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SOLAR DISTILLATION SYSTEM WITH NANO PARTICLE: A REVIEW

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ABSTRACT: For all living entities water is the basic requirement. Ponds, lakes, rivers and underground water are major resources for fresh water. We know that availability of fresh water on the earth is very limited. Due to overpopulation and industrialization, the requirement of fresh water increases day by day. The ocean water has high saline content, hence it needs to be desaline first (Panchal & Patel, 2017). In this present review, we have discussed different desalination methods and improvements, which are needed to commercialize these methods. Also, we have discussed different parameters that affect the performance of distillation system. From different desalination techniques and desalination method which integrates with renewable sources, we can summarize that solar desalination is most effective technique as it does not require external power or any other conventional energy sources. Solar desalination is also effective at remotely located area, where energy and water are not easily accessible or costly to meet the requirements of people. A lot of investigations and research have been carried out and much more are ongoing. In solar distillation system, the major disadvantage is that it has low productivity; so optimization of certain parameters is required to enhance the productivity of the system. The recent researches are based on the concept of Nanotechnology. Few researchers have studied the effect of Nano fluid on the productivity and they found that it shows positive effects on the output of the distilled water.

KEYWORDS

Solar Distillation, Passive Solar Still, Nano Fluid

Introduction

Potable water is the basic need of every human being for their daily livelihood. A person living in remote areas or islands, where fresh water supply by transport is expensive, faces the problem of water shortage every day. Many methods are used to purify the dirty water but all such methods require a significant amount of energy. The energy resources such as oil, natural gas and electricity used in water purification process, have both high cost and environmentally hazardous. The modern studies carried out in recent years, focused on increase the use of renewable energy resources as an energy source for purification of water. Desalination is one of the methods for water purification.

Water Salinity based on dissolved salts			
Fresh Water	Brackish Water	Saline Water	Brine
<0.05%	0.05 - 3%	3 - 5%	>5%

TABLE 1. Level of Water salinity in different water solution (Gupta, Mandraha, Edla, Pandya, 2013)

Different types of desalination techniques are used to purify water. It can be classified according to the source of energy used like; thermal, mechanical, electrical and chemical energy and various processes like evaporation, condensation, crystallization, and filtration techniques. Few of the desalination technologies are still under development like a solar chimney, greenhouse, membrane distillation, membrane bioreactor (MBR), forward osmosis (FO) and ion exchange resin (IXR). Largely implemented distillation technologies are the reverse osmosis (RO) method followed by multistage flashing (MSF) and multi-effects desalination (MED) systems. Along with the productivity of system, it is important to know the amount of conventional energy required by the desalination processes to understand why we need to move toward the renewable and sustainable energy resources. In the global warming phenomenon, the contribution of the conventional desalination systems can be assessed by estimating the amount of the fossil fuel needed to be burned to produce a certain amount of fresh water. In the average, producing 1000 cubic meters of freshwater by desalination technology consumes about 5 tons of crude oil which produces about 10 tons of carbon dioxide or about 5000 cubic meters of greenhouse gases. The total global desalination capacity has witnessed a severe increase within the last few years, from 66.48 million cubic meters per day in 2011 to 86.6 million cubic meters per day in 2015. Therefore, important forward steps toward integrating the desalination systems with the renewable and sustainable energy technologies are required to mitigate the negative effects of the desalination systems. (Alkaisi, Mossad & Sharifian-Barforoush, 2017).

Solar Still (SS) presents certain advantages due to its like easy construction, minimum skills for operation and maintenance of equipment as well as environment-friendly make it more acceptable to be used in these areas. The clean free energy and environment-friendly are two major advantages which strengthen the use of solar stills. The low yield of freshwater is the crucial disadvantage of SS in comparison with the other desalination systems. The average production capacity for a simple type solar still is only between 2–5 l/m^2/day. This makes the SS uneconomical compared to the other conventional desalination systems (Velmurugana & Srithar, 2011).

The basic principle of solar water distillation is very simple, yet effective, as distillation replicates the way nature makes rain. The sun's energy heats water to the evaporation temperature. As the water evaporates, water vapor generates. That vaporises and condenses on the glass surface for collection. This process removes impurities, such as salts and heavy metals, and eliminates microbiological organisms.

In the latest research, we find the application of Nanoparticle to enhance the productivity of SS. Nano-fluid has energy-absorbing properties due to which night productivity in both the cases of SS increased, due to the fact that at the time of high radiation, it absorbs energy and when it is needed, released it to the system (Velmurugan, Gopalakrishnan, Raghu & Srithar, 2008).

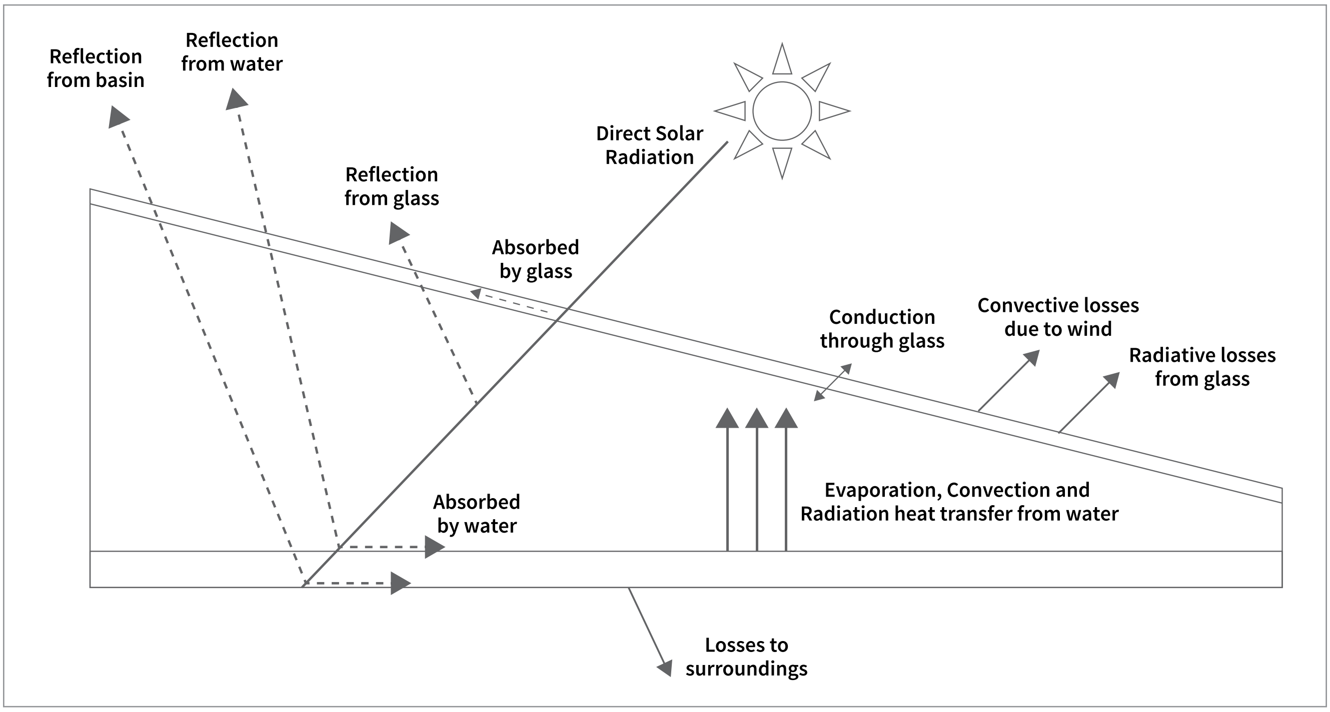

FIGURE 1. Simple solar water distillation process

No.	Name of the author	Enhancement method	% increase in production
1	El-Sebaii, Aboul-Enein & El-Bialy (2000)	Baffle suspended absorber	20%
2.	Nafey, Abdelkader, Abdelmotalip & Mabrouk (2001)	Black rubber with black gravel	20%
3.	Nafey, Abdelkader, Abdelmotalip & Mabrouk (2002)	Floating perforated plate	40%
4.	Hijileh Bassam & Rababa (2003)	Addition of Sponge	18%
5.	Badran Ali, Al-Hallaq Ahmad, Eyal & Odat (2005)	Solar still meshed with flat plate collector	52%
6.	Velmurugan et al. (2008)	Attachment of Fin	45.50%

TABLE 2. Percentage increase in production for various modifications

Several researchers have reviewed thoroughly on the recent work of solar stills such as classification of solar stills, design of solar stills, improvement techniques of solar stills, passive solar stills, active solar stills, inclined solar stills, stepped solar stills, wick type solar stills, and condensers with solar stills (Omara, Kabeel & Abdullah, 2017). The comparison of the performance of previous researcher's works is depicted in table 2 with reference to simple solar still.

Comprehensive reviews of different researchers on the development of Solar Still (SS)

Tanaka & Iishi (2017) researched on a single-effect diffusion still, instead of a multiple-effect diffusion still, combined with a tilted wick still was investigated experimentally. He was found that the single-effect still can be heated by vapor from the tilted wick still and solar radiation absorbed on the single-effect still. Thakur, Khandelwal & Sharma (2018) had been studied different methods of enhancing the productivity of solar still. Comparison of productivity of simple solar still having a water depth of 0.01 m has been done with solar still having nano fluid Al_2O_3 used in water basin and phase changing material in water basin for same depth. It was observed that productivity of SS reaches a maximum when nano fluid Al_2O_3 is used in water basin as compared to both cases. Due to heat storage capacity of nano fluid, the convective rate of heat transfer improves and finally productivity increases. Mahian, Kianifar, Heris, Wen, Sahin & Wongwises (2017) had analyzed the performance of a SS equipped with a heat exchanger using nano fluids both experimentally and theoretically through three key parameters, freshwater yield, energy efficiency and exergy efficiency. To discover the effects of nano fluids, a mathematical model is developed and validated by experimental data at different weather conditions.

To improve the performance of solar still Sharshir, Peng, Wu, Yang, Essa, Elsheikh, Mohamede & Kabeel, (2016) had experimentally investigated the use of graphite and copper oxide micro-flakes with different concentrations, different basin water depths, and different film cooling flow rates in an attempt. Gnanaraj, Ramachandran & Christopher (2017) had attempted to improve the performance of the SS. Instead of conventional solar still, a double slope single basin SS was fabricated. Pebbles were speeded at the bottom for internal modification. An External mirror was fitted for external. Internal modification enhanced the production marginally. They achieved outstanding improvement in production when both internal and external modifications were attempted. Deshmukh & Thombre (2017) used sand and servotherm medium oil (heat transfer oil) as passive storage material beneath the basin liner in their experimentally and theoretically investigation of the performance of a single slope single basin SS. The effect of varying depth of storage material for a given quantity of basin water is investigated and compared with the conventional SS for same parameters. El-Sebaii & El-Naggar (2016) investigated the thermal performance of a finned single basin SS experimentally and theoretically, using finned basin liner made of different materials such as aluminum, iron, copper, glass, stainless steel, mica, and brass. They used copper finned basin liner to validate their theoretical model experimentally. The year-round performance of the still in terms of the monthly average of daily productivity and efficiency was performed. Kumar, Esakkimuthu & Murugavel (2016) had proposed a new concept to overcome a major drawback of its low productivity of solar still. Improved evaporation and condensation rate will increase the productivity of the still. A conventional and a modified single basin single slope solar stills were used for experimental analysis. Two single basin single slope solar still of same dimensions were fabricated. One of the still was attached with a provision to give agitation effect and external condensation. Agitation effect was given by a shaft coupled with a DC motor and an exhaust fan was used to extract the vapor from still to an external condenser. Metha, Vyas, Bodar & Lathiya (2011) investigated the single basin single slope SS, they observed the optimum angle is 30° which is near to the latitude of the site.

Hashim & Alramdhan (2010) experimented different types of stills i.e. single slope, double slope, pyramid type etc are investigated by varying different parameters like inclination angle of the glass cover and different basin area, and they concluded that double slope solar still has the highest productivity. They also found that as we increase the inclination angle, productivity increases and while area is increasing, productivity reduced. Kumar & Shantharaman (2015) investigated single slope solar still and found that it shows that the performance of blackened surface of still is more efficient than having normal surface still. Panchal (2015) has done an investigation on single slope double basin solar still with vacuum tubes and with black granite gravel. He observed that the overall productivity of double basin SS with vacuum tube and vacuum tube with black granite gravel is increased to 56% and 65% as compare to alone double basin solar still. Black granite gravel not only worked as an energy absorbing material but it also releases this energy in no-sun shine conditions. Panchal, Patel, Patel & Thakkar (2015) investigated single slope single basin SS with the use of sandstones and marble pieces and concluded that energy absorbing material has the high impact on productivity, even in sunshine hours. We can get high productivity by using sandstones as compare to marble pieces. Velmurugan et al. (2008) used fin to enhance the productivity of solar still. In their works, to augment evaporation of the still basin water, fins were integrated into the basin of the still. Thus production rate accelerated. Also, for further increase in exposure area sponges were used. They found that 29.6% productivity increased, when wick type solar still was used, 15.3% productivity increased when sponges were used and 45.5% increased when fins were used.

Modification	Date	Average solar radiation in W/m^2	Production rate in kg/m^2 /day	
			Experimental	Theoretical
Still only	16.08.06	545	1.88	2.07
Still with sponge	13.08.06	527	2.26	2.4
Still with wick	06.04.06	620	4.07	4.5
Still with fin	28.08.06	533	2.81	3.09

TABLE 3. Effect of modification in SS productivity (Velmurugan et al. 2008)

References, location	Modification	Max. enhancement in productivity
Sharshir et al. (2016) China	- Highest productivity occurs at concentrations of graphite and copper oxide micro flakes, ranged from 0.125% to 2% to get the ideal concentration. - The flow rate of the glass cooling water is changed from 1 kg/h to 12 kg/h to get the best cooling film rate with micro-flakes. - Brine depths ranged from 0.25cm to 3cm are investigated to get the optimum depth with micro-flakes. - Single slope.	47.80% and 37.02%, using copper oxide with and without film cooling, respectively. 57.60% and 43.10%, using graphite with and without film cooling, respectively.
Nijmeh et al. (2005) Jordan	- Using potassium permanganate: (KMnO4) and potassium dichromate (K2Cr2O7). - Single slope.	26% using $KMnO_4$. 17% using $K_2Cr_2O_7$.
Elango et al. (2015) Tamil Nadu, India	- Using Aluminum Oxide (Al2O3), Iron Oxide (Fe2O3), and Zinc Oxide (ZnO) nanoparticles. - Single slope.	29.95% using Aluminum Oxide. 18.63% using Iron Oxide. 12.67% using Zinc Oxide.

References, location	Modification	Max. enhancement in productivity
Kabeel et al. (2014) Egypt	- Using the cuprous oxide and aluminum oxide nanoparticles with providing vacuum. - Single slope.	133.64% using cuprous oxide with a vacuum. 125.0% using aluminum oxide with a vacuum.
Kabeel et al. (2014) Egypt	- Using aluminum-oxide nanoparticles and external condenser. - Single slope.	116% using aluminum-oxide with external condenser.
Madani & Zaki (1995)	- Investigated the productivity of a still with porous basins. - An average productivity of 2.5–4 kg/m^2/day was obtained when carbon powder. - Single slope.	Not Given.
Sahota & Tiwari (2016) India	- Using aluminum-oxide nanoparticles. - Double slope.	12.2% using aluminum oxide.

TABLE 4. Comparison between different research works about SS with nano fluids

In last decade researcher are more interested towards the use of Nano Fluid. Because it has many special properties compared to its base liquid, like high thermal Conductivity and high solar intensity absorptivity, which will help to enhance the still productivity. Recently some researchers studied the influence of different types of Nano fluids on the yield of solar still. Elango, Kannan & Murugavel (2015) used Nano fluids; Aluminum Oxide (Al2O3), Tin Oxide (SnO2) and Zinc Oxide (ZnO) to intensify the output of the still. Nano fluids have 29.95%, 18.63%, and 12.67% higher productivity, respectively compared with the still without Nano fluid. The efficiency of solar still was increased by 29% when the violet dye was used. (Nijmeh, Odeh & Akash, 2005). Summary of research on that topic is shown in above table.

Conclusion

It can be concluded that the most effective method of water refinement in the contemporary time is solar desalination. The standards of safe drinkable water can be measured by distillate water. Optimization of various constraints can fetch high productivity of the system.

In this works review, the possible research work can have thought for the ground of improving the productivity of solar still.

- The leaning position is one of the significant aspect in the improvement of productivity. It should be adjacent to the latitude of the site.
- By purveying insulation, the heat transfer can be decreased. Therefore, insulation is purveyed to the bottom and side wall of the solar still to lessen the heat loss from the basin.
- The output can also be affected by both the external and internal modification. As a result, for the cause of external modification, mirrors can be sited on the side wall to exploit the use of radiation that is communicated on the solar still.
- Besides this, using energy absorbing materials that can increase the productivity and efficiency of the system can create a healthy balance by providing energy in the non-sun shining hours.
- In the case, when high wind speed decreases the temperature of glass cover which, in turn, increases the temperature difference between glass cover and water. Likewise, it too increases the concentration rate of evaporation. This outcome is significantly attained by usage of Nano fluid. It demonstrations the great impact on the yield of the still. Nano fluid has provided the prospect to develop the productivity and effectiveness, by taking benefits of belongings of Nano fluid and several investigators have exposed the same.

Thus, it can be concluded from the examination taken above that getting the highest yielding of distilled water is quite difficult which increases the cost and time duration. Therefore, additional researchers are required in this ground to improve the productivity and as a result, it could be channelized to market place. In this field of research, at last, the manipulation of Nanotechnology is one of the inordinate advancement.

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