A Review on Performance Enhancement of Solar Still Using NanoParticle

Santosh Anand[1], Dr. Ajay Singh[2], Ashish Verma[3]

[1]*Scholar, Department of Mechanical Engineering, Radharaman Institute of Technology and Science, Bhopal, M.P, INDIA*
[2]*Head and Prof., Department of Mechanical Engineering, Radharaman Institute of Technology and Science, Bhopal, M.P, INDIA*
[3]*Assistant Professor, Department of Mechanical Engineering, Radharaman Institute of Technology and Science, Bhopal, M.P, INDIA*

ABSTRACT

The necessity of fresh water is growing day by day as the population and industrialization is increasing. As earth contains 71% of salinity water we have to convert that salinity water into fresh drinkable water. The device which converts salty water into drinkable water by using green source of energy that device is known as solar still. But due to its lesser efficiency it cannot be used in industrial purposes. To increase its productivity and efficiency many researcher has done improvement in various stills. Some researchers has used the nanoparticles due to their favourable thermo physical properties and optical characteristics. Nano particles and solid particles having the diameter in the range of 1 – 100 nm, are used from last two decades, and certainly a new approach among others. The ability of attaining the required thermo physical properties of nanoparticles, by the variation in the particle size, shape and concentration, rewarded them as one of focused area of research in the solar still. This paper contains the exhaustive review of literature on the utilization of nanoparticles in active and passive desalination system to investigate the best suitable nanoparticles for solar still. From review it was found that the efficiency and daily productivity of the still was increased by using nanoparticles in it.

Keywords – *Solar Desalination, Active and Passive Stills, Nanoparticles, Solar still, Nano fluids.*

I. INTRODUCTION

As the earth contain seventy one percentage of water and the remaining twenty nine percentage is islands and continents. Out of that seventy one percentage, ninety seven percentage of all the earth water is contained within the ocean and sea salty water, while the remaining three percentage is fresh water from lakes and frozen water [1]. A need of pure water is an important phenomena in day to day life, as the population and industrialization is increasing day by day so the demand of fresh water is also increases [2]. The water scarcity by 2025 will be increased by 2 billion people approximately as the report of UNO 2019 [3]. The TDS value which is permitted by the WHO is 500 parts per million for safe drinking water, but the sea water is having 35000 – 45000 parts per million. So we have to purify this water which involved the removal of dissolved, undissolved and harmful microbes. The undissolved substance can be removed by sand filtration and the microbes are killed through chlorination and by boiling. Desalination is the process which does all the three function and by using solar energy that devices is known as solar still [4].

1.1 Solar Desalination

The above mentioned technique is broadly classified on the management of solar energy. Hence, it is widely dissolved into two main categories: a) Direct: The absorption process and desalination takes place in the same apparatus. b) Indirect: Both absorption of solar energy and desalination are done through different processes and systems. The conventional methodology involving basin solar still is the most used method from ages and is hassle free for aspects related to convenience and maintenance. The basin which is covered up with a see-through cover and contains saline water which is unveiled in presence of solar radiation, is usually black stained to facilitate maximum radiation [5]. Once water changes its state of form (due to evaporation), it is made to condense once its particulates come in contact with the cover. Finally, the residual water is thereafter circulated to different facilities through proper mediums. However, major limitations involved in this simplified apparatus are its significant low efficiency due to liberated latent heat of condensation and thereafter-slow rise in water's evaporation temperature [6].

1.2 General Classification of solar still designs

The designs of solar stills are distinguished into two major categories i.e. Active and Passive stills altogether depending upon the process involved in heat source used for evaporation of saline water. Usually solar heaters, Photovoltaic thermal hybrid solar collectors and concentrators are used for this purpose. Nanoparticle To improve the solar still performance in the form of fresh water yield, nanoparticles, solid particles having the diameter in the range of 1 – 100 nm, are used from last two decades, and certainly a new approach among others. The ability of attaining the required thermo – physical properties of nanoparticles, by the variation in the particle size, shape and concentration, rewarded them as one of focused area of research in the solar still.

II. LITERATURE SURVEY

Seyed Sina Adibi Toosi et al. [7] performed the Experimental investigation on stepped solar still with Fe3O4 + graphene oxide + paraffin as nanofluid under constant magnetic field. The thermal conductivity of hybrid NPCM has been improved by the utilization of a constant magnetic field. The daily efficiency of State I, State II, and State III was about 6.9 %, 9.6 %, and 12.3 %, respectively, and reaches 13.6 % by using hybrid NPCM under the magnetic field. By considering the cost per liter and payback period of freshwater yield, it can be derived that the usage of hybrid NPCM under the magnetic field in the SSS is a cost-effective.

Bekele A et al. [8] investigated the modified pyramid solar still has a unique combination of modifications such as a v-corrugated absorber surface, a nano-coated absorber surface, internal reflective mirrors and nano-embodied phase change material. The experimental test result of the system gives a daily yield of 2.95 and 5.73 l/m^2 distilled water from conventional and modified solar still, respectively. This shows a yield improvement of 94.2%. Finally, the water quality is tested and drinkable as per the WHO standard. Bekele A et al investigated the

Ewelina Radomska et al. [9] investigated the influence of water mass and PCM mass on the long-term performance of a solar still (SS. The results of simulations for average days for each month show that the maximum productivity of the SS is in July (3039 mL/m2/day with 5 kg of water), while the lowest is in October (900 mL/m2/day). The greatest annual SS productivity is 488.8 L/m2/year in Poland and is achieved with 5 kg of water and without PCM. The daily productivity is inversely proportional to the mass of water and the mass of PCM. The PCM reduces productivity by up to 11%.

Varun Kumar Sonker et al. [10] developed a frugal solar still with cylinders filled with paraffin wax and blended with nanoparticles; significant enhancement in distillation output has been observed. The yield of solar distillate increased by 43.50% when PCM has been used, as compared to the base case when no PCM has been used. The yield increased by 32.90% when PCM and nanoparticles have been used, as compared to the case when only PCM has been used. The evaporative heat transfer coefficient has been increased in the case of NPCM. The proof of concept on a novel frugal solar still has been established and it has been observed that the cost of distilled water reduced from Rs. 5/L to Rs. 3/L (40% reduction in cost). It has also been observed that the payback period for our proposed novel economic model (SSNPCM) is 4.3 years which justifies the deployment of our solar still in resource constrained setting. This will also facilitate commercialization of the product.

Dsilva et al. [11] performed the numerical study on solar still with nanoparticles and latent heat storage material. The titanium oxide was used as nanoparticles and paraffin wax were used as latent heat storage material. The 6.6 L/m2 per day output were increased by using titanium oxide with paraffin wax as compared to plain paraffin wax.

The 88% more output were obtained from still when energy storage materials with nano particles were used as compared to traditional solar still.

Shafieian et al. [12] performed the experimental studied on thermal based solar still using aluminium oxide nanoparticles. The 18% and 22% of fresh water output was increased when nanoparticles was used during hot and cold weather respectively.

Behura et al. [13] also performed the experimental studied on solar still having phase change material with nanoparticles. The experimental setup consist of v corrugated absorber plate having paraffin wax combined with copper oxide nanoparticles. They revealed that when 0.1% weight concentration of nanoparticles were used, 440 ml/0.25m2 per day output was obtained. Similarly when 0.2% and 0.3% weight concentration of nanoparticles were used the 455ml/0.25m2 per day and 510 ml/0.25m2 per day was found. The result also revealed that when nanoparticles were used the output was increased by 62.74% as compared to traditional still.

Panchal et al. [14] performed the experimental studied on stepped solar still using nanoparticles. The Magnesium oxide and Titanium oxide of different concentration was used for experimentation. The range of nanoparticles concentration used for experimentation was 0.1% to 0.2%. From results it was found that for magnesium oxide with 0.1% concentration, 33.33% more fresh water was obtained, whereas for 0.2% concentration 45.38% was obtained. Similarly for Titanium oxide with 0.1% concentration 4.1% fresh water was produce and for 0.2% concentration 20.4% was produce. The high thermal conductivity and low specific heat capacity of Magnesium oxide as compared to Titanium oxide leads to higher fresh water output from still.

Sathyamurthy et al. [15] performed the experimental studied on stepped solar still layered using fumed silica nanoparticle in black paint. The concentration of nanoparticles varies from 10-40% and it is found that when the concentration of nanoparticles increased from 20% there is no effect in the output. During experimentation it was found that when 10% concentration of nanoparticles were used the output was increased by 27.2% as compared to normal black paint. Similarly when 20%, 30% and 40% concentration of nanoparticles were used the output was increased by 34.2%, 18.3% and 18.4% respectively as compared to ordinary black paint.

Nazari et al. [16] performed the experimental studied on single slope solar still consisting of thermoelectric cooling channel and copper oxide nanoparticles. They found that when 0.08% of copper oxide nanoparticles were used in solar still with thermoelectric cooling channel the 81% more output of fresh water was found whereas 80.6% more energy efficiency was produce.

Modi et al. [17] performed the experimentation on single slope double basin solar still with Al_2O_3 nanoparticles. During experimentation the mass of Al_2O_3 nanoparticles was varied i.e. 0.01%, 0.05%, 0.10% & 0.20%. The 0.01% mass of Al_2O_3 gives 17.6% distilled output, whereas for 0.05%, 0.10% and 0.20% gives 12.3%, 7.2% and 2.6% respectively as compared to still without nanoparticles.

Sharshir et al. [18] performed the experimental studied on pyramid solar still equipped with evacuated tube using nanoparticles. In experimentation 3 still are used such as conventional pyramid solar still, modified pyramid solar still with evacuated tube and modified pyramid solar still with nanoparticles. In this experimentation 2 different nanoparticles are used such as copper oxide and carbon black with 1.5 % weight concentration. The 4.77% and 26.6% more yield of fresh water were obtained from modified solar still as compared to conventional pyramid solar still and traditional solar still. When modified solar still with copper oxide was used the yield of fresh water was increased by 27.85% and 54.85% as compared to conventional pyramid solar still and traditional solar still respectively. Similarly when modified solar still with carbon black nanoparticles was used the yield of fresh water was increased by 33.59% and 57.098% as compared to conventional pyramid solar still and traditional solar still respectively. From result it was also found that the modified solar still was having 50% daily efficiency which was increased to 61% for modified solar still with copper oxide and 64.5% for modified solar still with carbon black.

Elavarasi et al. [19] performed experiment on 2 different solar stills having same dimension. In first still paraffin wax was used, while in second one the combination of silicon oil and copper oxide nanoparticles are used. The 25% enhancement in output were obtained when silicon oil and copper oxide nanoparticles was used.

Rufuss et al. [20] uses copper oxide nanoparticles mixes with PCM. They revealed that as the nanoparticles were mixed with the PCM the thermal conductivity was increased and due to which 60% more output was obtained from the solar still.

Sahota et al. [21] study the effect of Al_2O_3 nanoparticles on double slope solar still AND performed the experimental studied for different particle concentration. When 0.12 Vol. % of Al_2O_3 was used the yield obtained was 12.2% for 35kg of water and 8.4% for 80 kg of water as compared to still without nanoparticles.

Elfasakhany et al. [22] performed the experiment on single basin solar still containing the copper oxide nanoparticles with paraffin wax as PCM. They performed experimentation on 3 different cases, case 1: still without PCM, case 2: still with PCM, and case 3: still with PCM and copper oxide nanoparticles. They revealed that 125% and 106% overall everyday output was increased for case 3 as compared to case 1 and case 2 respectively. The 5 hour and 6 hour operational time of still were increased when PCM and Mixture of PCM with copper oxide nanoparticles was used in the still respectively.

Rajasekhar et al. [23] conducted experimentation on single slope solar still with nano-composite PCM. The paraffin wax was mixed with aluminium oxide (Al_2O_3) nanoparticles. The 2800 mL per day of overall yield was found. When PCM and PCM with Al_2O_3 was used they found 44.40% and 60% more everyday efficiency respectively. The 49.82% and 72.85% productivity was increased when still contains PCM and PCM nanoparticles respectively.

Somanchi et al. [24] performed the experiment on single slope solar still with two different PCM such as Magnesium Sulphate Heptahydrate and Sodium Sulphate mixes with Titanium Oxide (TiO_2) nanoparticles. They found that Magnesium Sulphate Heptahydrate has greater efficiency as compared to the mixture of Sodium Sulphate and Titanium oxide nanoparticles.

Kabeel et al. [25] performed the experimental investigation on traditional solar still containing nanoparticles and equipped with vacuum pump . For experimentation they used the copper oxide and aluminium oxide as nanoparticles having 76.5 and 46 W m^{-1} K^{-1} thermal conductivity respectively. From experimentation they found that 133.64% and 125% efficiency of still was obtained for copper oxide and aluminium oxide as nanoparticles with fan for maintain vacuum respectively which was dropped to 93.87% and 88.97% for copper oxide and aluminium oxide as nanoparticles without fan respectively.

Kabeel et al. [26] also done the experimental analysis on solar still containing Nano fluids, integrating with exterior condensers and found that 116 % output of still were increased by using nanoparticles with exterior condenser and reduces to 76% when exterior condenser were not operated. To identify the best nanoparticles Elango et al., [9] done comparative research on single basin single solar slope with 3 different nanoparticles such as “Aluminium Oxide, Zinc Oxide and Tin Oxide” . They found that 29.95% more output were obtained when Aluminium oxide was used as nanoparticles as compared to plain water. Similarly 18.63% and 12.67% more output obtained when Tin oxide and zinc oxide were used as nanoparticles.

III. Conclusion

This paper review the literature related to efficiency of solar desalination system using nanoparticles. The main conclusion from the paper is given below:

1. The everyday output from the still was increased when volume concentration of nanoparticles increases.
2. The total efficiency of still was increased by using the nanoparticles in the still as compared to traditional solar still, as thermal conductivity increases using nanoparticles.
3. When the nanoparticles has lesser density the concentrations of nanoparticles in the water increases, which increases the thermal conductivity of water.
4. The Phase Change Material when combined with nanoparticles the output from still was increased, as the PCM increases the latent heat.

5. When fan were used in the still it also increase the efficiency of still, as it leads to forced convection, which enhance the temperature gradient.

6. Lastly, it is found that aluminium oxide nanoparticles are the best-suited nanoparticles for solar desalination as compared to other nanoparticles.

References:

[1] Pichel N, Vivar M, Fuentes M 2018 The problem of drinking water access: A review of disinfection technologies with an emphasis on solar treatment methods, Chemosphere, 218 1014. doi: 10.1016/j.chemosphere.2018.11.205.

[2] Ahmed F, Hashaikeh R, Hilal N 2019 Solar powered desalination – Technology, energy and future outlook, Desalination, 453 54 - 76. doi: 10.1016/j.desal.2018.12.002.

[3] U. WATER 2019 The United Nations World Water Development Report 2019.

[4] Katekar V 2020 Brackish water distillation system for gorewadawater gorewadawater treatment plant, Nagpur using solar energy - A case study, Wjert, 5 198 - 215.

[5] Sharon H, Reddy K 2015 A review of solar energy driven desalination technologies, Renew. Sustain. Energy Rev., 41 1080. doi: 10.1016/j.rser.2014.09.002.

[6] Kaviti A, Yadav A, Shukla A 2016 Inclined solar still designs: A review, Renew. Sustain. Energy Rev., 54 429 - 451. doi: 10.1016/j.rser.2015.10.027.

[7] Seyed Sina Adibi Toosi, Hamid Reza Goshayeshi, Iman Zahmatkesh, Vahid Nejati, Experimental assessment of new designed stepped solar still with Fe3O4 + graphene oxide + paraffin as nanofluid under constant magnetic field, Journal of Energy Storage,Volume 62,2023,106795.

[8] Bekele, Addisu, Adugna Dinkissa, and Tarekegn Limore. "Investigating the Yield Improvement of Modified Passive Solar Still Using Nanoparticle Coatings and Nanoparticle-Enhanced Phase Change Materials." *International Journal of Sustainable Energy* 42, no. 1 (2023): 1079–91.

[9] Ewelina Radomska, Łukasz Mika, Long-term modeling of the performance of a solar still with phase-change material, Applied Thermal Engineering, Volume 235, 2023, 121339

[10] Varun Kumar Sonker, Jyoti Prasad Chakraborty, Arnab Sarkar,Development of a frugal solar still using phase change material and nanoparticles integrated with commercialization through a novel economic model, Journal of Energy Storage,Volume 51, 2022, 104569

[11] D. Dsilva Winfred Rufuss, S. Arulvel, S. Iniyan, L. Suganthi, Numerical study of titanium oxide nanoparticle enhanced energy storage material in solar desalination,Materials Today: Proceedings,Volume 43, Part 2,2021, Pages 805-808.

[12] Shafieian A, Rizwan M, Khiadani M, Kanti T 2020 Performance improvement of thermal-driven membrane-based solar desalination systems using nanofluid in the feed stream, Sustain. Energy Technol. Assessments, 39.

[13] Behura A, Gupta H 2020 Use of nanoparticle-embedded phase change material in solar still for productivity enhancement," Mater. Today Proc., 10 -13.

[14] Sathyamurthy R, Kabeel A, Balasubramanian M, Devarajan M, Sharshir S, Manokar A 2020 Experimental study on enhancing the yield from stepped solar still coated using fumed silica nanoparticle in black paint, Mater. Lett., 272 127873.

[15] Panchal H 2019 Annual performance analysis of adding different nanofluids in stepped solar still," J. Therm. Anal. Calorim., 138 3175 - 3182.

[16] Nazari S, Safarzadeh H, Bahiraei M 2019 Performance improvement of a single slope solar still by employing thermoelectric cooling channel and copper oxide nanofluid: An experimental study, J. Clean. Prod., 208 1041 - 1052.

[17] Modi K, Shukla D, Ankoliya D 2019 A Comparative Performance Study of Double Basin Single Slope Solar Still with and Without Using Nanoparticles, J. Sol. Energy Eng. Trans. ASME, 141.

[18] Sharshir S, Kandeal A, Ismail M, Abdelaziz G, Kabeel A, Yang N 2019 Augmentation of a pyramid solar still performance using evacuated tubes and nanofluid: Experimental approach, Appl. Therm. Eng., 160 113997.

[19] Elavarasi R, Senthilkumar P, Shanthi P 2018 Performance analysis of multipurpose Solar Still Employing Nano particles, Int. J. Manag. Technol. Eng., 8 732 - 738.

[20] Rufuss D, Iniyan S, Suganthi L, Pa D 2017 Nanoparticles Enhanced Phase Change Material (NPCM) as Heat Storage in Solar Still Application for Productivity Enhancement, Energy Procedia, 141 45 - 49.

[21] Sahota L, Tiwari G 2016 Effect of Al2O3 nanoparticles on the performance of passive double slope solar still, Sol. Energy, 130 260 - 272.

[22] Elfasakhany A 2016 Performance assessment and productivity of a simple-type solar still integrated with nanocomposite energy storage system, Appl. Energy, 183 399 - 407

[23] Rajasekhar G, Eswaramoorthy M 2015 Performance evaluation on solar still integrated with nanocomposite phase change materials, Appl. Sol. Energy, 51 15 - 21.

[24] Somanchi N, Sagi S, Kumar T, Kakarlamudi S, Parik A 2015 Modelling and Analysis of Single Slope Solar Still at Different Water Depth, Aquat. Procedia, 4 1477 - 1482.

[24] Kabeel A, Omara Z, Essa F 2014 Improving the performance of solar still by using nanofluids and providing vacuum, Energy Convers. Manag., 86 268 -274.

[26] Kabeel A, Omara Z, Essa F 2014 Enhancement of modified solar still integrated with external condenser using nanofluids: An experimental approach, Energy Convers. Manag., 78 493 - 498.

.