Devising A Low-Cost and Portable System for Remotely Monitoring Water Quality in Real-Time

ABSTRACT

Bangladesh suffers from a scarcity of pure drinking water despite being a country with around 700 rivers. Polluted water is being used every day by people for drinking and daily use, which is giving rise to various water-borne and skin diseases. In this paper, we propose a real-time water monitoring solution where basic water quality parameters (pH, turbidity, tds) are measured in a cost-effective system; helping users to identify the usability of the supply water. Our proposed solution alerts users in both offline and online mode whenever the water quality is below the standard level. Such devices can be used for domestic purposes in day-to-day life, raising awareness among people.

KEYWORDS

real-time, portable, water quality, remote-monitoring system

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1 INTRODUCTION

Water quality is one of the main challenges the third world countries face in the 21^{st} century. Industrial waste, city sewage are some of the prime reasons for water pollution. Both surface and groundwater sources are contaminated by different toxic metals coming from industrial wastes. Unaware of the effect, the citizens also contribute to the pollution of water. This gives rise to various water-borne diseases and makes water unusable for daily use. Bangladesh, being a riverine country with a vast population suffers greatly from water pollution and lacks pure drinking water. People consume polluted water without being aware of it which leads to severe health effects.

Recent work focused on measuring the water quality of rivers, tanks, and different water bodies with the transmission of data to an online web system. In Bangladesh, such proposed systems are not always suitable since the systems need to be integrated via authority which cannot be ensured due to the lack of transparency in government activities and the large demand of the population. Also, the collection of data through an online system may not work during natural disasters as electricity and network fail to be available during such times.

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Our proposed system includes the following features:

- Small and portable design with a small power consumption
- Overall inexpensive and available components
- Works both in online and offline mode

Being affordable and small, our proposed system can be used as a testing kit in households. Our system also has the facility to alert users in both online and offline mode. Since the components are available and inexpensive, they can be easily developed by manufacturers to meet the large demand of our population.

2 RELATED WORK

Various experiments[11][3][13][7][15] have been conducted throughout the world to develop a water quality monitoring system. In [13], water quality with notifications system uses Raspberry Pi, pH sensor, Turbidity sensor, TDS sensor, and a GSM module. The system monitors different water parameters such as TDS, turbidity, and pH through respective sensors. Upon monitoring the water data, the processor sends the data over the internet and sends SMS to the user's phone through an online bulk SMS service.

The core system of the water quality monitoring system [7] consists of an Arduino development board based on ATmega328P. The system also employs several sensors for monitoring water parameters such as pH, turbidity, conductivity, and temperature. The water quality data is sent to the user through a Bluetooth module as a communication device.

In [11], A smart water quality monitoring system proposed in Fiji uses IoT and remote sensing technology. The system measures Temperature, pH, ORP (Oxidation-Reduction Potential) and, conductivity for analyzing the water quality. The system is comprised of sensors, a Waspmote micro-controller board, an SD card storage, and a GSM module. The data collected through the sensors are saved either on the SD card or sent to an FTP/cloud server through the GSM module.

The IoT-based water quality monitoring system [15] mainly consists of an Arduino development board and key sensors for collecting different water quality parameters such as pH, conductivity, turbidity, dissolved oxygen, and temperature. The system proposes wireless technology such as WiFi, GSM to send the water quality data to a cloud server. When water quality parameters exceed the threshold, an SMS is sent to a user's phone by the cloud server.

In Ukraine, an IOT based system [2] was developed to monitor the pH, conductivity, turbidity, dissolved oxygen, and temperature of surface water. In Mosul, Iraq a low-cost system for drinking water was developed [1] which measured the pH, turbidity, temperature, and conductivity of water. An IoT-based water quality monitoring system using solar energy is developed in [9] which sends the sensed data to the cloud which can be accessed daily, weekly, or monthly.

In Bangladesh, an IoT-based real-time river quality monitoring system was proposed [3] which measured pH, temperature, turbidity, and ORP level of rivers. An arduino based water quality measurement system was proposed in [12]. This system measured the pH, salinity, dissolved oxygen, turbidity, temperature and displayed the data in an online system. In [10], a low-cost system was developed which monitors the pH, temperature, and dissolved oxygen of the Karnaphuli river in Chittagong, Bangladesh.

Studying the recent works above, we found some noteworthy disadvantages in a few of them. For example, one of the water quality monitoring systems [7] uses Arduino as the controller unit along with a Bluetooth module as a communication device. However, it is not an ideal solution for a remote monitoring system as it requires users to have a Bluetooth-equipped mobile. Also, the Bluetooth network does not provide coverage for a large area. Similarly, the water monitoring systems proposed [11] [15] [1] [12] are mainly based on cloud service- depending on an internet connection to operate. Mainly two problems arise in such circumstances- (i) during poor network connectivity, the system fails to operate, and (ii) the system is dependent on an internet service such as GPRS, WiFi, or Ethernet. The use of Arduino or similar microcontroller boards is not a cost-effective solution.

3 METHODOLOGY

We propose a microcontroller-based design that monitors the water quality parameters. To measure the water quality parameters, different sensors were interfaced with the microcontroller. A communication module was used to transfer the sensed data. The sensed data was always shown in a display that can be used in offline mode. The microcontroller reads the sensed data from the sensors continuously and transfers it over a communication module. The flowchart of the overall process is given in Figure 1.

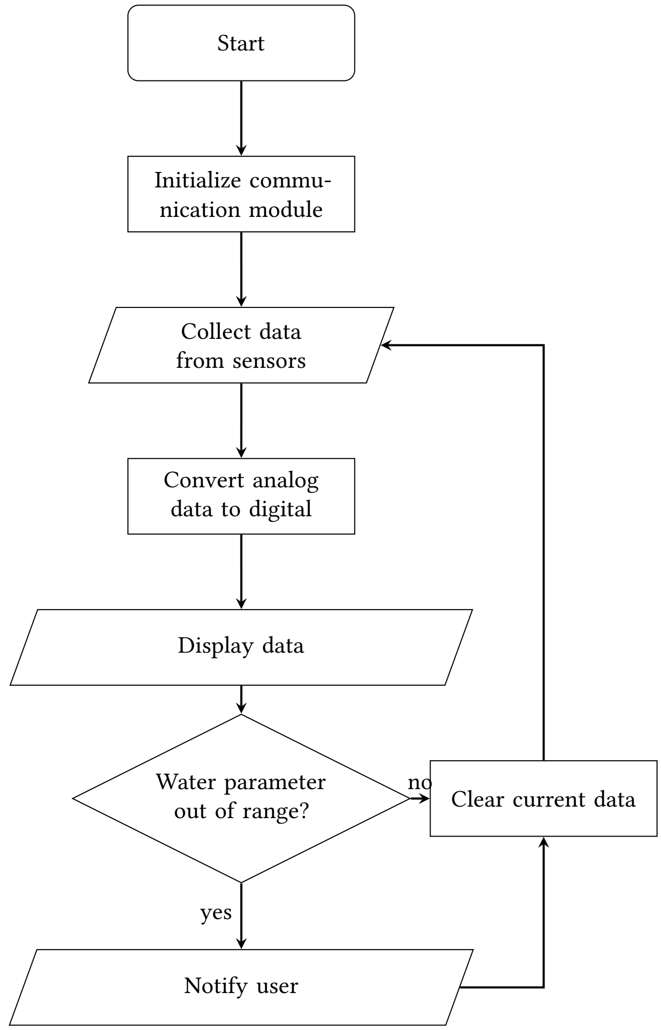

Figure 1: Flowchart of the overall process

4 SYSTEM COMPONENTS

We focused on measuring 3 water quality parameters: pH, turbidity, and TDS (Total Dissolved Solids). These 3 parameters were chosen since by measuring them, we can identify if the water is drinkable or not. Also, the sensors needed for measuring these parameters are available and comparatively cheap.

4.1 pH Sensor

A pH sensor measures the pH level of the given solution. It provides 3 output pins. One for analog output (P_o), one for digital (D_o) and one for temperature (To). The level of pH for supply water is between 6.5 and 8.5. The model of the pH sensor we used was PH 4502C of the DIY TECH brand. The equation used for measuring pH is :

$$pH = -(5.7 * volt) + 21.34 \tag{1}$$

where $volt$ is the analog reading of the pH sensor. To use the pH sensor, calibration is a must which is achieved by dipping the pH electrode on solutions of known strength. To get the right reading of the pH sensor, the potentiometer placed on Signal Conversion Board needs to be rotated.

4.2 Gravity TDS meter

TDS (Total Dissolved Solids) indicates how many milligrams of soluble solids are dissolved in one liter of water. A TDS meter is an electrical charge (EC) meter whereby two electrodes equally spaced apart are inserted into the water and used to measure charge. The result is interpreted by the TDS meter and converted into a ppm figure. Since dissolved solids carry the charge, the resulting ppm figure will be proportional to the number of dissolved solids. The TDS level of supply water should be below 1000 mg/L. We used the Gravity: Analog TDS Sensor/Meter for Arduino of DFRobot[5].

The temperature of the water is also needed to compute TDS which can be measured from the pH meter. To compute the TDS value from the analog voltage output of the sensor, the following equations were used:

$$tempCoeff = 1.0 + 0.02 * (temp - 25)$$

$$tds = \frac{((133.42 * volt^3) - (255.86 * volt^2) + (857.39 * volt)) * 0.5}{tempCoeff} \quad (2)$$

where $volt$ is the analog voltage output of the sensor and $temp$ is the temperature reading of the temperature output of the pH sensor.

4.3 Turbidity Sensor

A turbidity sensor measures the amount of light that is scattered by the suspended solids in water. As the total amount of suspended solids increases, the water's turbidity level (haziness/cloudiness) increases. The turbidity level of supply water should be below 10 NTU. The model that we used was Turbidity sensor SKU SEN0189 of DFRobot[6].

The equation used for measuring the turbidity is-

$$ntu = -1120.4 \times volt^2 + 5742.3 \times volt - 4353.8 \quad (3)$$

where $volt$ is the analog voltage output from the sensor. To get the desired result, the potentiometer of the signal connector board needs to be rotated.

The parameters of water were measured and compared against the standard value of drinking water which is provided in Table 1.

Parameters	Standard level
pH	6.5-8.5
TDS	1000 mg/L
Turbidity	10 NTU

Table 1: Drinking water quality standards

The standard level of the water parameters 1is taken from the website of the Department of Public Health Engineering, Bangladesh [4].

4.4 GSM Module

Our system employs a SIM900 Mini GSM module[14] as a communication device. The SIM 900 Mini is one of the suitable devices with an affordable price and better quality. The module with help of its antenna is capable of sending text messages, phone calls over GSM mobile networks. In our design, we used the module to remotely notify the user by sending a text message containing the water parameters values whenever they update. The module requires less power to operate, serves the purpose of a wireless communication device, covers a large area- thus giving the upper hand compared to other implementations. The module is controlled using AT commands by the microcontroller.

5 SYSTEM DESIGN

Our system is controlled by an ATMega32A microcontroller chip. A SIM900 Mini GSM module was used for wireless communication. Our system also used a 16x2 LCD and an active buzzer. To determine different water parameters, three basic sensors were used for the following parameters: pH, turbidity, total dissolved solids (TDS), and temperature. We used a breadboard power supply powered by a 12V DC adapter to power all devices.

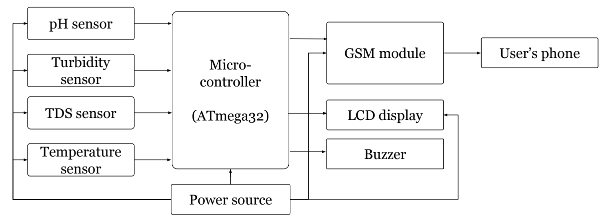

Figure 2: Block diagram of the proposed system

5.1 System Diagram

The block diagram of the proposed system is shown in Figure 2.

5.2 System Workflow

At first, the system is powered up by connecting the breadboard to a 12V DC adapter. When it is not possible to use the DC adapter without household electricity, a battery is needed. A 9V battery is quite powerful when it comes to powering the whole system for quite a long time. After powering up the system, the GSM module usually takes few seconds to start and connect to the network.

Meanwhile, the sensors are submerged in the water according to their way. Each sensor monitors its parameter continuously and sends output voltage. At the same time, the microcontroller; in this case, the ATmega32 receives the analog data from the sensors and displays the value in LCD. This process is continuous, meaning moving the sensors from one water source to another changes the values on the LCD accordingly. In case, any of the water parameters value goes out of standard level, the microcontroller notifies the user in mainly two ways.

Firstly, the buzzer connected to the microcontroller is activated and it starts emitting noise. Secondly, the user is notified by an SMS sent through the GSM module. The user's phone number is set in the microcontroller beforehand. After the water quality comes back to standard level, the microcontroller deactivates the buzzer, thus stopping the noise. Meanwhile, another SMS is sent to the user's phone number containing the water parameters values. The whole system keeps working continuously as long as enough power is supplied to each of the components. All components are subjected to a 5V voltage, thus keeping the overall power consumption low.

5.3 Unit Cost

The components used in our system are available and low-priced. Thus, our overall system is quite inexpensive. The cost analysis of our system is given in Table 2.

6 EXPERIMENTAL SETUP

The water demands of the ever-increasing population of Dhaka city are met by DWASA (Dhaka Water Supply and Sewerage Authority). For monitoring the supply water of Ward #32, Dhaka South, we

Component	Quantity	Price (USD)
ATmega32	1	2.94
GSM Module	1	11.76
TDS Sensor	1	11.80
pH Sensor & Probe	1	21.36
Turbidity Sensor	1	11.58
Breadboard	1	0.7
16x2 LCD Display	1	1.35
Miscellaneous	-	1.17
Total Unit Cost		62.66

Table 2: Cost analysis of the proposed system

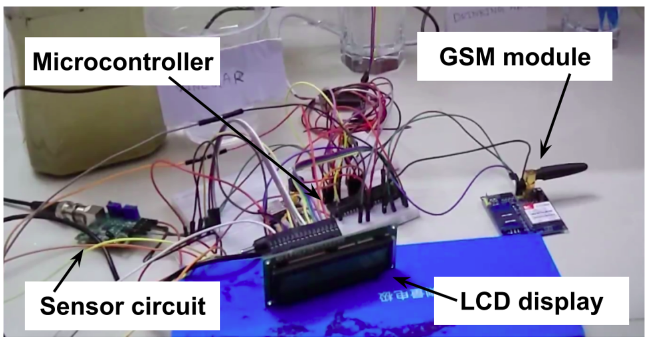

Figure 3: Experimental setup of the proposed system

used our recently developed system. Over 12 hours from 11 AM to 10 PM in Local Bangladesh Time, on August 19th, 2021, we collected 12 individual water parameter data every 1 hour. The results are shown below in a graphical manner where three basic water parameters- pH, turbidity, and TDS (Total Dissolved Solids) are mentioned.

7 EXPERIMENTAL RESULT

During the experiment, the water was collected from a household supply line from 11 AM to 10 PM. Each reading was taken with an interval of 1 hour in between, for a whole period of 12 hours. The data obtained from the experiment provides insight into the supply water quality. Basic water parameters such as pH, turbidity, and TDS are shown in their graphs below.

In Figure 4, the value of pH observed throughout the experiment gives us insight into whether the water is acidic or alkaline. The value of pH observed during the experiment remained between the standard limit of 6.5 – 8.5 mentioned in the table1. The highest and the lowest observed value throughout the experiment are 7.2 and 7.1 respectively. The difference in pH value over the whole time is quite negligible.

In Figure 5, the value of TDS observed throughout the experiment gives us a more interesting insight than the pH. The standard level of TDS for drinking water is 0 – 1000 mg/L mentioned in the table1. The highest and the lowest value of TDS observed throughout the experiment are 267 mg/L and 251 mg/L respectively.

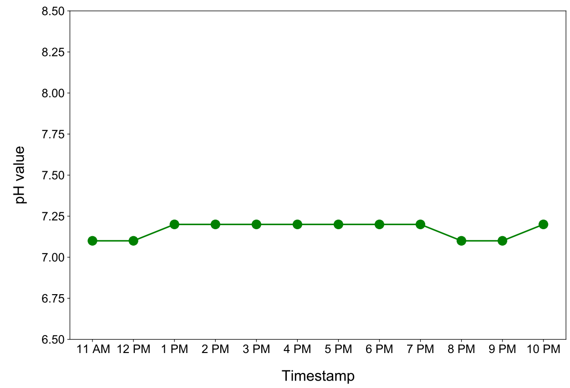

Figure 4: Supply water pH over 12 hour s

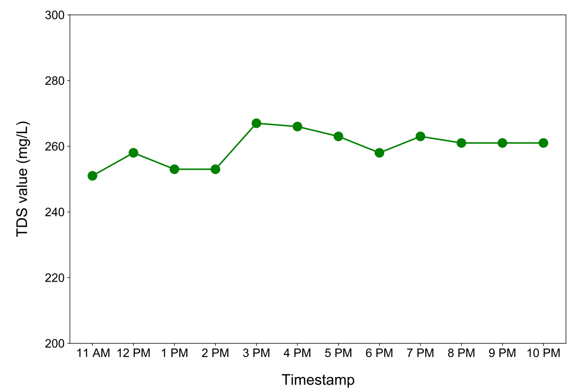

Figure 5: Supply water TDS over 12 hour

In Figure 6, the value of turbidity observed throughout the experiment is another interesting insight. The standard level of turbidity is 0 – 10 NTU, mentioned in the table1. The turbidity value observed throughout the whole experiment remained 0 NTU over 12 hours. The value of turbidity being zero denotes the water to be clear in texture.

8 DISCUSSION

The low-cost implementation of our design enables people from all walks to afford our device at a low price. Our proposed system is also designed to keep certain things in mind. Being a riverine and a tropical country, we are always prone to natural disasters such as floods, hurricanes, tsunamis, etc. The scarcity of clean drinking water increases during and after such disasters- especially in rural and coastal areas. Sometimes the situation becomes so worse that the relief takes weeks to reach. Moreover, the situation worsens with the shortage of electricity and also with the downfall of wireless communication systems such as mobile networks and the internet. As a fallback to such problems, the LCD and buzzer in our system can easily help users to monitor the water quality. The LCD used in

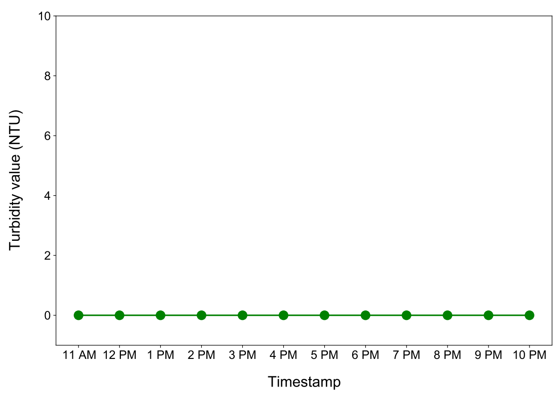

Figure 6: Supply water turbidity over 12 hour

our system shows water parameters value and the buzzer provides audible notification.

An economic mindset is one of the core ideas followed throughout the development of our proposed system. It is to be mentioned that the sensors used in the development of this system are not for large-scale use. Thus, the system is more suited for domestic use, rather than an industrial one. As a water quality monitoring system, it can easily serve the demands of a small-scale application. Also due to the COVID situation, we couldn't test our system in different areas of the country. More data can be collected to get a comparative study between localities.

9 FUTURE WORK

The water quality monitoring system proposed in this paper is more suitable for domestic applications such as households, institutions, etc. However, the base model of the proposed system can be applied to other applications of water quality monitoring. A switch controlling module can be added to the existing system easing the effort of a user. By thus, our system can easily start/stop the motor according to the water quality. Such an improvement can contribute in few areas as below.

In the agriculture domain, water is an absolute necessity. The overall quality of crops depends on the water it consumes. Due to the water's acidity/alkalinity, crops are more prone to turn out bad in quality. Being one of the agriculture-dependent countries, clean water plays an important role in our economy. In Bangladesh, every year, the saline-prone coastal region yields a loss of approximately 20-40% in major crops (cereals, potato, pulses, oil-seeds, vegetable, species, and fruit crops) [8]. Our proposed system can be adapted for such applications in the agricultural domain.

With the increasing population, the demand for protein is also increasing at a rapid speed. To cope up with the demand, many animal farms are constructed every day. Many farm animals are affected by water diseases, which creates an effect on our food chain. The animal farms established in urban areas quite now and often fail to provide clean drinking water for their livestock. However, our proposed system can also be used in such animals farms to monitor the water quality. Having a wireless notification system with an automatic switch becomes easier to maintain- even on a large farm.

10 CONCLUSION

Being one of the necessities of human life, the importance of clean water is increasing more than ever- due to the increasing population. While substantial progress has been made in access to clean drinking water and sanitation, billions of people- mostly rural, still lack these basic services. The demand for clean water is so important that it is now one of the SDGs (Sustainable Development Goals). With a low-cost and portable remote system, monitoring water quality has become easier and more adaptive for people to use. The real-time nature of the data adds a new dimension to the water quality monitoring system. Proper implementation and use of the system will help households and play a vital role during natural disasters as well.

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