Solar Powered Portable Water Filter

ECE 445 Project Proposal

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1 Introduction

1.1 Problem

There are many places in the world where people do not have access to clean drinking water, and they are forced to drink contaminated water to survive. The World Health Organization estimates that 29% of the world's population does not have access to clean drinking water. It has also been reported that contaminated water can transmit diseases such as diarrhea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 485000 diarrhoeal deaths each year [1].

Hiring the installation of a filtration system is expensive and many people do not have enough resources to afford it. In less developed countries, the problem is even greater as it cannot be installed because they obtain water directly from lakes or rivers. In addition, these undeveloped countries do not have access to electricity, so many water disinfection techniques are limited.

1.2 Solution

We propose the creation of a portable water filtration system capable of removing most impurities, metals, and bacteria from water. It will be a two-tank system. The first one will have our water filter and the second one will use UVC rays to disinfect the water. Our water purification system will remove heavy metals and impurities using a conventional Brita water filter [2]. We will detect any water left in the first tank using a water level sensor. When all the introduced water is filtered and there is no water left in the first tank, ultraviolet light will be activated to disinfect the water in the second tank. That would eliminate most of the possible bacteria and viruses. An LED will indicate to the user that the ultraviolet light is active. When the LED is off, it means that the water is completely clean and perfect for drinking. Additionally, we will use a water flow sensor at the end of the water filter to know when the filter has reached the end of its lifetime and needs to be replaced. The system will automatically warn the user by turning on another LED that they need to replace the filter.

1.3 Visual aid

Figure 1. Visual aid to help interpret our product

1.4 High-level Requirements

- Demonstrate that water has been purified by our project by measuring the bacterial content as well as the turbidity before and after use of our filter. We will do this by collecting a water sample and measuring the bacterial content and the turbidity content of that sample in a university lab. Then we will use the same source for another water sample but this time we will filter it using our device. We will then measure the bacterial content and the turbidity content of that sample in a lab. If a university laboratory cannot be used to perform the analysis, we will use a TDS meter to test impurities dissolved in water [3].
- Demonstrate that the filter change detection system is functioning properly. For verification, demonstrate that the LED indicating the replacement of the filter is on when the device manual indicates that the filter should be changed.
- Demonstrate that the product uses only solar power and does not need to be connected to the grid at any time. We will do this by showing that our device is powered by a battery that has only been charged using a solar cell.
- Demonstrate that the filtering system is automatic, and that the user does not need to interact with the product beyond changing the filter and adding the water. This is quite self-explanatory. If the user does not need to push any buttons or do any work during the purification process, then the filter is automatically doing its work.

2 Design

2.1 Block Diagram

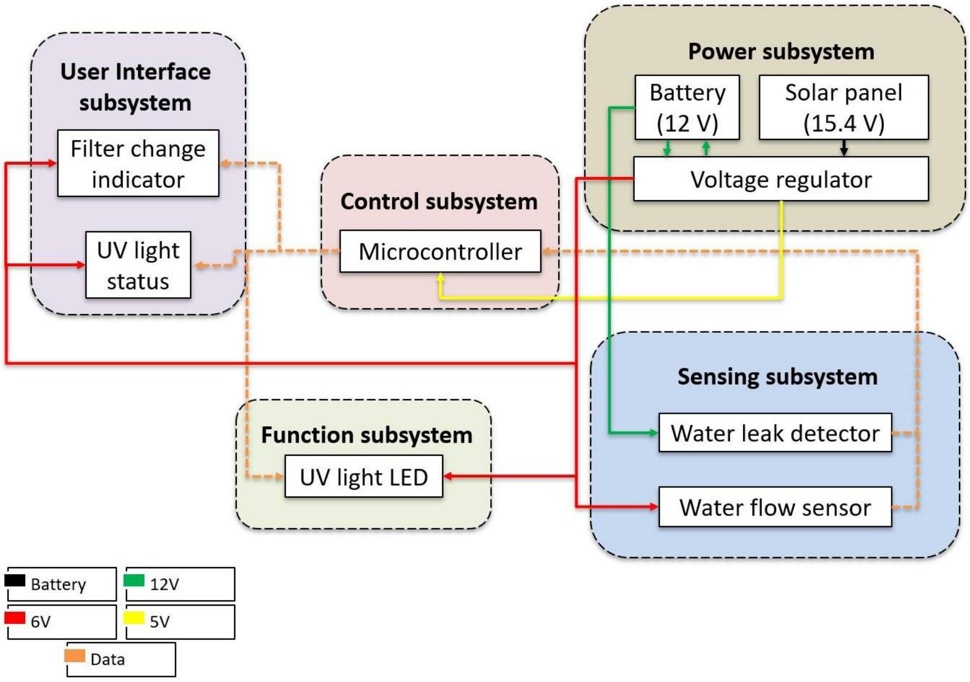

Figure 1. Block diagram of our product divided into subsystems

2.2 Subsystem Overview

- Power subsystem

  This subsystem consists of only a solar panel, a battery, and a voltage regulator, which together serve as a power supply for the other subsystems.

  First, the photovoltaic panel converts the sun's rays into photovoltaic energy, acting as a voltage source of 15.4 V. Then, the voltage is reduced to 12 V using a voltage regulator.

  After reducing the voltage to 12V, the energy is stored in a battery which is necessary since the solar panel is not a constant voltage source and in periods without light, the product would be useless.

  Using as a constant power source the battery and a dc-dc converter we will power the rest parts of our product.

  The power of the battery would be reduced using step down transformer circuits from 12 V to 5 V for the microcontroller and from 12 V to 6V for every other part of the device except the water leak indicator. That is directly powered by the 12 V.

- Control subsystem

  We would be using a CY8CKIT-044 microcontroller from Cypress Semiconductor as our microcontroller. This microcontroller would control when different modules are turned on and off. The following are the requirements for this subsystem -

  1. It would operate at about 5 V. It would be powered from the 12 V battery after it has been stepped down from 12 V.
  2. It would act as the switch to turn on all different parts of the device.
  3. It would also send signals to the LEDs to send appropriate information to the user.

- Sensing subsystem

  The sensing subsystem consists of a water sensor and a water flow sensor whose operation is explained below.

  The water sensor would detect if the tank on the top has water in it and decide if the UV lights module should be turned on based on that. It would detect if the tank had water or not using a water leak detector. This water leak detector would detect if there is water present in the tank using two probes at the end of the sensor. If there is no water present in the tank, it would send a signal to the microcontroller that there is no water present in the tank. The microcontroller would then turn on the UV light module. The following are the requirements for this subsystem -

  1. This sensor is a SEN0454 by DFRobots. It operates at 12 V. It would get power directly from the battery and not through the step-down transformer as its minimum voltage is 7 V and it operates between 7-18 V.
  2. This water leak detector sensor would be powered through a 12 V battery.
  3. The microcontroller would control when the water leak detector is turned on. It would only be turned on during the time there is water in the first tank. It would stop as soon as the UV lights are turned on. This is done to conserve energy.

The water flow sensor would measure the changes in the flow rate of water and compare it with the range of flow rates of water for a clean filter. The microcontroller would access the water flow levels and the time taken to filter and determine if the filter is working properly or if we need a replacement. If there is a need to change the filter, we would have an LED on the outside of the container that would light up. The following are the requirements for this subsystem.

1. A water flow sensor. We will be using a Seeed Studio flow sensor. It would operate at about 6 V (it can operate at a voltage range of 5 - 24 V but 6 V would be ideal for our project).
2. This water flow sensor would be powered through a 12 V battery that has been step downed to 6 V.
3. The water flow sensor would be connected to the microcontroller. It would receive the signals from the water flow sensor. If the water flow levels are too low and the time taken to filter is longer than the expected time range, that means the filter needs to be changed. This is when it would send a signal to the led to light up and it would light up outside the device. It would also control when the water flow sensor is turned on. It would only be turned on during the time there is water in the first tank. It would stop as soon as the UV lights are turned on. This is done to conserve energy.

- User interface subsystem

  We would have three LEDs on the outside that would constitute the user interface. It would tell the user information about what kind of process is going on inside the device and when it is safe for him/her to take out the water from the device.

  During the process, first, the yellow LED will light up indicating that the water is being filtered correctly. When the yellow LED turns off, the purple LED will turn on indicating to the user that the UV light is on. Once both LEDs turn off, the water is ready to drink.

  Finally, the third LED will light up indicating to the user that the filter is very worn out and according to the manufacturer, it is time to replace it as it may start filtering worse until it eventually does not filter at all.

- Function subsystem

  To perfectly purify and clean the water, we will be using a Brita standard filter and a UV light.

  The Brita standard filter will start filtering the water as soon as the user puts the water into the first tank. This filter does not receive data or power from any other subsystem and that is why it is not drawn in the block diagram. But it is fundamental in the operation of the final product since it oversees removing mercury, copper, chlorine, cadmium, and zinc that may be dissolved in the water and are harmful to human health.

  The UV lights would get a signal from the microcontroller to turn on when the first tank has no water left and all of it has gone through the filter. We would be using a network of two UV lights. The UV lights would be turned on for about 10-12 seconds. After 10 seconds the UV light will turn off to save energy as any bacteria and viruses that may be contained in the water will have been eliminated and the water will be in good condition.

  The following are the requirements for this subsystem -

  1. The UV lights operate at 6 V each. Each of them produces light of the wavelength of the order of 278 nm. This is required because this wavelength of light is in the range of wavelengths of UVC lights and only these ranges of wavelengths can kill bacteria and viruses to make water suitable for drinking.
  2. This module would be powered through a 12 V battery that has been step downed to 6 V.

2.3 Tolerance Analysis

Our main risk of operation is to detect changes in the water flow coming from the filter, to later indicate to the user if the filter needs to be replaced.

There are studies that indicate that as time goes by and the number of filterings, the filtering speed decreases, so by measuring the flow rate we could know if the filter is very used or not. The problem is that no manufacturer has indicated how the filtering velocity varies with use and the critical water flow rate must be obtained by performing experiments.

Another option to decide when to change the filter is to calculate the total volume of filtered water from the water flow measurement and time. A priori it seems that this way is more sensible since the manufacturers usually indicate the number of liters that the filter can filter correctly. The problem is that this amount of water indicated by the manufacturers is usually water in good condition from a tap in the United States.

Our intention is that the product is universal and can be used in countries also in African countries that have poorer water quality. As the water is worse and contains fewer impurities, the filter will wear out more in each filtration and therefore will be able to filter a smaller amount of water correctly. If in the end, we decide to use this method we should estimate the number of liters that can be filtered correctly in each region and program according to this value the maximum number of liters filtered per filter.

3 Ethics and Safety

3.1 Ethical requirements

1. We pledge that we would not entertain any kind of plagiarism while making this project and adhere to any copyrights that we encounter while making this device. If we do use other resources, we will cite them properly and give credit to anyone who has a hand in making our device. Hence, we comply with parts of sections 7.8.I-1, 7.8.I-3, 7.8.I-4, and 7.5.I-5 of the IEEE Code of Ethics[4].
2. Our project does not breach any ethical guidelines and strives to help people get access to clean drinking water. We aim to help every person who cannot access clean drinking water due to any reason purify their own drinking water using our device. Hence, we comply with section 7.8.II-7 of the IEEE Code of Ethics[4].
3. We pledge that we will accept any kind of feedback and criticism that would help us improve our device and make it safer for its users. This is because we understand that our device has the potential to impact many people. Hence, we comply with section 7.8.II-5 of the IEEE Code of Ethics[4].

4. We pledge that we would treat all persons involved in this project with respect, entertain no kind of harassment, and avoid injuring others by adhering to strict codes of safety. Hence, we comply with parts of section 7.8.I-7, 7.8.I-8, and 7.5.I-9 of the IEEE Code of Ethics [4].
5. We also pledge that we would follow all labs rules and regulations while using the lab and will make sure that we do not damage any equipment in the lab.

3.2 Safety requirements

While no federal regulations exist for residential water treatment filters and purification systems, we plan to adhere to a strict code of safety conduct as our device does have the potential to harm humans.

1. We pledge that we would prioritize the safety of all people working in the project as well as the safety of the user. Our project uses UVC lights to disinfect the water. These lights are harmful to our skin as well as our eyes. Hence, they are a hazard to people's health. We will make sure we test our device and confirm that there is no leak of UVC lights outside using a UV light sensor.
2. We pledge that we would make sure that we do not harm any person present in the lab.
3. We pledge that we will always be honest about the efficiency of our device and the extent to which it can purify water as safe drinking water is one of the most important things in the world as we believe that wrong information about devices that specialize in water purification can harm a lot of people.
4. We also pledge that we will make sure our product is safe for use by other people before we try to demonstrate its working to other people.

These guidelines are applicable to each of our team members as individuals as well as our project, and we aim to abide by and hold each other accountable to these guidelines as specified by 7.8.III-10[4].

References

[1] https://www.who.int/news-room/fact-sheets/detail/drinking-water#:~:text=Contaminated%20water%20can%20transmit%20diseases,000%20diarrhoeal%20deaths%20each%20year

[2] https://www.brita.com/products/standard-replacement-filters/

[3] https://www.amazon.com/-/es/Probador-calidad-HoneForest-temperatura-acuarios/dp/B073713G5F/ref=sr_1_3?keywords=TDS+meter&qid=1644375163&sr=8-3

[4] IEEE Code of Ethics