COLLEGE OF SCIENCE AND TECHNOLOGY

"IOT BASED REMOTE MONITORING OF WATER QUALITY IN TANKS: CASE OF WASAC"

Student's Name: **Madeleine YANKURIJE**

College of Science and Technology

School of Engineering

Masters of Internet of Things in Wireless Intelligence Sensors Networking

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"IOT BASED REMOTE MONITORING OF WATER QUALITY IN TANKS: CASE OF WASAC"

By

Student's Name: **Madeleine YANKURIJE**:

Reg. No:219013815

A dissertation submitted in a partial fulfillment of the requirement for degree of Masters in Internet of Things-Wireless Intelligence Sensors Networking (**IOT-WISNet**).

In the College of Science and Technology (CST)

Main Supervisors: **Dr. Pierre BAKUNZIBAKE**

Co-Supervisor: **Dr. Philibert NSENGIYUMVA**

February,2021

DECLARATION

I declare that this dissertation contains my own work except where specifically acknowledged.

Madeleine YANKURIJE (Registration Number. 219013815)

Signature………………………………………….

Date: ……………………………………

BONIFIDE CERTIFICATE

This is to certify that the project entitled "**IoT BASED REMOTE MONITORING OF WATER QUALITY IN TANKS: CASE OF WASAC**" is a record of original work done by **Madeleine YANKURIJE** with Registration Number **219013815** in partial fulfillment of the requirement for the award of masters of Sciences in Internet of Things in College of Science and Technology, University Rwanda, Academic year 2018-2020.

This work has been submitted under the guidance of Dr. Pierre BAKUNZIBAKE and Dr. Philibert NSENGIYUMVA.

Main Supervisors:

Dr. Pierre BAKUNZIBAKE

Signature:

Co-Supervisor:

Dr. Philibert NSENGIYUMVA

Signature:

The Head of Masters and Trainings

Names: Dr. Didacienne MUKANYIRIGIRA

Signature:

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ABSTRACT

Water is considered as a basic need for human in their daily life. It is needed in different situations including, at home, in agriculture, in industry and manufactures, in hospital etc. To survive in a good life the quality of water should be monitored on highly level frequently and efficiently. Water pollution can be caused by different factors including large number of people who move from rural environment to urban (as long as the city get more rising number of people the waste management become an issue therefore these can provoke pollution in environment), more industries that provide different kind of waste, erosion etc. Unsafe water could lead to different diseases such as diarrhea, cholera, cancer. Generally, the quality of fresh water is described by chemical, biological and physical content and methods used in monitoring the quality of water usually were Water Sampling, Test Sampling and Investigative Analysis. But these methods are performed by the scientists in laboratories, and are found that they are slow.

In this project we proposed an affordable system design for monitoring the quality of water remotely in tanks of WASAC by using technology known as Internet of Things (IOT) and this technology provides the required results in real time. A prototype was designed and developed with the use of hardware component together with the software program for implementing this project. The implementation of this project will carry a greater contribution to WASAC (Water and Sanitation Corporation) which is an organization company in the government of Rwanda (GoR). WASAC has different department but this project is applicable only on the side of water quality monitoring department. The system is built in a way that the technician can automatically receive a message through email about the state of water without going to the site.

KEY WORDS

IoT, Remote monitoring, East African Standard on potable water, Water quality detection, things peak, pH sensor, Turbidity, Microcontroller, NodeMCU and Notification

LIST OF SYMBOLS AND ACRONYMS

ADC:	Analog Digital Conversion
AI:	Artificial Intelligent
APEC:	Asia-Pacific Economic Cooperation
API:	Application Programming Interface
BLE:	Bluetooth Low Energy
BNC:	Bayonet Neill Concelman
BRD:	Banque Rwandaise pour Development
D5:	Digital five pin
D6:	Digital pin six
DC:	Direct Current
Dr.:	Doctor
DTU:	Data Transfer unit
EAC:	East African Community
EH:	Energy Harvesting
GND:	Ground
GoR:	Government of Rwanda
GPIO:	General Purpose Input Output
GSM:	Global System Mobile
GUI:	Graphical user interface
I/O:	Input/Output
IFTTT:	If This Then That
IJITEE:	International Journal of Innovative Technology and Exploring Engineering
IoT:	Internet of Things
IOT-WISNet:	IoT-Wireless Intelligence Sensors Networking
KB:	Kilobytes
LAN:	Local Area Network
LCD:	Liquid-Crystal Display
LED:	Light Emitting Diode
MCU:	Micro-Controller Unit
MININFRA:	Ministry of Infrastructure
NTU:	Nephelometric Turbidity Unit

ORP:	Oxidation and Redaction Potential
pH:	Potential Hydrogen
RS:	Remote Sensing
RS-EAS:	Rwanda Standard -East Africans Standard
RX:	Reception
SL:	Standard Limits
SMS:	Short Message Service
TX:	Transmission
USB:	Universal Serial Bus
VCC:	Voltage Common Collector
WASAC:	Water and Sanitation Corporation
WDS:	Water Distribution System
WHO:	World Health Organization
Wi-Fi:	Wireless Fidelity
WQM:	Water Quality Monitoring
WSN:	Wireless Sensor Network

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CHAPTER 1: INTRODUCTION

This chapter sheds light on the background and motivation, problem statement, study objectives (general objectives and specific objectives), scope of the study, significance of the study and how the work is organized from the beginning up to the end.

1.1. Background and motivation

Monitoring the quality of water refers to controlling the level of physical, chemical and biological parameters that are contained in water reservoir or tank various activities to survive[1].Therefore water quality can be understood as the appropriate range of variables which limit water usage[2].

Most of infectious diseases are caused by contaminated water which leads to millions of deaths every year. The incapacity of not having enough power for distributing water with quality to all people in real time is the key which can different illness [3].Generally, several transmitted diseases like hepatitis, cholera, typhoid, paratyphoid etc. are caused by drinking unsafe water[4].

Some factors of having low quality of water include, pollutions, mining, too much fertile contained in the soil, erosion, etc. [5]. A number of developing countries including Rwanda use traditional method to monitor the quality of water, this involves the collection of water sample from different locations. These water samples are then tested in the laboratory using the analytical technologies. Such approaches are time consuming and give appreciation results and also the cost is high and offer low measurement accuracy [6]. There are so many devices used for measuring the quality of water those are Dr. Meter TDS-3C Water Quality, Sunny Water Tester, and Water Quality Meter by Generic, Play X-STORE Water Quality Meter, APEC Water Systems Digital Meter and Started Filter Tester. These devices are cost, not affordable, not everyone is easy to get it at home and are difficult to practice with them[7]. “According to the information given in Water and Sanitation in Central Laboratory Officer of WASAC (Water and Sanitation Corporation) organization which is in charge of monitoring quality of water and in their reports displays that they use the manual method for monitoring the quality of water and this done through water sampling[8]. Hence to overcome that issue there is need of developing better methodologies to monitor the water quality parameters in real time.

This project proposes a solution about remote monitoring the quality of water in the public tanks of WASAC (Water And Sanitation Corporation) localized in Kigali city where most of people get supply of water from the tanks of WASAC installed in different areas with the use of an IoT (Internet of Things) technology which allows several devices to be interconnected at the same time and perform task in real time without delay , it provides interface to monitor and operate remotely from anywhere and anytime and save human job[9].The proposed project focuses on monitoring the quality of water stored in those tanks remotely with the application of Wireless Sensor Network (WSN). Various sensors that are used comprise pH which measures the concentration of hydrogen ions and it shows the acidity or alkalinity of water and neutral. pH is measured in the range from 0 up to 14 pH, drinking water is scaled between 6.5-8.5pH, at 7pH water is neutral, less than 7pH water has acid, more than 7pH water has alkaline. Another sensor is the turbidity sensor which measures the level of suspended particles in water which is invisible and normal water should be ranged between 0-5NTU (Nephelometric Turbidity Unit). So higher the turbidity or pH in water the more risk of diarrhea, cholera and others diseases comes[10]. The system also uses Arduino UNO as a microcontroller to allow data collected from the sensors to be processed, node MCU ESP8266 for sending data to ThingSpeak. This system provides the way for monitoring the quality of water based on the use of ThingSpeak platform which can analyze and visualize data by using MATLAB. Here all sensed parameters have to be uploaded to the ThinkSpeak and the system has to send an email message notification to the technician of WASAC automatically through IFTTT protocol once the abnormal parameters are sensed[11]. Some modern countries such as in India have this system of monitoring quality of water remotely by using system like Eco -Mapper, Robotic Fish and Digital Camera placed into the rivers or lakes.

WASAC (Water and Sanitation Corporation) is the company in charge monitoring and controlling water distribution in Rwanda. The purpose of WASAC is to supply water to people in rural and urban area. Its vision is that in 2020 all Rwandan should be able to get access to clean water and having the source of water in few kilometers. Using IOT in monitoring the quality of water, stakeholders such as the help of organization called Water for People that work in different area of districts, national and private sectors are the main elements for achieving our goal.

1.2. Problem Statement

Drinking and using unsafe water can cause diarrhea and chorea especially for children and other diseases such as cancer. Old method of monitoring water quality in the water management system were not efficiently safe and takes time consuming to be successful, not accurate and require human intervention, therefore it was not economic[6]. People in these days are not able to get access to clean water due to the use of manual method in monitoring the quality of water. Therefore, we need a system model that will allow to remote monitor the quality of water in real time and the collected parameters should be retrieved on a website by technician who is in charge of water quality and an automatic short message will be sent to him. This project is engaged in designing a system which will allow detecting the turbidity level and pH level contained in water tanks of WASAC organization. Once the abnormalities are sensed a short message will be sent to the technician who is in the charge of monitoring the quality of water.

In many developing countries, dirty or contaminated water is being used for drinking without any treatment. The records show that more than 14,000 people die every day worldwide. In 2019the report made by WHO (World Health Organization) estimated that, in Rwanda 29% of children under five years killed by diarrheal. The main reason for this is the use of unsafe water for drinking, for domestic working, for food production in industries and the lack of the system that can monitor the quality of water in real time which creates serious health issues.

1.3. Study Objectives

1.3.1. General Objective

The current method used to monitor quality of water in WASAC Company is time consuming. The general objective of this project is improving the way of monitoring the quality of water in WASAC organization by using Internet of Thing (IOT) and this system will be affordable, require low power consumption, offering high detection accuracy and will not require the physical presence of the technician on the site.

1.3.2. Specific Objectives

The specific objectives of this system are summarized in the following three main points:

- The first one is to support the technician of WASAC in charge of water quality to be capable to know if water that are distributing to the consumers are safe or note and this will be recognized remotely.
- The second is that this system will help technician to make a report easily and in real time and
- The last one is cost saving as it will reduce the need of fuel for circulating to different sites.

The implementation of this system will help people having water with quality for drinking or doing their daily life activities, therefore, this will facilitate them living in safe health.

1.4. Study Scope

The scope of this study should be implemented in Kigali city especially in WASAC organization at NZOVE branch (Nyabugogo) which is the one of the stations where WASAC make the treatment of water. This research project is limited to the treatment of physio-chemical parameters only regarding pH and

Turbidity parameters as they are the mains parameters that can cause too more consequences to the health of human.

1.5. Significance of the Study

This project makes a contribution to WASAC organization precisely in terms of helping in water quality monitoring (WQM) as it will help them to use this low-cost system in monitoring the quality of water in real time. This should be done remotely meaning without intervention of human, and this will reduce the movement of technician. Also, this system is beneficial to all people living in Kigali city as they will be able to obtain clean water in real time.

1.6. Organization of this document

The first chapter of this research work consists of an introduction. In this chapter we discussed about background and motivation, problem statement, study objectives (general objective and specific objective), study scope, significance of the study, organization of the study and the organization of the remaining work. The remaining part of this document is organized as follows:

Chapter 2 is about the literature review. In that chapter consist of some related work that discusses on different method used for monitoring the quality of water, then we briefly present the East African Standard (**about the specifications of potable water**) that show us the guideline of how we can achieve the best results and definition of terms. Chapter 3is the methodology used for implementing this research project. Chapter 4 is about system architecture, design and functionality; Chapter 5 is about the prototype, results and analysis and finally the last chapter presents the conclusion and recommendations.

CHAPTER 2: LITERATURE REVIEW

In this chapter we reviewed works of different authors in the area of water quality monitoring? We discussed about their different technologies that have been used, types of microcontrollers used, the communication protocols used, where the data should be stored. We discussed also the standard specification guideline for potable that have printed out by Rwanda standard -East African Communities (RS-EAC) and finally some technical terms used in this project.

2.1. Related work

Aanchal M. Pande and his team[6] developed the system to remote monitor the quality of water in the river and lakes based on IOT with the purpose of notifying the user in real time about water quality parameters. This system involves the use of sensors including turbidity, pH, Temperature to detect the contaminated water. The sensed data are processed by usingESP8266 Wemos which is a mini Wi-Fi -board based on ESP 8266EX .This board is considered as an Arduino IDE ,hence it can be programmed by using either Arduino or its particular Lua compiler[12]. Data are sent to the raspberry pi through WIFI module To improve this system one sensor which is pH sensor should be connected directly to the microcontroller which is Arduino UNO and Turbidity sensor should be connected to the another microcontroller which is NodeMcu ESP8266 , and once the collected data finish to be processed, they should be sent to the ThingSpeak and through IFTTT a notification should be sent remotely and automatically to the technician in the form of email message once the sensed data exceed the limit values required.

International Journal of Innovative Technology and Exploring Engineering(IJITEE) in December 2019[13] published a system to monitor quality of water based on IOT technology. Starting with analytical method they used sensors device to collect data from the tanks, Arduino and raspberry as computing device, BLE (Bluetooth low energy) and WIFI to send data to the server. This system also is expensive and requires human intervention. To make it inexpensive we need to develop a system that allow to monitor quality of water in real time by using Arduino UNO as a microprocessor and NodeMcu which in this thesis plays the role of microcontroller as well as a Wi-Fi module that helps to push the data to ThingSpeak.

Kevin Ashton[14] developed the concept of IOT applied in Water Distribution System (WDS) by using wireless sensor network(WSN), AI (Artificial Intelligent), and EH (Energy Harvesting) to monitor quality of water and give warnings to the user to take corrective measure. In this thesis the system is built in such way that the technician receives the warning through he/her email as notification, therefore depending on the measures receiving, she /he can take decision of going to the site for making treatment.

There were some books that present several sensors for measuring water quality parameters including temperature sensor to test coldness and hotness of water, turbidity sensor to test acidity contained in water, dissolved oxygen, conductivity and data can be accessed through use of internet on cloud computing. One method[15] was the use of Raspberry Pi as a core microcontroller which is run in Linux that require keyboard and monitor around. The drawback of this system requires human intervention for inputting data every time and output the reading on specified interval.

Mohamad Salah Uddin Chowdury et al.[16] Proposed a system that allows to remote monitor the quality of water with IOT (Internet of Things). Its design is about the use of wireless sensors networks (WSN) which aims at measuring parameters such as pH, dissolved oxygen, turbidity, and conductivity. The system involves the use of Arduino board which is mega 2560, sensors LCD for display and Wi-Fi module. Once the abnormal data is sensed the message will be sent to the authority. This system is good and is affordable but it needs some improvement, like using Arduino UNO as microcontroller, NodeMcuESP8266 as a Wi-Fi Module for sending data to the ThingSpeak.

Vashnavi V. Daigavane and Dr. M.A.Gaikkwad[10] proposed a system for monitoring quality of water remotely based on IOT. The system will use node MCU as microcontroller and sensors to collect data, WiFi that help the user to access data on internet. To update this system, we will use Arduino UNO and GSM to allow authority to receive message mobile phone.

K.K.Warhade[17] developed a system based on IOT to remote monitor the quality of water based on IOT which consist the use of sensors nodes placed in different production site of water and Wireless communication for connecting all selected location. Water parameters such as pH, turbidity, conductivity, are collected from the production and remotely sent to server. The collected data should be displayed on visual format on Pc server with aid of MATLAB and once the system sense abnormal parameter automatically will send a notification to a respective user in form of SMS. Some of disadvantages of this system include lack of alarms and NodeMcuESP8266 which has a Wi-Fi module which enable every sensor node that is emerged into the tank to access any Wi-Fi that is available

The work presented by Dong He et.al.[3][6]developed an IOT system consists of wireless monitoring network and remote data center. Microprocessor CC2430 is used as a core hardware platform. Every terminal node consists of turbidity, temperature and pH value. The WSN is built on ZigBee protocol. WSN samples the parameters data and by using GPRS DTU which has built in TCP/IP protocol the data is send to internet. The collected data is analyzed for further processing at remote data center through internet. This system is good but it is high cost.

According to T. Lambrou et al[1][6] he proposed the system to monitor quality of water by testing parameters such as conductivity, pH, turbidity, ORP(Oxidation -Reduction Potential), flow, and temperature. Sensors were connected to node PIC32MCU board, and sensed parameter were transmitted to ARM Platform via gateway to the internet after the email or SMS will be sent to notification node with use of ZigBee transceiver.

In India, the following were the system used to remote monitor the quality of water[18]:

Eco Mapper: This is an autonomous vehicle submerged into water for measuring the quality of water in rivers. One of the disadvantages of this method is its life span which varies in the range between eight hours and fourteen hours on the speed of 2-4 knots.

The second method was the use of Robotic Fish for measuring the level of oxygen contained in water. Disadvantage of this system is that the battery can be low when the system is still working.

Another method is the use of digital camera placed under water to monitor the movement of protozoa contained in water sample. The drawback of this method is the inability to measure the level of contaminants in water without analysis. All these systems are not affordable.

A.N. Prasad et.al[19] developed a smart water quality monitoring system in the Fiji Island located in the vast Pacific Ocean by using the internet of thing (IOT) with remote sensing(RS) methods. The purpose of this system was to measure various parameters including Potential Hydrogen (pH), Oxidation and Redaction Potential (ORP), Conductivity and temperature by using a remote sensing technology.

Ms. Ch. Sowmya et.al[20] also developed the system for an online monitoring the quality of water in real time by using a Wireless Sensor Network(WSN) technology. The system was able to measure parameters such as pH, Temperature and Conductivity in the overhead tanks, in the distributing pipe and in the river. The system was composed by the sensor nodes consisting by Arduino microcontroller, Xbee module, Graphical user interface (GUI) and sensors for collecting the desired parameters. The measured values are supposed to be sent to the data center as they collected from different locations.

Aanchal M. Pande et.al [6]designed a system for remote monitoring the quality of water in real time based on IOT. The system was developed to offer safe water for drinking for housing tank society. Parameters designed to be detected are Potential Hydrogen (PH), Turbidity level, Temperature and Humidity. Sensed data are sent to the ESP8266 Wemos d1 Mini for processing, and the processed data are sent remotely to the raspberry pi via Wi-Fi, and with this, it will allow the raspberry pi to show information on a single graphical interface on diverse time of period.

S. KaviPriya et.al[21] have developed a low cost system for remote monitoring quality of water using wireless sensor network and internet of things(IOT). The system was capable to measure parameters like pH (Potential Hydrogen), Turbidity, conductivity, Temperature and Oxidation Reduction Potential (ORP). Once the polluted water is sensed, the sensing unity together with ZigBee sends the indication to close the valve in the pipeline in order to avoid the movement of contaminated water supply to consumers.

2.2. East African Standard

RS-EAS (Rwanda Standard East Africans Standard)[22] in its edition made in 2018 has developed the standards about potable water that should be followed by all EAC (East African Community) in order guarantee the delivery of safe and quality of drinking water for human . This edition shows the characteristics of the microbiological and that of physico-Chemical parameters that should be measured in water for maintaining its quality and show the standard limits (SL) for pollutants that can affect safety and water quality of drinking water for each parameter.

Table1 shows the various physico-chemical parameters together with their standard that could be treated in order to make it safe:

NO	Parameter	Treated potable water limit	Natural potable water limit
1.	Colour TCU, Max	15	20
2	Turbidity, NTU, Max	5	20
3	pH	6.5-8.5	5.5-9.5
4	Conductivity MS/Cm, Max	100	250
5	Suspended Matter, mg/l	Not detected	Not detected
6	Total dissolved solid/mg/l, Max	1000	1500
7.	Total hardness, as CaCo3.mg/l	300	600
8.	Aluminum (AI), mg/l, Max	0.2	0.2
9.	Chloride (Cl), mg/l, Max	250	250
10.	Total Iron	0.3	0.5
11.	Sodium (Na), mg/l, Max	200	200
12.	Sulphate (S_{04})	400	400
13.	Zinc (Zn) mg/l, Max	5	5
14	Magnesium (Mg), mg/l, Max	100	100
15.	Calcium (Ca),) mg/l, Max	150	150
16.	Potassium(K), mg/l, Max	50	50

Table1: Physico-chemical parameters

Table 1 show that to monitor the quality of water, there are various parameters to be treated. But it is found that some parameters are correlated one to another. This thesis focuses to only two parameters which are pH and turbidity because these parameters enclose others. so, once they are treated well you can ensure that the quality of water is successful[23].

2.3. Definition of Terms

In this thesis there are technical terms that should be explained more. Those are Node Mculolin v3 ESP8266, IOT. ThingSpeak, pH sensor, turbidity sensor, water quality/potable water.

2.3.1. NodeMcuLolin v3ESP8266

NodeMCU V3 is an open-source firmware and development kit that plays a vital role in designing an IoT product using a few script lines. NodeMCU V3 ESP8266 has a number of GPIO Pins. Following figure shows the Pinout of the board.

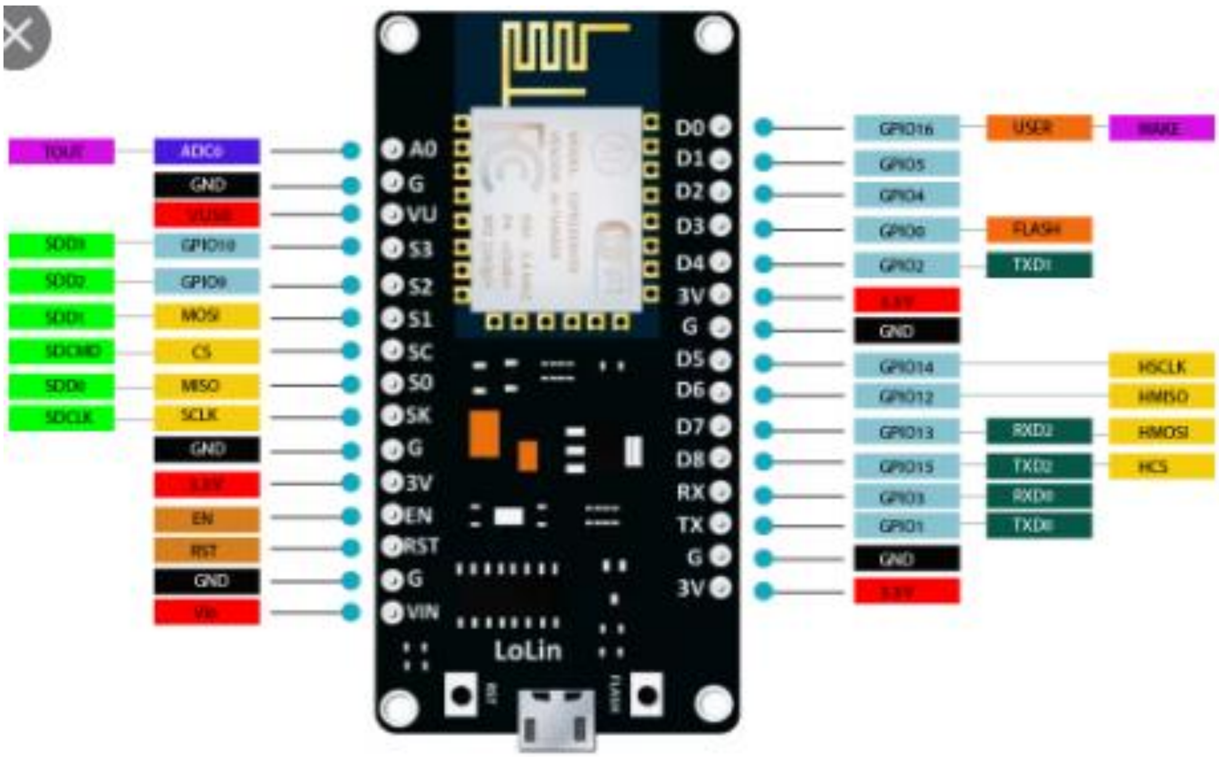


Figure1: NodeMcu Lolin v3 pinout

Numerous GPIO (General purpose input/output) pins on this board allow us to connect the board with other peripherals and are capable of generating PWM, I2C, SPI, and UART serial communications. The interface of the module is mainly divided into two parts including both firmware and hardware where the former runs on the ESP8266 Wi-Fi SoC and the latter is based on the ESP-12 module[24].

There is a candid difference between Vin and VU where the former is the regulated voltage that may stand somewhere between 7 to 12 V while the latter is the power voltage for USB that must be kept around 5 V.

Feature of NodeMcu lolin v3 ESP8266 :

1. It is an Open-source
2. NodeMcu is a hardware like Arduino
3. MicroUSB port
4. It has Reset/Flash buttons
5. It is Interactive and Programmable
6. It is Low cost
7. It is ESP8266 with inbuilt wifi
8. USB to UART converter amd GPIO pins

9. Advanced API for hardware IO, which can dramatically reduce the redunwork for configuring and manipulating hardware.
10. Offers Greatly speed up your IOT application developing process.
11. Lowest cost WI-FI
12. Less than $2 WI-FI MCU ESP8266 integrated and esay to prototyping development kit.
13. We provide the best platform for IOT application development at the lowest cost.
14. I/O pins can work only at 3.3V
15. It has 17 GPIO (General Purpose Input Output) pin.

2.3.2.ThingSpeak

ThingSpeak is defined as a Web Service (REST API) that lets you gather and store sensor data in the cloud and develop Internet of Things applications. It is an IOT analytics platform service that is used for collecting and storing sensed data to the cloud and it is mostly work with an internet of things application. ThingSpeak also provide a service that allow someone to perform online analysis[25]. The sensed data can be sent to ThingSpeak from any hardware that can communicate using a REST API. REST in full words is representational state transfer, and API is Application Programming Interface. In this thesis The ThingSpeak API as an open-source interface which listens to incoming data, timestamps it, and outputs it for both human users (through visual graphs) and machines (through easily parse-able code).

To connect any object to the IoT, this may require two main parts; those are the part of hardware and the part of software. In this project we the part of hardware include Arduino UNO, NodeMcu, and sensors while on the part of software we discussed about ThingSpeak and IFTTT. The data sensors should be uploaded to the network, this network in this project refers to cloud API, which is an interface that provides a simple communication capability to the object within an IOT environment. This technology allows changes to be made to the 'virtual' server either on the part of software update or any changes in storage space.

The IoT brings everything together and allows us to interact with our things and, even more interestingly, allows things to interact with other things. In this project we have connected object via ThingSpeak API. ThingSpeak allows us to build applications around data collected by sensors. It permits data to be collected in real time, data processing, and it allows simple visualizations for its users. Data are stored in the channels which provide the user with a list of features. Each channel in ThingSpeak allows the user to store up to 8 fields of data, using up to 255 alphanumeric characters each. All incoming data is time and date printed and receives a sequential ID. Once a channel has been created, data can be published by accessing the ThingSpeak API with a write key, a randomly created unique alphanumeric string used for authentication. So, a read key is used to access channel data in case it is set to keep its data private. Channels can also be made public in which case no read key is required. When we say things is an object given to the sensors for collecting the data. Data is sent and received via simple **Hypertext Transfer Protocol** (HTTP) POSTs, much like going to a web page and filling out a form. This communication happens through plaintext, JSON or XML. The data is then uploaded to the cloud and from there can be used for a variety of purposes. The figure below shows how API works in case of ThingSpeak website.

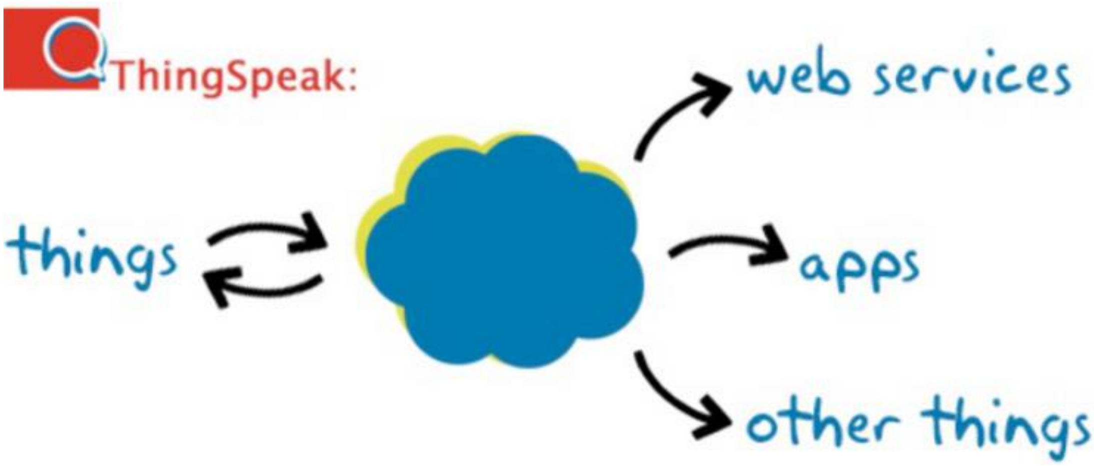


Figure2: A ThingSpeak representing itself as a cloud interface[26]

When a device sends data through a HTTP request (communication), it is processed by the IoT service (in this case ThingSpeak), which communicates with a virtual server. Both the server and the IoT service communicate directly with the application.

2.3.3. pH sensor

Normally we define pH as a combination of two different terms, those are p which belong to mathematics and H which belong to chemistry. The alphabet p written in lower case in mathematics represent the negative logarithm coefficient, and alphabet H written in capital letter represent the concentration of hydrogen ion. Measuring pH is essential as it helps in judging the level of acidity or alkalinity in a certain aqueous solution[27]. The formula is pH=-log [H], where H is hydrogen ion concentration and it is expressed in gram mole/litter or simply H+/L.

The type pH sensor that is used in this project is called Liquid pH 0-14 value detector sensor module. It is use for measuring the quality of water and it is scaled in the range from 1 up to 14. Pure water should have

7, when the measurement shows the values less than 7 this indicate acid, above 7 it indicates basic or alkaline and drinking water is ranged between 6.5-8.5 [28].

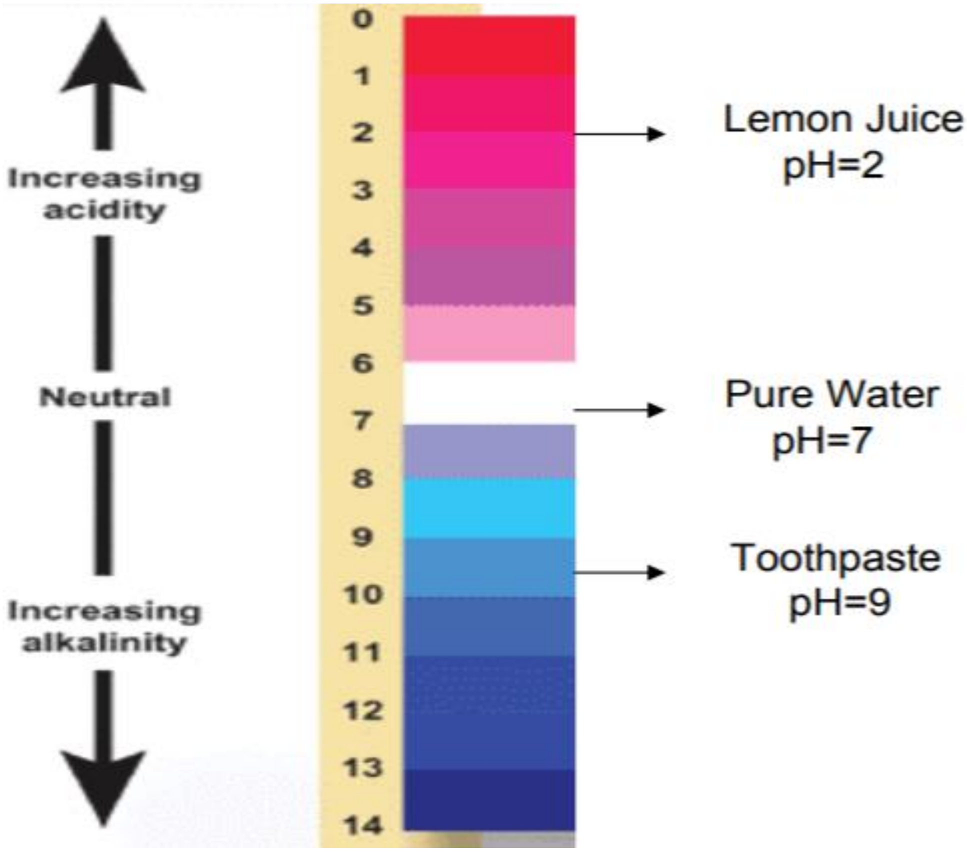


Figure3: pH determination[29]

In the figure3 demonstrate the determination of water when doing a testing of water quality in different aqueous solution. Generally, pH value is specified in the range 0-14pH. In the center of figure3 pH is 7; these waters are pure and neutral. From4 to 1 there is an increasing in acidity, from 10 to14 there is increasing alkalinity.

Figure4: pH sensor

The specification of this pH sensor is following:

- Power voltage: 5v
- Measurement range:0-14pH
- pH sensor Work with BNC (Bayonet Neill–Concelman) connector.
- Best environment temperature is 25^0c
- Module Size: 43 x 32mm (1.69×1.26″)
- Measuring Temperature: 0 – 60 ℃
- Response Time: ≤ 1min
- Power Indicator LED
- Typically, the output voltage is ranged from-430mv to+430mv[30]
- 430mv output voltage is converted to the range of 0 to 3.2v for the purpose of interfacing it with the microcontroller ADC module.
- pH 0 = +414.12m0V (Acidic)
- pH 4 = +177.480mV (Acidic)
- pH 7 = 0.000mV (Neutral)
- pH 10 = -177.480mV (Basic)
- pH 14 = -414.120mV (Basic)

In the table 2 shows the reference about the conversion mill volt to pH value:

Voltage (mV)	pH value	Voltage (mV)	pH value
414.12	0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00	-295.80	12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00

Table2: Conversion of voltage to pH value[31]

In the table2 there is the specification about the pH values that should be obtained in water quality monitoring system (WQMS) with different type of liquid.

Liquid	pH value
Lemon	2.2
Tomato juice	4.13
Tap water	6.85
Distilled water	7
Soap water	11.8

Table3: pH values in WQMS specifications

2.3.4. Turbidity sensor

Turbidity is defined as the amount of cloudiness in the water. Turbidity is caused by many factors such as silt, mud, sand, bacteria, germs and chemical hasten .Turbidity is usually measured in nephelometric turbidity units (NTU)[32]. The turbidity sensor is based on transmission and 90◦ scattering variations with the total suspended particles in a solution[33].

Figure5: Turbidity sensor COM42

Feature of Turbidity sensor

- Its working voltage is DC5V
- The output way is analog output 0-4.5v
- Operating temperature -30^{o}C-80^{o}C

- Operating Current: 30mA (MAX)
- Response time: <500ms
- Insulation Resistance: 100M [Min];
- the output way: high / low signal (High: 5V, Low: 0V)
- Storage temperature: -10-80^{o}C.
- Weight: 55g
- Size: 30mm * 20mm * 12mm

2.3.5. Water Quality

Water quality is defined in three terms, such us chemical, biological and physical features of water with respect to its suitability for intended usage. Water need to monitored as it is an essential element for all living things[34].

CHAPTER 3. RESEARCH METHODOLOGY

3.0. Introduction

This chapter describes ~~t~~he methodology that was used to address the research problem, research area, method used for collecting data and an IoT based water quality monitoring system.

3.1. Research area

The research area of this study is in Kigali. Kigali is comprised by three districts, including Gasabo, Nyarugenge and Kicukiro. Nowadays, Kigali city is highly dominated by a greater number of population due to different factors like too many people who prefer to move from rural areas to urban, people from outside the country who prefer to implement their business in Rwanda, all those causes provoke Kigali city to be more saturated. According to the values published by MININFRA in 2012, the number of people who lived in Kigali city was estimated to10.7% of all Rwandan population, while in this vision 2020, that value is doubled[35].This means that as the is an increasing values of population in the city ,the need of water with quality is required in order to prevent diseases.

Figure6 shows the map of Kigali City with three districts and its surrounding**:**

Figure6: Map of Kigali City

Due to the increasing population in Kigali city, it is understandable there are too much waste that can lead to water contamination. Furthermore, water as it is the basic need for people, its quality is needed to be monitored at the high level to ensure the health of people safe, that is why this study emphasis to Kigali city to see how to remote monitor the quality of water in real time. We gathered the information that can providing how to implement this system through an online interview and questionnaire with WASAC technician in Kigali. He provides us the main parameters they measure and their standard limit[22].

3.2. Case study

In short, a case study is defined as the one of the strategies that the researcher can use in his/her research methodology for the purpose of understanding more about the phenomena that she or he is studying. Some of the strategy used in case study includes, psychology, sociology, political science, social work and business. In additional, case study may use naturally current information sources such as people and interactions between people within the scope of the case[36]. In this project we have considered our case study to WASAC Company as it is the company which is charge of controlling and monitoring the use and the distribution of water to people in different areas. Based on the current methodology that WASAC is using in monitoring the quality of water, this study aimed at demonstrating the method of monitoring the quality of water in real life and it is done automatically and remotely and this project has implemented through prototyping.

3.3. Data collection

The primary methods used for collecting the data involves questionnaires, interviews, focus group interviews, observation survey case study etc**.**[37]. In this thesis the methods used for collecting data includes, questionnaire and interviews.

1. **Questionnaire**: This method used for gathering information preparing a set of questions and give them to the responder.
2. **Interviews**: This also the method use for collecting data by asking the question to the interviewee orally. The person who asks the question is called interviewer. The interview can be made in different form such as individual, face to face interviews and face to face group interviewing. Asking questions and answering them can be arbitrated by telephone or any other electronic devices for example a computer.

All these above methods both interviews and questionnaire have been applied in this thesis, a set of questions has been developed, and it was given to the technician of WASAC in charge of water quality in Kigali and it was sent to him through email. Interview also was use in this research through telephone and face to face.

Based on the information collected through the interview made and, in the responses received from the questionnaire, WASAC in these days is on the level of monitoring different water quality parameters including pH, Turbidity, temperature, Mn, Fe, E, coli, Total coliforms, salmonella, etc. All these parameters are tested in the laboratories with water sampling. Continuing on these methods used testing quality of water; an online water quality testing is needed to help testing of various parameters automatically and in real time.

3.4. IoT based water quality monitoring

This project aims at demonstrating the method of real time monitoring the quality of water in tanks of WASAC installed in different locations in Kigali city in order to offer safe water to people in real time. WASAC company has the ability to monitor various parameter, in this project we have been focused only on measuring two parameters, pH and Turbidity as they are the main ones that can provoke too many diseases to people[38].

The system requires some hardware components like sensors, Arduino UNO as a microcontroller, tanks, mobile phone, node MCU ESP8266 Module and laptop. Sensors should be plugged in water tanks for collecting the required parameters and send them to Arduino and the sensors that will be used includes turbidity sensor for detecting suspended particles contained in water tank and pH Sensor for measuring the level of acidity or alkalinity contained in a water tank. Arduino UNO is a microprocessor that will accept data collected by the sensors and process them. The sensors will be connected to Arduino via wired communication. The system uses Node MCU ESP8266 as a communication technology to allow the detected data to be sending to the ThingSpeak (a platform of a cloud) which is place for storing all the detected data from the selected tanks and to allow the message to be sent to the technician. The system also has used Arduino language for writing the codes for programming and uploading them in order to visualize that to serial monitor. The system functions automatically and independently according to the code uploaded to the microcontroller.

CHAPTER 4: SYSTEM ARCHITECTURE, DESIGN AND FUNCTIONALITY

In this chapter we describe the designing system of the project, how the system is functioning, how the sensors are interfacing with the microcontroller, how this board is connected to NodeMcu ESP8266 and the system technology used.

4.1. System design and functionality

The system consists of numerous numbers of tanks; tank 1, tank 2 and tank n of WASAC that are placed in different location in Kigali city. The system is designed in a way that each tank has its own sensor node means turbidity and pH sensors plugged inside it and its own Arduino UNO board for the processing. Once the sensors sense any parameter either turbidity, or pH parameters the data collected will be sent to Arduino UNO for processing; and processed data should be sent to the ThingSpeak (which is an IOT analytics platform) via node MCU ESP8266.ThingSpeak can be used to store data in a private channel, but when you want to share data to someone, we create what we call an IFTT (IF THIS THEN THAT) which a web service that allow different applications and devices to be connected. IFTTT can be defined as a very known simple programming platform where their applets can control more than four hundred (400) services of IoT devices and web applications[39].Mostly the role of IFTTT is to allow end user(here end user is the technician of WASAC)to get the channel that can allow him/her to automatically receive the email-message showing the condition or state of water[40].

ThingSpeak can be defined as an open source IOT application and API that is intended for storing and retrieving data from hardware devices and different instrument like Sensors. This technology uses HTTP protocol over the internet or LAN for its communication. The MATLAB analytics is included to examine the data received from the hardware or sensor devices.

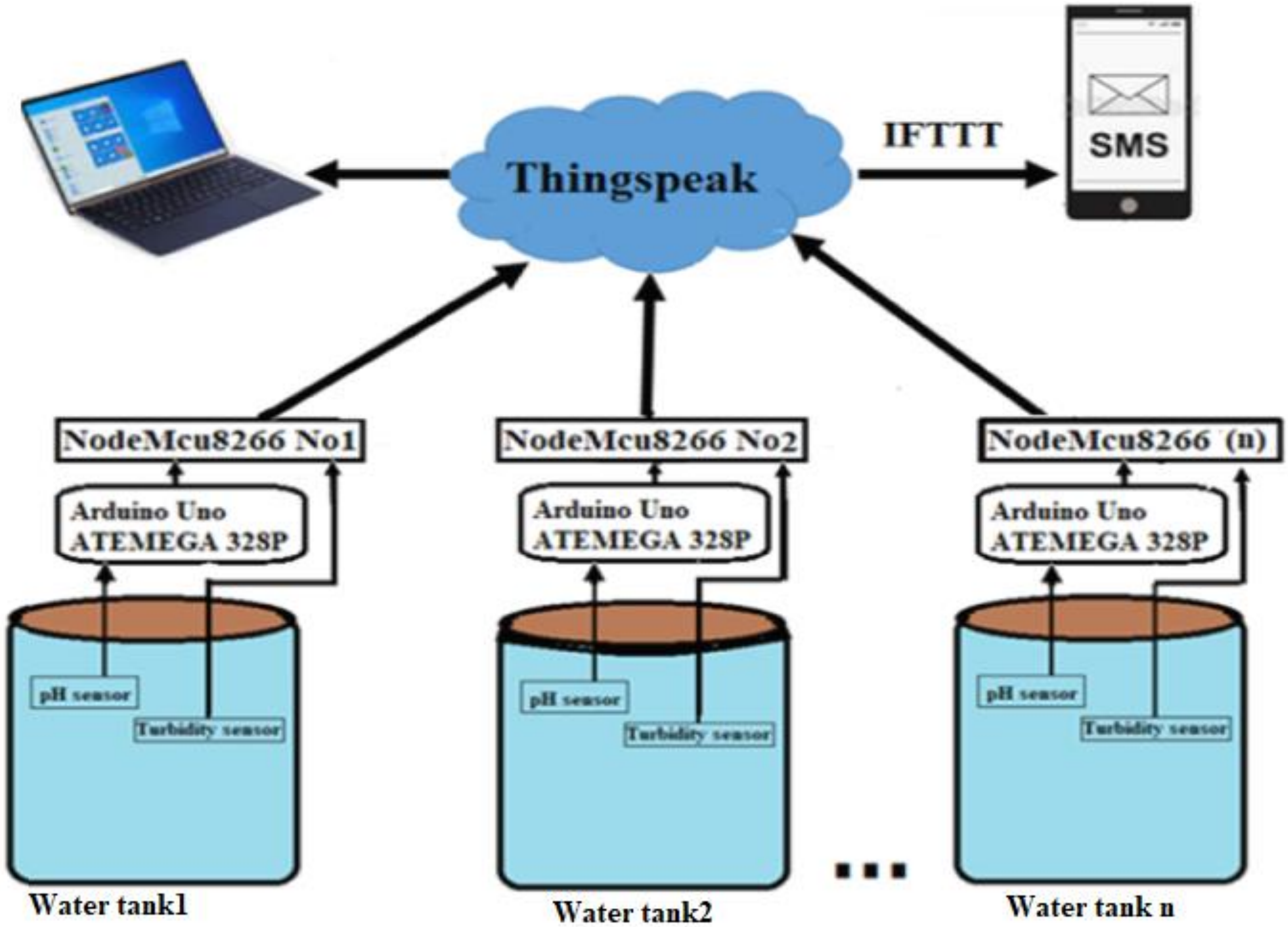


Figure7: Block diagram of the system

The above figure shows how the system is functioning. The working principle of one tank is similar to others tanks. Generally, the arrowhead drowns in this design indicate the follow of information from one step to another. The system is designed in a way that numerous tanks shall be controlled and monitored regularly. Data that are collected in the tanks by pH and Turbidity sensor are sent to Arduino UNO and NodeMcu respectively. Arduino processes data from pH and after processing they should be sent to the NodeMcuESP8266.Thisboard takes both data from Arduino and Turbidity and pushes them to ThingSpeak via a Wi-Fi module. The microcontroller NodeMcu ESP8266 has a WIFI Module which enables it to send data to the ThingSpeak and it is capable of being connected to any Wi-Fi located in any given area. In this project where technician can access data through a website or receive an SMS on his or her email. The laptop here shows that technician will use it to access data through their website with internet connection.

4.2. Hardware and Software requirement

4.2.1. Hardware part

NodeMcu ESP8266	Microcontroller
Arduino UNO	Microcontroller
pH	Sensor
Turbidity	Sensor
Jumper wires	Males and Females
Breadboard	For connection

Table4: Hardware components

The hardware components that were used in this project are explained here below:

a) **pH sensor**: The pH in full words means Potential Hydrogen. This sensor will be used for measuring the level acidity or alkalinity contained in a water tank, and then the measured values will be sent to the Arduino UNO for processing. pH is scaled in the range from 1 to 14, normal water is scaled from 6.5-8.5, below 6 this indicate that has more H^+ which means acid, if the values of pH is above 8.5 this indicate that water contain basic. pH sensor is not available in proteus software that will help me in simulation, this sensor will be replaced by a potentiometer sensor.

b) **Turbidity Sensor**: Turbidity is defined as the amount of cloudiness in water. The turbidity is caused by too many factors like sand, salty, mud, bacteria and other germs, and chemical causes[32]. This sensor measures the level of suspended particle contained in water that are caused by the clay soil particles, mood and small metals that can travel with water during water distribution. The data sensed will be sent to the microcontroller which is Arduino UNO. Mostly turbidity indicates the clearness and transparency of water. The unit of turbidity is Nephelometric Turbidity Unit (NTU) and the normal range is scaled from 0 to 5NTU. It is considered as an important parameter to be measured in the water quality monitoring system. Drawback of turbidity in water include increasing temperature of water and reducing its clarity, this means that too much suspended particle can provoke temperature in water to be high. The turbidity sensor can work as proximity sensor, as turbidity is measured using LED (Light Emitting Diode) as a transmitter and photodiode as a receiver but, proximity sensor has both transmitter and receiver at the same time. The level of turbidity increases as the reflection of light becomes less. In simulation turbidity sensor will be replaced by LED together with photodiode or proximity sensor.

c) **Arduino Uno**: Arduino is a microcontroller board based on the ATmega328P. It is used for processing data from the sensors. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP(In Circuit Serial Programming) header and a reset button[41].

Figure8: Arduino UNO R3 BRD41

The main features of Arduino UNO are:

- Microcontroller: ATmega328
- Operating voltage:5v
- It has I/O pins:14
- Analog input pin:6
- DC Current per I/O Pin :40mA
- DC current per I/O pin :50Ma
- Flash memory:32KB
- Clock speed :16Mhz

d) **Mobile Phone**: This is the communication device that the technician will use for receiving a message.

e) **Breadboard:** The purpose of the breadboard is to make quick electrical connections between components.

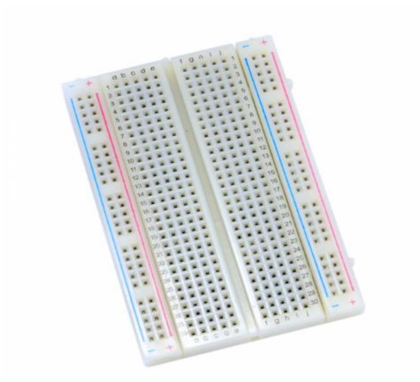


Figure9: Solderless breadboard

f) **Jumper wires**

In this system both wires, Males and Females have been used.

f) **NodeMcuLolin v3 ESP8266**: This I an open source firmware WIFI internet expansion board that is used in prototyping IOT project with Arduino or in LUA.

Figure10: NodeMcu Lolin v3 ESP8266 WIFI Internet Development Board BRD 46

The flowchart showing the system of remote water quality is indicated here below:

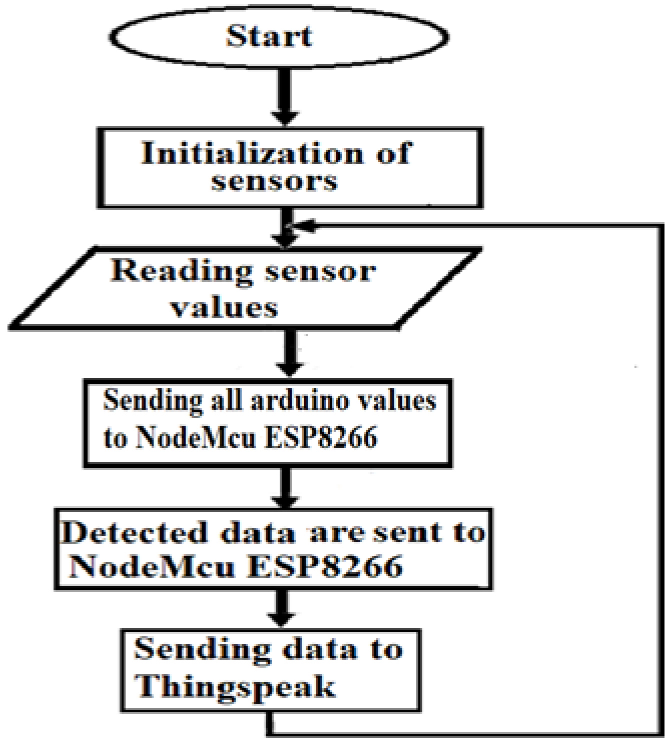


Figure11: Flowchart of water quality monitoring

In the **figure11**above flowchart shows the process of how we can remote monitor the quality of water in a given tank. The fest step will be initializing sensors in the tank. As this project concern with remote monitoring the quality of water from different tanks, all the selected tanks whenever there are located will follow this step. The second step is that the sensors will read the data and send them to Arduino for processing. After processing the values are sending to the NodeMCUESP8266 which is in return send the data to the ThingSpeak. The system provides an endless loop. In ThingSpeak I have to create a public channel that allow me to share data to the technician of WASAC in charge of water quality so that he or she can access data via internet connection or receive a short message on his or her email. Technician after receiving a message, it's up to him to take a decision depending on the data received. Normally, the turbidity values for safe water can relies in the range of 0-5 NTU, pH values for drinking water varies between 6.5 up to 8.5 pH beyond this limited range water are polluted; below 6pH we say that water has acid, above 8.5ph water has alkaline and once acid or alkaline are contained in water they can cause the health problem to human being. Recognize that this is an endless program once it finishes to sense for the first part it will continue that is shown by the arrowhead from ThingSpeak to the reading sensor value indicates.

4.2.2. Software

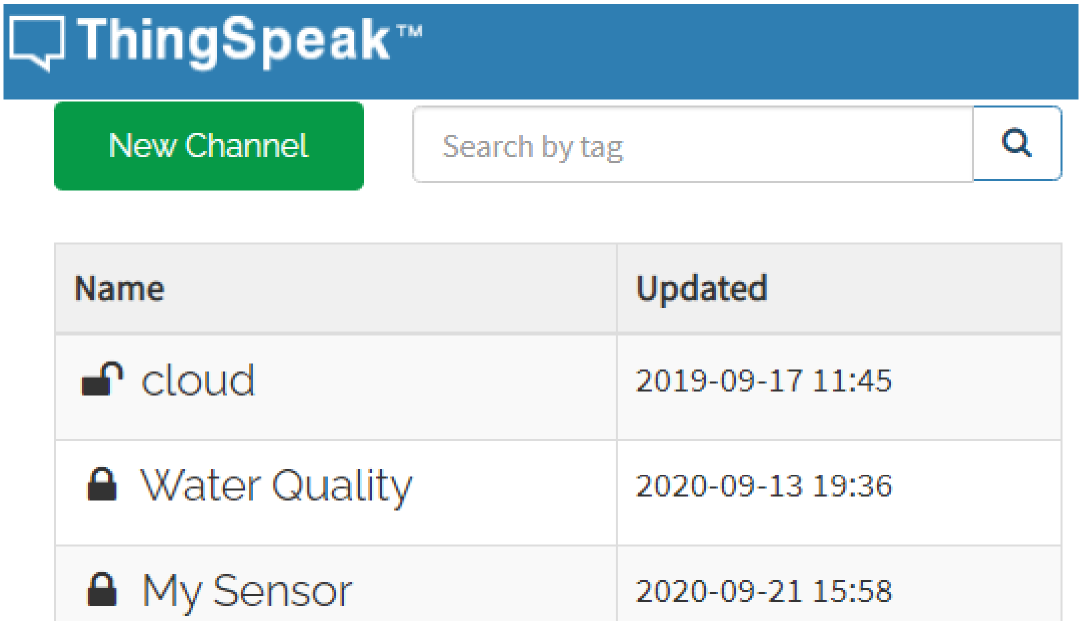
This thesis has provided two parts of software, the first one is the Arduino IDE and the second is u ThingSpeak together with of IFTTT.

1. **Arduino IDE**: Arduino IDE is used to program Arduino UNO and NodeMCU. It is open-source software that is mainly used for writing and compiling the code into the Arduino Module. Both Arduino UNO and NodeMCU are connected through serial communication in Arduino IDE.
2. **ThingSpeak& IFTTT**: Currently**,** ThingSpeak is an IoT platform which permits someone to gather, visualize, analyze live data and react according to it. ThingSpeak is an open source application initially launched in 2010 by a Bridge. It facilitates one to build IoT systems without need of setting up extra servers. The data collection is done using REST API or MQTT. MQTT is written as a Message Queuing Telemetry Transport and it a protocol used for exchanging messages among devices. It is often used in IOT[42]. The data analysis and visualization are done using MATLAB analytics. ThingSpeak provides apps that allow us for an easier integration with the web services, social networks and other APIs. It includes Thing Tweet app to tweet alerts and messages, Tweet Control app which respond to tweet having some trigger words, Time Control App to perform or schedule some specific actions, react app to do some actions when some conditions are met, Talkback app to send command to devices and Thing HTTP app to interface with various web services and APIs. The main component of ThingSpeak is its channel which stores data send from various devices. Each channel can save up to eight fields along with device location, URL etc. The channel can be made public which can be seen by other users or private who need the API key to view the data. The private channel can be shared for some specific users[43].

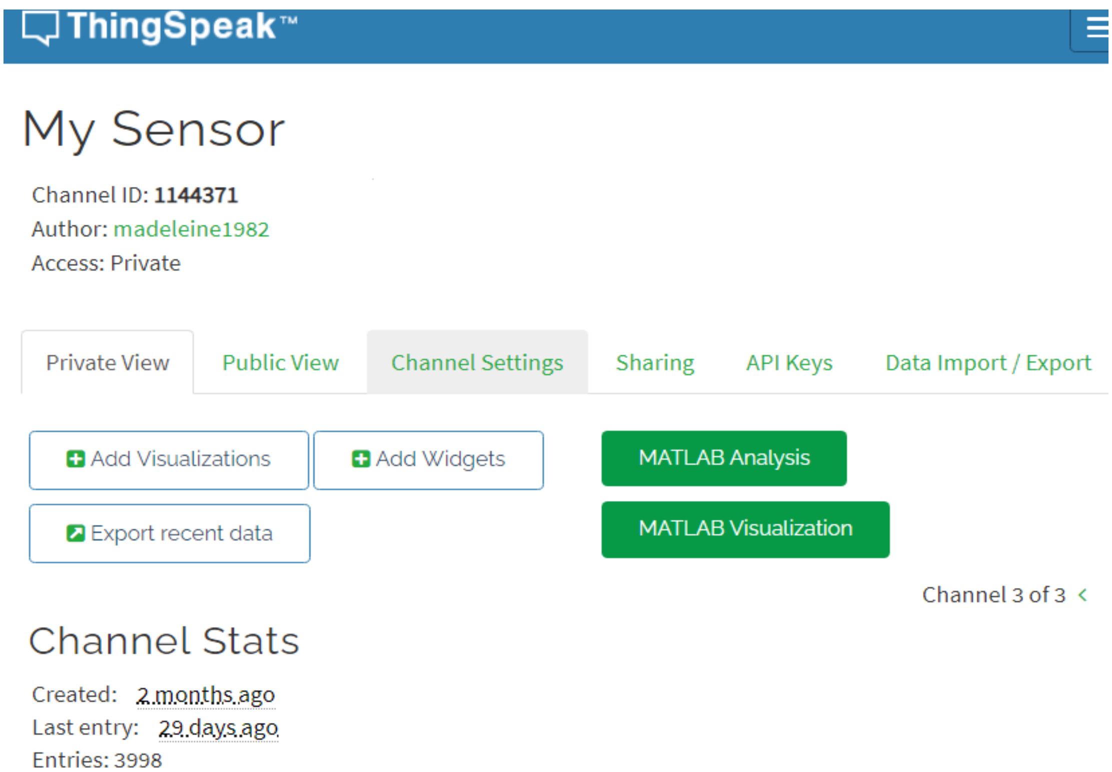
In this project ThingSpeak which is an open source together with API helps the user to store, visualize and analyze the data from devices. The data collected by pH sensor and Turbidity sensor are sent to Arduino UNO and NodeMcu respectively, which in return sent to ThingSpeak for being analyzed, stored and visualized. With IFTTT technology the Technician is able to retrieve the data in the database of ThingSpeak and will be to receive an automatic email message as notification once the abnormal parameters are sensed.

For achieving an API, we start by creating a channel. Below are the steps proceeding and that have been used in this project is called My Sensor as chow below.

Step1: Creating a channel in ThingSpeak

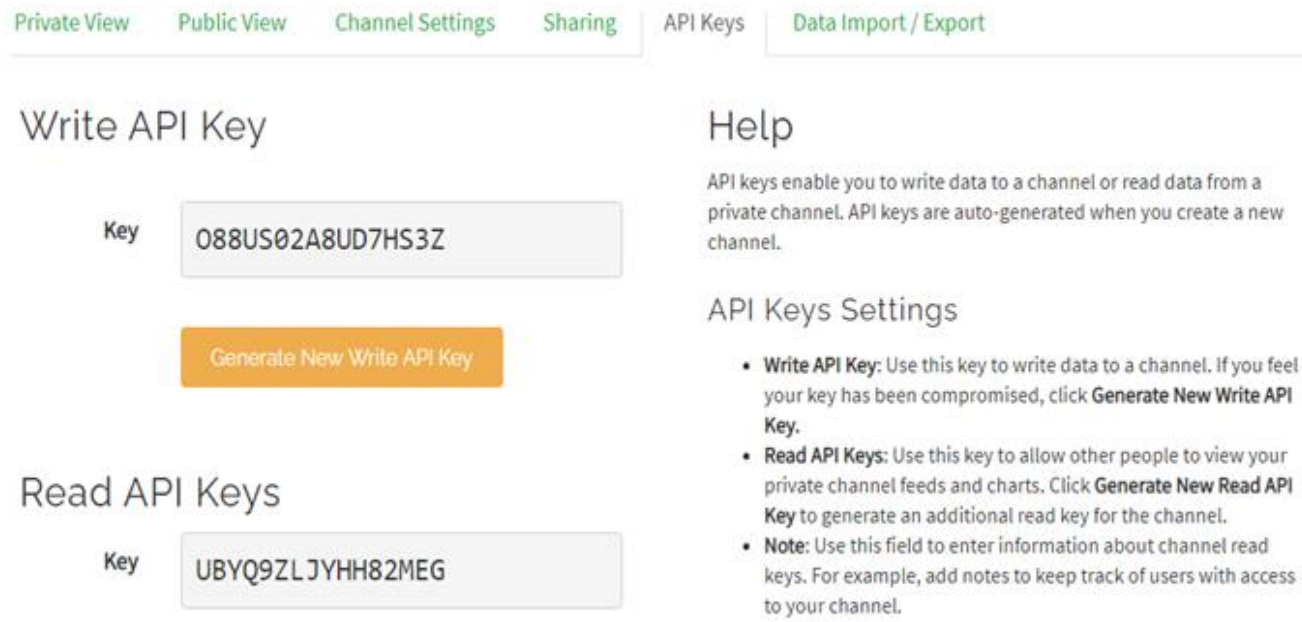


Step2: By clicking my sensor we get



Step3: Click on API Key in the tab for viewing the Write API key and Read API Keys

IFTTT is a web service that allows users who have the internet on the mobile phone or laptop to c



IFTTT is a web service that allows users who have the internet on the mobile phone of laptop to connect between web services and retrieve the required information. IFTTT allows the users to create chains of conditional statements triggered by modification made that occur within other web services. To accomplish their tasks, the applets are used as a result of combinations of various services connected together. To achieve the result IFTTT has created chains (called applets) and these ones are connected to ThingSpeak and once the system meets the conditional statement the alert notification is sent to the Technician through email. The picture below shows the email that I received after creating an account in IFTTT.

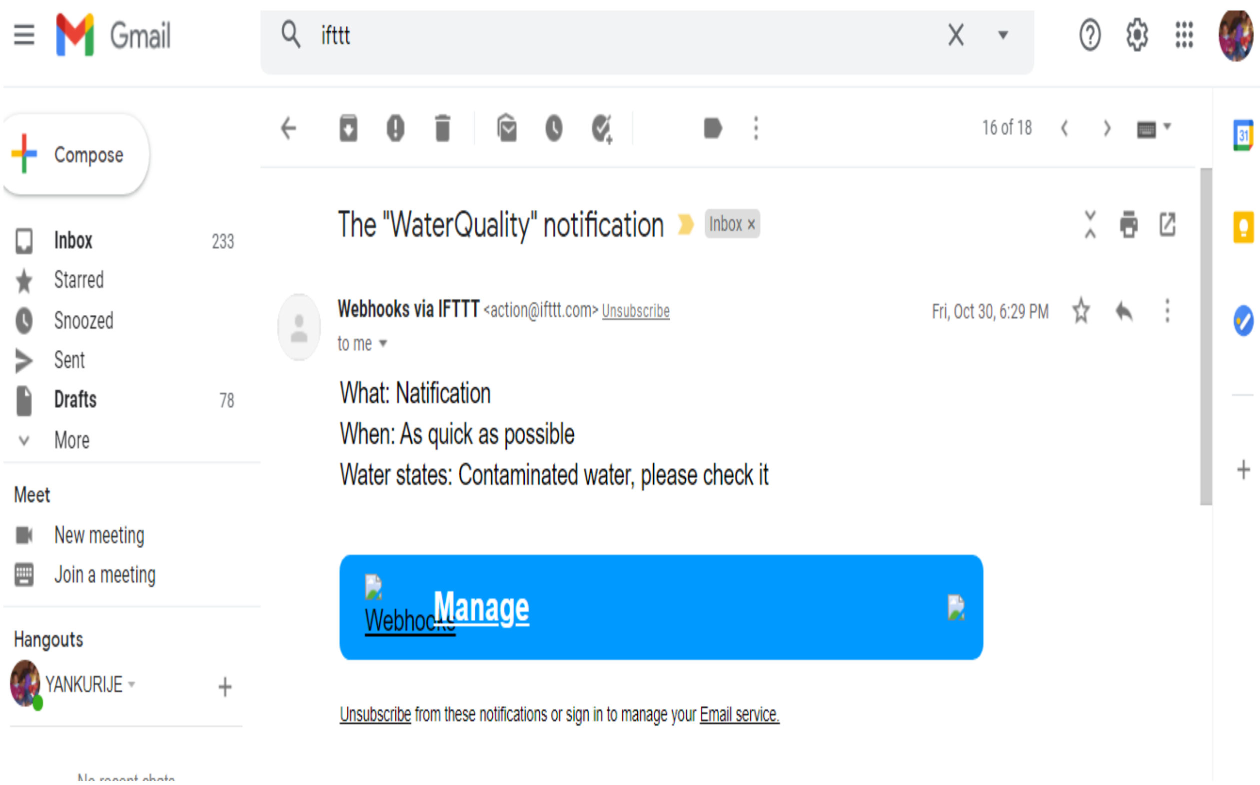


Figure12: Notification of Email message format

4.2.3. ThingSpeak Features

- ✓ Collect data in private channels
- ✓ Share data with public channels
- ✓ Restful and MQTT APIs
- ✓ MATLAB analytics and visualizations
- ✓ Event scheduling
- ✓ Alerts
- ✓ App integrations

4.2.4. Flowchart on the part of Network

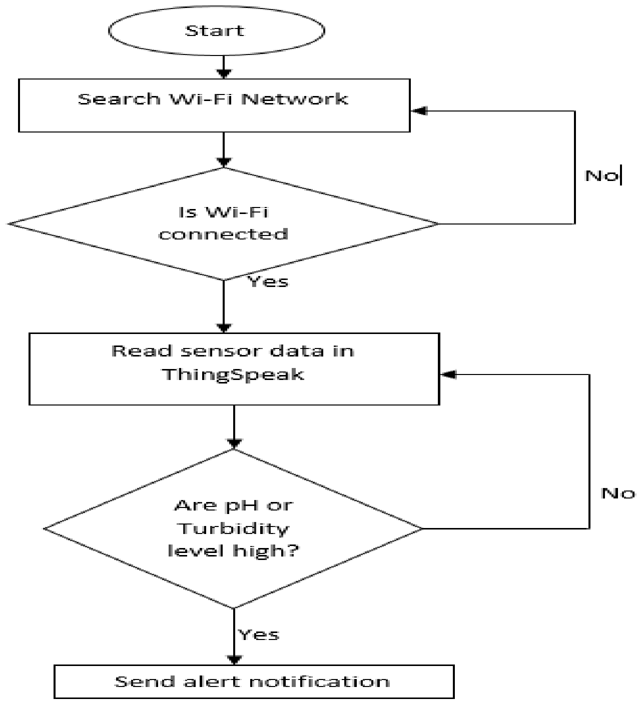


Figure13: Flowchart of water quality monitoring on the part of software

Figure13 is the flowchart shows that on the part of network, it is necessary to check if the network is available. If it is yes, the system will send the sensed data to ThingSpeak; if it is No return back to the search wi-fi. When the data of pH or Turbidity are high, the system sends alert notification to the technician through IFTTT.

Below there is a table that show the standard values for water quality parameters of pH and Turbidity sensors.

Water quality parameter	Standard values range and unit
pH	6.5-8.5
Turbidity	0-5 NTU

Table5: Water quality parameter standard values

CHAPTER 5: PROTOTYPE, RESULTS AND ANALYSIS

In this chapter we describe prototyping, interface of sensors to Arduino, the result and analysis of the data obtained on the serial monitor and how the data are transmitted to the ThingSpeak, the interpretation of the data in ThingSpeak and the End- user can receive an email message by using IFTTT technology

5.1. Prototype

Prototyping is an important part in the development of any organization company that allow the researcher to demonstrate what he/she want to do on her/his study by using the inductive ethnographical observation for making the study more understandable and it can help the research to do the analysis of the data[44].

The image below shows a prototyping about my project. Turbidity sensor is plugged into dirty water for measuring the level of suspended particles inside the water. pH sensor is plugged into clean water for measuring the level of acidity or alkalinity contained in water tanks or checking if it is pure water.

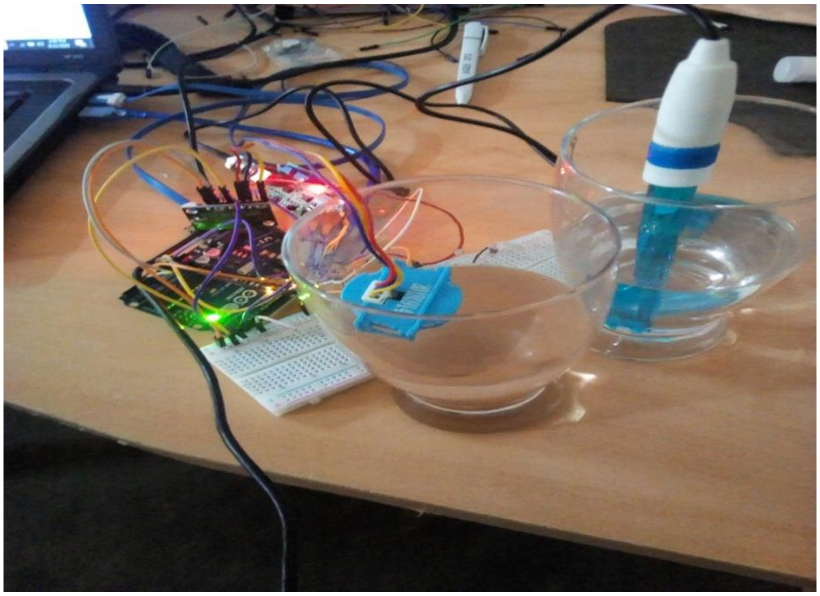


Figure14: Prototype Testing

The system comprises hardware devices including use two microcontroller board, one is Arduino UNO and another one is NodeMcu ESP8266.NodeMCU has only one pin for analog data that is why Arduino is integrated here for analog data expansion as all the sensors used in this system are analog input. Other hardware devices used include also Turbidity sensor, pH sensor, USB cables, breadboard, two glasses containing water sample (one contains clean water, another has dirty water) and jumper wires. pH sensor is connected to Arduino UNO while Turbidity sensor is connected to node MCU ESP8288.

5.1.1. The interface of pH sensor to Arduino UNO

Analog data Po on pH is connected to A2 of Arduino UNO, ground to ground and VCC to VCC

pH pins connectors	Arduino UNO
P0 →	A2
GND →	GND
GND →	GND
VCC →	VCC

5.1.2. The interface of Turbidity sensor to node MCU ESP8266

Turbidity pins connectors	Node MCU ESP8266
A →	A0
GND →	GND
VCC →	VCC

N.B. For more clarification here A which is indicated on turbidity sensor represent data while on pH data is represented by P0.

The system is designing in a such way that the data are transmitted to the ThingSpeak by using NodeMCU ESP8266.To allow the serial communication between Arduino and node MCU ESP8266, we need to convert analog data to digital form named analog digital conversion (ADC).

5.1.3. The serial communication between Arduino and NodeMcu

Arduino UNO	Node MCU ESP8266
D5 (RX) →	D5(TX)
D6 (TX) →	D6(RX)

Digital five pin (D5) of Arduino which a receiver is connecter to digital pin five of Node MCU ESP8266 which a receiver; and Digital pin six (D6) on Arduino which is a transmitter is connected to digital pin six of node MCU ESP8266.

See the code below:

To arrive to the results, the system is programmed within two separate codes. The first code is for pH and is written in Arduino language. The second code is typed in NodeMcu but with serial communication that is shown above NodeMcu combine all the sensed data that are from Arduino with those of Turbidity and those for ThingSpeak.

Code for Arduino

```
#include <SoftwareSerial.h>
SoftwareSerials(5,6);//RX,TX(Receiver/Transmitter)
#define pHpin A2                    //pH meter Analog output P0 to Arduino Analog Input A2
float pH;
void setup(void)
{
Serial.begin(9600);
s.begin(9600);
}
void loop(void)
{
pH = (1023 - analogRead(pHpin)) / 73.07;
if(s.available()>0)
{
s.write(pH);
}
}
```

a) Code for NodeMcu

```
#include "ThingSpeak.h"
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
```

```
#include <SoftwareSerial.h>
SoftwareSerials(D6,D5);//(RX,TX)
#define Turbidity A0                    //Turbidity output data A is connected to A0 on NodeMcu
unsigned long ch_no = 1144371;//Replace with Thingspeak Channel number
const char * write_api = "O88US02A8UD7HS3Z";//Replace with Thingspeak write API
charauth[] = " madeleine1982";                    //Name of author give in ThingSpeak
const char* ssid = "ICT LAB 3"; //Your Network SSID
const char* password = "TTC.BYUMBA3"; //Your Network Password

unsigned long startMillis;
unsigned long currentMillis;
const unsigned long period = 10000;
WiFiClient  client;

long duration1;//

void setup()
{
pinMode(Turbidity,INPUT);
s.begin(9600);
Serial.begin(115200);
 String msg =s.readStringUntil('\r');
Serial.println (msg);

WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED)
  {
  {
delay(500);
Serial.print(".");
  }
Serial.println("WiFi connected");
```

```
Serial.println(WiFi.localIP());
ThingSpeak.begin(client);
startMillis = millis();  //initial start time

  }

}
void loop()
{
float pH;
intSensorValue=analogRead(Turbidity);
float voltage=SensorValue*(3.0/1024.0);

s.write("s");
if (s.available()>0)
  {
pH=s.read();
Serial.print("pH = ");
Serial.println(pH);
if(voltage>=6 || ( pH>8.5 && pH<=14) ||(pH>=0 && pH<6.5))
{
Serial.print("Polluted Water:");
Serial.println(voltage);
Serial.print("Turbit:");
Serial.print("pH:");
Serial.println(pH);
 }
else
 {
Serial.print("Clean Water:");
Serial.print("Turbit:");
Serial.println(voltage);
```

```
Serial.print("pH:");
Serial.println(pH);
  }
currentMillis = millis();
if (currentMillis - startMillis>= period)
  {
ThingSpeak.setField(1, pH);
ThingSpeak.setField(2, Turbidity);
ThingSpeak.writeFields(ch_no, write_api);
startMillis = currentMillis;
  }
  }
}
```

b) **Data on serial monitor**

```
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
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Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
pH = 5.00
Polluted Water:1.51
Turbit:pH:5.00
```

C) Graph in thing speak

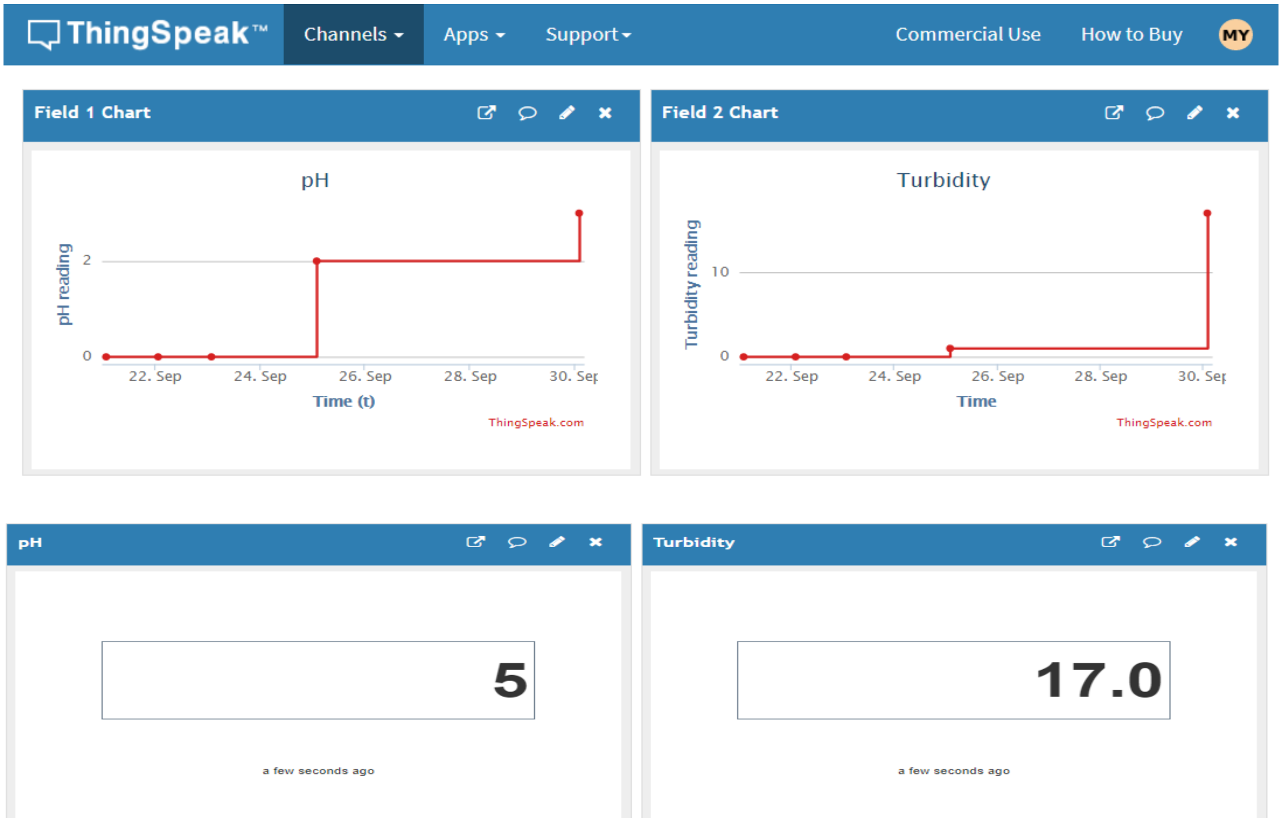

Figure15: shows pH and Turbidity graphs in ThingSpeak

In the above graph the value of pH sensor is five which indicate that water contain some acid which is not on higher level while turbidity sensor read 17 NTU which indicate that water has fewer particles inside. (https://thingspeak.com/channels/1144371/private_show)

5.2. The transmission of the data to ThingSpeak

The microcontroller NodeMcu in this project plays the role of a transmitter. It means that the data that have been processed by both Arduino UNO (means data of pH sensor) and NodeMcu (data of Turbidity sensor) are simultaneously transmitted to ThingSpeak via NodeMcu ESP8266. The data are hosted to the **cloud servers which is a receiver in this system.** To log in to the channels created in ThingSpeak the technician must have an account and with internet connection on either mobile phone or laptop, she /can log in to the account and retrieve the required data and once the abnormal parameters are sensed he/she will receive the email message.

5.3. IFTTT Technology

The full words of the abbreviation IFTTT is “If This Then That”. This popular software platform that allows different devices to be connected from different developers so that the required data should be triggered easier in automation manner. It helps the end user t interface between different channels having IOT devices and online service[45][46].IFTTT can be explained as a web-based service that allows user to create a set of rules called conditional chain in the given programming that can be triggered by change that occur within other web-services, such as Gmail, Facebook, Telegram, Instagram etc. This service is obtainable in freeware payment. The conditional chain is called Applets. The applet allows to send an email message to the end-user which is a technician in this project and the technician has to do first of all is to do the registration in IFTTT.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

In this study we provide an affordable system for monitoring the quality of water quality and this system can be applicable in different area and it cover a large distance. In this thesis also we address the issue of remote water quality monitoring based on IOT (Internet of Things) via a prototype system. The system is provided by the hardware devices including two microcontrollers Arduino UNO and NodeMcu 8266 LolinR3, two sensors, pH sensor and Turbidity sensor and Jumper wires. The sensed parameters are analyzed through the ThingSpeak and a notification is sent to the technician vie IFTTT technology in the form of email message. The prototype methodology was used for achieving the required results.

6.2. Recommendation

In the future research, the researcher must update this thesis on the following points:

1. Developing a system that can be able to measure too many parameters instead of two as it is indicated in this thesis.
2. Improving the method of collecting the data, instead of using prototyping, the future researchers may collect the data on the site and the test must be done frequently in different period.
3. Try to test water quality first of all in the laboratories before an online water quality monitoring is taking place. This will facilitate the user to ensure that the data that are sending are accuracy.
4. Try to implement IOT cloud based on water quality monitoring with android application.

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