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PORTABLE ARDUINO-BASED INTEGRATED WATER QUALITY ANALYZER WITH REAL-TIME DATA TRANSMITTER

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Abstract

In our society, there is an accelerated rate of morbidity and mortality worldwide stemming from various water-related diseases. Thus, safety is the most critical factor in decision making for safe-drinking water. Moreover, prompt acquisition of on-the-spot information regarding water quality is still a challenge due to the unavailability of portable devices that can give vital information which hinders the resolution of water-related problems. Another challenge is the transport time of data from one location to another especially from distant or isolated places and

the limitation of the locals to interpret the information. In this study, all the problems are solved by the development of a user-friendly portable Arduino-based integrated water quality analyzer which measures the temperature, pH, turbidity, and the total dissolved solids (TDS) of the water which are the core parameters in determining the water quality in just one sitting. Furthermore, the device has a Global System for Mobile Communication (GSM) module which sends real-time data to identified professionals and institutions. To ensure the accuracy of the device, the sensors were subjected to various tests, verifications, and comparisons with standard laboratory equipment. The results show that both the device and the lab equipment had no significant differences, with the data values acquired from the device all falling within $\pm 5\%$. The t-test was also done. The p-values for all four parameters are greater than the α value (0.05) which means that the device is indeed accurate with the prototype and laboratory values having no significant difference. The device has great potential in helping people ranging from the locals up to the professionals and institutions by reducing the time of data transport and simplifying the analysis regarding water quality which is crucial in the decision making and action-taking processes of water treatment. The device is expected to be tested in the field as soon as recommendations are well integrated.

Keywords

Water, Water Quality, Information, Arduino, Sensors, Device, Data

1. Introduction

Hydrological resources are a fundamental part of the ecosystem. It is the key to development and provides sustenance to all communities by providing water, which is an essential resource for all life on the planet. In today's developing society, the realization of the importance of good water quality has necessitated the designing of new globally viable water quality monitoring regimes aiming at striking a balance between the safe use of water and its protection. Water quality, which measures the physical, chemical, biological, and microbiological characteristics of water, is important in determining the overall potability of water. Due to industrialization and globalization, the world is facing health issues due to water contamination and remains plagued by the lack of access to safe drinking water (United Nations Environment Programme, 2016). This severely affects the health of humans hence it is essential to preserve the pristine quality of water.

Remediation efforts such as water treatments are hindered due to poor water quality monitoring techniques that are currently conducted. Also, water samples are collected at regular periods for chemical evaluation in the laboratory, which entails additional costs. There's also a lack of prompt acquisition and transmission of information due to the unavailability of portable devices that can give vital information immediately. These hindrances slow down the information dissemination process, hinders the resolution of water-related problems, and affects the assurance of safe drinking water especially in remote and challenging areas. Therefore, there is a need for a readily available and portable on-site water quality monitoring system that can provide accurate information and deliver real-time data at an affordable cost. Recent advances in open-source technologies, such as Arduino, show potential for the development of low-cost water quality analyzing devices. Development of water quality monitoring devices utilizing Arduino includes the researches of Akshatha et al. (2017), Solis et al. (2010), Myint et al. (2018), and Nasir et al. (2020).

People in rural and isolated areas often rely solely on hydrological resources for consumption. This requires daily management to assess any sign of contamination which can cause health hazards. This research can help in minimizing the health risks of the residents, and also allows the authorities or the residents to monitor the quality of the water without the need of collecting samples to be analyzed in a laboratory. It can also aid in the fast transport of data to identified authorities and professionals which is crucial in decision making and the action-taking process of water treatment.

The principal objective of this study is to develop a Portable Integrated Water Quality Analyzer (PIWQA). The specific objectives of the study are as follows:

- Design and construct the PIWQA using Arduino Uno;
- Monitor water pH, temperature, total dissolved solids, and turbidity using the PIWQA;
- Evaluate the accuracy of on-the-spot readings and results when used on a water sample;
- Provide and display accurate readings using the PIWQA;
- Disseminate real-time information regarding water potability to respective locals and authorities using a Global System for Mobile Communications (GSM) module.

2. Research Issues

This research focuses on developing a portable integrated water quality analyzer using Arduino Uno. The water analyzer will only be able to measure the pH, temperature, total dissolved solids, and turbidity of the water which are considered to be the core parameters in determining the water quality and its overall portability (Environmental Protection Agency, 2014). Threshold values used are based only on the standard values set by the World Health Organization (WHO), the Environmental Protection Agency (EPA), and the Department of Environment and Natural Resources (DENR).

This study is only limited to the development of the device and the collection, data gathering, laboratory analysis, data analysis, and result interpretation of water samples using the developed portable integrated water quality analyzer. The sensors that will be integrated into the microcontroller are limited only to a liquid pH sensor, temperature sensor, total dissolved solids sensor, and turbidity sensor. This device is only suitable for measuring the potability of the water and should not be used for indicating diseases such as Amoebiasis, etc.

Moreover, the speed and the range of data transmission via the GSM module is not in the scope of this study. The accuracy of the sensors and the device itself in comparison with standard laboratory equipment is the main focus of the study.

Any recommendations regarding the device's speed and accuracy will be taken into consideration for future improvements of the study.

3. Literature Review

For this study, it's crucial to establish a clear definition of what water quality monitoring is, the parameters involved, and the technology involved. Various studies in the past also tackled water quality monitoring and its challenges. These studies are a vital part of this research and have been an inspiration for what this study aims to do and what it could be in the future.

3.1 Water Quality Monitoring

Water quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for the designated use. The specific standards of drinking water quality are decided by different organizations and agencies across the world like the World Health Organization (WHO), and the Environmental Protection Agency (EPA).

Water quality monitoring provides the objective evidence necessary to make decisions on managing water quality today and in the future. It is used to alert us on current, ongoing, and emerging problems; to determine compliance with drinking water standards, and to protect other beneficial uses of water (Nasir, & Mumtazah, 2020). Water quality testing is an important part of environmental as well as health hazards monitoring (Myint, & Soe, 2018).

3.2 Water Quality Parameters

There are many sources of water quality criteria and standards both locally and internationally. Furthermore, the various levels specified will take into account the differing uses for which water quality must be maintained. The ultimate objective of the imposition of standards (which may necessitate extensive treatment before use) is the protection of the end uses, be these by humans, animals, agriculture, or industry.

In this study, four parameters were used, namely pH, turbidity, total dissolved solids, and temperature. Studies such as those of Myint & Soe (2018), Nasir & Mumtazah (2020), and Akshatha et. al. (2017) used these parameters in their own respective water monitoring devices.

4. Methodology

The goal of the research is to develop a portable and accurate integrated water quality analyzer with a notification system. To accomplish this, the development was divided into 4 parts: (1) The designing of the device, (2) the assembly of the main circuitry, (3) the construction of the device chassis, and (4) the accuracy tests.

4.1 System Design and Layout

The device contains five main parts, namely the sensors, the microcontroller (Arduino Uno), the display, the GSM module, and the power supply. The power supply is composed of a battery with enough voltage to power the other parts. The sensors are comprised of the liquid pH sensor, the waterproof temperature sensor, the analog TDS sensor, and the analog turbidity sensor. Data acquired using the sensors is brought to the microcontroller, which interprets the data. The data, along with an analysis, is then displayed via the 16x2 LCD and sent to authorities through an SMS. The block diagram shown in Figure 1 shows the flow of how the device works. Additionally, Figure 2 shows the basic working logic of the device system.

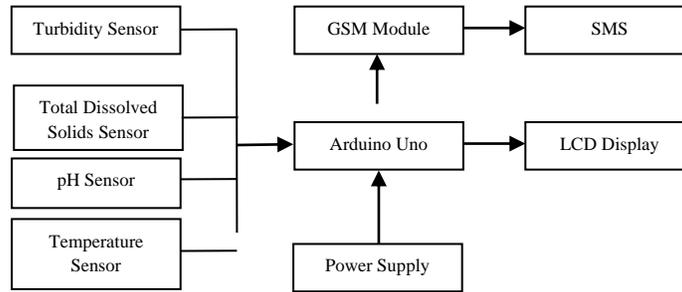


Figure 1: Block Diagram of the System

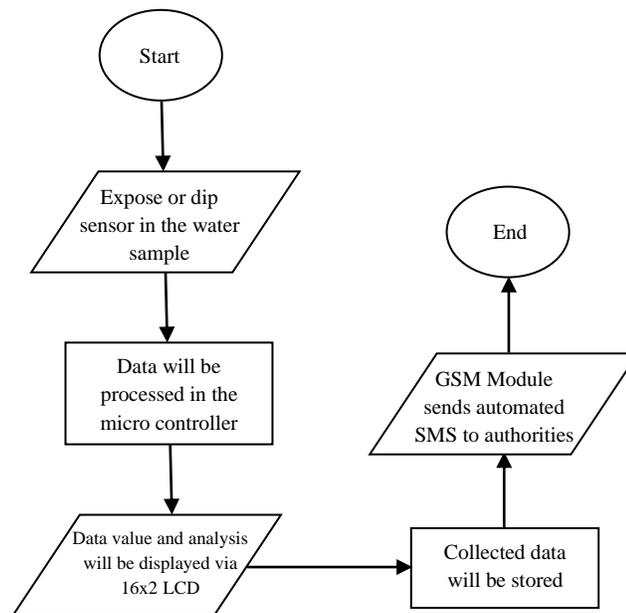


Figure 2: Flowchart of the System

4.2 Construction and Assembly

The water quality analyzer contains four sensors (namely the liquid pH sensor, the waterproof temperature sensor, the analog total dissolved solids sensor, and the analog turbidity sensor) which are connected to one main microcontroller (Arduino Uno) together with the SIM900A GSM module. The case of the device, made out of acrylic due to its low cost, water resistance, and common availability, is rectangular shaped. It houses all the main parts of the device.

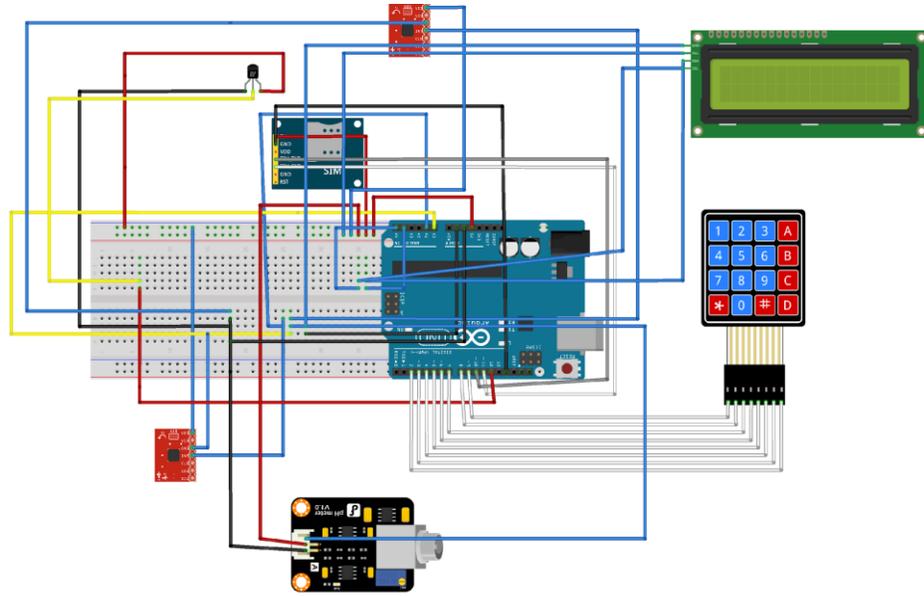


Figure 3: Schematic diagram of the System

Figure 3 shows the schematic diagram of the system. It displays the circuitry of all of the sensors, the keypad, the LCD, and the GSM module.

4.3 Device Accuracy Tests

For the gathered results to be credible, it was compared to the traditional method of data collection for each parameter. Each datum gathered by the device must be within $\pm 5\%$ error of the test results of the traditional method, to be deemed accurate.

4.3.1 pH Test

For the pH test, a pH meter was used to accurately measure the pH of a sample. The pH meter is more preferable compared to the more commonly used pH strip or litmus test which, although cheap, tends to measure only within one or two units of the actual pH value and is more suitable for qualitative measurements rather than quantitative ones.

4.3.2 Temperature Test

For the temperature test, the temperature was measured and recorded using a digital laboratory thermometer. The thermometer was placed in the solution for three minutes and the measurement was subsequently recorded.

4.3.3 Total Dissolved Solids Test

For the TDS test, the conductivity of the sample was first measured using an electrical conductivity meter and was then used in calculating for the TDS. The formula below is the basic formula for calculating total dissolved solids (TDS). In the formula, TDS is measured in mg/L,

EC is the conductivity of the water sample (the reading from the electrical conductivity meter), and KE is the correlation factor. The correlation factor of water is 0.7.

$$\text{TDS} = \text{KE} \times \text{EC} \quad (1)$$

4.3.4 Turbidity Test

For the turbidity test, the turbidity tube method, which uses the correlation between visibility and turbidity to approximate a turbidity level through a tube, was used. A marker was placed at the bottom of the tube until it can no longer be seen from above. This height from which the marker can no longer be seen correlates to a known turbidity value. These values can be used to mark the turbidity tube directly or to convert measured values into turbidity units. The length to turbidity conversion used was based on the conversion table of Myre and Shaw (2006).

5. Results and Discussion

The goal of the research is to develop a portable and accurate integrated water quality analyzer with a notification system. To accomplish this, the development was divided into 4 parts: (1) The designing of the device, (2) the assembly of the main circuitry of the device, which includes the sensors, the 16x2 LCD, and the GSM module, (3) the construction of the device chassis, and (4) the accuracy tests.

The design of the device as well as the assembly of the main circuitry and the construction of the chassis made of acrylic has been accomplished. For the accuracy tests, the sensors were subjected to a variety of tests to check the limitations of their technological capabilities.

5.1 Design and Construction of the Device



Figure 4: *The Data Display Format (left) and the First Prototype (Centre and Right).*

Figure 4 shows the zoomed-in pictures (left) of the readings regarding the water sample's temperature, pH, total dissolved solids, and turbidity displayed on the LCD of the device arranged in sequence from top to bottom, respectively. Additionally, Figure 4 (centre and right) shows the prototype.

5.2 Accuracy Test of Prototype Sensors

Based on the results, the sensors were able to provide accurate readings in a wide range of conditions (hot and cold for temperature, acidic and basic for pH, saline and non-saline for TDS, and turbid and clear for turbidity) with no difficulties and with the data values falling within $\pm 5\%$ error (as shown in Table 1).

Table 1: *Prototype and Standard Laboratory Equipment Data Values for Temperature*

Parameter	Trial	Data Values		Percentage Error
		Laboratory	Prototype	
Temperature (°C)	1	29.4	29.44	+ 0.14%
		29.4	29.37	- 0.10%
		29.3	29.31	+ 0.03%
	2	10.2	10.58	+ 3.73%
		12.4	12.44	+ 0.32%
		14.4	14.50	+ 0.69%
	3	82.0	81.94	- 0.07%
		43.5	43.60	+ 0.23%
		44.2	44.50	+ 0.68%

Table 2: *Prototype and Standard Laboratory Equipment Data Values for pH*

Parameter	Trial	Data Values		Percentage Error
		Laboratory	Prototype	
pH	1	9.16	9.18	+ 0.22%
		4.18	4.16	- 0.48%
		6.56	6.51	- 0.76%
	2	7.14	7.19	+ 0.70%
		7.23	7.21	- 0.28%
		8.56	8.61	+ 0.58%
	3	7.02	7.03	+ 0.14%
		3.83	3.85	+ 0.52%

		6.82	6.84	+ 0.29%
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Table 3: *Prototype and Standard Laboratory Equipment Data Values for Turbidity*

Parameter	Trial	Data Values		Percentage Error
		Laboratory	Prototype	
Turbidity (NTU)	1	0	0	0.00%
		30	31.45	+ 4.61%
		45	47.05	+ 4.55%
	2	100	101.27	+ 1.27%
		150	144.05	- 3.97%
		50	50.35	+ 0.70%
	3	250	255	+ 2.00%
		245	250	+ 2.04%
		240	250	+ 4.17%

Table 4: *Prototype and Standard Laboratory Equipment Data Values for TDS*

Parameter	Trial	Data Values		Percentage Error
		Laboratory	Prototype	
Total Dissolved Solids (TDS) (ppm)	1	1938.50	1935	- 0.18%
		722	720	- 0.28%
		3899.50	3900	+ 0.01%
	2	1423	1426	+ 0.21%
		1111	1113	+ 0.18%
		4898.50	4896	- 0.05%
	3	1604	1604	0.00%
		2176	2176	0.00%
		1050.50	1005	- 4.33%

The data gathered by the sensors were successful based on the criteria of the accuracy test, which is falling within $\pm 5\%$ of the data provided by the laboratory equipment. Therefore, it was concluded that the sensors of the prototype provided accurate and reliable results when

exposed to different water samples with varying differences in their temperature, pH, salinity, and turbidity.

The t-test was also done to evaluate if the prototype data values have no significant difference with the existing standard laboratory equipment data values. The p-values of the temperature parameter, the pH parameter, the turbidity parameter, and the TDS parameter are 0.9927, 0.9916, 0.9652, and 0.9937, respectively. All p-values are greater than the α value (0.05) which means that the device is indeed accurate with the prototype and laboratory values having no significant difference.

5.3 Efficacy of the GSM Module

Based on the result, the GSM module has proven to work efficiently as to its function of sending an immediate text message which is essential in sending information and data to identified authorities and institutions. Figure 5 is an image of sample messages sent using the GSM module incorporated in the device. It proves that the GSM module works. The messages sent were cross-checked with the actual results provided by the device, and were all identical.

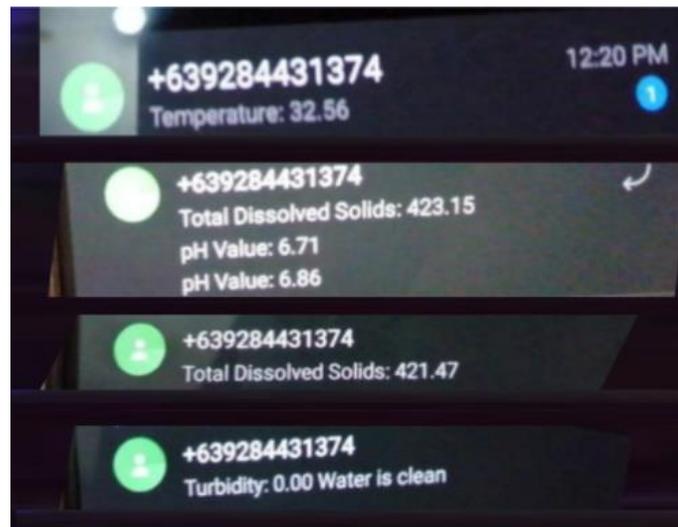


Figure 5: Sample Text Messages

The text message format itself is simple with the message containing just the values and the analysis. This format would allow a person to interpret the information easily which leads to faster decision-making and immediate action-taking.

Not only can the GSM module reduce the time of data transport, but the text message it sends simplifies the analysis regarding water quality.

5.4 Portability

To test the device's portability, the device was weighed and compared to the weight of other devices. It weighs 1,038g excluding the power bank and weighs less compared to the devices made by Akshatha et al. (2017), which weighs 2,672g, and Solis et al. (2010), which weighs 4,936g.

6. Summary and Conclusion

In summary, all data values acquired using all the prototype's sensors fell within $\pm 5\%$ error when compared with the data values acquired from the standard laboratory equipment. The 16x2 LCD displayed the readings accurately, and the GSM module was able to send a text message containing accurate values as well as the analysis. Also, the device weighs less, at 1.04kg, compared to the devices made by Akshatha et al. (2017), and Solis et al. (2010).

To conclude, a functioning, portable, and accurate water quality analyzer equipped with the capabilities of monitoring water pH, temperature, total dissolved solids, and turbidity, displaying the acquired values via the 16x2 LCD, and instantly transmitting the acquired data through SMS via the GSM module was developed to provide clear and concise water quality data, shorten data transmit time, and to decrease health hazards. With this, it can be proven that with the present limitations and lack of portable water quality analyzers, the rise of open-source technologies, such as Arduino, have proved to be fundamental to the development of said devices with comparable data collecting capabilities to that of standard laboratory equipment. Although the device is not yet capable of treating water on-the-spot, the accurate water quality analysis it provides can significantly influence the decisions of the locals, the professionals, and the institutions regarding water treatment to ensure that the water is safe to drink, which in turn can reduce causalities due to water-related diseases.

7. Recommendations and Future Scope

The recommendations for further iterations or improvement of the device include the addition of more sensors, on-the-spot water treatment, further tests regarding the range and the speed of the GSM module, the use of printed circuit board (PCB) rather than a breadboard, and the utilization of a better, environmentally friendly power source that can manage to supply the needed voltage required by the prototype to function without any power shortage.

After the recommendations are well integrated with the device, it will be tested and observed in the field. Improvements of the device will be made concerning how it performs in the field test as well as recommendations from the residents of the community and other professionals.

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