Performance Evaluation of Solar Water Purification System Using Parabolic Dish Concentrator in Tropical Climate

Aneesh V, Sandeep O S & Vishnu S

Adishankara Institute of Engineering and Technology, Kerala, India
[1]aneesh.me@adishankara.ac.in, [2]sandeep.me@adishankara.ac.in &
[3]vishnu.me@adishankara.ac.in

Abstract: *All over the world, access to potable water to the people are narrowing down day by day. Even today, many under developed countries and developing countries face a serious water scarcity. Water purification without affecting the ecosystem is the need of the hour. In this context, many conventional and non-conventional techniques have been developed for purification of saline water. Among these, solar distillation proves to be both economical and eco-friendly technique particularly in rural areas. In this project, the utilization of parabolic dish concentrator for distillation of impure water is proposed. The reflectors in concave shape prove to be more efficient in energy concentration when compared to concentrators with different geometries. The ultimate aim of this activity is to incorporate a parabolic dish reflector as a medium of energy concentration, enabling purification of water. This technique proves to be economical and free of any harmful effect. A performance evaluation is done and relationship between distillate production rate and the factors affecting distillation like time, temperature etc. were obtained and nature of distilled water is analysed .*

Keywords: **solar desalination, parabolic dish concentrator, performance evaluation.**

1. Introduction

Oceans and The vitality from the sun is utilized for different purposes principally as force era known as sun based power era framework and modern procedure heat applications. The vitality utilization in private division is generous as it records for roughly 33% of general conveyed vitality use and carbon dioxide discharges of this conveyed vitality use, around a quarter is for water warming. Water warming is by and large given by blazing non- business fills, in particular kindling as in provincial zones and for this application country people groups are slicing trees to incomplete satisfaction of their day by day vitality necessities, this makes consumption of woods and along these lines it impact on environmental change and business energizes, for example, lamp oil, melted petroleum gas LPG, coal; through either their immediate burning or using power in urban ranges this employments of fossil powers make air contamination and as the expenses of normal asset exhaustion. The sun is the main star of our nearby planetary group situated at its inside. The sun is a circle of seriously hot vaporous matter with a measurement of 1.39x m and is around 1.5x m far from the earth, the sun turns on its hub once about like clockwork. The power of sunlight based radiation per unit time on a unit surface outside the world's air is known as "sun based consistent". Its quality is 1353 W/m2.

About 70% of the planet is covered in water, yet of all of that, only around 2% is fresh water, and of that 2%, about 1.6% is locked up in polar ice caps and glaciers. So of all of the earth’s water, 98% is saltwater, 1.6% is polar ice caps and glaciers, and 0.4% is drinkable water from underground wells or rivers and streams. And despite the amazing amount of technological progress and advancement that the current world we live in has undergone, roughly 1 billion people, or 14.7% of the earth’s population, still do not have access to clean, safe drinkable water. Indian villages are posed with problem of overexploitation of ground water due to increasing dependence on it as other fresh water resources are dwindling fast. There is an important need for clean, pure drinking water in

many developing countries. Often water sources are brackish (i.e. contain dissolved salts) and/or contain harmful bacteria and therefore cannot be used for drinking. However, boiling is relatively expensive, consumes substantial amounts of fossil energy and the associated wood gathering contributes to depletion of forests. Energy resources are getting depleted day by day at a very alarming rate. So continuous research is going on around the world to harness energy from other renewable sources. Coastal areas are facing problem concerning water like intrusion of sea water into fresh water aquifers and making it saline, which results in reduced availability of good quality drinking water. Coastal areas have limited availability of clean water resources and the abundance of impure water. Access to drinking water is one of the crucial problems faced by the people in these areas. With most of the water turning saline, the limited potable water available cannot meet the demand. Keeping in notice the free Solar Energy, a water distillation and desalination system has been introduced which aims at purification of water in minimum cost without any harmful effect for meeting the requirements of the locals.

Radhwan [2] performed a transient performance analysis of a stepped solar still with built-in latent heat thermal energy storage. The still performance parameters were analyzed and the results showed that, decreasing the air flow rate has an insignificant effect on the still yield. H. Tanak, Y. Nakatake, K. Watanabe [3] performed a theoretical parametric investigation for a developed vertical multiple-effect diffusion-type solar still coupled with a heat-pipe solar collector. It was found that productivity increases with an increase in the partition numbers and the feeding saline water temperature and reducing the solar collector area compared to the thickness of gaps between partitions. K. Srithar, T. Rajaseenivasan [12] reports about the recent reformation carried out in the solar still and humidification and dehumidification desalination system using renewable sources for improving the fresh water production rate. Solar still distillate improves with the reduction in solar height, pro- vision of fins, cooling of glass cover, using energy storing materials, mixing of nanoparticles in basin water and increasing the basin water temperature. Simi Shoukathali, Sonia Dathan, Mary George [11] experimented water purification using a solar still coupled with evacuated tube collector. Thermo-syphon principle work successfully for heating of water inside the desalination unit and is helpful in increasing the temperature of water during working of system. Integration of evacuated tubes helps in increasing the water temperature inside the basin and inside the evacuated tubes.

Z.M. Omara, Mohammed A. Eltawil [8] present hybrid of solar dish concentrator, new boiler and simple solar collector for brackish water desalination with automatic tracking system. The results indicated that, the daily average of distillate water was 6.7 l/m2/day for SDC with preheating of brackish water, while the distillate productivity was 1.5 l/0.5 m2/day for CSS. In the present study, the daily average efficiency of SDC and CSS was 68 and 34%, respectively. The increase in distillate production for SDC is about 244% and 347% higher than that of CSS without and with preheating, respectively.Vikas MMahale, Anwesh Virkunwar [10] worried with design and fabrication of helical coiled solar water heater with auto GPS beacon. Helical loops are minimized in size and gives particular advantage like higher film coefficient, more compelling usage of accessible weight drop, which results in effective and less costly plan and additionally because of auto GPS beacon, high temp water will accessible entire day. Sonal C Yogi, Mayank Madia, Rahul Kumar Sen [9] worked on design and fabrication of a two axis parabolic dish collector. When the sun is overhead at 12pm and 1pm, the dish deflects maximum from its original position. The chain drive so developed, minimizes the jerks given by the 60 rpm power window motor. If a 2 or 3 rpm geared motor will be used, the system will work more smoothly. R. Tripathi, G.N. Tiwari [4] found out that the distillate output decreased significantly with the increase of water depth in the basin of the solar still. V. Velmurugan, M. Gopalakrishnan, R. Raghu, K. Srithar [6] integrated a basin-type solar still with fins to increase the distillate production rate. The results showed the evaporation rate augmentation of about 45.5%.

M.S. Eman-Bellah, A.M.R. Ghazy [5] carried out experiments to investigate a method to improve the thermal conductivity of paraffin wax by embedding aluminium powder in it. The size of the aluminium powder particles is 80 μm. Results showed that the value of the average heat transfer coefficient is greater for composite than for pure paraffin and charging time decreased by 60% for composite than that for pure paraffin wax. Useful heat gained increases with the addition of aluminium powder to the paraffin wax. T. Arunkumar, D. Denkenberger, A. Ahsan, R. Jayaprakash [7] developed a basin solar still coupled with hemispherical concentrator and phase change material to augment the efficiency and distillate yield. The experimental results indicated that the productivity increases by using PCM. N.D. Kaushika, K.S. Reddy [1] design, development and performance characteristics of a low cost solar steam generating system which incorporates recent design and materials innovations of parabolic dish technology, Preliminary yield measurements and cost.

2. Working principle

The main components are parabolic dish collector, spherical absorber tank, main storage tank, copper tubes, steel pipe, vertical stand and a dish stand. The cold water which is stored in the main storage tank is made to flow through steel pipe and it will reach the spherical absorber tank. The absorber tank is kept at the focal point of the parabolic dish collector. Thus the water gets heated up because of concentration of solar radiation at the focus of the concentrating collector. The use of spherical absorber leads the solar radiation to be distributed in an area and not in a point, the focal point of the parabola. More specifically, all the solar rays after their reflections are directed to the focus of the parabolic dish. The center of the sphere is located on this focus, which means that all the rays arrive in the down hemisphere of the absorber. In the case that all the solar energy was delivered to a smaller area, the concentrating ratio will be huge, leading to higher temperature level than the desired for heating proposes. The main storage tank and the absorber unit is kept at same height from ground level and a steel pipe is placed connecting both tanks so that the water level in both are maintained the same. The main storage tank is painted black and is covered by a glass plate at it's top surface. So that it acts as a solar still and perform preheating operation. Thus the steam generated in the absorber is accelerated and is taken through a copper tube well insulated by a wet cloth. The steam thus travels through copper tube is condensed to pure water by natural cooling and is then collected in a collecting tank.



Figure 1. Photographic View of Modified Solar Still.

3. Design

Uninvolved single incline sun oriented still with bowl zone of 0.6 m X 0.4 m was manufactured utilizing GI sheet. Bowl was painted with dark plaint as bowl liner for expanding the ingestion pace of the bowl. A 3 mm thick glass cover with 120 tendencies was fixed at top of the vertical dividers of the sun oriented still. Side dividers of the still were created utilizing compressed wood and 3 mm thick thermocol was utilized to limit the warmth misfortune from the sun based still. The vacuum fixing was finished with silicon. J-type thermocouples were introduced having a scope of 0˚ C to 350˚ C.

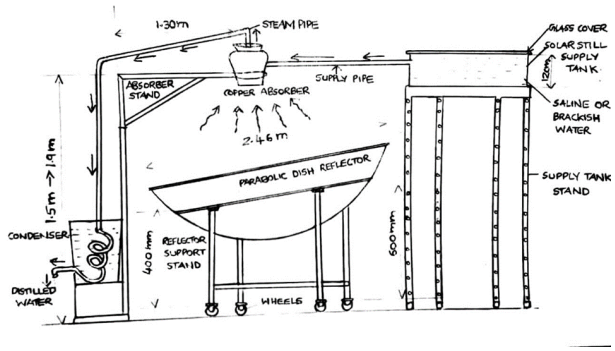

Figure 2. Photographic View of Modified Solar Still.

The details of the part used in the experiment setup given below. All values are arrived by optimizing the literature input and feasibility.

3.1. Design of parabolic dish

Table 1. Specification of Parabolic Dish

Parameter	Value	Unit
Material	Galvanised Iron Sheet	-
Diameter	2.50	m
Depth	45	cm
Aperture area	4.91	
Theoretical focal length	86.81	cm
Original focal length	01	m

3.2. Design of supply tank

Table 2. Specification of Supply Tank

Parameter	Value	Unit
Material	Plastic	_
Length	45	cm
Breadth	35	cm

Height	09	cm

3.3. Design of dish stand

Table 3. Specification of Dish Stand

Parameter	Value	Unit
Material	Mild Steel	_
Short leg (2)	40	cm
Long leg (2)	60	cm
Side links (4)	110	cm
Ring rod diameter	01	cm
Ring diameter	150	cm

3.4. Design of absorber stand

Table 4. Specification of Absorber Stand

Parameter	Value	Unit
Material	Galvanized Iron	_
Vertical arm	150 -190	cm
Horizontal arm	135	cm
Ring rod diameter	01	cm
Ring diameter	16	cm

3.5. Design of absorber

Table 5. Property Values of Copper

Density (Kg/m^3)	Thermal Diffusivity (m^2/s)	Specific Heat(c) (J/KgK)	Thermal Conductivity(K) (W/mK)
8954	112.34×10^{-6}	383	386.0

Table 5 Specification of Absorber Design

Parameter	Value	Unit
Height	17	cm

Max dia	16	cm
Base Area	78.54	cm^2
Total Volume	2.5	Litre

3.6. Design of supply pipe

Table 6. Specification of Supply Pipe Design

Perimeter	Value	Unit
Material	Stainless steel	-
Length	125	cm
Diameter	1.27	cm
Thickness	0.1	cm
Thermal Conductivity	13.4	W/mK

3.7. Design of steam pipe

Table 7. Specification of Steam Pipe Design

Perimeter	Value	Unit
Material	Copper	-
Length	140	cm
Diameter	1.3	cm
Thermal Conductivity	386	W/mK

3.8. Design of heat exchanger

Table 8. Specification of Heat Exchanger Design

Parameter	Value	Unit
Copper tube length	135	cm
Copper tube diameter	1	cm

Hose length	100	cm
Hose diameter	0.8	cm
Copper coil diameter	15	cm
Copper coil height	20	cm

4. Results and discussions

4.1. Variation of distillate production rate with time :

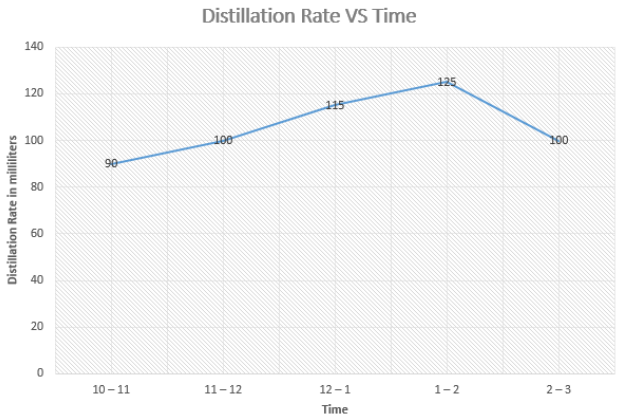

Figure 3. Distillation Rate Vs Time

The hourly assortment of yield began from10.00 am and arrived at the most extreme at 2.00 pm and afterward diminished for every one of the three arrangements. The maximum distillation rate of water is between 1pm and 2pm. That is the efficiency of the system will be maximum at that time period.

4.2. Variation of absorber wall temperature with time

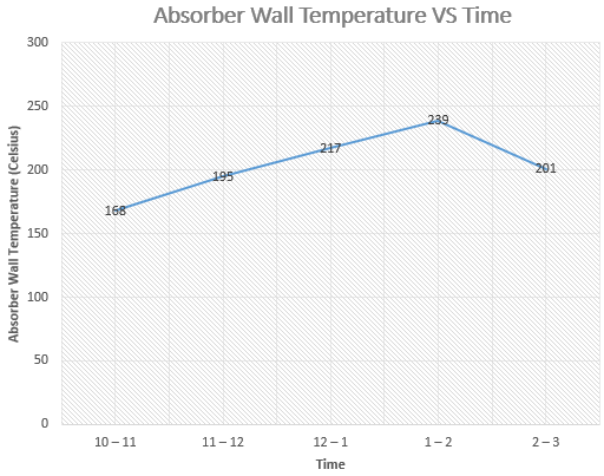

Figure 4. Absorber Temp Vs Time

The absorber temperature is increases gradually with the ambient temperature and there is maximum distillation and highest temperature. The maximum temperature attained after 1PM and this is due to the convective heat transfer by the atmosphere.

4.3. Variation of distilled water temperature with time

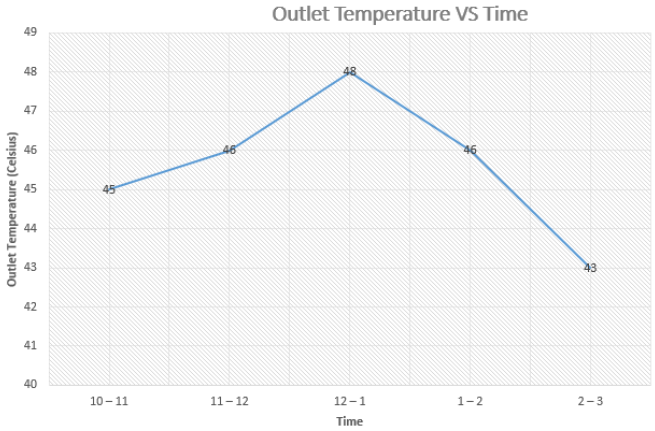

Figure 5. Distilled Temperature Vs Time

The distilled water temperature is almost remain constant irrespective of time. This leads to the fact that the heat exchanger ensure complete condensation of water vapor and good cooling. And the maximum yield obtained after at the peak temperature in the collector.

5. Conclusion

Water purification system using parabolic dish concentrators will be the solution for fresh water scarcity issue with no fuel or power requirements. This unit can be installed on roof tops of houses industries etc. This system will be cost effective with lower installation and maintenance cost compared to other methods. The efficiency is improved by using phase change materials and solar tracking. Solar distillation proves to be both economical and eco-friendly technique particularly in rural areas. Parabolic dish solar concentrator could be assessed as an attractive method of distillation, which is both cost effective and does not use any kind of fossil fuel or electricity. The output obtained using this system will be higher than conventional solar still and concentrators due to preheating in main collector tank.

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