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SOLAR POWERED WATER PURIFICATION SYSTEM

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Abstract

Water purification is a term used to describe the process of converting unclean water into clean, drinkable water. The concept of converting unclean water into clean water is an old concept that has been used since ancient times. In modern times, as years go by technology advances and new methods of purifying water are developed, access to clean, drinkable water is still a problem for many people around the world, especially in places where clean water is not accessible. Two popular methods of purifying water are used today: reverse osmosis and UV light. The problem with both methods is reverse osmosis kills all the minerals in the water, leaving a pure liquid with no minerals for the consumer to benefit from. UV light is an expensive method that not everyone can afford. To solve the problems of modern methods, a solar-powered water purification system is introduced. Solar panel with photovoltaic (PV) mechanism is used in water purification system to be a clean source for the environment and the system to operate. The system is designed to be easy to install anywhere, especially in rural areas where access to clean water is difficult. The water purification system uses a boiling method to purify water, which does not deprive the consumer of the minerals in the water. It is also manufactured using standard components, making it affordable for the majority of people.

Keywords: Photovoltaic (PV), Reverse osmosis, Solar panel, UV light, Water purification.

1. Introduction

Everyone should have access to clean and safe drinking water - it's essential for our health and for our communities to grow and thrive. However, many people around the world still don't have access to safe drinking water, causing many health and economic problems. Water purification is not a new process introduced in recent decades. It has been around since the dawn of civilisation. The ancient Egyptians, for example, used clay to distil water to remove bacteria and germs [1]. The Greeks also had their own way of purifying water and turning it from undrinkable to drinkable [2].

Moving on to the modern days we live in today. As technology has developed, new methods of purifying water have been discovered and used. For example, reverse osmosis and ultraviolet (UV) [3, 4]. These two methods have improved their effectiveness in treating and purifying water. The problem is that not everyone can install reverse osmosis or afford UV. This is especially true for people who live in desert areas and have limited access to electricity. This means that some communities cannot use these methods because they are too expensive or not good for the environment, especially those living in small towns away from large cities that don't have the same facilities as big cities [5].

In response to these problems, solar-powered water purification systems have become a viable option [6]. Solar-powered water purification systems provide a sustainable and decentralised way of treating water [7]. By using solar energy, this system can purify water without using electricity or fossil fuels from the grid [8]. The system can also be installed anywhere, as long as the area has a water supply. Using solar energy to purify water is not a new idea [9]. But now, with better solar technology and more concern about climate change and protecting our environment, people are becoming interested in investing in equipment or systems that are environmentally friendly [10]. Solar-powered water purification systems use solar panels to convert sunlight into electricity. This electricity is used to power a battery that is used to clean and purify water using a heating coil [11].

Solar-powered water purification systems can be used in different locations and different environmental conditions. This means it is flexible in size and can be built in different sizes depending on the amount of water that needs to be purified. It can be used in many different types of environments. Solar-powered water systems can be used in small areas and tailored to the needs of local communities. The water purification system does not require a large infrastructure or a lot of money to set up like modern traditional water treatment. This way of doing things without a central infrastructure not only means it doesn't depend on one place but also makes us better able to deal with problems like natural disasters or infrastructure failures when moving from one place to another [12].

In addition, solar-powered water purification systems are better for the environment than traditional purification methods. By using solar power, these systems reduce the need for fossil fuels, which helps reduce pollution and the impact of climate change. Solar-powered systems help reduce the pollution caused by traditional water treatment methods, such as using chemicals and discharging wastewater [13].

This research paper includes a comprehensive comparative analysis of existing solar-powered water purification systems currently available. This comparative approach is critical to understanding the current state of the technology and identifying areas where significant improvements can be made.

By comparing the proposed system with existing solutions, the significance and potential impact of the proposed system in addressing global clean water challenges will be clearly demonstrated. This comparative approach ensures that the proposal here makes a meaningful contribution to the field of solar water purification. The proposed system also uses a different mechanism for purification that is not commonly used in the market. The mechanism is boiling, which purifies the water and retains its minerals for the benefit of the consumer.

2. Methods

2.1. Design structure of solar power system

The solar-powered water purification system, as the title suggests, uses a solar panel as the primary source of power for the water purification system [14]. The solar panel receives light from the sun during the morning of the day. Using a photovoltaic (PV) mechanism, it converts the sunlight into electricity. The solar panel is connected to a solar controller before it is connected to any device to avoid overcharging any device connected to the solar panel.

In the system, a battery is the device connected to the solar panel via the solar controller. When the battery is charged, the electricity goes to a coil that heats and purifies the water. The water source in areas where the system is installed will not be fully drinkable. The reason the water is undrinkable is because it contains germs and bacteria. The main function of the heating coil is to boil the water and kill germs and bacteria. This process makes the water safe to drink by killing the germs. The heating coil is connected to the rechargeable battery so that it can heat water using solar power. This makes the heating process efficient and easy to control.

After the water is boiled, it passes through two double condensers. The double condenser cools the water to room temperature so it's ready to drink. After the water is cooled and purified, it is ready to drink. The whole process of cleaning the water using a solar panel and making sure it's safe to drink is all connected and automatic. It doesn't require much repair or maintenance.

In simple terms, the solar-powered water purification system works by using sunlight to help heat a coil, which then boils the water to make it clean and safe to drink. This provides a good and reliable way for people in remote or underserved areas to access clean drinking water.

2.2. Block diagram

The system consists of a 100W solar panel which generates electricity to power the heating coil. A solar controller is used to regulate the current between the solar panel and the battery to avoid overcharging the battery.

A 12V battery is used to generate electricity directly to the heating coil to boil the water and kill the germs in the water. The heating coil is the main component in the water system used to purify the water.

The final stage of the water purification process is to cool the water to room temperature. The reason for cooling the water is to provide the user or consumer of the system with immediate access to water for consumption. Block Diagram for The Solar-Powered Water Purification System as shown in Fig. 1.

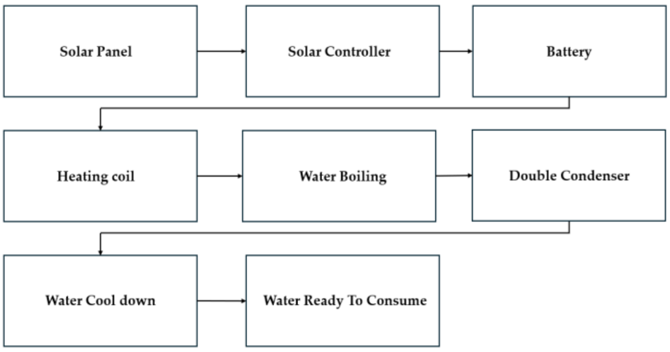

Fig. 1. Block diagram for the solar-powered water purification system.

2.3. Components

Solar Panel: A 100W solar panel is the primary power source for the water purification system to operate 24 hours 7 days a week.

7.2A rechargeable battery: The role of the battery in the system is to charge the heating coil, and the heating coil will boil the water to kill the germs and bacteria contained in the water for purification purposes.

Solar Controller: The solar controller is used to connect the solar panel to the battery. It allows the solar panel to generate electricity for the battery via a solar regulator and prevents the battery from overcharging by controlling the current that goes from the solar panel to the battery.

Heating coil: The heating coil is used to boil water and turn it from undrinkable water to drinkable water.

Double condenser: After boiling, the water passes through the double condenser to cool and prepare it for consumption. The components used in the development of the water purification system as shown in Fig. 2.

100W Solar Panel [15].

Rechargeable Battery [16].

Solar Controller [17].

Heating Coil [18].

Double Condenser [19].

Fig. 2. The components used in the development of the water purification system.

2.4. Flow chart

The flow chart in Fig. 3 illustrates the experimental setup for the development of a solar-powered water purification system. The process begins with a solar panel, which captures solar energy. This energy flows to a solar controller, which regulates whether the energy is directed to the battery for storage. If sufficient energy is available, the controller channels it to the battery. The stored energy then powers a heating coil, which heats the water. The heated water is subsequently passed through a double condenser, facilitating condensation and purification. This setup optimises the use of solar energy for effective water purification.

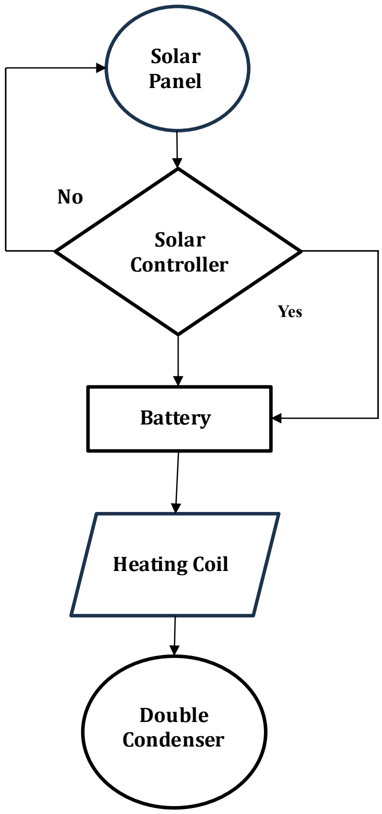

Fig. 3. Flow chart of the experimental flow in the development of solar powered water purification system.

2.5. Experimental setup

Figure 4 shows the detailed experimental setup of the solar-powered water purification system. The system begins with a solar panel that harnesses energy from sunlight. This energy is directed to a solar controller, which manages the flow of power to a rechargeable battery. The battery stores the energy and supplies it to a heating coil inside the water tank. As the water heats up, it produces steam, which passes through a double condenser. The condensation process purifies the steam, which is then collected as clean water in a water container. This setup demonstrates an efficient utilisation of solar energy for water purification.

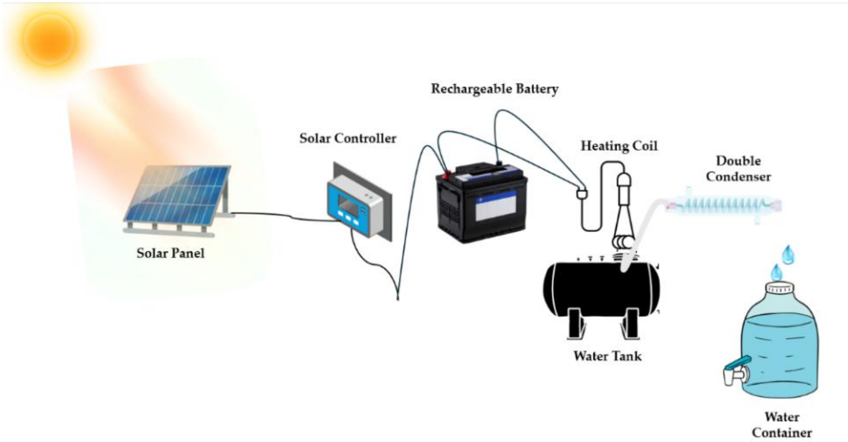

Fig. 4. The experimental setup of the solar-powered purification system.

3. Results and Discussion

To understand how long it will take the solar panel to charge the battery, an energy calculation must be made. The solar panel is measured in watts, so the battery capacity must first be converted to watts and then calculated to determine how much time it will take to charge the solar panel.

The following equation is used:

Power Available in Battery (Watt Hour) = (Battery Size AH) × (Battery Voltage) (1)

Applying equation (1), Power in Battery = 7.2AH × 12V = 86.4WH

The result of the above equation is the number of watts in the battery.

Time required to fully charge the battery using a 100W solar panel in an ideal case:

$$\frac{\textbf{Power Available in Battery}(\textbf{WH})}{\textbf{Power in Solar Power }(\textbf{W})} \quad (2)$$

$$\frac{\textbf{86.4}}{\textbf{100}} = \textbf{0.864 hour} = \textbf{52 Minutes}$$

Calculation of raised heating to water, the temperature that the heating coil can reach to kill the germs is 95 C. Using the following equation to determine how much power is required from the battery to power up the heating coil.

$$Q(w) = (V_w)(\rho_w)(C_{p,w})(\Delta T_w) \quad (3)$$

Q (w) = Total heat Input, (V_w) = Volume of the water, ρ_w = density, $C_{p,w}$ = specific heat that the water will reach, and ΔT_w = Temperature rise.

Assuming the number of litres targeted to purify is 5 litters means that the V_w equals to 0.005 m^3. The density of water ρ_w equals to 1000 kilograms per cubic meter at room temperature.

The heat capacity of water $(C_{p,w})$ approximately equals 4.18 kilojoules per kilogram per Celsius kJ/kg °C.

ΔT_w is the temperature difference between initial and final temperatures (25 ℃ – 95 ℃).

$Q(w) = (V_w)(\rho_w)(C_{p,w})(\Delta T_w) = 0.005 \times 1000 \times 4.18 \times (95 - 25) = 1463$ kJ

Practically, the total heat input required will vary depending on the number of litres. For example, the average Malaysian household consists of 4 people, each of whom uses 4 litres, or 16 litres per day in total.

$\mathrm{Q(w)} = 0.016 \times 1000 \times 4.18 \times (95 - 25) = 4681.6$ kJ

In theory, an increase in temperature causes molecules to dissociate into ions. As ions are charge carriers in water, an increase in the concentration of ions leads to an increase in conductivity as shown in Fig. 5.

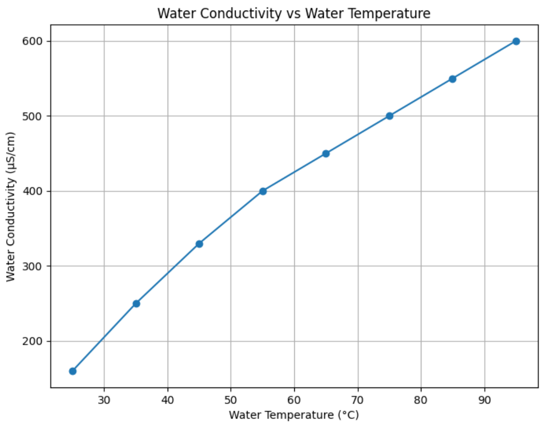

Fig. 5. Water conductivity vs water temperature.

Total dissolved solids (TDS) in water are various minerals such as salts and other substances. Figure 6 describes TDS measured all substances in water, not just substances that contribute to conductivity. However, many substances are ionic, which explains why TDS increases with respect to conductivity [20].

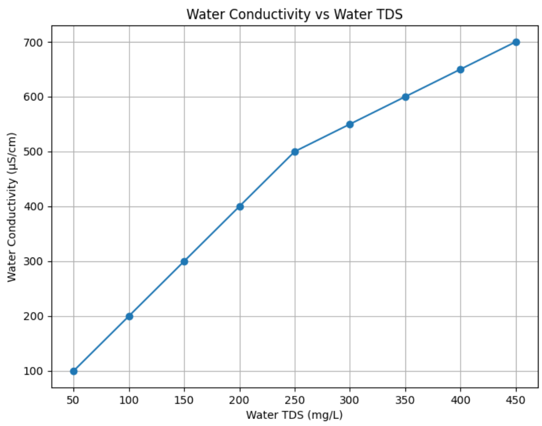

Fig. 6. Water conductivity vs water TDS.

Figure 7 shows as the solar power output increases, the battery increases by default due to the direct connection between the two components via a solar controller. Solar power is proportional to sunlight. In real life, clouds block most of the sunlight, which means the sunlight is affected and doesn't fully expose its photons to the photovoltaic solar panel. This is one reason why the performance of solar panels varies and cannot be constant all the time. On the other hand, the battery capacity is consumed depending on the amount of water the heating coil heats. The greater the quantity, the higher the rate of consumption of battery capacity.

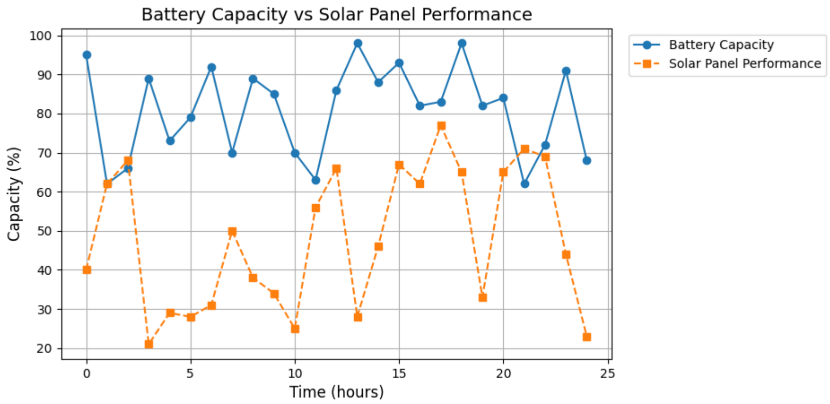

Fig. 7. Battery capacity vs solar panel performance.

4. Conclusions

The solar-powered water purification system proposed in this paper presents a groundbreaking solution for providing clean drinking water, especially in rural and underserved areas. By leveraging solar energy to power the boiling and condensation processes, this system negates the necessity for an external power supply or reliance on fossil fuels, epitomising a decentralised and autonomous approach to water purification. The design's simplicity, incorporating easily accessible components such as a solar panel, rechargeable battery, heating coil, and condenser, not only underscores its cost-effectiveness but also ensures ease of installation and maintenance, making it highly accessible to communities with limited resources.

The analysis and experimental results detailed in this paper compellingly illustrate the efficacy of solar-powered water purification in eliminating harmful bacteria and contaminants. The boiling process effectively eradicates pathogens while preserving essential minerals, ensuring the purified water remains safe for consumption and retains its nutritional value. Moreover, the system's sustainable and environmentally friendly nature contributes to reducing carbon footprints and promoting green technology adoption in water purification practices.

This innovative approach not only addresses immediate water safety concerns but also offers a long-term, sustainable solution for water-scarce regions. By empowering communities with a reliable, self-sufficient, and eco-friendly water purification method, this system holds the potential to significantly improve public health outcomes and enhance quality of life. The insights and empirical evidence presented herein advocate for broader implementation and further development of solar-powered water purification systems as a viable and transformative tool in the global effort to ensure clean water access for all.

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