Al-Furat Journal of Innovations in Mechanical and Sustainable Energy Engineering (FJIMSE) Published by Al-Furat Al-Awsat Technical University (ATU) / Iraq

A Review on ImprovementTechniques of Freshwater Productivity for Solar Distillation Systems

Hawraa Fadhel[1, a,*], Qahtan A Abed[2,b], Dhafer M. Al-Shamkhee[1,c]

[1]Department of Technical Power Mechanics, Technical EngineeringCollege / Najaf, Al-Furat Al-Awsat Technical University (ATU), Najaf, Iraq

[2]Technical Institute / Al-Rumaitha, Al-Furat Al-Awsat Technical University (ATU), Najaf, Iraq

[a]hawraa.fadhel@student.atu.edu.iq

[b]qahtan.abed@atu.edu.iq

[c]coj.dfr@atu.edu.iq

[*]Corresponding Contact: hawraa.fadhel@student.atu.edu.iq

https://dx.doi.org/10.52262/130221-01

Abstract. Solar desalination is known as a method used to turn brackish into potable water owing to high population density and automation, consumable water demand continues to increase. and the system used for desalination is known as a solar still. The main types of solar stills include active and passive solar stills fresh water is obtained from passive solar stills without the use of high-grade energy(electrical energy). several researchers framed mathematical expressions, performed experiments, and confirmed the outcome of the different types of solar stills This paper analyzed the methodologies used in previous years to enhance the efficiency of active and passive solar stills. using types of absorbent materials, reflectors, and a sun tracking device is introduced the solar energy intensity is maximum and thus improves absorption production by 380%, an overall increase in efficiency of 2% will increase production to around 22% in some research, Through this study, The results showed that the use of wire nets and sand in the container increases the daily output of freshwater by about 3.1%, 13.7% in winter, about 3.4% and 14.1% in summer. It also turns out that the productivity of distillation is 20 L / m^2 over the inverter compared to 5 kg / m^2 in the conventional system. Results also show that the efficiency of the solar still is affected by the kinds, design, and heat storage system.

Keywords: Solar Desalination, Solar Concentrator, External Reflector

1. INTRODUCTION

Solar water desalination is the technique in which salty or brackish water is a very important problem the shortage of freshwater is growing. This problem is increasing continuously, due to changes in weather conditions and population growth, which affect many countries of the world. As the earth contains mostly saline water by more than 97% .therefore, it is possible to use different water treatment processes to produce fresh water from brine the solution to this problem is solar water desalination.

Researcher Hamza et al.[1]study shows that using sponge cubes can greatly enhance daily production, the increase was 255% in the production of distillates compared to the same conditions to a water basin empty from sponge cubes. Yasuhito et al.[2] theoretically studied a basin with external and internal reflectors, an engineering method has been proposed to find the solar radiation reflected by these reflectors, the results showed that the use of these reflexes increases the production of water distillation. Researcher Shukla et.

al.[3] use jute to increase the evaporation output, a tip of jute is placed in the water basin the jute deck over the sink was an exhibit to sunlight the evaluation was done based on outer and inner cover temperatures, the experimental results showed agreement with theoretical results using internal heat transfer factors.

Hassan et. al.[4]made an experiment in the gradient solar energy and adopted the internal negative capacitor and stored the phase change energy, and the commixture would condense the glass plate, the commixture is an admixture of paraffin wax, water, and paraffin oil in a certain proportion this substance was added to aid in conduction heat transfer, to get persistence desalination of water even after sunset, the operational, environmental and design criteria were also examined on the constant efficiency and productivity, the outcome indicated that the adoption of energy storage materials greatly improves the steady yield of 5.2kg/m^2/day. Sebaii et.al.[5] used a storage medium as phase change material (PCM), for single-slope monophasic solar without PCM under the distillation tank liner, utilizing computer simulations, the static performance was examined and numerical calculations were made, using a fatty acid like PCM, the results were obtained, increased production at night and decreased production at day because found that after sunset, and using integrated solar energy PCM, water efficiency was achieved at 84.3% in summer, this paper aims at how to improve the efficiency of solar distillation by using different techniques to produce freshwaters, such as choosing the best angle of inclination of the glass cover, and using the sun tracking system to increase the ability to capture solar energy and obtain better results, and using the types and materials of the absorbent part, as well as knowledge of the technology of using a solar capacitor or an external reflector.

Velmurugan et al.[6]used to combine the fins (size of 900*35*1mm^3) in the stator basin, and a sponge (size 20*35*35mm^3) was used to increase exposure to the water surface, and the energy balance equations were solved and compared with the experimental results, showing through the results, the productivity will increase from 1.88 to 2.8 kg / m^2 / day.Rahim et al. [7] suggested an approach to conserve surplus energy during the daytime in a traditional still that can be used to resume evaporation at night, the heat storage capacity of the water was around 35 % of the overall volume of solar energy entering the remaining water. Kalidasa et al.[8] used wick materials such as light cotton fabric, light jute cloth, and sponge layer of 2 mm thickness and porous materials such as the washed natural rock of average size 3/8 'x 1/4' and quartzite size 3/8' as spreading materials are compared to the efficiency of the still. The findings indicate that the still with blacklight cotton cloth as spread material is found to be more effective.

Voropoulos et al. [9] combined a conventional solar energy storage unit with a field to collect solar energy and conduct tests as well as a hot water storage tank, the result shows that if it is combined with the solar collector field and hot water storage tank, the performance of conventional solar energy can still be greatly improved, drawing a volume of hot water equal to 1/4, 1/2, or the volume of one tank reduces the distilled water output by 36%, 57%, or 75% respectively. Qeblawi et al. [10] described different desalination techniques for use in remote areas such as, the direct method and the indirect method were determined, the direct approach is used to directly manufacture the distillate limited need for water in the solar collector, the indirect approach consists of many processes, such as multi-stage flashing desalination, steam pressure, reverse osmosis, membrane distillation, etc. Abdullah et al [11] examined the experimental outputs with a solar air heater of graduated solar energy sources negative solar slope, under a graded foundation still used for saltwater heating, hot air flows from the solar air heater, their results revealed that when connecting the solar air heater and cooling the glass cover, for the gradient solar heating, the water efficiency was 112 % greater than traditional distillation.

2. IMPROVEMENT METHODS OF SOLAR DISTILLATION

Solar achievement continues to be affected by operation and design. research work is to boost solar distillation production the techniques by which good performance is obtained are shown. this paper contains, how to work on modification the tilt of the glass cover to the sun and sun pursuing system, thermal energy and storage types as well as types of absorbents and materials.

2.1. The Tilt Angle of Glass Cover

The evaporating water from the tank still comes into touch with the inner roof of the glass aquarium lid condenses along the inclined surface of the aquarium. Then water is distilled from the condensed steam in a pool below the edge of the glass cover plate. The collector capacitors are free from all impurities. and tilt angle of the glass cover is an important factor determining solar energy performance.

Tiwar et.al.[12]studied how to optimize the slope of the glass cover as well as studying the relationship and the glass and water cover temperature. Note that the valuable points for paperwork are the greater the slope, the greater the yield in winter, and in summer the opposite is true, the tendency of the optimum glass cover is 101 depending on the Delhi climate the angle is bigger in winter. Abdul-Jabbar [13] investigated the angle of the tendency of the cover and affected on throughput, the relationship between the simple solar energy output is still indifferent, and tilt angle cover results show from the research is that as the angle of inclination increases, the yield decreases and increases heat losses from the cover due to increased reflected radiation, as shown in Figure 1.

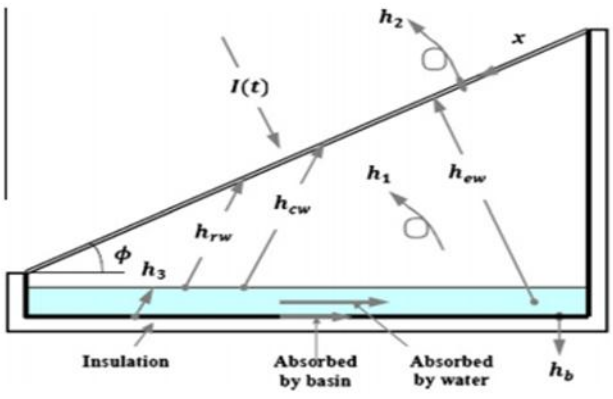

Figure 1. Diagram Showing the Power Flow of a Simple Solar System[13]

Samuel et. al.[14]studied experimentally, how an oblique type of solar energy could operate with chains of different materials on different absorber plate configurations,(Wool, jute, nylon, charcoal cloth, coconut fiber, waste cotton, water coral wool, cotton). Many experimental and digital studies were conducted on various configurations of solar collectors for optimum design an important parameter is the angle of inclination, different investigators have used different angles of inclination for the glass cover where were the tilt angles of the cover as low as 4 °[14,15].

2.2. Sun Tracking System

Conventional solar power has its major drawback is its low quantity of distilled water per unit area, so the performance of conventional solar energy should be improved still by the combined action of the still sun and the sun-tracking device to larger the ability to capture solar energy. Ibrahim et.al.[17]designed a uniaxial sun-tracking device, depend on the RS 485, that the data is plotted as a graph and the monitoring is on a computer screen, the results obtained indicate that the solar collectors with a stationary device are less efficient than the device that adopts solar tracking devices, as shown in Figure 2.

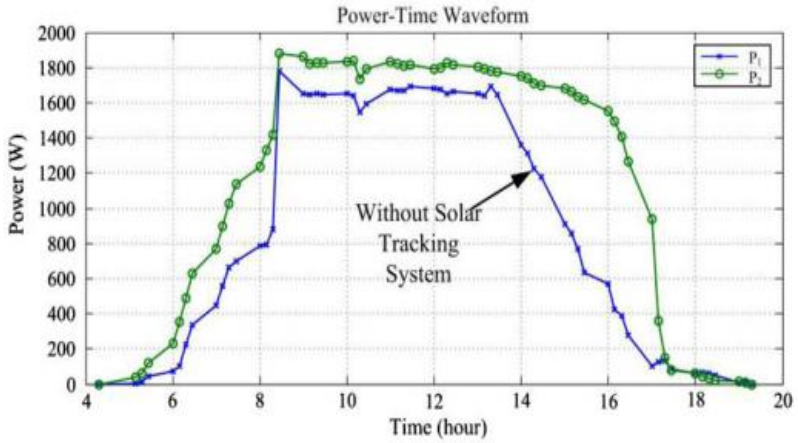

Figure 2. An Altered Relationship Between the Immovable System and The Sun-Tracking System[17]

Conducted by researchers Salah et. al. [18]three adjustments in one slope solar energy is still like (1) introducing reflective mirrors, through which output increases 30%, (2) instead of a traditional flat sink, a tiered basin is inserted, which causes increase the surface area by 40% and this leads to increased heat transfer so that the productivity is improved to 180%, and(3) to sense the direction, the sun tracking system is introduced the solar energy intensity is maximum and thus improves absorption production by 380%. Use the researcher Abdullah et al.[19] the system moves with the sun to rotate the still sun, a comparison of sunlight and static solar tracking shots showed that the use of sun-tracking was due to an overall increase in efficiency of 2%. The output will increase to about 22%, has been proven that the stationary device is less effective than the sun tracking device, as shown in Figure 3.

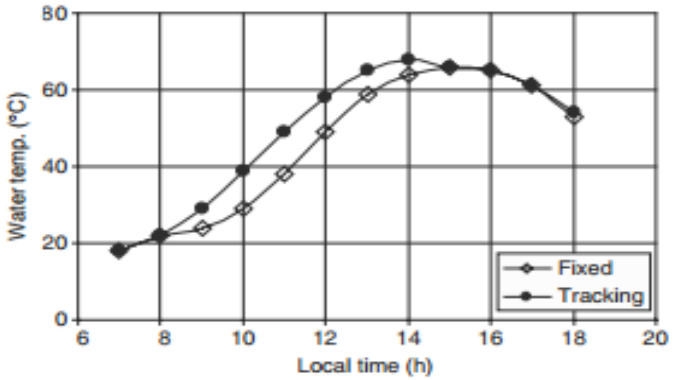

Figure 3. Temperature Change of Water Basin for Both Fixed and Sun Tracking System [19]

Kalogirou [20] description of the sun-tracking device with uniaxial solar capacitors, the sun, and its state are determined by the three resistors; the first shows if the collector is concentrate, the second shows if there is a cloud, and the last shows if it is night or not.

2.3. Thermal Energy Storage Type

Thermal energy storage (TES) has three types, depending on if the temperature is reasonable, latent, or chemical.
Sensible thermal storage the test is done by increasing the temperature of the storage medium to the degree of heating. The storage medium absorbs energy and releases it as the temperature decreases and increases, and the sensible heat is stored either in a liquid or solid medium.

The latent heat has to do with phase changes. The energy needed through charging is used to change a liquid into a gas or a solid into a liquid as paraffin wax, these materials have the highest heat capacity but their disadvantage is poor performance.

Chemical reactions that absorb heat require a certain temperature so that in a reversible chemical reaction a chemical product is separated. the evolution of these interactions is already at an early very phase and since the temperature of the interaction must include the discharge and charge temperature of the Heat transfer fluid, from research it was found that the best option is to use reasonable storage of heat, such as molten salt and pressurized water [21].

Gang [22] reviewed possible technologies for storing reasonable heat under change work conditions. The factors affecting the external energy performance as well as energy were investigated. the performance was compared with the latent thermal storage system. this research is important for engineers and researchers to obtain a more efficient design and reasonable storage systems, as shown in Figure 4.

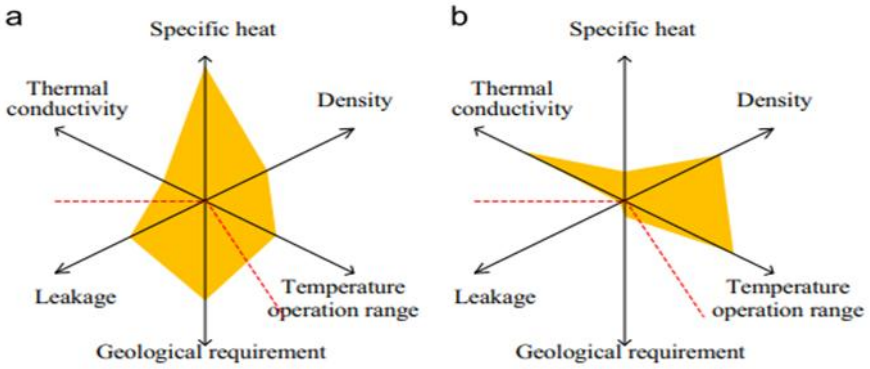

Figure 4. Diagram Showing the Comparison Between Sensible Thermal Materials' Heat Properties [22]

Lugolole et. al.[23] compared and evaluated three plausible heat storage systems with 3 change flow rates of (12,8,4) mL / s. use liquid sunflower oil to transfer heat, also use small pebbles to Thermal Energy Storage (TES) finally, large-sized pebbles. It was found by the results that the pebbles are large it is slower to increase the temperature compared to small pebbles which are faster to increase the temperature because they reach thermal equilibrium easily, as shown in Figure 5.

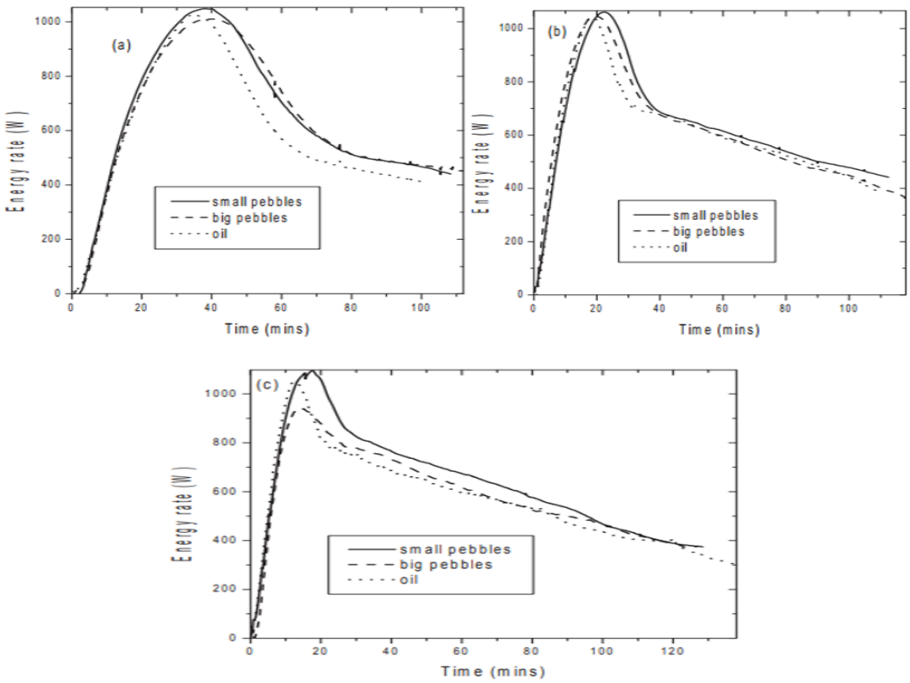

Figure 5. Diagram Showing the Energy Average Profiles for the Three Sensible Thermal Storage Devices During 260 ° C and Changed Flow Rates: (4,8,12) mL / s, [23]

2.4. Types and Materials of the Absorbing Part

Energy storage materials release heat through night timepieces and store through sunshine timepieces, after which the distillate from solar distillation increases by using different energy-absorbing materials.

2.4.1. Dyes Type

Use Sodha and et. al.[24]violet, black dyes, and other dyes for investigation influence of dye on the work of the solar distillation apparatus, where it was found in the results that the black and violet dyes are larger effects than other dyes, it increases the yield of the shredder.

2.4.2. Absorbing Material is Mica Plate

Sebaii et.al.[25] used mica plates as absorbent material suspended in one solar basin during the experiment. The still monocrystalline solar with suspended absorption, productivity conventional still is about 15-20% less daily productivity when using sheet metal as suspended absorbers.

2.4.3. Aluminum Absorber Sheet

Use Rahim [7] a heat storage component of aluminum sheets, by placing a sheet of aluminum black coated on the upper roof and thermally separated on the lower 25 mm under the water standard creates a heat storage area, results after the experiment found that the rated efficiency and productivity of the device is greater than that of shallow ponds.

2.4.4. Porous Absorbers Material (Blacked Jute Cloth)

Use Pankaj et .al.[26] pored absorbers are built of the jute cloth is black and is heat-insulated as an energy storage material in solar distillation where, on clear days, approximately 68% distillation is obtained, and 35% of the cloudy days are obtained, as shown in Figure 6.

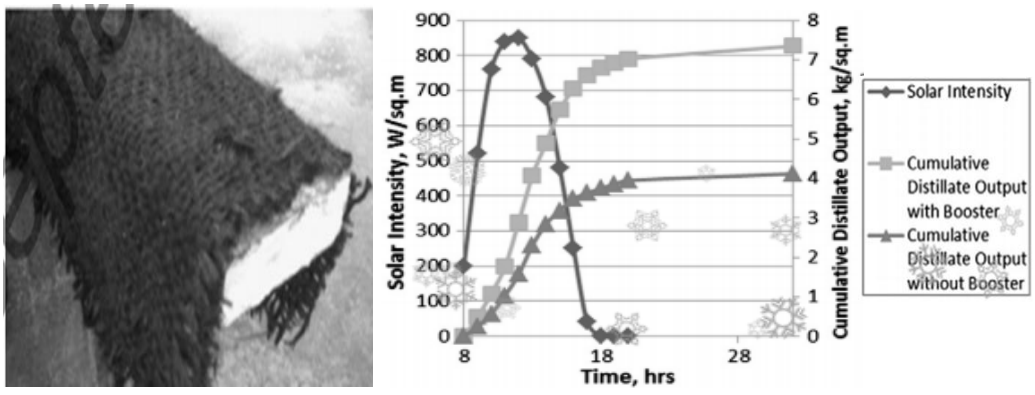

Figure 6. Porous Absorbent on Heat Insulator[26].

3. TECHNIQUE OF USING SOLAR CONCENTRATOR OR EXTERNAL REFLECTOR

An external inverter is used to boost the power input to the climbed still. Reflecting an external reflector part of the radiation, whether it is upper or lower, on the roof of the water, which increases the temperature of the glass and the water a solar concentrator is a mechanism that collects sunlight across the largest area and then reflects this light onto a receiver.

3.1. Integration of External Reflector with Distillation Systems

Bahi et al. [16] did an integrated still check with an external capacitor, a reflector build of stainless steel, and this reflector has been added to the glass lid to reverse the radiation in the static image of the basin and to grant shade to the condenser through the glass lid. The study showed that solar energy efficiency still exists they hardened to approximately 70% and the daily yield was 7 L / m^2 a day, as shown in Figure 7.

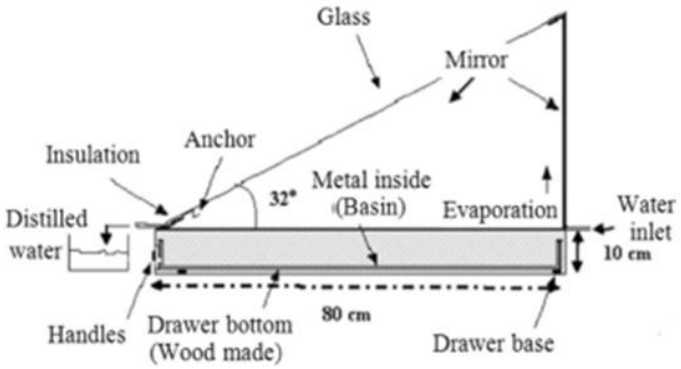

Figure 7.A BowlSolar Still and Internal Reflectors (IRs)[16]

Madhlopa et al.[27] suggested an account of the distribution of solar radiation is a model inside a traditional apparatus equipped with a reflector and an external capacitor. the system contains three pans, one inch an evaporation room, and two bowls in the condenser room, above the evaporator bowl, is a glass cap as well as an opaque condenser cap above the third bowl, water steam condensing from the first bowl down the glass cap and the rest flows to the condenser through disinfection, diffusion, and condensation down the liner from the second bowl, it was located that the freshwater nearly 2.2 kg /m^2 day, as shown in Figure 8.

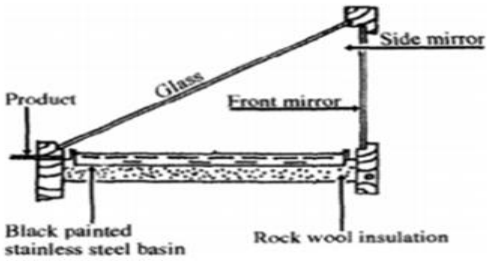

Figure 8.A BowlSolar Still and FoundInternal Reflector (IRs) [27]

Shanmugan and et. al.[28] attached a reinforced (acrylic) mirror directly over the glass a cap of solar distillation, which reverses the solar radiation, and to obtain an ideal reflection the mirror can be adjusted according to the angle of movement of the sun, as shown in Figure 9.

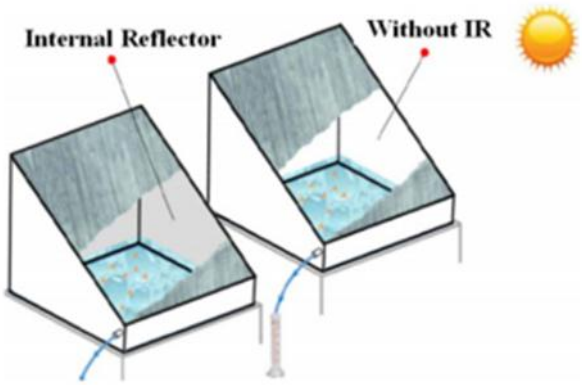

Figure 9.A Monocular- Incline Solar Still and Internal Reflector (IRs) [28]

Sebaii [29] have been used outside mirrors to check the work of a single-incline double slope solar bowl, whereas, the rapid damage that occurs to the interior mirrors within solar distillation has been identified. It was found that there is an increase in the incident radiation using the outside mirrors, as shown in Figure 10.

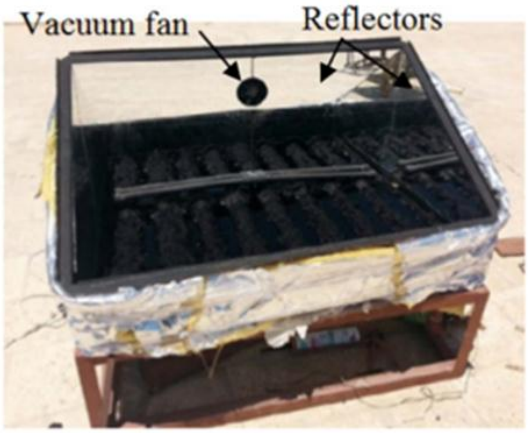

Figure 10. Reflectors and Vacuum Fan and There Corrugated Wick Solar Still [29]

Researcher Hiroshi et al.[30] achieved a sophisticated system this system consists of wheels for manual azimuth tracking and reflector flat plate, multi-effect vertical diffusion still type, it showed their results the corner of the plane sheet reflector must be stable at nearly 10 degrees along the year, as shown in Figure 11.

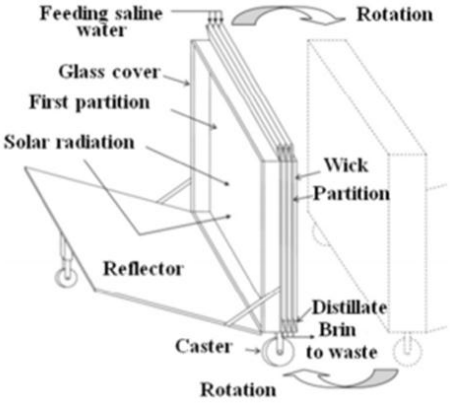

Figure 11.Diffusion Type Solar Still and External Reflector (ER) [30]

Yasser et.al.[31] have been conducted experiments with solar energy desalination an evacuation-based system containing a concave mirror used to focus the solar energy, Figure 12, through the results, it appeared that the productivity of distillation is 20 liters /m^2a when utilizing the reflector compared to 5 kg/m^2 in the conventional system. the outcome appears that output was still the same nearly 303%.

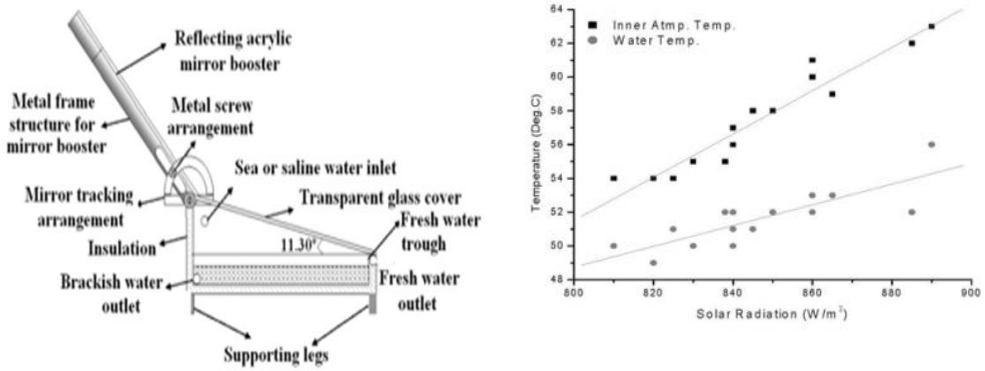

Figure 12.View Mirror Booster with Solar Distillation Unit[31]

Kabeel et al [32]experimental attempts are made by using nanofluids to improve the efficiency of the solar still and also by combining the still basin with the external condenser, which acts as additional and powerful heat and mass drain through convection from water to glass. The findings show that the solar integration with the external condenser still raises the yield of distillate water by around 53.2 %.

3.2. Integration of Concentrating with Distillation Systems

The use of direct sunlight for desalination has long been used by solar distillation plants for small communities to provide desalinated water near remote coastal areas, simple to operate when unskilled Personnel, maintenance requirements are not difficult and there is no running cost but there are

disadvantages of high cost, and for a conventional basin, the productivity is zero when there is no sunlight [33].

Jamel et.al.[34] experimentally studied the impact of incorporating a flat plate collector and the work of conventional single incline solar distillation in addition to the parabolic trough collector supported by a glass-filled spherical layer, which serves as a heat storage middle for the devices, the results show that solar energy combined with Parabolic trough collector, Flat Plate Collector, and heat storage middle has a maximum freshwater output rate of 2.775 kg/m^2/day through winter and 6.036 kg/m^2though summer.

Hamdi et. al. [35] have been worked experimentally to project the effect of middle from saltwater on the work of dual-action solar energy using a parabolic trough collector. Three media of saltwater was utilized in the bowl: steel wire mesh, clear saltwater, and sand impregnated with saltwater. The results show that the use of wire nets and sand larger the daily output of freshwater by nearly 3.1%, 13.7% in winter, nearly 3.4%, and 14.1% in summer. Hamdy et.al. [36] experimentally conducted the effect of brine middle and capacitor kind on single slope work of solar energy. Two types of static solar are checked; A conventional solar stator fitted with a glass condenser and a still solar fitted with a flipper coated heat sink condenser. The results show that the use of a wire reticulum condenser, and heat dispersed and sand condenser larger the freshwater output and efficiency. Mohamed et.al.[37] have been performed experimental research on the coupling work of the parabolic trough collector with a compound slope solar apparatus, the fallen solar energy on the Parabolic Trough Collector is conveyed to the solar power from during means of oil tubes linked to a toroidal heat exchanger with finned tubes embedded in the solar devices. The results show that conventional solar freezers have lower temperature and lower throughput compared to stationary solar power with higher temperature and higher throughput of PTC. Lourdes et al [38] suggested and commercially tested distillation into a solar parabolic trough collector, Pure vapor, which boils as it circulates through the solar collectors, is the thermal fluid of the solar region. This solar distillation system is compared to multi-effect plants connected to traditional fossil fuel-powered collector areas with parabolic troughs and distillation plants, the findings obtained help find the most acceptable conditions for solar energy in solar desalination with traditional energies.

Nafey et al. [39] studied a co-solar organic Rankin cycle using reverse osmosis and using different heat transfer fluids (toluene, water, hexane, and butane), the results showed the superiority of toluene and water as working fluids, efficiency compared to hexane and butane at increased temperature. Rahul et al.[40] designed Solar thermal active device "Integrated Tubular Solar Collector" this modernized device can process 630 kg/m^2 of distilled water annually, compared to 327 kg/m^2 of distilled water per year from one solar slope. The current maximum overall thermal efficiency of 30.1% is foundThe annual average was found to be 21.3 %.

4. CONCLUSIONS

More researches need to be performed to enhance freshwater output for solar distillation devices, the key points are explained below.

1. Any method in the desalination process to store heat utilizing solar energy is effective by:
    - Sebaii et.al.Prove that the charcoal particles work a good absorption medium produces about 15% more yields.
    - Pankaj and et .al have been pored absorbers are built of the jute cloth is black approximately 68% distillation is obtained, and 35% of the cloudy days are obtained

- Use Rahim a heat storage component of aluminum sheets, results after the experiment found that the rated efficiency and productivity of the device is greater than that of shallow ponds

2. The annual sun yield remains at condensation the incline of the glass cap is equal to the latitude of the place.
3. Abdullah and et al showed The sun-tracking device is a device with higher efficiency than a stationary device it can improve the output of the shredder by about 22%.
4. Researcher Yasser et al conclude if using an evacuation-based system with a concave mirror utilize to focus the solar energy, the distillation output would be 20 L/m^2 when utilizing an inverter compared to 5 kg/m^2 in a conventional system. Also, Jamal, Hamdi et al using the distillation device with solar concentrates, the maximum freshwater production rate is 2.775 kg/m^2/day during the winter and 6.036 kg/m^2during the summer. The results showed that the use of wire nets and sand in the distillation apparatus increases the daily output of freshwater by about 3.1% and 13.7% in the winter and about 3.4% and 14.1% in the summer.

REFERENCES

[1] B. A. K. Abu-Hijleh, M. Abu-Qudias, and S. Al-Khateeb, "Experimental study of a solar still with screens in basin," *Int. J. Sol. Energy*, vol. 21, no. 4, pp. 257–266, 2001, doi: 10.1080/01425910108914374.

[2] H. Tanaka and Y. Nakatake, "Theoretical analysis of a basin type solar still with internal and external reflectors," *Desalination*, vol. 197, no. 1–3, pp. 205–216, 2006, doi: 10.1016/j.desal.2006.01.017.

[3] S. K. Shukla and V. P. S. Sorayan, "Thermal modeling of solar stills: An experimental validation," *Renew. Energy*, vol. 30, no. 5, pp. 683–699, 2005, doi: 10.1016/j.renene.2004.03.009.

[4] H. E. S. Fath, S. Elsherbiny, and A. Ghazy, "A naturally circulated humidifying/dehumidifying solar still with a built-in passive condenser," *Desalination*, vol. 169, no. 2, pp. 129–149, 2004, doi: 10.1016/S0011-9164(04)00521-1.

[5] A. A. El-Sebaii, A. A. Al-Ghamdi, F. S. Al-Hazmi, and A. S. Faidah, "Thermal performance of a single basin solar still with PCM as a storage medium," *Appl. Energy*, vol. 86, no. 7–8, pp. 1187–1195, 2009, doi: 10.1016/j.apenergy.2008.10.014.

[6] V. Velmurugan, M. Gopalakrishnan, R. Raghu, and K. Srithar, "Single basin solar still with fin for enhancing productivity," *Energy Convers. Manag.*, vol. 49, no. 10, pp. 2602–2608, 2008, doi: 10.1016/j.enconman.2008.05.010.

[7] N. H. A. Rahim, "New method to store heat energy in horizontal solar desalination still : Rahim, N. H. A. Renewable Energy, 2003, 28, (3), 419–433," *Fuel Energy Abstr.*, vol. 44, no. 4, p. 236, 2003, [Online]. Available: http://www.sciencedirect.com/science/article/pii/S014067010383000X.

[8] K. Kalidasa Murugavel, K. K. S. K. Chockalingam, and K. Srithar, "An experimental study on single basin double slope simulation solar still with thin layer of water in the basin," *Desalination*, vol. 220, no. 1–3, pp. 687–693, 2008, doi: 10.1016/j.desal.2007.01.063.

[9] K. Voropoulos, E. Mathioulakis, and V. Belessiotis, "A hybrid solar desalination and water heating system," *Desalination*, vol. 164, no. 2, pp. 189–195, 2004, doi: 10.1016/S0011-9164(04)00177-8.

[10] H. M. Qiblawey and F. Banat, "Solar thermal desalination technologies," *Desalination*, vol. 220, no. 1–3, pp. 633–644, 2008, doi: 10.1016/j.desal.2007.01.059.

[11] A. S. Abdullah, "Improving the performance of stepped solar still," *Desalination*, vol. 319, pp. 60–65, 2013, doi: 10.1016/j.desal.2013.04.003.

[12] G. N. Tiwari, J. M. Thomas, and E. Khan, "Optimisation of glass cover inclination for maximum yield in a solar still," *Heat Recover. Syst. CHP*, vol. 14, no. 4, pp. 447–455, 1994, doi: 10.1016/0890-4332(94)90048-5.

[13] A. J. N. Khalifa, "On the effect of cover tilt angle of the simple solar still on its productivity in different seasons and latitudes," *Energy Convers. Manag.*, vol. 52, no. 1, pp. 431–436, 2011, doi: 10.1016/j.enconman.2010.07.018.

[14] R. S. Hansen, C. S. Narayanan, and K. K. Murugavel, "Performance analysis on inclined solar still with different new wick materials and wire mesh," *Desalination*, vol. 358, pp. 1–8, 2015, doi: 10.1016/j.desal.2014.12.006.

[15] M. A. Porta, N. Chargoy, and J. L. Fernández, "Extreme operating conditions in shallow solar stills," *Sol. Energy*, vol. 61, no. 4, pp. 279–286, 1997, doi: 10.1016/S0038-092X(97)00051-0.

[16] A. El-Bahi and D. Inan, "A solar still with minimum inclination, coupled to an outside condenser," *Desalination*, vol. 123, no. 1, pp. 79–83, 1999, doi: 10.1016/S0011-9164(99)00061-2.

[17] I. Sefa, M. Demirtas, and I. Çolak, "Application of one-axis sun tracking system," *Energy Convers. Manag.*, vol. 50, no. 11, pp. 2709–2718, 2009, doi: 10.1016/j.enconman.2009.06.018.

[18] S. Abdallah, O. Badran, and M. M. Abu-Khader, "Performance evaluation of a modified design of a single slope solar still," *Desalination*, vol. 219, no. 1–3, pp. 222–230, 2008, doi: 10.1016/j.desal.2007.05.015.

[19] S. Abdallah and O. O. Badran, "Sun tracking system for productivity enhancement of solar still," *Desalination*, vol. 220, no. 1–3, pp. 669–676, 2008, doi: 10.1016/j.desal.2007.02.047.

[20] S. A. Kalogirou, "Design and construction of a one-axis sun-tracking system," *Sol. Energy*, vol. 57, no. 6, pp. 465–469, 1996, doi: 10.1016/S0038-092X(96)00135-1.

[21] A. Gil *et al.*, "State of the art on high temperature thermal energy storage for power generation. Part 1-Concepts, materials and modellization," *Renew. Sustain. Energy Rev.*, vol. 14, no. 1, pp. 31–55, 2010, doi: 10.1016/j.rser.2009.07.035.

[22] G. Li, "Sensible heat thermal storage energy and exergy performance evaluations," *Renew. Sustain. Energy Rev.*, vol. 53, pp. 897–923, 2016, doi: 10.1016/j.rser.2015.09.006.

[23] R. Lugolole, A. Mawire, K. A. Lentswe, D. Okello, and K. Nyeinga, "Thermal performance comparison of three sensible heat thermal energy storage systems during charging cycles," *Sustain. Energy Technol. Assessments*, vol. 30, no. July, pp. 37–51, 2018, doi: 10.1016/j.seta.2018.09.002.

[24] M. S. Sodha, A. Kumar, G. N. Tiwari, and G. C. Pandey, "Effects of dye on the performance of a solar still," *Appl. Energy*, vol. 7, no. 1–3, pp. 147–162, 1980, doi: 10.1016/0306-2619(80)90055-0.

[25] A. A. El-Sebaii, S. Aboul-Enein, M. R. I. Ramadan, and E El-Bialy, "Year-round performance of a modified single-basin solar still with mica plate as a suspended absorber," *Energy*, vol. 25, no. 1, pp. 35–49, 2000, doi: 10.1016/S0360-5442(99)00037-7.

[26] P. K. Srivastava and S. K. Agrawal, "Experimental and theoretical analysis of single sloped basin type solar still consisting of multiple low thermal inertia floating porous absorbers," *Desalination*, vol. 311, pp. 198–205, 2013, doi: 10.1016/j.desal.2012.11.035.

[27] A. Madhlopa and C. M. Johnstone, "Computation of solar radiation distribution in a solar still with internal and external reflectors," *Sol. Energy*, vol. 85, no. 2, pp. 217–233, 2011, doi: 10.1016/j.solener.2010.12.010.

[28] S. Shanmugan, P. Rajamohan, and D. Mutharasu, "Performance study on an acrylic mirror boosted solar distillation unit utilizing seawater," *Desalination*, vol. 230, no. 1–3, pp. 281–287, 2008, doi: 10.1016/j.desal.2007.12.004.

[29] T. Eprijournal, "07 Alternative energy sources (solar energy)," *Fuel Energy Abstr.*, no. November, pp. 2000–2000, 2000.

[30] H. Tanaka and Y. Nakatake, "Factors influencing the productivity of a multiple-effect diffusion-type solar still coupled with a flat plate reflector," *Desalination*, vol. 186, no. 1–3, pp. 299–310, 2005, doi: 10.1016/j.desal.2005.07.005.

[31] Y. F. Nassar, S. A. Yousif, and A. A. Salem, "The second generation of the solar desalination systems," *Desalination*, vol. 209, no. 1-3 SPEC. ISS., pp. 177–181, 2007, doi: 10.1016/j.desal.2007.04.039.

[32] A. E. Kabeel, Z. M. Omara, and F. A. Essa, "Enhancement of modified solar still integrated with external condenser using nanofluids: An experimental approach," *Energy Convers. Manag.*, vol. 78, pp. 493–498, 2014, doi: 10.1016/j.enconman.2013.11.013.

[33] A. Bhattacharyya, "Solar Stills for Desalination of Water in Rural Households," *Int. J. Environ. Sustain.*, vol. 2, no. 1, pp. 21–30, 2013, doi: 10.24102/ijes.v2i1.326.

[34] J. Madiouli, A. Lashin, I. Shigidi, I. A. Badruddin, and A. Kessentini, "Experimental study and evaluation of single slope solar still combined with flat plate collector, parabolic trough and packed

bed," *Sol. Energy*, vol. 196, no. October 2019, pp. 358–366, 2020, doi: 10.1016/j.solener.2019.12.027.

[35] H. Hassan, M. S. Ahmed, and M. Fathy, "Experimental work on the effect of saline water medium on the performance of solar still with tracked parabolic trough collector (TPTC)," *Renew. Energy*, vol. 135, pp. 136–147, 2019, doi: 10.1016/j.renene.2018.11.112.

[36] H. Hassan, M. S. Ahmed, M. Fathy, and M. S. Yousef, "Impact of salty water medium and condenser on the performance of single acting solar still incorporated with parabolic trough collector," *Desalination*, vol. 480, no. January, p. 114324, 2020, doi: 10.1016/j.desal.2020.114324.

[37] M. Fathy, H. Hassan, and M. Salem Ahmed, "Experimental study on the effect of coupling parabolic trough collector with double slope solar still on its performance," *Sol. Energy*, vol. 163, no. January, pp. 54–61, 2018, doi: 10.1016/j.solener.2018.01.043.

[38] L. García-Rodríguez, A. I. Palmero-Marrero, and C. Gómez-Camacho, "Application of direct steam generation into a solar parabolic trough collector to multieffect distillation," *Desalination*, vol. 125, no. 1–3, pp. 139–145, 1999, doi: 10.1016/S0011-9164(99)00132-0.

[39] A. S. Nafey and M. A. Sharaf, "Combined solar organic Rankine cycle with reverse osmosis desalination process: Energy, exergy, and cost evaluations," *Renew. Energy*, vol. 35, no. 11, pp. 2571–2580, 2010, doi: 10.1016/j.renene.2010.03.034.

[40] R. Dev and G. N. Tiwari, "Annual performance of evacuated tubular collector integrated solar still," *Desalin. Water Treat.*, vol. 41, no. 1–3, pp. 204–223, 2012, doi: 10.1080/19443994.2012.664715.