INTEGRATED IoT BASED WATER QUALITY AND QUANTITY MONITORING SYSTEM

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Abstract

Smart and cost-effective solutions for water quality monitoring are gaining attention with the recent advancement in information and communication system technology. This paper aims at the design and development of the internet of things (IoT) based low-cost and portable water quality and quantity monitoring (WQQM) system. The proposed system not only monitors the water quality but also monitors the amount of water being utilized by the consumer. The main objective of designing WQQM is to ensure both purity and conservation of water. The water quality meter measures six qualitative parameters of water viz. potential hydrogen (pH), water temperature, atmospheric temperature, turbidity, and total dissolved solids (TDS). Whereas, the water quantity meter measures the water level and water flow to calculate the amount of water being used. A custom printed circuit board (PCB) is designed to integrate all the sensors for quality and quantity measurement. The results generated by the WQQM system are wirelessly transferred, using Wi-Fi, to the online monitoring system.

Keywords: IoT, water quality, water quantity, TDS, pH, turbidity.

I. Introduction

Water is one of the biggest gifts of nature and an essential requirement for the nourishment of human beings, animals and plants. Currently, the world is facing problems to fulfill the drinkable water requirements. There is a number of reasons which has worsened the quality of water including limited water resources, growing population, excessive use of the sea for salt extraction and dumping of industrial and human waste into the water bodies. Because of water contamination, numerous water-borne diseases growing day by day which in several cases ultimately results in death. Apart from asymptomatic hepatitis and dysentery, typhoid fever is the most common disease caused in human beings due to drinking of contaminated water [II]. Many viral, bacterial, and pathogens are present in contaminated water and become the reason for 2.5 million deaths every year [III]. Henceforth, maintaining water quality is of paramount importance. Otherwise, it will damage the life and ecological balance of different species [IV].

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The drinking water is said to be safe if it doesn’t have any synthetic material, microorganisms including worms and protozoa, and physically if it doesn’t have any turbidity, smell, and tastes [V]. Conventionally, the water quality check is performed manually where different samples of water are obtained initially and subsequently sent to the laboratory to perform a water quality check using different tests. Such a method is not only time consuming and costly but also required a lot of human resources.

In this paper, we report an integrated IoT based device which gathers information about water quality and quantity with the help of different sensors. The proposed integrated device measures different parameters which include total dissolved solids (TDS), potential hydrogen (pH), turbidity, temperature, water flow, and water level. Moreover, it has the ability to transmit data wirelessly using IoT technology and hence reduce the human resource required otherwise for the conventional way of water testing.

II. Literature survey

A.S. Rao et al. [VI] built up a device for the water quality check. The device can check different parameters such as pH, conductivity, broken down oxygen, conductivity, etc. However, it needs a separate PC for monitoring and had complex wiring and -XM ARM processor for the corresponding interface.

Theofanis P. Lambrou et al. [VII] discussed a portable, reliable and low-cost real-time sensor network for monitoring drinking water. Here the authors have used radio frequency (RF) transceivers used wireless communication over the web. The proposed work measures various parameters such as potential hydrogen, temperature, dissolved oxygen, etc.

N. Vijayakumar et al. [VIII] proposed the IoT-based idea of checking the permanent quality of observable water. Their framework includes some sensors that can verify the quantity of some basic parameters of water, for example, temperature, pH level, conductivity, dirt and debris, and oxygen levels. On-site distribution can be viewed using computing. However, it runs on the Linux system and requires customers to place an order each time they feel to read the values of the sensors should only be used during a specified time interval.

A.N. Prasad et al. [IX] discussed water monitoring through the smart device using remote sensing and IoT technology. The authors ensured the delivery of accurate and consistent data. The mobile user gets real-time data via SMS through a GSM module.

Md. Omer Faruq et al. [X] proposed the design and implementation of a low cost and accurate water quality monitoring system. The proposed device is sensitive to various water parameters with a high level of precision including pH, turbidity and temperature. The authors compared the results with conventional equipment and errors are calculated.

III. Methodology

There is a number of parameters that need to be determined for a water quality check. The proposed device measures some of the key parameters including pH, turbidity, TDS, and temperature. For the water conservation aspect water level and water flow sensor are also integrated into the proposed device. The main objective is
to develop a device that can monitor water quality and quantity in remote areas. Moreover, it should be low cost and has low power consumption with high level of accuracy. This project has used seven sensors (Potential hydrogen, total dissolved solids, turbidity, water temperature, water level, water flow, and atmospheric temperature) as shown in figure 1. These sensors are connected with the Arduino-Mega board (core module). For transmitting the data through Wi-Fi, ESP8266 (Node MCU) is used in the proposed device. Moreover, the TFT screen is used for data display on the device.

The Arduino Mega board, the main microcontroller unit, is an essential part of the proposed device, especially for monitoring water quality and quantity. It can consume less power. Moreover, its small size makes it a better candidate for an important point-of-sale technology benchmark. All the sensors gather data in the form of analog signals which are then translated into digital signals through an analog-to-digital converter (ADC) on the Arduino Mega board. The necessary mathematical equations are used to convert the analog values to digital values (0 to 5 V). Moreover, calibration is done with the help of standard measurement meters to ensure data accuracy. The Arduino Mega is programmed, using C++, with the help of the Arduino IDE (integrated development environment) software.

The system schematic is made using Proteus software and tested before the hardware is developed. The printed circuit board (PCB) design is also made with the help of Proteus software. The system casing was designed in CAD software and printed with the help of a 3D printer using plastic material.

**Arduino Mega**

The Arduino Mega is an At-mega 2560 based microcontroller which is used as a core controller in this framework. The controller can be programmed using the Arduino IDE software. The At-mega comes with an already installed bootloader. The

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**Fig. 1:** Block diagram of WQQM device

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controller has a flash memory of 256 KB and has 54 digital input/output pins along with 16 analog input pins. It can be powered through a USB connection with a 5V power supply and has a clock oscillation of 16 MHz.

**Node MCU**

This is an open-source, programmable, simple and low-cost IoT platform that consists of ESP8266 Wi-Fi chip and ESP-12 module hardware. It is a combination of firmware and a development kit that enables us to make a prototype of an IoT based product.

**Sensors for monitoring**

The sensors used in the proposed system are discussed below.

**Potential hydrogen sensor**

To monitor the potential hydrogen in water, a pH sensor (SKU: SEN0161) shown in figure 2 is used. The pH value from 6.5 to 8.5 is considered safe for drinking water. Anything below or above this range is considered dangerous for consumption. Potential hydrogen (pH) is the calculation of hydrogen ions present in the water. The pH is high for an alkaline solution and low for an acidic solution [X].

**Turbidity sensor**

The number of atoms present in the water mainly due to silt, sand, clay and plant waste disturbed the clarity of the water. The clarity of the water is thus calculated by using a turbidity sensor as shown in figure 2. The sensor checks the clarity by detecting the suspended particles in the water using light transmission and dispersion rate. The low level of turbidity indicates the purity of water while the high-level shows indicate the presence of bacteria, viruses, and other pathogens. An increase in turbidity can reduce not only marine life but human life is also affected [XIII]. The turbidity sensor generates both analog and digital mode output. Moreover, it can stand at 100-900 degrees Celsius at maximum. The turbidity is measured in NTU (Nephelometric Turbidity Units) and according to the world health organization (WHO), the water is safe to drink when turbidity is less than or equal to 5NTU.

**Temperature sensor**

The temperature directly affects the pH and turbidity of water so constant monitoring of water temperature is needed. In this work DS185B20, water temperature is used as shown in figure 2.

**TDS sensor**

The TDS sensor (SEN0244), as shown in figure 2, is used to indicate how many milligrams (mg) of soluble solids are dissolved in 1 liter of water. In general, a higher value of TDS corresponds to more solids dissolved in water and water is less clean. Henceforth, TDS is one of the indicators for the cleanliness of the water.

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Fig. 2: Sensors and TFT screen used in the WQQM device.

Water flow sensor

The water flow sensor (YF-S201), as shown in figure 2, is used to measure the amount of water passed through it. It purely works on the principle of the Hall Effect. The sensor is attached to the inlet of the water supply and the rotor inside the sensor rolls. The speed of that rotation changes with the flow of the water which is then measured to calculate the total amount of water being passed through it. This model works in the 5V-18V range and can handle a water speed of 2mpa. Moreover, its working flow rate is 1-30 Lit/min.

Ultrasonic sensor

To check the water level, an ultrasonic sensor (HC-SR04), as shown in figure 2, is used in this work. This sensor provides a measurement range of 2cm-4m and consists of three parts including ultrasonic transmitter, receiver and control circuit. It has four pins, VCC, ground, trigger and echo that are connected to Arduino. The sensor transmits a wave of 40 kHz and receives back the echo subsequently after striking the obstacle (water). The total time taken to receive back the wave is translated into the distance and hence the water level is measured.

IV. Results and discussion

The prototype of the WQQM system is initially made as shown in figure 3. All the sensors are calibrated and after ensuring the accurate measurement PCB layout is designed with the help of Proteus software. The detailed PCB design is depicted in figure 3. Finally, the WQQM device is made as evident in figure 3. This device measures both water quality and quantity. The device can show data for both water quality and quantity on the TFT screen which is incorporated in the device. Moreover, the device also can send data directly to the server using the ESP8266 device. The data can be access on a computer using Wi-Fi.

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The device is turned on using 12-volt battery/power. After power-up, the Arduino-Mega board, sensors, ESP module and TFT screen get initialized. After initialization, the ESP module is connected to the local server and sensors start taking readings. The data is then sent to the microcontroller and finally displayed both on the TFT screen and on the cloud. The working mechanism of the WQQM device is illustrated in figure 4.

**Fig. 3**: Development process of WQQM device

**Fig. 4**: Process flow of WQQM device operation
For safe drinking water the suggested parameters, pH, turbidity, TDS and temperature, need to be monitored all the time. The suggested parameters with their safe range are mentioned in table 1. Whereas, the issues related to health if the drinking water is not in the safe range are elaborated in Table 2.

### Table 1: Suggested parameters and their safe ranges.

| S.No | Suggested Parameters | Safe Range | Units | References |
|------|----------------------|------------|-------|------------|
| 1    | pH                   | 6.5 – 8.5  | pH    | EPA<sup>(XII)</sup> |
| 2    | Turbidity            | 5 – 10     | NTU   | WHO<sup>(XIII)</sup> |
| 3    | TDS                  | <1000 mg/l | PPM   | WHO<sup>(XIV)</sup> |
| 4    | Temperature          | 10 – 19    | °C    | WHO        |

A series of experiments are performed using a proposed WQQM device. Water monitoring is performed on both tap water and the water from the RO plant installed at the U.S-Pakistan Center for Advanced Studies in Energy (USPCAS-E), University of Engineering & Technology Peshawar, Pakistan. The results obtained are summarized in table 3.

### Table 2: Health issues if the parameters are not in the safe range.

| Suggested Parameters | health issues                                                                 |
|----------------------|-----------------------------------------------------------------------------|
| pH                   | pH > 11 – Eye irritation and skin disorders                                   |
|                      | pH 10-12.5 – Hair fibers to swell and gastrointestinal irritation             |
|                      | pH < 4 – redness and irritation of the eyes                                   |
|                      | pH < 2.5 – Damage to the epithelium                                          |
| Turbidity            | Nausea, cramps & headache                                                   |
| TDS                  | Undesirable taste; gastrointestinal irritations                              |
| Temperature          | High temp shows the presence of the microorganism                           |

### Table 3: Parameters measured with different water samples

| Parameters   | Tap water | Water from RO |
|--------------|-----------|---------------|
| pH           | 7.9       | 7.0           |
| TDS          | 369       | 230           |
| Turbidity    | 6         | 5             |
| Water temp   | 22        | 22            |

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The table 3 shows that the RO plant installed at USPCAS-E is working very well. It reduced the pH value from 7.9 to perfect 7. Similarly, the TDS value is also reduced significantly, from 369 ppm to 230 ppm, after passing through the RO plant. Moreover, the turbidity is also reduced from 6 NTU to 5 NTU, making the tap water cleaner.

Table 4: Results of key parameters after adding contaminants (salt)

| Number of contaminants in mg | pH   | Total dissolved solids (PPM) | Turbidity (NTU) | Temperature (°C) |
|-----------------------------|------|-----------------------------|----------------|------------------|
| 5                           | 7.9  | 371                         | 5              | 22               |
| 10                          | 7.8  | 372                         | 6              | 22               |
| 15                          | 8    | 383                         | 7              | 22               |
| 20                          | 8.2  | 394                         | 8              | 22               |
| 25                          | 8.1  | 505                         | 8              | 22               |
| 30                          | 8.2  | 523                         | 8              | 22               |

Another experiment is performed to check the performance of the WQQM device. The experiment is called the salt test. The key parameters are checked in the same 100ml tap water by increasing the salt concentration gradually. The results obtained are summarized both in table 4 and figure 6.

![Fig. 5: Performance evaluation of WQQM device using the salt test](image)

The TDS value for tap water was initially 369 ppm, which increased with the increase of salt added as shown in figure 5. At 30 mg of salt in water, the TDS value

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reaches 523 ppm. The pH does not have much effect by increasing the amount of salt in the water. It increased by a fraction from 7.9 to 8.2. Similarly, the temperature also remained constant with the increase of salt in water. The turbidity affects significantly by increasing the amount of salt in the water, complementing the fact that the turbidity sensor is rightly measuring the clearness of the water.

V. Conclusions

This work proposed an inexpensive, accurate, and efficient IoT based device for monitoring real-time water quality and quantity. The proposed system used several sensors that are interfaced with Arduino Mega and Wi-Fi hardware. The system ensures long-term monitoring of water, thereby, avoiding the need for human resource. The proposed system is flexible enough to incorporate other sensors, as may require, by changing the relevant software program. The WQQM device can be used to monitor water at households, industries, and swimming pools etc. Moreover, it is an important tool for irrigation management as well.

Conflict of Interest :

No conflict of interest regarding this article

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