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Internet of ThingsPotable Water Quality Monitoring

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Abstract- *ESP32 considers an open source of IoT platform, it performs two different tasks in the same time: firstly, processing sensors reading, and the second is transmission the data to internet via a built in Wi-Fi module in ESP32, in this paper ESP32 works together with several sensors to monitor parameters of water quality in real time.The potable water sources in Khartoum state are susceptible to contamination as a result of effects of huge number of latrine wells at the absent of the sewerage network. The challenge is to monitor water quality for more than 2000 wells in real time. The traditional method of water quality testing fails to deliverdata in real-time, not able to meet the demands of monitoring of water quality for a huge number of drinking wells. The system has been proposed to overcome this difficulty,in this paper four sensors(Temperature, Turbidity, TDS, and pH)capture the data in the form of analog signals, ESP32 converts these signals into the digital format, and sent these digital signals to the router or access point via a compact Wi-Fi module in ESP32, the system includes simple web server to display water quality parameters on internet througha browser application using a special IP address via the smart phone/PC from anywhere in the world, at the same time the ESP32 client makes an HTTP POST request to a PHP script to insert sensors reading into MySQL database on local test server under XAMPP platform,the sensors readingflows smoothly through the database, and thedata refreshes about every one minute. The results of sensors reading which take from the database as a sample is more suitable and acceptable within the standard limits of water quality parameters in real time. The uniqueness of the proposed paper is to obtain an automation more efficient, effective system monitoring water quality, and it is so cheap.This system presents close monitoring on potable sources, it can keep a strict check on the pollution, will immensely protect the quality of potable water from the risk of chemical and biological contamination, and help decision makers to make the right decision, and be able to provide an environment for safe drinking water.*

Key Words: *Internet of Things,ESP32, Temperature, Turbidity, TDS, pH, MySQL,PHP, XAMPP.*

1-Introduction According to the web of Khartoum state water corporation (KSWC) more than 5.5 million people live in Khartoum state, they drink potable water from revers Nile and 2,000 underground wells. On the other hand, there are about 700,000 latrine wells not correspond with the standard specifications of the depth, because of weak monitoring on drilling wells, due to the drilling operations are executed at night and during the weekends. Although the law prohibits anyone digging sewer, latrine or the source of any contamination beyond the depth of the water surface layer, and no person may use drilling machines in underground drilling wells for the purpose of Sanitation, nonetheless, the number of latrine wells increasing. At a time in which the sewerage network was hit by aging, though they do not cover more than 8% of the capital, and it's so difficult to create an integrated sewerage network currently.'Internet of Things' (IoT) is an exciting field that proposes to have all the devices that surround us connected to the Internet and interacting with us, but also between each other. 'Internet of Things' is based on device which is capable of analyzing the sensed information and then transmitting it to the user, ESP32 considers an open source of IoT platform[1]. In this method ESP32 transmit the sensors data in real time to database.The system is designed for continuous onsite sensing and real time reporting of water quality data where the officials can access the data on the smart phone/PC via Internet.Parameters to bemonitored or ensuring water quality areTemperature, Turbidity, TDS, and pH [2].Water quality monitoring is necessary to identify any changes in water quality parameters from time-to-time to make sure its safety in real time, helps in evaluating the nature and extent of pollution control required, and effectiveness of pollution control measures [3].

2. Literature Review

K. Spandan, V.R. Seshagiri Raoentitled "Internet of Things (Iot) Based Smart Water Quality Monitoring System". This paper highlightsthe system consists of microcontroller, multiple sensors, Analogue to digital converter, to monitor water parameters, the ESP8266 utilities as Wi-Fi module interfaces between transducers and the sensor network on a single chip, the collected data of water parameters are transmitted to the web server wirelessly by using Wi-Fi module. The data is monitored frequently and displayed on every action because the system is set in a continuous mode. The data is refreshed for every 5seconds [4].

Gowthamy, Chinta Rohith Reddy, Pijush Meher, Saransh Shrivastava, Guddu Kumar entitled "Smart Water Monitoring System using IoT". This paper describes that Arduino uses Arduino Software IDE is the main processor of the system which control and process the data generated by the sensors. The system consists of different type of sensors like water flow sensor, pH and turbidity sensor and ultrasonic sensor. A Wi-Fi module is connected to the Arduino device which help to transfer the data to the cloud server via Wi-Fi module ESP8266. So this application will be the best challenger in real time [5].

Vaishnavi V. Daigavane and Dr. M.A Gaikwad entitled "Water Quality Monitoring System Based on IOT". This paper presents the Arduino is a microcontroller connects to several sensors (temperature, pH, turbidity, flow), which helps to measure the real time values, and LCD shows the displays output from sensors. The ESP8266 Wi-Fi module gives the connection between hardware and software. The sensed data will be automatically sent to the web server [6].

Priya S. Bhagat, Dr. Vijay S. Gulhane, Prof. Tanuj S. Rohankar entitled "Implementation of Internet of Things for Water Quality Monitoring". This paper presents number of sensors which are used for measuring the parameters of the water; these parameters are temperature, pH, turbidity, and CO2 of the water. The measured values of the parameter from the sensors can be processed by Arduino pro mini microcontroller which can be used as a core controller. Sensors are connected with the Arduino pro mini and this can send the parameter value to the Wi-Fi module ESP8266 which require internet for sending this parameter values to thinger.io from the thinger.io anyone can see the real-time values of the water parameter and these values are also shown on the LCD screen which is connected to the microcontroller [7].

All theseabove studies implement two separate units:firstly,a microcontroller for processing sensing data; secondly ESP8266 as Wi-Fi module to transmission data to internet. Versus the purposed system presents ESP32 as one unit to performed two tasks: Processing sensors reading, and transmission data to internet as Wi-Fi module in real time.The reduce cost of components is a key features of the system.

3.Problem Statement

The potable water sources in Khartoum state are susceptible to contamination as a result of effects of huge number of latrine wells at the absent of the sewerage network, this consequently harms human health. The challenge is to monitor quality of water for more than 2000 wells in real time. The traditional method of water quality testing, samples are collected manually and then analyzed in the laboratory. This methodfails to deliver real-time data, not able to meet the demands of monitoring of water quality for a huge number of drinking wells, wastes too much manpower need the material resource, has the limitations of the samples collecting, long-time analyzing, the aging of experiment equipment and other issues[8].**4.Proposed System**

Theproposed system has been designedtoovercome the existing issue of the traditional methods formonitorwater quality, allowing frequent sampling, increasing the range of sampling, sophisticated testing on-site, and binding response efforts to detection systems. This allows to prevent substantial contamination and related disasters.

5. Implementation

The whole system is shown below in system architecture Fig.1.The proposesystem contains ESP32 which programmed with Arduino IDE to receive and processfour sensorsreading (Temperature, Turbidity, TDS, pH), sensors capture the data in the form of analog signals, except Temperature sensor it is in digital format. ESP32 converts these signals into the digital format, and sentthese digital signals to the router or access point via Wi-Fi module,the system includes simple web server to display water quality parameterson internet through a browser applications using a special IP address via the smart phone/PCfrom anywhere in the world, at the same time an ESP32 client makes an HTTP POST request to a PHP script to insert sensorsdata into a MySQL database on local test server under XAMPP platform.The local server XAMPP which allows the use of the software tool phpMyAdmin written on PHP and that operates with the MySQL database management system, such that it can be accessed from anywhere, anytime. The system uses Hyper Text Markup Language (HTML) format to define layouts of created page. PHP and JavaScript were used as the server side languages with PHP used to create page and JavaScript used to host the website allowing the implementation of highly responsive user interfaces. XAMPP which provides free web hosting using PHP and MySQL, was used to develop and maintain web applications. TheXAMPP provides a platform to create, read, update and delete files and folders. Web services were used for URL calls and the following CALL methods were used: GET, POST. The web server software used is Apache.

5.1 System Circuit Diagram

The execution of the projected system is shown below in system circuit diagramFig.2. It consists ESP32and several sensors such as (Temperature, Turbidity, TDS, pH), ESP32 connects to three terminals for any sensor (DATA, VCC, GND), ESP32 processessensing data and sendsit to the router or access point via a Wi-Fi module. Although these sensors work in the Arduino environment, their outputs are compatible with ESP32maximum voltage (3.3V).The analog output ofpH sensor more than maximum voltage (3.3V) for ESP32, so it connects to voltage divider (10 & 20 k Ohms) to be save and compatible with ESP32 [9]. Each of these components is described in details below:

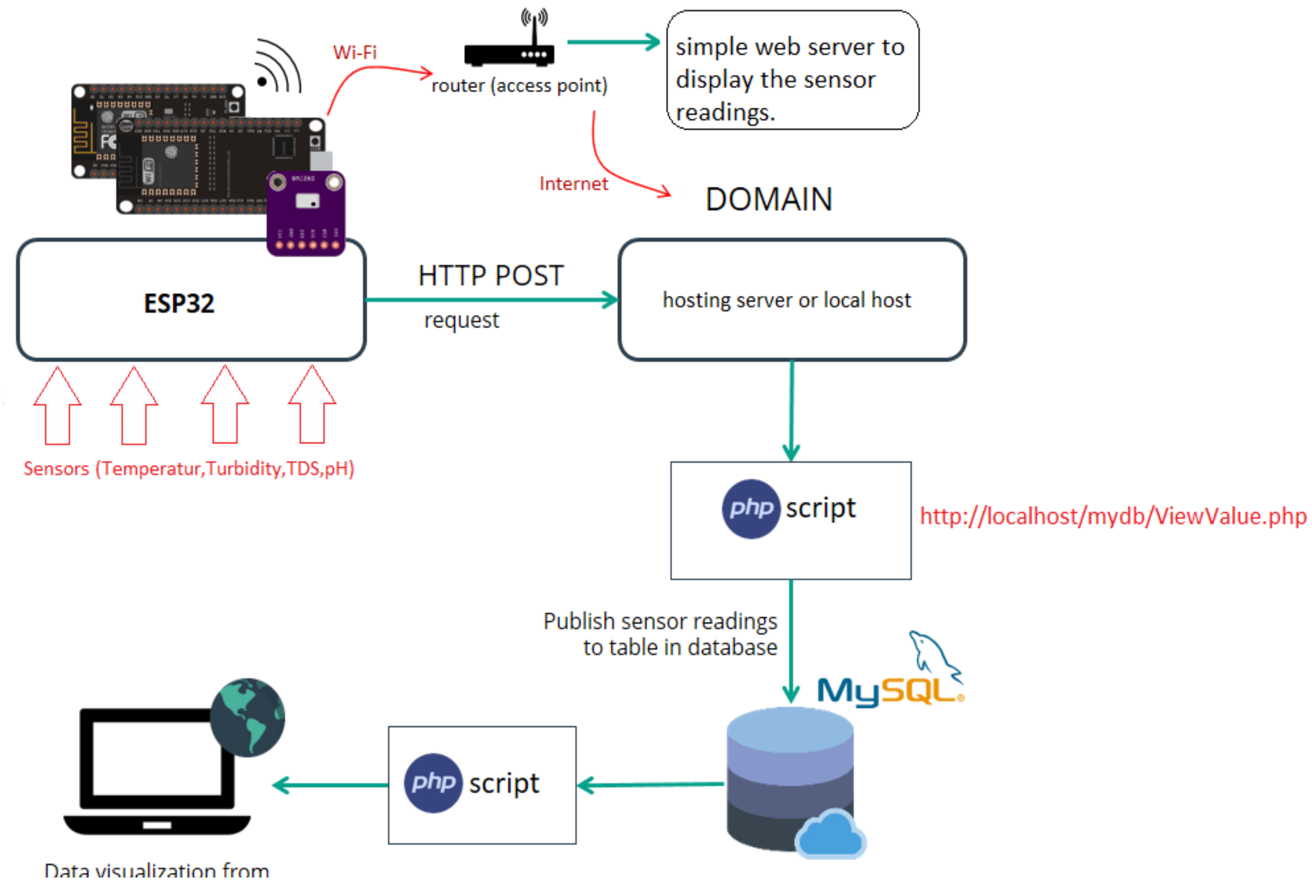


Fig.1. System ArchitectureThe real diagram from (https://randomnerdtutorials.com/visualize-esp32-sensor-readings-from-anywhere)

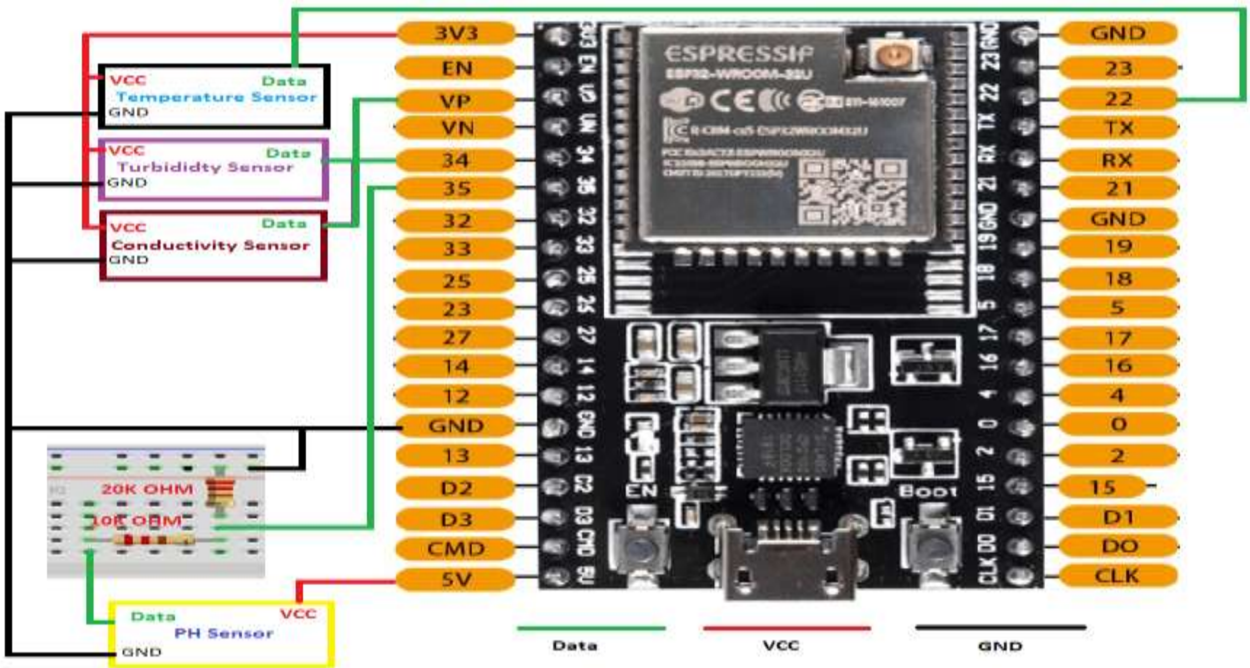


Fig.2. System Circuit Diagram

5.1.1ESP32 ESP32 (WROOM-32U) is a dual-core system with two Harvard Architecture Xtensa LX6 CPUs as shown above in system circuit diagramFig.2.

All embedded memory, external memory and peripherals are located on the data bus and/or the instruction bus of these CPUs.It now combines Wi-Fi and Bluetooth wireless capabilities. is an open source IoT platform, it includes firmware which runs on the ESP8266 Wi-Fi SoC from Expressive Systems, and hardware which is based on the ESP-12 module[10].

5.1.2TemperatureSensor

Thewaterprooftemperature sensorThe DS18B20 is a Digital Thermometer which offers 9 to 12-bit (configurable) temperature impression.as shown in figure.(3,a)[11].**5.1.3TurbiditySensor** Turbidity level sensor is used to measure the clarity of water or muddiness present in the water as shown in figure(3,b). The turbidity of the surface water is usually between 255 NTU(Nephelometric turbidity unit). The standards for drinking water is 130 NTU to 250 NTU [12].This paperdoes not use NTU as a turbidity unit, itconstructs a way to display the data from the sensor tests,as relative percentage; 0% = clear water. Turbidity expressed by a simple equation:turbidity = 100.00 - (dataturbidity*3.3/4095/Vclear) * 100.00,where dataturbiditycorresponding sensor reading, and the value of Vclear is 2.25 voltsgets from sensor tests,the sensor gives out around 2.25 volts when the water is clear and 0 volts at the muddiest water. **5.1.4 TDS Sensor** TDS (Total Dissolved Solids) indicates that how many milligrams of soluble solids dissolved in one liter of water as shown in figure (3,c).TDS analysis is very important because it can illustrate groundwater quality. In general, the higher the TDS value, the more soluble solids dissolved in water, and the less clean the water is. Therefore, Conductivity (EC) and total dissolved solids (TDS) are water quality parameters, which are used to describe salinity level. These two parameters are correlated and usually expressed by a simple equation: TDS = k EC (in 25 °C). The process of obtaining TDS from water sample is more complex than that of EC. Meanwhile, TDS in water is determined by multiplying the conductivity by a factor of0.67[12].**5.1.5pH Sensor**

The pH stands for “Potential of Hydrogen,” referring to the amount of hydrogen found in water. pH is measured on a scale that runs from 0 to 14. 7 is neutral, meaning there is a balance between acid and alkalinity. A measurement below 7 means acid is present and a measurement above 7 is basic (or alkaline)[13]. Liquid PH 0-14 Value Detection Regulator Sensor Module as shown in figure(3,d).

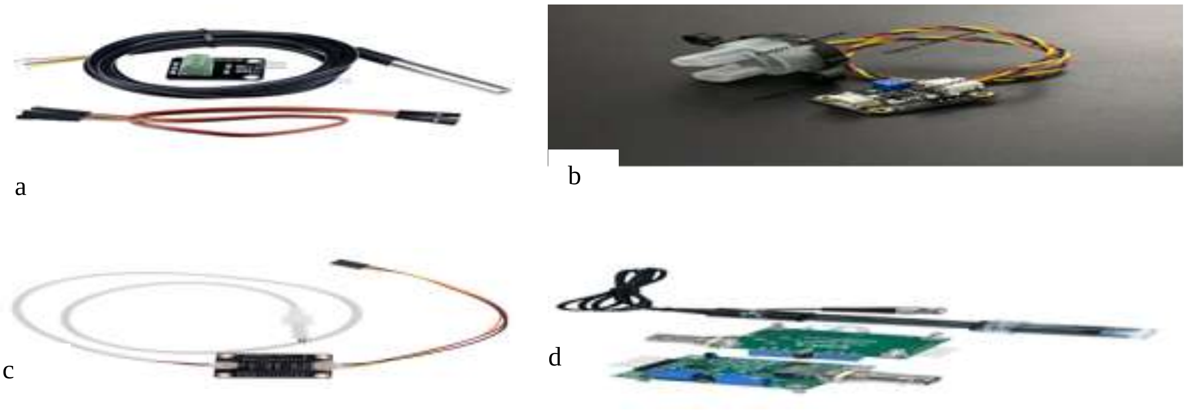


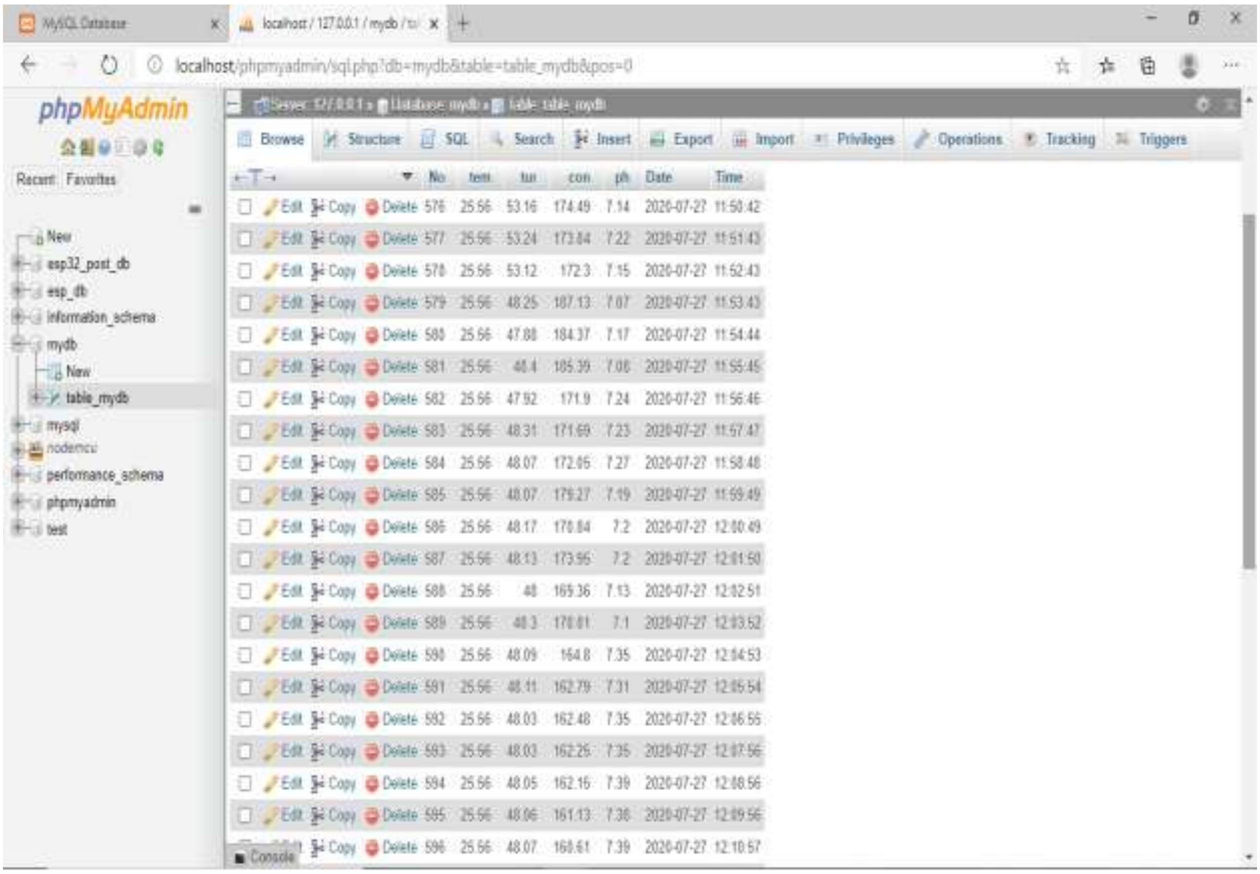
Fig.3. (a) Temperature sensor (b) Turbidity sensor (c) TDS sensor (d) pH sensor.

5.2 Software Design of the System5.2.1 Arduino IDE

TheArduino Integrated Development Environment contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the ESP32 hardware to upload programs and communicate with them. [14].**5.2.2 XAMPP** XAMPP is a free and open-source cross-platform web server solution stack package developed by Apache Friends, consisting mainly of the Apache HTTP Server, MySQL database, and interpreters for scripts written in the PHP and Perl programming languages [15].**6.Results**

The overall design solution was tested to evaluate its performance and effectiveness. After successful connection of sensors to the ESP32, data from all four sensors are sent to the web server for monitoring. sensors reading insert into a MySQL database called (mydb) on local test server under XAMPP platform.A createdtable called (table_mydb)on databasecontains six columns (No, tem for Temperature, tur for Turbidity, con forTDS, pH, Date, Time). System updates sensors readingon these columns about every one minute, as shown below in Table1.

Table 1: MySQL database's tableupdate Sensors Reading about every one minute (Screenshot)



No	tem	tur	con	ph	Date	Time
576	25.56	53.16	174.49	7.14	2020-07-27	11:50:42
577	25.56	53.24	173.84	7.22	2020-07-27	11:51:43
578	25.56	53.12	172.3	7.15	2020-07-27	11:52:43
579	25.56	48.25	187.13	7.07	2020-07-27	11:53:43
580	25.56	47.88	184.37	7.17	2020-07-27	11:54:44
581	25.56	48.4	185.39	7.08	2020-07-27	11:55:45
582	25.56	47.92	171.9	7.24	2020-07-27	11:56:46
583	25.56	48.31	171.69	7.23	2020-07-27	11:57:47
584	25.56	48.07	172.05	7.27	2020-07-27	11:58:48
585	25.56	48.07	179.27	7.19	2020-07-27	11:59:49
586	25.56	48.17	170.84	7.2	2020-07-27	12:00:49
587	25.56	48.13	173.95	7.2	2020-07-27	12:01:50
588	25.56	48	165.36	7.13	2020-07-27	12:02:51
589	25.56	48.3	170.01	7.1	2020-07-27	12:03:52
590	25.56	48.09	164.8	7.35	2020-07-27	12:04:53
591	25.56	48.11	162.79	7.31	2020-07-27	12:05:54
592	25.56	48.03	162.48	7.35	2020-07-27	12:06:55
593	25.56	48.03	162.25	7.35	2020-07-27	12:07:56
594	25.56	48.05	162.16	7.39	2020-07-27	12:08:56
595	25.56	48.06	161.13	7.38	2020-07-27	12:09:56
596	25.56	48.07	160.61	7.39	2020-07-27	12:10:57

Furthermore,XAMPPenvironment providesto monitor data from all over the world via internet, which able to show sensors reading on local host, as shown below in Table (2), no different in readings between table1 and table2, tables are similar in values and time. Table2 illustrates corresponding sensor readings on MySQL database which update about every one minute also contains six columns (No, Temperature, Turbidity, TDS, pH, Date, Time).

IOT POTABLE WATER QUALITY MONITORIN

No	Temperature	Turbidity	TDS	PH	Date	Time
581	25.56	48.4	185.39	7.08	2020-07-27	11:55:45
582	25.56	47.92	171.9	7.24	2020-07-27	11:56:46
583	25.56	48.31	171.69	7.23	2020-07-27	11:57:47
584	25.56	48.07	172.05	7.27	2020-07-27	11:58:48
585	25.56	48.07	179.27	7.19	2020-07-27	11:59:49
586	25.56	48.17	170.84	7.2	2020-07-27	12:00:49
587	25.56	48.13	173.95	7.2	2020-07-27	12:01:50
588	25.56	48	169.36	7.13	2020-07-27	12:02:51
589	25.56	48.3	170.01	7.1	2020-07-27	12:03:52
590	25.56	48.09	164.8	7.35	2020-07-27	12:04:53
591	25.56	48.11	162.79	7.31	2020-07-27	12:05:54
592	25.56	48.03	162.48	7.35	2020-07-27	12:06:55
593	25.56	48.03	162.25	7.35	2020-07-27	12:07:56
594	25.56	48.05	162.15	7.39	2020-07-27	12:08:56
595	25.56	48.06	161.13	7.38	2020-07-27	12:09:56
596	25.56	48.07	160.61	7.39	2020-07-27	12:10:57
597	25.56	48.12	160.32	7.49	2020-07-27	12:11:57
598	25.56	48.14	159.19	7.47	2020-07-27	12:12:58
599	25.56	48.15	158.02	7.42	2020-07-27	12:13:58
600	25.56	48.01	158.97	7.39	2020-07-27	12:14:59
601	25.56	48.52	156.91	7.5	2020-07-27	12:16:00
602	25.56	48.43	154.18	7.53	2020-07-27	12:17:01

Table2: Sensors Reading on local host update about every one minute (Screenshot)

To access the data of IoT Potable Water Quality Monitoringlogging on the website using IP address of ESP32,as shown below Fig (4). web page displays corresponding values of (Temperature, Turbidity, TDS, pH) in real time to determine water quality, Fig. (4)shows the readings as follow: Temperature sensor is 25.56, Turbidity is 47.88, TDSis 169, and pHis 7.39, all sensors readingupdate automatically.

Fig.4. The Sensors Readingon web page using IP address (Screenshot)

Fig.7 below illustrates a plan for 20 readings from four sensors(Temperature, Turbidity, TDS, pH), which have taken inthe date 27/07/2020,the duration about twenty minutes started at 11:50 to 12:09 AM, the values of sensorsreading are suitable within standard range.

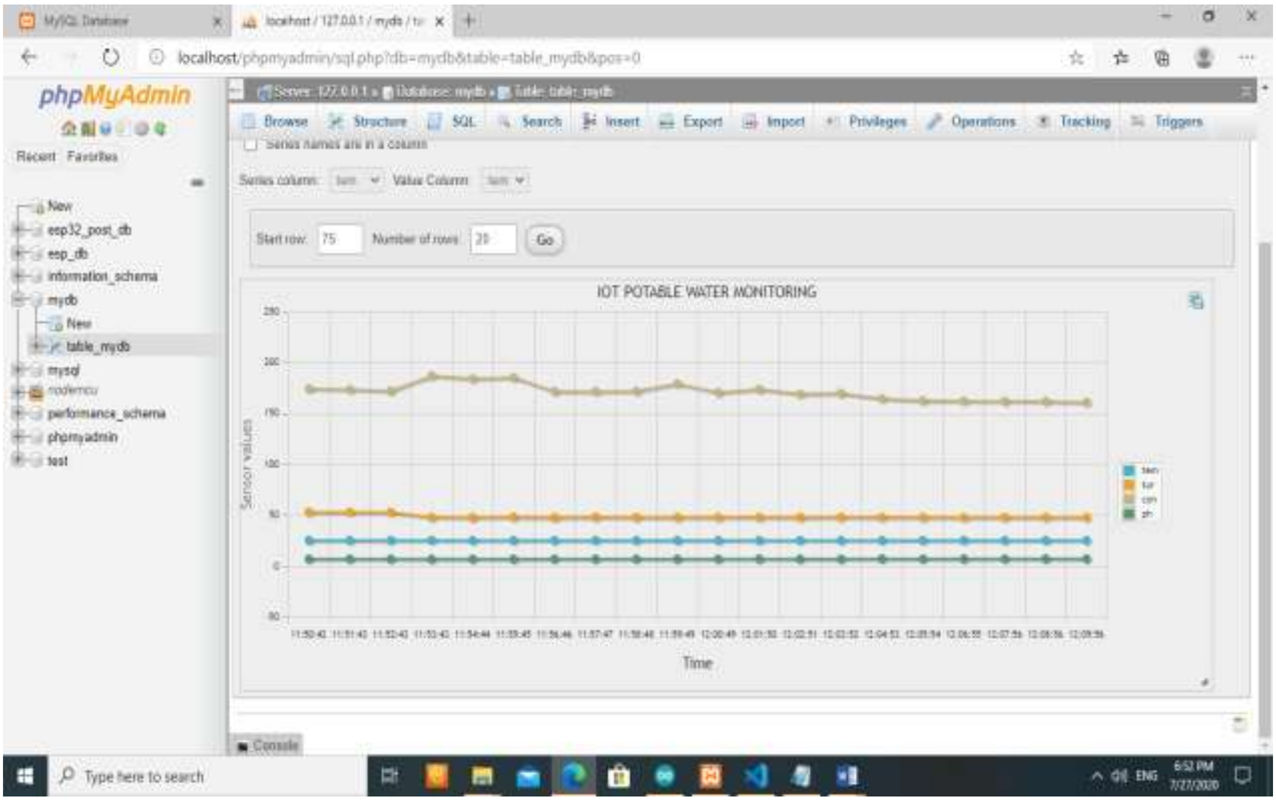


Fig7. Time graphsGeneral View for All Sensors Reading(Screenshot)

The real time data from different sensors are to be monitored on the individual chart as follow: 1/ Reading of Temperature sensor is stable in 25.56℃as shown below in Fig.8.

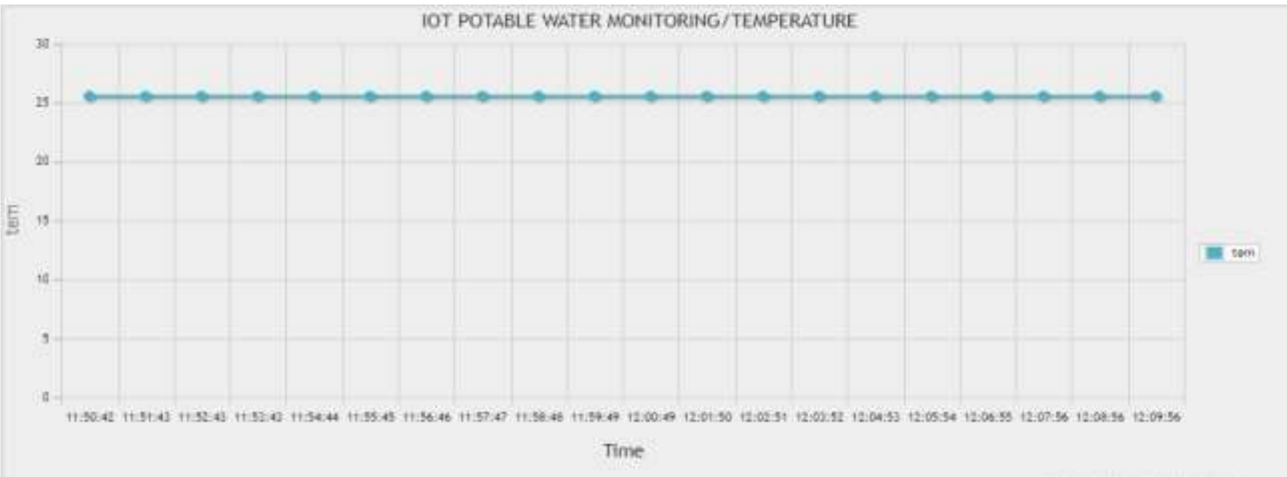


Fig8. Time Graph of Temperature Sensor Readings(Screenshot)

2/ The maximum Turbidity reading is 53.24% anda minimum reading is 47.88%.Season ofrain these days in Sudaneffects on water clarity, so it is acceptable range. Fig.9 below shows the time graph of Turbidity sensor readings.

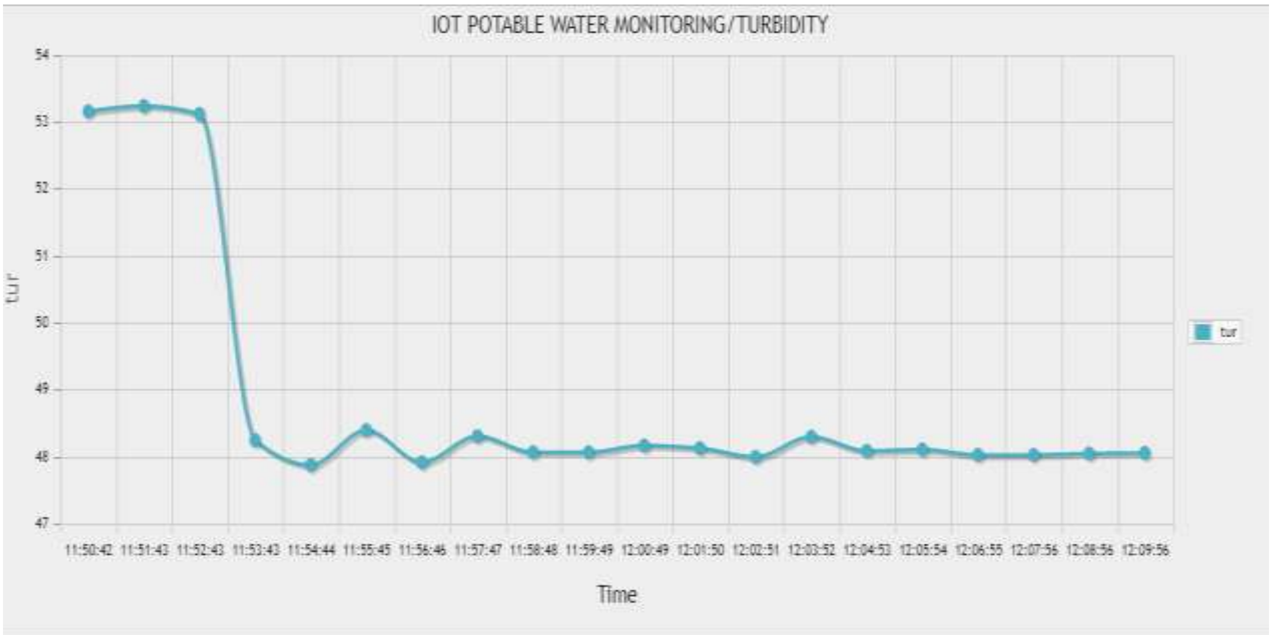


Fig9. Time Graph of Turbidity Sensor Readings(Screenshot)

3/As Fig.10 below shows the time graph of TDS sensor readings between 187.13 ppt as maximum and 160.6 ppt as a minimum reading.

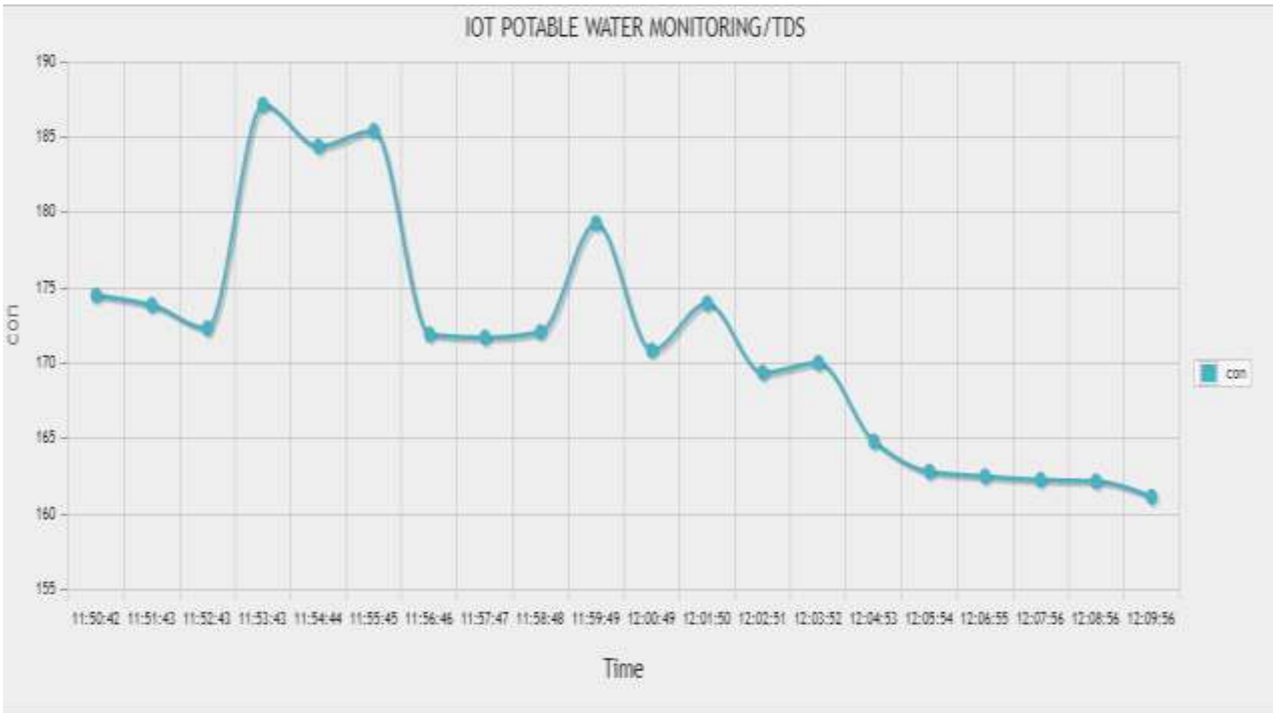


Fig10. Time Graph of TDS SensorReadings(Screenshot)

4/ Fig.11 below shows the time graph of pH sensor, the maximum reading of pH sensor is7.39 and the minimum reading is7.07, it is acceptable range for drinking water,

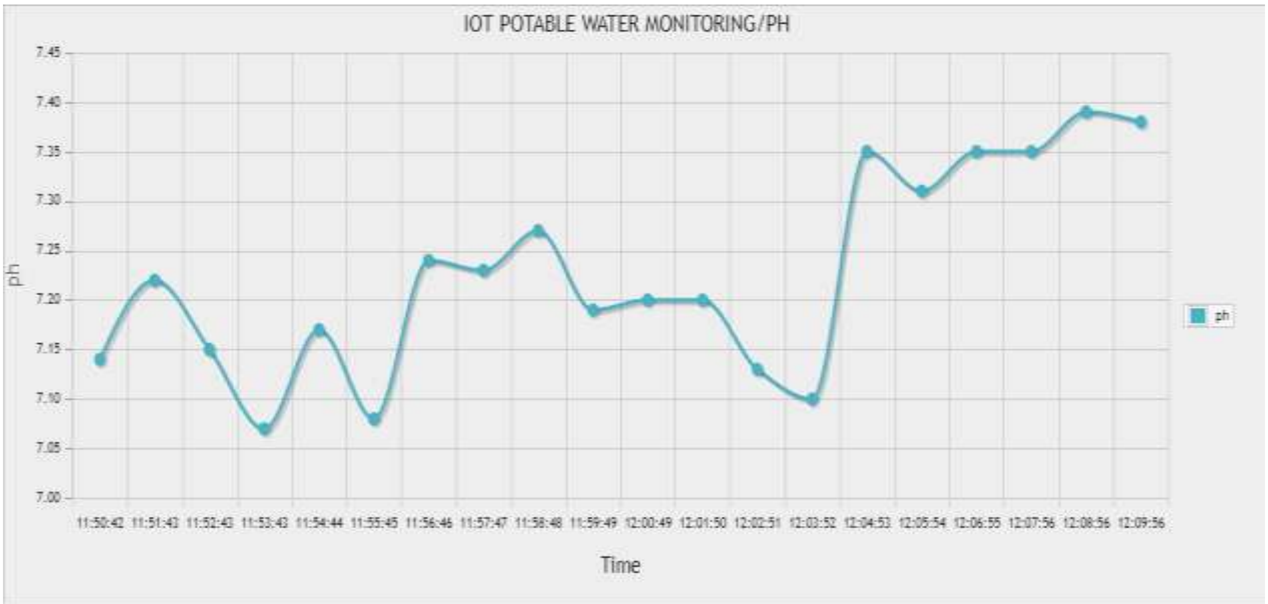


Fig11. Time Graph of pH Sensor Readings(Screenshot)

7.Discussion

Based on a study of existing water quality monitoring system and scenario of above results we can say that: 1/The purpose system is more suitable to monitor water quality parameters in real time, Table3 below showsa synopsis of maximum and minimum values of sensorsdata, which are acceptable within the standard limits, especially in the season of rain in Sudan. Thus, this system can be relied upon to achieve goals related to monitor potable water quality, and its results can be trusted Enhancement of water quality data acquisition and provides reliable alerts to water utilities

Table3: Synopsis of Sensor Readings

Temperature	Turbidity		TDS		pH	
Constant	Min	Max	Min	Max	Min	Max
25.56°C	47.88%	53.24%	160.6 ppt	187.13 ppt	7.07	7.39

2/Water quality monitoring is necessary to identify any changes in water quality parameters from time-to-time to make sure its safety in real time, helps in evaluating the nature and extent of pollution control required and effectiveness of pollution control.

3/The low cost of components is a key features of the system. Table4 below shows the costof each of the components and the overall cost of the designed system. As can be seen,the overall cost is just $41.32. It is indeed a low-cost system solution comparedto the available commercial system solutions which are in thousands of dollars.

Table 4. Bill of Materials

S/N	COMPONENT	QTY	PRICE
1	Breadboard 830 Point Solderless PCB Bread Board Test Develop DIY	1	1.63
2	100pcs Metal film resistor 1/4W series 1R~2.2M 1% resistance 10K 22K 47K 100K 100 220 1K5 100R 220R 1K 1.5K 2.2K 4.7K 4K7 ohm	1	0.52
3	ESP32-DevKitC core board ESP32 development board ESP32-WROOM-32D ESP32-WROOM-32U	1	4.05
4	DS18B20 Temperature Sensor Module Kit Waterproof 100CM Digital Sensor Cable Stainless Steel Probe Terminal Adapter For Arduino	1	1.06
5	Dupont 120pcs 10cm/20cm/30cm male to male + male to female and female to female jumper wire Dupont cable for Arduino Resistor	1	1.44
6	DFRobot Gravity Analog / Digital Turbidity Sensor, 5V DC support both signal output compatible with arduino for Water Testing	1	9.89
7	Liquid PH 0-14 Value Detection Regulator Sensor Module Monitoring Control Board Meter Tester + BNC PH Electrode Probe Controller	1	9.7
8	Analog TDS Sensor Water Conductivity Sensor for Arduino Liquid Detection Water Quality Monitoring Module DIY TDS Online Monitor	1	12.7
9	Power Supply Module 3.3V/5V For Solderless Bread Board	1	0.33
Total			41.32$

8.Conclusion

In this paper, the design and development of potable water quality monitoring in real time base on IoT environment are presented. The proposed system consists of ESP32 and several water quality parameter sensors. These devices are low cost, more efficient and capable of processing, analyzing, sending to the mobile device through Wi-Fi, and viewing the publish sensor data into a database on local test server under XAMPP platform. As such, the data can be read and accessed at anytime from anywhere on a real-time basis. This can implement for suitable environment monitoring, ecosystem monitoring, and the data can be viewed anywhere in the world. The purpose system shows that The sensors reading are more suitable to monitor water quality parameters in real time, which are acceptable within the standard limits, also the system responds to changes on sensorsreading about every minute. In the future, we plan to install the system in several locations of potable water distribution network to collect water quality data and send to the water board, it can also easily be configured to handle more sensors, also planning to publish sensor data into a database in an own server domain, but those services can have several disadvantages: restrictions on how many readings can publish, number of connected devices, who can see the data, etc. Additionally, the cloud service can be discounted or change at any time.

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