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Analysis of the Effectiveness of a Solar-Powered Parabolic Trough Water Filtration System

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Abstract: *Clean water is critical for sustainable development and there has been a growing demand for quality drinking water worldwide. Hence, this present research evaluated the effectiveness of solar-powered parabolic trough water purification system. A parabolic trough with a predetermined rim angle and length was considered for this experiment and the system was constructed and evaluated for its efficiency. From the observation of the system, the maximum temperature recorded in the cylindrical parabolic trough with a glass cover was 95⁰C, and the maximum temperature recorded in the cylindrical parabolic trough with a glass cover was 63.79 %, whereas the efficiency of the same device without a glass cover was 39.4%. This demonstrates that the glass cover served its purpose well in preventing solar insolation from escaping the parabolic trough. No considerable change was found in the (PH) value of the water after the condensation. The pH value stayed in the range of 7.0 to7.5 throughout the experiment. The finding has implications for sustainable quality water.*

Keywords: *Parabolic Trough, Solar, Filtration System, Water*

INTRODUCTION

There has been a growing demand for quality drinking water worldwide. Drinking water is one of the most essential goods for humankind and necessary elements of survival, but also a factor that significantly impacts health. Water quality worldwide has been labeled poor (De La Mora-Orozco *et al.*, 2017; Nichols *et al.*, 2018; Zinn *et al.*, 2018; Kumari & Rai, 2020; Ohanenye *et al.*, 2020; Ahuja, 2021; Lopes *et al.*, 2022; Makubura *et al.*, 2022; Robledo-Peralta *et al.*, 2022; Chaudhary *et al.*, 2023). Climate change, demand increase, population growth, poor management, and severe droughts have stressed the scarce freshwater resources worldwide, resulting in severe water shortages in many regions [11], even though some advanced countries enjoy relatively clean water.

Portable water describes water that is suitable for human consumption. Insinuation suggests that most drinking water assumed to be portable for consumption may contain many traces of contaminants. Water quality and purity are essential because water is crucial for human survival (Salchi,, 2022). Accordingly, the United Nations emphasized that people are entitled to adequate, continuous safe, acceptable, natural, and accessible water for personal and home use. Potable water is inaccessible unavailable for us in most of the communities in Nigeria (Oloye *et al.,* 2013). Due to the insufficiency of portable water, rainwater harvesting from rooftops has been favoured as an alternative source of water supply by most rural communities in Nigeria (Ezemonye *et al.,* 2016). Rainwater harvesting (RWH) describes the collection and storage of rainwater in natural or artificial containers either for immediate use or use before the onset of the next season for domestic, agricultural, industrial, and environmental purposes. Accordingly, the concern for safe water consumption has attracted huge research attention in Nigeria (Onu et al., 2016; Egun & Oboh, 2018; Zinn *et al.,* 2018; Kaoje *et al.,* 2019; Morufu & Oluwaseun, 2020; Olusegun *et al.,* 2022).

Governments or international organizations usually determine what constitutes acceptable quality for drinking water. Depending on the end use, these guidelines will specify either a minimum or maximum level of contaminant that can be present in the water. Water purity has predominantly been studied from various perspectives (Machell *et al.,* 2015; Pantuchowiz, 2023). To purify water means to rid it of impurities such as dissolved solids, gases and harmful microorganisms to make it safe for drinking and suitable for various applications. There have been many different approaches taken throughout history to clean water. Filtration, sedimentation, and distillation are examples of physical processes and biological processes like slow sand filters or biologically active carbon. Chemical processes like flocculation and chlorination and electromagnetic radiation like ultraviolet light are examples of chemical processes. Indeed, water filtration can lower the concentration of various dissolved and particular materials, as well as suspended particles, parasites, algae, viruses, bacteria, and fungi. A visual examination cannot determine if water is of appropriate quality. Thus, various purification procedures have been indicated as sufficient for treating all possible contaminants present in water from an unknown source. Numerous authors have underscored various water –purification processes for contaminant-free drinking water (Baik, 2021). For instance, (Kim & Kim, 2022) developed a venture tube with a spiral-shaped fin for water treatment. It was established that the volume fraction and turbulent kinetic energy of the developed water purifier were improved compared with the standard venture tube without the spiral-shaped fin. Many distillation techniques that utilize solar energy to run the purifying unit were developed. Accordingly, (Shin *et al.,* 2019) found efficiency in solar-energy-based water purifies of single-slope type by incorporating N similar evacuated tubular collectors (ETCs) with series connection. The parabolic trough has been experimentally investigated by (Baik, 2021) for water purification, and the purification efficiency was observed by altering the inflow height in relation to the parabolic trough base. Also, a model of a solar RO water purifier powered by solar PV cells was proposed by (Kim & Kim, 2022; Sharma *et al.,* 2022).

Using RO technology and other technologies, such as multi-effect distillation, multi-flash distillation, etc., requires significant initial investments. There has been observed to be massive waste of water in the reverse osmosis process. Considering these problems, it is observed that the possible solution for this is to use concentrated solar power as it gives better efficiency for the desired purpose, and water wastage is also less compared to other distillation processes. A parabolic-trough collector (PTC) represents a linear-focus solar collector comprised of a parabolic-trough-shaped concentrator that reflects direct solar radiation onto a receiver or absorber tube located in the focal line of the parabola.

Among various solar collectors, PTC has attracted substantial attention from investigators due to their operating temperature range feasible of power generation (Krishna *et al.,* 2022). Parabolic trough collector currently has more installations than other concentrated solar power technology around the globe Krishna *et al.,* 2022 (). Most conventional heat transfer fluids in PTC have poor heat transfer and light-to-heat conversion properties. Therefore, it is beneficial to enhance the thermophysical properties of heat transfer fluid to increase the system's overall efficiency. Well-engineered nano-enhanced heat transfer fluid is beneficial because a meager nanoparticle mass fraction significantly enhances thermo physical properties. Rural areas are likelier to benefit the most from solar water treatment since they lack the infrastructure for conventional water distillation and, more crucially, the electricity to power such systems. Thus, the present study examined the effectiveness of a solar-powered parabolic trough water filtration system.

MATERIALS AND METHODS

A parabolic trough with a predetermined rim angle and length was considered for this experiment. Calculations for determining different parameters, such as aperture and focal length, and selecting various materials for manufacturing the unit were based on this rim angle and length. The thickness of the galvanized iron sheet used to construct the parabolic structure is 0.7mm. This structure is where the reflecting component is permanently attached. It comprises a cylinder-shaped parabolic reflector and receiver made out of a metal tube located at the focal plane. The aperture diameter, rim angle, absorber size, and form describe the concentrator, among other characteristic. Reflectors were made of bent silver glass, aluminum sheets, and aluminized Mylar sheets. Though, it is difficult to bend a massive piece of glass into a curved shape, hence a sheet of metal was utilized to create the parabolic cylindrical shape and reflectance of 0.89 was exhibited by metal. The aluminum conductivity was given at 235 W/mK. It was assumed that the thickness of the aluminum sheet was 0.5mm. The receiver, described as the absorber tube, was responsible for taking in the incoming photons of sunlight and converting them into thermal energy. The fluid flowing into the tube receives this thermal energy as it is transferred to it. The absorber tube was built of copper material that has a coating of heat-resistant black paint. A coat of dark was applied to its surface to maximize the item's capacity to absorbed heat. Copper has better conductivity than steel and hence the tube was made of copper instead of steel. From measurement, copper has an absorptivity of 0.4 and a heat conductivity of 384W/mK.

In order to more effectively retain heat within the parabolic collector, a glass cover is typically utilized. Glass cover reduces the amount of heat lost through the system due to convection. This increases heat transfer efficiency from the absorber tube to the water (working fluid) and the measured conductivity of the glass was 0.75 W/mK and it has a heat-trapping effect. The PVC pipes and couplings were utilized to link the input tank to the outlet tank at both ends of the parabola. Also, water tanks with a size of five liters were used and to Control the flow of water through the pipes required the installation of two stopper valves, one at each of the intake and output portions. According to the system's operating concept, the area of the parabolic collector with a reflecting surface was used to gather solar insolation coming from a specific direction. The entire radiation is then concentrated along the trough's line. At the focal axis of cylindrical parabolic concentrators was the absorber tube. The fluid only flows through the tubular shape of the absorber or receiver. The solar parabolic collector must be directed toward the sun to achieve the best results. An inlet tank of 5 liters capacity was taken from a tank of a height of 1m from the base of the parabolic trough. A PVC pipe was connected to the tank from the parabolic trough's inflow. A brief segment of clear pipe was employed at the inlet and a stop valve at the exit was slightly opened to measure the bulk flow rate, while a one-litre beaker was set near the outlet. The amount of time it took to fill the one-liter beaker was recorded 1.5lt/hr was found to be the bulk flow rate. The mass flow rate was calculated, and it was determined that the testing conditions were favorable. The tank's water was tested at its initial temperature of 28^0C and the testing began around 9am in the morning local time. While the temperature of the water was checked in an hour interval.

The copper tube was filled to a specific level, and the inflow tank's stop valve was open. The level was chosen so that the stop valve at the outlet section would only partially open, allowing vapour to exit. Condensed and gathered in the outlet, the vapor. The water was subsequently tested for pH and TDS using the method outlined by Ben-Chioma *et al.,* (2015).

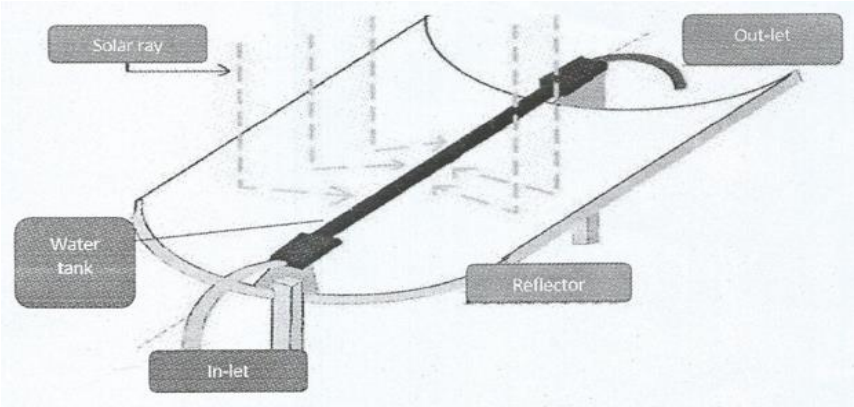

Fig. 1 Flow diagram of the system

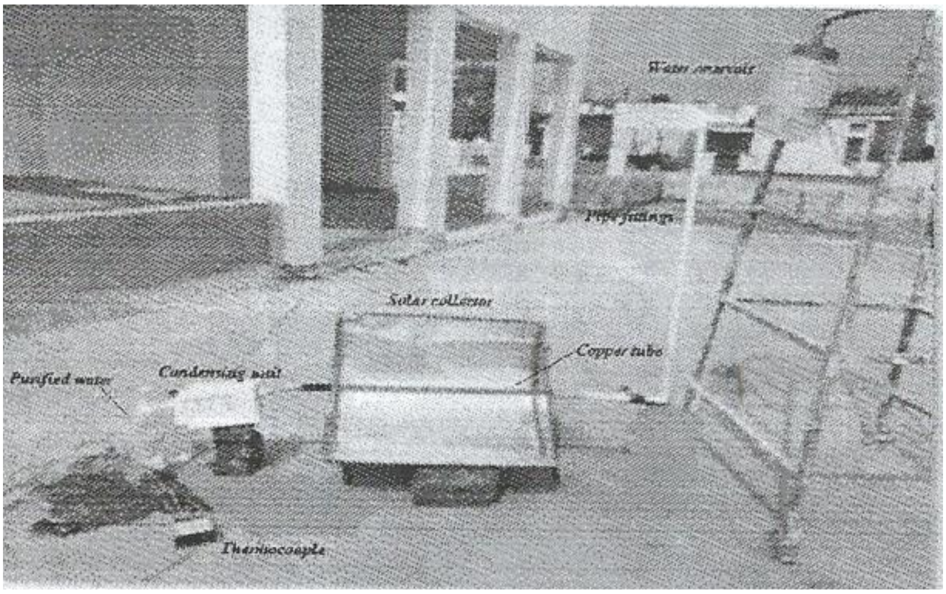

Fig. 2 Experimental setup

RESULTS AND DISCUSSION

A cylindrical parabolic trough with a glass cover was tested. The effect of the glass cover on the cylindrical parabolic trough was first investigated under specific weather conditions. In dry weather, with an initial temperature of around 26 ^{0}c in the morning, the water in the system was measured with a thermocouple once each hour. Later in the afternoon, the highest water temperature of 95 degrees Celsius was recorded. Therefore, 711 W/m^2 was the highest recorded solar insolation for the day. The results showed that the parabolic trough protected by glass was 63.79% efficient. Significantly, the pH of the water was determined to be between 7.0 and 7.5. the water's initial Total Dissolved Solid (TDS) concentration was measured at 330ppm, and its final TDS concentration was measured at 300 pmm. Subsequently, the cylindrical parabolic trough was tested without the glass cover.

The temperature of the water was recorded every 1 hour with the help of a thermocouple. The recorded temperature was 28 ^{0}C in the morning. The maximum temperature was observed to be 66^{0}C during the day. The initial value of the water was found to be 7.0 to 7.5. The maximum temperature of the water reaches up to 66^{0}C in the afternoon. Maximum solar insolation was found to be 735W/m^2 during the day period. The efficiency of the parabolic trough without the glass cover was found to be 39.8%. This reduction in efficiency is due to energy loss from the concentrator. The final TDS of water was found to be 310ppm. From observation, the maximum temperature attained by the fluid in the parabolic trough when the glass cover is used is approximately 95^{o}C. Moreover, the maximum temperature attained by the fluid is 66^{0}C when the glass cover is not used. From the above two temperatures, it is clear that glass traps the heat inside it and helps attain a much higher temperature.

CONCLUSION

The present paper examined the efficiency of a solar-powered parabolic trough water purification system. The system was constructed and evaluated for its efficiency. From the observation of the system, the maximum temperature recorded in the cylindrical parabolic trough with a glass cover was 95^{0}c, and the maximum temperature recorded in the cylindrical parabolic trough without a glass cover as 66^{0}c. The information presented above propelled the conclusion that the efficiency of the cylindrical parabolic trough with a glass cover was 63.79%, whereas the efficiency of the same device without a glass cover was 39.4 %. This demonstrates that the glass cover served its purpose well in preventing solar insolation from escaping the parabolic trough. No considerable change was found in the pH value of the water after the condensation. The pH value stayed in the range of 7.0 to7.5 throughout the experiment. As a result, it was concluded that the change in temperature has a negligible impact on the pH and may be ignored. In the case of the cylindrical parabolic trough with a glass cover, the total dissolved solid was decreased from 330ppm to 300ppm, whereas in the case of the parabolic trough without a glass cover, the total dissolved solid was reduced from 330pm to 310ppm. People living in rural areas may benefit from the use of this solar water purification system because it is efficient in terms of cost, needs very little upkeep, and can be utilized frequently to obtain pure drinking water, even in places where the infrastructure necessary to run such systems is lacking.

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

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