Water Quality Monitoring System based on IoT

Dr. Khawla A. Alnajjar, Mahmoud M.A Fahmy and Yousef M. Ali
Department of Electrical and Electronics Engineering, University of Sharjah, Sharjah, United Arab Emirates,
kalnajjar@sharjah.ac.ae, U18103149@sharjah.ac.ae, U18100948@sharjah.ac.ae.

***Abstract*— People's lives have always prioritized having the best possible water quality. Since pollution sources are continuously expanding, water quality monitoring systems became more essential. However, such monitoring systems remains too expensive. Fortunately, with the recent growth of IoT technology and the ongoing development of smart monitoring systems, a low-cost smart water quality monitoring system can be implemented. This paper will present new methodology for water quality monitoring systems, allowing smart acquisition of water data, real-time monitoring, and the maintenance of the optimal water quality required for the intended audience. The paper will provide the necessary monitoring options in a reliable and cost-efficient manner. The system design consists of both Hardware and Software Architectures.**

Keywords—Water Quality Monitoring, real time monitoring, Data Acquisition, IoT, Automation.

I. Introduction

Nowadays, many Water Quality vendors use traditional water quality monitoring systems which include many manual procedures that could be automated. Current water quality monitoring systems are vulnerable to human error, loss of documents and unreliability. In addition, such monitoring systems cost vendors more money than it should when automated [1].

Thankfully, due to the growth of IoT technology, the water quality monitoring process can be automated. In the following, the methodology of automating the monitoring system is discussed [2].

The Water Quality monitoring system will be divided into two main parts: software and hardware designs. For low-cost projects, using a microcontroller is found to be the best option to have. The microcontroller will serve as the system's main processing unit.

Moreover, certain parameters should be measured to collect the proper data about a water sample's quality [3]. Parameters mentioned below is the main parameters to be evaluated:

- The potential of hydrogen (pH).
- Turbidity of water.
- Total Dissolved Solids (TDS).
- Water Temperature.

Accordingly, four sensors will be used to determine the value of each parameter in a tested water sample. Most related sensors will use analog measurement to serve the need [4].

Finally, a user interface, which will be a mobile application, will be designed to complete the process of monitoring and match the needs of the system. Mobile Application will consist of three main sections which are live monitoring system's data, display list of alerts, events and controlling the system components such as relays and sensors. The mobile application will be designed using one programming language that is suitable for a certain application developing tool.

Smart monitoring systems need to follow some criteria. In the following, hardware design criteria the system will comply to:

- Ease of configuration.
- Cost.
- Portability.

Additionally, software design will also follow some criteria as follows:

- User Friendly.
- Well organized.
- Ready for updates.

However, the scopes of the proposed monitoring system will be as follows:

- The system should be able to monitor and report alerts in real time.
- The system should be able to take actions upon certain readings and alarms immediately.
- Provide current system status including water parameters and its real time reading though user interface or SMS.
- Control certain components through the user interface.
- View and monitor previous system alerts and readings through user interface.

II. Hardware Components

The Hardware components in the proposed system will be responsible of reading data taken from water samples in order to control the system upon certain measurements. In addition, components will communicate with different clients through cloud databases. The following will discuss each component used in the proposed monitoring system and its purpose.

- NodeMCU ESP8266: low-cost Wi-Fi microchip with integrated TCP/IP networking software and a microcontroller. It offers sufficient on-board processing and storage capability to allow it to be integrated with sensors and other application-specific devices via its GPIOs with minimal development and load during runtime [5].
- pH Sensor PH0-14: can detect alkalinity and acidity levels in water and other liquids [6].
- Turbidity Sensor: Calculate the amount of light reflected by the water's suspended particulates

through two emitting and receiving light detectors. The turbidity level of water increases together with the total amount of suspended solids (TSS) in the water [7].

- TDS Sensor: stands for Total Dissolved Solids, which effect water conductivity. The sensor consists of two terminals, a voltage waveform is transmitted from one terminal to deliver a digital representation after the second terminal receives the waveform signal [8].
- Temperature Sensor DS18B20: measures water temperature using one wire mechanism [9].
- ADC ADS1115: Analog to Digital Converter used to digitalize analog signals received from the used sensors [10].
- GSM Module SIM800L: contains micro-SIM Card slot and a mounted antenna that can be used to send and receive SMS from/to the system [11].
- Relay Module: electromagnetic switch that is controlled by small open and close signals.
- DC Water Pump: 2.5-6 VDC Motor that can control water flow from and to a water tank in flow rate of 80-120L/H [12].
- DC Step Down Converter LM2596: is a step-down switching regulator that has good line and load regulation and can drive a 3-A load. It can take input from 3-40V and step down to 1.5-35V [13].
- Local LCD screen: 16x2 LCD screen used to display certain characters upon instruction provided.

III. How the Proposed System will work

In the proposed system, hardware and software designs will be implemented to provide faster, more reliable and convenient method for the monitoring process of the water quality, which will solve many issues related to the traditional methods currently in use. Having a software user interface to such monitoring systems will help automating the process and prevent human errors more easily. Moreover, the proposed system will be able to take actions upon normal and up normal inputs. The system will include multiple alert interfaces which will be through mobile application, SMS alerts and local LCD screen.

The esp8266 microcontroller will serve as the core of the system. The microcontroller will be used to control the monitoring process based on inputs taken from water parameter sensors. The esp8226 will be able to upload sensor data to a certain cloud database that will be used to provide service to the mobile application.

A DC water pump will control the water flow from the measured water sample to a destination water tank. The water pump is controlled using a relay module receiving open and close commands from the microcontroller based on input data measured by sensors.

The user interface (mobile application) will be capable of performing real time live monitoring for sensors data, provide users with daily reports about the system's results, control certain components through application and allow user to receive alerts reported by the system.

In addition to the mobile application warnings, the GSM Module SIM800L will be used to send SMS alerts to authorized clients. Based on certain water parameters, the microcontroller will send commands to the GSM module in order to send SMS warnings to specified cell numbers.

IV. Hardware Desgin

The proposed system's hardware design as shown in Figure 1, consists of four water parameters sensors as input devices which will directly connect to the ADC ADS1115 data pins. The ADS1115 will communicate with the esp8266 through I2C ports (SCL and SDA) which will allow the esp microcontroller to read and process analog sensors data as per the standards required. As a result, the esp will perform the following actions in case of sensors readings are matching pure water standards:

1- Send close command to the relay module allowing the DC water pump to flow the water from the tested tank to a desired tank for pure water only.

2- Send commands to the local LCD screen indicating that the tested water is pure.

However, in case of undesired water parameter readings received by the sensors the following actions will be performed:

1- Send open command to the relay module in order to immediately stop the waterflow through the DC water pump.

2- Send commands to local LCD screen indicating that the tested water is impure and waterflow has stopped.

3- Send commands to the GSM module in order to send SMS alert to authorized administrators.

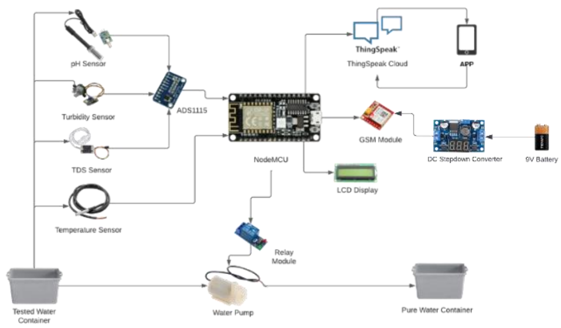

Figure 1: Hardware Design

In both cases, the esp will upload sensor data to certain cloud database in order to provide service needed for the mobile application.

V. Software Design

The system's software design will consist of the cloud database where the sensor data are uploaded by the microcontroller, and the system's user interface which is the mobile application.

The cloud database used will be Thingspeak cloud. Thingspeak is an IoT cloud platform that allows uploading sensor data to its storage and perform analytics and visualizations in order to view data locally from the cloud interface. Moreover, Thingspeak uses ***REST API*** and json files to store uploaded data. The esp microcontroller will be programmed to communicate with Thingspeak client after every measurement in order to upload its local sensor data on the system specified cloud storage on Thingspeak.

Mobile application will be designed to consist five main section that will provide the service needed for the monitoring system. Figure 2 illustrates the proposed mobile application flowchart.

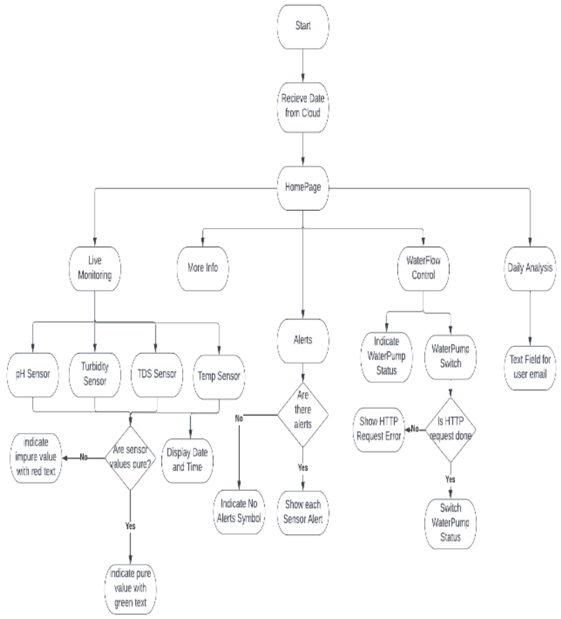

Figure 2: Mobile Application Flowchart

Every application section will be demonstrated in separate page as follows:

- Live Monitoring Page: designed to extract sensor readings from Thingspeak database and display them on screen. The live monitoring page will illustrate the following for each sensor:

- Green/Red text indicating the latest reading measured.
- Green/Red text indicating the latest reading measured status (pure/impure).
- Indication of the date and time of the latest reading measured.

- Daily Analysis Page: prompts the user to enter an email address to receive analysis sheet of the last 100 readings measured by system's sensors.

- Waterflow Control Page: designed to let the user control the DC water pump manually if required. In addition, contains live indication of the water pump status (ON/OFF).

- Alerts Page: designed to allow user to access previous and current system alerts which indicates alert details, date and time of the alert. Ideally, the mobile application will push notification that will direct the user to this page, however; user can access this page from the top app bar.

- More Info Page: designed to hold extra information about the system which are standard pure water parameters, administration contacts and application time zone.

VI. Analysis and Results

The following section will discuss the system results in different situations. The section will include results (outputs) of hardware and software parts, measure of accuracy and feedback about the overall outcomes.

A. Results in pure sample

This subsection will demonstrate the system results in when tested in pure water samples. Tested water sample is mineral water (drinking water).

1) Hardware Results

System sensors were able to give accurate results about the pure water tested. Table 1 below illustrates the accepted range, accuracy and average reading of every sensor during 10 seconds (one measurement per second).

Table 1: Sensor Results

Sensor	***Measured Value***	***Accepted Value/Range***	***Accuracy Status/%***
pH Sensor	7.43	6.5 – 8.5	0.93%
Turbidity Sensor	6.1%	0 – 8%	Accepted
TDS Sensor	107.45ppm	50 – 150ppm	Accepted
Temperature Sensor	25 °C	10 – 30 °C	Accepted

According to mineral water parameters (Tested Water Sample) which has a pH of 7.5, Turbidity less than 8% and TDS of 50-150ppm, the system results were accepted since they are accurate and in the accepted standard range. However, sensor readings are not always fixed and may fluctuate by 0.5V every 5 – 10 seconds, which is an acceptable fluctuation since analog sensors can easily be

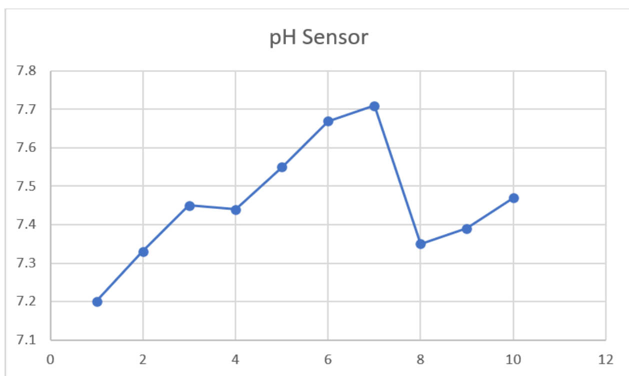

Figure 3: pH sensor readings

affected by external noise. Figures 3, 4 and 5 demonstrate the fluctuation happened during the 10 seconds measurements.

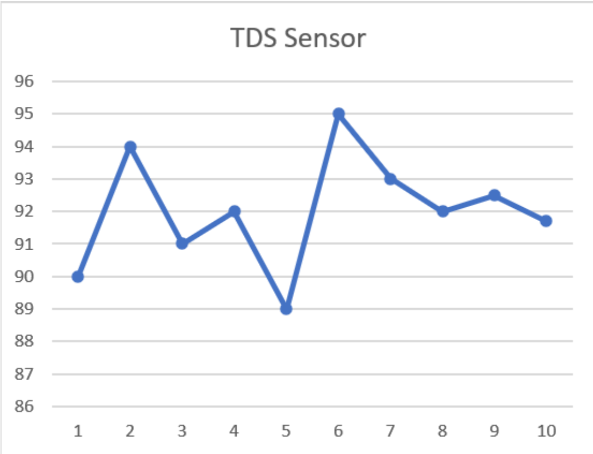

Figure 4: TDS sensor readings

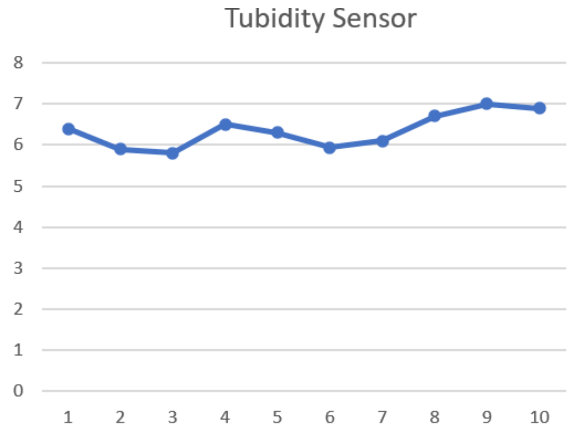

Figure 5: Turbidity sensor readings

From the sensor readings charts provided, we can conclude that all sensors have acceptable fluctuations. TDS and turbidity sensors showed more accurate results since the small voltage changes don't heavily affect its result. On the other side, pH had more fluctuations due to its high impedance output which can be easily affected by external noise, bias current and solder flux residue.

2) *Software Results*

In the following, software results during pure water testing are discussed. Software results consists of cloud database test and mobile application test.

a) Thingspeak database test

After the system's hardware measure the testing water samples, Thingspeak should be able to receive sensor data uploaded by the esp microcontroller and store them in the cloud database. By viewing Thingspeak web cloud interface, we can confirm that Thingspeak is able to receive sensor data and update it every **five** seconds.

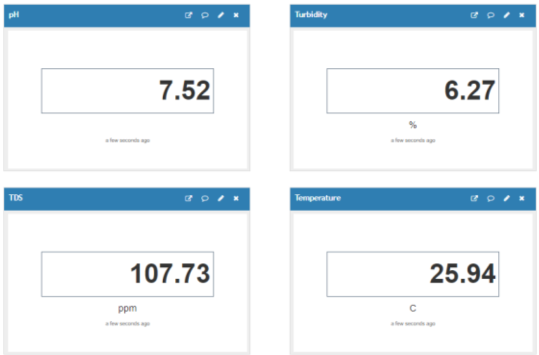

Figure 6: Thingspeak web interface

b) Mobile Application test

The mobile application was able to take the latest sensor data from the Thingspeak database and display it on screen for the user. The mobile application was able to process the received values in order to provide details for each sensor reading (readings status, date and time). Figure 7 shows example of the mobile application live monitoring screen in during the pure water testing.

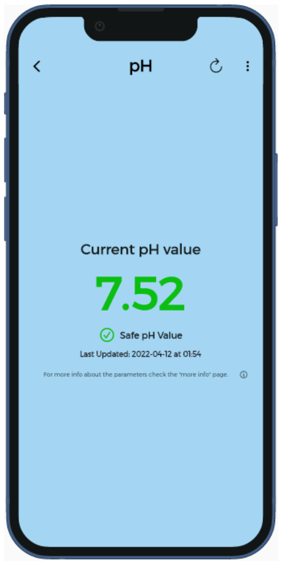

Figure 7: pH reading during pure water testing

B. *Results in polluted samples*

This subsection will discuss the system hardware and software results while measuring different polluted water samples. Five samples will be testing five different scenarios that could face the system which are Vinegar (Acid – low pH), Clorox (alkaline – high pH), tap water (high TDS), dark solution (high turbidity percentage) and boiled water (high temperature).

1) *Hardware results*

The system's microcontroller was able to send open command to the relay module connected to the DC water pump in order to stop the waterflow as expected. In addition, the GSM module was able to send SMS alert to the provided administrator number.

2) *Software results*

During the polluted samples test, the mobile application was able to detect that sensor values taken from Thingspeak database were impure. Accordingly, the application provided alert notifications as well as details about the impure measurements in the live monitoring page as shown in figures 8 and 9.

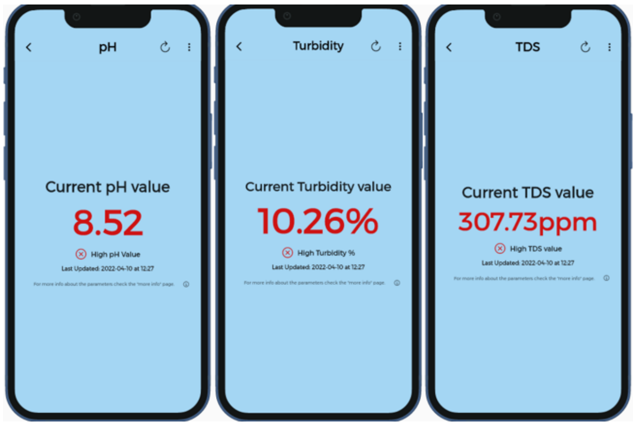

Figure 8: Live monitoring page during impure samples test

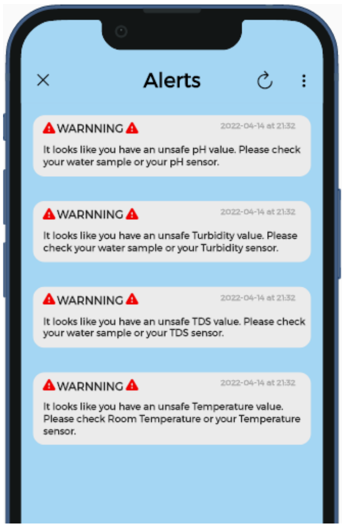

Figure 9: Alerts page during impure samples test

C. *Other features results*

Addition to the results acquired during the testing phase of pure and impure samples, some additional system features that the system provides were tested as follows:

- Waterflow control though user interface: The waterflow control page was able to send open and close commands via HTTP requests to the microcontroller in order to control the DC water pump which is controlling the waterflow from the tested tank to the pure water tank. Additionally, the page was able to indicate the water pump status as shown in figure 10.

- Daily Analysis: mobile application was able to send (through email) a link contains a daily analysis sheet includes the last 100 readings the system has registered. The user was able to type the desired email and receive the sheet in approximately one minute as shown in figure 11.

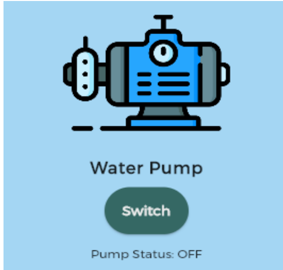

Figure 10: Waterflow application page

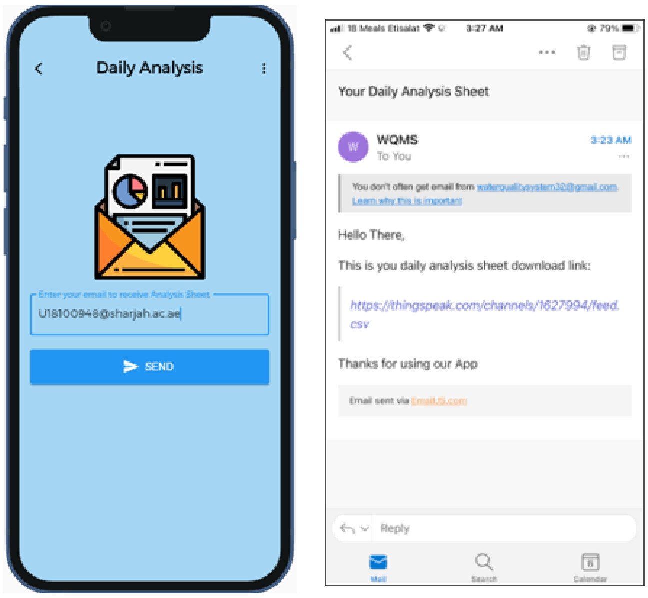

Figure 11: Daily Analysis test result

VII. Concustion

We have proposed a low-cost smart water quality monitoring system that is based on IoT equipment and software, which is an improvement to the currently used monitoring systems. The whole proposed system operation is controlled by a small microchip that is capable of performing hardware, software and communication tasks. Along with the mobile application designed, a complete monitoring system is able to read and identify alerts more easily and effectively.

References

[1] Rasin, Z., & Abdullah, M. R. (2009). Water quality monitoring system using zigbee based wireless sensor network. International Journal of Engineering & Technology, 9(10), 24-28.

[2] Balakrishna, S., Thirumaran, M., & Solanki, V. K. (2018). A Framework for IoT Sensor Data Acquisition and Analysis. EAI Endorsed Transactions on Internet of Things, 4(16).

[3] Rao, A. S., Marshall, S., Gubbi, J., Palaniswami, M., Sinnott, R., & Pettigrovet, V. (2013, August). Design of low-cost autonomous water quality monitoring system. In 2013 International Conference on Advances in Computing, Communications and Informatics (ICACCI) (pp. 14-19). IEEE.

[4] Lakshmikantha, V. (2021, November). IoT based smart water quality monitoring system. ScienceDirect. https://www.sciencedirect.com/science/article/pii/S2666285X2100090X.

[5] ESP8266 Introduction. (n.d.). https://fabacademy.org/archives/2015/doc/networking-esp8266.html

[6] (S. (2020, January 27). Types of pH Sensors: What You Need to Know. Sensorex.(*https://sensorex.com/blog/2019/09/09/ph-sensors-need-to-know/)

[7] (Endress+Hauser Middle East. (2019). Turbidity sensors and transmitters for all industries | Endress+Hauser. https://www.mesc.endress.com/en/field-instruments-overview/liquid-analysis-product-overview/turbidity-sensors-transmitters)

[8] (S. (2020b, May 18). Why Electrical Conductivity of Water is Important for Industrial Applications. Sensorex. https://sensorex.com/blog/2019/10/08/electrical-conductivity-water-important-industrial-applications/)

[9] (Temperature - Aquaread. (n.d.). Aquaread. https://www.aquaread.com/parameters/temperature)

[10] Gong, L. (2020, November 5). Analog-to-digital converter—— ADS1115. ADS1115. https://www.seeedstudio.com.

[11] Engineers, L. M. (2022, August 4). Send Receive SMS & Call with SIM800L GSM Module & Arduino. Last Minute Engineers. https://lastminuteengineers.com/sim800l-gsm-module-arduino-tutorial/

[12] Mini Submersible Water Pump 5V To 12V DC Aquarium Fountain Pump Micro Pump-buy at a low prices on Joom e-commerce platform. (n.d.). Joom.

[13] LM2596 DC-DC Buck Converter Step-Down Power Module - Senith Electronics. (n.d.). http://www.senith.lk/shop/item/1081/lm2596-dc-dc-buck-converter-step-down-power-module