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A Review of High Performance Solar Stills for Desalination of Waste Water

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Abstract: Pure water is renewable resource on the earth, it getting impure now a days. Solar desalination is one of the best way to produce fresh water from any type of impure water in a sustainable way. A solar still is a simply design device used to purify the water by using solar energy by the process of evaporation and condensation. Generally, the productivity of the conventional solar still is about 1–5 L/m2/day. But this quantity is not sufficient for an individual to fulfill daily needs of water in life. Hence either more than 1 L/m2 is required per person or better for modifications to improve the solar still design for the demand of the fresh water (likely more than 5 L/m2/day). In this work, an attempt has been made to categorize the different solar still designs with productivity more than 5L/m2/day. Here, we identify as such efficient high productivity of solar stills and discuss their modifications and heat transfer mechanism to reach at useful conclusions. This review will be a reference guide for future researchers who wish to concentrate only on efficient high productivity of solar stills to improve the productivity or efficiency.

I. INTRODUCTION

Water is one of fundamental source for survival of mankind and living things on the globe. Salty water contains dissolved and undissolved substance. But it is not usable for drinkable, so there are various methods which used for the purification of water, one of them is solar still for purification but there is a lot of work need to done on it. In this article to enhance the productivity of fresh water several techniques are mentioned by different researchers. A complete review to enhanced the condensation, evaporation, both condensation and evaporation comparative experimentation of an solar still has been presented. In this present review paper, various methods of improvement works done by researchers have shown, and focused on main primary methods like use of phase change material increased In productivity was 42.2 % to 52.2% , solar parabolic dishes with two identical coned tanks which was gave the more productivity of 40 % to 60% as compared to conventional solar still, black stone as sensible material,parabolic reflector, different types of fins, photovoltaic thermal module, nanofluid of solar still have discussed with increased in productivity . All of above methods are used to increased in productivity and beneficial for improvement in distillate output of solar still. The distillate water can be used for drinking and other household purposes.

II. THERE ARE DIFFERENT TECHNIQUE'S WHICH HELPS TO INCREASES EVAPORATION, CONDENSATION AND BOTH EVAPORATION & CONDENSATION RATE AT DIFFERENT CONDITIONS.

A. Methods To Increase Evaporation Rate

Mohamed et al. (2019a) experimentally focused on improving the heat and mass transfer that was done by using black stone as sensible storage materials of different sizes of 1 cm, 2 cm, 3 cm. Productivity improved by 19.8%, 27.86%, 33.37%.They Calculated Nusselt and Sherwood number.

Mohamed et al. (2019b) has been examined productivity of solar still by doing some modifications, in which a fine natural stone (black basalt) used as an absorber.

Two models with the same design and specification (common and advanced) were tested and compared. By changing the size of the different stones the product were tested at 1cm, 1.5cm and 2cm the size of the stones was approximately 0.901, 1.005 and 1.075L / m^2 with improvements of about 19.81, 27.86 and 33.37%, respectively. The result shows that the maximum solar thermal energy was 22.6% with a rock size of 2cm with an improvement of 32.07%.

Cheng et al. (2019a) focused on the shape stabilized phase change material. The productivity per day of the solar still with shape-stabilized phase change material was up to 3.41L/m^2. The thermal conductivity of shape-stabilized phase change material was 1.50W/m k which was 6 times more than paraffin wax, so the productivity increased with increased in thermal conductivity and was ranges from 42% to 52.5%.

Vigneswaran et al. (2019) experimented on solar still to increase the production by using phase change material.In this paper, solar still is combined with single and multi-phase change material. Three cases experimented: -1.Conventional solar still 2.Solar still with single phase change material 3. Solar still with two phase change material**.** Solar still with two phase change material had highest productivity of 4.40 L/sq/day, which was 19.6 % and 9.5% higher than the other two cases The efficiency were found to be 38.72% , 42.29% and 46.29%.

Yeo et al. (2019) studied the effect of different heat sources on the performance of hybrid multiple effect diffusion solar still. The paper cleared that the productivity and efficiency of hybrid multiple effect diffusion (HMED) was higher than basin surface of any solar still. The productivity was 21.65 kg/m^2 at supply of heat or thermal energy i.e. Q(in) = 23.08 MJ by using electric heater as a heat source**,** future work was improvement of structure of reflecting fins used in hybrid multi effect diffusion respectively.

Elashmawy (2019) studied the effect of atmospheric emissions using solar energy in which they used a black cotton cloth bed filled with calcium chloride. They studied at night in which they used three air fan at different speed to circulate ambient air inside air inside tube at night hour and the production of fresh water was 467 mL/m^2 day for 4 m/s air speed which was higher air speed while 230 mL/m^2 day for natural air circulation.

Kabeel et al. (2019a) examined efficiency of solar still with two identical solar panels installed in two solar-connected circular tanks. The effect of the depth of the basin water is calculated at two different values at 10 and 20 mm.Result shows that the daily distillate output in one solar dish is 8.8, 5.54 kg / day and with two solar dishes is 13.48 and 7.5 kg / day at two water depths of 10 and 20 mm respectively.

Kabeel et al. (2019b) conducted experimental investigation on solar still which contains internal reflector and black gravel phase change material. Solar energy, energy and economic and product analysis has been investigated.

Kabeel et al. (2019c) examined tubular solar still. Productivity range is from1.6 to 26.6 kg / m^2 for single effect tubular solar still and for five effect is approximately about 86 kg / m^2. By Increasing the effect of tubular solar still leads to the level of water production.

Modi and Modi (2019) studied the performance of a single slope double basin solar still, using two different materials at the basin with two different water depths at 0.01 and 0.02m.Jute Cloth and Black Cotton cloth used in the basin as an absorber, from observation showing that at 0.01 and 0.02m water depths. Improvement of 18.03% and 21.46% of yield was obtained. The test result revealed that at water depth of 0.01m with a small piece of jute cloth in the bottom container gives a maximum productivity.

Mevada et al. (2019) studied different types & effects of fin on solar still. They reviewed about the fin which increases absorber temperature, rate of evaporation, etc. Increasing number of fin and thickness then it decreases the productivity of solar still & also fin material does not affect the productivity.

Modi et al. (2019) studied the effect of spherical basin solar still which is combined with parabolic reflector. In this they performed a various brackish water mass investigated such as 1L, 2L, 3L, 4L and then they got a daily yield of 3.54L/m^2 4.76L/m^2, 6.71L/m^2 , 7.47L/m^2 , 8.25L/m^2 by this they found that distilled water increases with increase of brackish wsater mass in basin.

Xinxin et al. (2019) focused on photovoltaic thermal module to improve productivity.

The solar still design operates as a hybrid low photovoltaic / thermal module. Use of photovoltaic / thermal module and tracking subsystem produce clean water. Energy efficiency it increases up to 15.50% and the average efficiency was 14.02% respectively.

Xiao et al. (2019) experimented to increase productivity of solar still by using photovoltaic. The channel is designed to improve the heat transfer rate which was improved by 44%,the depth of the lower channel (H) is 0.01 m. Daily freshwater production improved by 51.7%, thermal efficiency and exergy efficiency also increased by 17% and 3%. When H = 0.03 m productivity decreased by 17%, so the minimum channel depth (H) was 0.01 m respectively.

Abdullah et al. (2019) experimented on drum distiller to increase evaporative surface area by which they reduce the thickness of the salt water film with the help of drum distiller. They got a 6420L / m^2 productivity which was much higher than when they used conventional distiller.

Bahrami et al. (2019) experimented on a solar parabolic dish collector system.They got a productivity of 2.5Kg/m^2.

Mehdiabadi et al. (2019) investigated the performance of a single basin double slope solar still experimented with phase change material and PV / T collector used to improve clean water during daylight hours and used paraffin wax due to double slopes the productivity increased by 10.6% as compared to the normal solar still.

Manokar et al. (2020) investigated pyramid solar still because solar still offers a large surface area than the basin type solar still. From experiment they checked the productivity with or without insulation by changing water depth from 1 to 3.5 cm respectively. They obtained a maximum productivity at 1 cm water depth with and without insulation as 3.72 & 3.27 kg / m^2.

Maliani et al. (2020) experimentally developed conventional solar still which was integrated with parabolic trough concentrator in order to improve its thermal performance. From experiment they achieved total productivity about 3.76 l/day.

Sharshir et al. (2020) experimentally investigated developed pyramid solar still. They introduced both together firefly algorithm - random vector functional link for thermal performance of developed pyramid solar still. Material used graphite nanofluids along with copper basin. From the experiment they yeild productivity of developed pyramid solar still about 5.26 L/m^2.

Madiouli et al. (2020) conducted research on a single slope solar still integrated with a flat plate collector. Experiment performed in summer and winter season. They get the productivity as 6.036 kg / m^2 / day in summer and as 2.775 kg / m^2 / day in winter.

Maghlany et al. (2020) theoretically conducted an experiment on water depth under continuous and discrete makeup water. They checked the productivity by varying water depth from 0.5 cm to 20 cm. From the theoretical and experimental results found that water depth decreases with increasing productivity. They obtained maximum productivity 0.25 L/day at initial water depth 1 cm.

Elashmawy (2020) studied the effects of black gravel on a tubular solar still integrated with parabolic concentrator solar tracking. Three kilograms of black gravel are used as sensible heat storage medium. From experiment a productivity of tubular solar still-parabolic concentrator tracking solar with & without black gravel gives 4.51 L / m^2 / day and 3.96 L / m^2 / day.

Shehata et al. (2020) investigated various strategies that help to improve solar still productivity. They checked the productivity under various conditions such as phase change material, ultrasonic humidifiers and evacuated solar collectors and phase change material with ultrasonic humidifiers are integrated with solar collector. They find that the maximum daily productivity is 5.34 and 7.4 kg per day with 25 and 35 mm respectively using solar still with phase change material and ultrasonic humidifiers integrated with exhaust solar still. Ultrasonic humidifier was as powerful as possible which improves daily productivity. Daily production was about 25 and 44% at water depths of 25 and 35 mm respectively.

Alwan et al. (2020) experimented modified solar still with solar collector. In this rotating cylinder is used in solar still to increase surface area and to calculate the three rotational speed and shows that at decreasing rotational speed of hollow cylinder, its output is 5.5L / m^2 compared to tubular solar still 1.4L / m^2

Kabeel et al. (2020a) experimentally approached augmentation of the tubular solar still system using hybrid storage medium and CPC .They used paraffin wax and graphite to absorb the solar radiation also helps to increase the evaporation rate and they produce a product that has accumulated over the course of a day between 9.56-9.811m^2 of MTSS as compared to CTSS which is 5.79-5.94.

Kabeel et al. (2020b) experimentally studied on tubular solar still using grapheme-oxide nanoparticle in phase change material. In this paper comparison of phase change material and nanoparticle of doped phase change material at this they founded that evaporation is more on nanoparticle of doped phase change material as compared to phase change material then the daily yield is found to be 5.62kg/m^2 as compared to phase change material 3.55kg/m^2 and daily efficiency of doped phase change material is 50.85% as compare to phase change material 30.31%.

Dumka and Mishra (2020) performed experiments on a single slope solar still intensified by ultrasonic fogger placed in a container and increase the rate of heat transfer. They compare this solar still with simple solar still in this evaporative and convective heat transfer coefficient is also increase and give 33.26% distilled output from 11am to 6pm and distilled water costs are low compared to simple solar still.

Singh et al. (2020) performed experiment on single slope solar still using the iteration method for heat transfer coefficient which is based on numerical computation in which numerical value changes hours of an internal convective heat transfer varies between 1.3 to 1.5 W/m^2 degree celsius and after fourth iteration it is reduced by 11.7% as compared to first iteration. So here it will show only iteration method.

El-Said and Abdelaziz (2020) conducted experiments on tubular solar still, made using a high frequency ultrasound atomizer and atomized salt water use for expansion. The humidification process inside the solar still.Simple solar still gave the productivity of about 3.58 L / m^2 while using high frequency ultrasound provided a Production of 4.41 L / m^2.

El-Said et al. (2020) experimented on tubular solar still advances using the installation of a wire mesh packaging under harmonic movement. In this case a porous packed media was developed and a vibrator was connected in it to perform a forced vibration and the vibrator is used to eliminate surface tension and boundary layer of salt water increases the rate of heat transfer and the rate of vaporization. In this case the daily productivity was 4.2 L / m^2.

Essa et al. (2020) performed augmentation of solar still with eco-friendly coffee based colloid was used as an organic base colloid which had added in basin of solar still and the improved photo thermal property. It had also improved the water productivity which was higher than the simple solar still by 35.14% and efficiency was 46.44% as compared to simple solar still.

B. Method To Increase Condensation Rate

Ketabchi et al. (2019) experimented and performed in the cooling system and reflector. Experimentation of a modified solar still which is connected with the cooling system and external flat plate reflector. The still was modified by using external reflector on the top and bottom of the cooling system fitted on the external surface of the glass cover. The productivity of cooling water flows over through glass cover increased which was higher than conventional with respect to inclination angle.

Khanmohammadi and khanmohammadi (2019) experimentally investigated the different insulation and phase change materials in solar still. The SSDS with PCM in numerical simulation was conducted by various mathematically modelling technique's.

Amarloo and Shafii (2019) instead of using auxiliary radioactive panel, they used an integrated collector for absorption of solar radiation & emission of radiation for radioactive cooling. They got daily productivity of 2.805Kg/m^2.

Essa et al. (2020) work on the prediction model of active solar still .In this they use Artificial Neural Network and Harris Hawk optimizer they also used arduino and fan for increasing in condensation and by using this device they will predict the productivity.

C. Methods to increase both evaporation and condensation rate

Kabeel and Abdelgaied (2020) examined pyramid shaped solar still using absorber plate which is made up of graphite materials with a thickness of 25 mm to increase evaporation rate and cooling glass cover is used in which film cooling water is flowing over glass to increase the condensation. Then its productivity of fresh water is about 9-9.19L/m^2. From graph it is seen that at night from 7pm to 9pm it will produce 0.2 to 0.3 L/m^2 of fresh water.

Sanserawal et al. (2020) studied single slope single basin solar still. They provided review of different materials which help in improving the performance by using materials such as galvanized steel, black paint, plexiglass basin, internal reflector, etc.

Parsa et al. (2020) examined solar still integrated with thermoelectric heating with nanoparticles also with dobke slope external condenser. From the experiment they achieved daily productivity of solar still with nanofluids/condenser, solar still with nanofluids without condenser & solar still without nanofluids/condenser was 25.42%, 22.01%, and 16.58% respectively. They got highest productivity by solar still with nanofluid/condenser as 7760 cc/m^2/day.

Katekar and Deshmukh (2020) investigated by identifying the best design for domestic as well as
Industrial application. They observed different designs & found that excellent design for domestic applications; a single basin single slope passive solar still is more operational and economical, tubular solar still with the wick is the most appropriate design.

III. CONCLUSIONS

The following result are obtained from the present study:-

Black stone used as absorbent the size of stone is also responsible for increasing rate of evaporation. The productivity of black stone is increased by 19.8%, 27.86%, & 33.37 respectively.

1) Solar still provide more productively by using multiple PCM as compared to the conventional solar still.
2) Air fan increases convention, heat transfer and condenser rate inside the solar still. Black cotton bed filled with calcium chloride, using three fan at air speed of 4m/s gives more productivity as 467 ml/m^2 /day compared to natural air circulation.
3) Productivity varies at different water depth. Minimum water depth gives more productivity.
4) Different wick materials such as black cotton cloth acts as a absorber in the basin and provide more productivity. The experimental result revealed that at 0.01mm water depth gives more productivity, with a piece of jute cloth in the lower basin gives the maximum productivity.
5) Increases of brackish water in the basin gives more distillate output.
6) Drum distiller helps to increases evaporative surface area & decreases thickness of saline water film. They provide productivity of 6420L/m^2 which is higher than conventional distiller.
7) Productivity of solar still with and without insulation (external or internal) at 1 cm water depth gives productivity 3.72 & 3.27 Kg/m^2.
8) Increasing the effects of the proposed tubular solar still lead to the rate of water production.
9) Modification in solar still with cooling system and external flat-plate reflector. Provide more productivity cooling system with reflector.
10) The materials such as galvanized steel, upper glazing, black paint etc helps in improving the performance.

IV. FUTURE RESEARCH DIRECTIONS

A. In future modification in the solar still will provide a major role in increasing the productivity. Material like coal cinder acts as heat storage material. The main advantage of coal cinder is to maintain the productivity of solar still in day and night time. By using coal cinder at optimum thickness in basin as absorbant will achieve a higher productivtity in solar still.

B. Dimensions can also be differs to increase the productivity.

C. Researchers can use solar still using various active and passive heat sources like flat plate collector, concentrators, evacuated tube collectors, water heaters, internal & external reflectors can be use for enhancing heat transfer in the basin.

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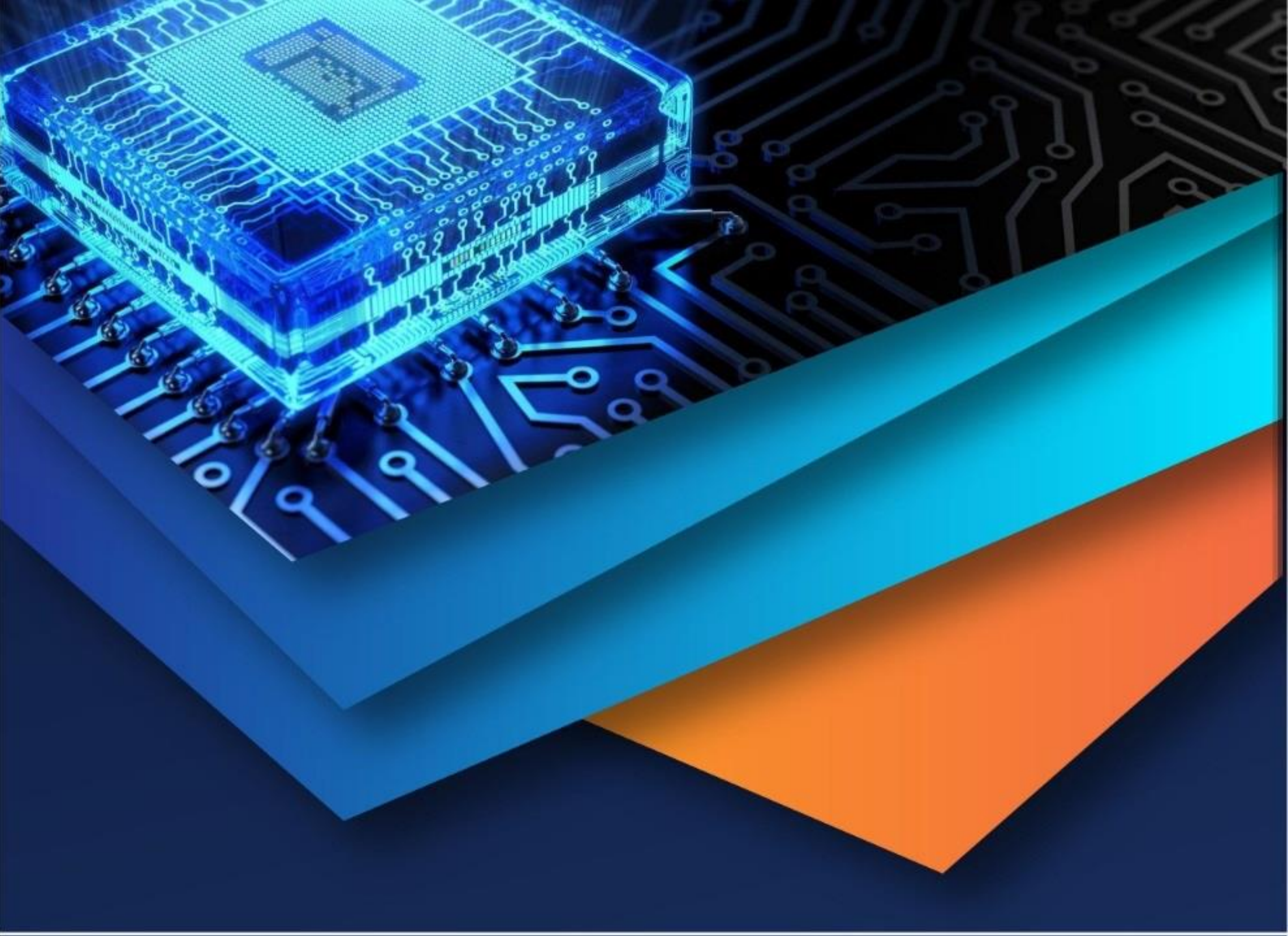

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