UNIVERSITY OF
CENTRAL FLORIDA

Senior Design: Divide and Conquer 1.0

Smart Water Bottle

Prepared by:

Group #5
Self-Sponsored

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Project Description

Project Narrative and Motivation

According to the CDC, between 30 and 70 percent of global explorers suffer from traveler's sickness. Of those individuals, more than 80 percent fall ill due to bacterial pathogens [1]. One of the most common ways that travelers get exposed to bacteria is through the consumption of biological contaminants in water from underdeveloped sanitation systems. A single sip of improperly treated hydration can expose people to various gruesome diseases including typhoid, cholera, salmonellosis, and a myriad of unpleasant maladies. With sterility in the vogue, virus and disease prevention has prime real estate in the minds of much of the population. And, due to a continuous need for water, pure drinking water is integral to personal wellbeing. This holds not only to people travelling through foreign nations but also applies to those merely going about their daily routine. Thus, this project seeks to design a long-term, portable, affordable solution for consumers seeking more assurance both abroad and throughout their workweek.

The proposed product is a smart water bottle that can sanitize its contents using UV irradiation and generating a potability report of said contents based on spectral analysis. After sanitization is complete the user will have the option to remove any remaining non-biological contaminants with a standard filter. The sanitization process will start whenever the user initiates the procedure via a button on the bottle. One intent behind this product is to ensure peace-of-mind for international travelers concerned by water-borne pathogens and parasites. However, this product is for more than just jetsetters (who are an endangered species among the laymen). Our product is also appealing to the tech savvy consumer that likes to have "smart" devices with added functionality for ease in daily life. Therefore, an app will be created so the user can receive more detailed information about the quality of their water (information which cannot be displayed on the device).

From a technology standpoint, several systems will be considered for implementation into the smart water bottle. It will have wireless charging built into the cap to allow for convenient recharges of the device as well as improved water resistance. The optics system will consist of a UV diode for sanitizing the biological contaminants and a Raman spectroscope for determining the content's potability post-sanitization. The bottle will also have LEDs for status and result indications, a Bluetooth module for communications with a paired device, a reed switch to ensure the sanitizer only runs in appropriate conditions, and an embedded microcontroller. All of the electronics will be contained inside of the cap so that users may choose any compatible metal water bottle. The Bluetooth functionality will potentially pair with an app that displays a cumulative water score based on the EPA's regulatory maximums [2]. The intent is to keep the product as simple and coherent as possible for any traveler to use while still allowing the owner to access more detailed data via the app.

Most smart bottles in the market today implement less useful features such as glowing to remind you when to drink, a built-in Bluetooth speaker, and water intake tracking. Some bottles are also UV sanitizing but tend to run on a schedule and do not allow the user to simply press a button to initiate sanitization. Other senior design smart water bottle projects also had water sanitization and smart features such as water intake and a Bluetooth app- however, these projects did not incorporate wireless charging or introduce a CREOL focus on fine-tuning optics technology for the purposes of water quality assurance and monitoring. Previous projects also lack modularity, a feature of significant importance as the proposed device can be used with a variety of vessels.

Project Components

Water Quality Sensor

This component will perform spectral analysis of the contained fluids. The sensor will consist of a spectrometer that projects the spectrum of the radiation pumped into the sample by the sanitization component onto a CCD or CMOS sensor. The stainless-steel bottle's reflective surface will serve as a feedback system, amplifying the admittedly insignificant influence of Raman scattering to the point of measurability. The spectrum will then be normalized to account for variations in transmissibility and compared to a spectrum produced by potable water. Significant deviation will trigger a warning LED via the embedded hardware. A copy of the spectrum will then be transmitted to a paired device for more detailed analysis.

Sanitization

This component is going to help with the sanitization of the water in the bottle. The components for this are going to be placed in the bottle cap. We are going to build a tunable UV laser with a wavelength ranging from 210 nm to 300 nm. According to NIST the tunable laser is more efficient in killing the biological contaminants in the water [3]. This laser will help kill the biological contaminants present in the water and make it safer to drink the water. This will help prevent from water-borne diseases, like typhoid and cholera, that are caused by the biological contaminants in the water.

Device Power

The device will be powered by a rechargeable battery. It has yet to be fully explored which chemical composition of battery would best suit the project needs, but the two options under investigation are Nickel-Metal Hydride and Lithium-Ion battery technologies. The charged battery will supply power to the rest of the components with DC-DC voltage regulators, specified by the various voltage requirements for each individual component.

Charging the battery is to be achieved by wireless transmission of AC voltage supplied by a standard US 120 Volt wall outlet. The initial intention is to create a charging pad that will contain the inductive AC power transmission coil to be closely aligned with the top to the water bottle cap while not in use. A manual switch will be included in the pad to turn the charging off and on as needed. There will be a set of permanent magnets installed to help the charging pad sit properly aligned on top of the water bottle. The wireless power transmission will be received by inductive coils within the water bottle cap and the AC voltage will be rectified and connected to a regulator in order to charge the battery.

Embedded Hardware

The device hardware will mainly involve sensors, LEDs, a microcontroller, and a Bluetooth module. There will be a CMOS sensor for determining the water quality, a sanitizing LED controlled by the microcontroller, and a reed switch for determining if the cap is on. Having a reed switch is especially important since UV-C light is harmful to human beings and therefore needs to be contained inside the bottle. All of the sensors will be controlled by the microcontroller. It is preferable to use a TI microcontroller due to the familiarity of embedded programming software. The microcontroller also must have enough I/O pins to support the sensors (reed switch included), LEDs, and the Bluetooth module. A microcontroller with a low power mode is strongly desired to improve the battery life of the product. Due to some of the peripherals, it will also have to be compatible with common communication protocols such as UART and I2C (perhaps also SPI). The microcontroller (even with high-drive current pins—thermal limitations) most likely will not be able to drive enough current to the laser, so a MOSFET switching circuit will likely be implemented for enabling/disabling the UV-C laser diode. A red/green/yellow LED (preferably in one package) will be used to provide rudimentary water quality info. to the user after sanitization has taken place. It is proposed to include an Integrated Circuit to provide a dot/bar voltage display that shows the charge status of the battery in an array of 10 LEDs [4]. An additional button may also be necessary for the device to enter BT pairing mode. From a design standpoint: EAGLE PCB design software will be utilized due to ongoing familiarity, and the boards will most likely be ordered and assembled by PCBWay. A turn-key assembly is desired due to the current industry-wide chip shortage.

Software

The software will be comprised of embedded firmware for the board itself, and then rudimentary app development. Most likely Code Composer studio will be utilized for creating the firmware for the microcontroller. The firmware must be able to check that the cap is on before activating sanitization, enable/disable sanitization, check the quality of the water (via the CMOS sensor), display rudimentary water quality information via LEDs, and wirelessly communicate with the iOS app via Bluetooth. It will require a significant amount of time to learn about the various sensors and how to interface with them (via the microcontroller). The sensors will require implementing standard communication protocol functions such as UART Tx/Rx and I2C commands. A lot of development overhead will also go into implementing Bluetooth wireless protocols to successfully transmit water quality data to the application. It will also be necessary to include code for processing and storing the various water quality statistics. When the device is not readily being used, the microcontroller should also enter low power mode to conserve energy.

The app will receive data via Bluetooth from the device and then report more in-depth water quality data to the user. The app will most likely be programmed on iOS since this platform is much easier and cheaper than programming for an android device. Apple products also have very capable processors which should help hasten computational analysis on the application. Device pairing will be a very important feature due to Bluetooth protocols. Simplicity will be emphasized in the app as the project members have limited experience with coding apps.

Requirements/Specifications

Physical Characteristics/Dimensions

Water Bottle Lid	Round 3" diameter x 4" tall Plastic top to allow for inductive charging
Water Bottle Body	Round 3" diameter x 10" tall

Cost Constraints

Water Bottle Body	$20

Performance

Auto-safety UV-C shutoff	When the cap is removed from the bottle during sanitization, the laser should shut off immediately so that user cannot be potentially exposed to the laser diode. This can be achieved through an interrupt to the microcontroller (of very high priority) that shuts the laser off if a mechanical tab is no longer depressed
Time for one sanitization cycle	1 minute
Sanitization effectivity	Kills 99.9% of contained micro-organisms
Sensor detects the presence of	Arsenic, lead, and copper explicitly with indirect detection of other materials

Water Quality Sensor

Sensitivity	The spectrometer must be capable or reliably separating the spectra of sampled light and registering wavelengths which contain less than 1% of the cumulative spectra
Size	The spectrometer must utilize mirrors to function in the confines of the cap, and occupy less than ¾" in height of the base of the cap (threaded region not included)

Sanitization

Pump Source	Will compare between mercury lamp, excimer lamp and LED sources.
Lenses	The design must be compact so the focusing and collimating lenses will be chosen according to the distances.
Second Harmonic Generator	To get the correct wavelength of 210 nm to 300 nm appropriate non-linear crystal will be used.
Output Coupler	Will need to research more on this to find out how to tune the laser from 210 nm - 300 nm for the output.
Output lens	Will most likely be a dispersing medium like an LED or a dispersing lens as the light needs to travel in different directions.

Device Power

Battery	Battery Life lasts the user at least for one entire day, which would include at least 10 cycles of the sanitization and sensor modules. 3.7V, 4,400 mAh

Inductive Charge	There is an inductive charging system oriented upward in the cap. This power supply should fully charge the battery within 8 hours.
Charging Pad	The pad will plug into a standard 120 VAC wall outlet and consist of an inductive transmitter coil, an on/off switch, protective housing, and a permanent magnet (for coil alignment).

Embedded Hardware

Microcontroller	Bluetooth compatibility, TI family (similar to MSPFR430 or MSPFR6989), about 10-20 GPIO pins. Low power mode functionality with current in the 1s of microamps. Input voltage: approx. 3.3/2.8V. Serial communication support for I2C and UART
Wireless Communication Protocols	BLE: reduced power consumption. OTA data rate: 125 kbit/s – 500 kbit/s. 6ms Latency
Wired Communication Protocols	UART: Full-duplex serial system. I2C: Device addressing-serial bus
CMOS Sensor	12-bit parallel output. Pixel size: 3.75 um. Supply voltage: 2.8V. Power consumption: 250 mW.
LEDs	Red, green, yellow: indicate water quality Blue: indicate when device sanitizing Green array: indicate battery charge status
Bluetooth Pairing	Device will have a button to hold down and enter device pairing mode.

Software/App

Application	iOS platform. Bluetooth pairing and compatibility Displays the acquired spectra contrasted with a benchmark (pure) spectra, and singles out the spectra of key contaminants
Interrupt Handling	Reed switch for cap being attached to bottle, and whenever sanitization is currently taking place (based on button press)
Communication Protocols	I2C, UART, and Bluetooth (most likely 4.0/BLE)
Microcontroller low power mode	Enable low power mode to allow for a sleep current of 10 uA or less
Water Quality	Transfer CMOS outputs to microcontroller to evaluate the presence of biological contaminants

Figure 1: Technical Requirement Tables

Block Diagrams

Responsibility Legend
Dean Pickett
Ryan Koons
Matthew Woodruff
Neeil Gandhi
Unassigned

Water Quality Sensor

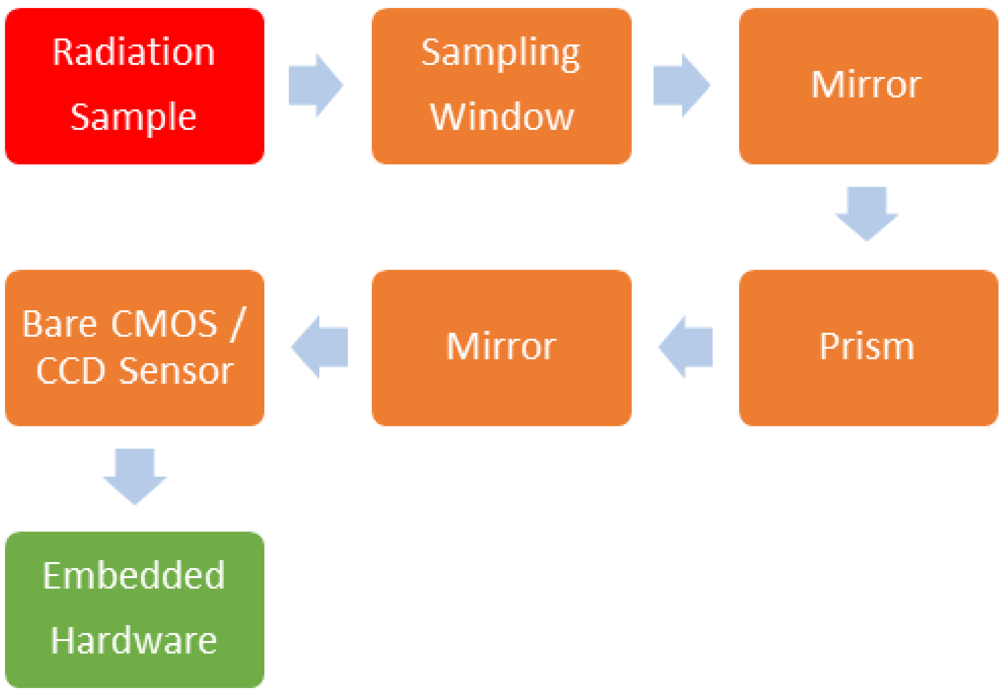

Figure 2: Water Quality Sensor Block Diagram

Sanitization

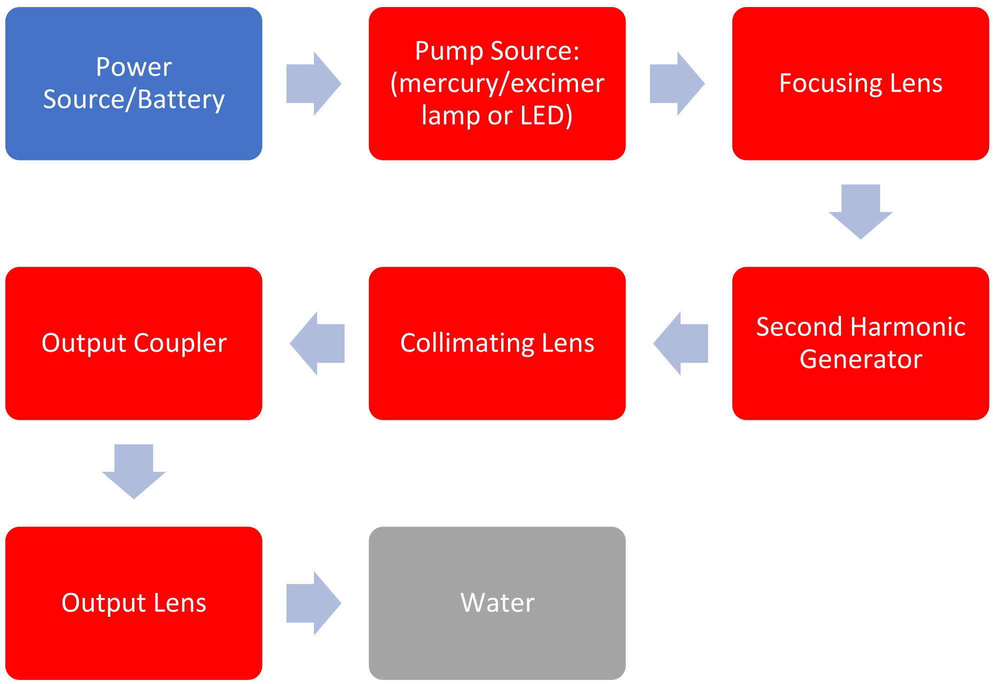

Figure 3: Sanitization Block Diagram

Device Power

Dean will be responsibility for the majority of this section, but Ryan will assist with *Voltage Regulation and DC-DC converters for the embedded hardware.*

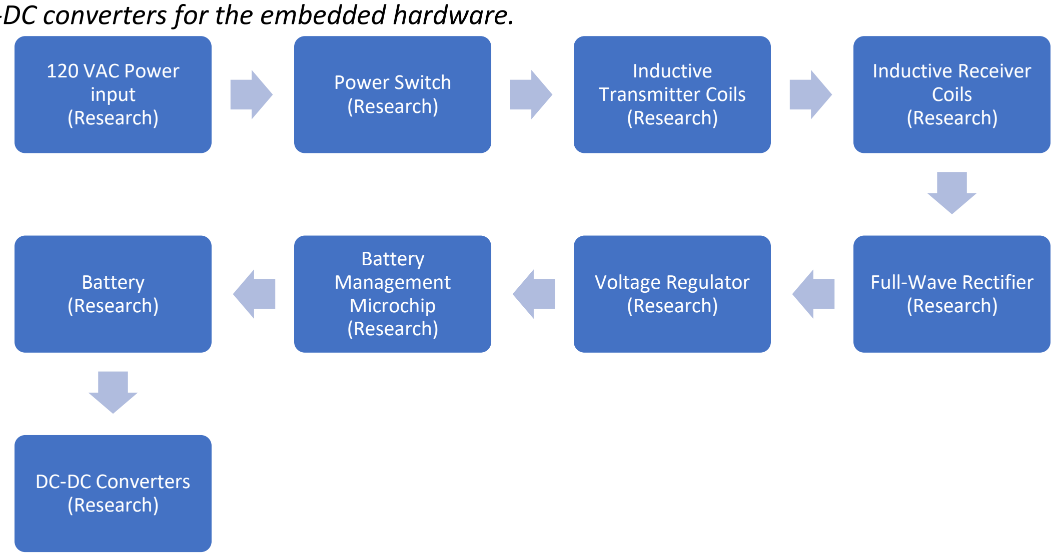

Figure 4: Device Power Block Diagram

Embedded Hardware

Ryan will mostly be responsible for this section with some assistance from Dean.

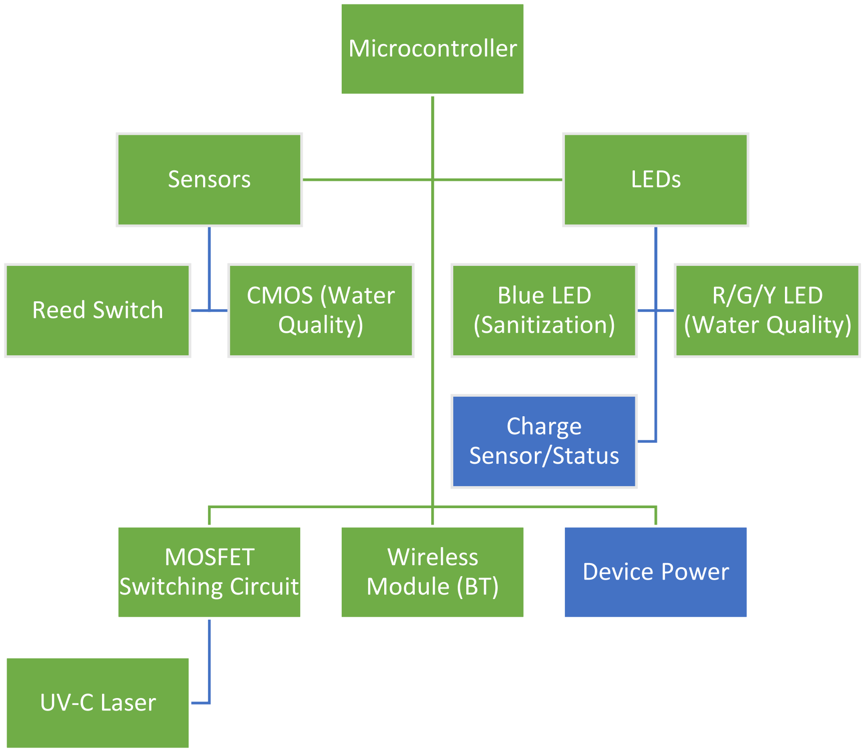

Figure 5: Embedded Hardware Block Diagram

Software

Ryan and Dean will work on this section, with some assistance from Matthew.

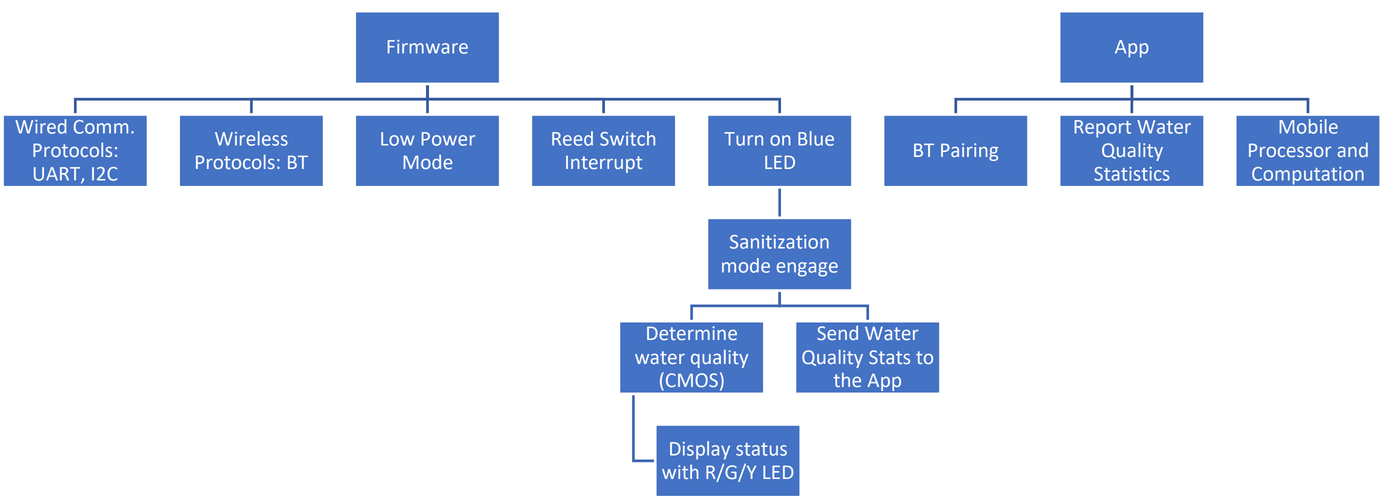

Figure 6: Software/App Block Diagram

Estimated Budget and Financing

Component	Approximate Cost
Stainless Steel Double Walled (Generic) Bottle and Lid	$15.00
PCB, solder mask, and Assembly (PCBWay) Price per Unit (will order 5 boards around $100.00 total)	$20.00
R/G/Y LED	$2.00
Buttons (Sanitization, BT Pairing)	$2.00
Blue LED	$0.50
Reed Switch	$2.00
Wireless module	$10.00
Breadboard Prototype Kit	$20.00
UV Sanitizing Diode (includes couplers, source and crystal)	$20.00
MOSFET	$1.00
Raman Spectroscopy Sensor (Water Quality)*	$36.00
Bridge Rectifier	$0.42
Power Receiver voltage regulator	$0.44
Enameled Magnetic Wire Spool	$9.70
Power Transmitter Switch	$1.60
Battery Management Microchip	$2.05
Rechargeable Battery (Depends on capacity needs)	$20.00
Voltage Display Chip	$0.69
Power Display LEDs ($0.50x10)	$5.00
Voltage Regulator Components($0.60 x3)	$1.80
TI Microcontroller (10-20 I/O)	$7.00
SMT Passive Components	$5.00
Approximate Total:	**$ 182.20**

*This purchase requires more copies of some components than are required for a single device.

Figure 7: Estimated Budget Table

Initial Project Milestones

Legend
SD1 Hard Deadlines
Tentative deadlines

Senior Design 1:

Date	Details
5/21	Project Conceptual Brainstorming. Optics and Electrical Engineering
5/27	Project Idea Discussion
5/28	Project Selection: Decided on Smart Water Bottle
6/9	Divide & Conquer v1.0 Complete the D&C
6/11	Divide & Conquer v1.0 Due. Submit the completed D&C
6/15	D&C V1.0 Meeting with Dr. Richie Discuss project idea, gain approval.
6/23	Divide & Conquer v2.0 Complete. 25 pages approximately
6/25	Divide & Conquer v2.0 Due Submit the final D&C
6/28	Paper V1 30 draft
7/2	Paper V1 45 draft
7/5	Paper V1 60 draft
7/9	60 page Paper V1 Due 60 Pages
7/16	80 page draft
7/23	100 Page Paper V2 Due
7/30	Finishing touches
8/3	Final document due
8/6	Order prototype boards (PCBWay)

Senior Design 2:

8/23	First day of Fall Semester goals
9/27	September goals -Build and test optical components
10/25	October goals- Work on software
11/24	Thanksgiving Wednesday- Have everything ready and work on testing and final paper and presentation
12/3	Last Day of Class goals – Presentation of the project
12/11	Last day of final exams – Submit the final report

Figure 8: Project Milestones Table

References

1. Connor, Bradley A. (2019) “Travelers' Diarrhea - Chapter 2 - 2020 Yellow Book,” *Centers for Disease Control and Prevention*. [Online]. Available: https://wwwnc.cdc.gov/travel/yellowbook/2020/preparing-international-travelers/travelers-diarrhea. [Accessed: 08-Jun-2021].

2. (2018) “Drinking Water Requirements for States and Public Water Systems,” *Environmental Protection Agency*. [Online]. Available: https://www.epa.gov/dwreginfo/chemical-contaminant-rules. [Accessed: 10-Jun-2021].

3. Larason, T. (2020), NIST Transportable Tunable UV Laser Irradiance Facility for Water Pathogen Inactivation, Review of Scientific Instruments, [online], https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=930308 (Accessed June 10, 2021).

4. Swagatam. (2019) “3v, 4.5v, 6v, 9v, 12v, 24v, Automatic Battery Charger Circuit with Indicator,” *Homemade Circuit Projects*. [Online]. Available: https://www.homemade-circuits.com/3v-45v-6v-9v-12v-24v-automatic-battery/. [Accessed: 10-Jun-2021].

5. Bates, Matthew. (2013) “Build Your Own Induction Charger,” *Nuts & Volts Magazine*. [Online]. Available: https://www.nutsvolts.com/magazine/article/august2013_Bates. [Accessed: 05-Jun-2021].