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Renewable Energy Powered Water Purification System

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Abstract. *This study focuses on designing and implementing a renewable energy-powered water purification system to provide clean water for Diplahan National High School. The system utilizes solar energy to power a filtration unit, addressing the school's need for an affordable and sustainable water purification solution. The project was developed to ensure water safety by removing contaminants while minimizing operational costs through the use of renewable energy. Testing revealed that the system effectively improves water quality, making it a viable option for enhancing the school's access to potable water. This study highlights the potential of renewable energy in supporting sustainable solutions for educational institutions.*

Keywords: *Renewable energy, Water purification system, Solar energy, Sustainable solution, clean water, Filtration unit, Affordable water purification, Contaminant removal, Potable water, Educational institutions.*

Introduction

Water plays a vital role in health, in terms of use for utilities such as cleaning and hygiene. Although water is readily available, some schools struggle to find sanitary water that is safe for cleaning. It is now well recognized that an important component influencing learning is not only the caliber of instruction but also the surrounding environment, particularly the availability of clean, safe, usable water, proper sanitation, and hygienic habits (Marielle Snel, 2002). This is a concern because students and school staff are vulnerable to the dangers of contaminated water.

Between November 2002 and June 2003, a study was conducted to determine the frequency and distribution of ringworm infection among elementary school students in northern Ebony State, eastern Nigeria. 59 (21.1%) of the 279 students randomly selected from four schools had ringworm.(T Fox, 1872). As noted by Jeremiah Zac (2023), neglect of basic hygiene measures further exacerbates the spread of such infections. The combination of close contact among students and insufficient hygiene practices creates an ideal setting for fungal infections to proliferate. To address this, schools should prioritize regular cleaning, provide access to clean water, and instill good hygiene habits among students. Such measures are crucial in reducing the frequency and impact of ringworm and other similar infections.

According to Raimann, J.G., Boaheng, J.M., Narh, P. et al., (July 2020), viral infections and coliform bacteria frequently contaminate water. The issue is made worse by elements such as a dearth of hygienic facilities, poor hygiene habits, and significant floods during rainy seasons, which could potentially be harmful to our health. Other water contaminants, like mosquito larvae that dwell in stagnant water sources or dirty water, could potentially be one of the factors affecting most health issues.

Although buying water would be the safest and most convenient option, using renewable energy-powered water purification systems is an eco-friendlier and budget-safe option for public schools nationwide. According to Huda Elasa et al. Al.'s renewable energy-powered water purification system provides a reliable and flexible system that meets the community demands throughout both the wet and dry seasons.

With a restricted, clean, accessible supply of water and some students experiencing financial instability, investing in environmental protection strategies while addressing the water resource crisis is a win-win opportunity for educators and students. Because of its initiative to address the issues concerning most school areas. As stated by Mark Sobsey in 2003, such comprehension of the function of safe, usable water supports and facilitates the promotion of health and the prevention of disease, with the with the ultimate objective of supplying communally piped water that is safe for all people on the planet, inexpensive, secure, and easily accessible.

Since the beginning of human evolution, one of the most common and natural biological processes in humans has been excretion. However, it is evident that present sanitation procedures need to be improved given that many sections of the world lack access to basic sanitation (Mooyoung Han and Shervin Hashemi, 2016). A clean water system in school ensures constant hygiene and sanitation especially in dispose of fecal matter, urine and other human waste. Having safe and clean water promotes a healthy and clean environment that is highly beneficial to students and school staff. In the study of A T Merchant, C Jones, et. Al., 2002 sanitation and access to water are separately linked to better child development. This further shows the must of having clean water for personal and environmental hygiene. Disinfection of water is one of the main achievements of our time in the protection of public health.

The use of chlorine for the destruction of microbiological pathogens is essential to protect the public from outbreaks of waterborne disease. Chlorine, as well as other disinfectants, produces a variety of chemical by-products. The risk from the presence of microbial pathogens in clean water is estimated to be several orders of magnitude greater than the risk from chlorination by-products. Any efforts to control these by-products must not compromise the microbiological quality of water. The use of chlorine and its compounds for the disinfection water has played a central role in reducing the incidence of these diseases and can be considered one of the most important success stories of our times for the preservation and promotion of public health. Galal (1996).

Another beneficial factor that this prototype offers is its green-based technology that uses renewable energy resources from the sun. The prototype prioritizes the safety of the environment and offers a clean, sustainable water system to meet the school's demands. A move towards renewable energy sources is now required due to the rising demand for energy and gasoline emissions (Qais Aslam and Syed Baker, May 2024). Petrol emissions or fossil fuel-generated energy may be convenient and faster than renewable energy systems; however, the risk to the environment and health issues is alarming. The use of fossil-generated energy costs is increasing for its high demand and decreasing in its supply. Therefore, developing ways to use energy through renewable and eco-friendly energy is a must to slowly eliminate environmental and health issues.

It is important that schools investigate the "renewable energy-powered water purification system" for its potential benefit to students' health and access to clean sanitation and hygiene. Installation of a solar-powered energy system provides schools with a sustainable and accessible clean water system that could potentially reduce the risk of water contaminants that can affect students and school staff's health and academic performance. This study fills a critical gap by offering school-doable ways to improve children's learning environment and overall well-being.

Statement of Objectives

This study investigated the renewable energy powered water purification in Diplahan, Zamboanga Sibugay S.Y.2024, specifically to ensure it met optimal safety and cleanliness standards.

Specific Objectives:

1. To design renewable energy powered water purification system.
2. To determine the level of energy consumption the renewable energy powered water purification system acquires

2.1. Power Consumption;
2.2. Battery Capacity;
2.3. Energy Usage

3. To determine the amount chlorine per liters of water to achieve the desired PPM concentration.

Methodology

This research took an experimental design path to develop and test a renewable energy-driven water purification system at Diplahan National High School. Adopting an agile and iterative design process, the researchers combined solar panels, batteries, inverters, and a sequence of filtration elements—such as a geo water filter, thermal purification unit, and chlorine disinfection—to develop a sustainable system that can generate clean water. The system was built and tested under real conditions, performance being assessed via power consumption analysis, battery capacity testing, and water quality readings, such as pH and chlorine levels before and after treatment. By mimicking real-world environments and quantifying useful outputs, this experimental approach allowed the team to systematically improve the system's efficiency, safety, and sustainability.

Results and Discussion

This chapter presents the results of the Renewable energy powered purification system and discusses the findings related to statement of objectives. Each specific objective is addressed, and the results are discussed in detail. Relevant data are included to support the findings.

1. Designed a renewable energy powered water purification system

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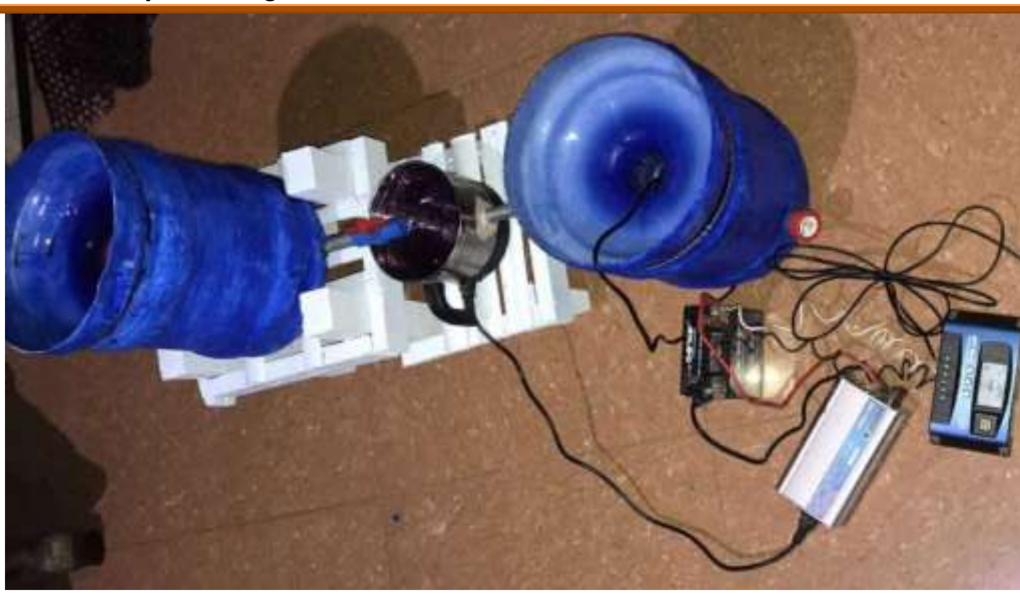


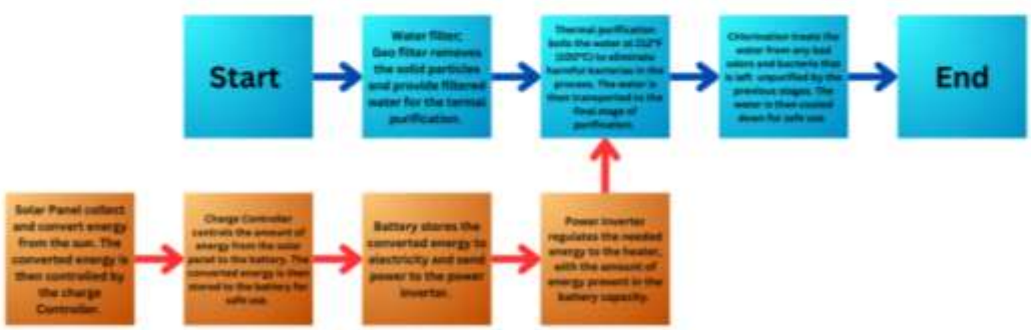
The first objective involved attaching each component to form the renewable energy-powered purification system. This included integrating the solar panel, charge controller, battery, and power inverter as the renewable energy source, along with the geo water filter, thermal purifier, and chlorination system, which were associated with the water pump. The system was tested using the school's water source, and it successfully purified the water, producing clean and safe output.

Renewable Energy Source: The solar panel absorbed sunlight and converted it into electrical energy, storing it in the battery through the charge controller. The system successfully provided a steady power supply to the purification system components.

Purification System: The geo water filter, thermal purifier, and chlorination unit, powered by the renewable energy source, operated seamlessly with the water pump to treat the school's water source

Flowchart:

The diagram illustrates the process of converting renewable energy into electrical power to operate the purification system, showcasing the seamless flow from energy capture to water treatme



Hardware Diagram:

The provided diagram shows a renewable energy-powered water purification system, where power is sourced from a solar panel, processed through a charge controller, stored in a battery, and then inverted for use in the purification stages.

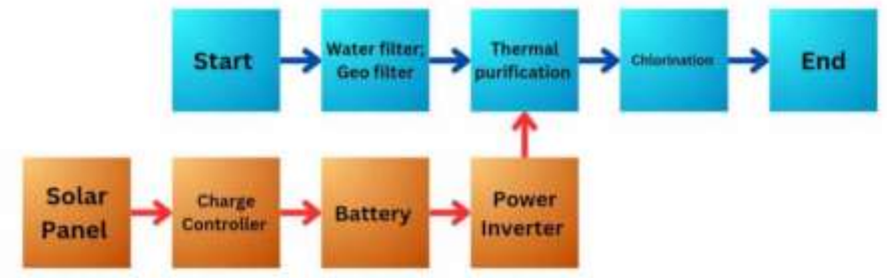


Figure 1. Flow Chart

2. The Level of Energy Consumption the Renewable Energy Powered Water Purification System

This acquires by following the formulas; for Current (Amps) for the power consumption, Battery Capacity Formula to calculate the battery capacity needed by the heater and water pump and the energy consumption to calculate the energy usage to express energy usage in kilowatt-hours (kWh). The solar panels and battery are calculated to determine the needed capacity.

With the given data as shown as,

- Solar Panel Voltage (V): 1000 V
- Solar Panel Current (I): 0.5 A
- Battery Capacity: 5–10 Ah (taking the average, 7.5 Ah)
- Heater Power (P): 300 W

The Operational Time (t) of the equipment is determined.

Solar Panel Power Output

Solar panel power output can be calculated as:

$$P\ (solar) = V \times I$$

$$P\ (solar) = 1000V \times 0.5\ A = 500W$$

Battery Energy Capacity

Battery energy capacity is calculated as:

$$E\ (battery) = \text{Battery Capacity} \times \text{Voltage}$$

For simplicity, we'll use a 12 V battery (common in such setups):

$$E\ (battery) = 7.5Ah \times 12V = 90Wh$$

Heater Energy Consumption

The energy consumed by the heater depends on its power and operating time:

$$E\ (heater) = P\ (heater) \times t$$

To find the maximum operational time t divide the battery energy capacity by the heater power:

$$t = \frac{\text{E (battery)}}{\text{P (heater)}}$$

$$t = \frac{90\ Wh}{300\ W} = 0.3\text{hours} = 18\text{minutes}$$

Energy Supplied by Solar Panel

If the solar panel operates at 500 W, it can recharge the battery and power the heater simultaneously. However, excess energy beyond the heater's consumption may go toward recharging the battery.

If the heater consumes 300 W, the surplus power from the solar panel is:

$$P\ (surplus) = P\ (solar) - P\ (heater) = 500W - 300W = 200W$$

This surplus can extend the system's operation by recharging the battery while running the heater.

Solar Panel Output: 500 W Heater Consumption: 300 W

Battery Energy Capacity: 90 Wh

Max Heater Runtime on Battery Alone: Approximately 18 minutes (0.3 hours)

With Solar Panel Assistance: The system can operate continuously under full sunlight, with 200 W surplus energy available for recharging the battery.

3. The Amount Chlorine Per Liters of Water in PPM Concentration.

This configuration demonstrated a balanced and efficient system design. The solar panel supported continuous operation during daylight hours, while the battery provided a backup for short-term usage when sunlight was unavailable. The calculated parameters indicated that the renewable energy system was both functional and sustainable for its intended application.

The final objective involved determining the optimal amount of chlorine per liter of water to achieve the desired parts per million (PPM) for effective disinfection. This process included measuring the pH levels of different water solutions from the school's water source before and after chlorination. The findings are summarized below:

Parts per million (PPM) is a way of expressing very dilute concentrations of substances. 1 PPM means 1 part of a substance per million parts of the solution.

The formula to calculate the amount of chlorine needed in milliliters (ml) per liter of water to achieve a specific PPM is:

$$\text{Volume of Chlorine (ml)} = \frac{\text{Desired PPM} \times \text{Volume of Water (liters)}}{1000}$$

If you want to achieve a chlorine concentration of 2 PPM in 1 liter of water:

$$Volume\ of\ Chlorine = \frac{\text{2PPM X 1 Liter}}{1000} = 0.002 \text{ Liter or 2ml}$$

Therefore, you would need to add 2 ml of chlorine solution to 1 liter of water to achieve a concentration of 2 PPM. For practical applications, such as maintaining safe chlorine levels in swimming pools, the CDC recommends keeping chlorine levels between 1-3 PPM for optimal safety.

Water solutions	PH measurement before chlorination	pH Scale Description	PH measurement after chlorination	pH Scale Description
Rain water	5.6 – 5.5	Slightly acidic	6.5 -8.5	Neutral
Tap water	6.5 – 8.5	Neutral	6.5 – 8.5	Neutral

This table illustrate the ph scale of each distinct water solutions before and after the chlorination.

With the given data, the results show that the pH of rainwater increased from an initial range of 5.5 to 5.6 (slightly acidic) to a range of 6.5 to 8.5 after chlorination. This demonstrates that chlorination is not only effective in disinfection but also in neutralizing the acidity of the water. The resulting pH of the rainwater after chlorination is comparable to most tap water, as tap water is also treated with chlorine to ensure its safety for consumption.

The results confirmed that chlorination was an effective method not only for water disinfection but also for balancing the pH levels of various water sources. Specifically:

Rainwater and groundwater, which had acidic to slightly acidic pH values, were neutralized and adjusted to fall within the recommended range for potable water.

Tap water, which was already within the desired pH range, remained stable after chlorination, showing no adverse effects from additional treatment.

Conclusion

In conclusion, this study successfully designed a renewable energy-powered water purification system that integrates solar energy with advanced filtration methods, including chlorination, a geo-water filter, and a thermal heater. This multi-stage system ensures the removal of impurities, effective disinfection, and enhanced water quality, providing a sustainable and efficient solution for areas lacking stable access to clean water and electricity.

The study also determined the system's energy requirements, including battery capacity and power consumption, ensuring its practicality and reliability in various conditions. The integration of renewable energy with chlorination for disinfection, geo-water filtration for removing sediments and impurities, and thermal heating for additional purification demonstrates the effectiveness of this holistic approach. This project highlights the potential of combining clean energy with innovative water purification technologies to address global water scarcity while minimizing environmental impact. The findings serve as a valuable reference for future efforts to develop eco-friendly, adaptable systems that promote clean water access and sustainable development in underserved communities.

Recommendation

To further the system's efficiency and scalability as it runs on renewable energy-based water purification, the future improvements suggested are that it should upgrade to a high-capacity water pump to streamline water transfer and cut down delays while filtering. Efficiency in terms of energy also needs to be met by opting for hybrid sources of renewable energy, like using both solar and wind power together, to facilitate perpetual operation even under low-sunlight conditions. The addition of high-capacity energy storage devices would also stabilize system performance. Further, the process of filtration could be optimized with locally available and environmentally friendly materials, an automated monitoring system, and the system designed for modular expansion would boost reliability and flexibility. All these suggestions are meant to enhance the system's robustness, affordability, and applicability for wider community usage.

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