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Design and development of Smart Water Quality Monitoring System Using IoT

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ABSTRACT

As water is one of the basic needs of human beings, shortage of water we cannot live on. Water pollution and scarcity, are current global problems that require modification ofwater resources, and guiding principles from the international level to individual wells. Water pollution is the leading cause of diseases worldwide. Previously, water quality monitoring was done through a physical collection of data; there was no smart sensor system. This led to inefficiency, especially, in real-time data access, device monitoring, and less accurate collection of data. There is a need to integrate mechanism to monitor water quality in real-time, to ensure a safe supply of drinking water. Hence, the idea of Internet of Things (IoT) which allows connections between various devices that can exchange and gather data emerged. To solve these issues, a low-cost real-time that is a real-time platform based on the Internet of Things (IoT), and LoRa (Long Range) technology is proposed for monitoring water quality. The platform will measure and collect critical information about water quality. Such quality involves parameters like pH value, the turbidity, and temperature of the surrounding atmosphere. The platform will additionally establish communication to the end-user, through LoRa Gateway and the internet. It will simultaneously provide data access, accurate data collection, and supervision of the component, whereby the user will notice if the virtual deviceis not receiving any data at a given time interval. The developed platform will consist of five different parts: sensor devices, IoT Board, Lora Gateway, cloud server, and user domain.
The Lora Getaway will transmit the sensor data to the cloud through the internet to the cloud server. The cloud server is equipped with Matlab analysis and visualisation application which manipulate and analyse the data, to monitor the quality of the water. In the end, the useful information is visualised from the user domain for any decision-making process. The paper argues that the proposed platform is important in ensuring a safe supply of quality drinking water for people worldwide.

Key Words: *pH sensor, Turbidity sensor, Temperature sensor, LoRa Gateway, Cloud server, IoT.*

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1. INTRODUCTION

Water is a very crucial part of life. Without water, we cannot live. Around 71% of the Earth's surface is covered with water-; 96.5% of water is in the sea, and 3% of water is fresh. As only 3% of water is fresh, the provision of clean and safe drinking water is one of the new real-world challenges Shafi et al., Siregar et al.[1-2]. Reports show that by 2017 at least 2.3 billion people worldwide, do not have guaranteed access to drinking water (WHO,) [3].
Due to the limited drinking water resources, and the growing population, the availability ofquality drinking water has significantly worsened Chen & Han,[4], Meng et al.,[5].

Currently, water pollution increased due to the fast-growing population. In that situation, water quality monitoring in real-time faces challenges because of global warming and limitedwater resources. It is, therefore, important to search for a solution for water quality monitoringand a control system.

Hence, there is a need of developing better methodologies to monitor the water quality parameters in real-time. The water quality parameters, such as pH, measure the concentration of hydrogen ions. It shows if the water is acidic or alkaline. The range of pH is 0-14 pH. Pure water has a 7pH value, which means that if the water has less than 7pH then it is acidic. On theother hand, if the water has more than 7pH then it is alkaline. For drinking purposes, the pH should be 6.5-8.5. Meanwhile, turbidity measures a large number of suspended invisible particles in water. The higher the turbidity the higher the risk of diarrhea, cholera to the consumers of the water. On the contrary, the lower the turbidity the clean the water. Besides, temperature sensor measures coldness or hotness of water.

The traditional methods of water quality monitor involved the manual collection of water samples from different locations. Therefore, the Internet of Things (IoT) is a revolutionary newconcept that can turn virtually anything "smart". A 'Thing' in this context, is defined as an object such as a cardiac monitor to a temperature sensor. This extraordinary technology has captured the attention of millions. Why is this so big today? So, imagine a world where machines function without any notion of human interaction. A future where machines communicate with other machines and make decisions based on the data collected andindependent of an end-user. IoT is a technology that uses the collection devices that work together (described as the network of devices) communicate among themselves with the help of a controller. It has the power to send the data of the surrounding environment. These devices are sensors, embedded systems, and microchips for data analysis.

This research proposes to monitor water quality through collecting critical information, and establishing communication to the end-user using LoRa Gateway and the internet. The platform will simultaneously provide data access, accurate data collection, and supervision ofthe component, whereby the user will be able to notice if the virtual device is not receiving anydata at a given time interval. The platform will consist of five different parts: sensor devices, IoT Board, LoRa Gateway, cloud server, and user domain. The Lora wireless data transmissionwill be used to transmit the sensor data to the cloud server through the internet. The cloud server is equipped with Matlab analysis and visualisation application that can manipulate and analyse data to monitor the quality of the water. The web-based user interface makes user interact the content that stored on cloud servers via web browsers.

This research is set some sensors that measure the water quality. For water quality analysis, many parameters are required.

The list of sensors that are mainly used to measure water quality are shown in Table 1 below. In this research, we have used temperature, pH as well as turbidity sensors to measure the respective parameters.

Table 1: Description of water quality sensors

Name of sensors	Description of the sensors
Temperature sensor	Measure temperature of its environment.
pH sensor	Determines the acidic or basic of the water.
Turbidity sensor	Determines the number of solid particles.
Conductivity sensor	It is Indicates the number of dissolved ions existing in the water.
Dissolved oxygen sensor	This varies as per temperature, Measure theamount of dissolved oxygen in the water.
Conductivity sensor	Determines ionic strength in water.
Humidity	Measure humidity of its surrounding

Table 2: Water quality parameters proposed by WHO and South Africa, DWA [6].

S/N	Parameter	Quality Range	Units
1	pH	6.5–8.5	pH
2	Electrical Conductivity	500–1000	µS/cm
3	Turbidity	0–5	NTU
4	ORP	650–800	mV
5	Temperature	–	^{o}C

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6	Free Residual Chlorine	0.2–2	mg/L
7	Dissolved Oxygen	–	mg/L
8	Nitrates	<10	mg/L

The rest of this paper is organised as follows: -

Section II discusses the theoretical background, Section III, shows objectives of the research, and Section IV shows the methodology. Section V highlights the Proposed system while Section VI indicates the experimental results and discussion and finally, Section V concludes the research and presents directions for future work.

2. THEORETICAL BACKGROUND

The quickly growing population has resulted in the deficiency of water and reduction of water quality. People have had increased awareness in recent years and put effort into water cleanliness manually, but sensing technological advancement plays a big role in monitoring water quality remotely. The Wireless Sensor Network (WSN) is one of the technologies used to transmit data coming from sensors for analysis purposes. Our research used WSN to measure the water quality parameters like temperature, pH, and turbidity using different sensors.

This section reviews other states of art related to this research. narrowly. Weaknesses, as well as strengths of the reviewed works are also shown:

K. Murphy et al.[7], collected data of water quality parameters from sensors to a remote server using a GPRS network order to enable the end-users view the data remotely. However, unfortunately, one of the nodes failed to work, and the course path of data transmission was lost. Satyam et al., [8] on the other hand, proposed the smartphone-based water quality analysis in which a water impurity warning would be sent to the users via social network sites.In this research, they proposed a handheld embedded system by connecting mobile applications via a Bluetooth model. One of the challenges they face is the power consumption in Bluetooth-based localisation. Additionally, MarcoTeránet et al [9] also, showed that a Bluetooth is alow energy technology.

Zulhani Rasin et al.[10] used Zigbee protocol based on Wireless Sensor Network for water quality monitoring system. They connected Zigbee ZMN2405Hp module to measure thequality of water. The challenge of this research is that the researchers implemented high-powerZigbee in their system for small area networks, therefore, there is a necessity for having data stored in the base station. Azure cloud platform based on water quality monitoring system that uses NodeMCU microcontroller implemented by Nikhil et al. [11]. The system collected data from sensors. However, their analysis used Jason format.

Nazleeni Samiha Haron et al. [12], proposed a remote water quality monitoring system using wireless sensors for the eradication of cost-consuming works of manual monitoring. They implemented a GSM modem. The limitation of this system is that it is not suitable for long- distance.

Another method was the use of Ubidots, a cloud-based platform - to store the information received from the mobile sensors Jaime Alonso et al. [13]. The challenge of performance is that the IoT-based communication progressively decreases the movement from one layer toanother in the IoT network to reach the cloud platform.

A portable smart sensing prototype integrated LoRa activity was developed by Fowzia et al, [14] to surveil water quality and get results. But a machine learning algorithm is the one that trains the system to determine the temperature, as well as pH level in all water samples. Inour research, we analysised the cloud server to emission the time complexity of machine learning heavy algorithm. Analyzing their proposed system Mohamed Alshehri et al, [15] gathered data to provide the maximum efficient approach for water desalination operations. Additionally, Purkayastha et al, [16] showed an App developed on the Android platform to visualise real-time sensor data that are uploaded in the designed web server and displayed sensor data on the android mobile.

The sensors data processed by the MCU and updated to the ThingSpeak server Daigavane & Gaikwad,[17] employing the Wi-Fi data communication module ESP8266 (NodeMCU) to the cloud server. As declared by S. K.M. & S. R. M.S,[18] the existing water quality monitoring systems mainly use wireless technologies that are short-range and consume much power, which is not suitable for sensors nodes in WSN. Nevertheless.

From the above benchmarks we see that WiFi, Zigbee, and BLE have limited range, than theproposed prototype which has a low cost and long-range for communication and scalable approach. Water quality monitoring using LoRa module is

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more efficient than previous existingsystems. In this case, this research will provide new insights on a blue economy era by insuringan excellent quality of water in promoting tourist activities.

3. OBJECTIVES OF THE RESEARCH

Main objective

The objective of this research is to Design and development of Smart Water Quality Monitoring System using IoT.

Specific objectives are to:

1. Design the system that will be sensing in time water quality on various water parametersin terms of pH, Turbidity, and Temperature for domestic use.

2. Develop programming code that will be controlling the sensors.
3. Analyse data in the cloud using IoT.

4. METHODOLOGY

In this proposed system, the complexity reduces, and the performance increases by collecting the data of the water parameters like pH, turbidity, and temperature. The information collected is updated on the cloud that can be retrieved from anywhere in the world.

The pH of a solution is the measure of the acidity or alkalinity of that solution. The pH scale isa logarithmic scale whose range is 0 - 14, with a neutral point being seven (7). Values above seven (7) indicate a basic or alkaline solution, while values below seven (7) indicate an acidicsolution. The system operates on a 5V power supply, and it is easy to interface with an IoT board. The normal range of pH is 6 to 8.5. To calculate the pH of an aqueous solution, you needto know the concentration of the hydronium ion in moles per litre (molarity). The pH calculated using the expression: pH = - log [$H3O^+$].

Figure 1: LoRa Gateway and nodes used to deploy our network

4.1. **Hardware**pH sensor

The pH value alone does not guarantee the good quality of water, so we have considered other parameters such as temperature and turbidity.

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Figure 2: pH sensor

Turbidity sensor

Turbidity is a measure of the cloudiness of water. Turbidity indicates the degree to which the water loses its transparency. A good measure of the quality of water is considered. Turbidityblocks out the light needed by submerged aquatic vegetation. It can also raise surface water temperatures above normal because suspended particles near the surface facilitate the

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absorption of heat from sunlight. Unsafe considered if the turbidity is above five (5) NTU. If water has much mud, then it will rise up to one hundred (100) NTU. The sensor produces bothdigital and analogue mode output Shafi et al.,[1].

Figure 3: Turbidity sensor

Temperature sensor

Temperature decides the quality of water. Water Temperature indicates how hot or cold the water is. The range of a DS18B20 temperature sensor is -55 to +125. This temperature sensoris a digital type that gives an accurate reading. The temperature range from 10-15 o C is safe for drinking.

Figure 4: Temperature sensor

Lora

Lora is a physical layer proprietary scheme for LPWAN for communication technology. It is primarily based on a spread spectrum that trades bandwidth for S/N. It achieves long-range wireless data transmission that deep indoor penetration. It also uses linearly varying frequencypulses, chips, that are motivated by radar signals. It has a high capacity of a communications channel. According to the device specifications, coverage reaches up to 10 km without any obstacles.

Figure 5: LoRa Outdoor Gateway RAK7249

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IoT board

The IoT board is a kit and board that combine a microcontroller and processors that have wireless chips and other components like ADC, RTC (Real-time clock) that all pre-built with wireless chips. LoRa network deployment does not require the backing of operators. LoRa is healthier for scenarios that require a low budget, longer battery life, as well as less frequent communications Jia, Y, [19].

The capacity of a communication channel

LoRa uses CMSST technology to transfer wireless signals in wide signal bandwidth.

It has lower power and stretched distance communication. To improve the performance of devices and accommodate aggregate demands of battery-worked devices, it is prodigious to analyse all these frequencies Utkarsh et al. [20].

In that case, we dedicate the capacity of communication channels in accordance to our MSCM, From Shannon's formula then we dedicate a bit per second to every MSCM.

$$C = B * \log 2\left\{1 + \left[\frac{S}{N_0} * B\right]\Big|1\right\}/N_t$$

Capacity ,bit-per second   Total Number of MSCM (dedicated)

B->Bandwidth , S->Received signal power , No->Noise power density

Now every MSCM base station with *n* number of the sensor has their capacity for their communication channel depending on the effectiveness of transmitted power, data rate, and interference and receiver sensitivity.

4.2 Software

ThingSpeak server

ThingSpeak is an IoT data collection application for the analysis of various sensors, e.g. pH,turbidity, and temperature. The data collector collects data from edge node devices Das & Jain, [21]. End-users view instant visualisations of live data from the internet through web browsers as well as mobile applications. To accelerate the improvement of IoT analytics, Matlab code analyses and visualise new sensor data. In our research, after data from different sensor nodes are collected, end-users access data by using one of the TTN protocols known as Message Queuing Telemetry Transport (MQTT) through TCP as a transport layer. Security applicable is Transport Layer Security (TLS).

Web-Based User Interface

The web-based user interface enables a user to interact to the content stored on cloud servers via web browsers.

5. PROPOSED SYSTEM

The proposed system of water quality monitoring using IoT, adopted in this research, is presenting in figure 5. The developed system is designed to determine like pH value, the turbidity, and temperature of the surrounding atmosphere.

It consists of an IoT board, water container, and LoRa Gateway as a communication module. The overall block diagram of the proposed method shows how the sensors collect real-time information of the water quality parameters; pH turbidity and temperature, in the IoT environment presented.

This proposed block diagram, which consists of several sensors (temperature, pH, turbidity) is connected to the IoT board. The IoT board is accessing the sensor values and processing them by establishing communication to the end-user

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through LoRa Gateway and the internet. IoT board is used as a core controller. The cloud server is equipped with a difficult intelligentapplication that manipulates and analyse the data.

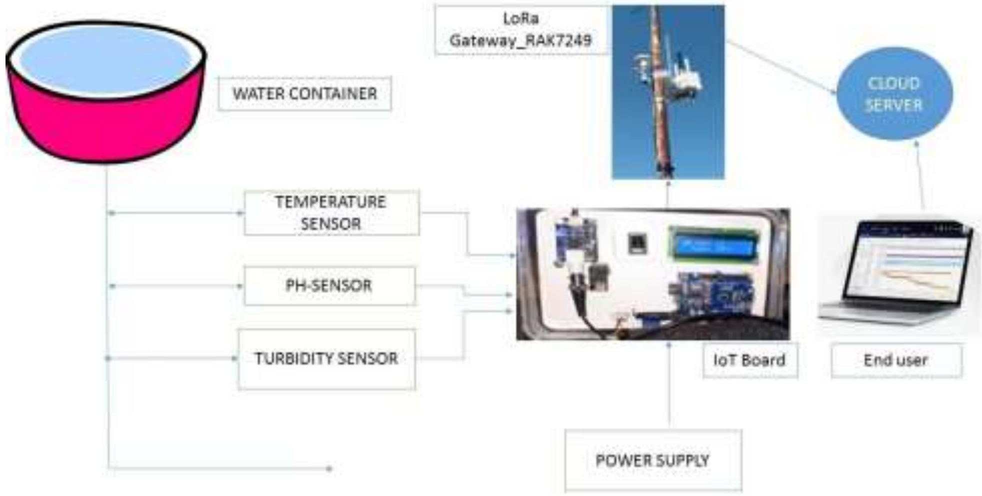

Figure 6: Block diagram of the prototype

6. EXPERIMENTAL RESULTS AND DISCUSSION

This implementation model used IoT board through LoRa Gateway. Inbuilt LoRa Gateway connects the embedded device to the internet. Sensors had been connecting to the IoT board formonitoring. The IoT board has an on-chip, ADC that converts the corresponding sensor readingto its digital value and from that value, the corresponding environmental parameter will be evaluated.

Turbidity sensor measures the light that can pass through the water at which if the water isclean then the voltage ranges from 3.90V to 4.55V. On the contrary, if the water is cloudy thenthe voltage ranges from 2.70V to 3.89V, and finally if the water is ducking the voltage ranges from 0.01V to 2.69V. Hence, the voltage is normally converted to Nephelometric Turbidity Units (NTU). The other two sensors also operate under five volts with each proper and fixed unit calculated to get the required volume.

Therefore, after sensing the data from different sensor devices placed in a particular area ofinterest, the sensed data processed by the IoT board is automatically updating to the cloud server using the Lora Gateway communication module to the server device.

Figure 7: pH and temperature of the water

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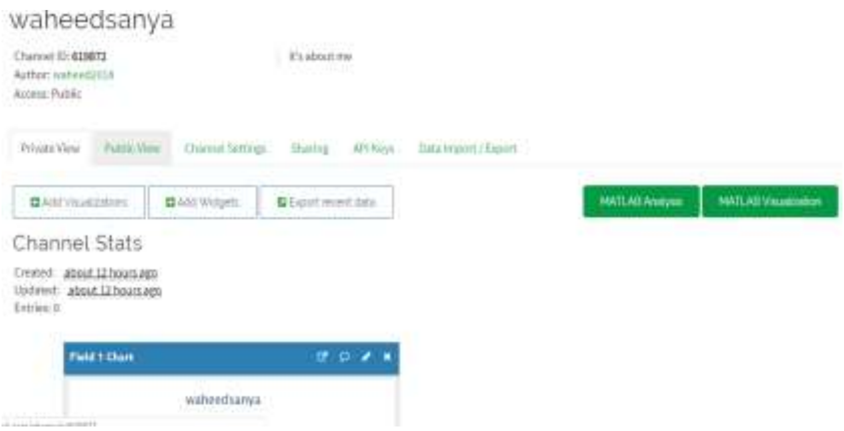

Figure 8: channel created in Thing Speak

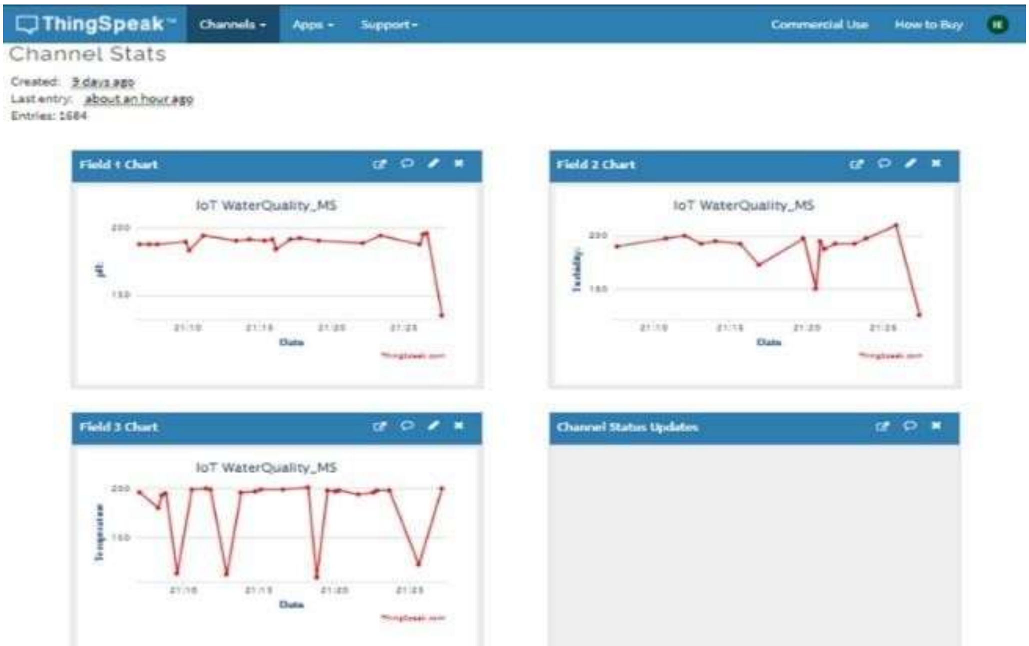

Figure 9: Results in a graph form in the cloud

As shown above, in Figure 7, the experimental setup consists of an IoT with a sensor network that proceeds samples for every 10 seconds from the water container and the parameters are displaying on the IoT board serial monitor. For the real-time monitoring, a LoRa updates the ThingSpeak server every 5 minutes of those diverse parameters.

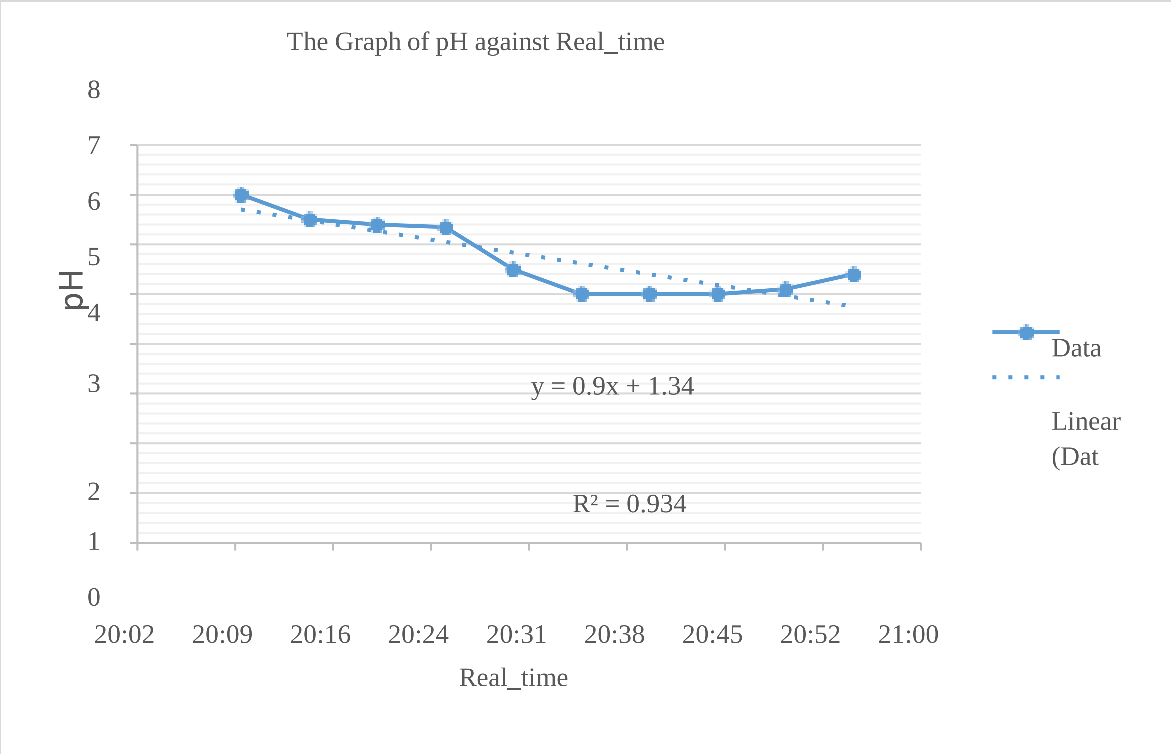

Figure 10: A graph of tap water pH parameter

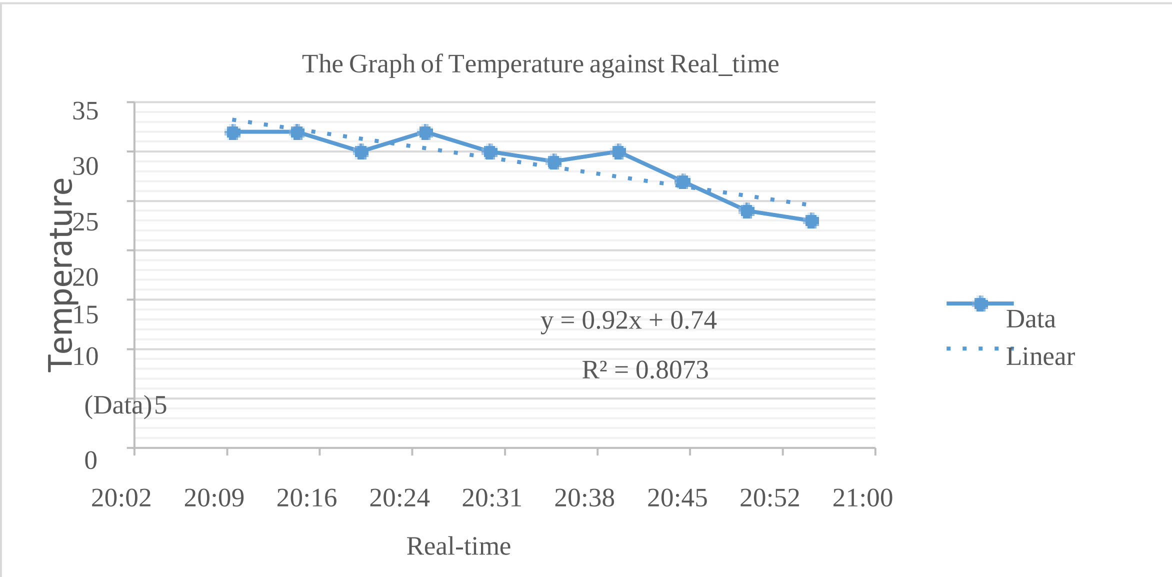

Figure 11: A graph of tap water through a temperature parameter

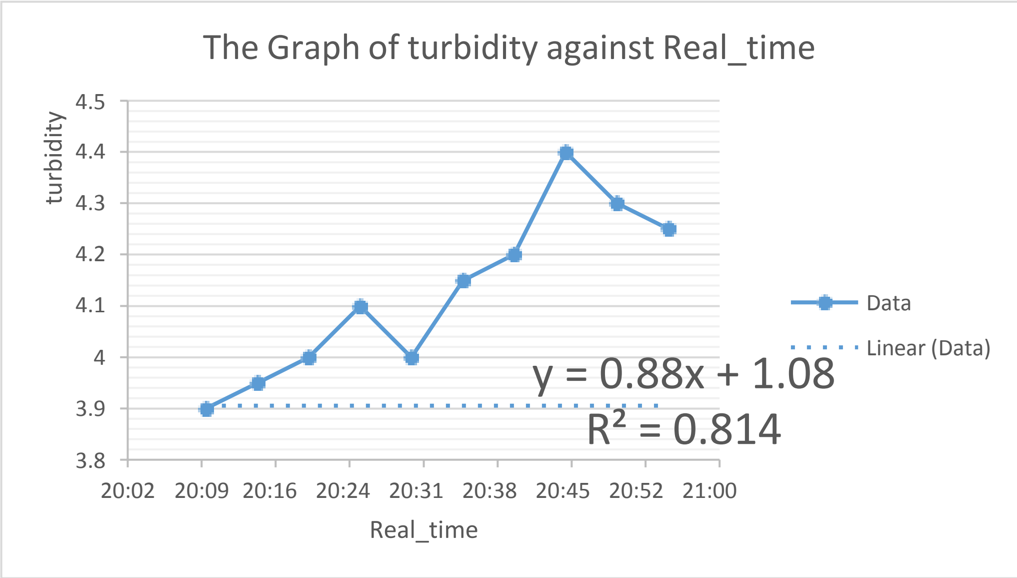

Figure 12: A graph of tap water through Turbidity parameters

The results obtained above have also demonstrated that the data from the sensor has a significant role for tape water and proves with the present range the benchmark WHO standardsof water parameters for safe human usable water.

Furthermore, from the graphs above show the Regression analysis for each parameter and conclude that it has some effect on water quality and validity of the results.

The Regression analysis R >0.8 shows that there is a strong correlation between the variables and two continuous variables.

Table 3. Analytical validation parameters for pH, temperature, and nitrite obtained fromsensor devices.

Parameters			
Real-time	**pH**	**temperature**	**turbidity**
20:10	7	32	3.9
20:15	6.5	32	3.95
20:20	6.4	30	4
20:25	6.35	32	4.1
20:30	5.5	30	4
20:35	5	29	4.15
20:40	5	30	4.2
20:45	5	27	4.4
20:50	4	24	4.3
20:55	7	23	4.25
Regression analysis(R)	0.934	0.8073	0.814

7. CONCLUSION AND FUTURE WORK

In this research, an efficient inexpensive IoT solution for a smart water quality monitoring system is implemented by using a LoRa Gateway. The system can monitor water quality automatically, The measured pH value ranges from 6.5 to 8.5. Turbidity sensor measures the light that can pass through the water at which if the water is clean then the voltage ranges from 3.90V to 4.55V, while if the water is cloudy then the voltage ranges from 2.70V to 3.89V and finally if the water is ducking the voltage ranges from 0.01V to 2.69V. A web-based application Things Speak was used to monitor the parameters of pH value, the temperature of the surroundings, and turbidity of the water through webservers. Water quality testing was found to be more economical, convenient, and fast. The system has good flexibility. Only by replacing the corresponding sensors and changing the relevant software programs, this system uses to monitor other water quality parameters. The operation is simple. The time is short, and the costis low in this environmental management. It concludes that LoRa technology is widely used for long-distance but with a limited data rate. The Regression analysis R>0.8 shows that thereis a strong correlation between the variables as well as a relationship between two continuous variables.

In the future, there is a need to upgrade network performance for coverage, by integrating many gateways and sensors to have a bigger network, by applying Artificial Intelligence Algorithms and Big Data techniques to solve different water pollutions problems in coastal areas. The proposed model is succefully desined and used to determine the objective.

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