Design and Analysis of Solar Water Purifier

Ganesh Shankar Shukla, Niranjan Patel, Satyaprakash Sharma, Amar Singh, Manish Kumar, Rahul Patel*, M. Z. R. Khan

Department of Mechanical Engineering, KIPM College of Engineering and Technology, GIDA Gorakhpur Uttar Pradesh 273209, India

*Corresponding author's e-mail: rahul.etm@gmail.com
doi: https://doi.org/10.21467/proceedings.161.28

ABSTRACT

The majority of people in underdeveloped nations struggle to find safe, clean, and drinkable water. The amount of dirty water is abundant while clean water supplies are few in coastal locations. One of the most significant issues that the residents in these communities deal with is access to clean drinking water. The demand cannot be met by the limited supply of potable water since the majority of the water is turning salty. A water distillation and desalination system has been designed that intends to purify water for the inhabitants at the lowest possible cost without causing any negative side effects, keeping in mind the free Solar Energy.

Keywords: Parabolic trough Collector, Salty Water, Coastal Area

1 Introduction

More than 97% of the earth's water is salty; rest around 2.6% is fresh water. Less than 1% water is fresh water is within human reach. Even this small fraction is believed to be adequate to support life and vegetation on earth [1].

Distillation and collection of drinking water, which is necessary for day-to-day survival in deserts and at sea, can be accomplished using solar energy. It is simple to operate, lightweight, and compact. The military has been using this crucial and indispensable piece of survival gear for a long time. The need for clean water has increased significantly as a result of the planet's population growing rapidly over the years. industrial and sewage pollution of rivers, lakes, and groundwater is a further issue. A useful short-term remedy for the impoverished dry communities suffering from a lack of clean water will be a solar distillation system. Solar still depends on the amount of accessible solar radiation [2].

2 Literature Review

K Sampathkumar *et al.*, (2010) [3]. In this study, we discovered that underdeveloped and developing nations experience severe water scarcity due to unforeseen mechanisms and pollution brought on by human activity. The current situation calls for effective water treatment without harming the ecosystem. Many standard and unconventional methods for purifying saline water have been developed in this context. Solar distillation stands out among them as a cost-effective and environmentally benign method, especially in rural areas. The issue of decreased distillate yield in passive solar stills has led to the development of numerous active distillation methods. This article is a study of the development of active solar distillation across time.

Caroline S.E. Sardella *et.al.*, (2012) [4]. In this study, we analyse the production rate of distillate water, which is anticipated to range from 100 to 590 l/d per bucket depending on the system's effectiveness. The drinking water tank's water extraction is anticipated to be within the bacteriological and mineralogical suggested limits, with no negative health consequences noted. During the process of mixing the distillate with the collected rainwater, some remineralization of the distillate is anticipated. Nevertheless, during the pilot project, precise water quality monitoring and analysis are advised.

Proceedings DOI: 10.21467/proceedings.161; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-8-2

Alpesh Mehta *et al*., (2011) [5]. In this study, we found that the time between 11:15 am and 1:30 pm is when evaporation is at its highest and temperature increases the most. At 1:30 pm, the temperature reaches its highest point of 53'C before falling. The goal of this project was to purify the available brackish water. We supplied 14 litres of brackish water, and at the end of the trial, we had 1.5 litres. The experiment was conducted over the winter. The obtained purified water has a TDS level of 81 PPM. Therefore, the water obtained is drinkable. The experiment should theoretically yield 2.33 litres. Consequently, the system's efficiency is 6%.

3 Methodology

The design of a thermosyphonic-based solar water purification system, which consists of two main components, parabolic trough solar collector, a basin that is also known as a solar still. Both the condensing basin and the parabolic trough solar collector are analysed. This water filtration system is made to produce an estimated 5 to 6 litres of clean water each day, which is more than enough for our needs.

3.1 Working

After entering the three pass copper tube with where the water is heated by concentrated solar radiation, its temperature rises. Initially, the water comes from the filthy water tank, where its temperature is not very high—it is between 28 and 30 °C. Water enters the condensing basin through the outlet of the copper tube, where it is heated further because the condensing basin has a top glass cover that enables some radiation to enter the condensing basin.

Warm water tries to evaporate over time and condenses on the top glass cover. The droplets of evaporated water that adhere to the top glass cover are collected through the output tube and placed in a separate freshwater storage tank.

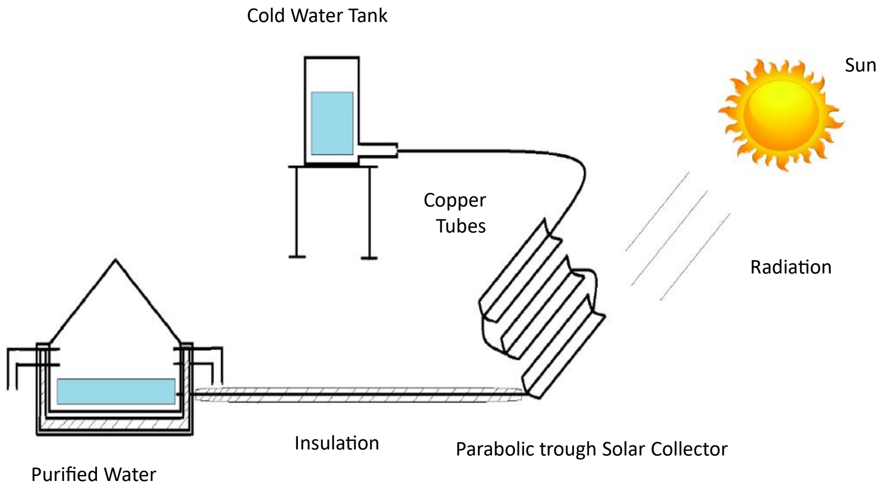

Figure 1: *Solar Water Purifier setup*

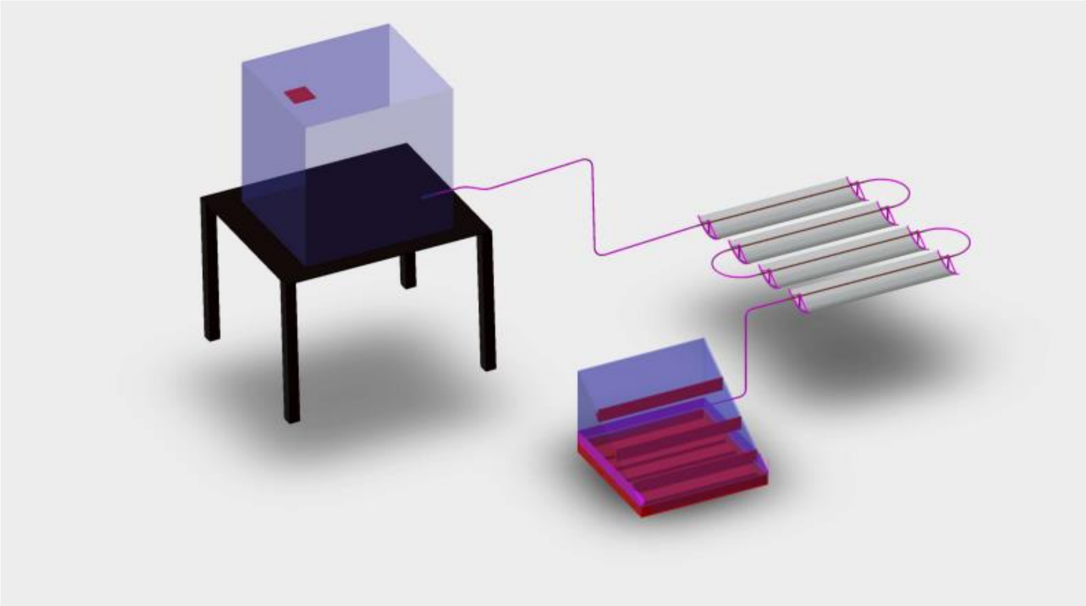

Figure 2: *3D-design of Solar Water Purifier experimental setup*

4 Calculation

Diameter(d) = 200 mm = 0.2 m

Depth(h) = 40 mm = 0.04 m

Parabolic trough design specification,

Focal point can be determined as,

$$f = \frac{a^2}{16h}$$

$$f = \frac{0.2}{16 \times 0.04}$$

$$f = \frac{0.2}{0.64}$$

$$f = 0.3125\ m$$

$$concentration\ ration = \frac{aperature\ area}{receiver\ area}$$

$$aperature\ area = widht\ of\ collrctor \times lenght\ of\ collector$$

$$= 0.2 \times 0.7$$

$$= 0.14\ m^2$$

$$receiver\ area = \pi \times d \times l$$

Where, d is outer diameter of copper tube.

$$= 3.14 \times 0.00687 \times 0.7$$

$$= 0.0151\ m^2$$

Concentration Ratio,

$$concentration\ ration = \frac{0.14}{0.0151}$$

$$Concentration\ ratio = 9.271$$

Thermal Analysis,

$$Solar\ Irriadiation = S \cdot Cos\theta$$

Where, S is surface area of trough.

$$I = S \cdot Cos\theta$$

$$I = 4.646\ \frac{KWh}{m^2}$$

$$I = 9292\ \frac{W}{m^2}$$

Radiation Available on Solar collector,

$$Q = I \times Ac$$

$$Q = 9292 \times 0.14$$

$$Q = 1300.88\ watt$$

Heat Available on concentrator after reflecting solar radiation from parabolic collector,

$$Qcon = Q \times \rho$$

$$\rho = Reflectivity\ of\ material = 0.75$$

$$Qcon = 1300.88 \times 0.75$$

$$Qcon = 975.66\ watt$$

Temperature of concentrator,

$$Tcon = 82.4\ °C$$

Mass flow rate through concentrator,

$$m = \rho AV$$

$$m = 988 \times 0.0152 \times 3.706$$

$$m = 0.56\ kg/s$$

ρ= Density of fluid Flowing

V= Velocity of fluid

However, the law of conservation of energy causes the dirty water tank to rise initially from the datum (ground) at a specific height. The fluid's potential energy is then turned into kinetic energy.

$$Potential\ Energy = Kinetic\ Energy$$

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

$$v = \sqrt{2 \times 9.81 \times 0.7}$$

$$v = 3.706$$

Discharge Volume Flow Rate,

$$Q = A \times V$$

$$Q = 0.152 \times 0.005$$

$$Q = 0.00076$$

$$Q = 7.6 \times 10^{-4}\ m^2/s$$

Water Purification Rate,

Now, we analysed that maximum sunshine hours is 5 hours throughout the day,

So total heat

$$Q = 975.66 \times 5 \times 3600$$

$$Q = 17561.88\ KJ$$

Energy Balance Equation for Unsteady State,

$$m1\left(h1 + \frac{V1^2}{2}\right) + Q = m2\left(h2 + \frac{V2^2}{2}\right)$$

$$m_1 = 5\ kg$$

$$h_1 = 29\ ℃ = 121.55\ \frac{kj}{kg}$$

$$h_2 = 100℃ = 2257.9\ kj/kg$$

v_1 =3.706 m/s

$$v_2 = 4.5\ m/s$$

$$Q = 17561.88\ kj$$

$m_1\left(h_1 + \frac{v_1^2}{2}\right) + Q = m_2\left(h_2 + \frac{v_2^2}{2}\right)$

$5\left(121.55 \times 10^3 + \left(\frac{3.706^2}{2}\right)\right) + 17561.88 \times 10^3 = m_2\left(2257.9 \times 10^3 + \left(\frac{4.5^2}{2}\right)\right)$

$5(121.55 \times 10^3 + 6.867) + 17561.88 \times 10^3 = m_2(2257.9 \times 10^3 + 10.125)$

$$18169664.3 = m_2(4515820.26)$$

$$m_2 = 4\ kg$$

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

$$\%\ of\ purified\ water\ = \frac{water\ output}{water\ input}$$

$$= \frac{4}{5} \times 100$$

$$= 0.8 \times 100$$

$$= 80\%$$

5 Conclusion

The design and analysis of this solar water purifier took solar radiation into account. This analysis enables one to investigate how certain internal and external parameters affect the operating system. By taking the design parameter into account for an unsteady condition and a time period of five hours of sunshine, the research revealed that unclean water heated to 355 K (82 °C) water is partially vaporised.

Hence, the estimated daily filtration rate for water is between 4.5 and 5 litres. Hence the solar water purifier has an efficiency of about 80%.

6 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Shukla *et al.* (2023). Design and Analysis of Solar Water Purifier. *AIJR Proceedings*, 248-253. https://doi.org/10.21467/proceedings.161.28

References

[1] Panchal, H. Effect of different parameters on double slope solar still productivity. International Journal of Advanced Science and Engineering, 1(2), 17-21,(2011).

[2] Rustam Mamrook, Omar Barden, "Fuzzy sets implementation for the evaluation of factors affecting on solar still production", Desalination 203(2007) pp.394-402.

[3] Sampathkumar, K., Arjunan, T. V., Pitchandi, P., & Senthilkumar, P. (2010). Active solar distillation—A detailed review. Renewable and sustainable energy reviews, 14(6), 1503-1526.

[4] Sardella, C.S. Evaluation of the implementation of the solar still principle on runoff water reservoirs in Budunbuto, Somalia, (2012) .

[5] Alpesh Mehta, Arjun Vyas, Nitin Bodar, and Dharmesh Lathiya, Design of Solar Distillation System. International Journal of Advanced Science and Technology, Vol. 29, pp. 67-74, (2011).