar İlker ALKAN (İzmir Institute of Technology İzmir, Turkey April 2003) has presented the full length thesis on the solar still desalination system and given his result of experiment that how various factors affect the still performance

According to experiments, following points may be concluded:

• The important factor which affects productivity of the solar still is solar radiation, when higher solar irradiation is received the productivity of the solar still increase.

• Efficiency of the solar still has a little alteration with increasing of ambient air temperature

• When the temperature difference between the interface temperature and glass cover temperature increase, amount of distilled water from the still raise.

• The reflector which is used to concentrate solar radiation into the still increased solar radiation value 13.77 to16.93 MJ/m2 on 04.04.2003.

• The maximum amount of distillate obtained from the still on 09.05.2003 is 3615 ml/m2.

Prof. Alpesh Mehta, Arjun Vyas, Nitin Bodar and Dharmesh Lathiya has presented the paper and observed the performance of a solar still and given his observations about the production rate performance and showed that the PRP was Maximum between 11:30 to 1:30 in the noon.

T. Arunkumar, K. Vinothkumar , Amimul Ahsan , R. Jayaprakash , and Sanjay Kumar (2012) has presented the research article about the fabrication of seven solar still designs and their performance evaluation of converting brackish water into fresh potable water.

He concluded that the still having largest surface area for solar radiation incident and condensation of water vapour has maximum yield

Kanika mathur, mathewlal Thomas, Parth lineswala, Siddharth nayar (2015) has presented a paper and given analysis of solar still with and without solar still reflector and they showed that amount of incident solar energy is increased by an amount equal to 28% and the volumetric efficiency increases about 3.33%.

Volume of water poured (liters)	10	15	20
Volume of water obtained without reflector (liters)	3.3	3.5	3.2
Volume of water obtained with the reflector (liters)	3.7	4	3.5

CONCLUSION

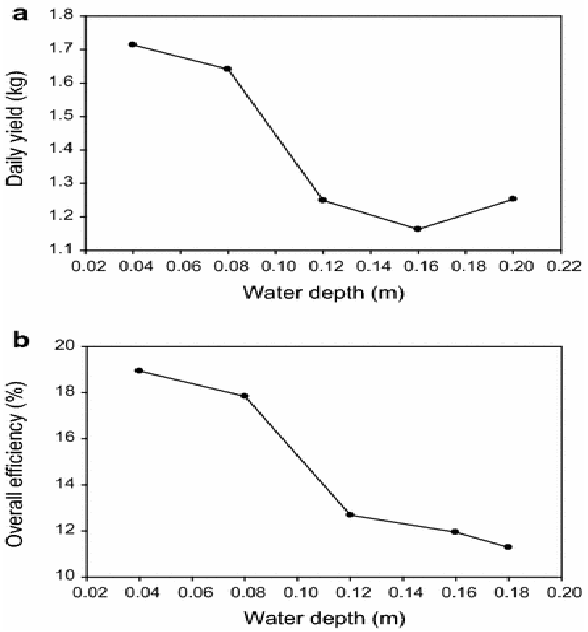
Water desalination is the need of an hour. Demand for pure water where pure refers to drinkable is constantly increasing and it has to be fulfilled anyhow. But the resources available of water are limited. And much of the water available is either saline, contaminated or containing salts and other dissolved toxic elements. To fulfill the world's demand of fresh water the available water needs to be purified. The water can be purified by any of the method such as RO, MEMBRANE PROCESS, SOLAR STILL DESALINAION, ETC. in all the above methods solar desalination using solar still is a cheaper, simple, convenient, way which uses the renewable energy of the sun.

Various designs of solar stills have been made over the years and the fresh water need is being fulfilled to some extent but to make it affordable worldwide its performance needs to be increased. On reviewing the various papers to increase the still performance following conclusions are made.

1. The spherical shaped solar still have showed maximum yield in all conditions because of large surface area.

2. The performance of the still in terms of distilled water output is Maximum between 11:30 to 1:30 in the noon.

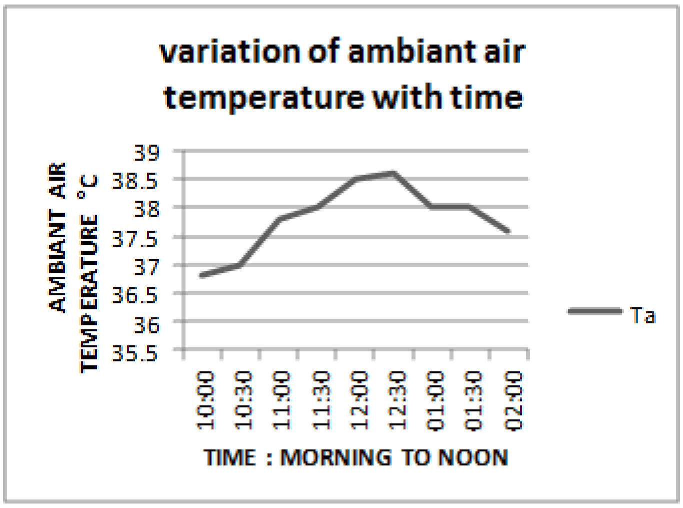
3. Lower water depth in the basin gives more yearly distillate output of water [12]. The reason is less energy of evaporation is required. An increase in the water depth from 12.7 cm to 30 cm reduces the output by 30% [13].



The productivity of the solar still is increased near about 10% to 15% due to the use of heat storage material [16].

5. For best distillate output the frontal height of 50 to 70 mm is suited.

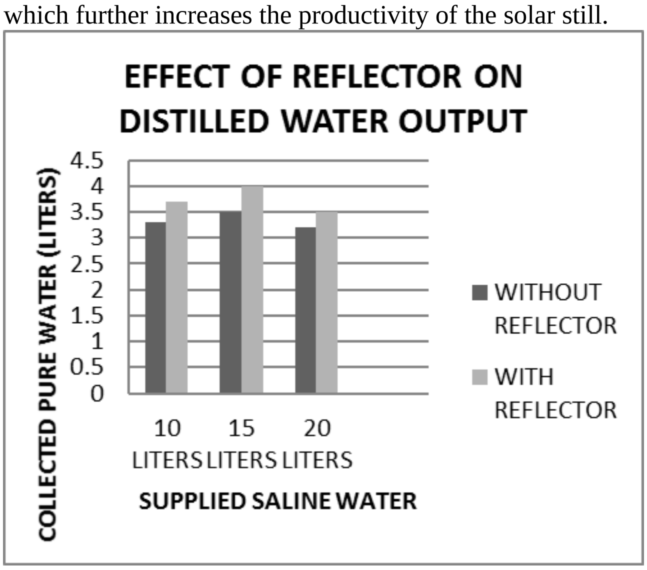
6. More the ambient air temperature will more be the productivity of the solar still desalination. A slight increase of 3% in the solar still productivity was gained by the increase in the ambient air temperature by 5 °c [17]



The graph above shows that ambient air temperature is Maximum between 11:30 to 12:30 at which the distilled output is Maximum.

7. Reducing the gap distance between the evaporating surface and the condensing cover improves the still performance. The effect of the gap distance is much important than the effect of the cover slope. Reducing the gap distance from 13.0 cm to 8 cm for the same cover slope increases the output by 11%. [13]

8. Reflector increases the rate of incident of solar radiation, which further increases the productivity of the solar still.



9. For the basin the material used must have low thermal conductivity, low density and high absorptivity. From our analysis among the three mild steel is best suited for the basin material.

10. For the side wall the wood and thermocol are equally good their use depend upon the weight of structure and still capability.

References

[1] Prem Shankar and Shiv Kumar, ―Solar Distillation - A Parametric Review‖ VSRD-MAP, Vol. 2 (1), 2012, 17

[2] K. Sampathkumar, T.V. Arjunan, P. Pitchandi, P. Senthilkumar ―Active solar distillation―A detailed review‖, Renewable and Sustainable Energy Reviews 14 (2010) 1503-1526.

[3] D. Jamieson, Experimental Methods for the Determination of the Properties of Saline Water, Measurements and Control in Water Desalination, edited by N. Lior(Elsevier, Netherlands, 1986) p:219-240

[4] Solar Radiation Resource Information - http://rredc.nrel.gov/solar/

[5] Solar Radiation for Energy - http://www.eren.doe.gov/consumerinfo/refbriefs/

[6] M.A.S. Malik, G.N Tiwari, A. Kumar and M.S. Sodha. “Solar Distillation”, Pergamon Press, Oxford, UK,1982.

[7] A. Kumar, A. Kumar, G.D. Sootha and P.Chaturvadi,” Performance of a multi-stage distillation system using a flat-plate collector”, Extended Abstract, ISES Solar World Congress, Kobe, Japan, 1989.

[8] Akash BA, Mohsen MS, Osta O and Elayan Y ,”Experimental evaluation of a single-basin solar still using different absorbing materials”,renewable energy- 14, 1998,307-310

[9] S.Kalogirou, “Use of parabolic trough solar energy collectors for sea-water desalination,” Applied Energy, vol. 60, no. 2, pp. 65-88, 1998.

[10] Al-Hayeka and O.Badran, “The effect of using different designs of solar stills on water distillation,” Desalination, vol. Various designs 169, no. 2, pp. 121-127, 2004.

[11] Tripathi R, Tiwari GN. Effect of water depth on internal heat and mass transfer for active solar distillation. Desalination 2005; 173:187-200.

[12] G.N Tiwari. “Solar Energy; Fundamentals, Design, Modelling and Applications” Narosa Publishing House 2008, p 278.

[13] A. Ghoneyem, Experimental Study on the Effects of the Cover and Numerical Prediction of a Solar Still Output,î M.S. Thesis, METU, Ankara, (1995).

[14] www.engineeringtoolbox.com

[15] Wikipedia

[16] A.A. EI-Sebaii, S.J. Yaghmour, F.S. AL-Hazmi, Adel S Faidah, F.M. AI-Marzoki, AA AI-GHAMDI ,SENSIBLE STORAGE MEDIUM, (2009)

[17] A.S. Nafey, M.Abdelkader A.Abdelmotalip and A.A. Mabrouk (2000).