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Water Quality Detection Using Cost-effective Sensors Based on IoT

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Abstract Polluted water may cause a variety of diseases in humans and animals, affecting the ecosystem's life cycle. Owing to the great worldwide demand for water, the examination of water quality must be put into consideration. To ensure a constant supply of fresh water, this quality must be checked regularly. With an up-to-date advancement in communications, sensors, and IoT technologies, the whole problems accompanied by monitoring water deterioration have already been tackled. In the present work, a proposed smart and low-cost, high-efficiency IoT appliance water quality detected device that continuously checks for pH, TDS, temperature, and turbidity water quality parameters. Forty tests of water samples were collected from four groups of different sources were used to evaluate the created model for water sample that is safe for drinking and Water Quality Index classified as drinking purpose. The framework's Wi-Fi module sends data from the sensors to the Arduino, which then sends the data to the cloud and displays it on a mobile/webpage application. This framework can maintain a close eye on water asset pollution and can provide a successful scenario for suitable drinking water or not using a WQI analysis of the water sample. In contrast, this allows for a water quality standard that is well regulated.

Keywords: Water quality index; Drinking water; Sensors; IoT; Arduino.

1 Introduction

The consumption of fresh and/or potable water produced from several human activities such as industrial, commercial, and agricultural ones render this source of water of great importance. The water supply units have now encountered inevitable concerns [1, 2]. Due to the vast growth rate in the world population concomitant with the shortage of supplying water, a consequent water deterioration is imminent [3, 4]. Whether directly or indirectly, the illegal disposal of wastewater into the water bodies, industrialization producing toxic chemicals, groundwater pollution, etc., have all contributed to the water quality decline [5]. As a result, unexpected consequences have already arisen in human mortality through water-borne diseases. Generally, to overcome such probable consequences, the need to qualify water is of great necessity through modern criteria and grab sample analyses conducted in the most reliable laboratories [6].

Monitoring and detecting water quality is defined as the process of collecting information from specific locations and at specific or regular intervals to provide and compile information and special data that can be used to determine current conditions and their trends in the short and long term [7].

The primary goals of determining and monitoring water quality via the Internet include measuring important variables such as physical, chemical, and biological parameters to determine changes in these properties and determinants, as well as developing an early warning system for the risks resulting from the increase of these variables and their impact on the environment due to their direct impact on human health [8]

One of the simplest methods of measuring the indexes of the water quality is the WQI which enables us to monitor water quality changes and detect water trends [9]. New sensor technological advancements through telecommunications are provoked at which modern discoveries in the field of sensor networking are promising. The internet of things connects a variety of devices,

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allowing them to interact and gather data [10-12].

This study aimed to describe and use the IoT platform to create a smart and inexpensive system for water quality examination. The bio and physicochemical characteristics including temperature (T), turbidity (Tur.), total dissolved solids (TDS), and hydrogen potential (pH) of several water samples are monitored using four separate sensors connected to an Arduino Uno microcontroller were data presented on ThingSpeak platform and Mobile application used in measuring water samples whether they are safe or harmful for drinking purposes for those who live in outskirt area that hardly uses the WQI test appliances in Iraq.

2 Martial and Methods

The water quality examination kit is generally composed of temperature, turbidity, pH, and total dissolved solids sensors as well as the Wi-Fi module (ESP8266) to transmit data and microcontroller. **Fig. 1** illustrates the schematic diagram for the aforementioned kit in which the core controller receives any of the four input sensor data represented by the turbidity, pH, TDS, and temperature and displays them via an LCD system. The core controller usually compares the received data with stored standard values.

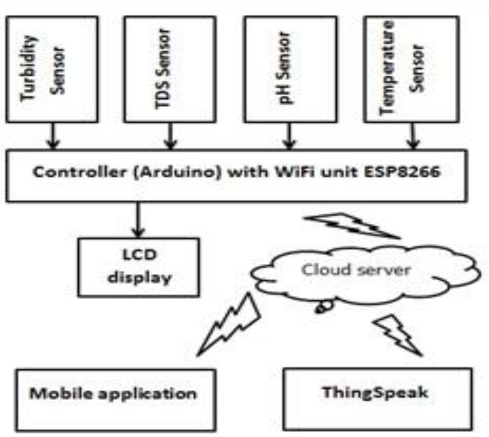

Fig. 1 Schematic diagram of water quality detected device

The schematic circuit diagram of the hardware arrangement of the proposed work of the water quality system is shown in **Fig. 2**. The hardware consists of key parameters monitored sensors that help to measure the real-time values were turbidity, total dissolved solids, pH, and temperature. Each sensor includes three wires of various colours, including black, red, and others. The red lines are for the +5V power supply, the black wires for the ground, and the others are for data estimate. Sensors are directly interfaced to the Arduino Uno microcontroller since the proposed water quality detected system. The sensor parameters are measured by placing the sensor into different water sample sources to identify and classify water for drinking uses. The measured parameters can be displayed by using LCD. Arduino has a built-in analogue to digital (ADC) converter and Wi-Fi modules. The Wi-Fi module establishes a link between the hardware, the cloud, and the mobile application, which may be linked to the nearest Wi-Fi hotspot for web access. The smart and cost-effective device for measuring water quality was assembled in the Sanitary Engineering Laboratory at the University of Baghdad to conduct tests for all water samples to determine their compliance with drinking water standards and specifications. **Table 1** represents the comprehensive details of the components of the device. It is possible to use a 3D printer to make an enclosure with holes drilled for the device. The total price of this device was about 120 USD.

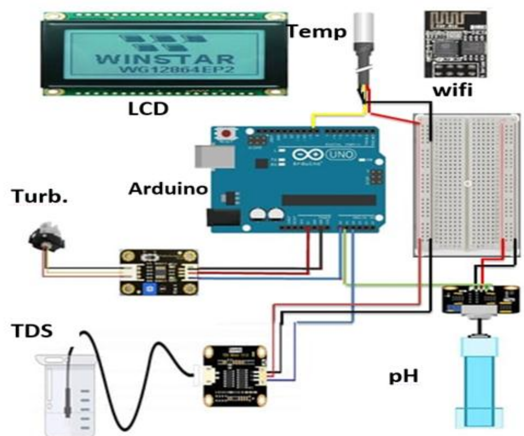

Fig. 2 Schematic diagram of the hardware arrangement for the water quality detection device

The water quality system is growing smarter as IoT technology progresses, reducing power usage and making it easier to operate. The smart water quality monitoring system's working flow chart is shown in **Fig. 3**.

The microcontroller is equipped with a pH sensor, a TDS sensor, a turbidity sensor, a temperature sensor, and other sensors. To be tested, the sensor leads are immersed in water. The ADC converter will process the sensor values before reading them and uploading them to the cloud. The readings will be checked regularly to ensure a basis to see if the sensor input value exceeds the threshold one and thus notifying and instructing the end-user on what might be carried out then after. Once the input value is less than threshold one, the aforementioned four parameters should be tested again for a new water source.

ThingSpeak is an IoT data visualization and analytics open-source platform, Also describes a simple and affordable way to incorporate the IoT's power into your business or research. ThingSpeak's design and engineering stack were created to provide our users with reliable, white-glove expertise. Device-friendly APIs (accessible via HTTP/TCP/MQTT/UDP protocols) make it simple and secure to send and retrieve data in real-time to and from our cloud service [13].

Table1: Hardware specification of the smart and cost-effective device system

No.	Hardware type	Main Characteristics	Cost
1	pH sensor E201-C-9	Probe connector: - Measurement range (1-14) - Temperature range (0-80 °C) - Response time (≤5 Sec)	30 USD
2	Temperature sensor DS18B20	Waterproof Digital Thermal Probe - Operating range (-55°- 125 °C) - Fairly precise (±0.5 °C)	3 USD
3	TDS sensor	Probe connector: - Measurement range (0 ~1000ppm) - Measurement accuracy (± 10%) - Temperature range (0-40 °C)	20 USD
4	Turbidity sensor	Probe connector: - Response time: < 500 ms - Operating temperature (-30-80°C).	20 USD
5	Arduino Uno R3	Microcontroller board based on the ATmega328P	10 USD
6	LCD	Graphical LCD 128x64 Blue Backlight 5V	12 USD
7	Wi-Fi module ESP8266	Connect microcontroller projects to a Wi-Fi network -Integrated TCP/IP protocol stack -Input power3.3V	5 USD
8	Accessories	Breadboard + Box + Jumper Wires	15 USD

Thingspeak feature is used for the proposed work to obtain water quality data sent from the controller in a real-time dashboard to analyze data or control devices and share the data over public links also allows for logging, social network status updates, location tracking, and others [14]. Thingspeak shows the data in real-time useful for displaying water quality data for each sample test. In the end, the Numero Index [15] was implemented to estimate the water quality as to whether being drinkable or not, making use of the WQI determination which is dependent upon the environmental permissible for drinking water adopted by WHO [16] were mentioned in **Tab. 2**.

Table 1 Maximum Permissible Concentration for each parameter of water quality detection device

No.	Parameter	Maximum Permissible Concentration
1	pH	6.5-8.5
2	Temperature	10-22 °C
3	TDS	500 ppm
4	Turbidity	5.0 NTU

When the WQI value is less than 1, the water sample is drinkable. On the other hand, WQI, greater than 1.0 indicates the presence of impurities in the water, necessitating treatment before usage. Therefore, a WQI value between (1-5), the water quality classified as less polluted, and between (5-10) is considered moderately polluted, but if it exceeds 10, it represents polluted and not drinking water. WQI is calculated and read on LCD, stored in the cloud, and displayed on the ThingSpeak platform, finally, using a mobile application, notifications will be transmitted to the appropriate authorities.

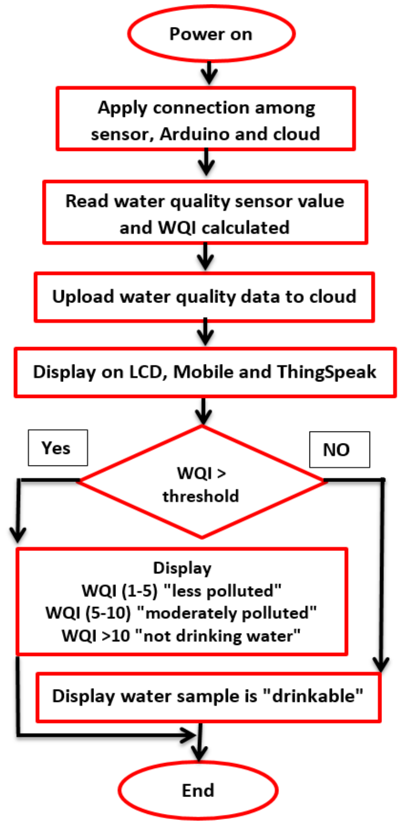

Fig. 3 Flowchart of water quality detection device

3 Results and Discussion

Owing to the shortage in drinking water resources in different regions of Iraq, as well as the overpopulation as well as the decrease in the water quantity of the main rivers, this has led to a significant deterioration in the quality of water available to people. The proposed smart inexpensive system for examining and determining the water quality suitable for drinking and classifying it based on the WQI and environmental permissible level. Four parameters namely TDS, pH, temperature and turbidity, are analyzed using the investigational setup. The proposed setup of water quality results as seen from the mobile application and ThingSpeak platform was an IoT data collection application for analysis of the sensors. Furthermore, results are compared with the maximum allowable concentration of different quality criteria recommended by the WHO for safe drinking water were considered in the present work if the water quality measurement of each sensor of the selected parameters is less than the maximum allowable concentration, then the sample as water would be safe for drinking and WQI classified it as drinking water. If these parameters are higher than the specified maximum allowable concentration, then the water sample is ineligible for drinking purposes and WQI is classified as polluted water.

Dashboard including widgets used to examine the outcomes of data collected from the stored cloud for a water quality sample in the ThingSpeak platform was shown in **Fig. 4** for Turbidity measure value with NTU units Fig. 4 A, TDS measure value with ppm units Fig. 4 B, pH value Fig. 4 C, temperature measure value with °C units Fig. 4 D, beside WQI calculated value Fig. 4 E.

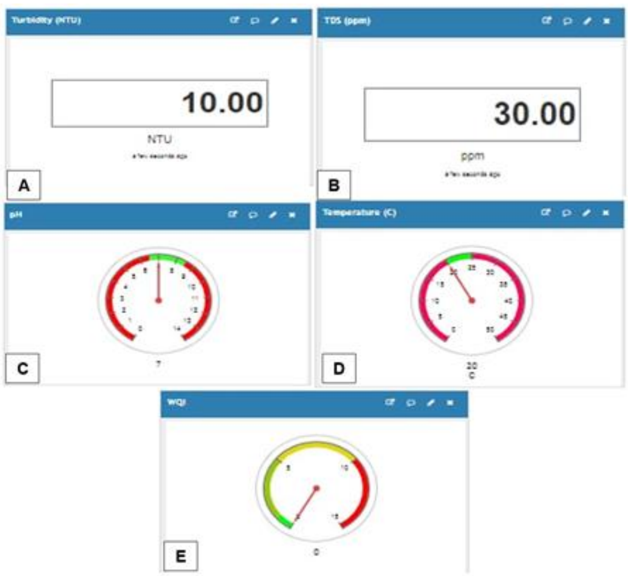

Fig. 4 Result of water quality detected device on ThingSpeak platform A. Turbidity value B. TDS value C. pH value D. Temperature E. WQI value

On the other hand, the mobile application displays the results of data collected for a water quality sample illustrates in **Fig. 5**.

Fig. 5 Result of water quality detected device on mobile application

Results of the water quality detecting device are tested with four different water samples collected from different water sources namely, the T1 group of samples were collected from bottled drinking water available at local stores, T2 samples were collected from a different location in the drinking water supply network in the city of Baghdad, T3 samples were taken from the Tigris River in the city of Baghdad and T4 group of samples obtained from wastewater. All the four group samples which are used to quantify the pH, TDS, and turbidity for each test are shown in the bar chart presented in **Fig. 6** A for the average turbidity measure value, **Fig. 6** B for the average pH value, and **Fig. 6** C for the average TDS measure value compared with the general rule adopted for each water quality parameter recommended by WHO.

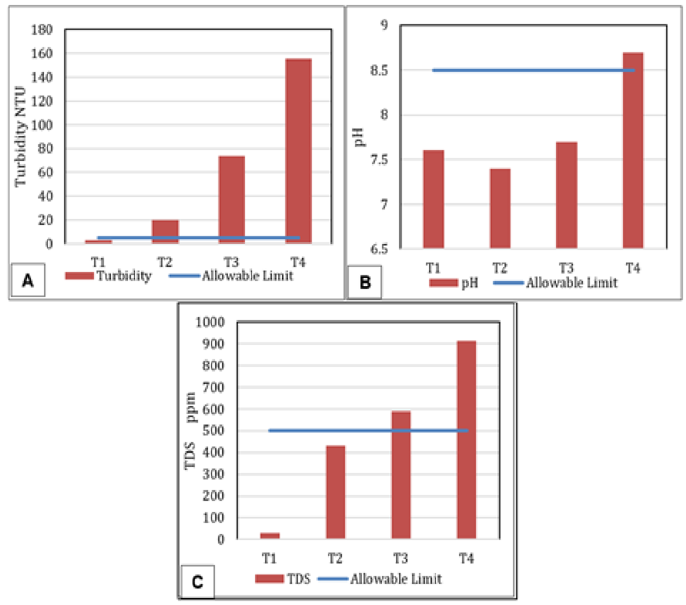

Fig.6 Result of various water sources compared with environmental limitation for A. Turbidity value B. pH value C. TDS value

The descriptive statistics of the physicochemical analysis of 10 water samples for each group are summarized in **Tab. 3**. A WQI formulation has been applied to the pH, TDS, and turbidity analysis of four groups of samples collected from different sources in the Baghdad city area to evaluate the drinking suitability and classification. The descriptive statistics of the parameters are provided in **Tab. 3**. The current quality index is based on the permissible and threshold levels of turbidity, pH, and TDS as defined by the WHO specification. The maximum, minimum, average, and standard deviation characteristics of water quality parameters in the present study of WQI are illustrated in **Tab 3**. Depending on the WQI calculation in the cloud, the WQI values swerve from 0.639 to 0.814, with an average value of 0.74 for the bottled water sample (T1 group), and 1.178 to 2.619, with an average value of 1.66 for the drinking water supply produced from the pipeline system sample (T2 group). The WQI value of water samples collected from the river varied from 7.72 to 2.77, with an average value of 4.53 (T3 group), and 10.25 to 5.32, with an average value of 8.78 for the wastewater samples (T4 group).

Table 3 Maximum, minimum, average, and standard deviation characteristics of water quality parameters and WQI samples

Sample No.	Parameter	Max.	Min.	Avg.	SD	Allowable level
T1 group	pH	7.7	6.8	7.56	0.291	6.5-8.5
	Tur.	5.1	1.2	3.2	1.487	5
	TDS	67	21	39	16.81	500
	WQI	0.814	0.639	0.74	0.068	0-1
T2 group	pH	7.9	7	7.36	0.32	6.5-8.5
	Tur.	41	12	22.8	10.96	5
	TDS	580	310	430	104	500
	WQI	2.619	1.178	1.66	0.507	0-1
T3 group	pH	8	7.3	7.67	0.226	6.5-8.5
	Tur.	140	41	74	28.71	5
	TDS	653	500	589	50	500
	WQI	7.72	2.77	4.53	1.435	0-1
T4 group	pH	9	7.9	8.66	0.309	6.5-8.5
	Tur.	189	90	155	26.58	5
	TDS	1160	804	912	125.47	500
	WQI	10.25	5.32	8.78	1.327	0-1

Table 4 illustrates that only bottled samples (T1) are excellent for drinking, and 90% of the samples collected from the local network of drinking water (T2) fall into the slightly polluted category due to a decrease in the efficiency of drinking water treatment plants, as well as the age and fractures in the old drinking water distribution network. In addition, 60% of the river samples (T3) are marginally suitable for drinking and may be used for drinking after some primary treatments.

Table 4 Classification of water samples based on WQI.

WQI	Class	No. Samples			
		T1	T2	T3	T4
0-1	Drinkable	10	1		
1-5	Slight polluted		9	6	
5-10	Moderate polluted			4	8
>10	Not Drinking				2

The WQI value between 5 and 10 indicates that water quality was influenced by anthropogenic activities, which limits its applicability for drinking. Eighty per cent of the wastewater samples (T4) have values between 5 and 10, mainly ascribed to high pollution caused by domestic activities. In contrast, 20% of the samples are collected in the periphery of domestic and industrial activity areas, which have the highest WQI value, more than 10, mainly influenced by the extreme concentration of dissolved solids. All of these parameters have concentrations far exceeding the adapted WHO permissible limits, graphical representations of WQI are shown in **Fig. 7**

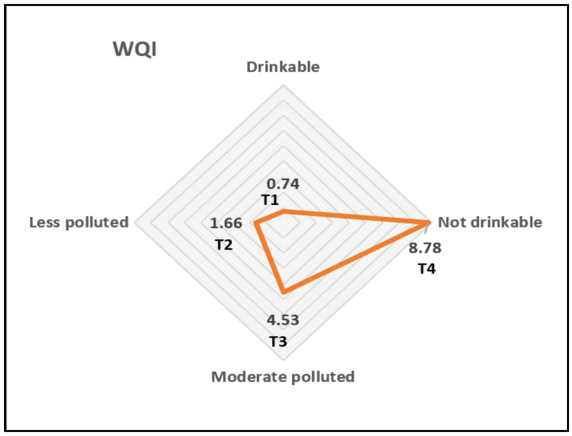

Fig. 7 Result of various water sources classified depend on WQI

4 Conclusion

Water pollution has become a serious concern in every country since it harms health, the economy, and wildlife. The causes and impacts of water pollution are discussed in this paper. Despite the existence of several outstanding smart water quality monitoring devices, the study topic remains a challenge. This article compares and contrasts real-world applications of water quality sensor wireless sensors. Many sensors, on the other hand, maybe purchased commercially on the website. The majority of them are expensive, and there is a demand for low-cost, easy-to-assemble sensors. The proposal and implementation of low-cost sensors for environmental monitoring applications for the drinking water quality index are discussed in this work. For this objective, a low-cost alternative sensor mote for drinking applications has been designed utilizing the Arduino platform and four distinct sensors (pH, TDS, turbidity, and temperature) characteristics were data presented on the ThingSpeak platform and Mobile application that were used to determine if the tested water samples are safe or harmful to drinking purpose. Forty tests of water samples were collected from four groups of different sources to support the achievement and application of this smart, low-cost system were examined, and findings determine whether the water is drinkable or not, based on WHO guidelines and WQI classified procedure. It is recommended that new sensors must be used to detect different quality parameters.

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