International Journal of Mechanical Engineering and Technology (IJMET)
Volume 10, Issue 2, February 2019, pp; 1331-1340 Article ID: IJMET_10_02_138
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=2
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

INVESTIGATIONAL STUDY ON FRESH WATER IMPROVEMENT IN CONVENTIONAL SOLAR STILL WITH PV SUBMERGED IN NANOFLUID

Madhu Balasubramanian
Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai
Department of Mechanical Engineering, Vel Tech Rangarajan

Balasubramanian Esakki
Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai
Department of Mechanical Engineering, Vel Tech Rangarajan

ABSTRACT

This work mainly aims on improving the yield of fresh water and power generation from the PV panel submerged in nano fluids kept inside the basin and compared with those of solar still with water as base fluid. The results of temperature profile indicated that the maximum temperature of 80°C is observed in the case of solar still with Al_2O_3 nano fluid while the basin type still with TiO_2 exhibited a temperature of 70°C before the noon. Similarly, the temperature of MgO is observed as 78°C during the lower solar intensity condition as it is observed in the case of Al_2O_3 nano fluid which exhibited the same behavior. There is an improvement in water temperature to about 2°C and 15°C for MgO and TiO_2 nano fluid. Results indicated that the fresh water produced from the base type still improved with the use of Al_2O_3 nano fluid followed by MgO nanofluid, water and TiO_2 nano fluid.

Keywords: Solar still; PV panel; Partially submerged; Yield; Power Production

Cite this Article; Madhu Balasubramanian, Balasubramanian Esakki And Dr. Sagunthala Investigational Study on Fresh Water Improvement in Conventional Solar Still with Pv Submerged in Nanofluid *International Journal of Mechanical Engineering and Technology* (IJMET) 10(2), pp;1331-1340
http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=2

1. INTRODUCTION

Demand on fresh water is rapidly increasing in the developing and developed countries as water is one of the most crucial for development of sustainable, economically balanced system and for human to survive. One of the best methods in providing fresh water is through desalination technique. Among the several methods developed in providing potable water, use of eco-friendly energy sources such as solar, wind and biomass energy sources plays a vital role. Distillation using solar energy and well among solar still is one of the economical methods in providing fresh water. Based on the types, solar still were divided into active and passive desalination system [1-48].

Abdelal and Taamneh [49] used carbon fiber/CNT-modified epoxy composites as absorber plate on a pyramidal solar still for enhancing the potable water produced. The composition of graphene in the epoxy composite is varied at 2.5 and 5%. Results of the study indicated that the carbon fiber/CNT modified epoxy composites enhanced the fresh water yield up to 65 and 109% for 2.5 and 5% CNT composition respectively. Also, use of nano graphene enhanced the potable water produced up to 30%.

Chaichan and Kazem [50] enhanced the production of potable water from conventional basin type still using nano enhanced phase change material at the bottom of basin. Their results showed that the nano enhanced PCM extended the potable water production during sunset and enhanced to about 61% than solar still without PCM. Also, the potable water production enhanced by 10% than solar still without PCM.

Kabeel et al. [51] analysed a solar still with absorber plate coated with black nano paint at different weight proportion and compared the economic analysis. From their results, it was found that concentration of nano particle in the paint improved the potable water linearly and was found to about 25% for 30% weight fraction. Economic analysis of their study revealed that the payback period of modified still was higher (96 days) while comparing with black paint coated without nanoparticles.

Elango et al. [52] improved the production of potable water from conventional basin type solar still using different nano fluids namely Al_2O_3, ZnO, and SnO_2. Results showed that nano fluids improved the production of potable water by 30, 13 and 19% for Al_2O_3, ZnO, and SnO_2 respectively. Results also exhibited excellent stability of nano fluids during the preparation. There was also an excellent improvement in the water temperature while comparing it with of water as fluid inside the basin.

Kabeel et al. [53] used cuprous and aluminium oxide nano fluid in a single slope solar still with additional condenser as modified solar still. Through natural and induced convection technique the vapour formed in the triangular enclosure is taken into the external condenser and two conditions namely with operating fan and without operating fan were determined. Examined results showed that the use of fan exhibited a maximum daily efficiency of 89% and 68% for cuprous oxide and aluminium oxide nano fluid respectively with optimum concentration of 0.12%.

The main objective of the present study is to improve the fresh water yield produced from the solar still and increase the power output of PV panel submerged inside the solar still using three different nano materials namely Al_2O_3, TiO_2 and MgO at a constant concentration of 0.1%.

2. EXPERIMENTAL SETUP AND METHODOLOGY

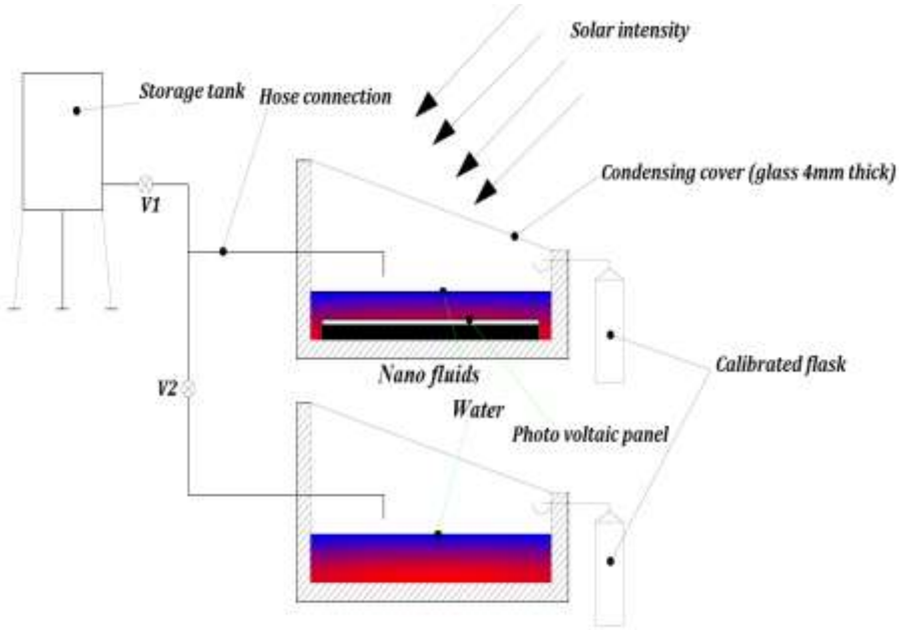

Figure 1 Schematic diagram of hybrid and conventional solar still

Fig. 1 and 2 shows the schematic diagram and experimental photograph of hybrid solar still. The experimental setup is constructed in such a way that two identical solar still made of same material and dimension. The length and breadth of solar still were 1 m x 0.5 m with height of 0.21 m in one side and 0.3 m on the other side. Glass cover with 4 mm thick is placed over the solar still to condense the vapour formed in the inner surface due to evaporation from the top water surface. Saline water is stored in a tank and continuously fed into the basin to maintain constant water depth inside the basin. Two different conditions were analysed in hybrid solar still namely, placing the PV panel inside the basin by partially submerging it (Hybrid solar still with 2 cm water depth). Other method is fully submerging the entire PV panel in water (Hybrid solar still with 3 cm water depth). Similarly, conventional solar still has been tested in 2 and 3 cm water depth. To avoid short circuit of current, the terminals in the back side of the PV panel are sealed. Voltmeter and Ammeter were connected in series to measure the voltage and current from the PV panel. To validate the effect of submerging the solar panel water, tests were conducted in open condition.

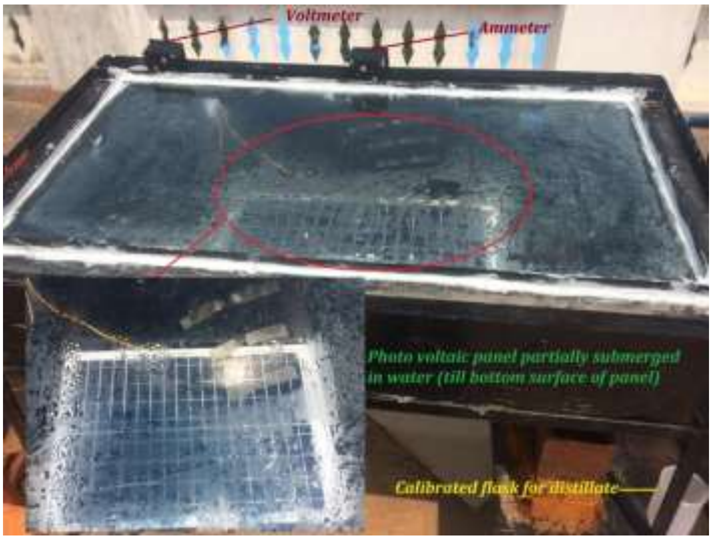

Figure 2 Experimental photograph of hybrid solar still with water

3. RESULTS AND DISCUSSION

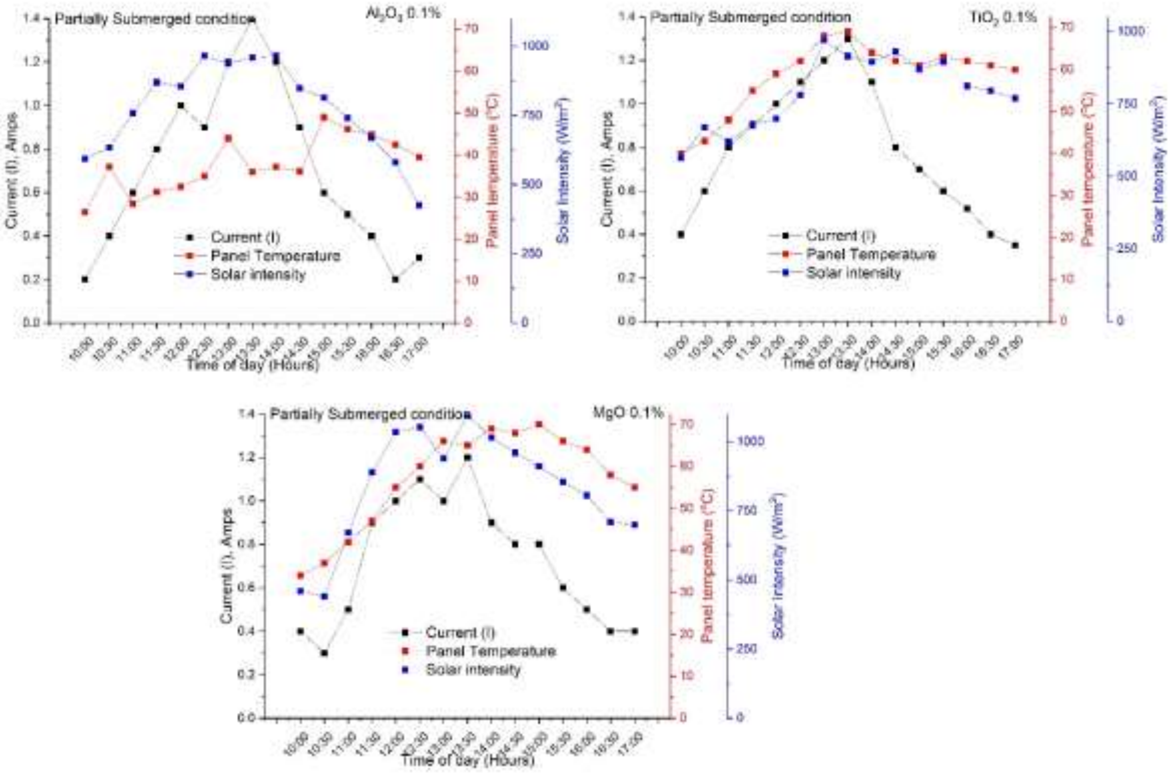

Figure 3 Diurnal variations in panel temperature, current and solar intensity of modified solar still

Fig. 3. shows the diurnal variations in panel temperature, current and solar intensity of modified solar still using Al_2O_3, MgO, TiO_2 nanofluids in the present modified solar still. It can be observed that there is a marginal deviation in the solar intensity during the test conditions. A maximum of 1.4 amps is produced in the current produced in the solar still using Al_2O_3 and TiO_2 nano fluids inside the basin whereas, in the case of MgO the amount of current produced is found as 1.2 amps. It is also seen that the panel temperature of PV panel in the case of Al_2O_3 nano particle is in the average of 36°C which the main phenomenon in the increase of power

output from the PV panel under partially submerged condition is. Similarly, there is an increase in the temperature of the fluid inside the basin which simultaneously reduced the amount of current produced. Due to the energy stored in the fluid, the same is rejected in the form of heat which increased the temperature of vapor formed in the enclosure.

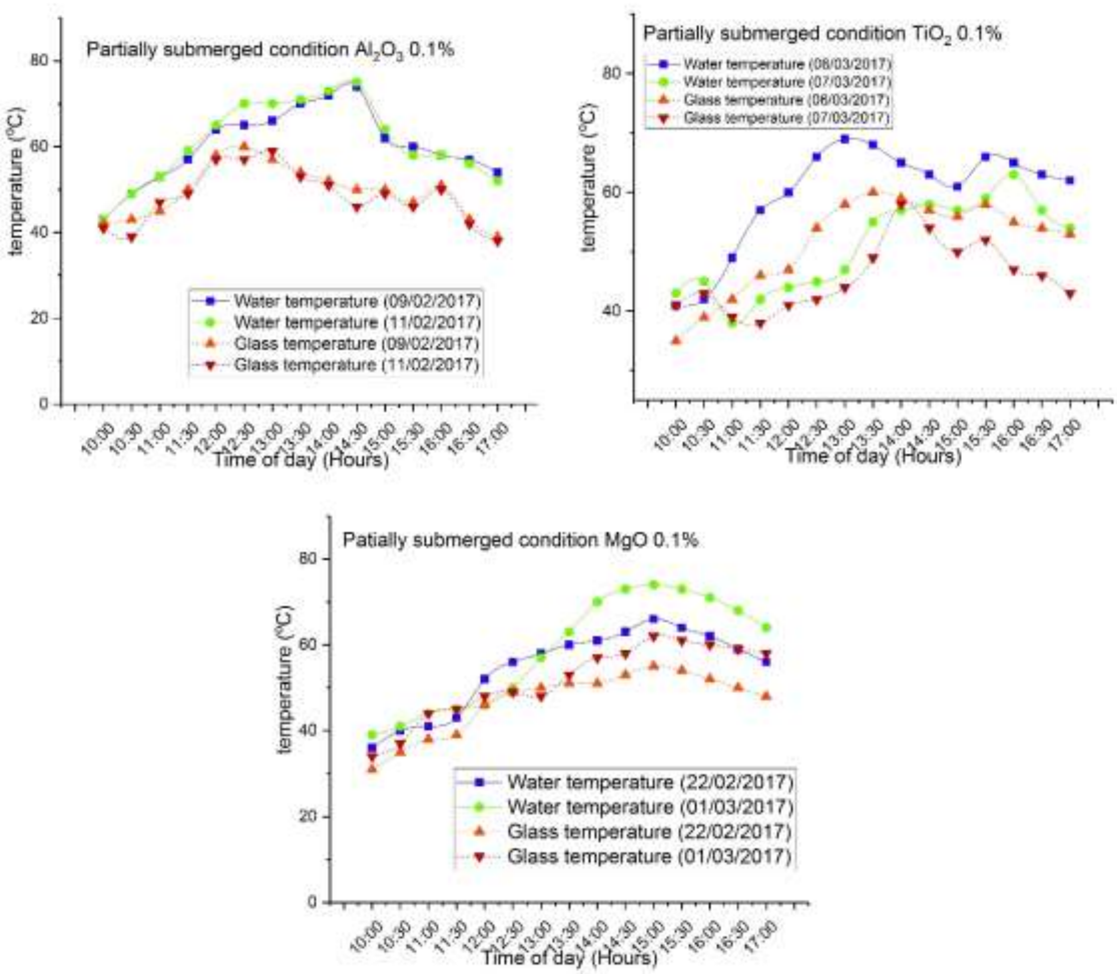

Figure 4 Variations in water and glass temperature of modified solar still with Al_2O_3, TiO_2 and MgO nano fluids

Variations in water and glass temperature of modified solar still with Al_2O_3, TiO_2 and MgO nano fluids is shown in Fig. 4. From the figure, it can be observed that the maximum water temperature of 78 and 77oC for is recorded on 09.02.2017 and 11.02.2017 respectively for the maximum solar intensity. While comparing the other nano fluid, Al2O3 nano fluid exhibited higher water temperature due to its excellent heat carrying capacity and absorption rate. Similarly, the maximum glass temperature of 60 and 58°C is observed on 09.02.2017 and 11.02.2017 respectively. With higher temperature difference between water and glass the productivity of potable water produced is increased during the lower solar intensity period. On comparing it with the water and glass temperature of TiO2 nano fluid, the water to glass temperature difference is higher during the sunshine hours which increased the productivity of potable water produced during morning hours as shown in Fig.4.

The hourly variations of water and glass temperature of PV panel partially submerged solar still with 0.1% MgO concentration is shown in Fig. 4. The maximum water temperature of 72 and 64°C is recorded on 01.03.2017 and 22.02.2017 respectively. Similarly, the maximum glass temperature of 61 and 54ºC is observed on 01.03.2017 and 22.02.2017 respectively. Due to higher thermal conductivity of MgO nano fluid compared to that of water fluid, the temperature of fluid enhanced.

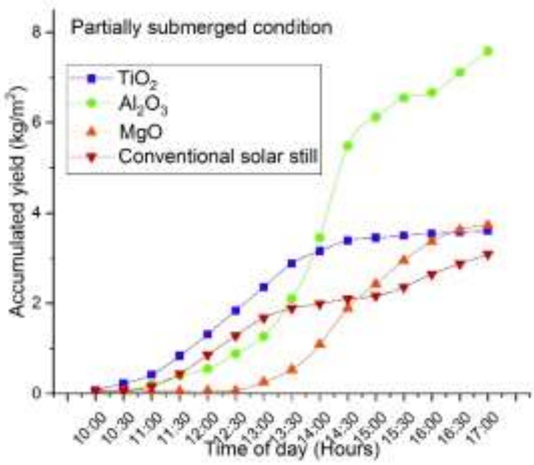

Figure 5 Variations in accumulated yield of Al_2O_3, TiO_2 and MgO nano fluids of modified solar still

The accumulated yield produced from the CSS, the CSS with Al_2O_3, the CSS with MgO, and the CSS with TiO_2 are plotted in Fig. 5. From the figure, it can be found that the yield produced from the CSS is maximum during the sun-shine hours and during the off sun-shine hours the yield is maximum for the CSS with Al_2O_3 is 7.4 kg/m^2, the CSS is 3.6 kg/m^2, the CSS with MgO is and the CSS with TiO_2 is 3.8 kg/m^2 . The 51.35 % increase in yield was obtained for the CSS with $Al2O_3$ and 13.9 % decrease in yield was obtained for the CSS with TiO_2 as compared to the CSS.

CONCLUSIONS

From the experimental analysis the following conclusions were arrived at: -

- The PV efficiency decreases with MgO nano fluid under partial submerged condition.
- The yield from solar still decreases with increase in water depth from solar still without PV submerge, whereas, in the case of partial submerged condition the accumulated yield increases.
- The accumulated yield from solar still with PV and with the use of nano fluids is found to be 8, 3.8 and 3.6 kg/m^2 for Al_2O_3, MgO, TiO_2 respectively.

REFERENCES

[1] El-Agouz, S. A., Sathyamurthy, R., and Muthu Manokar, A., "Improvement of humidification–dehumidification desalination unit using a desiccant wheel." *Chemical Engineering Research and Design* 131 (2018): 104-116.

[2] A. Muthu Manokar, YazanTaamneh, A.E. Kabeel, Ravishankar Sathyamurthy, D. Prince Winston, Ali J. Chamkha, Review of different methods employed in pyramidal solar still desalination to augment the yield of freshwater, *DESALINATION AND WATER TREATMENT*, *136*, 20–30.

[3] Sathyamurthy R, El-Agouz E. Experimental analysis and exergy efficiency of a conventional solar still with Fresnel lens and energy storage material. Heat Transfer—Asian Res. 2018;1-11. https://doi.org/10.1002/htj.21412

[4] Muthu Manokar A, Prince Winston D, Kabeel A. E, Ravishankar Sathyamurthy, Arunkumar T. (2018). Different parameter and technique affecting the rate of evaporation on active solar still-a review. *Heat and Mass Transfer*, *54*(3), 593-630.

[5] Winston, D. P., Pounraj, P., Manokar, A. M., Sathyamurthy, R., & Kabeel, A. E. (2018). Experimental investigation on hybrid PV/T active solar still with effective heating and cover cooling method. *Desalination*, *435*, 140-151.

[6] Manokar, A. Muthu, D. Prince Winston, Jayanta Deb Mondol, Ravishankar Sathyamurthy, A. E. Kabeel, and Hitesh Panchal. "Comparative study of an inclined solar panel basin solar still in passive and active mode." *Solar Energy* 169 (2018): 206-216.

[7] Panchal, Hitesh, Yazan Taamneh, Ravishankar Sathyamurthy, A. E. Kabeel, S. A. El-Agouz, P. Naveen Kumar, A. Muthu Manokar, T. Arunkumar, D. Mageshbabu, and R. Bharathwaaj. "Economic and exergy investigation of triangular pyramid solar still integrated to inclined solar still with baffles." *International Journal of Ambient Energy* (2018): 1-6.

[8] Arunkumar, T., A. E. Kabeel, Kaiwalya Raj, David Denkenberger, Ravishankar Sathyamurthy, P. Ragupathy, and R. Velraj. "Productivity enhancement of solar still by using porous absorber with bubble-wrap insulation." *Journal of Cleaner Production* (2018).

[9] Pounraj, P., Winston, D. P., Kabeel, A. E., Kumar, B. P., Manokar, A. M., Sathyamurthy, R., & Christabel, S. C. (2018). Experimental investigation on Peltier based hybrid PV/T active solar still for enhancing the overall performance. *Energy Conversion and Management*, *168*, 371-381.

[10] Manokar, A. M., Vimala, M., Winston, D. P., Ramesh, R., Sathyamurthy, R., Nagarajan, P. K., & Bharathwaaj, R. Different parameters affecting the condensation rate on an active solar still—A review. *Environmental Progress & Sustainable Energy*.

[11] El-Agouz, Elsayed, Abd Elnaby Kabeel, Jothirathinam Subramani, A. Muthu Manokar, Thirugnanasambantham Arunkumar, Ravishankar Sathyamurthy, Parasumanna Krishnamurthy Nagarajan, and Devarajan Magesh Babu. "Theoretical analysis of continuous heat extraction from absorber of solar still for improving the productivity." *Periodica Polytechnica Mechanical Engineering* 62, no. 3 (2018): 187-195.

[12] Panchal, H., Sathyamurthy, R., Pandey, A. K., Kumar, M., Arunkumar, T., & Patel, D. K. (2017). Annual performance analysis of a single-basin passive solar still coupled with evacuated tubes: comprehensive study in climate conditions of Mahesana, Gujarat. *International Journal of Ambient Energy*, 1-14.

[13] Madhu, B., Balasubramanian, E., Nagarajan, P. K., Sathyamurthy, R., Kabeel, A. E., Arunkumar, T., & Mageshbabu, D. (2017, February). Improving the yield of fresh water from conventional and stepped solar still with different nanofluids. In *Presented at the Fifth International Conference on Water*.

[14] Kabeel, A. E., Manokar, A. M., Sathyamurthy, R., Winston, D. P., El-Agouz, S. A., & Chamkha, A. J. (2019). A Review on Different Design Modifications Employed in Inclined Solar Still for Enhancing the Productivity. *Journal of Solar Energy Engineering*, *141*(3), 031007.

[15] Panchal, H., Mevada, D., & Sathyamurthy, R. (2018). The requirement of various methods to improve distillate output of solar still: A Review. *International Journal of Ambient Energy,* (just-accepted), 1-16.

[16] Kabeel, A. E., Taamneh, Y., Sathyamurthy, R., Naveen Kumar, P., Manokar, A. M., & Arunkumar, T. Experimental study on conventional solar still integrated with inclined solar still under different water depth. *Heat Transfer—Asian Research*.

[17] Madhu, B., Balasubramanian, E., Kabeel, A. E., El-Agouz, S. A., Manokar, A. M., Prakash, N., & Sathyamurthy, R. (2018). Experimental investigation on the effect of sensible heat energy storage in an inclined solar still with baffles. *DESALINATION AND WATER TREATMENT*, *116*, 49-56.

[18] Kabeel, A. E., El-Agouz, S. A., & Sathyamurthy, R. EXERGY ANALYSIS OF SINGLE SLOPE SOLAR STILL WITH LOW COST ENERGY STORAGE MATERIAL.

[19] Madhu, B., E. Balasubramanian, Ravishankar Sathyamurthy, P. K. Nagarajan, D. Mageshbabu, R. Bharathwaaj, and A. Muthu Manokar. "Exergy Analysis of Solar Still with Sand Heat Energy Storage." *Applied Solar Energy* 54, no. 3 (2018): 173-177.

[20] Manokar, A. Muthu, D. Prince Winston, Ravishankar Sathyamurthy, A. E. Kabeel, and A. Rama Prasath. "Experimental investigation on pyramid solar still in passive and active mode." *Heat and Mass Transfer* (2018): 1-14.

[21] Awasthi, A., Kumari, K., Panchal, H., & Sathyamurthy, R. (2018). Passive solar still: recent advancements in design and related performance. *Environmental Technology Reviews*, *7*(1), 235-261.

[22] Arunkumar, T., R. Velraj, G. Otero Prado, D. C. Denkenberger, Omid Mahian, R. Sathyamurthy, K. Vinothkumar, and A. Ahsan. "Effects of concentrator type and encapsulated phase change material on the performance of different solar stills: an experimental approach." *Desalination and Water Treatment* 87 (2017).

[23] Sathyamurthy, R., Kennady, H. J., Nagarajan, P. K., & Ahsan, A. (2014). Factors affecting the performance of triangular pyramid solar still. *Desalination*, *344*, 383-390.

[24] Arunkumar, T., Velraj, R., Denkenberger, D. C., Sathyamurthy, R., Kumar, K. V., & Ahsan, A. (2016). Productivity enhancements of compound parabolic concentrator tubular solar stills. *Renewable energy*, *88*, 391-400.

[25] Sathyamurthy, R., El-Agouz, S. A., & Dharmaraj, V. (2015). Experimental analysis of a portable solar still with evaporation and condensation chambers. *Desalination*, *367*, 180-185.

[26] Sathyamurthy, R., Nagarajan, P. K., El-Agouz, S. A., Jaiganesh, V., & Khanna, P. S. (2015). Experimental investigation on a semi-circular trough-absorber solar still with baffles for fresh water production. *Energy Conversion and Management*, *97*, 235-242.

[27] Sathyamurthy, R., Samuel, D. H., & Nagarajan, P. K. (2016). Theoretical analysis of inclined solar still with baffle plates for improving the fresh water yield. *Process Safety and Environmental Protection*, *101*, 93-107.

[28] Sathyamurthy, R., Nagarajan, P. K., Subramani, J., Vijayakumar, D., & Ali, K. M. A. (2014). Effect of water mass on triangular pyramid solar still using phase change material as storage medium. *Energy Procedia*, *61*, 2224-2228.

[29] Arunkumar, T., Velraj, R., Denkenberger, D., Sathyamurthy, R., Vinothkumar, K., Porkumaran, K., & Ahsan, A. (2016). Effect of heat removal on tubular solar desalting system. *Desalination*, *379*, 24-33.

[30] Arunkumar, T., Denkenberger, D., Velraj, R., Sathyamurthy, R., Tanaka, H., & Vinothkumar, K. (2015). Experimental study on a parabolic concentrator assisted solar desalting system. *Energy Conversion and Management*, *105*, 665-674.

[31] Kabeel, A. E., Arunkumar, T., Denkenberger, D. C., & Sathyamurthy, R. (2017). Performance enhancement of solar still through efficient heat exchange mechanism–a review. *Applied Thermal Engineering*, *114*, 815-836.

[32] Sathyamurthy, R., Nagarajan, P. K., Kennady, H., Ravikumar, T. S., Paulson, V., & Ahsan, A. (2014). Enhancing the heat transfer of triangular pyramid solar still using phase change material as storage material. *Frontiers in Heat and Mass Transfer (FHMT)*, *5*(1).

[33] Nagarajan, P. K., Vijayakumar, D., Paulson, V., Chitharthan, R. K., Narashimulu, Y., & Sathyamurthy, R. (2014). Performance evaluation of triangular pyramid solar still for enhancing productivity of fresh water. *Res. J. Pharm. Biol. Chem. Sci.*, *5*(2), 764-771.

[34] Sathyamurthy, R., Samuel, D. H., Nagarajan, P. K., & El-Agouz, S. A. (2015). A review of different solar still for augmenting fresh water yield. *Journal of Environmental Science and Technology*, *8*, 244-265.

[35] Harris Samuel, D. G., Nagarajan, P. K., Arunkumar, T., Kannan, E., & Sathyamurthy, R. (2016). Enhancing the solar still yield by increasing the surface area of water—A review. *Environmental Progress & Sustainable Energy*, *35*(3), 815-822.

[36] Manokar, A. M., D. P. Winston, A. E. Kabeel, S. A. El-Agouz, R. Sathyamurthy, T. Arunkumar, B. Madhu, and A. Ahsan. "Integrated PV/T solar still-A mini-review." *Desalination* 435 (2018): 259-267.

[37] Sathyamurthy, R., Harris Samuel, D. G., Nagarajan, P. K., & Arunkumar, T. (2016). Geometrical variations in solar stills for improving the fresh water yield—A review. *Desalination and Water Treatment*, *57*(45), 21145-21159.

[38] Naveen Kumar, P., Harris Samuel, D. G., Nagarajan, P. K., & Sathyamurthy, R. (2017). Theoretical analysis of a triangular pyramid solar still integrated to an inclined solar still with baffles. *International Journal of Ambient Energy*, *38*(7), 694-700.

[39] Nagarajan, P. K., El-Agouz, S. A., DG, H. S., Edwin, M., Madhu, B., Sathyamurthy, R., & Bharathwaaj, R. (2017). Analysis of an inclined solar still with baffles for improving the yield of fresh water. *Process Safety and Environmental Protection*, *105*, 326-337.

[40] Manokar, A. M., Winston, D. P., Kabeel, A. E., & Sathyamurthy, R. (2018). Sustainable fresh water and power production by integrating PV panel in inclined solar still. *Journal of Cleaner Production*, *172*, 2711-2719.

[41] Arunkumar, T., Velraj, R., Denkenberger, D. C., & Sathyamurthy, R. (2016). Influence of crescent shaped absorber in water desalting system. *Desalination*, *398*, 208-213.

[42] Panchal, H., & Sathyamurthy, R. (2017). Experimental analysis of single-basin solar still with porous fins. *International Journal of Ambient Energy*, 1-7.

[43] Sathyamurthy, R., Nagarajan, P. K., & Vijayakumar, D. (2016). Experimental validation of fresh water production using triangular pyramid solar still with PCM storage. In *International Journal of Engineering Research in Africa* (Vol. 20, pp. 51-58). Trans Tech Publications.

[44] Mousa A, Bassam A/K. Water film cooling over the glass cover of a solar still including evaporation effects. Energy 1997; 22: 43–48.

[45] Murugavel K K,.Chockalingam Kn.K.S.K, Srithar , Progresses in improving the effectiveness of the single basin passive solar still, Desalination 2008; 220: 677–686.

[46] Sathyamurthy, R., El-Agouz, S.A., Nagarajan, P.K., Subramani, J., Arunkumar, T., Mageshbabu, D., Madhu, B., Bharathwaaj, R. and Prakash, N., 2017. A Review of integrating solar collectors to solar still. *Renewable and Sustainable Energy Reviews*, *77*, pp.1069-1097.

[47] Samuel, DG Harris, P. K. Nagarajan, Ravishankar Sathyamurthy, S. A. El-Agouz, and E. Kannan. "Improving the yield of fresh water in conventional solar still using low cost energy storage material." *Energy Conversion and Management* 112 (2016): 125-134.

[48] Sathyamurthy, R., Nagarajan, P.K., Edwin, M., Madhu, B., El-Agouz, S.A., Ahsan, A. and Mageshbabu, D., 2016. Experimental Investigations on Conventional Solar Still with Sand Heat Energy Storage. *INTERNATIONAL JOURNAL OF HEAT AND TECHNOLOGY*, *34*(4), pp.597-603.

[49] Abdelal, Nisrin, and Yazan Taamneh. "Enhancement of pyramid solar still productivity using absorber plates made of carbon fiber/CNT-modified epoxy composites." *Desalination*419 (2017): 117-124

[50] M.T. Chaichan, H.A. Kazem, Single slope solar distillator productivity improvement using phase change material and Al2O3 nanoparticle, *Solar Energy 164 (2018) 370–381*

[51] Kabeel, A. E., Omara, Z. M., Essa, F. A., Abdullah, A. S., Arunkumar, T., & Sathyamurthy, R. (2017). Augmentation of a solar still distillate yield via absorber plate coated with black nanoparticles. *Alexandria Engineering Journal*, *56*(4), 433-438.

[52] T. Elango, A. Kannan, K. Kalidasa Murugavel, Performance study on single basin single slope solar still with different water nanofluids, Desalination 360 (2015) 45–51

[53] A.E. Kabeel, Z.M. Omara,F.A. Essa, Theoretical with experimental validation of modified solar still using nanofluids and external condenser, Journal of the Taiwan Institute of Chemical Engineers (2017), http://dx.doi.org/10.1016/j.jtice.2017.01.017