Department of Electrical and Computer Engineering

Sustainable Drinking Water Device: Final Proposal

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Advisor	Name	Signature	Date

I. Introduction

i. Objective

This proposal is aimed to introduce a sustainable device that can produce clean water through UV radiation and detect turbidity and waterborne pathogens using biosensor circuits. This device is intended to suggest an improvement to current drinking water accessibility throughout the world and possibly develop a case for further investigation.

ii. Background

Many drinking water sources throughout the world are contaminated by various pathogenic bacteria. When pathogenic bacteria are not properly detected it could lead to illness and death to individuals drinking from these sources. It has been reported that waterborne pathogens cause 10-20 million deaths each year worldwide. From these numbers the assumption that current testing and purification methods that use chemical, manual and mechanical approaches seem to be inefficient. Their inefficiencies could be a result of them being time consuming, unsustainable and/or inaccessible. A technically appropriate (easy-to-use) sustainable automated device that can produce clean drinking would be an addition to the progress of finding a solution to accessible clean water sources throughout the world. This proposal introduces a prototype that will be designed and developed to integrate a closed vessel UV reactor and subsystems that detect waterborne pathogens using biosensor circuits.

II. Problem

i. Problem Definition

Design and develop an integrated drinking water quality analytical system that is sustainable, portable and easy-to-use to provide real-time results for worldwide applications (urban, rural, underdeveloped, remote locations, etc.).

ii. Problem Formulation

The contamination of drinking water by pathogens is the most important aspect of drinking water quality [7]. This problem occurs as a consequence of contamination by fecal matter, particularly human fecal matter, containing pathogenic organisms [7]. It has been reported that waterborne pathogens cause 10-20 million deaths each year [5]. In addition to the aforementioned deaths it was reported that each year more than 200 million people are affected by non-fatal infections [5]. “Currently studies focused on optically based transduction methods aim to achieve a more robust, easy-to-use, portable, and inexpensive analytical system. [6]” The

integrated system introduced here is intended to introduce a technical alternative to drinking water quality testing and purification that can progress the aforementioned quote stated in "Advances in biosensors for detection of pathogens in food and water."

iii. Design Requirements

Function	Requirements
Power	• The battery should be recharged by solar energy
Detection	• Red LED should light upon detection • Green LED should light when nothing is detected and after proper purification
Selection	• The device should go directly to UV radiation if no Turbidity is detected
Time	• Purify 2 liters of water within 10 minutes
Quantification	• Test with known contaminated water and known purified water
Size	• 3'x3' (Rough Estimation)

III. Current Status of Art

Drinking water quality monitoring and purification systems have been researched, experimented and developed for years. The three major water purification methods that are used within developing and remote locations are Biosand filters, solar distillation, and chemical disinfection tablets.

The Biosand filter is a manual method that uses several physical components. A basic example of how this method works is a plastic container that has an opening for dirty water to be input and output is packed tightly with a layer of gravel at the bottom with sand tightly packed on top of it. The dirty water enters the top of the container and travels through the sand. As the dirty water is traveling through the sand along with the bacteria it may contain is trapped and the clean water is dispensed at the other end after it has gone through the gravel. The following figure provides an illustration of this method.

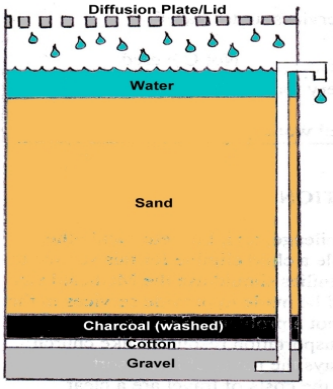


Figure 1: Biosand Filter

<u>Major drawbacks of solar distillation:</u>

- Time; lengthy process that can take 30-40 minutes
- Only produces water $\leq$ 4 liters of water a day
- Takes one month for the filter to reach full efficiency

Solar Distillation is another manual method that produces clean water from the sun. The process of solar distillation is as follows, the water is separated from salts, solids, inorganic compounds, and impurities through evaporation. The following figure provides an illustration of how this method works

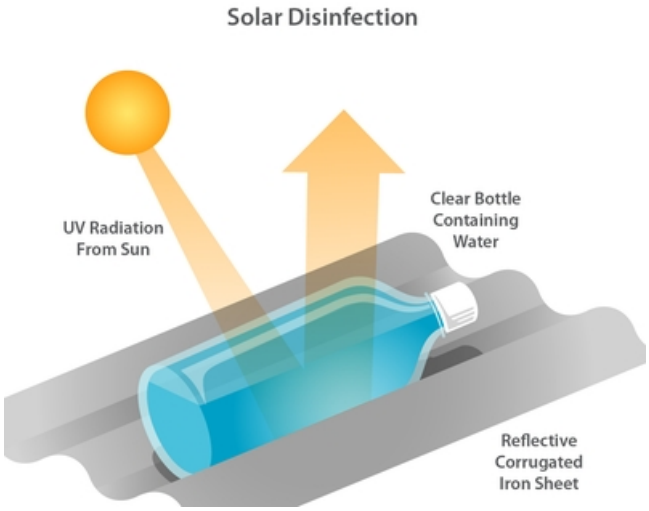


Figure 2: Solar Distillation

The water vapor condenses on a collection area for later use. A similar method that also uses solar energy is a Single-Basin Solar Still. This method uses a basin covered with a sloped glass or plastic that is absorbed by solar energy which causes the water to heat up, evaporate, and later condense. One more example of solar distillation is the Emergency Still; which is an in-situ design that uses a bowl, cup, rubber band, and plastic wrap. During this process the contaminated water is placed within the bowl and the empty cup is placed in the center of it. The bowl is then covered tightly with the plastic wrap and secured using the rubber band. The bowl and cup are then placed in the sunlight where the water is evaporated and condensed. The Emergency Still is often used in developing areas with the lack of proper materials, but the method is still inefficient and not a solution for multiple users.

<u>Major drawbacks of solar distillation:</u>

- Availability of water bottles
- Low effectiveness of rate of turbidity reduction
- Inefficiency of distillation
- Over 40% of your water can be lost using this method

Chemical tablets are a disinfection method used to kill pathogens in drinking water. These tablets are often used in rural areas and in conditions where natural drinkable water is not present. Chemical tablets come in various forms and often contain chlorine, chlorine dioxide, or iodine. Through the combination of these sorts of chemicals the bacteria, viruses, pathogens and parasitic protozoan's can be disinfected and harmless for human consumption. Most chemical tablets address deadly pathogens, but do not address turbidity reduction. The following image provides an illustration of chemical disinfection.

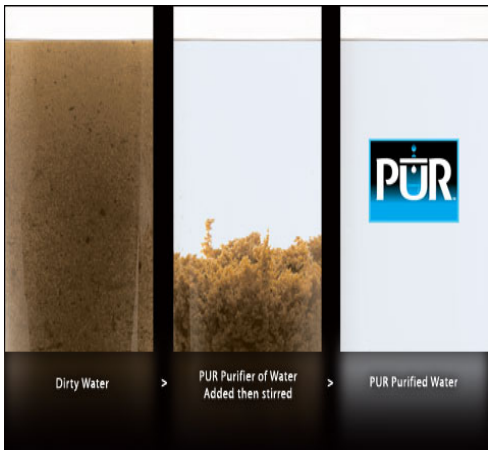


Figure 3: Chemical Disinfection

Major drawbacks of solar distillation:

- Can leave an undesirable taste in the purified water
- Limited per the amount made available to a community
- Only purifies one glass of water

IV. Engineering Approaches

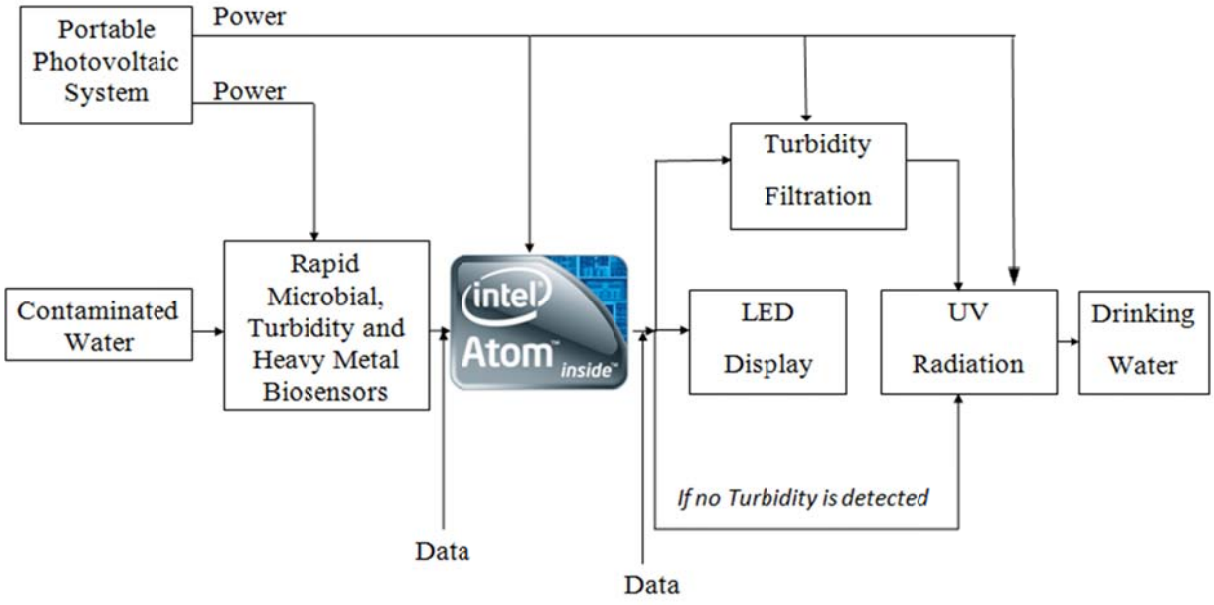


Figure 4: First Draft of Integrated System

a. Photovoltaic (PV) Cell

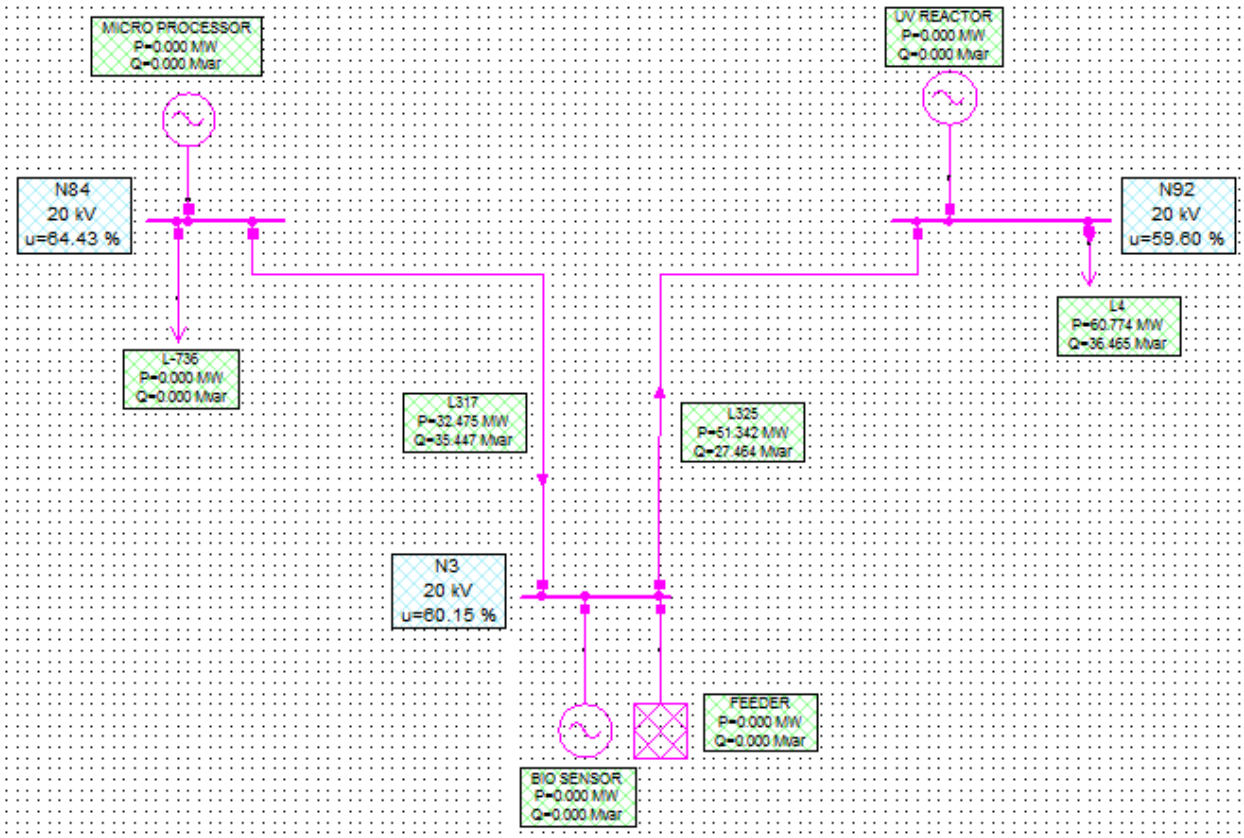
The device will be powered by portable PV cells. This approach is intended to satisfy the goals of developing a sustainable device. The electricity generated by the panel is direct current, but by installing an inverter it becomes alternative current. This method of sustainable energy is ideal for this type of device rather than other renewable energy sources such as wind, hydrogen, geothermal, ethanol and biofuels due to portable PV cell technology being very handy for remote locations where transmission lines are not environmentally desirable or financially practical [9]. The portable PV cell will have a rechargeable battery installed for the purposes of powering the device in situations when solar energy is not available. For example, during the day solar energy from the sun will be used to charge the battery so the device can be powered at night when the sun is not available.

The device will use Direct-Current (DC) load and no conversions to Alternating-Current will take place. DC voltage will be used to power the entire device. Currently, it is known that the microprocessor requires 12 V with DC current, but the closed vessel UltraViolet (UV) reactor and biosensor voltage requirements are unknown. Once the power requirements for the two unknown components are

identified, the DC power flow of the device will be analyzed. This will be done by the DC power flow equation:

$$p_i = \sum_{j \neq 1} B_{ij} \theta_j \ (i = 1,2, \ldots n) \qquad (1)$$

Then quantify our results using the NEPLAN software. The following diagram is intended to provide an example of how the DC power flow analysis will be modeled through NAPLAN. Here the biosensor is being used as a reference point and is connected to the micro processor and closed vessel UV reactor.



b. Rapid Microbial Indicator and Turbidity detection subsystems

The rapid microbial indicator subsystem is intended to detect multiple pathogen contaminants. This device is intended to detect different pathogens recognized as high health significance by the World Health Organization (See Table 1).

Pathogen	Health significance[b]	Persistence in water supplies[c]	Resistance to chlorine[d]	Relative infectivity[e]	Important animal source
Bacteria					
Burkholderia pseudomallei	High	May multiply	Low	Low	No
Campylobacter jejuni, C. coli	High	Moderate	Low	Moderate	Yes
Escherichia coli – Pathogenic[f]	High	Moderate	Low	Low	Yes
E. coli – Enterohaemorrhagic	High	Moderate	Low	High	Yes
Francisella tularensis	High	Long	Moderate	High	Yes
Legionella spp.	High	May multiply	Low	Moderate	No
Leptospira	High	Long	Low	High	Yes
Mycobacteria (non-tuberculous)	Low	May multiply	High	Low	No
Salmonella Typhi	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
Shigella spp.	High	Short	Low	High	No
Vibrio cholerae	High	Short to long[g]	Low	Low	No
Viruses					
Adenoviruses	Moderate	Long	Moderate	High	No
Astroviruses	Moderate	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Hepatitis A virus	High	Long	Moderate	High	No
Hepatitis E virus	High	Long	Moderate	High	Potentially
Noroviruses	High	Long	Moderate	High	Potentially
Rotaviruses	High	Long	Moderate	High	No
Sapoviruses	High	Long	Moderate	High	Potentially
Protozoa					
Acanthamoeba spp.	High	May multiply	High	High	No
Cryptosporidium hominis/ parvum	High	Long	High	High	Yes
Cyclospora cayetanensis	High	Long	High	High	No
Entamoeba histolytica	High	Moderate	High	High	No
Giardia intestinalis	High	Moderate	High	High	Yes
Naegleria fowleri	High	May multiply[h]	Low	Moderate	No
Helminths					
Dracunculus medinensis	High	Moderate	Moderate	High	No
Schistosoma spp.	High	Short	Moderate	High	Yes

Table 1: Table containing pathogens for which there is some evidence of health significance related to their occurrence in drinking- water supplies [2].

Technologies for rapid detection of bacteria have two general steps in their application [10].

1. Capture – Here the microbial species or group of interest is removed, tagged or amplified to differentiate it from the remaining material in the sample [10].

2. Detection – Here the captured, tagged or amplified material is counted or measured quantitatively. The detector typically acts as a transducer, translating the biological, physical, or chemical alteration into a measureable signal [10].

i. There are a number of detection methods that were considered and our current plan of action is to implement biosensors. Within biosensors the use of fiber optics may be implemented as well because they appear to be promising for environmental application because of the ability to make remote in situ measurements and the inherent sensitivity of optical approaches [10]. Fiber optic biosensors involve the use of a combination of immune-based capture approaches [10].

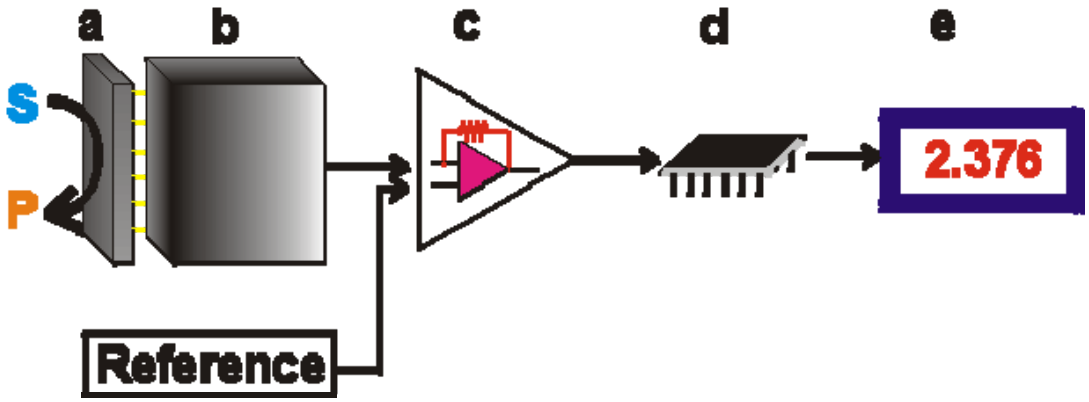


Figure 2: Schematic Design showing the main components of a biosensor [15]

(a) The biocatalyst; which converts the substrate to a product
(b) The transducer; which converts the reaction in (a) to an electric signal
(c) Here the output of the signal in (b) is amplified
(d) Here it's processed
(e) Displayed results (The current plan for the integrated system is that color coordinated results will be displayed)

c. Purification System

The device will use a suitable Closed Vessel Ultraviolet Reactor to purify and contaminated water that is detected. Ultraviolet radiation has been shown to effectively purify water for almost a century. The process of UV radiation to purify water is done by absorbing the organisms through the light from the electromagnetic spectrum. This causes a photochemical reaction altering the essential molecular components that are needed for the cell to function [18].

d. LED Display

The system is intended to use a simple LED display that will show the level of pathogen contamination in the drinking water by color coordination with respect to a certain range of data (e.g. If E. coli is detected by the biosensors and the Maximum

Contamination Level (MCL) exceeds or is equal to 5% red will display, but if the MCL is at 0% green will display, etc.). This approach is an aspect of the system that will satisfy the goals of being technically appropriate or easy-to-use system.

e. Turbidity Subsystem

When purifying or producing clean drinking water it is imperative to filter turbidity. When turbidity is not filtered it decreases the efficiency of any purification system due to the cloudiness of the water. Therefore, it is planned for this device to have a turbidity subsystem to conduct the proper filtration and reduce the cloudiness of the contaminated water before it is input into the closed vessel UV reactor.

V. Tasks and Deliverables

Each member has been assigned a specific subsystem or part of the integrated system to focus on. The tasks have been assigned as follows:

Task

Adegboyega:

1. Develop coded algorithms to read in electric signal from the biosensors to the microprocessor
2. Develop coded algorithms to output the data from the microprocessor to the purification system of turbidity filtration system
3. Develop coded algorithms to light the appropriate LED upon detection of contamination or purified water

Eric:

1. Ensure that the appropriate biosensors are being used and develop the circuitry need to complete a biosensor circuit that outputs data at a measurable electric signal
2. System integration ensure that the appropriate platform is being used to integrate each component of the device and develop the circuitry needed to do so
3. Develop the circuitry needed for the LED display

Henok:

1. PV Cell System and Energy Storage
2. Conduct DC power flow analysis using equation (1) and NEPLA software
3. Ensure that the appropriate portable PV cell system is being used and the device is meeting all power requirements
4. Ensure that the rechargeable battery is storing enough energy

Deliverables

A Stationary, sustainable and technically appropriate device that can detect and purify contaminants in 2 Liters of drinking water within 10 minutes or less.

VI. Project Management

Timeframe	*Task*	*Deliverables*
	Analysis Phase	
October 2012- November 2012	1. Learn atom processor 2. Literature Search	1. Identify Strengths and Limitations 2. Literature to reference throughout our analysis
November 2012 – December 2012	1. Asses and analyze the integrated systems components	1. Identified all the requirements needed for each subsystem
	Build Phase	
December 2012 – February 2013	1. System production 2. System Integration	1. Each subsystem will be developed independently 2. An integrated system
	Testing/Modification Phase	
February 2013- March 2013	1. Prototype testing and Modifications	1. Tested subsystems and integrated system
April 2013 – May 2013	1. Final Report 2. Presentation for ECE Day	1. Present at ECE Day

VII. Conclusions

In conclusion, our aim is to develop a technical device that is sustainable, robust, time-efficient and easy-to-use for people in developing countries who do not have access to purified water.

VIII. References

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