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Research Article

Performance Enhancement of Solar Still using Energy Storage Material

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Abstract

Desalination of seawater and brackish water is an issue of concern of many researchers in today's scenario. Solar energy is realizable, simple, profitable choice for water distillation. The present experimental study shows the effect of different operating parameters (water depth, solar radiation, energy storage materials) on a single slope plane solar still. An improvement of distillate output of solar still has been recorded using energy storage material. A comparison between the modified still and conventional still was carried out under the same climate conditions with 5 cm depth of water. The effect of sensible heat storage material have been investigated. The average distilled water production achieved was 2065 ml/m²/day.

Keywords: *Desalination, Solar energy, Distillate, Single slope solar still, Sensible energy storage material.*

1. Introduction

Fresh water availability is a challenging job for societies in all developed or developing parts of the world. Water is fundamentals need for living organisms on the earth and People have to depend on river, lake, pond, sea and underground water. Scarcity of fresh water is the major problem due to increasing population and industrialization, the sewage polluted the water of lake, river and sea. Survey shows that about 78% of water presented on earth is salty only one percent is fresh and rest 20% is saline water. And only 0.36% of 2.53% fresh water is directly available for mankind. Thermal technologies such as Multi Stage Flash (MSF), Multi Effect Distillation (MED), and Reverse Osmosis (RO) are commercially applied at large scale in cities having high efficiencies based on electrical power consumption. But these technologies are not suitable for isolated villages, waterless area and small islands, to fulfill this requirement using solar energy for purification of brackish water is a blessing for civilizations because of its simple technology, non-requirement of highly skilled labor and low energy consumptions. Till today, many experimental and theoretical studies are commenced to modify the solar still using different configurations and to improve its yield, (L. Cherrared,1999) in his work did a systematic comparison between a simple solar and solar water-heater still and conclude that water temperature has significant influence on still efficiency and daily production of the solar still. (Bilal A. Akash,*et al*, 2000) experimentally instigates the efficiency of a solar still at different inclination angles of the cover 15°, 25°, 35°,45° et 55°. They found that highest yield output is obtained with an inclination angle of 35°. (Sahota and Tiwari, 2016) used Al_2O_3 Nanoparticles in the basin of double slope solar still at different concentrations of 0.04 %, 0.08 % and 0.12 %. They concluded with Al_2O_3 Nanoparticles efficiency of 12.2 % and 8.4 % in the system. (Bhupendra Gupta, et *al*, 2016) also used nanoparticles in his work, they found significant output increment in the modified solar still. (Bhupendra Gupta,*et al,*2017) in his another work experimented with Al_2O_3 Nanoparticles in basin and water sprinkle on glass cover the increase in overall effectiveness was found to be 54.54%.(Shanmugan,*et al*, 2015)did an experimental analysis of a double Slope-Tri basin solar still.

They found that with Nanofluids the performance of first, second and third basin is enhanced by 35.71%, 35.7% and 28.5%. (Panchal and Mohan, 2017) have discussed various methods applied to solar still fruitage, he concluded that fin, energy storing materials are positive modification for improvement in distillate yield. (Bhupendra Gupta, *et al*, 2013) in their review paper disussed the various factors affecting the efficiency of solar still. (Sellamia, *et al*, 2017) experimented with different thickness layers of 0.5 cm, 1.0 cm and 1.5 cm sponge absorber in solar still basin. And found yield increment 58%, 23.03% and 30%, respectively. (Arunkumar,*et al*, 2013) premeditated the effect of thermal storage material on the output of the concentrator-coupled hemispherical basin still. They concludes that, the distillate water production of the still with PCM was comparatively 26% higher than the still without PCM.(V. Velumurugan,*et al*, 2008)used

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wick and sponges in a single basin solar still, and found that the productivity increased up to 29.6% as compared to 15.3%. The productivity is increased when sponges are used in the same still, when fins were used, the augmentation observed was 45.5%. (Gowtham Mohan,*et al*, 2011) used paraffin wax as the absorbing material inside the solar still to increase the productivity of solar still, solar air heater was also connected in series so as to increase the heat inside the still. It was also found that different paraffin compounds can be used as the heat storage material. (J.S. Gawande, *et al*, 2013) in their experiment used different absorbing materials in a single basin solar still of area 0.6 m2 with. Black color was painted in the basin surface with to increase the absorptivity of the solar still. Ink and black dye were used as absorbing material. The results showed that the best results were obtained when the dye was used as compared to lesser production with ink solution. (S. Shanmugam,*et al*, 2013) carried out an experiment with concrete stones as an absorbing material inside the solar still. It has found that, the fresh water output 8.40 liter / day. The arrangement of feeding saline water dripped drop by drop in the basin has been done. The water as the feed was fed inside the still of. It was observed that, with concrete stone maximum output found as compared with the pebble and granite stones it was also determined that the maximum temperature rise is obtained by the concrete stones when compared to other materials under similar conditions. (Hitesh N Panchal,*et al*, 2011) in their experimental observation used cow dung cakes to increase heat absorption rate inside the solar still. A comparative study was done with the same still with different absorber plate made of steel. Result shows that that the distillate productivity of the still with cow dung cakes as absorber was 25% more than the solar still with steel plate absorber. (A. S. Solanki,*et al*, 2014) used black ink as an enhancer to the heat absorbing element in a single slope solar still, hemispherical shaped solar still is used for this experiment. They found significant increment in the productivity and efficiency. The efficiency of the solar still increased by 20 % when 1.25 % ink was added to the water. Devashish Tiwari, *et al*, 2016) carried out an experiment in which the aluminum turning was used as an absorbing material. Increased productivity was found not only in the day but also during the night hours. The result showed 35% increment in productivity in the day time when aluminum turning was used. (Bhupendra Gupta, *et al*, 2016) modified a single slope solar still by painting the inner side walls with white color and compared it with conventional solar still. Also constant water flow rate sprinkler isattached on the glass cover they found 21% overall efficiency improvement over the conventional solar still.

This paper presents an approach to enhance the productivity using concrete cement block as energy storage material to increase the net convective heat transfer coefficient which enhance the distillate output. The objective is to improve the economic aspect of the still so as to make it readily available at less cost and optimized effect.

2. Effect of heat storage materials

Output of Solar still can be increase by using heat storage material in basin or in construction wall of solar still. Heat storage material increases the absorptivity of solar heat and hence increase the yield in day time as well as in night. Heat storage material stores heat in day time and release back in night to saline water increasing overall performance of solar still. There are two types of Heat storage systems:

- Sensible Heat Storage System(SHSS)
- Latent Heat Storage System (Phase Change Materials. PCM)

In case of SHSS liquid or solid material is used to store the heat by increasing the temperature where as in LHSS a Phase Change Material (PCM) is used at constant temperature to store the excess heat. The ability of storing more thermal energy at almost constant temperature latent heat thermal energy storage LHTES technique has received noteworthy attention (M. Fatih Demirbas, (2006). But specially designed PCM still is needed and it increases the cost. So for low cost SHSS is better option. (El-Sebaii, *et al*, 2009) experimentally studied the effect of sand on solar still performance having he used 10 kg of Sand and found daily yield of 4.005 and 2.852 kg/m^2/day with and without sand respectively, having a daily efficiency of 37.8 % and 27 %. (Tabrizi,*et al*, 2010) did an experiment on solar still combined with sandy reservoir. Result shows the productivity was 3 kg/m^2, while productivity of conventional solar still was only 1.7 kg/m^2. (Murugavel,*et al*,2010) also examines the effect of various materials on solar still output using quartzite rock, washed stones, red brick pieces, cement concrete pieces and iron scraps as a heat storing material. He found that material quartzite rock was the most effective among all materials, with a productivity of 2.1 Kg/m2/day with increase of 6.2 % compared to conventional still.

3. Material and method

An actual photographs of experimental setup, Solar Still made of 1 mm thick galvanized iron sheet is shown into Figure 1. Two identical single slope single basin passive solar still were design and tested at climate condition of JEC Jabalpur, India. One still was a conventional still with base area and 1m^2 front height 22 cm and rear wall height is 64 cm .Thermocol sheets are attached outside to prevent heat losses from the solar still. Plywood having thickness of 10 mm is used at outer side in both solar still, A black matte paint was applied on all internal surface of still to absorb more solar radiation. Both stills were covered by 5 mm thick

transparent toughened glass lean approx. 23° with horizontal as 23° is the latitude of Jabalpur, India. 12 number of concrete cement blocks of 300 g each are placed inside the basin of modified still. A digital temperature indicator and k-type thermocouple was used for temperature measurement and display. Solar Power Meter used to measure Solar Radiation.

Transparent Beaker was also used to measure distilled output. Experiments were started from 8.00 AM to 6.00 PM at 5cm depth of water in the month of January. From the observation of Experimental days, all temperatures, Solar Radiation and yield output were measured at every one 1 hour.

Fig. 1 Actual photographs of experimental setup

4. Result and discussion

The performance analysis of two different Solar Stills, one having concrete cement blocks as a SHSM, other as a conventional Solar Still, have been carried out. Figure 2 and 3 shows the variation of different temperatures with hours, e.g. Inner Temperature of Glass Cover (T_{gi}), Outer Temperature of Glass Cover (T_{go}), (T_v) Vapour temperature, basin water temperature (T_w) and Ambient Temperature (T_a) at 5 cm depth of water. It is seen from the Figure that, Inner Temperature of Glass Cover, Outer Temperature of Glass Cover Vapour temperature and water Temperature gradually increases from 8 AM to 3 PM and after that it starts decreasing as direct solar radiation(I_g) falling on it decreases. Figure 4 shows the variation of ambient temperature with solar radiation. The solar radiation shows parabolic nature and reached its highest value 820 watt/m² at 1 pm. Maximum ambient temperature measured was 35˚C during the experiment. Figure 5 shows the Hourly variation (Hrs.) of Distilled output (ml). It is clear from the graph that Distilled output, becomes maximum at 5 PM. From Experiment it is confirmed that Solar Still with energy storage material gives 51% increment in day time distilled output and 25% overall increment as compared to conventional still. From figure 6 it is confirmed from experimental results that water temperatures were higher in modified still than conventional still and reached up to 59˚C. Figure 7 shows the hourly variation of vapour temperature for both still. The maximum vapour temperature reached up to 63˚C for modified still and 61˚C for conventional solar still. Fig. 10 shows the variation in distilled output. Accumulated freshwater yield is approximately up to 2065 ml/m² day for the solar still with concrete blocks while its value was 1645 ml/ m² day for the conventional solar still at water depth of 5 cm.

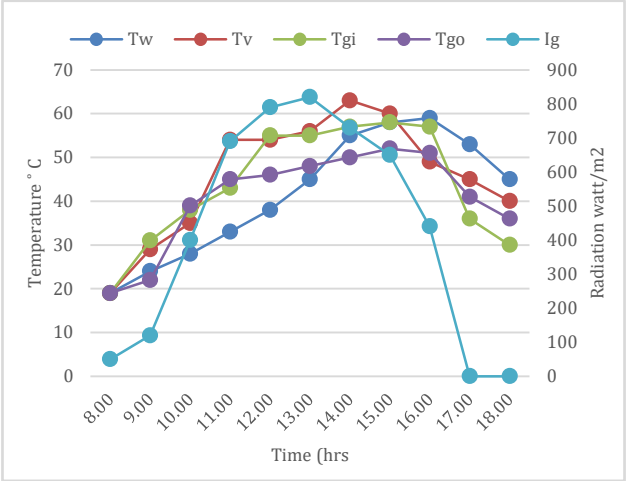

Fig.2 Variation of temperatures for modified still

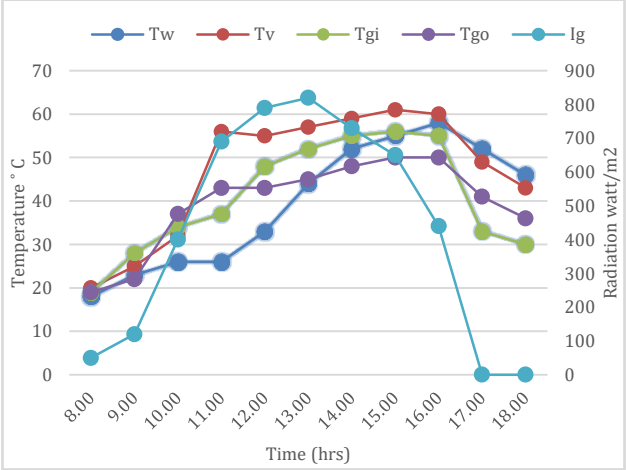

Fig.3 Variation of temperatures for conventional still

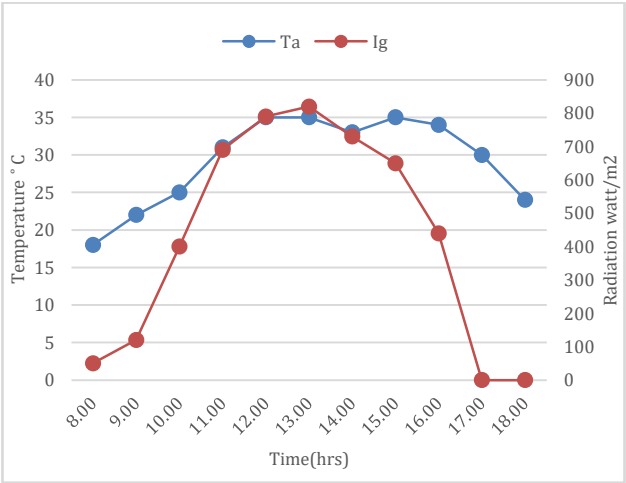

Fig.4 Ambient temperature with solar radiation

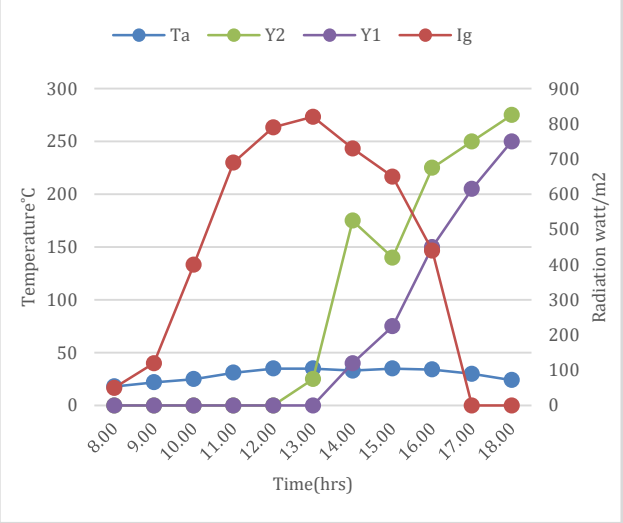

Fig. 5 Hourly variation of distillate for both still

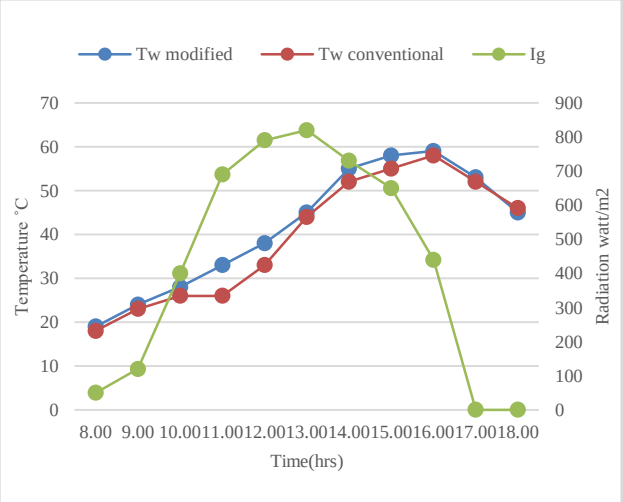

Fig. 6 Hourly variation of water temperature for both still

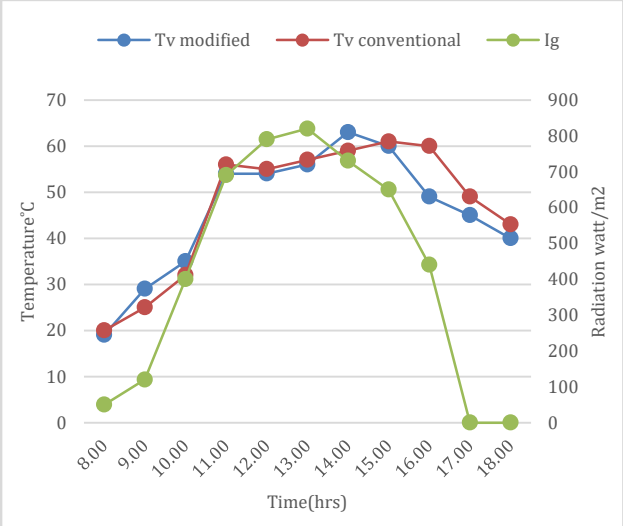

Fig.7 Hourly variation of vapour temperature for both still

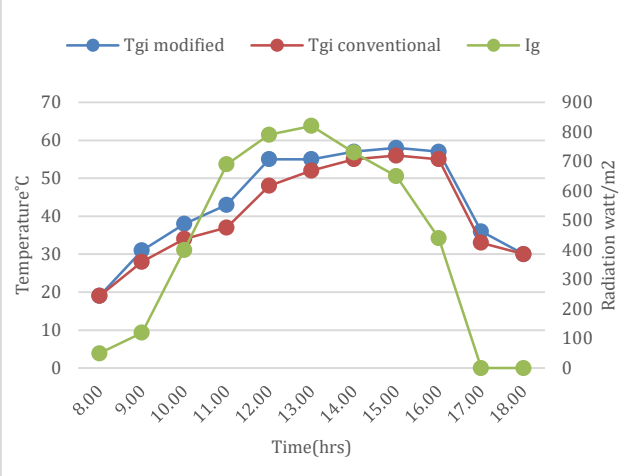

Fig.8 Hourly variation of inside glass temperature for both still

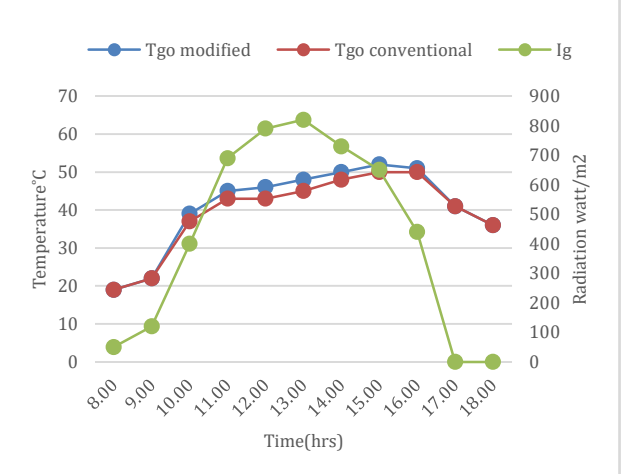

Fig.9 Hourly variation of outer glass temperature for both still

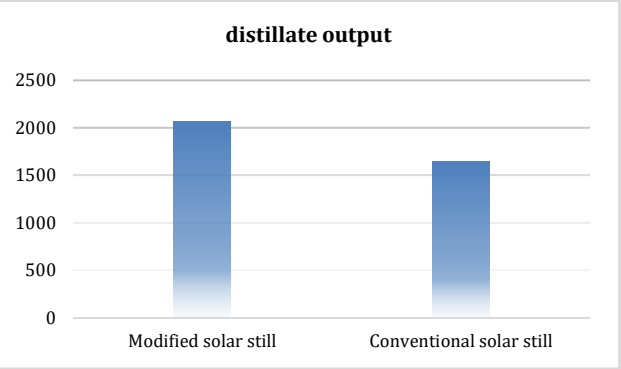

Fig.10 Variation in distilled output

Conclusions

Two identical Solar Stills were constructed, one having concrete cement blocks as SHSM, and other is reference still to evaluate the effect on the distilled output. The following conclusions made from this work:

1) As temperature difference between Basin liner and Inner Glass Surface increases distilled output is increases.
2) Daytime productivity of modified still is 51% higher than conventional still at while the overall yield increase by 25%. This implies that yield is always better in modified still with the concrete cement block.
3) Units with sensible heat storage materials give higher daytime productivity.

References

G.N Tiwari,Solar, 2008, Energy; Fundamentals, Design, Modelling and Applications, *Narosa Publishing House*, pp 278.

He ZN, 2009, Solar thermal utilization, China: *Press of University of Science and Technology of China,* p. 404, 48–52.

CherraredL Amélioration du Rendement d'un DistillateurSolaire à Effet de Serre. Energ. Ren. Valorisation; 1999, 121-124.

Bilal A. Akash, Mousa S. Mohsen, Waleed Nayfeh,2000, Experimental study of the basin type solar still under local climate conditions,*Energy Conversion & Management*,41, 883-890.

L. Sahota, G.N. Tiwari, 2016, Effect of Al2O3 Nanoparticles on the performance of passive slope solar still, *Sol. Energy*, 130, 260–272.

Bhupendra Gupta, Prem Shankara, Raghvendra Sharmaa, Prashant Baredar, 2016,Performance Enhancement using Nano Particles in Modified Passive Solar Still, *Procedia Technology* ,25 ,1209 – 1216

Bhupendra Gupta, Anil Kumar, Prashant V. Baredar, 2017, Experimental Investigation on Modified Solar Still Using Nanoparticles and Water Sprinkler Attachment,
https://doi.org/10.3389/fmats.2017.00023

S. Shanmugan, Kottai Raj, Sree Ragh Arunnarayanan, 2015, Design and performance analysis of an innovative V-shape double slope Tribasin solar nano still, *Int. J. Appl.Eng. Res*, 10 (83) 261–266.

Hitesh Panchal, Indra Mohan, 2017, Various methods applied to solar still for enhancement of distillate output, *Desalination*, 415 (1) 76–89.

B Gupta, TK Mandraha, PJ Edla, M Pandya, 2013, Thermal Modeling and Efficiency of Solar Water Distillation: A Review,*American Journal of Engineering Research*, 2, (12)203-213

M.H. Sellamia, T. Belkisa, M.L. Aliouara, S.D. Meddoura, H. Bouguettaiab, K. Loudiyic,2017, Improvement of solar still performance by covering absorber with blackened layers of sponge, *Groundwater Sustain.Dev,*5, 111–117.

T. Arunkumar, D. Denkenberger, A. Ahsan, R. Jayaprakash, 2013,The augmentation of distillate yield by using concentrator coupled solar still with phase change material, *Desalination,* 314, 189–192

V. Velmurugan, M. Gopalakrishnan, R. Raghu, K. Srithar, 2008, Single basin solar still with fin for enhancing productivity, *Energy Convers. Manag,* 49, 2602–2608.

G. Mohan, H.N. Soundararajan, 2011, Solar desalination with latent heat storage materials and solar collector, *Journal of Mechanics Engineering and Automation,* 1, 126–134.

J.S. Gawande, L.B. Bhuyar, 2013, Effect of shape of absorber surface on the performance of stepped type solar still, *Energy and Power Engineering, 5*, 489–497.

S. Shanumugam,2013, Experimental investigation of various energy absorbing materials on performance of single slope solar still with hot water provision, *IJIRSET*,2 ,7760–7769.

H.N. Panchal, M. Doshi, P. Chavda, R. Goswami, 2011,Effects of cow dung cakes inside basin on heat transfer coefficients and productivity of single basin single slop solar still, *Int. J. Appl. Eng. Res,*1, 675–690.

A.S. Solanki, U.R. Soni, P. Patel, 2014,Comparative study on hemispherical solar still with black ink added, *International Journal of Engineering Research and General Science*,2 ,315–324.

D. Tiwari, A.K. Rai, 2016, Effect of sensible, energy storage medium on the productivity of solar still, *Journal of Mechanical Engineering and Technology, 7*, 1–7.

Bhupendra Gupta, Raghvendra Sharma, PremShankara, Prashant Baredar, 2016, Performance enhancement of modified solar still using water sprinkler: An experimental approach, *Perspectives in Science*, 8, 191—194.

M. Fatih Demirbas, 2006, Thermal energy storage and phase change materials: an overview, *Energy Sources B*, 1, 85–95.

A.A. El-Sebaii, S.J. Yaghmour, F.S. Al-Hazmi, Adel S. Faidah, F.M. Al-Marzouki, A.A. Al-Ghamdi,2009, Active single basin solar still with a sensible storage medium. *Desalination*, 249, (2), 15, 699–706.

Tabrizi FF, Sharak AZ, 2010, Experimental study of an integrated basin solar still with a sandy heat reservoir. *Desalination*, 253,195–9.

Murugavel KK, Sivakumar S, Ahamed JR, Chockalingam KKSK, Srithar K,2010,Single basin double slope solar still with minimum basin depth and energy storing materials. *Applied Energy,* 87,514–23.