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A Review on Solar Water Distillation Using Sensible and Latent Heat

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Abstract

Energy and water are the two major issues faced by human beings nowadays. Owing to increase in the energy costs and the adverse effect on the environment caused by the burning of fossil fuels, renewable energy sources are being used worldwide to contribute in meeting the energy demand. Renewable energy denotes a clean, nontoxic energy source that cannot be exhausted. The primary renewable energy sources are the sun, wind, biomass, tide, waves and geothermal energy. Harnessing the abundance of solar energy has been one of the most attractive energy alternatives. The development of an efficient and economical solar energy storage system is of major concern. Energy storage plays an important role in conserving available energy and improving its utilization. Electrical energy consumption varies during day time and night time. Solar energy is available only during the day. Hence its applications require efficient thermal energy storage so that the excess heat collected during sunshine hours may be stored for later use during the night time. The main problem while utilizing solar energy is its availability which is often intermittent, variable and unpredictable. These problems can be addressed by the storage of thermal energy. Thermal energy storage (TES) will improve the efficiency and output of solar power. A thermal energy storage system mainly consists of three parts, the storage medium, heat transfer mechanism and containment system. Thermal energy storage (TES) applications have significantly increased because of the increase in the energy prices and environmental regulations. Latent heat storage (LHS) is one of the efficient ways of storing thermal energy. Unlike the sensible heat storage (SHS) method, the latent heat storage method provides much higher storage density with a smaller temperature difference between storing and releasing heat. There are large numbers of phase change materials that melt and solidify at a wide range of temperatures. The reason behind using phase change materials is due to their advantages such as low cost, high storage density and isothermal operation. For the solar desalination process, they are used as a bridge to cross the gap between the energy source, the sun and the desalination unit.

Keywords: Solar distillation, Thermal Energy Storage, Latent Heat, Sensible Heat and Phase Change Materials;

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1. Introduction

Energy is an essential factor for the social and economic development of the societies. Renewable energy is accepted as a key source for the future on this earth. The combined effects of the deflection of fossil fuels and the gradually emerging consciousness about environmental degradation have given the first priority to the use of renewable alternative energy resources in the 21st century. All of renewable, solar thermal energy is considered to be practically unlimited in the long term and is a very abundant resource in the world. Many conventional and non-unconventional techniques have been developed for purification of saline water. Among these water purification systems, solar distillation proves to be economical and eco-friendly technique.

Among the non conventional methods to disinfect the polluted water, the most prominent method is solar distillation. The solar distillation method is more attractive than other methods. This method require simple technology as no skilled workers needed, low maintenance and it can be used anywhere without problems.

There are two different types of solar systems; those are active type and passive type. In active type solar system extra thermal energy is supplied to the basin through an external mode to increase the evaporation rate and productivity of pure water. Passive solar systems give lower yield when comparing with active solar systems. In the present days, most of the solar stills are passive solar stills. Because, they need only sunshine to operate it, and there are no moving parts to wear and power consuming. In a passive solar still, the solar radiation is received directly by the basin or solar still water and is only source of energy for raising the water temperature, so the evaporation leading to a lower productivity of pure water.

The passive solar still of a conventional design is basically a sealed enclosure containing a shallow body of uniform temperature brine solution. This brine solution is heated by absorption of solar radiation admitted through the top transparent condensing glass cover. The convective circulation of humid air induces the temperature difference between the brine solution and the top condensing glass cover. This causes the transport of water vapor from the brine surface to the top transparent glass cover and from there it condenses into the distillate chamber.

The parameters which are affecting the solar still are; water depth in the basin, material of the basin, wind velocity, solar radiation, inclination angle of glass cover and ambient temperature. The yield of water from the solar still is depend on the temperature difference between the water in the solar still or basin and glass cover inner side temperature. The yield from solar still is directly proportional to the temperature difference of water in solar still and in side of the glass cover.

Thermal processes for the distillation of sea water are known to be among the first technologies adapted to solar energy. The idea of saline water evaporation by using solar thermal energy for getting pure water is the best technique. It is very fortunate that in times of high water demand, solar radiation is also intense. It is beneficial to exploit solar energy directly by installing solar stills because they are clean and friendly to the environment.

Numerous studies on solar stills of various designs to increase the productivity of potable water and efficiency of solar still have been carried out theoretically and experimentally. The work done by previous researchers in obtaining distilled water using solar energy is listed below:

Table 1. Work done by previous researchers in obtaining distilled water using solar energy

Sr. No	Authors	Year of Publication	Distillation Process	Augumented by		Efficiency (Distillate)
1	Anil K Rajvanshi	1981 (USA)	Solar still Adding Dyes	Red	50 ppm	3.60 kg
					100 ppm	3.05 kg
				Black	50 ppm	4.31 kg
					172.5 ppm	5.60 kg
				Green	50 ppm	5.55 kg
					100 ppm	5.19 kg
2	Bilal A Akash et al	1998 (Jordan)	Single basin solar still	Black rubber mat		38%
				Black ink		45%
				Black dye		60%
3	Nafey A.S et al	2001 (Egypt)	Solar still with	Black Rubber Thickness: 10 mm		20%
			Solar still with	Gravel Size: 20-30 mm		19%
4	Mona M Naim et al	2002 (Egypt)	Solar still	Using PCM		40 ml/min
				Solar heating		4.536 l/m^2
5	Safwat Nafey et al	2002 (Egypt)	Solar still with floating aluminum perforated black plate	3 cm		15%
				6 cm		40%
6	Valsaraj.P	2002 (India)	30 mm water depth	Normal still		1600 kg/m^2
				Perforated and black Aluminium sheet		1700 kg/m^2
				Aluminium sheet folded into "V" wave		43% 2400 kg/m^2
7	Hassan E.S.Fath et al	2004 (Egypt)	Solar still with passive condenser	With natural circulation		56% (5.1 $kg/m^2/day$)
				At glass cover		42% (2.1 $kg/m^2/day$)
				At condenser		58% (2.9 $kg/m^2/day$)
8	Imad Al-Hayek and Omar O Badran	2004 (Jordan)	Solar still	SGHT		45%
				ASGHT		56%
9	Hikmet S Aybar et al	2005 (Turkey)	Three different variants	Bare plate		1290 ml/day
				Black cloth wick		1705 ml/day
				Black fleece wick		2995 ml/day
10	Janarthanan.B et al	2005 (India)	Floating tilted wick solar still	Open cycle		Efficiency increases in closed cycle
				Closed cycle		
11	Nijmeh.S et al	2005 (Jordan)	Single basin solar still using	$K_2Cr_2O_7$		17%
				$KMnO_4$		26%
				Violet dye		29%
12	Janarthanan et al	2006 (India)	Floating cum tilted wick type solar still deviations between numerical and experimental results	Glass cover		8%
				Tilted wick water surface		2%
				Floating wick water surface		1%
				Flowing water at the lower end of the glass cover		2%
13	Velmurugan.V et al	2006 (India)	Solar still	Still alone		2.77 $l/m^2/day$
				With sponge		3.3 $l/m^2/day$
				With mini solar pond		3.4 $l/m^2/day$

				With mini solar pond integrated with sponge	4.4 l/m^2/day
14	Velmurugan.V and Srithar.K	2007 (India)	Solar still integrated with	Mini solar pond	27.60%
				Pond and sponge	57.80%
15	Selva Kumar.B et al	2008 (India)	"V" type solar still	Without charcoal	24.47%
				With charcoal	30.05%
				With boosting mirror	11.92%
				Boosting mirror and charcoal	14.11%
16	Velmurugan.V et al	2008 (India)	Stepped solar still using	Stepped solar still alone	(1.01 l/8h)
				Sponges	60.39% (1.62 l/8h)
				Fin	76%
				Sponges + Fin	96% (1.98 l/8h)
17	Vinoth Kumar and Kasturi Bai	2008 (India)	Solar still	Condensation	30% (1.4 l/m^2/day)
18	El-Sebaii.A.A et al	2009 (Saudi Arabia)	Single basin solar still	Without PCM	4.998 kg/m^2/day
				With stearic acid (PCM)	9.005 kg/m^2/day
19	Khaled M S Eldalil	2009 (Egypt)	Solar still with	Backed helical wires	35% (3.4 l/m^2/day)
				Vibration	60% (5.8 l/m^2/day)
20	Salah Abdallah et al	2009 (Jordan)	Solar still	Coated metallic wiry sponges	28%
				Uncoated metallic wiry sponges	43%
				Black rocks	60%
21	Velmurugan.V et al	2009 (India)	Solar still	Using Pebbles	67%
				Using Baffles	70%
				Using Fin and Sponges	80%
22	Velmurugan.V et al	2009 (India)	Stepped solar still with	Solar still alone	0.83 l/m2
				Fin	53.3% (1.27 l/m2)
				Fin + pebble	65% (1.37 l/m2)
				Fin + sponge	68% (1.4 l/m2)
				Fin + pebble + sponge	98% (1.65 l/m2)
23	Dr.Srithar.K	2010 (India)	Solar still coupled with	Activated carbon and Methanol	24.19%
				Activated carbon and Methanol with sponges	27.41%
				Activated carbon and Methanol with sponges and Pebbles	30.23%
				Activated carbon and Methanol with sponges and sand	32.32%
24	Al-Hamadani and Shukla S.K	2011 (India)	Solar distillation	Still alone	30%
				Lauric Acid	127%
25	Rajendra Prasad et al	2011 (India)	Solar still	Without gel	36%
				With graphite filled silica gel	49%
26	Swetha K and	2011	Single sloped solar still	Using Lauric acid (PCM)	36%

	Venugopal J	(India)			
27	Swetha.K and Venugopal.J	2011 (India)	Single slope solar still	Using Sand	13%
				Using PCM as Lauria acid	36%
28	Teltumbade T.R and Walke P.V	2011 (India)	Single basin solar still	Rubber mat, Black ink and Sponge are some absorbing materials	Rubber mat gives more yield
29	Sampathkumar Karuppusamy	2012 (India)	Solar still	Solar still alone	1965 ml
				Coupled with Evacuated Tubes	49.7% (3910 ml/day)
				Using black gravel	8%
				Using black gravel with evacuated tubes	59.48%
30	Shobha.B.S et al	2012 (India)	Solar still	Coupled with an Evacuated tube collector type solar water heater	39% - 59%
				With $KMnO_4$ + River water	46.9% - 48.8%
31	Mitesh I Patel et al	2013 (India)	Single sloped active solar still Water depth of 10 cm	Without dye	10104 ml
				With Red dye	18.40% (11963 ml)
				With Blue dye	25.48% (12679 ml)
				With Black dye	30.38% (13173 ml)
32	Sampathkumar K et al	(India)	Solar still with	Still alone	1965 ml/day
				Black gravel	8%
				Evacuated tubes	49.7% 3910 ml/day
				Black gravel with evacuated tubes	59.48%

2. Conclusions

Energy and water are the basic necessity for all of us to lead a normal life on this beautiful earth. Solar energy technologies and its usage are very important and useful for the developing and under developed countries to sustain their energy needs. The use of solar energy in distillation process is one of the best applications of renewable energy. The solar stills are user friendly to the human being in the nature.

Solar energy is abundant and never lasting, free of cost and environment friendly. Solar distillation is the best solution for small communities who facing problems with lack of fresh water. Solar still is good for operation, maintenance and repair. Solar still have good chance to success in India. The improvement in solar still distillation due to the use of several ways i.e. sponges, gravels, dyes etc.

From the previous literature review and experimental work, it is observed that, previous researchers conducted experimental investigations on obtaining distilled water with the help of solar energy in the presence of different water depths, glass cover inclination angles, dyes and energy storage materials like black rubber mat, gravel, sponges and pebbles. But the work using combination of sun tracking system (single axis or double axis) coupled with PCM, dyes, sponges and nano-materials are limited. Hence, there is a scope to conduct experimental investigations on this topic.

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