Transportable Water Purifying Device Using Biosand Filtration and Ultraviolet Light Treatment With Android Application For Monitoring

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***Abstract*—This study presents an Arduino-based transportable solar-rechargeable water purification device using Biosand filtration and Ultraviolet Light treatment with Android connectivity provided for monitoring and maintenance. Biosand filtration is responsible for removing pathogens and eliminating physical parameters like turbidity, iron, color and odor. However, Ultraviolet Light treatment is added to the process for more efficient removal of biological contaminants. Water parameters such as pH and turbidity level are monitored real-time throughout the purification process in an application installed on an Android unit connected to the device via Bluetooth. The process continues until acceptable range of parameters for drinking water are met according to Philippine National Standards of Drinking Water (PNSDW). Accuracy of the device is determined by comparison of results with the parameters provided by PNSDW. Physical parameters like pH, turbidity, Total Dissolve Solids (TDS) and microbiological parameters such as Fecal Coliform, Total Coliform and Heterotrophic Plate Count (HPC) of the output water from the device are also tested by a water testing laboratory for verification of results. The device was proven to be efficient and has the capability to produce potable water.**

***IndexTerms*—Android Connectivity; Biosand Filtration; Solar Energy; Ultraviolet Light Treatment.**

I. INTRODUCTION

Water is essential to all known forms of living things. Although 70.9% of the Earth's surface is covered by bodies of water, only 1% can be used as the source for drinking. Approximately 800 million people, nearly 11% of the world's population lack access to an improved drinking water supply [1]. Different kinds of water purifier are constantly developed due to problems regarding water pollution. There have been studies about biosand filter proving its efficiency. However, disinfection of the filtered water using biosand filter can be improved when other filtration method is added [2]. The portability of the water purifying system must also be considered for the use of every individual and if it can also provide sufficient amount of water needed by the consumer.

Several studies regarding water purification have been conducted to develop new water treatment techniques and methods that can provide clean drinking water to people living in remote areas such as Proportional-Integral-Derivative (PID) Control, Microwave Plasma UV Lamp, vacuum filtration, electric discharge and packed bed reactor. PID Control, proportional-integral-derivative controller, helps in controlling pH of water, clarity and presence of microorganisms in water [3]. Microwave Plasma UV Lamp emits light which destructs most waterbone bacteria and viruses, conventional lamps are limited to a maximum output power of 30W per metre while MPUVL can deliver any amount of power per unit length and tube can any be of any shape, length, or diameter [4]. Two-dimensional Graphene oxide (GO) membrane with their ultrafast permanence, outstanding mechanical properties, and high chemical stability is used for water purification process and fabricated by vacuum filtration [5]. Used of electric discharge and packed bed reactor focused on removing *Escherichia coli* (E. coli) [6][7].

This study aims to design an Arduino-based transportable solar-rechargeable water purification device using Biosand filtration and Ultraviolet Light treatment with Android connectivity via Bluetooth for monitoring that will verify general water quality indicators such as its turbidity and pH level.

It is significant to keep drinking water from uncontaminated sources for the health of the community as well as for economic and environmental reasons. This study of water purification is possible to quickly and easily filter just about any source of water such as rainwaters and tap waters making it safe to recycle in houses and other places. It will effectively reduce and remove bacteria such as E. coli and Protozoa which can cause diarrhea, abdominal cramps, and vomiting overtime on wastewaters. Furthermore, this study can lessen the usage of bottled waters hence, can help the environment while it is still transportable and convenient to use. This study is also battery operated – which is rechargeable with solar power, aside from its AC source. Moreover, the project uses Biosand Filtration (BSF) and Ultraviolet (UV) water purification to allow homeowners and business owners to efficiently remove a range of biological contaminants in their water supply. These kinds of water treatment offer several advantages compared to other methods of water purification. This study helps to maintain clean and safe potable water in disaster-prone zones and lessen the number of sickness due to lack of clean water and electrical sources during calamities such as typhoons and landslides.

II. BIOSAND FILTER

The Biosand filter is easy to use and can be produced locally anywhere because it is built using readily-available materials. It removes pathogens such as bacteria and protozoa and can also eliminate physical parameters like turbidity, iron, color and odor [8]. Succeeding effectiveness and removal efficiency of the filter increase throughout its period. The filter was observed to have higher flow rates which makes it suitable for use by a larger family for the production of clean water for both drinking and cooking purposes. Health impact studies estimate a 30%-47% reduction in diarrhea among all age groups, including children under the age of five, an especially susceptible population group [9].

Biofilm or biological layer takes 20-30 days to develop to maturity. The filter is required to be used on a regular basis to prevent the microorganisms to die in the biological layer. Dissolved chemicals, such as organic pesticides or arsenic, are not removed by the filter. The filter can be difficult to move or to transport due to its weight [10].

A study was conducted in Artibonite Valley of Haiti to evaluate the use and performance of Manz Biosand filter. Shallow, hand-dug wells provided the only source of water for 61% of the households, 26% was from springs or deep wells, 13% have the access to both and only 3% had plumbing in their household. The overall bacterial removal efficiency for the filters was calculated to be 98.5%. In the filtered water, the turbidity was decreased to 0.9 NTU from an average of 6.2 NTU in source water samples [11]. Another study was aimed at designing, constructing and evaluating a cost-effective biosand filter with the addition of zeolites for the removal of chemical contaminants from water such as calcium, magnesium and iron. Results indicated that the BSFZ had higher removal efficiency of chemical contaminants and hence can be used for production of higher quality water at lower costs [12].

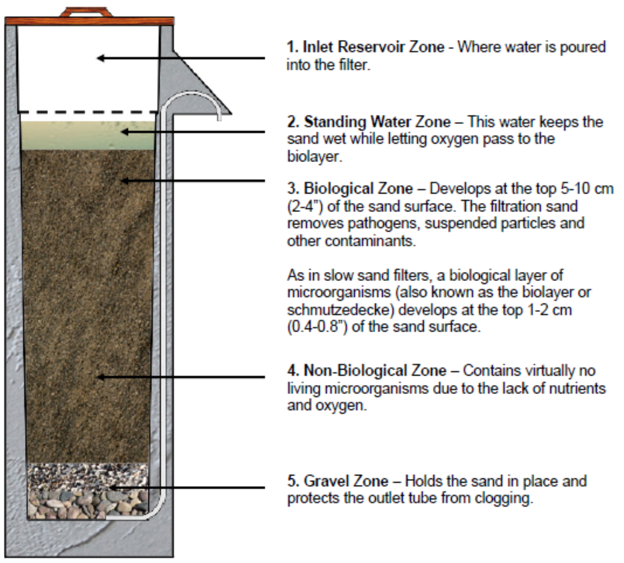

Figure 1: Biosand Filter [10]

III. METHODOLOGY

The project consists of two processes of purifying water: Biosand filtration and Ultraviolet Light Treatment for disinfection. Water parameters such as pH and turbidity is monitored real-time throughout the process of UV light treatment. Final output of water is obtained upon reaching the standards of drinking water. It uses 12V DC lead-acid battery as an alternative power source, rechargeable by a 20W solar panel in case 220V AC main power source is unavailable. The device was designed with handle and wheels, which can be a convenient way of transporting the device from one place to another.

Figure 2: External part of the device

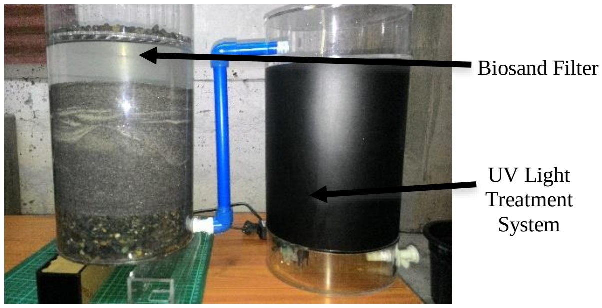

Figure 3: Internal part of the device

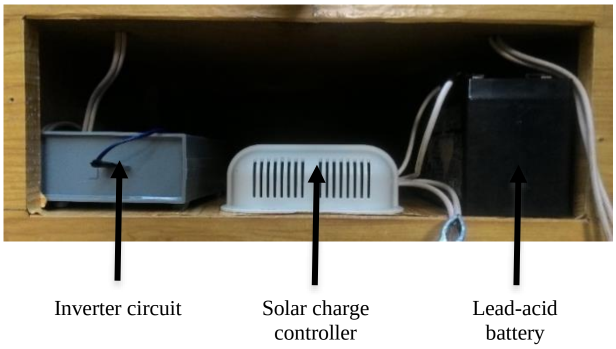

Figure 4: Internal parts of the compartment of the device

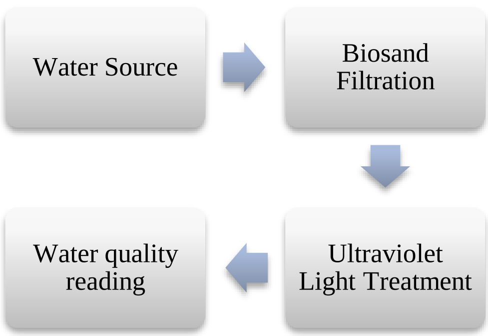

Figure 5: Main block diagram

Figure 5 represents the main processes that takes place throughout the water purification. Water source is a factor in the effectiveness of the device. If suitable source is available, the purification can be started through the Biosand Filtration. Disinfection of output water from the filter takes place in the

UV Light treatment system. Quality of the water is monitored real-time throughout the process to guarantee safety of water produced by the device.

A. Water Source

The water purifying device can be used with any water source such as rainwater, deep groundwater, shallow ground water, river, lakes or other surface water except chlorinated water because chlorine kills microorganisms in the biofilm resulting in low pathogen removal performance. Turbidity of the source water is also a key factor in the operation of the filter. Higher turbidity levels will clog the sand layer quickly so it is recommended to use water source with turbidity of less than 50 NTU [13].

Figure 6: Turbidity levels water sample [14]

B. Biosand Filtration

Physical and biological processes take place in the biofilm layer and within the sand layer. This is where pathogens and suspended solids are removed. These processes include mechanical trapping, predation, adsorption and natural death [15].

- *Mechanical trapping*

  Spaces between the sand grains physically trap the pathogens and suspended solids.
- *Predation*

  Other microorganisms in the biological layer consume the pathogens.
- *Adsorption*

  Pathogens become attached to each other, suspended solids in the water and the sand grains.
- *Natural death*

  If there is not enough food or oxygen for survival, pathogens die.

C. Ultraviolet Light Treatment

Biosand filter removes pathogens effectively but the development of the biofilm takes some time. It is necessary to disinfect the water coming from every purification process to ensure safety. Ultraviolet rays have strong germicidal (inactivating) ability, making it an effective disinfectant. It disinfects water containing bacteria, viruses, *Giardia lamblia* and *Cryptosporidium cysts* [16].

Ultraviolet light occurs at a range of 200 to 390 nanometers (nm). The device uses 260 nm of UV lamp that is close to the most effective wavelength frequency, 254 nm. From the point-of-view of microbiological disinfection, this is where the optimum energy intensity is found [17].

D. Water Quality Reading

The device is programmed to continue the process until acceptable range of water quality indicators are met. An android application is developed for real-time monitoring that will verify the output turbidity and pH level of the water. Data are sent via Bluetooth module. The application is also created for observing, checking, and keeping a continuous record of data during the purification process.

The device recognizes two general water quality indicators for the entire process of purification: pH and turbidity. Table 1 shows the acceptable limit for drinking water according to Department of Health (DOH) [19].

Table 1
Water Indicators Used and Its Limit

Indicator	Acceptable Limit
pH	6.5 – 8.5
Turbidity	<5 NTU

IV. Results and Discussion

The deep well in San Jose Del Monte, Bulacan is used as the source of water for the device. The water is treated repeatedly to obtain thirty (30) water outputs. To determine the accuracy of the device, water quality indicators (pH and turbidity) in final readings is taken for comparison with the acceptable limit of parameters for drinking water according to PNSDW, as shown in Table 2.

Table 2
Water Quality Test Readings from Groundwater

Water	Initial Reading		Final Reading		Accuracy	
Sample	pH	Turbidity	pH	Turbidity	pH	Turbidity
1	8.36	15	7.36	0.5	1	1
2	8.36	15	7.38	0.68	1	1
3	8.36	15	7.26	0.89	1	1
4	8.36	15	7.81	1.22	1	1
5	8.36	15	7.53	0.89	1	1
6	8.36	15	8.2	0.77	1	1
7	8.36	15	7.96	1.29	1	1
8	8.36	15	8.03	0.83	1	1
9	8.36	15	7.35	1.23	1	1
10	8.36	15	7.05	1.42	1	1
11	8.36	15	7.16	0.68	1	1
12	8.36	15	7.57	0.8	1	1
13	8.36	15	8.59	1.2	0	1
14	8.36	15	7.06	1.57	1	1
15	8.36	15	7.85	0.97	1	1
16	8.36	15	8	0.73	1	1
17	8.36	15	7.93	1.14	1	1
18	8.36	15	6.89	1.53	1	1
19	8.36	15	7.23	0.64	1	1
20	8.36	15	7.65	1.02	1	1
21	8.36	15	8.34	1.21	1	1
22	8.36	15	6.37	0.9	0	1
23	8.36	15	6.79	1.42	1	1
24	8.36	15	6.88	0.82	1	1
25	8.36	15	7.32	1.18	1	1
26	8.36	15	7.96	1.2	1	1
27	8.36	15	7.35	0.74	1	1
28	8.36	15	7.31	1.34	1	1
29	8.36	15	8.08	0.76	1	1
30	8.36	15	7.45	0.91	1	1
					28/30 = 93.33%	30/30 = 100%

Standard Drinking Water Parameter (PNSDW)
pH: 6.5 – 8.5
Turbidity: < 5

With 28 over 30 samples meet the standard range for pH level, the device shows 93.33% accuracy while 100% accuracy for turbidity level having all 30 samples fall within the standard for turbidity level.

For comparison and verification of results, samples are brought to Waterlab Water Testing Laboratory Inc., a laboratory accredited by the Department of Health and

Technological University of the Philippines – Manila Chemistry Department Testing Laboratory.

Tables 3 to 8 shows the qualitative results of Physico-Chemical Test and Microbiological Test from the water testing laboratory and Table 9 shows the qualitative results from TUP Chemistry Department on untreated water and the filtered water of the system. The tables show that the device is 100% accurate on the corresponding water parameters when compared with the acceptable values. It comprises the three analysis prescribed by the Philippine National Standard for Drinking Water (PNSDW) with pH level and turbidity to determine the potability of the water.

Total Dissolved Solids Test (TDS) measures the combined content of charged ions, minerals, salts or metals dissolved in a given volume of water.

In pH and turbidity Level test, the pH value and turbidity level are considered general water quality indicator. High and low pHs can indicate how corrosive water is. Corrosive water may further indicate that metals like lead or copper are being dissolved in the water as it passes through distributions pipes. And for turbidity or the lack of clarity in a water sample indicates that bacteria is present [20].

Microbiological test which includes Total Coliform, Fecal Coliform, and HPC. Total Coliform determines the presence of coliform bacteria such as E.coli, as well as other types of harmful bacteria that are naturally found in the soil. Fecal Coliform indicates the potential presence of pathogens as well as human wastes and animal wastes that has been dissolved on the water. And Heterotrophic Plate Count (HPC) determines the ability of the water to culture colony formation of the bacteria [21].

Table 3
Waterlab Water Testing Laboratory Inc. Physico-Chemical Test Result for pH Level

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
pH Level	6.5-8.5	7.22	7.10	1
		8.63	7.15	1
		8.90	7.90	1
				3/3 = 100%

Table 4
Waterlab Water Testing Laboratory Inc. Physico-Chemical Test Result for Turbidity

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
Turbidity	<5 NTU	0.10	0.10	1
		2.12	0.15	1
		12.50	3.00	1
				3/3 = 100%

Table 5
Waterlab Water Testing Laboratory Inc. Physico-Chemical Test Result for Total Dissolved Solids

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
TDS	500.0/<10.0 mg/L	452.0	402.0	1
		592.0	403.0	1
		567.0	431.0	1
				3/3 = 100%

Table 6
Waterlab Water Testing Laboratory Inc. Microbiological Test Result for Total Coliform

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
Total Coliform	<1.1	<1.1	<1.1	1
		2.5	<1.1	1
		4.6	<1.1	1
				3/3 = 100%

Table 7
Waterlab Water Testing Laboratory Inc. Microbiological Test Result for Heterotrophic Plate Count

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
HPC	<500 CFU/mL	100 CFU/mL	120 CFU/mL	1
		1000 CFU/mL	120 CFU/mL	1
		1500 CFU/mL	25 CFU/mL	1
				3/3 = 100%

Table 8
Waterlab Water Testing Laboratory Inc. Microbiological Test Result for Heterotrophic Plate Count

Analysis	PNSDW Limit (MPN/100mL)	Raw Water	Filtered Water	Accuracy (Filtered Water)
Fecal Coliform	<1.1	<1.1	<1.1	1
		<1.1	<1.1	1
		<1.1	<1.1	1
				3/3 = 100%

Table 9
Tup Chemistry Department Water Test Result

TDS		pH		Heterotrophic Plate Count Coliform Count	
Deep Well	Filtered	Deep Well	Filtered	Deep Well	Filtered
0.58	0.56	8.4	7.8	3.3×10^2	1.2×10^2
0.58	0.59	8.8	7.9	2.2×10^2	1.2×10^2
0.57	0.61	8.8	8.3	1.8×10^2	1.2×10^2
Most Probable Number (MPN) per 100 mL (Method: Multiple Tube Fermentation Technique)		Deep Well: > 1.1 Filtered: < 2.2 safe to drink			

V. Conclusion

A transportable water purifying device using Biosand filtration and Ultraviolet Light treatment system was designed successfully and was able to use renewable resources such as solar energy for 12V DC rechargeable lead-acid battery that serves as an alternative power source to AC supply. An application that can be installed on any Android unit was developed for monitoring, checking, and keeping a continuous record of data during the purification process. The device was proven to be efficient and has the capability to produce potable water with 99.17% accuracy according to laboratory tests.

VI. Recommendations

This project study has been successfully developed and proven to be working to its agreeable functionality. However, further improvements are suggested for the project: (1) to make a lighter and smaller version of the device, thus making it portable (2) to use additional sensors for other water quality indicators that is not used in the project and (3) to overcome the system's restriction to use chlorinated water, saltwater and water from excessive dirt places like drainage, flood and septic tank systems.

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