Proceedings of the 2022 Sustainable Research and Innovation Conference
JKUAT Main Campus, Kenya
5 - 6 October, 2022

Water Level and Quality Monitoring System using Message Queuing

Shaibu A. Juma, Newton K. Ollengo and Salome Chepchirchir

Abstract—More than 3 billion people lack access to safe water for drinking. Availability and access to water services are fundamental in preserving the health and well-being of humans. The quality of water has to be of a certain degree to be considered safe for consumption. Storage vessels tend to develop microbes over time lowering the quality of water. These microbes are capable of causing infectious diseases such as flu and measles. There is also strong evidence that they may play a role in non-infectious chronic diseases like cancer and heart disease. Water level monitoring is also of utmost importance when dealing with water storage tanks. This paper seeks to address the challenges of water quality and level monitoring by use of low-power sensors on an MKR WIFI 1010 module to obtain data on the state of water in the tank. The data is then sent to a Mobile app for observation and initiation of the required response. The prototype utilized a Message Queuing Telemetry Transport (MQTT) IoT technology.

Index Terms—Water Quality, MQTT, IoT, Microbes, MKR WIFI1010, Mobile app

I. Introduction

Achieving safely managed water and sanitation services will require a universal commitment to make it the core of sustainable water development [1-3]. Water delivered by the water service companies in developing countries need to be monitored if it is fit for human consumption by the time, it reaches the end user [4]. Due to lack of reliable adequate water supply, most households are forced to have a water storage to ensure they have access to water at all times. However, storage of water over a long period may lead to unsafe water for consumption lowering the water quality. Prolonged water supply interruptions are often associated with longer storage time and lower chlorine residue, indicating the presence of bacteria. The study on microbial succession revealed how some containers promote the growth of microbes in water storage vessels [1].

Safe water storage is essential for ensuring water quality, especially when lack of access to piped drinking water necessitates household storage [5]. Also, constant monitoring of water levels is paramount to avoid the loss of water through water overflow. There has been a growing demand for consumer-driven humanitarian projects that can be developed quickly using Internet of Things (IoT) technology [6]. A monitoring system that measured water level and quality in real-time was developed to reduce the loss of water in overhead tanks and contamination of the stored water. There was a wireless, low power consumption, and a multisensory system arranged for accurate water monitoring in tanks [7]. In [8] monitoring solution for large positioned water collection bodies such as tanks and dams was provided for governmental purposes, however, no attention seemed to be paid to water quality. A message notification-based system was proposed in [9] to monitor only water quality values whilst the automation of level and cleaning was not considered. Solution on water quality and level monitoring was stated in [10], utilizing Wi-Fi for its connectivity but fell short on cost. Other similar-based papers include [7-12] on Wi-Fi solutions for water level as well as quality monitoring capacities but the cost was still on the higher side. Notably, environmental researchers have recently intensified their application of wireless communication and low-power sensors to collect ecological data instantaneously. The devices can also be used to perform remote analysis of data collected, and they can configure, power, and operate themselves [9], [13]. Such devices have also gained popularity because they need less human intervention to work, thus, they can be located in inaccessible places [11-17]. However, under such circumstances, there should be a timely transfer of recorded data [18]. The Traditional Manual Laboratory-Based (TMLB) method was introduced with the evolution of Traditionally Manual based In Site (TMIS), ending with a description of a Wireless Sensor Network (WSN) system that provides real-time transmission of data and continuous water quality analysis. The devices could also be used to perform remote analysis of data collected, as well as performing configurations and operating without human interaction [13], [14]. This paper looks at the design and development of a water

S. A. Juma, Department of Energy Systems, Mzuzu University (phone: +265995329007; e-mail: juma.s@mzuni.ac.mw.)

N. Ollengo, Department of Electrical and Electronic Engineering, Dedan Kimathi University of Technology (phone: +254702526264, email: Newtonkelvin75@ieee.org)

S. Chepchirchir Department of Electrical and Electronic Engineering, Dedan Kimathi University of Technology (salomekones97@gmail.com

level and quality monitoring system that makes use of Message Queuing and Telemetry Transport (MQTT) technology.

II. METHODOLOGY

This section encompasses the design and development of the prototype for monitoring the water level and quality in real-time. The prototype was tested in a laboratory set up and the data received from the mobile app was analysed to gauge the effectiveness of the complete system.

A. Design Concept

The system was realized by the utilization of sensory elements and an MQTT-enabled microcontroller unit. The analog pH sensor and turbidity sensor were used to sense and collect data on the water quality parameters. The information on the water level in the overhead tank was obtained using the ultrasonic sensor. The device operation was achieved by comparing the current reading of the ultrasonic sensor to the intended minimum limit reading of water in the tank for appropriate action to be taken into consideration. In completing the layout of this system, a universal method that integrates the use of sampling and concurrent deployment of instruments to measure all water quality parameters was employed. Aspects such as calibration, repair, and upgrade of outdated and faulty devices were considered in this approach. Data stored by the *Blynk App* was also retrieved from an internet-based database and visualized in the form of charts amongst other various widgets that were considered.

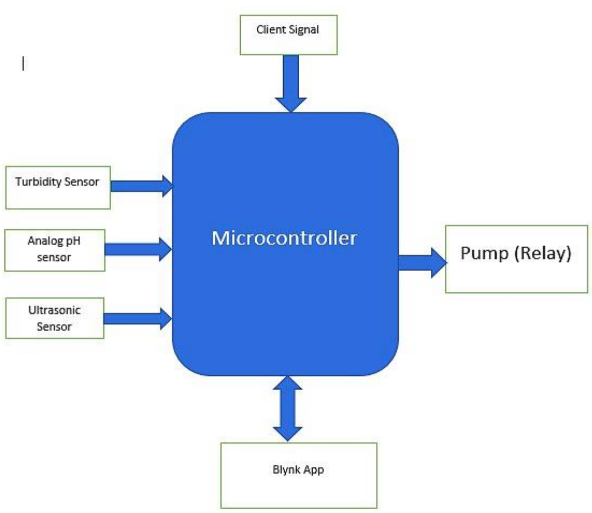

Fig. 1. Block diagram showing System Operation

B. Hardware Implementation

The block diagram in Fig. 1 shows the system operation of the developed prototype. MKR WIFI 1010 microcontroller was used due to its capability of onboard ESP8266 which enables it to easily connect to the cloud server, and create HTTP requests without the need for constant refreshing, and its fast connectivity to Wi-Fi. It also does not require external crystal oscillators and timing libraries for it to constantly send data to the cloud server. The data collection is an extremely necessary part of the device. The analog pH sensor, the turbidity sensor, and the ultrasonic sensor were used to obtain the data in real-time from the tank. The following gives a detailed discussion on the parameters of interest and the sensors used:

1) Turbidity

It is a measure of the level of cloudiness of water. Microorganisms and floating particles are responsible for such cloudiness. *Turbidity Unit (TU)* was obtained by using the *ISO 7027* approach, where infrared light scatters at right angles to cross beams. *TU* is indicated in *Nephelometric Turbidity Units (NTU)*. Escalated growth of microbes is susceptible in turbid water as it provides sufficient food and shelter for pathogens. Therefore, *TU* should characteristically be kept below *5 NTUs*.

Turbidity sensor: A cheap and adequately precise sensor was used in this study to track water's turbidity in a tank. The sensor was created in the turbid meter ratio design. The intensity of both transmitted and diverted light was measured to limit errors due to drifts in the infrared energy and variations of sample absorption capabilities. The *IR* emitter produced an 860nm beam through a specified visual gap into the water sample. Two 1cm-separated photodiodes received the right angle-diverted light in tandem with that of the transmitted light. After that, the sensitivity of the photodiodes fit for the infrared source was identified. First, the infrared emitter had a pulse of approximately 1 kHz. The signal, which is a square wave, is transformed from light to current before a CMOS amplifier rejects the light to convert it into photocurrent, subsequently, voltage. The trans-impedance amplifier also converts each AC output into DC by detecting active peaks. The right-angled light deflections are conditioned through 0 NTUs, further amplifying and eliminating any existing nulling effects.

The process is followed by a sampling of the voltage outputs using a 10-bit Analog-Digital converter with an output voltage of 1.1V as reference. A program was developed to convert the voltage values read such that the higher values provided could indicate higher levels of clarity and hence indicate the water as being clear and suitable for human consumption based on the presence of microorganisms detected in the water.

2) Analog pH Meter.

The level of acidity or alkalinity in water is indicated by the use of a negative algorithm of hydrogen ion concentration in water. The sensor collected the data on the acidity or alkalinity of the water used for testing the developed prototype. Various solutions were used to determine the effective operation state as well as the calibration of the sensor. For potability, the desired pH should range from 6.5-8.5 pH. The level of pH does not cause any health complications unless it has levels outside the range of 6.5-7.5. A level outside this range even by 0.5pH units can lead to contamination which will require for water to be chlorinated at such low pH values. During the measurement of pH, a combined pH electrode is utilized to ensure accuracy.

pH value sensor: The developed program adopted a two-point calibration method, that could automatically identify two standard buffer solutions (4.0 and 7.0), with ease and convenience. The DF Robot analog pH sensor obtains values of

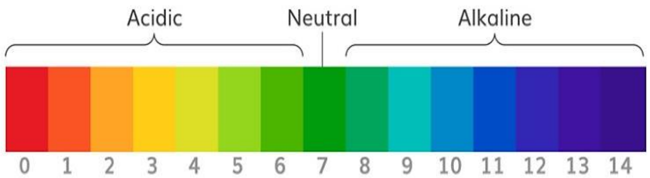

Fig. 2. pH scale

the alkalinity's water state. The value obtained was measured based on an expected output which was an analog value. Then as per the calibration done, the microcontroller stored a value in its EEPROM against which measured the state of water and the level of alkalinity/acidity. This data was then sent as a data packet to the Blynk server and displayed on the Blynk mobile application.

pH Sensor data values analysis: The *pH* is the negative log of the concentration of hydrogen ions in the solution. *pH* values can range between 0 and 14. The given *pH* value of pure water is 7, which is neutral. Values less than 7 are considered acidic, while values greater than 7 are considered alkaline. The system design is implemented such as to achieve a value of range 6.5 to 7.5 *pH*. The difference between the electrochemical potentials determines the *pH* value based on the *Nernst equation.* The glass electrode response is governed by the *Nernst Equation* given as:

$$E = E_0 - 2.3\left(\frac{RT}{NF}\right)\ln Q \qquad (1)$$

Such that: Q is the Reaction coefficient, E is the millivolt output from the electrode E_0 is Zero offset for the electrode R, the Ideal gas constant at 8.314J/mol -K, T is Temperature given in degrees K, F is Faradays' constant of 95,484.56C/mol, N is the Ionic Charge.

When the pH of water is within range of the recommended pH, the microcontroller sends a signal to the relay which then opens the valve and allows the inflow of water if the water level in the tank is too low. When the pH is out of range then the solenoid closes the valve even if water is below the expected level.

3) *Water Level*

The placement of the sensor at the upper part of the tank to take readings of the water levels enabled it to calculate the distance between the sensor and the water level hence setting the limit boundary that the water level should not exceed before declaring a low state of water. The ultrasonic sensor was positioned at the top of the tank, therefore, being able to determine the level of water by sending sonic pulses and utilizing the amount of time that has elapsed to calculate this distance. The system incorporated a formula that took into consideration the distance the sensor measures the radius and the actual height of the tank to establish the volume of water contained. The formula used is as follows:

$$actual\ height = maximum\ range - distance \qquad (2)$$
$$volume = ((3.14*(radius * radius))*(actual\ height)) \qquad (3)$$
$$capacity\ in\ litres = volume/1000 \qquad (4)$$

An ultrasonic sensor yields measurements by evaluating the time taken for the sound to travel between transmission and reception (direct detection), or a process of heckling whether the transmitted signal has been received (detection by beam interruption). The placement of the sensor at the upper part of the tank to take readings of the water levels enabled it to calculate the distance between the sensor and the water level hence setting the limit boundary that the water level must not exceed before declaring a low water state.

C. Interface with the MQTT

The process involved the use of electrical and mechanical switches to realize the automation of the system. The MKR WIFI 1010 module ensured a perfect sync in monitored periods as to when the pump should be on and off. However, in the implementation, a solenoid valve was used in place of a pump to control the water supply in the tank. The solenoid is a high current device, a relay and transistor were used to switch it on.

1) Relay: It is used as a switching mechanism as the system requires the actuating action of a pump, but the power demands of the micropump could not be managed by the *MKR Wi-Fi 1010*. To control the pump, a signal was sent to the relay using the *BC547* transistor. The transistor required a biasing voltage of *0.6V* for it to operate, which was small and could be registered as noise by the microcontroller pins. Therefore, there was need to drop the voltage to a reasonable level as the microcontroller pin voltage is extremely high and can lead to the destruction of the transistor. A current drop resistor of *200 ohms* was used to protect the transistor from current surges that might destroy it.

2) Microcontroller Interfacing with the Blynk App: The microcontroller, was required to control the pump using the actuation system design of a relay switching mechanism. However, there is a need for the client to be able to observe the situation of the tank. Despite the availability of the automation aspect, the client needs to be an active participant in the system control and utilization, hence the algorithm to input the client's control action was included. On the Blynk app, a button switch was used to indicate the situation of the pump as depicted in Fig. 3. At extreme periods the client can realize a control

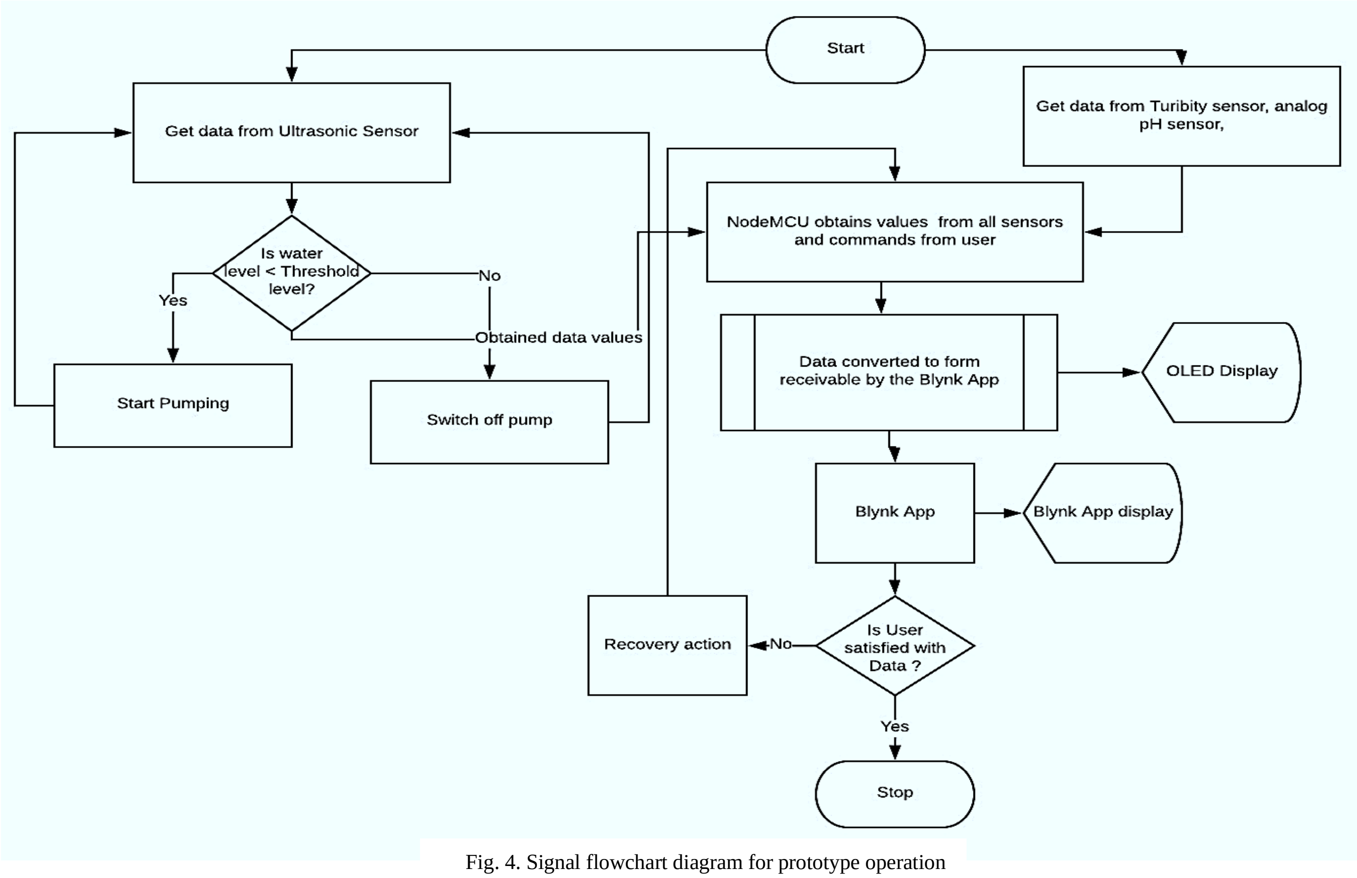

Fig. 4. Signal flowchart diagram for prototype operation

mechanism, and switch the button to control the pump. However, the microcontroller would check if the established parameters (water level: $6<L<18$) were met before actuating the pump. An alert service that sends an email if the threshold is not met was also implemented.

Fig. 3. Blynk App data Display

Flowchart: The prototype operation followed the signal flowchart diagram shown in Fig. 4.

3) Blynk App: Blynk is a mobile app used to control Arduino, MKR Wi-Fi 1010 amongst other devices over the Internet [19]. The dashboard is achieved by the use of a graphic interface implemented by simply dragging and dropping widgets. It needs no specific board/shield nor any hardware of your choice [20]. Blynk was designed for the IoT, to control hardware remotely, display sensor data, store the data, and allow the analysis of data. There are three major components in the platform [21]:

- *Blynk App*
  Allows creation of amazing interfaces for different projects using various widgets that are provided.
- *Blynk Server*
  Responsible for all the communications between the phone and hardware. Can be run as a Cloud or private local server. Open-source, and could easily handle thousands of devices.
- *Blynk Library*
  Allows hardware platforms to communicate with a server that processes incoming and outgoing commands from software libraries.

The developed system utilized Blynk due to the following characteristics:

- Similar *API* and *UI* for all supported hardware devices,
- Connection to the cloud using Ethernet, Wi-Fi,
- Widgets that are simple to use,
- No code is required for direct pin manipulation,
- Simple to integrate and add new functionality since virtual pins are utilized,
- Data monitoring of aggregated past events via the History Graph widget,
- Device-to-Device communication using Bridge Widget.

Fig. 5. Blynk App Overview

For insurance against malfunctioning or exceeding the limit of messages sent to the application, the system sends a standard text message to the client's mobile phone, via *Twilio* Application Programming Interface (*API*).

4) Arduino IDE: The Arduino IDE renders a software library from the wiring prototype, which provides a universal input and output procedures. User-written code only requires two basic functions, to start a sketch, known as *void setup*, and the main loop, often termed as *void loop function*, compiled and linked with a program stubbed *main ()* into an executable cyclic executive program with the *GNU* toolchain. The software development for the *MKR Wi-Fi 1010* shall be written on this platform due to its mentioned abilities. The platform has the required libraries for the development of the problem at hand making it user-friendly. The Arduino MKR Wi-Fi 1010 was an appropriate substitute for the *Node MCU* as it also manages to use the same libraries. In addition, it has an in-built clock timer that renders it a better choice as opposed to the *Node MCU*. The methods and means of connection remain the same for the two microcontrollers. Despite the differences in their architectures, they have similar operating characteristics.

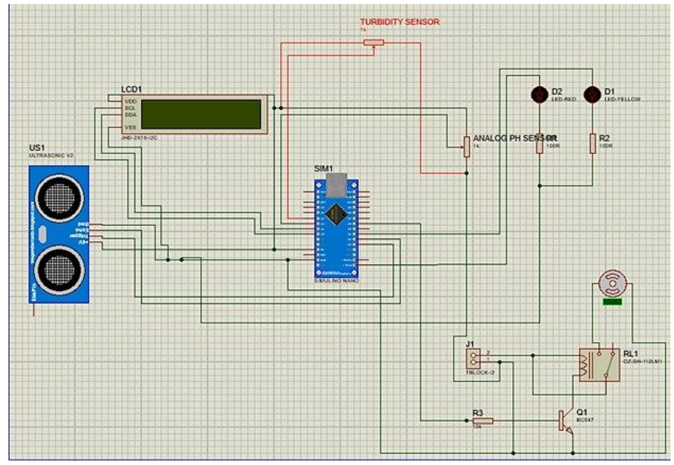

Fig. 6. Circuit diagram for software simulation without the MQTT

The turbidity sensor was interfaced with the analog pin (A1) of the microcontroller which is also connected to the Blynk app as a virtual pin such that the data that is collected is then mapped and sent to the Blynk app for visualization on the mobile app. The MKR Wi-Fi 1010 provided 3.3V at its power pin, however, the turbidity sensor required a voltage of 5V for its operation. Consequently, the interfacing required by the sensor and the board utilized a pin raised high to provide 5V for the sensor power shown in Fig. 6.

Firstly, the system was simulated in proteus IDE, enabling evaluation and observation of the parameters such as sensors and actuators if they worked. The circuit operation used representational modules in place of analog pH and for the turbidity sensor since they were not available on the proteus IDE. The analog data was displayed on the LCD screen. Lack of simulation for MQTT communication led to the test and evaluation of the component after development of the hardware prototype.

III. RESULTS AND DISCUSSION

A. Overview of the Prototype

A fully implemented and assembled prototype that realized the set objectives in the paper is depicted in Fig. 7. Evaluation of the system was done on the Blynk App. The conditions in which the device was to operate were recreated and simulated by deploying the prototype in areas of low internet connectivity to test for fail safe when there is no internet. The system only sent data at intermediate times when the internet connection was restored but kept water automation and control under full control.

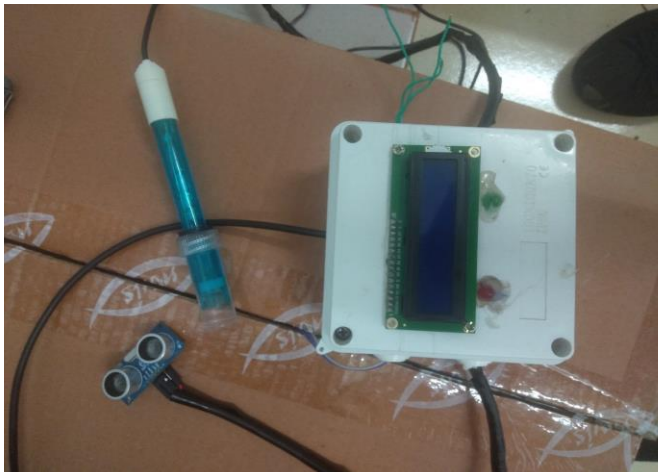

Fig. 7. Complete Prototype

The developed prototype monitors the set parameters and automates the process of pumping water into the tank. It checks for the level of water in the tank, if it goes below the expected level a signal is sent to the relay module, which either switches on the pump or opens a solenoid valve to allow the inflow of water. When the level of water in the tank exceeds the expected level, a switch turns off the pump or closes the solenoid valve stopping the inflow of water, consequently automating the pumping of water into the tank.

B. Evaluation of the automated water pumping process

The prototype collected the pH, turbidity, and water level data from the tank by the use of an analog pH sensor, a Turbidity sensor, and an Ultrasonic sensor and sent this data in real-time using the MQTT to a Blynk mobile application, for viewing and data analysis. For water to be pumped into the tank it had to meet *three* conditions;

1. The level of water must be below 6 litres,
2. Turbidity of water should less than *1 NTU*,
3. *pH* of the water should range between *6.5* and *7.5*.

In the code, when the ultrasonic sensor reading is below *6 litres*, the valves opened to allow the inflow of water. Consequently, when the water hoarded up to 18 litres, the valves closed to stop water from flowing into the tank. The sensor readings were displayed on the LCD as well as on the Blynk app. The LCD indicated whether the tank is full or empty whilst in Blynk app, water level readings were indicated above the water tank symbol as shown in Fig. 8.

Conversion of voltage values from Turbidity sensor into NTU values: The voltages were collected for different samples of water at different levels of cloudiness to establish a point where the water turbidity could be determined. At *5 NTU* unit turbidity, the sensor gives an output of approximately *4.2V*. Analog turbidity values were mapped to voltage values using equation (5);

$$y = -1120.4x^2 + 574.3x - 4352.9 \qquad (5)$$

where x is the analog read value and y is the NTU value
This gives the output turbidity of water ranging from *0 - 5 NTU*.

Fig. 8. Water Level Indication

According to WHO [4], the standard turbidity range for drinking water should be less than 1 NTU. Red LED and green LEDs were used to indicate the turbidity of water. When the turbidity of water is above *1.0*, a red LED blinks indicating that it has not met turbidity conditions hence the water pump switches off even if the level is below the required amount. Also, the client receives an email indicating that the water is too cloudy, see Fig. 1. Consequently, when the turbidity of water is below 1.0 it means that water is clear. When the green LED blinks, water gets pumped automatically if it is below the expected level. An email alert is sent to the client if the water is favourable for human consumption as shown in Fig. 11 and 12.

C. Analysis of water samples

Three water samples were used to test the turbidity and pH and the results were as follows;

1) Sample 1: Water was found to be cloudy since the turbidity ranges between *2.4* and *2.8*. In this scenario, the red LED blinked indicating that the water was not safe for human consumption. Also, the pH is out of the range. It indicated that the water being pumped into the tank was acidic hence, the microcontroller sent a signal to the relay to switch off the pump. There can be a possibility that the water pumped from the river had a lot of soil particles making the water turbid.

2) Sample 2: Turbidity ranges were between *4* to *5* NTU. This indicated that the water was not safe for human consumption since it did not meet turbidity conditions. In this case, the water sampled had many particles, making it turbid. Also, the *pH* reading in this sample ranged between *7* and *7.5*.

This is an indication that the water was neither acidic nor basic. It met the *pH* conditions which should range between *6.5* and *7.5*.

3) Sample 3: This is an ideal normal user case, where the sample meets turbidity conditions. It also meets pH conditions since it ranges between *6.5* and *7.5*. In this case, the red LED blinks indicating that the water meets WHO requirements. An email indicating that the water is safe for human consumption is sent to the client's email. However, if the level of water in the tank is below 6 litres, then the pumping action is automated since turbidity and pH conditions have been met. A graph of turbidity of water against voltage was plotted in Fig. 13. There is a drop in voltage as water turbidity increases.

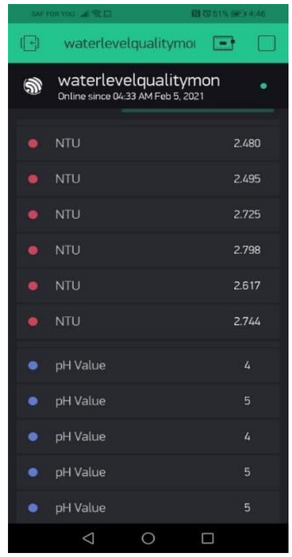

Fig. 9. *Sample 1* Turbidity and pH data

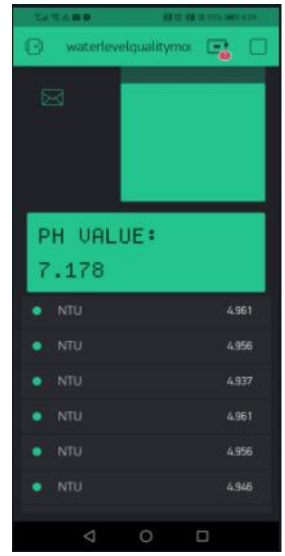

Fig. 10. *Sample 2* Turbidity and pH data

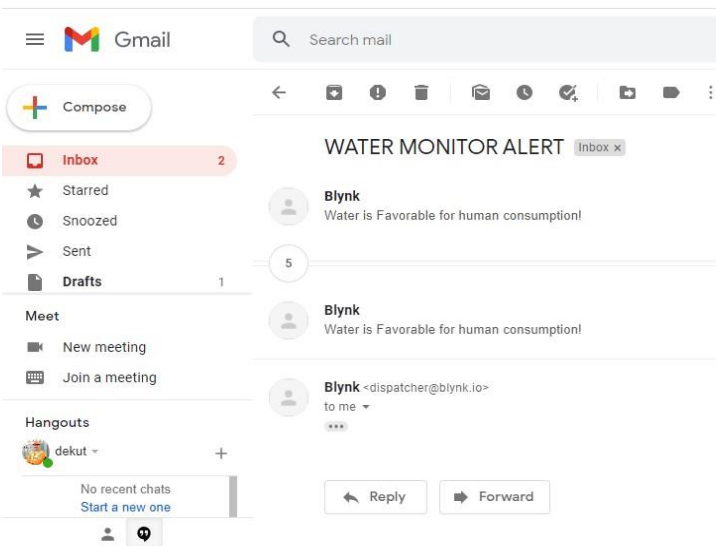

Fig. 11. Email Notification for Turbidity

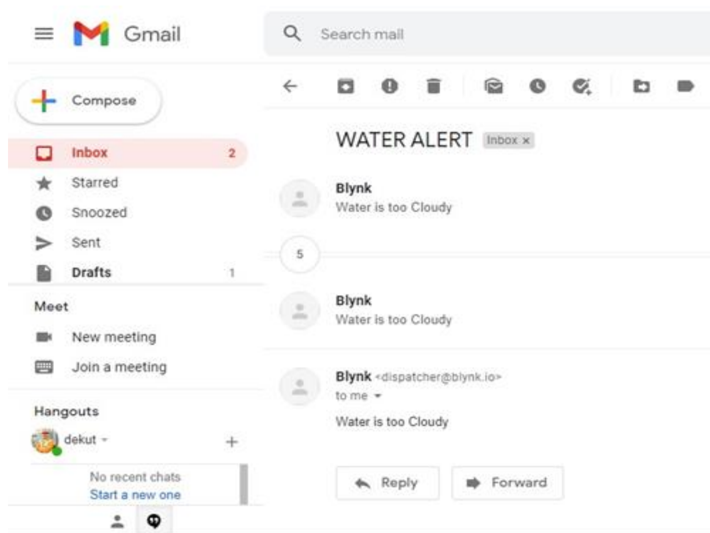

Fig. 12. Email Notification for Analog pH value

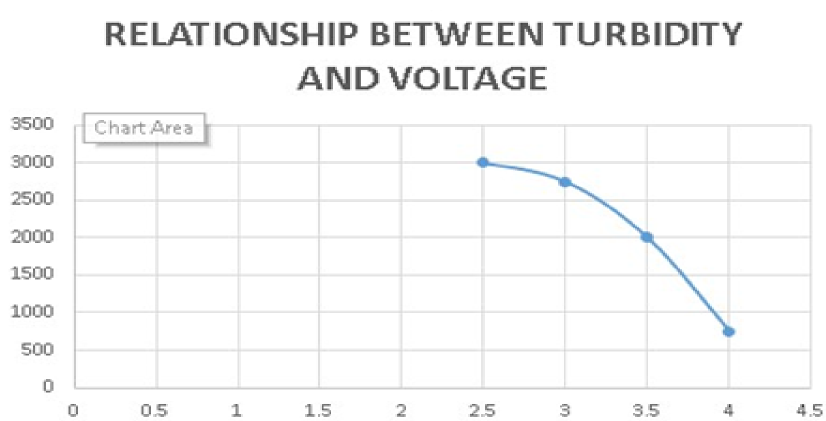

Fig. 13. Turbidity - voltage relationship

IV. CONCLUSION

The quality of water has to be monitored closely to avoid poisoning and infections that may arise in water tanks. This prototype aimed to improve water quality services in water storage systems. It also has capabilities and features to monitor and manage water usage easily while automating tank refill and pumping. The developed prototype was a low-cost effective system that availed the required data to the user/client using Message Queuing and Telemetry Transport (MQTT) technology for appropriate action in time.

APPENDIX

A. Software development

The program was structured in such a manner to utilize all the available hardware. In the implementation, the program was designed using the pseudocode below:

```
   SETUP:
   Call Required libraries;
   Define variables and pins used;
Initialize required pins;
Set the communication baud rate;
Check System; Print result of system check;
LOOP:
Call function to send data to Blynk app; Call functions, Turbidity,
water level, pH level, functions for data collection; TURBIDITY:
Read value from sensor pin;
Convert Analog Read value into NTU units;
Print the value on LCD Screen; If the NTU value is
< 3:
Send Email Notification; Stop Pump;
Send data to Blynk App;
WATER LEVEL;
Develop pulse to trig pin; Read echo value;
Convert echo value into the distance; Determine tank actual
height;
Obtain water volume using volume formulae;
Send data to Blynk app;
Print data value on the LCD screen;
If water value == 20;
Switch off the Pump;
State of the tank on LCD;
If the water value < 6; Switch on the
Pump; Print the State of the tank on
LCD;
Indicate given problem using LED;
Else;
Print state of the tank;
Switch off pump; ANALOG pH:
Obtain value from sensor pin;
Map the value to expected limits;
Print data value on LCD;
Send data to Blynk app;
```

ACKNOWLEDGMENT

A special thanks to the Dedan Kimathi University of Technology for financial and resource support in the realization of this project.

REFERENCES

[1] D. Majesty, C. Amadi, B. Amadi, C. Nsofor, and N. Humphrey, “Effect of different Storage vessel on water quality.,” Glob. Res. J. Sci., vol. 2, pp. 9–13, 2013.

[2] Singla, T., & Manshahia, M. S. Wireless Sensor Networks for Pollution Monitoring and Control, 2018.

[3] S. M. Saad, A. R. Mohd Saad, A. M. Y. Kamarudin, A. Zakaria, and A. Y. M. Shakaff, “Indoor air quality monitoring system using wireless sensor network (WSN) with web interface,” in 2013 International Conference on Electrical, Electronics and System Engineering (ICEESE), Dec. 2013, pp. 60–64, DOI: 10.1109/ICEESE.2013.6895043.

[4] UNDESA, "The Millennium Development Goals Report 2005," United Nations, p. 48, 2005, DOI: 10.1177/1757975909358250.

[5] C. Gonzalez, J. Erickson, K. Chavarr´ıa, K. Nelson, and A. Goodridge, “Household stored water quality in an intermittent water supply network in Panama," J. Water, Sanit. Hyg. Dev., 2020, DOI: 10.2166/washdev.2020.156.

[6] A. Ahmed Mohammed ahmed Eltaieb and Z. Jian Min, “Automatic Water Level Control System,” Int. J. Sci. Res. ISSN, vol. 4, no. 12, pp. 1505–1509, 2013, [Online]. Available: www.ijsr.net.

[7] R. K, S. Srinija, K. Bindu, and D. Kumar, “IOT based water level and quality monitoring system in overhead tanks,” Int. J. Eng. Technol., vol. 7, p. 379, 2018, doi: 10.14419/ijet. v7i2.7.10747.

[8] N. Dyavakkalavar, M. K. Kalamat, M. Ashmitha, S. D. Souza, and P. P. K. K, “Issn No: 2347-6060 Iot Based Water Utility Monitoring System,” vol. 5, no. 5, pp. 97–102, 2018.

[9] M. Pule, Y. Ahadi, and J. Chuma, “Wireless sensor networks: A survey on monitoring water quality," J. Appl. Res. Technol., vol. 15, 2018, DOI: 10.1016/j.jart.2017.07.004.

[10] Wmo, Planning of Water Quality Monitoring Systems, no. 3. 2013.

[11] M. S. U. Chowdury et al., “IoT based real-time river water quality monitoring system,” Procedia Comput. Sci., vol. 155, pp. 161–168, 2019, doi: 10.1016/j.procs.2019.08.025.

[12] G. Wiranto, “Design of online data measurement and automatic sampling system for continuous water quality monitoring," 2015, DOI: 10.1109/ICMA.2015.7237850.

[13] A. Johari, M. Abd Wahab, N. Abdul Latif, M. Ayob, M. Ayob, and M. Ayob, “Tank water level monitoring system using GSM network,” Int. J. Comput. Sci. Inf. Technol., vol. 4, no. 3, 2022.

[14] K. S. Adu-Manu, C. Tapparello, W. Heinzelman, F. A. Katsriku, and J.-D. Abdulai, "Water Quality Monitoring Using Wireless Sensor Networks: Current Trends and Future Research Directions," ACM Trans. Sen. Netw., vol. 13, no. 1, Jan. 2017, DOI: 10.1145/3005719.

[15] J. Bhardwaj, K. K. Gupta, and R. Gupta, "A review of emerging trends on water quality measurement sensors," in 2015 International Conference on Technologies for Sustainable Development (ICTSD), Feb. 2015, pp. 1–6, DOI: 10.1109/ICTSD.2015.7095919.

[16] K. Murphy et al., “A low-cost autonomous optical sensor for water quality monitoring,” Talanta, vol. 132, pp. 520–527, Jan. 2015, doi: 10.1016/j.talanta.2014.09.045.

[17] Adu-Manu, K. S., Tapparello, C., Heinzelman, W., Katsriku, F. A., & Abdulai, J. D. (2017). Water quality monitoring using wireless sensor networks: Current trends and future research directions. ACM Transactions on Sensor Networks, 13(1). https://doi.org/10.1145/3005719.

[18] Sugiharto, W. H., Ghozali, M. I., Susanto, H., Budihardjo, M. A., & Suryono, S. (2020). a Novel Framework of Wireless System Network for Water Quality Management. 39(3), 593-599UN.

[19] G. Kesavan, P. Sanjeevi, and P. Viswanathan, "A 24-hour IoT framework for monitoring and managing home automation," in 2016 International Conference on Inventive Computation Technologies (ICICT), Aug. 2016, vol. 1, pp. 1–5, DOI: 10.1109/INVENTIVE.2016.7823205.

[20] B. Bakare and W. Minah-Eeba, "A Comprehensive Review of Wireless Fidelity (Wi-Fi) Technology in Nigeria," vol. 13, pp. 37–42, 2019, DOI: 10.9790/2834-1303023742.

[21] H. S. Doshi, M. S. Shah, and U. S. A. Shaikh, "Internet of Things (IoT): Integration of Blynk for Domestic Usability," Vishwakarma J. Eng. Res., vol. 1, no. 4, pp. 149–157, 2017.