13th International Conference on Recent Innovations in Science, Engineering and Management
NANASAHEB MAHADIK COLLEGE OF ENGINEERING ICRISEM 18
Peth Naka, Tal: Walwa, Dist: Sangli
23rd February 2018 www.conferenceworld.in ISBN : 978-93-87793-02-6

A Review Paper on – How to Increase Efficiency and Productivity of Solar Distillation

Sumit S. Naygaonkar[1], Omkar A. Kadam[2], Mahesh A. Gadiwaddar[3], Samar R. Kadam[4], R. H. Yadav[5], Akash A. Lokhande[6]

[1,2,3,4]UG Student (Mechanical Department),[5,6] Professor

[1,2,3,4,5]Dr. J. J. Magdum College of Engineering, Jaysingpur, Shivaji University, Kolhapur(India)
[6]Sharad Institute of Technology Polytechnic, Yadrav – Ichalkaranji, Kolhapur(India)

ABSTRACT

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 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. Our main goal is to efficiently produce clean drinkable water from solar energy conversion. 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". Double slope single basin solar still using phase changing materials like (Paraffin wax) and Sensible heat storing elements like (black pebbles) with reflector plate which can increase the productivity of clean drinkable water.

Keywords: K-Type Thermocouple, Phase Changing Materials (Paraffine Wax), Reflector, Sensible Heat Storing Elements (Black Pebble), Solar Still.

I. INTRODUCATION

Undoubtedly, water is one of the essential resources on entire earth. No creature including human beings, animals, plants or insects can live without water. Water is one of the precious gift by the nature of mankind and we must save it for future generation.

Water covers 71% of earth's surface. On earth, 96.5% of water is found in sea and ocean, 1.7% in ground water, only 2.5% of water is fresh water. The increasing developments in technologies and population have resulted in a large demand of fresh water. Now a days, clean and fresh water are not easily available. Clean and fresh water is using for domestic purpose. Without clean and fresh water we can't survive.

Particularly, clean water is not available easily in arid, semiarid region and also in remote areas. The transportation of clean water in remote areas is expensive. So, necessity of this region to purify water easily with low cost. We know, various processes of purification water such as reverse osmosis, multi-effect distillation, nano filtration, membrane distillation. But these methods are economically very expensive. When we use solar energy for purifying water then it will be less expensive. Because of on earth solar energy is available abundantly.

In remote areas abundantly solar energy as well as water is available. But sea water is not useful for drinking purpose because of sorts of contaminants. Desalination In which sea or brackish water is convert into pure form of water by removing all sorts of contaminants. Solar still is the system of converting sea or brackish water into pure form of water by removing all sorts of contaminants. This 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.

1. BASIC CONCEPT OF SOLAR WATER DISTILLATION

The basic principles of solar water distillation are simple yet effective, as distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater. The Sol Aqua still is a passive solar distiller that only needs sunshine to operate. There are no moving parts to wear out. The distilled water from a Sol Aqua still does not acquire the "flat" taste of commercially distilled water since the water is not boiled (which lowers pH). Solar stills use natural evaporation and condensation, which is the rainwater process. This allows for natural Ph buffering that produces excellent taste as compared to steam distillation. Solar stills can easily provide enough water for family drinking and cooking needs.

Solar distillers can be used to effectively remove many impurities ranging from salts to microorganisms and are even used to make drinking water from seawater. Sol Aqua stills have been well received by many users, both rural and urban, from around the globe. Sol Aqua solar distillers can be successfully used anywhere the sun shines.

The Sol Aqua solar stills are simple and have no moving parts. They are made of quality materials designed to stand-up to the harsh conditions produced by water and sunlight. Operationis simple: water should be added (either manually or automatically) once a day through the still's supply fill port. Excess water will drain out of the overflow port and this will keep salts from building up in the basin. Purified drinking water is collected from the output collection port.

2. PRINCIPLE OF SOLAR STILL

Solar still works on the principle of solar distillation. A solar still duplicates the way as rainwater i.e. evaporation and condensation. Saline water is filled in the black painted basin of the solar still. This is enclosed in a completely air tight surface. A sloping transparent cover is provided at the top. Then solar radiations are allowed to fall on it. Solar radiation is transmitted through the cover and is absorbed in the black lining. The distillat or is designed so that an efficient amount of solar radiations get trapped inside it. This increases the internal temperature of distillator causing the saline water to evaporate leaving behind all the salt contents, insecticides, herbicides, bacteria, viruses etc.

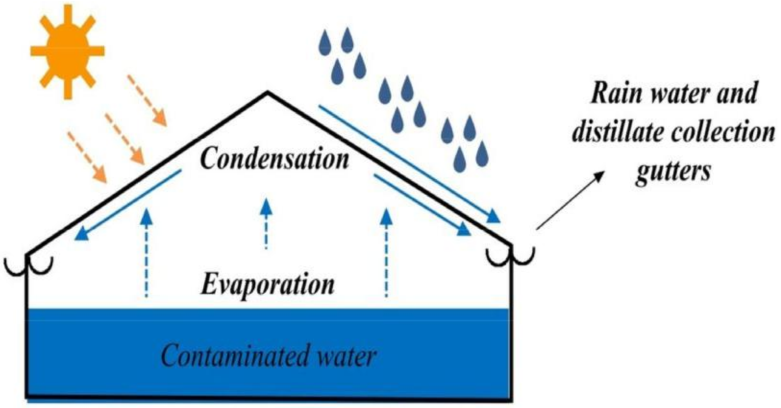

Fig. 1. Basic principle of solar still

The resulting vapour rises and condenses as pure water on the underside of the cover and is collected in the condensate channel due to the inclination provided to the glass covers. Finally fresh water is obtained.

- Solar still works on the principle of evaporation and condensation.
- Solar radiation falls on the solar still. These radiations are trapped inside the solar still.
- This evaporates the water leaving behind all the salt contents and other impurities.
- Resulting vapour rises and condenses on the glass cover and is collected in the condensate channel.

3. WORKING ON SOLAR STILL

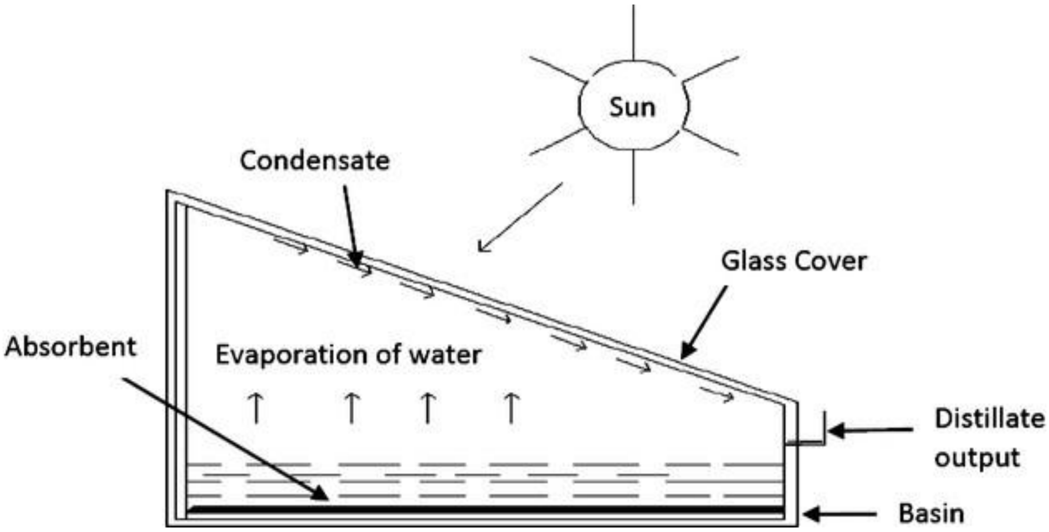

Fig. 2. Single slope single basin solar still

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.

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.

4. MODE 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.

Heat is defined in physics as the transfer of thermal energy across a well-defined boundary around a thermodynamic system. The thermodynamic free energy is the amount of work that a thermodynamic system can perform. Enthalpy is a thermodynamic potential, designated by the letter "H" that is the sum of the internal energy of the system (U) plus the product of pressure (P) and volume (V). Joule is a unit to quantify energy, work, or the amount of heat. Heat transfer is a process function (or path function), as opposed to functions of state; therefore, the amount of heat transferred in a thermodynamic process that changes the state of a system depends on how that process occurs, not only the net difference between the initial and final states of the process.

In engineering contexts, the term heat is taken as synonymous to thermal energy. This usage has its origin in the historical interpretation of heat as a fluid (caloric) that can be transferred by various causes, and that is also common in the language of laymen and everyday life.

The fundamental modes of heat transfer are:-

1-CONDUCTION

2-CONVECTION

3-RADIATION

CONDUCTION: The transfer of energy between objects that are in physical contact. Thermal conductivity is the property of a material to conduct heat and evaluated primarily in terms of Fourier's Law for heat conduction.

CONVECTION: The transfer of energy between an object and its environment, due to fluid motion. The average temperature is a reference for evaluating properties related to convective heat transfer.

RADIATION: The transfer of energy from the movement of charged particles within atoms is converted to electromagnetic radiation.

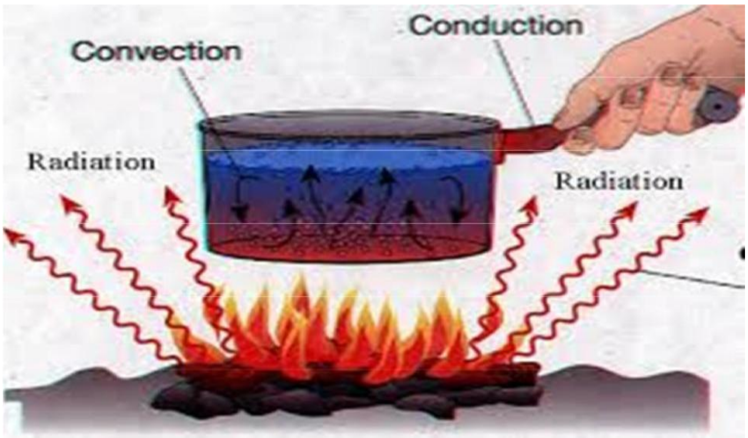

Fig. 3. Modes of heat transfe

II. METHODS OF IMPROVING EFFICIENCY AND PRODUCTIVITY

A.A. El Sebaiiet al.[1] The basin area of the still is 1 m^2 fabricated from a black painted galvanized iron sheet of thickness 0.2 cm leaving a gap under the horizontal portion of the basin liner. This gap can be loaded and/or unloaded with the PCM via a PVC pipe that will take care of the volume expansion of the PCM upon melting. Commercial grade stearic acid has been used as a latent heat storage material because of its low cost and large availability. This paper summarizes the thermo physical properties of commercial grade stearic acid. The bottom and sides of the basin are insulated by 3 cm layer of sawdust contained in a wooden frame of 1 cm thickness. The cover of the still is made up of 0.3 cm thick simple window glass, making an angle of 22.76with horizontal that equals to the latitude of Jeddah (22.76N). The fresh water is collected in an aluminum channel fixed at the lower end of the glass cover.

Yaghmouret al.[2] conducted the experiment based on solar still using sensible storage elements. The basin area is 1m^2 fabricated from the black painted galvanized iron sheet of thickness 2mm leaving the gap under the horizontal portion of the basin liner. Sand has been used as a sensible heat storage material cause of its low cost an abundance. The bottom and sides of the basin are filled with saw dust of 3cm layer. The cover of the still is made with thick soda glass making an angle of 21.76^o which equals latitude of Jeddah. The fresh water is collected in the Al channel fixed at the lower end of the glass cover.

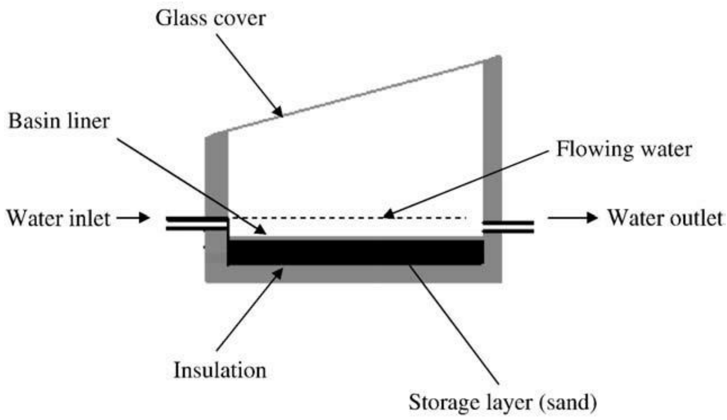

Fig. 4. A schematic diagram of the active single basin solar still (ASS) with the sensible storage material[2]

Murugavel, et al.[3] has conducted the experiment based on In this still the basin area is 1.75m^2 is fabricated and tested under laboratory conditions for a thin layer of water in the basin. For maintain the thin layer of water basin it is necessary to spread the water throughout the basin by some kind of porous materials. In this work performance of still is compared by wick materials like light cotton cloth and sponge sheet of 2mm thickness and porous materials like washed natural rock of avg. size 3/8 inch* ¼ inch quartz rock of some size. The actual solar radiation condition is simulated by 2kw electrical resistance heater placed below the basin liner.

Results show that still with the black light cotton cloth as a spread material is found to be more productive. At higher water and basin temperature the production increases with difference between water and the glass temperature.

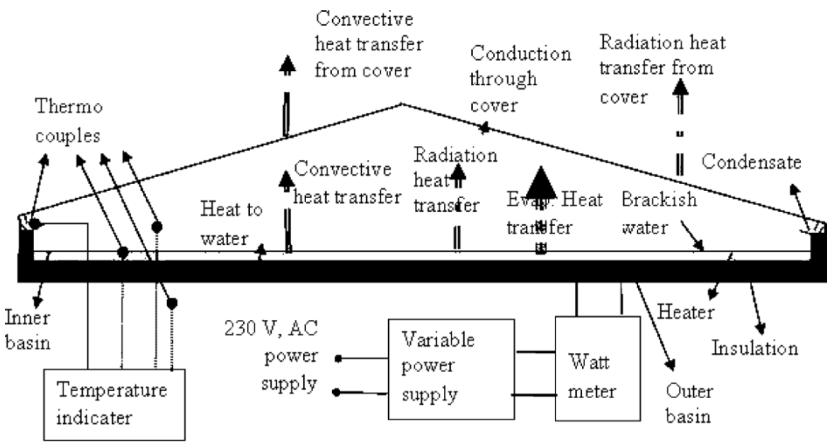

Fig. 5. Single basin double slope simulation still [3].

Selvakumaret al.[4] The thermal performance of a “V” type solar still with a charcoal absorber is analyzed and distilled water collection output is estimated. The internal heat transfer and external heat transfer modes are studied. The efficiency of the still is estimated under four ways. The overall efficiency of the still is 24.47% without charcoal, 30.05% with charcoal, 11.92% with boosting mirror and 14.11% with boosting mirror and charcoal. The performance ratio of the still, variation of the Nusselt number (Nu) and the Grashof number (Gr) are presented. The experimental properties of the still are also estimated. The experimental data for the four studies under similar climatic conditions are compared. The main advantage of the “V” type solar still is due to centre collection and all the condensation are easily directed to the outlet. So the distilled yield is collected without any hindrance.

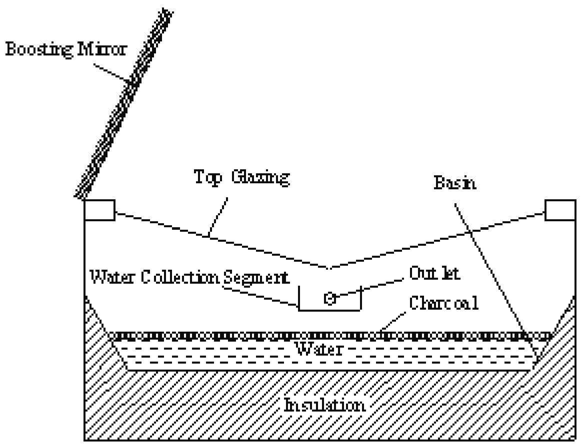

Fig. 6. “V” type solar still using a charcoal absorber and a boosting mirror[4].

Patilet al.[5] The distillation is one of the important methods of getting pure water from brackish water using solar energy. An experimental work is conducted on a double slope single basin solar still using Phase changing materials like (paraffin wax) and Sensible heat storage elements like (black pebbles) in Vishwanathrao Deshpande Rural Institute of Technology, Haliyal, Karnataka, India. A double slope single basin solar still with area of 0.7m2 was fabricated with Aluminium sheet metal and experiment is carried out in open environment conditions. An Aluminium tray of 0.40m2 is placed inside the still giving 10cm gap. Insulation is given in between the gap and the material used is thermocol. Two glass covers of 4mm thick with 0.35m2 area is placed on the top of the still given an inclination of 150 based on latitude of Haliyal. A performance analysis is done by conducting three experiments (black coated aluminium tray, with PCM, with SHSE) in the month of April and Analysis is carried out by using Pyranometer and K-type thermocouple. By conducting experiments like black coated aluminium tray, with PCM, and with SHSE, the output obtained is observed to be 1100ml of distilled water when PCM (Paraffin wax) is used, 954ml when SHSE (Black Pebbles) is used and 795ml when black coated tray is used and black coated tray readings were kept as standard readings and remaining set of readings (with PCM and SHSE) were compared with standard readings and analysis is done by showing set of graphs and tables. Thus the percentage productivity observed in case of Paraffin wax and black coated tray is 30%, black pebbles and black coated tray is 18%, Paraffin wax and black pebbles is 13%.

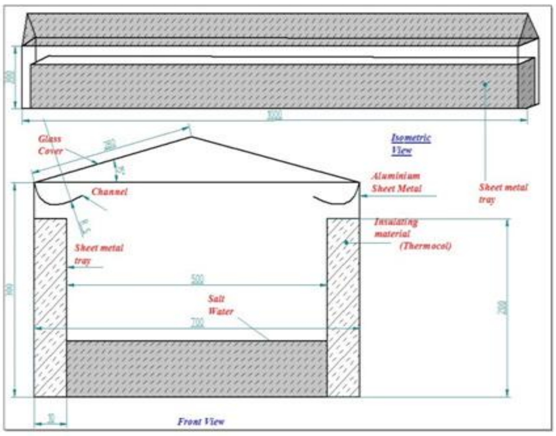

Fig. 7.Solar still using phase changing materials and sensible heat elements[5].

Elswifyet.al.[6] A solar still of double exposure is theoretically analyzed and experimentally tested. It is compared experimentally with other identical stills without modification (ordinary L-type) during a complete year. The concept of planer reflectors is introduced in this modification. It is found theoretically that the double exposure still gained much more daily energy than that of the ordinary one in winter and summer.

Experimentally, it is found that the double exposure solar still has 82.6% more daily yield than that of the ordinary one in winter time, and about 22% in summer time.

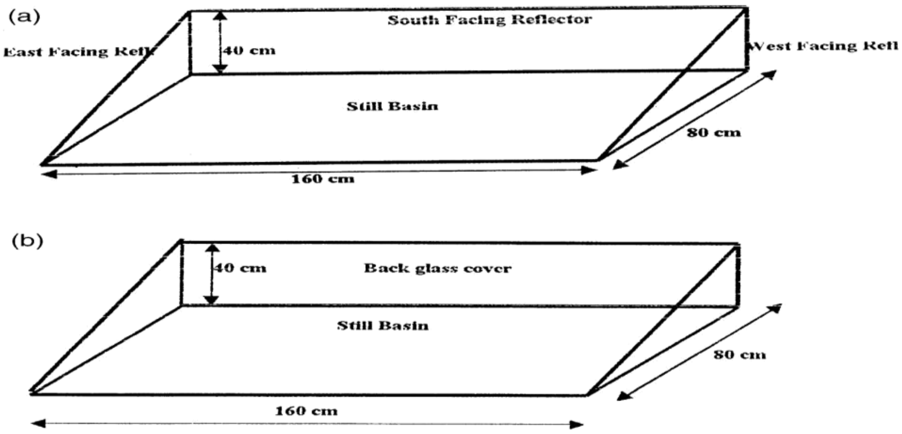

Fig. 8. (a) The double exposure solar still. (b) The ordinary L-type solar still[6].

Elsebaiiet.al.[7] In an attempt to decrease the preheating time of the basin water of basin type solar stills, a single slope single basin solar still with baffle suspended absorber (SBSSBA) was designed and fabricated using locally available materials. A transient mathematical model is presented for the still. The model uses the lumped system of analysis in which the system is divided into several elements, each of which was treated as a lumped system by itself. The energy balance equations for various parts of the still are solved analytically using the method of Gauss elimination. In order to validate the theoretical model, theoretical and experimental results are compared, and good agreement has been achieved. The effects of vent area and water depth of the upper and lower water columns on the daily productivity of the still were studied. Comparisons of the performance of the SBSSBA and the conventional unit, the single slope single basin solar still (SBSS), have been carried out. It is found that the daily productivity of the SBSSBA is about 20% higher than that of the conventional still (SBSS).

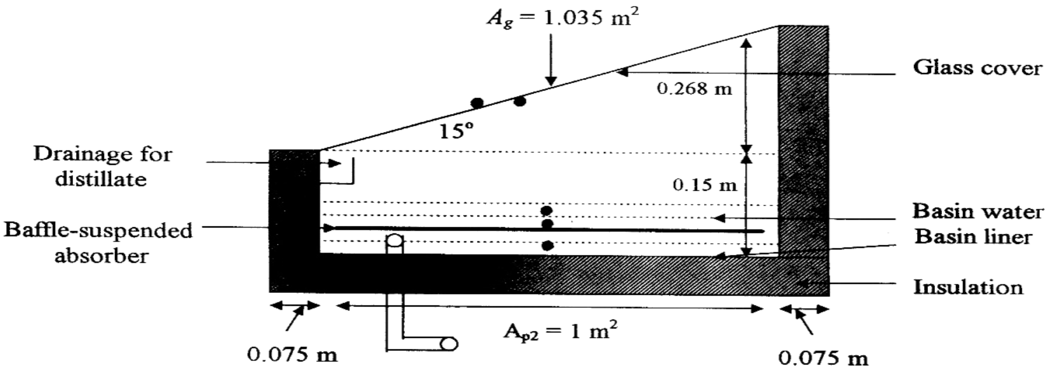

Fig. 9. A schematic diagram of the constructed SBSSBA; (.) Đ thermocouple position [7].

Tanaka et.al.[8] This paper presents a numerical analysis to investigate the effect of the vertical flat plate external reflector on the distillate productivity of the tilted wick solar still. We propose a geometrical method to calculate the solar radiation reflected by the external reflector and absorbed on the evaporating wick, and also performed numerical analysis of heat and mass transfer in the still to predict the distillate productivity on four days (spring and autumn equinox and summer and winter solstice days) at 30EN latitude. We found that the external reflector can increase the distillate productivity in all but the summer seasons, and the increase in the daily amount of distillate averaged over the four days is predicted to be about 9%.

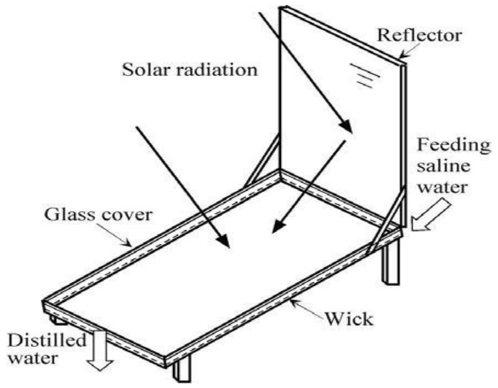

Fig. 10. Schematic diagram of tilted wick still with vertical flat plate external reflector [8].

III. PROPOSED EXPERIMENTAL SETUP

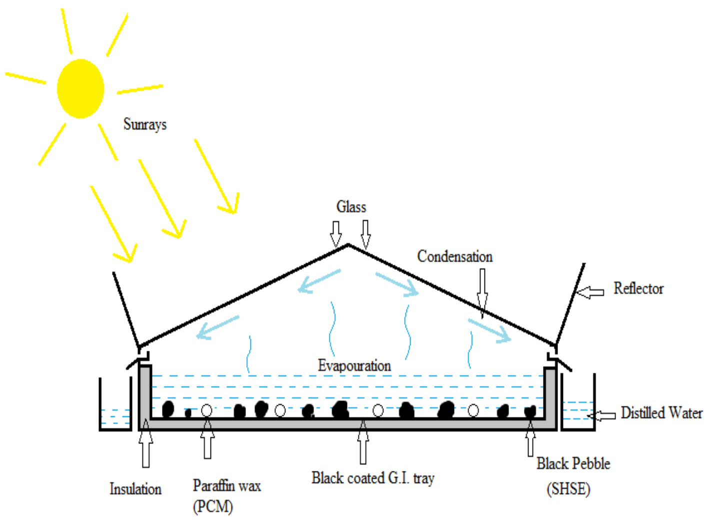

Fig. 11. Double slope single basin solar still using phase changing material (Paraffin wax), sensible heat storing element (black pebble) and reflector plate

Proposed setup of solar still is shown in fig. 11. A solar still, which has a basin made up of GI sheet metal of 0.54 m^2 area, having a length of 90 cm and 60 cm width with 30 cm height. Inside this basin another basin called try is placed with a distance of 10cm leaving a gap from bottom and sides and in between this gap an insulation material (glass wool) is placed to prevent loss of heat. At the top of the basin a transparent glass is placed at an inclination of 22º which is having a thickness of 3.5mm and the still is made airtight by gum tape. Condensate channel is provided inside the solar still chamber to collect the condensed water and this condensate channel is connected to the distillate collector to collect the distilled water. To measure the solar radiation an instrument called Pyranometer is used which is placed near to the solar still and hourly readings are taken and to measure temperature at different points in the still such as temperature of Water, basin, Insulation and Glass by using K-type Thermocouple.

Main components of solar still are:

- 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 absorptivity or very less reflectivity and very less transmitivity. These are the criteria for selecting the basin materials.
- 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.
- 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.
- TRANSPARENT COVER: Glazing glass is used and thickness of 3.5 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.
- INSULATION: Glass wool is used as insulator to provide thermal resistance to the heat transfer that takes place from the system to the surrounding.
- SEALANT: M seal and putty is used as sealant to make the distiller leak proof and air tight. UV Glue is used to join Metal to Glass. Silicon Glue is used to join Glass to Glass.
- SUPPLY AND DELIVERY SYSTEM: Three holes are made in the basin, one for supply and two for delivery.
- REFLECTOR: Reflecting sheet is used with one side silver coated and is supported by linkage to prevent its breakage.
- TEMPERATURE SENSOR: LM35 Temp Sensor along with its complimentary components is used. LCD reflecting temperature in °C.

The side and bottom walls need to be insulated. This can be achieved by using multi-layered insulator. Glasswool will be sand-witched between two metallic plates. This will ensure negligible heat loss to the surroundings. The main frame is composed of G.I. owing to its corrosion resistance, low weight, long life and easy cleanability. The inside of the complete distiller is coated with carbon black to increase absorption of radiation. The cover on the top is made of tempered glass so that the birds can't see their reflection and hence avoid nuisance.

By using PCM and SHSE we can improved evaporation rate during evening and cloudy climate. The storing solar thermal energy with a combination of SHSE and PCM and utilizing this energy to heat and evaporate the water during the day and beyond in solar still and this project involves the use of PCM and SHSE for thermal storage energy. Initially, the solid–liquid PCMs behave like sensible heat storage (SHS) materials; their temperature rises as they absorb heat. Unlike conventional SHS, however, when PCMs reach the temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature. The PCM continues to absorb heat without a significant rise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. A large number of PCMs are available in any required temperature range from−5 up to 190C within the human comfort range of 20° to 30°C,some PCMs are very effective.

Fig. 12. Paraffine wax[5]

Fig. 13. Black pebble[6]

In this project a solar still (single basin double slope), has been designed which in which PCM and SHSE material as storage medium for reducing the heat loss and increasing the temperature difference between the condenser and evaporator throughout the day and hence produces better productivity. For the purpose of

 ISBN : 978-93-87793-02-6

experimentation a conventional solar still has been fitted with tray containing paraffin wax as PCM and black pebbles as SHSE.

IV. CONCLUSION

1. Use of double slope glass cover can increase the efficiency and productivity of solar still.
2. The efficiency and productivity of solar still can increase by "V" type solar still using a charcoal absorber and boosting mirror.
3. The efficiency and productivity of solar still can be increase by use of tilted wick still with vertical flat plate external reflector.
4. By use of PCM like paraffine wax the efficiency and productivity of solar still will increase.
5. By use of sensible heat storing element like black pebble the efficiency and productivity of solar still will increase.
6. The efficiency and productivity of solar still increase with use of absorber carbon black coating.
7. The efficiency and productivity of solar still increase with use of reflector plate.

REFERENCE

[1] A.A.El-Sebaii, A.A.Al-Ghamdi, F.S. Al-Hazmi, Adel S. Faidah, "Thermal performance of a single basin solar still with PCM as a storage medium", Applied Energy 86 (2009) 1187–1195.

[2] A.A.El-Sebaii, S.J.Yaghmour, F.S.Al-Hazmi, Adel S.Faidah, F.M.Al-Marzouki, A.A. Al-Ghamdi, "Active single basin solar still with a sensible storage medium", Desalination 249 (2009) 699–706.

[3] K. KalidasaMurugavel, Kn.K.S.K.Chockalingam, K. Srithar, "An experimental study on single basin double slope simulation solar still with thin layer of water in the basin", Desalination 220 (2008) 687–693.

[4] B.SelvaKumar, SanjayKumar,R. Jayaprakash, "Performance analysis of a "V" type solar still using a charcoalabsorber and a boosting mirror", Desalination 229 (2008) 217–230.

[5] Bharat Kumar Patil, Sanjay Dambal, "Design and Experimental Performance Analysis of Solar Still Using Phase Changing Materials and Sensible Heat Elements", IJRMET Vol. 6, Issue 2, May - Oct 2016.

[6] M.E. El-Swify, M.Z.Metias, "Performance of double exposure solar still", Renewable Energy 26 (2002) 531–547.

[7] A.A. El-Sebaii, S.Aboul-Enein, E. El-Bialy, "Single basin solar still with baffle suspended absorber", Energy Conversion & Management 41 (2000) 661-675.

[8] Hiroshi Tanaka, Yasuhito Nakatake, "Improvement of the tilted wick solar still by using a flat plate reflector", Desalination 216 (2007) 139–146.