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Smart and cost-effective water quality monitoring system: University of Baghdad canal case study

Faik Kadim Obaid[1], Hussein Jabar Khadim[1], Asmaa A.Jawad [2]*

[1]Environmental Engineering Department/College of Engineering/University of Baghdad, Iraq.
[2]Forensic DNA Center for Research and Training, AL-Nahrain University, Baghdad, Iraq.

*Corresponding Author: Asmaa A.Jawad

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ABSTRACT: Polluted water causes diseases, affecting the ecosystem. Water quality is crucial due to high demand. Regular monitoring is essential for a consistent supply of fresh water. Internet of Things (IoT) advancements enable real-time monitoring and timely intervention for water quality issues. The current investigation evaluated a proposed smart, cost effective, high-efficacy IoT application of a water quality detection device that real-time monitors six measurement points along the University of Baghdad canal for five water quality parameters. With the Arduino platform and specific sensor properties, a low-cost monitoring system has been built. The data is shown on an LCD monitoring screen and presented on a Wi-Fi module before being transferred to the cloud and presented on a smartphone and internet platform. The results from the monitoring system for both winter and spring water quality are within the permissible limit according to standard limitations were average pH 7.687, total dissolved solid 406.75 mg/l, turbidity 25.883 NTU, and electrical conductivity 630.8 µS/cm. This framework may successfully offer an environment where there is enough water for agricultural purposes while also keeping a careful check on the contamination of water resources. On the other hand, this permits a well-managed water quality standard.

Keywords: Water quality, Sensor, Monitoring system, IoT, Arduino

1. INTRODUCTION

Water is a naturally occurring resource that is essential for human use. On Earth, there are approximately $326*10^{15}$ gallons of water. More than two-thirds of the water on Earth is frozen in ice caps and glaciers, and less than 3% of the water is freshwater. Despite being a plentiful natural resource, only 0.04% of it may be utilized [1] [2]. Freshwater sources, including ground and surface sources, are rapidly expanding due to industrial and agricultural activities, causing environmental pollutants and waste generation, making it crucial to maintain healthy and consumable water resources [3].

Globalization is causing water demand and contamination issues, necessitating attention to water quality to prevent issues arising from various activities. The method of gathering data from specified sites at frequent times to offer and collect data and special information that is used to evaluate present conditions and their trends over the short and long term is known as the Water Quality Monitoring System WQMS [4].

Water quality parameters are characterized into three categories: physical characteristics, chemical properties, and microbiological, including conductivity, turbidity, temperature, smell, and colour, and include various pollutants. Conventional methods of measuring water quality involve gathering water manually from several watershed regions, keeping samples in one place, and evaluating them in a lab [5] [6].

The primary objectives of implementing the WQMS via the Internet are to measure important variables such as chemical, physical, and biological variables to identify changes in water quality properties and to create a system of early alerts for the risks associated with an increase in these variables and their impact on the environment because they directly affect human health [7]. Novel developments in sensor technology via communications stimulate potential new findings in sensor networking. Numerous electronic devices are connected by the Internet of Things (IoT), enabling communication and data collection [8] [9]. As IoT technology develops, the water quality system becomes more

*Corresponding author: asmaa85ali@gmail.com

intelligent, using less electricity and becoming simpler to use. A real-time system for tracking critical water quality indicators can provide more rapid and precise detection of changes in water quality, enabling immediate action and improved water resource management. In addition, the technology provides immediate feedback on the water quality status by gathering and displaying data in real time. This can assist in identifying any problems before they get out of hand, enabling proactive water resource management [9].

Moreover, the WQMS framework enables data transmission to a user's PC or smartphone, therefore, it is possible to remotely check the water quality, which is particularly useful for rural or difficult-to-reach areas.

On the other hand, the project provides an inexpensive way to check the quality of the water because it makes use of inexpensive parts like sensors and a microcontroller. In addition, the system indicates that the project may be readily expanded and replicated, which qualifies it for a variety of uses. Water usage and the development of solutions to reduce it are two issues the world is now confronting [10]. In addition, remote water irrigation management may be managed during the quarantine [11].

In an earlier work, Mulyanti et al. successfully developed a sensor to gauge the ammonia levels in the pond, a metric of water quality. This technology is unreliable and useless because of the high expenses, delayed contamination detection, and lack of real-time information [6] [12].

The environmental impacts of monitoring activities on water surfaces vary across the globe and warrant increased attention. Low-cost IoT system that is capable of detecting the water quality of several sources. It comprises, Arduino and Bluetooth, in addition, to turbidity, TDS, pH, and temperature sensors. The system can controlled by a smart smartphone application, which will real-time of water sources from different sources in a rural area in Romania [13]. Drinking water quality at a Yangtze River pumping station in China was monitored using IoT technology, focusing on parameters such as dissolved oxygen, temperature, ammonia, pH, electrical conductivity, turbidity, and chemical oxygen demand [14].

An IoT-enabled wireless sensor network monitored water quality in real time at Curtin Lake, Malaysia. The system employed Zigbee wireless communication to collect data on, water level, and temperature, turbidity, carbon dioxide, and pH levels on the water's surface of the lake [15]. An IoT-based device for real-time water monitoring, developed at the University Salcedo Campus in the Philippines, measures electrical conductivity, pH, turbidity, and temperature. The device, equipped with an ESP32 for Wi-Fi and Bluetooth connectivity, has proven practical and usable during testing. It meets all specifications and can be deployed. When paired with the Water Quality Mobile Application [16].

Existing methods suffer from unreliability, slow response times, low robustness, poor efficiency, and high cost. By leveraging an efficient IoT device, many of these drawbacks can be mitigated. The aim of the study develop a design methodology for a Water Quality Management System (WQMS) tailored to the University of Baghdad's canal systems. The methodology separated hardware, software, and cost considerations .

A low-cost IoT platform measurement of water quality, temperature, pH, electrical conductivity, turbidity, and total dissolved solids has been used at the canal.

The specific object of this work is to design, implement and apply a smart and cost-effective device system to continuous real-time water quality monitoring of the water's surface in the university canal to achieve better efficiency, faster reaction, and enhanced robustness and reliability, an IoT-WQMS approach is proposed.

2. RESEARCH METHODOLOGY

2.1 Component of WQMS

Four sensors like turbidity, temperature, pH, and EC-TDS along with an Arduino microcontroller and a Wi-Fi unit (ESP8266) are commonly found in WQMS testing equipment.

The main microcontroller for the WQMS device is an Arduino Uno. The ATmega328P microprocessor board serves as its foundation. It contains a 16 MHz quartz crystal, 6 analogue inputs, 14 digital input/output pins (six of which may be used as PWM outputs), a USB port, a power connector, and a reset button. To power it up, all you have to do is connect it to a computer using a USB connection, or you may use an AC-to-DC converter or battery. Consequently, a straightforward and user-friendly platform for creating electronic projects. Considering the Arduino Uno is an open-source software platform, developers and consumers may use and alter the design files and source code for the board, making it a potent and dynamic tool [17].

Furthermore, a liquid crystal display (LCD) that can show both text and graphics is a graphical LCD with a blue backlight. Its display measures 128 by 64 pixels. Usually powered by a microprocessor, such a type of LCD needs a 5V supply voltage to operate properly. The ESP8266 Wi-Fi Module enables microcontroller access to a wireless network. To enable Wi-Fi, it may establish a connection with Arduino boards. The module features a self-calibrated RF for best performance and is cost-effective.

2.2 WQMS Sensors

A pH sensor is an instrument used to determine how acidic or alkaline a solution is; the scale of pH has a range of 0 to 14. The concentration of hydrogen $[H^+]$ ions in a given solution is indicated by the pH [18]. It may be precisely measured using a sensor that compares the potential differences between the two electrodes: a glass electrode that is sensitive to hydrogen ions and a reference electrode made of silver or silver chloride. The sensor produces an analogue signal as its output. A tool for determining a material's or solution's electrical conductivity is the EC-TDS sensor. The capacity of a substance to conduct electricity is known as electrical conductivity, and it is frequently used to calculate the amount of ions or salts that have dissolved in a solution. TDS also measures the overall concentration of salts, minerals, and other inorganic materials in a liquid.

Water quality is determined using a turbidity sensor, which measures the water's degree of cloudiness or haziness. By measuring the transmission of light and scatter rates, which vary with the total quantity of solids suspended in water, it is capable of detecting suspended particles in the liquid. There are two ways to output signals from this Arduino turbidity sensor: analogue and digital were used in a variety of applications, including water quality monitoring, environmental monitoring, and industrial process control [17] [19].

The DS18B20 temperature sensor is a single-wire device that monitors and detects temperature in multiple environments. There are several different kinds of temperature sensors, including infrared, thermistors, and thermocouples. The sensor is simple to use and only needs one data pin and a pull-up resistor to connect to the Arduino board [13]. Each category of sensors has unique features and is suitable for different applications. Figure 1 illustrates the screenshot for the above-mentioned WQMS device in which the microcontroller obtains sensor data and views water quality data through an LCD built-in system. Comprehensive detailed information on the WQMS device's components is shown in Table 1. A 3D printer may be used to create an enclosure with drilled holes for the box holding the sensors. Finally, the cost of the system is around US$125 in total.

FIGURE 1. - WQMS hardware components

2.3 Study area

The University of Baghdad is a public university located in Baghdad, the capital of Iraq. It was built in 1957, one of the oldest and most prestigious universities in Iraq. The university is organized into various faculties, including arts, science, engineering, medicine, agriculture, and education. It provides a large selection of undergraduate and graduate courses in the social sciences, natural sciences, engineering, and humanities, among other subjects. It is located in the Al-Jadriyah neighborhood, which is in the eastern part of the city, at the following coordinates: 33.3236° N, 44.3631° E. The campus is spread over a large area and includes several buildings and facilities, including classrooms, laboratories, libraries, dormitories, and sporting facilities. In addition, Baghdad University has a circular canal pumping irrigation flow directly from the Tigris River to irrigate many areas inside the university.

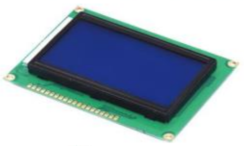
2.4 Data collection

Figure 2, displays the conceptual design of the hardware configuration for the planned WQMS application in the University of Baghdad canal. The water quality was detected and monitored by placing the sensor into the water surface of six site locations for the University of Baghdad canal to measure quality parameters. Through an LCD, the measured parameters may be displayed. Arduino features a wireless device and an integrated analog-to-digital (ADC) converter. The Wi-Fi unit creates a connection between the device, the cloud, and the Remote XY mobile application. It may also connect to the closest wireless internet hotspot to enable online browsing [10].

The Arduino microcontroller has been equipped with EC, pH, TDS, turbidity, and temperature sensors. The sensor indications are submerged in water at all locations along the university canal to be evaluated. Before reading and displaying the sensor values on the LCD and uploading the data to the cloud, the analog-to-digital converter will develop the sensor data. To be sure the sensor input data does not exceed the threshold, the data will be reviewed regularly [20].

The ThingSpeak platform is an open-source dataset for IoT analytics and data visualization, that the user interfaces (Web browsers) can display. The engineering and design stack of ThingSpeak was developed to offer our users dependable, in-the-trenches knowledge. The six sampling locations were selected in the canal to satisfy the application of WQMS in the wet (December-January) and dry (June- July) seasons for 2023. Details of WQMS sampling locations are shown in Table 2 and Figure 3.

Table 1. - Specification Hardware of the WQMS device

Hardware part		**Specifications**	**Cost**
Turbidity Sensor		. Operating voltage 5volts DC . High range temperature variation of 60–5°C. . Analog-to-digital (ADC) converter output	15 $USD
TDS/EC Sensor		. Measurement range 0-1000 ppm . Operating voltage 3-5volts DC . Module XH2.54-3P	15 $USD
pH Sensor		. Operating voltage 5volts DC . Response time less than 1 min . High range temperature variation of 60–0°C. . Measurement range 0-14, accuracy 0.1	35 $USD
Temperature		The probe is waterproof . Operating a variety of 55°–12.5°C. . It is fairly accurate, with an error of ±0.5°C.	8 $USD
Arduino		. Operating voltage 5 volts DC . 6 pins analogue input . Model ATmega328P	20 $USD
Graphical LCD		. Screen size of 128x64 pixels in width . Supply voltage of 5V to operate	15 $USD
Wi-Fi unit		. Supply voltage of 3.3V to operate . Analog-to-digital (ADC) converter output . 32-bit microcontroller	12 $USD

Accessories	5 $USD
Total Price	125 $USD

3. RESULT AND DISCUSSION

The primary WQMS components for managing a river or canal's water body, such as environmental sensors and a wireless connectivity device that transfers data from the cloud to an Arduino UNO, have been employed in this study. Sensors on the Arduino UNO were programmed using the Arduino IDE.

The user may access an electronic cloud and observe data using the Remote XY and web-browser applications. Figure 4 illustrates the dashboard with widgets for analyzing the data obtained from the cloud storage for a WQMS measurement in each location displayed on the ThingSpeak web service and the findings displayed by the mobile application.

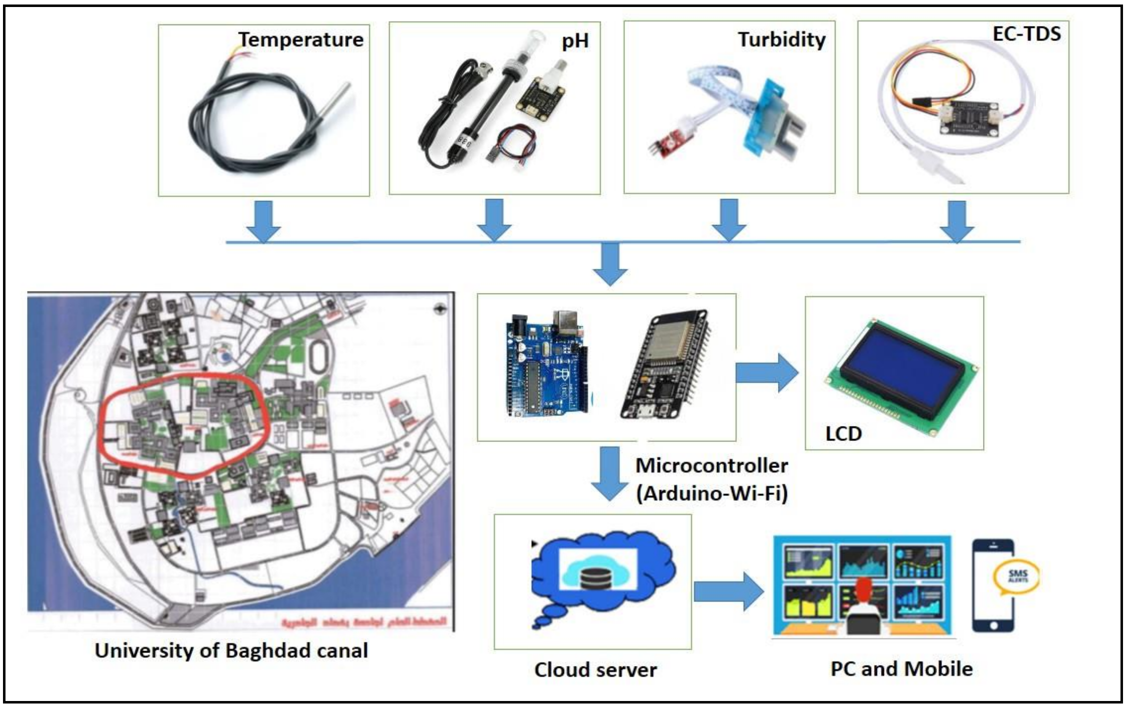


FIGURE 2. -Block diagram of water quality monitoring system for the University of Baghdad canal

The proposed device of WQMS is a smart and low-cost arrangement for investigative purposes and to determine the water quality appropriate for drinking/irrigation based on environmental allowable limitations.

Five quality constraints specifically pH, EC, turbidity, temperature and TDS used in the investigation and assessment of water quality along the University of Baghdad canal, Moreover, the results were matched with the permissible concentration recommended by the Iraqi standard. The properties of WQMS parameters that include maximum, minimum, average, standard deviation, and safe limit for the factors taken into consideration in this work are displayed in Table 2.

Table 2. - Location and description of sampling point in the University of Baghdad canal

Location	Description	Coordination
St. 1	Housing basin before pumping to the canal	33.266413 N, 44.382479 E
St. 2	Discharge point into the canal	33.276365 N, 44.376410 E
St. 3	Withdrawal point for irrigating the area at the university entrance	33.275869 N, 44.381245 E
St. 4	Withdrawal point for irrigating the area around the Central Library	33.271675 N, 44.375962 E
St. 5	Entry point to the College of Political Sciences Lake	33.271441 N, 44.376092 E
St. 6	Location before the outfall site at the Tigris River	33.266696 N, 44.379026 E

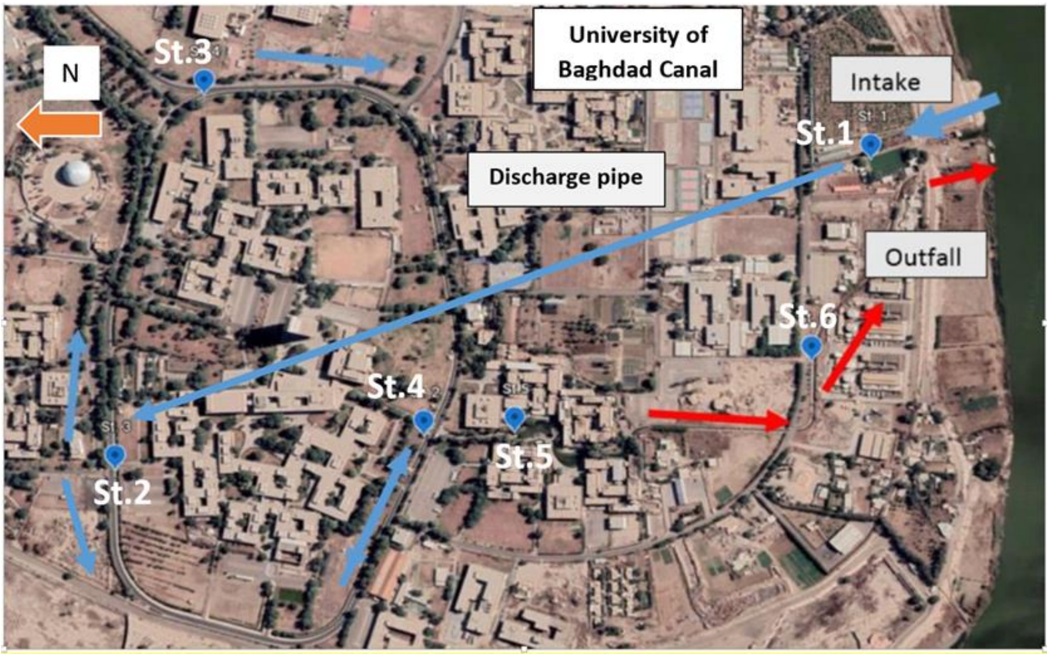


FIGURE 3. - **Location of the QWMS in the University of Baghdad canal**

There are six measuring locations along the canal, as was previously mentioned. The TDS, pH, turbidity, and EC measurement data are displayed in Figure 5. Both winter and spring water quality for pH are within the permissible limit according to standard limitations. However, it is essential to consider other water quality parameters to ensure that the water is safe and suitable for its intended use. When the concentration of carbon dioxide declines, the pH value rises. Before conducting measurement, also need to consider temperature as a component that influences the pH balance [19]. Water pH generally ranges from 7.4 to 7.8, indicating slightly alkaline conditions during the wet season. While similar during the dry season, pH values may be slightly lower at certain locations. A small canal's pH values can rise as a result of algae blooms. The pH may rise as a result of the oxygen released by growing and photosynthesizing algae. Variations in water flow, such as those that occur during periods of intense rainfall or drought, can lead to variations in pH value.

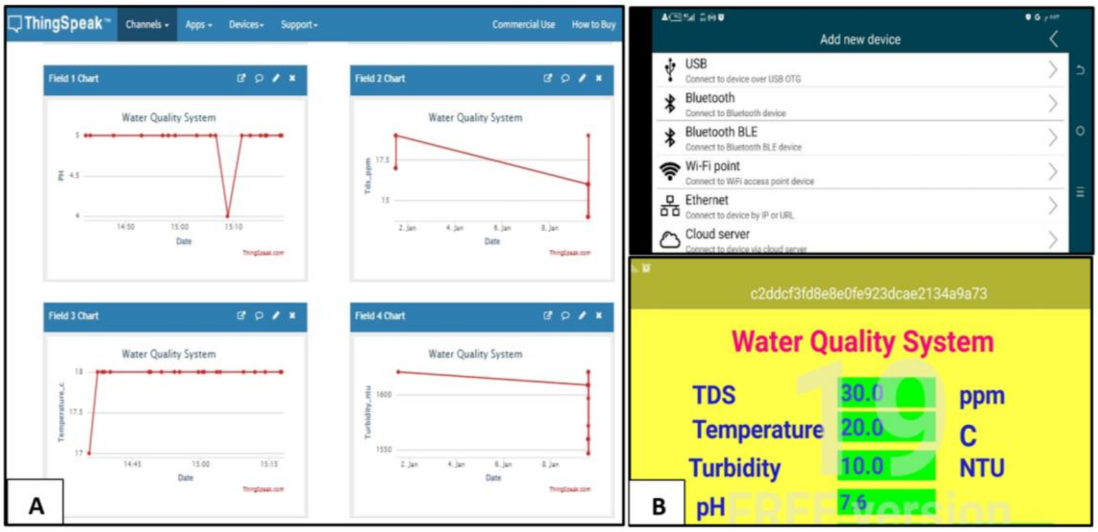


FIGURE 4. - **Result of WQMS device on (A) ThingSpeak platform; (B) API mobile application**

For TDS, based on the results provided in the Baghdad University canal, the winter water quality for TDS is within the permissible limit for all samples tested, as the maximum TDS value is 495 mg/L. The given results for the dry season of TDS indicate that all the samples tested are within the permissible limit, except the last station before canal outfall in the Tigris River the record TDS value is 510 mg/L. Although TDS levels below 500 mg/l are

generally considered safe and suitable for human and irrigation consumption, it is important to note that high TDS levels here in winter can affect the taste, odor, and overall quality of water.
The decomposition of leaves or dead plant materials can contribute to an increase in TDS values. Also, the changes in water flow and temperature (the operation system of the canal) affect the concentration of minerals in the water, which can impact the TDS value

The results of the wet and dry seasons of turbidity measurements in the canal showed a significant increase along the canal flow direction due to alga blooms increasing and suspended material deposits in the canal. The average turbidity values obtained by the monitoring system for different sites in the wet season were relatively low, and the turbidity rate was 20.5 NTU, while the turbidity in the dry season was the highest value, with an average value of 24 NTU. The results show that there are factors that contribute to increasing the turbidity value in the rainy season, such as the increase in the rate of rainfall and the high percentage of organic matter and sediment, or there are other environmental factors that led to this increase in the turbidity value in the canal.

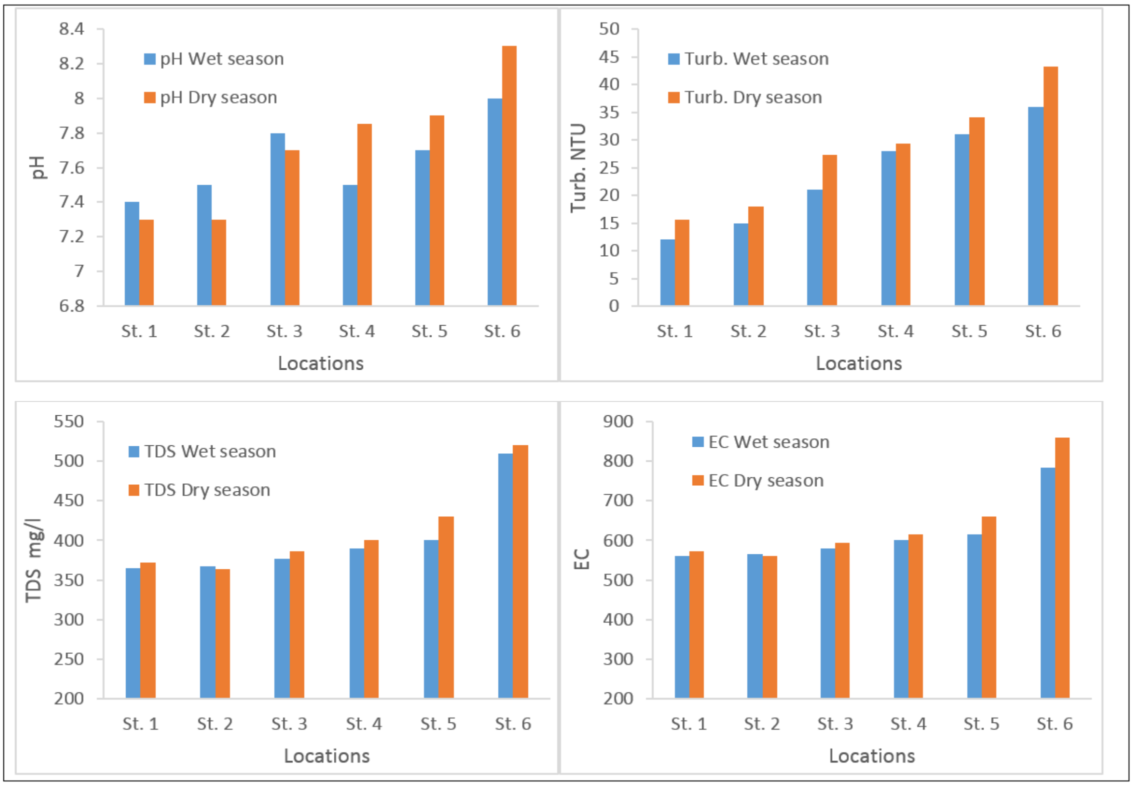


FIGURE 5. -**The results of WQMS for all locations in the University of Baghdad canal**

According to Baghdad University's winter electrical conductivity measurements, the average electrical conductivity (EC) value was 644 µS/cm with a range of 569 and 785 µS/cm. In the dry season, the EC values vary between 572 to 860 µS/cm, with an average of 618 µS/cm. The last station St.6 had the highest value in all seasons. Compared to wet, the EC levels in the canal during dry were slightly higher, but still less than the allowable limit of 1000 for irrigation purposes [21] [22].

The increase in EC levels in both winter and spring may be attributed to various factors such as organic matter decomposition, and a lot of organic matter in the canal, such as leaves or dead plants, the decomposition of these materials can contribute to an increase in EC values. When the water level and flow velocity were at their lowest during the hottest part of the dry season. Furthermore, the changes in water flow and temperature due to the canal operation system affect the concentration of minerals in the water, which can impact EC levels. Contains high levels of dissolved salts and minerals, which can increase the EC levels in the water. When the water level and flow velocity were at their lowest during the hottest part of the dry season. Finally, the temperature varied from 11.4°C to 31°C throughout the sampling across various seasons, and these values appeared to follow almost similar seasonal cycles as shown in Table 3.

Table 3. -The WQMS of the University of Baghdad Canal results

Parameter	Max	Min	Average	SD	Iraq Standard
pH	8.3	7.9	7.687	0.1	**6.5-8.5**
TDS mg/L	520	421	406.75	23.1	**500**
Temp C°	31	11.4	24	2.3	**-**
Turbidity NTU	43.2	12	25.883	3.6	**50**
EC µS/cm	860	562	630.8	35.5	**1000**

Measured parameters show increasing values from St. 1 to St. 6, indicating cumulative pollution or other factors. Leaf and plant decomposition, along with changes in water flow and temperature, contribute to the accumulation of minerals and pollutants in the canal. On the other hand, Turbidity, TDS, and EC exhibit seasonal variations, with higher TDS and EC levels during the dry season and higher turbidity during the wet season. Water quality declines downstream, particularly at St. 6 near the Tigris River outfall, indicating the accumulation of pollutants. Continuous monitoring and management of irrigation water quality are crucial, especially given seasonal variations and the increasing pollution levels in the canal. In conclusion of the results, the WQMS device enables secure, long-term monitoring of canal water quality data through the Internet. Observed values are viewed on a smartphone app, and control is managed through the ThingSpeak web server. The results of this study have been positive for the water surface canal system.

3.1 Limitation and future recommendation of WQMS

A lack of information exists on the low-cost sensors' accuracy, durability, precision, calibration process, and dependability that are required for certain applications. The majority of the research makes use of commercial sensors, which the producers state are appropriate for use in homes, laboratories, and education. To make sure the sensor satisfies the needs for data quality in the intended application, users should carefully assess the sensor's capabilities and limits. Inexpensive sensors, though appealing due to their low cost, may not always provide the precision, consistency, and reliability needed for particular applications. For future research, we propose long-term studies comparing multiple low-cost sensors. Additionally, research is needed to develop a calibration protocol for water sensors that meets environmental application requirements. Finally, we recommend the development of new low-cost sensors, particularly for chloride, metals, and BOD.

4. CONCLUSION

Finding methods and technology to reduce water use is one of the issues the world is now experiencing. Furthermore, during the quarantine, remote water irrigation management may be managed. The WQMS was created for this project to offer a straightforward and efficient way to monitor important water quality indicators like pH, temperature, EC turbidity, and TDS.

Real-time water quality parameter monitoring is made possible by the combination of a microcontroller and wireless unit, which also makes it simple to transfer data via the cloud to a user's computer or smartphone. Although the project's breadth, precision, and durability may be limited, the system has numerous potential uses in a variety of contexts, including industrial operations, agricultural settings, natural water systems, and commercial and residential structures. Lastly, modifications to the testing schedule and environment are possible. More experiment locations and regular data collection should yield much-needed extra information and accuracy in assessing the health of the canal or river and verifying the WQMS.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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