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Abstract

The aim of this dissertation is to optimize the performance of drinking water services in the city (or at home) to improve the quality of the water distributed to consumers. Conductivity and Turbidity water are the most features of drinking water. Currently, the normal method of challenging conductivity and turbidity is to collect samples manually and sent them to laboratory for water quality check. For this purpose, we propose an automatic system for detecting anomaly in the drinking water for reduced maintenance and prevention of water diseases. This system provides a real time monitoring of water quality, and it is distinguished by the advantages of time minimization, perfection and intelligent management of the services in the city.

Keywords: Water Networks, Automatic Control, Water Pollution Sensors.

Resumé

L'objectif de ce mémoire est d'optimiser les performances des services d'eau potable en ville (ou à domicile) afin d'améliorer la qualité de l'eau distribuée aux consommateurs. La Conductivité et la Turbidité de l'eau sont les principales caractéristiques de l'eau potable. Actuellement, la méthode normale pour contester la conductivité et la turbidité consiste à collecter les échantillons manuellement et à les envoyer au laboratoire pour un contrôle de la qualité de l'eau. Dans ce but, nous proposons un système automatique de détection de l'anomalie dans l'eau de boisson pour une maintenance réduite et une prévention des maladies de l'eau. Ce système offre un contrôle en temps réel de la qualité de l'eau et se distingue par les avantages du minimisation de temps, de la perfection et de la gestion intelligente des services dans la ville.

Mots Clés: Réseaux d'Eau, Contrôle Automatique, Capteurs de Pollution d'Eau.

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General Introduction

L'ordinateur parfait a été inventé :
on entre un problème et il n'en ressort jamais !
Al Goodman

Background and Motivations

WATER quality is the measure of the suitability of water for a particular use based on specific physical, chemical, and biological characteristics. Assessment of the quality of a water body, whether surface water or groundwater, can help us answer questions about whether the water is acceptable for drinking, bathing, or irrigation to name a few applications. The most common method to detect water quality parameters is to collect samples manually and send them to laboratory for detecting and analyzing. In the literature review, it is seen that there are many academic studies about the use of IoT technology in smart houses.

In this dissertation, IoT technology is used in smart houses to deliver analysis of drinking water quality in real time [16]. Using the standard internet protocol, this technology can transfer wirelessly the data obtained by digitizing the data of the object or the domain of the adapter that it is adapting to the server.

Problematic and Contributions

The traditional method of water quality monitoring faces many problems such as wasting a lot of human energy and material resources, restricting sample collection and long time analysis. Our contribution is how to use of IoT technologies to develop a real-time system for water quality monitoring?

Dissertation Organization

Our dissertation consists, in addition to the introduction and the conclusion, four chapters. The two first chapters are state of the art chapters, while the other last chapters are the contributions on smart montoring of drinking water. The dissertation is organized as follows:

We present in the **Chapter 1** an introduction to water quality monitoring that describes important definitions of water quality and its effects on human health.

Chapter 2 presents in the first part the Internet of Things and how it includes in the concept of home automatization. While the second part is about water quality monitoring

In **Chapter 3**, the evaluation and conception of the proposed system are presented

The implementation, tests and results of our system has been presented in **Chapter 4**.

Publications achieved

- A. Telli, F. Ben Aicha, "*Smart Monitoring of Drinking Water Network*". Algerian American Foundation for Culture, Education, Science and Technology (AAF-CEST). SUMMER UNIVERSITY, Batna, July, 28^{th} to August, 3^{rd} 2019.

Chapter 1

Water Quality

"At the bottom of a hole or well,
sometimes we see the stars."
Aristote

1.1 Introduction

DETERMINING water quality requires the measurement and analysis of specific characteristics which include such parameters as temperature, dissolved mineral content, and bacteria. These characteristics are often compared with standards set by regulatory agencies to determine if the water is suitable for a particular use. Some water quality parameters can be determined "in-situ" meaning that they are measured directly in the stream or well. These include temperature, pH, dissolved oxygen, conductivity, and turbidity. Other chemical and biological parameters are analyzed in a laboratory from samples collected in the water body of interest [1].

This chapter will focus on water quality analysis, characteristics and standards then we have a general observation about water quality in Algeria and its effects.

1.2 Water Quality Analysis

1.2.1 Definition of Water Quality

Water Quality can be defined as the chemical, physical and biological parameters of water, usually in respect to its suitability for a designated use. As we all know, water has many uses, such as for recreation, drinking, fisheries, agriculture and industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to support that use. For example, we expect higher standards for water we drink and swim in compared to that used in agriculture and industry [22].

1.2.2 Water Quality Parameters

Water quality parameters are divided into several types of parameters (physical, chemical, biological, ...). Like is showing in Figure 1.1 [2].

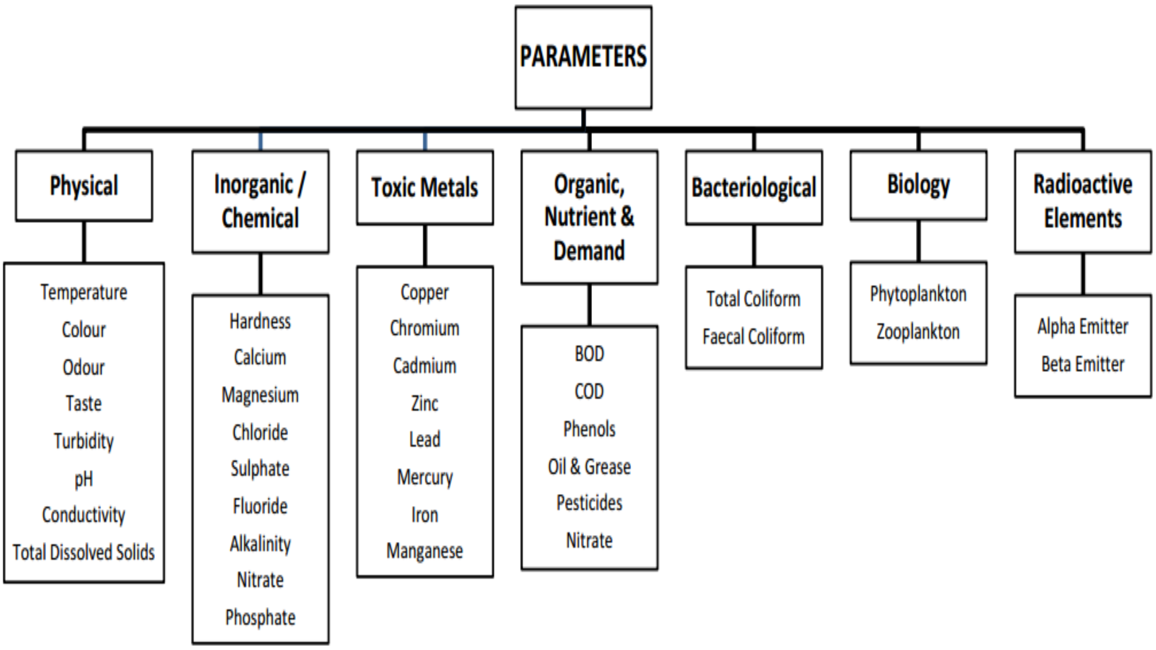

Figure 1.1: Water quality parameters.

1.2.3 Water Quality Analysis

Water quality standards are put in place to ensure the efficient use of water for a designated purpose. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard. Water quality analysis is required mainly for monitoring purpose. Some importance of such assessment includes:

- To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use.
- To monitor the efficiency of a system, working for water quality maintenance.
- To check whether upgradation / change of an existing system is required and to decide what changes should take place.
- To monitor whether water quality is in compliance with rules and regulations [22].

1.2.4 Water Quality Standards

Water quality standards (WQS) are provisions of state, territorial, authorized tribal or federal law approved by EPA that describe the desired condition of a water body and the means by which that condition will be protected or achieved. Water bodies can be used for purposes such as recreation (e.g. swimming and boating), scenic enjoyment, and fishing, and are the home to many aquatic organisms. To protect human health and aquatic life in these waters.

The WQS regulation requires states, territories and authorized tribes to specify goals and expectations for how each water body is used. Typical designated uses include [3]:

- Protection and propagation of fish, shellfish and wildlife.
- Recreation.
- Public drinking water supply.
- Agricultural, industrial, navigational and other purposes.

1.2.4.1 Examples of important parameters

According to all of the above, we can say that standards are the value that water quality standards take to be suitable for specific use. In this section we 're going to give definition of some important parameters [2]:

- **Temperature:** Temperature is an important water quality parameter because it affects the degradation rate of the biodegradable pollutants. Temperature also affects the level of dissolved oxygen in water. Moreover, temperature affects the treatment efficiency of both water and wastewater. Sharp increases or decreases of temperature cause high adverse impacts on the ecological system.

- **pH:** Considerable changes in water pH usually occurs as a result of industrial discharges. This in turn make the water unsuitable for drinking and other uses for industry and agriculture.

- **Dissolved oxygen:** is an important water quality parameter as it gives a good idea about how healthy the water is. High dissolved oxygen concentrations are usually associated with clean water while low dissolved oxygen are associated with polluted water. Dissolved oxygen in water is usually reduced due to organic pollution or due to thermal discharges from industries.

- **Salinity:** High salinity in water makes it unsuitable for drinking and other usages such as agriculture and industry. High salinity may be caused by natural sources such as the geological structure of soil or by man-made pollutants.

- **Electrical conductivity:** Electrical conductivity is determined by the concentrations of ions and cations that conduct electricity. High salinity is associated with high electrical conductivity. Pollutants from urban, agricultural and industrial sources usually increase the electrical conductivity of water and make it unsuitable for usage. Drinking water streams ideally should have a conductivity between 0 and 2800 µS/cm (See Annex A).

- **Turbidity:** High turbidity in water adversely affects its flora and fauna and makes the water unsuitable for drinking and other uses. It is measured in nephelometric turbidity units (NTU). Drinking water should have turbidity that is less than 5 NTU. (See Annex A).

1.3 Scope of Water Borne Diseases

Water borne diseases are numerous and they resulted from consumption of contaminated water. Some of the causes of this problem are poverty, negligence and corruption that often robe these nations of the necessary resources to combat these maladies. It is quite a challenge to eradicate water borne diseases. The WHO has set up programs in some one third world nation aimed at providing clean and sanitary water. Clean water is essential for life. But, one in eight of the world's population does not have access to it. The lack of clean water close to people's homes also affects people's time livelihood and quality of life. There are many different diseases that can be caught from dirty water.

Some examples of diseases associated with contaminated water are given below:

- **Cholera:** is acute water borne disease caused by the bacterium. Its scientific name is Vibro - cholera. Cholera may develop through the consumption of contaminated water.

- **Diarrhea:** It is also a symptom of water borne diseases. It often results frequent discharge of water faces from the bowels. Generally, diarrhea may lose for short time duration, usually from two or three days but may also linger for longer period depending on the intensity of infection.

- **Hepatitis:** is a disease that affects the human liver. It is an inflammation of liver. Two of the major virus that causes hepatitis has been identified by medical scientists as hepatitis A and hepatitis C [4].

- **Salmonella:** is commonly found in public water supplies and private wells. It is caused by a bacteria found in waste products that come from human and animal sources. Symptoms include abdominal cramping, fever, diarrhea, and it can last anywhere from a few days to a week. In some cases, medical treatment is needed, particularly in people who are immune-surpressed .

- **Malaria:** Water pollution has resulted in increased breeding of parasite-carrying mosquitoes. Malaria is a disease caused by parasites, which are spread by female mosquitoes called Anopheles. When mosquitoes bite a person infected with malaria, they can spread the infection to other people. This disease causes high fever, headache, and shivering. In severe cases, it can even lead to complications like severe anaemia, coma, and death.

- **Dysentery:** is a combination of nausea, abdominal cramps coupled with severe diarrhoea. In cases of acute dysentery, one may also experience a high fever and traces of blood in the faecal matter. There are two types of dysentery—Bacillary dysentery, caused by bacteria and Amoebic dysentery caused by amoebae. When either of these is ingested through contaminated water or food, one will develop dysentery within a gestation period of four [5].

1.4 Drinking Water in South Algeria

A study results show that the physical and chemical quality of the waters of southern Algeria is poor and rich in mineral salts: the conductivity is between a minimum of 1374 µs/cm and and a maximum of 4070 µs/cm while the European standards recommend values between 180 and 1000 µs/cm. The hardness is very high. It ranges between 42° F and 134° F. According to international and national standards, all waters have excessive fluoride levels. Moreover, Analyzed waters present an organic pollution represented by the concentration of the organic matter which is lower than the Algerian and European standards (5mg / l O2 dissolved) [21].

1.4.1 Cholera in Algeria

On 23 August 2018, the Algerian Ministry of Health (MoH) announced an outbreak of cholera in northern parts of the country, in and around the capital province Algiers. From 7 August to 6 September, 217 cases with cholera-like symptoms have been hospitalized, two of the patients died (CFR: 0.9 %). Cases have been reported from seven provinces (Wilayas). Of these, 83 have been confirmed as Vibrio choleraesero group O1 Ogawa at the Institut Pasteur Algiers. More than half of the confirmed cases have been registered in Blida Province, followed by Algiers, Tipaza, Bouira, Médéa and Ain Defla. A total of 21, including three private, water sources in the affected areas were tested for bacterial contamination, and 10 of these were deemed inappropriate for human consumption [6].

1.5 Conclusion

Due to the water shortage and the population growth; the amount of fresh water is limited in Algeria and very vulnerable to various types of pollution.In response to the current deficiencies concerning water resources: protection; management and all known pollution risks (uncontrolled urban and industrial waste water releases) of this rare commodity are required.

The next chapter focuses about a new technology based on IoT to analyze and monitoring drinking water.

Chapter 2

IoT and Water Quality Monitoring

"What a computer is to me is the most remarkable tool that we have ever come up with. It's the equivalent of a bicycle for our minds."
Steve Jobs.
"Le fer se rouille, faute de s'en servir, l'eau stagnante perd de sa pureté et se glace par le froid. De même, l'inaction sape la vigueur de l'esprit."
Léonard De Vinci 1519

2.1 Introduction

Existing scientific developments have enabled new technological approaches to emerge. 'Internet of Things' (IoT) technology is one of these approaches. A server or interconnected objects can be controlled remotely by the user via the Internet. In this regard, IoT technology offers significant opportunities for use in living spaces. The emergence of applications such as 'Smart Connected Homes' can be expressed in this context [16].

This chapter presents in the first part the Internet of Things wand how it includes in the concept of home automatization. While, the second part is comparaison between traditional water quality monitoring and the new methods which describes the related works.

2.2 Internet of Things (IoT)

IoT refers to an Internet of Things(IoT). Connecting any device (including everything from cell phones, vehicles, home appliances and other wearable embedded with sensors and actuators) with Internet so that these objects can exchange data with each other on a network. It is interesting to note that there is a difference between IoT and the Internet, it is the absence of Human role. The IoT devices can create information about individual's behaviours, analyse it, and take action (IoT is smarter than Internet :D. Figure 2.1.) [7].

Figure 2.1: Internet of Thing Devices

2.2.1 Application Areas for IoT

There is an increasing interest in new use cases such as smart manufacturing, augmented reality and a multitude of IoT applications, Let's check them out:

2.2.1.1 Smart Cities

Smart surveillance, automated transportation, smarter energy management systems, water distribution, urban security and environmental monitoring, all are examples of internet of things applications for smart cities. IoT will solve major problems faced by the people living in cities like pollution, traffic congestion and shortage of energy supplies etc. By installing sensors and using web applications, citizens can find free available parking slots across the city [7].

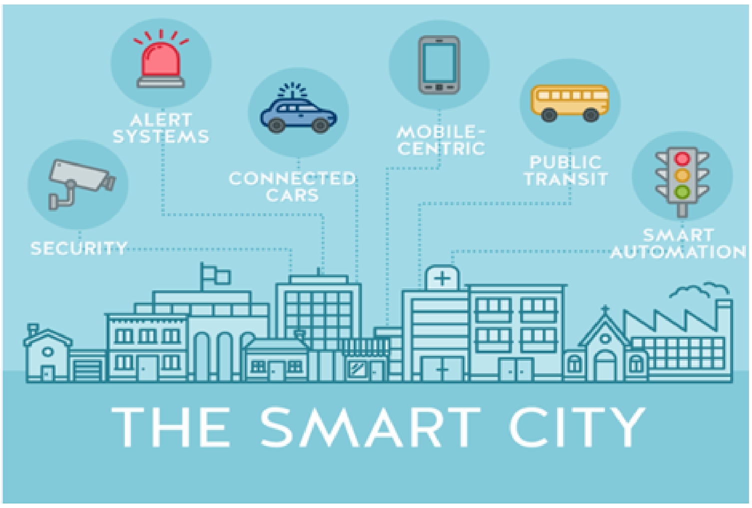

Figure 2.2: Smart City

2.2.1.2 Smart Home

The concept of Smart Home is brought up to save time, energy and money. With the introduction of Smart Homes, we would be able to switch on air conditioning before reaching home or switch off lights even after leaving home or unlock the doors to friends for temporary access even when you are not at home [16]. Smart Home has become the revolutionary ladder of success in the residential spaces and it is predicted Smart homes will become as common as smartphones.

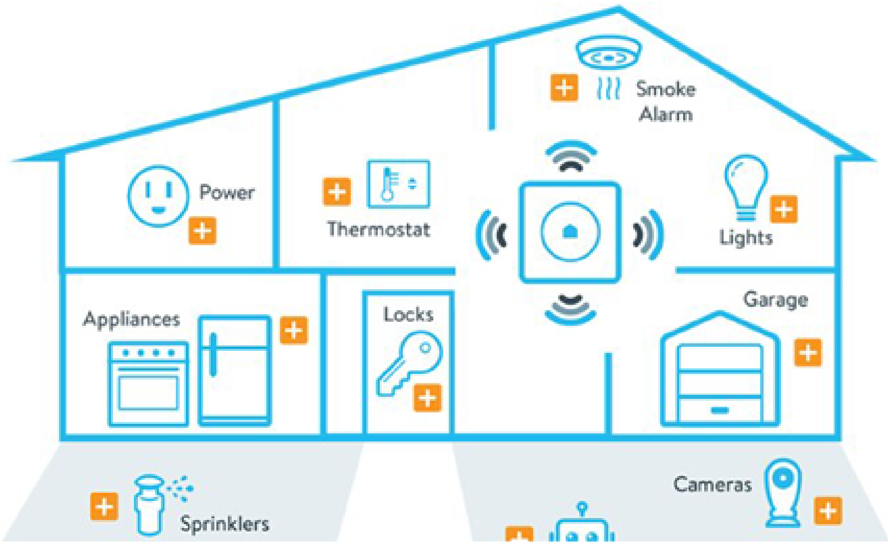

Figure 2.3: Smart House

2.2.1.3 Wearables

Wearable devices are installed with sensors and softwares which collect data and information about the users. This data is later pre-processed to extract essential insights about user. These devices broadly cover fitness, health and entertainment requirements. The pre-requisite from internet of things technology for wearable applications is to be highly energy efficient or ultra-low power and small sized [7].

Figure 2.4: Wearabels

2.3 IoT Based Smart Home System

Today, many companies are trying to equip modern houses with the technology used by a single device to control all systems and devices in the house. The targeted solutions seem to focus primarily on environmental monitoring, energy management, life support assistant, comfort and convenience. The IoT based smart home system relies on open platforms that use an intelligent sensor network to provide information about the state of the house. These sensors perform tasks such as power generation and measurement, heating / ventilation / air conditioning (HVAC), lighting, security system control [23].

IoT based smart home (IoT SH) refers to a system where all the devices in the house are connected and synchronized. The system that collects information about the user provides an estimate of its behavior and habits. For this reason, the IoT SH system can be characterized as a measurable analytical ecosystem of sensors and actuators designed to automate and control living areas [17]. In the coming period, IoT SH applications are likely to become a 'social laboratory' where the behavior and preference patterns of users are transformed into data and examined by various social engineering techniques in order to increase sustainability and economic efficiency [16].

2.3.1 Smart House Benefits

Smart homes offer several advantages over conventional homes [**24**]:

- **Monitoring:** we should be able to monitor in real time or historical, from any remote location, the house status. A smart house should provide live data and statistics about most of the systems integrated like energy consumption, water consumption, temperature and humidity monitoring, heating system status, security access alerts, proximity scanning and people presence counting.
- **Controlling:** remote control is critical for a smart house. But, while the user gains the privilege to control a system, that systems losses that privilege to control itself leaving to user the power to make decisions, which is not smart anymore. Thus, we should look at controlling the house as an emergency backup plan, in case anything goes wrong, and not as a day to day habit.

- **Efficiency:** It wouldn't be much of a smart if it can be more efficient than a regular house. First of all a smart house should provide low energy consumption rates. Therefore the core software should a have an energy process manager in order to continuously monitor and analyze data from the inside and outside sensors and make constant adjustments to all energy consuming systems.

  Also, most of the self adjusting systems works better when are connected with other self adjusting systems, so the house main central software should be able to connect with other houses and compare data in order to make more precise adjustments and better decisions. Finally, the house internal system should manage energy storage and how to distribute it depending on house loading and weather conditions.

- **Intelligence:** Intelligence or Home Intelligence (HI) is the most significant function of smart home and refers to intelligent behavior of the smart-home environment. This function is related to automatically making decision on occurrence of various events. HI creates an integrated environment in the smart home in which the AI mechanism can identify and suitably react according to changing conditions and events. By identifying abnormal or unexpected events HI can alert user and provide an immediate automatic response if desired. Some scenarios for illustration are automatically prepare coffee as soon as user arrives, send alert to user whenever suspected activity is detected at door or inside home, automatically order stuff whenever there is a shortage in refrigerator.

- **Security** Smart homes include advanced security systems with cameras, motion sensors and a link to the local police station or a private security company. Smart homes may also use key cards or fingerprint identification in place of conventional locks, making it harder for someone to break in.

- **Accessibility:** For elderly or disabled residents, a smart home may feature accessibility technologies. Voice-command systems can do things like control lights, lock doors, operate a telephone or use a computer.

2.4 Water Quality Monitoring

2.4.1 Traditional Water Quality Monitoring

In the traditional water quality monitoring system, different instruments been used to monitor the quality of water which include "Secchi disks (measure water clarity), probes, nets, gauges, meters", etc. The traditional method is just not enough to measure water quality and identify any drastic changes in it. This method not only impedes accurate water quality measurement but also at times fails to predict sudden changes in the water system. Hence, Information is also derived from satellite and aerial photographs by observing the surrounding environment and the changes in specific parameters such as flow of water, color in large overview, direction of water flow etc. There are three major steps to execute traditional water quality monitoring. The major three steps are as follows:

Water Sampling, water samples collected in large mass using various tools. These water samples are then examined in the laboratories. Water sampling and analysis are only performed by ISO-certified laboratories. Unreliable results enhance issues concerning pollution when a corrective response cannot be performed within time. Sampling and monitoring tests can be conducted by expert technicians. Further to sampling, Testing is carried out. Testing procedures and parameters been classified into "Physical, Chemical, bacteriological and microscopic" categories.

- **Physical tests:** these indicate properties that are detectable by the senses. They include Color, turbidity, total solids, dissolved solids, suspended solids, odor and taste.

- **Chemical tests:** these tests determine the parameters in water like "pH, hardness, presence of a selected group of chemical parameters; biocides, highly toxic chemicals, and B.O.D".

- **Bacteriological tests:** it shows the presence of bacteria, a characteristic of faecal pollution. These tests examine to identify the presence of microbial pathogen in the water that might occur with contamination. The presence of such organisms indicates the presence of faecal material and thus of intestinal pathogens.

Finally, the tested water samples are then thoroughly monitored and observed by an expert technician who can read through the lines of the resulted report. They then make an investigative analysis with a parallel consideration of the historical records of the previous water tests. Any similarity of the currently extracted results to the previous records will give way to an intense deliberation for prediction of any unknown changes or hazards to the water quality [14].

2.4.2 New Water Quality Monitoring (Related Work)

There are various studies of water quality monitoring system such discussed in [19], [8] and [20]. The studies in [19], the author proposed that an IoT based water monitoring system that measures water level in real-time. The model is based on idea that the water level can be very important parameter when it comes to the flood occurrences especially in disaster prone areas. A water level sensor is used to detect the desired parameter, and if the water level reaches the parameter, the signal will be feed in real time to social network like Twitter.

The author in [8] paper aims to develop a wireless water quality monitoring system that aids in continuous measurements of water conditions based on pH and turbidity measurements. These two sensors are connected to microprocessor and transmitted to the database by using a Wi-Fi module as a bridge. The developed system was successfully detect both the pH and turbidity values hence updating in IoT platform. Based on the results obtained, the test water sample can be classified to class IIB which is suitable for water recreational used body contact.

However, In [20], the author proposed that in recent times, tremendous growth of Internet of Things applications is seen in smart homes. The large variety of various IoT applications generally leads to interoperability requirements that need to be fulfilled. Current IoT project is achieved using physical platforms that lack intelligence on decision making. A architecture that implement Event-Condition-Action (ECA) method is proposed to solve the management of heterogeneous IoTs in smart homes. The proactive architecture, developed with a core repository stores persistent data of IoTs schema, proved to be an ideal solution in solving interoperability in smart homes.

In our proposal, we have developed a system for real monitoring water quality using IoT technology.

2.5 Conclusion

Currently, Internet of Things (IoT) is being used in different areas of research for monitoring, collecting and analysing data from different locations. Drinking water is a very precious commodity for all human beings as drinking water utilities face a lot of new challenges in real-time operation, These challenges originate because of limited water resources, and growing population, ageing infrastructure etc. Therefore, there is a need for better methodologies to monitor the water quality in order to ensure the safe supply of drinking water at home and it needs to be monitored in real-time.

In the next chapter, we intend to present the design and development of our system for real monitoring water quality in an IoT environment.

Chapter 3

Proposed Water Quality Monitoring System

"If art interprets our dreams, the computer executes them in the guise of programs!"

Alan J. Perlis.

3.1 Introduction

THE traditional method of water quality monitoring is not efficient. It takes more time and it needs a large materials to give a approximately results. Evideltly, with development of IoT technologies other solutions appear. For this aim, we propose a system that performs water quality monitoring and regulated water supply operation. We usu two sensors (conductivity sensor and turbidity sensor) to evaluate, calculate and taking continually the data about the state of water. Then, we analyze after an anomaly the water purity in order to send the alert message to the consumer (authorized person).

This chapter represents our contribution which contains a system architecture, description of needed tools and the sequences diagrams of all transactions registrations.

3.2 General Conception

An automated drinking water analysis system is a process that detects water pollution, is done without human intervention and is repetitive. This system performs a number of actions called tasks or operation. This section explains the complete block conceptual of the proposed system. It also presents the detail explanation of each and every block.

3.2.1 System Architechture

The overall block conceptuelle of the proposed system is as shown in Figure 3.1. This proposed diagram consiste a real-time networks and it includes with field sensors of measurement and control devices, as well as software and services. The data collected from all devices are gathered and sent to the Raspberry pi 3 model B.

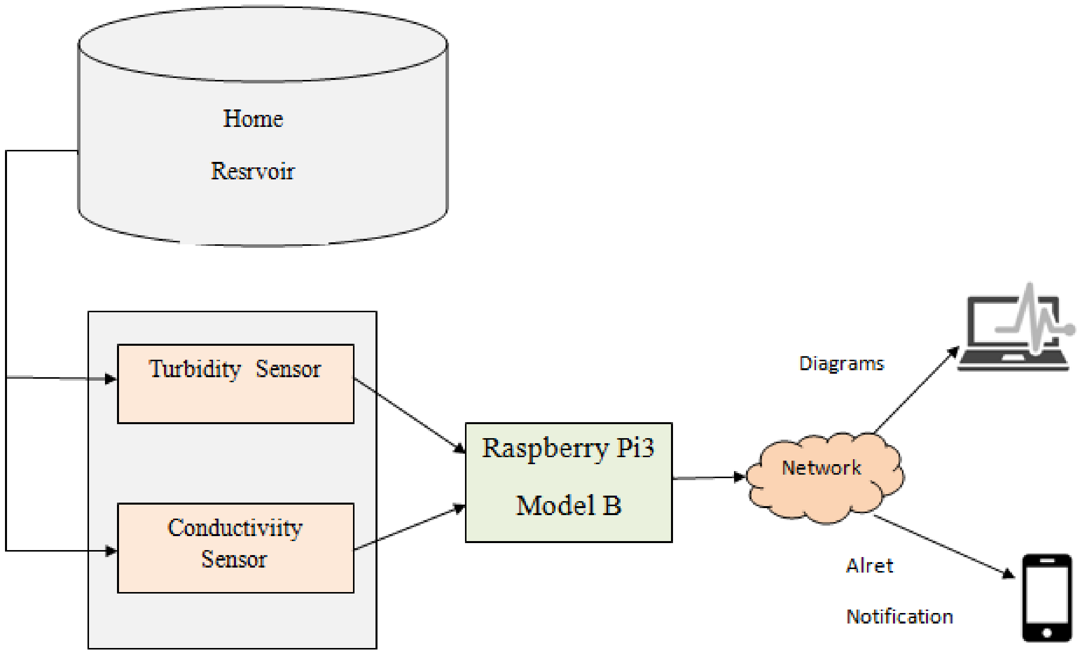

Figure 3.1: System Architecture of Our Proposed System.

3.2.2 System Operations

The operations of the water analysis at the level of the reservoir, and the treatment of notifications are managed automatically by our system so as to improve the quality of drinking water. To achieve the tasks of management the technical means are presented in Figure 3.2:

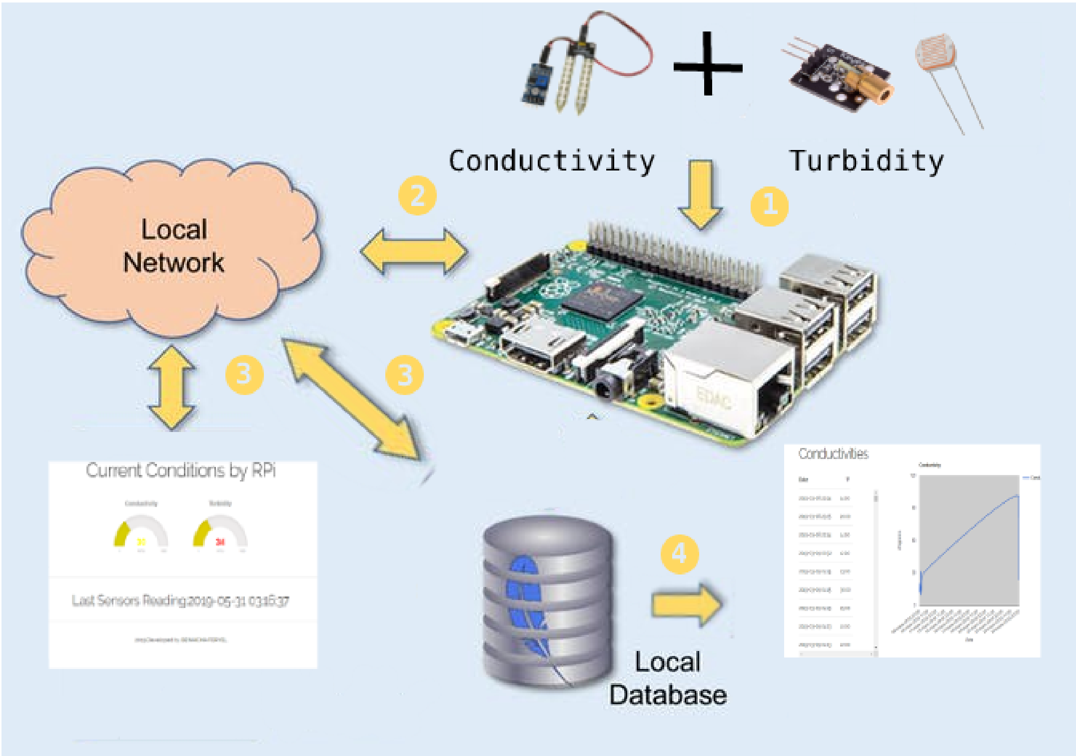

Figure 3.2: System Operations Diagram.

- **Reading turbidity and conductivity sensors data:** we will use specific sensors to measure conductivity and turbidity (See Chapter 4). These two sensors are connected to Raspberry which can read only digital signals that refers to different values according to sensors type.

- **Sending sensor data to web server:** in this part, we will host a server on computer, where Raspberry represents the client side which sends sensors data to server via WIFI. Note that, the data given by the sensors be in analog format, it must be converter to digital format using a Digital Convert such as ADS1115.

- **Display current and historical data:** we use the server machine to store data and draws turbidity and conductivity diagrams according to time. It is impossible to host the server on Raspberry because it has a small memory which does not able to store big quantity of data especially in our project case where the monitoring is in real time.

- **Sending alarm message:** an alarm will send to user if there is a water contamination or change in water quality. Indeed, to send notification from Raspberry to mobile application we will use Firebase Cloud Messaging which is a free, cross-platform messaging solution that lets us send push notifications to audiences without having to worry about the sever code (See Figure 3.3).

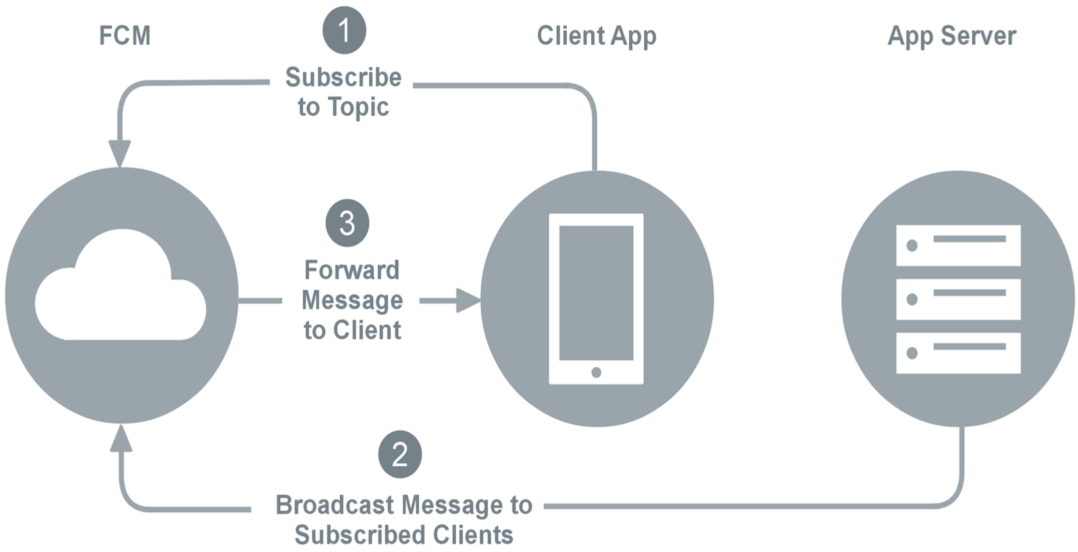

Figure 3.3: Notification With Firebase Cloud Messaging

The topic here receive data from Raspberry and it represents the identifier of each raspberry. Thus, the user should subscribe to topic that refers to his Raspberry to receive notification of his home reservoir. More detail about these tasks is in the next section.

3.3 Detailed Conception

3.3.1 Use Case Diagram

A use case diagram at is simplest a representation of a user 's interactions with the system that shows the relationship between the user and the different use cases in which user is involved. In this section we will describe user interaction with mobile application (See Figure 3.4).

3.3.1.1 Scenarios Description

- In the begining, the user is able to access each of registration, log in or reset password. When the user is already have an account, he can:
- Consults water quality parameters values (current values or historic values).
- Makes changes in his personal account (change password, change email, reset password, remove user and sign out).

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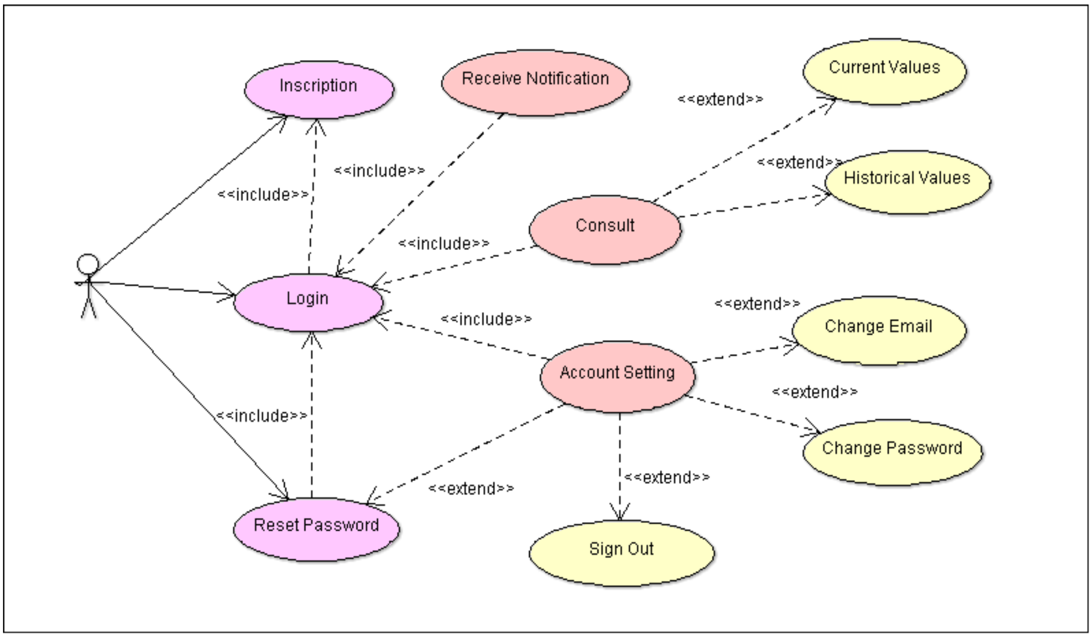


Figure 3.4: Use Case Diagram

3.3.2 Sequence Diagram

From use case diagram we can see different operations that user can obtain. But, by sequence diagram, we will detail in some of these operations:

3.3.2.1 Registration Sequence Diagram

- Registration process starts when the user has not an account.
- He types his information in registration user interface.
- Then, mobile application will check the format of these informations (email format and password length).
- Finally, it send them to FCM to create a new account.

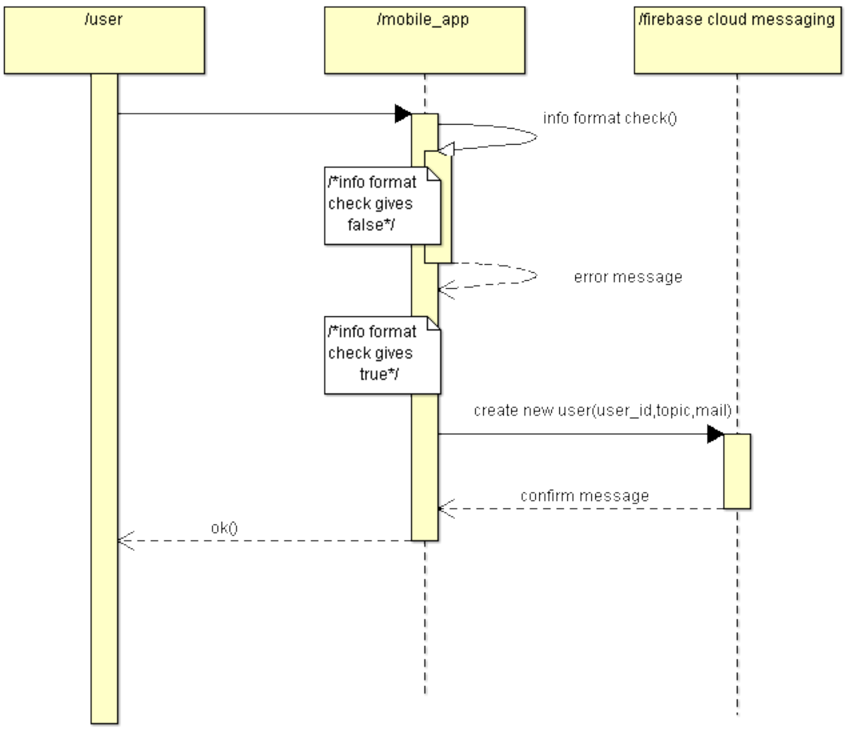


Figure 3.5: Registration Sequence Diagram

3.3.2.2 Notification Sequence Diagram

- Mobile application is able to receive notification when it is already login to an account.
- The notification happen when there is a change in water quality parameters.
- The Raspberry send push notification to specific topic with its server key and notification data using FCM.
- The last activate is notification to subscribed users.

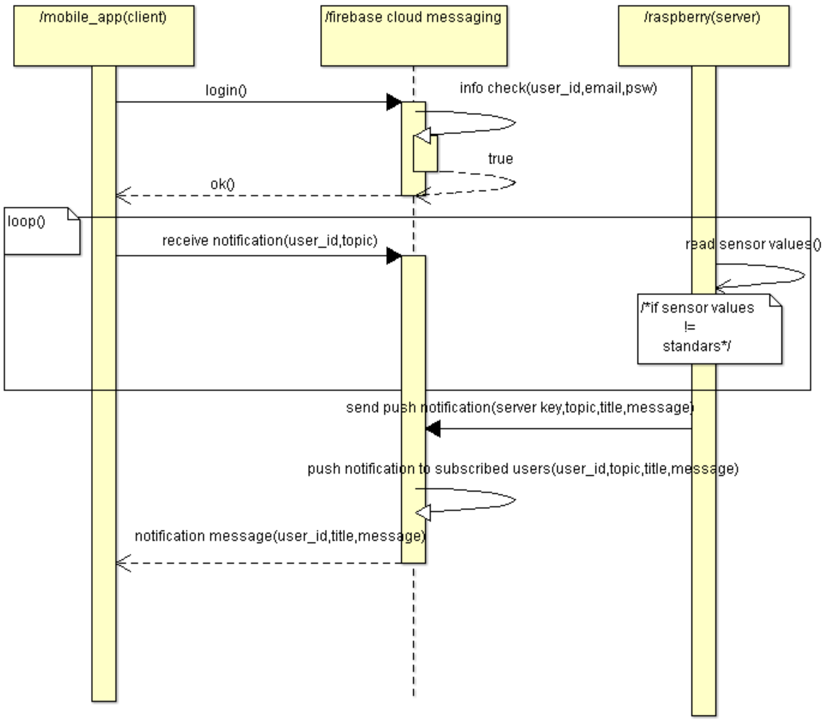


Figure 3.6: Notification Sequence Diagram

3.4 Conclusion

This chapter focused about our proposed monitoring system of turbidity and conductivity water drinking using corresponding sensors. This system can monitor water quality automatically, and does not require people on duty. Hence, the water quality testing will be more economical, convenient and very fast. Our system has good flexibility by contacting the corresponding sensors and changing the data between the server and the application mobile.

The implementation and testing of our system will be displayed in the last chapter.

Chapter 4

Implementation and Results

Verily, deeds are only with intentions. Verily, every person will have only what they intended. Whoever emigrated to Allah and His Messenger, then his emigration is for Allah and His Messenger. Whoever emigrated to get something in the world or to marry a woman, then his emigration is for whatever he emigrated for.

Sahih al-Bukhaari 54, Muttafaqun Alayhi

4.1 Introduction

IN this chapter, the focus is on experimentations studiens and evaluation of system. The implementation of our system makes it possible to evaluate the results obtained. This evaluations is performed using a set of tests. The tests make it possible to estimate the quality of drinking water and to compare with the standards described in official newspaper (See the Annex A).

The rest of this chapter is includes a description hardwares and software needs. In addition, the defferents mobile applications interfaces relased. In addition, it presents the different interfaces of mobile applications realized.

4.2 Implementation

4.2.1 Hardware Description

All the experiments are performed on a ProBook Pro laptop with 2.10GHz Intel Core (i3) processor and 4 GO RAM. Howevet, The material used for the realization our system are following:

4.2.1.1 Raspberry Pi3 Model B

The Raspberry Pi3 Model B[1] is a wonderful platform that can be used to build automation systems. Clearly, the Raspberry Pi3 model B board is perfect when being used as a "hub" for automation systems, connecting to other open-source hardware parts like sensors. Raspberry Pi3 Model B is a small sized single board computer which is capable of doing the entire job that an average desktop computer does like spread sheets, word processing, Internet, Programming, Games etc.

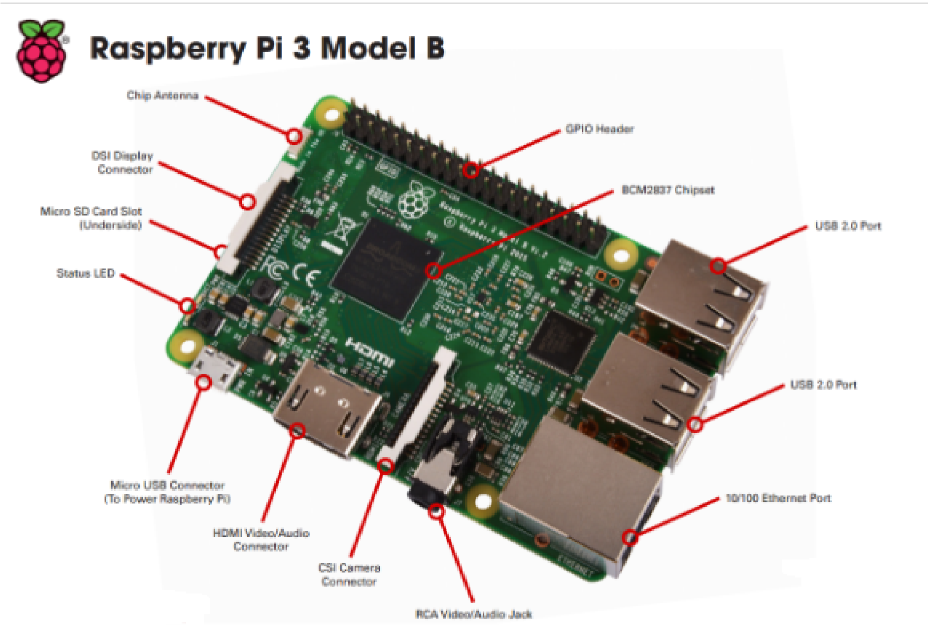


Figure 4.1: Raspberry Pi Model B.

[1] `https://www.raspberrypi.org/`

Specification: Raspberry Pi3 Model B Built on the latest Broadcom 2837 ARM v8 64 bit processor. The new generation Raspberry Pi3 Model B is faster and more powerful than its predecessors. With built-in wireless and Bluetooth connectivity, it becomes the ideal IoT ready solution.It consists of 1.2 GHz QUAD Core Broadcom, 1 GB RAM, 4x USB 2 ports, 40 pin extended GPIO, HDMI and RCA video output. It does not have any internal memory other than the ROM. It has an SD card slot which is capable of reading up to 32 GB. The GPIO pins of the Raspberry Pi3 Model B are programmed using Python programming language. The I/O devices like sensors are givento GPIO pins whenever needed.

Software installation: Raspberry Pi3 Model B runs on Linux kernel based operating systems. It boots and runs from the SD card. Beginners should start with the NOOBS (New Out Of Box Software) operating system installation manager, which gives the user a choice of operating system from the standard distributions. SD cards with NOOBS pre-installed should be available from any of our global distributors and resellers. Alternatively, you can download NOOBS. Raspbian is the recommended operating system for normal use on a Raspberry Pi.

General Purpose Input/Output (GPIO: one powerful feature of the Raspberry Pi3 Model B is the row of GPIO pins along the edge of the board (Figure 4.2).

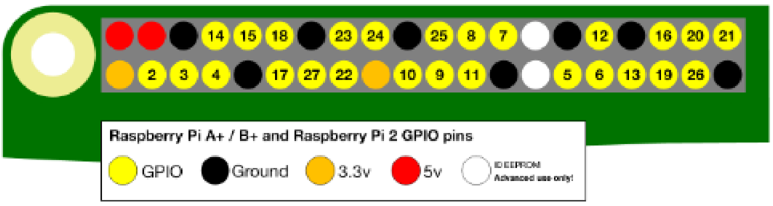


Figure 4.2: GPIO pins

The voltages of GPIO is: two 5V pins and two 3V3 pins are present on the board, as well as a number of ground pins (0V), which are unconfigurable. The remaining pins are all general purpose 3V3 pins, meaning outputs are set to 3V3 and inputs are 3V3-tolerant. The outputs of GPIO pin designated as an output pin can be set to high (3V3) or low (0V). However, its inputs designated as an input pin can be read as high (3V3) or low (0V). The program can be written on the pins to interact in amazing ways with the real world.

For example,the output can do anything, from turning on an LED to sending a signal or data to another device. If the Raspberry Pi3 B is on a network, you can control devices that are attached to it from anywhere and those devices can send data back. Connectivity and control of physical devices over the internet is a powerful and exciting thing, and the Raspberry Pi3 model B is ideal for this [15] [9].

Accessories: There are a wide variety of accessories for the Raspberry Pi Pi3 model B which we need them in our project (See Figure 4.3).

Figure 4.3: Raspberry Accessories.

4.2.1.2 Turbidity Meter

Turbidity is an internationally recognized criterion for assessing drinking water quality. Turbidity Meter is an optoelectronic instrument that assesses turbidity by measuring the scattering of light passing through a water sample containing colloidal particles that harbor pathogens. Turbidity is most commonly quantified by the Nephelometric Turbidity Unit (NTU). Nephelometry refers to the process of aiming a beam of light at a sample of liquid and measuring the intensity of light scattered at 90° to the beam [18].

For measuring turbidity, we will use two componants; an **LDR** (Light Dependent Resistor) or photoresistor wich will change it resistance based on the light around it. This property helps the LDR to be used as a Light Sensor [10]. We will use also **Laser Transmitter Module** as light resource (See Figure 4.4).

Really, a Turbidity Meter holds one light source that is directed through a water sample, a chamber to hold the water sample, and one or more photodetectors placed

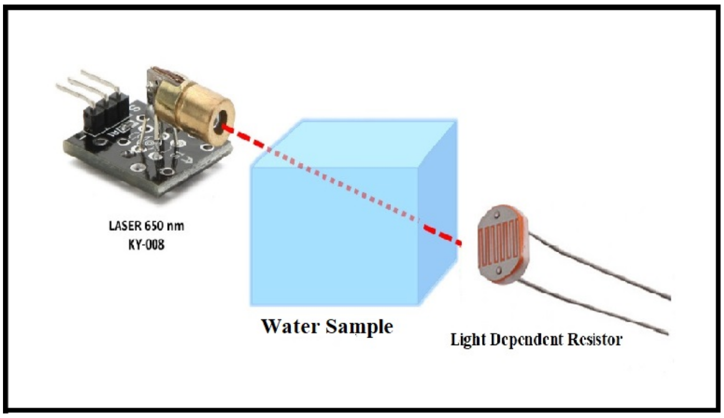


Figure 4.4: Turbidity Meter.

around the chamber. This meter only monitors light scattered by particles suspended in water to generate an output voltage proportional to turbidity or suspended solids. It operates on the principle that when light is passed through a sample of water, the amount of light transmitted through the sample is dependent on the amount of suspended particles in the water. As the amount of total suspended solids increases, the amount of transmitted light decreases. The rest of the electronics in the system circuitry then measures the amount of transmitted light to determine the turbidity of the sampled water.

4.2.1.3 Conductivity Sensor

Conductivity is the reciprocal of the resistance, which is related to the ability of the material to carry the current. In the liquid, the reciprocal of the resistance, the conductivity, is the measure of its ability to conduct electricity. Conductivity is an important parameter of water quality. It can reflect the extent of electrolytes present in water. The salinity of the drinking water is an important parameter affecting the clarity water. The presence of high salt levels is your warning sign to make adjustments. Low-salt levels could lead to nutrient deficiencies [18]. Effectively, the soil moisture sensor be used to detect soil moisture/ relative humidity within the soil. Thus, the conductivity of water quality can be illustrated using this sensor. We use this analog electrical conductivity sensor to measure the electrical conductivity of aqueous solution (Figure 4.5).

The conductivity of water can reflect the level of electrolytes present in the water. Depending on the concentration of the electrolyte, the conductivity of the aqueous

Figure 4.5: Soil Moisture Sensor(YL-69)

solution is different.

4.2.2 Hardware Complementary

Below is the list of items complementary we will need to get through our project:

- **Analog To Digital Converter ADS1115:** the ADS1115 are great analog to digital converters that are easy to use with the Raspberry Pi using its I2C communication bus.The ADS1115 is a higher precision 16-bit ADC with 4 channels [11] (See Figure 4.6).

  We use the Analog to digital converter in our project for reading analog sensors because Raspberry has only digital pins. More technically, ADC connection to the Pi as follows:

  - ADS1x15 VDD to Raspberry Pi 3.3V.
  - ADS1x15 GND to Raspberry Pi GND.
  - ADS1x15 SCL to Raspberry Pi SCL.
  - ADS1x15 SDA to Raspberry Pi SDA.

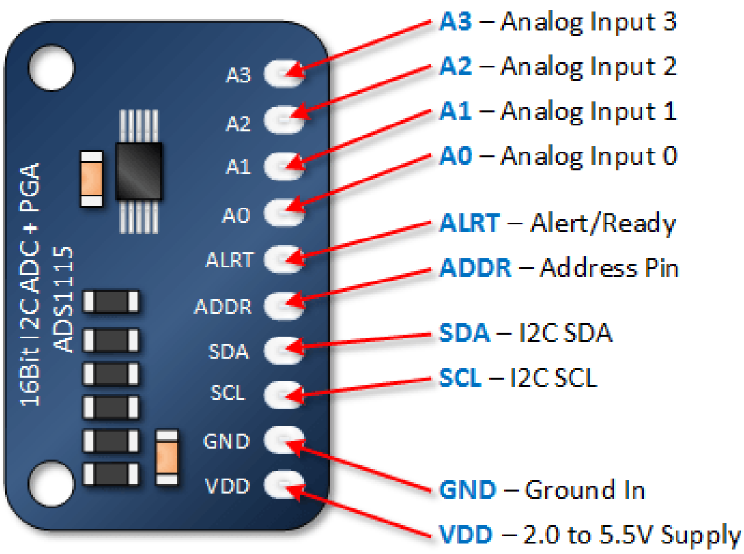


Figure 4.6: Analog To Digital Converter(ADS1115)

On the other hand, ADC connection to the Sensors as follows: Sensor Connection as follows: A0 & Analog pins (from ADS1115); GND & GND, and VCC & VCC.

- **Breadboard:** very important item when working with ARaspberry is a solderless breadboard (See Figure 4.7). Using a breadboard allows you to create temporary prototypes and experiment with different circuit designs. Inside the holes (tie points) of the plastic housing, are metal clips which are connected to each other by strips of conductive material.

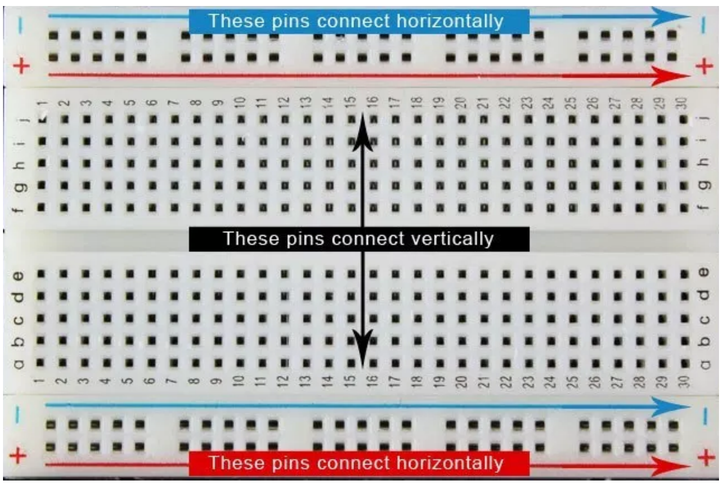


Figure 4.7: Breadboard.

- **Jumper Wires:** practically, the breadboard is not powered on its own and needs power brought to it from the Raspberry board using jumper wires (See Figur 4.8). These wires are also used to form the circuit by connecting resistors, switches, sensors, and other components together.

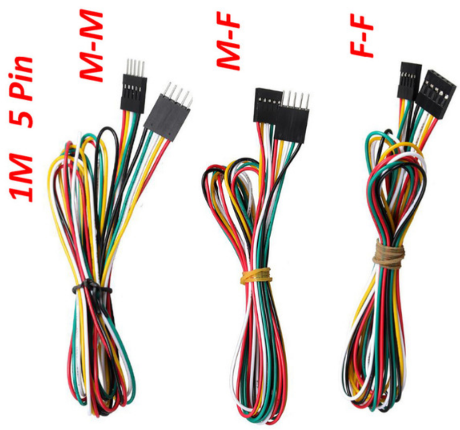


Figure 4.8: Jumper Wires.

- **Resistors Circuit:** we use the resistors as electronic components which have a specific, never-changing electrical resistance in order to protect the circuit and sensors.

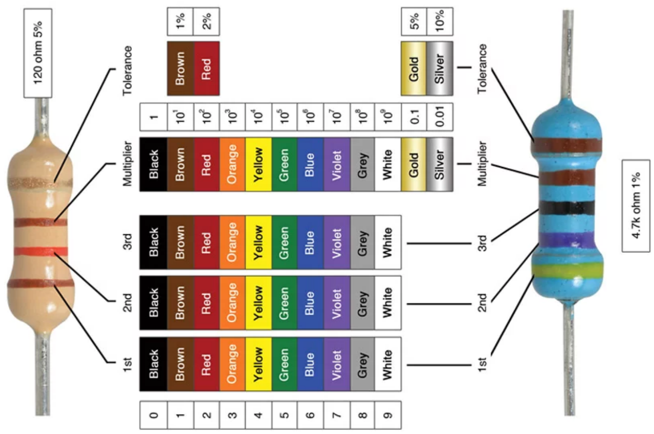


Figure 4.9: Resistors Circuit.

4.2.3 Software Description

During the implementation of our project, we need two different kind of softwares. First, we have utilized certain open source programming languages. Secondly, we developed some applications by softwares IDE.

4.2.3.1 Programing Language

- **Python[2]:** is a high-level programming language designed to be easy to read and simple to implement. Raspberry Pi3 Model B and the Web server code are written in Python languge.
- **SQLite[3]:** SQLite is a relational database management system contained in a C programming library. SQLite database files are commonly used as containers to transfer rich content between systems and as a long-term archival format for data.
- **HTML[4]:** Stands for "Hypertext Markup Language". HTML is the language used to create webpages. "Hypertext" refers to the hyperlinks that an HTML page may contain. "Markup language" refers to the way tags are used to define the page layout and elements within the page. The web server is implemented using HTML and SQLite.
- **Java[5]:** Java is a high-level programming language developed by Sun Microsystems. It was originally designed for developing programs for set-top boxes and handheld devices, but later became a popular choice for creating web applications. The mobile application requires both Java and XML laguages.
- **XML[6]:** Stands for "Extensible Markup Language." XML is used to define documents with a standard format that can be read by any XML-compatible application [12]. We use the XML language to describe items that may be accessed when a Web page loads. It allows as to create a database of information without having an actual database.

[2] `https://techterms.com/definition/python`
[3] `https://matthijskamstra.github.io/haxephp/11mysql/about.html`
[4] `https://techterms.com/definition/html`
[5] `https://techterms.com/definition/java`
[6] `https://techterms.com/definition/xml`

4.2.3.2 Software IDE

- **Pycharm[7]:** The PyCharm development platform is easy-to-use and helps you quickly create embedded programs that work. The PyCharm editor and debugger are integrated in a single application that provides a seamless embedded project development environment. We used it for the implementation of our web server for different reasons such as it make facilities, source code editing, program debugging, and complete simulation in one powerful environment.

Figure 4.10: Logo of PyCharm.

- **Android Studio[8]:** Android Studio is the official integrated development environment (IDE) for Android application development. It is based on the IntelliJ IDEA, a Java integrated development environment for software, and incorporates its code editing and developer tools [13]. We used this IDE softwer to develop our part of mobile application.

Figure 4.11: Logo of Android Studio.

[7] `https://www.jetbrains.com/pycharm/`
[8] `https://developer.android.com/studio`

4.2.4 Firebase Cloud Messaging Configuration

First, we need to add FCM service to our mobile application after login to Firebase using an email and create a new project.

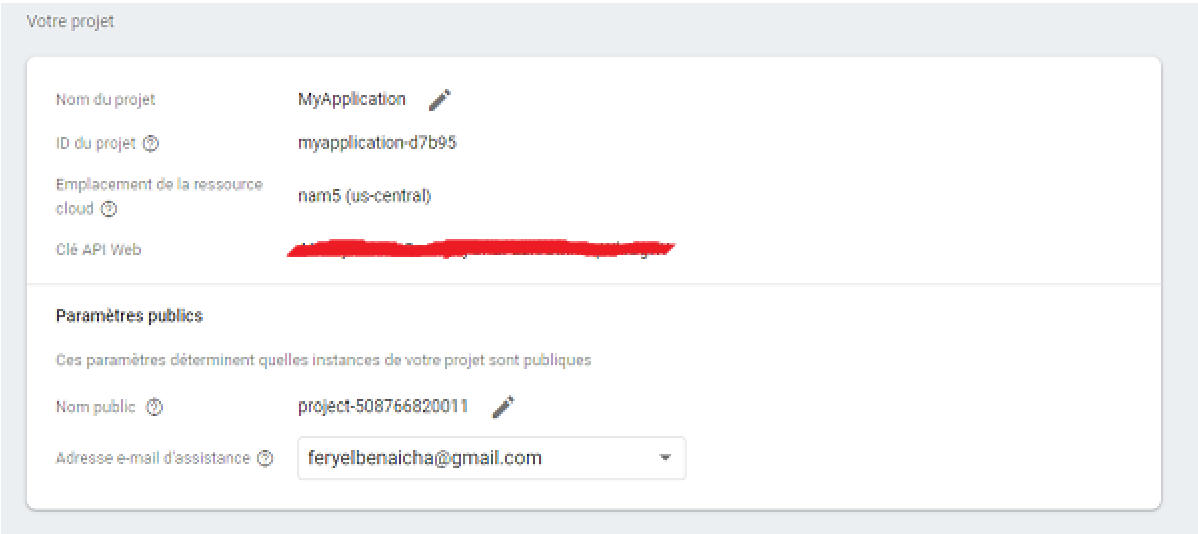


Figure 4.12: Firebase Cloud Messaging Configuration.

Client Side Case: takes as parameters both of message title and message body. Then, we will generate our notifications as a result of a received FCM message.

```
@Override
public void onMessageReceived(RemoteMessage remoteMessage) {
    FirebaseMessaging.getInstance().subscribeToTopic( s: "rasp");
    // TODO(developer): Handle FCM messages here.
    // If the application is in the foreground handle both data and notification messages here.
    // Also if you intend on generating your own notifications as a result of a received FCM
    // message, here is where that should be initiated. See sendNotification method below.
    Log.d(TAG, msg: "From: " + remoteMessage.getFrom());
    // Check if message contains a data payload.
    if (remoteMessage.getData().size() > 0) {
        Log.d(TAG, msg: "Message data payload: " + remoteMessage.getData());
    }
    if (remoteMessage.getNotification() != null) {
        Log.d(TAG, msg: "Message Notification Body: " + remoteMessage.getNotification().getBody
    }
    //The message which i send will have keys named [title,message] and corresponding values.
    String title = remoteMessage.getNotification().getTitle();
    String message = remoteMessage.getNotification().getBody();
    sendNotification(title, message);
```

Figure 4.13: Receive Notification Source Code.

Server Side case: we use Raspberry as server because it handles a short time than web server machine.

```
from pyfcm import FCMNotification

# Your api-key can be gotten from:  https://console.firebase.google.com/project/<project-name>/settings/cloudm
push_service = FCMNotification(api_key="AAAAdnTdlqs:APA91bHVWjZICB0Bp-WNmGniYeNoMO7sWsjyVrEwXnztzycTB2gm0OmEvF

#result = push_service.notify_single_device(topic=specific_topic,
# registration_id=registration_id, message_title=message_title, message_body=message_body)
result=push_service.notify_topic_subscribers("rasp",message_title="alret",message_body="water is contaminated"
print result
```

Figure 4.14: Push Notification Code Source.

4.2.5 Web Server Processes

4.2.5.1 Displaying Real Data

We will introduce some Gauges to present actual Conductivity and Turbidity values on a better way by using JustGage on our html/css files that allows us to generate and animate nice and clean gauges. If sensors does not give values no-sensor.html page will be displayed.

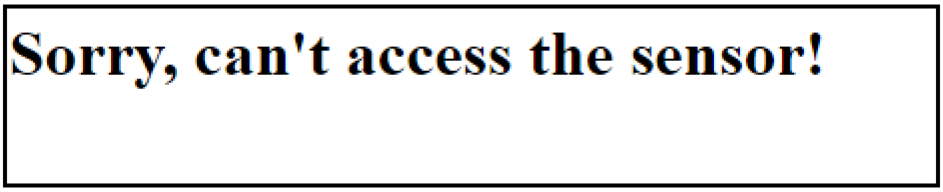


Figure 4.15: No Sensor Web Page.

However, if not current.html page will be displayed.

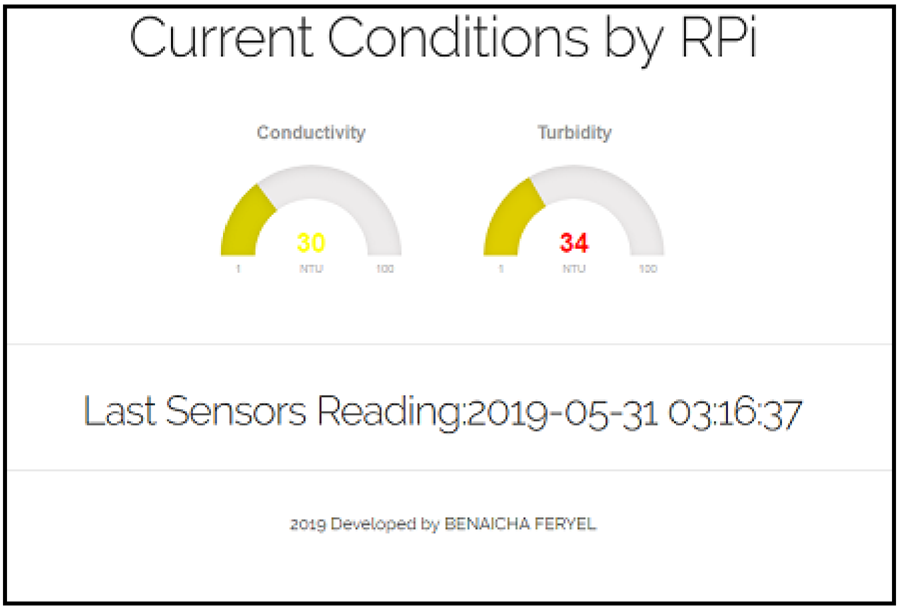


Figure 4.16: Current Sensors Values Web Page.

4.2.5.2 Displaying Historical Data

In order to log conductivity and turbidity sensors measured data on the database, we created two tables (a database can contain several tables). Our tables named “conductivies” and "turbidities" and they have 3 columns, where we will log our collected data: time(date and hour),conductivity or turbidity value and an identifier for each of table.

```
def insert_values(sensor_id, cond, turb):

    conn=sqlite3.connect('C:/feryel-M2/memoire/Pi-Temp-master/lab_app/app.db')  #It is importa
                                                  #absolute path to the database
                                                  #file, otherwise Cron won't be
                                                  #able to find it!
    curs=conn.cursor()
    curs.execute("""INSERT INTO Conductivities values(datetime(CURRENT_TIMESTAMP, 'localtime')
         (?), (?))""", (sensor_id,cond))
    curs.execute("""INSERT INTO turbidities values(datetime(CURRENT_TIMESTAMP, 'localtime'),
         (?), (?))""", (sensor_id,turb))
    conn.commit()
    conn.close()
```

Figure 4.17: Insert Sensor Values In Database.

We have build our graphics based on historical data, sending as a input parameter the period that we want to analyse it to be retrieved from our database.

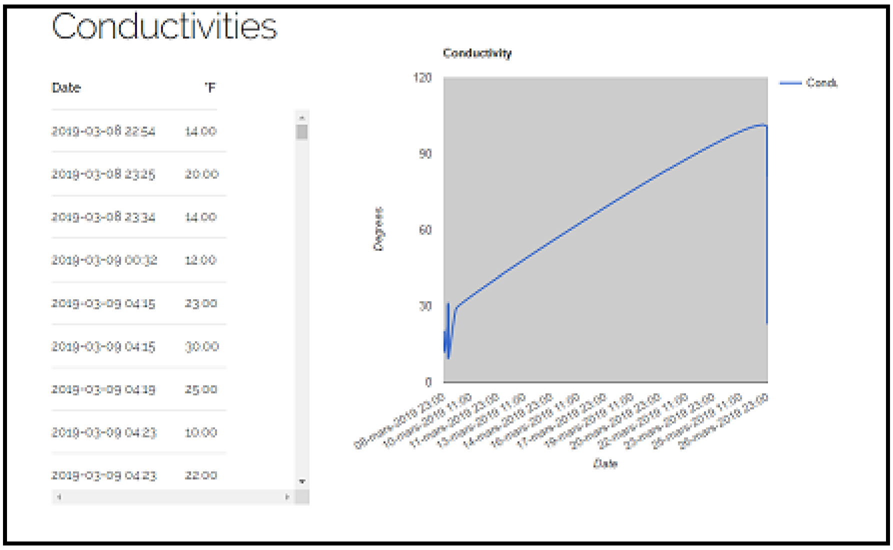


Figure 4.18: Historical Sensors Values Web Page.

4.2.6 Mobile Application Interfaces

4.2.6.1 Login Interface

The user login to application using an email and a password. An Interface login offers the ability to user, view status and check personal.

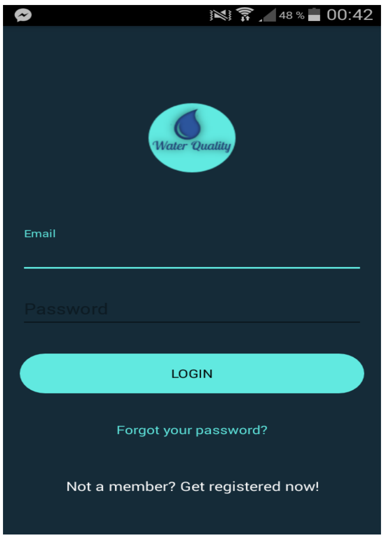


Figure 4.19: Login Interface

4.2.6.2 Registration Interface

We're looking for the key information you'll need to sign in to account and access the other benefits of an interface account. Thus, the registration contains an extra field that is Raspberry identifier.

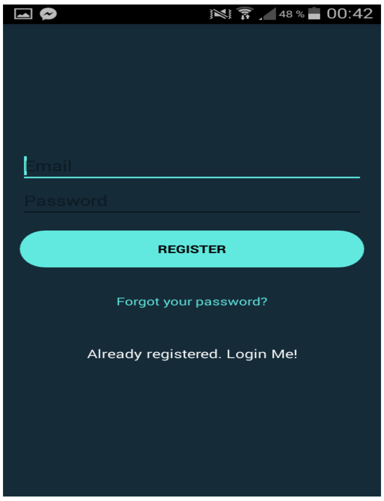


Figure 4.20: Registration Interface

4.2.6.3 Reset Password Interface

In case of forget password, the user is able to reset his password by receiving mail to get new password when he click the Forgot password link.

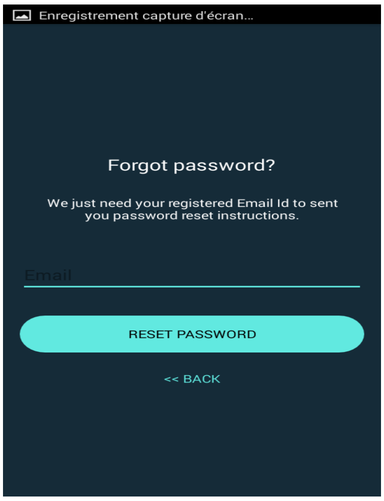


Figure 4.21: Reset Password Interface

4.2.6.4 Home Interface

This interface is the main one, it contains four fields, two of them are to displaying current and historical data, one for account sitting and other is tips to help user to get healthy water.

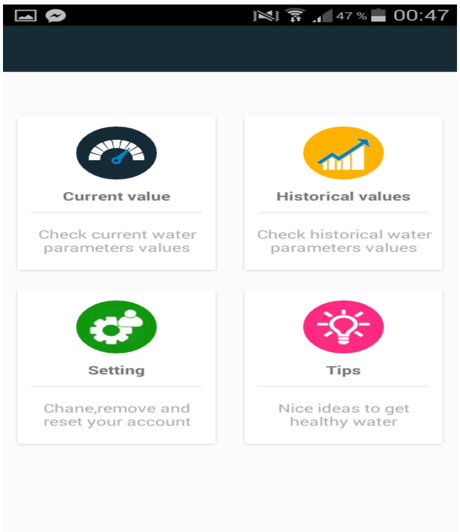


Figure 4.22: Home Interface

4.2.6.5 Account Setting Interface

In this interface, we have all account opertions of changing password, email, reset password, remove user, and sign out.

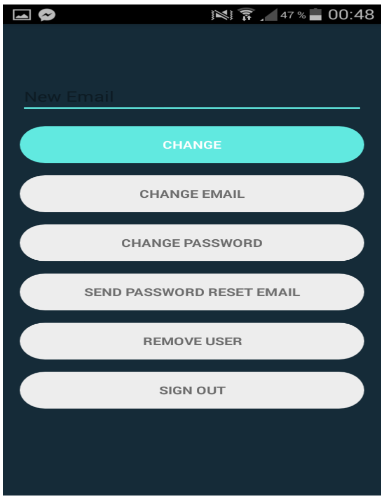


Figure 4.23: Account Setting Interface

4.2.6.6 Tips Interface

This interface represent an option to user to consult some of home methods to get clean water.

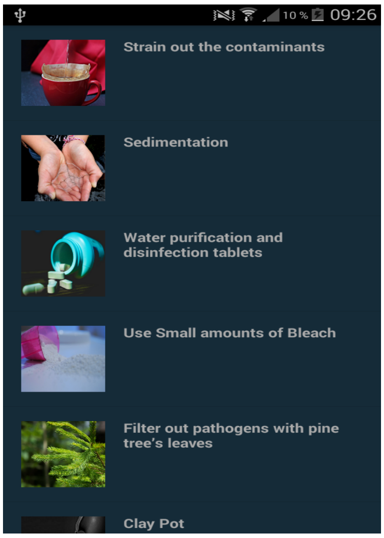
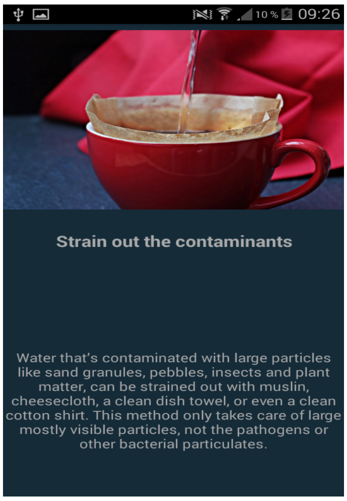


Figure 4.24: Tips Interface

The following Figures 4.25 give two examples of tips interfaces:



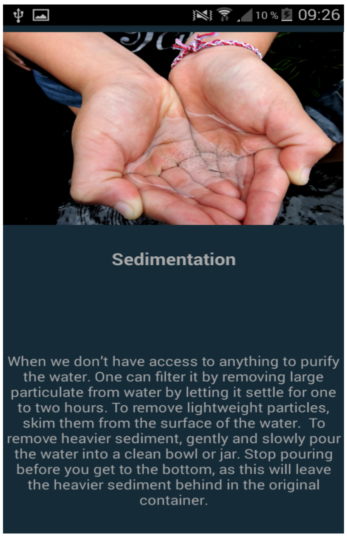


Figure 4.25: Examples Of Tips Interfaces

4.3 Results and Discussions

4.3.1 Work Environment

As shown in the past Chapter 3, our project environment contains both of: Raspberry, Sensors, computer and other accessories.

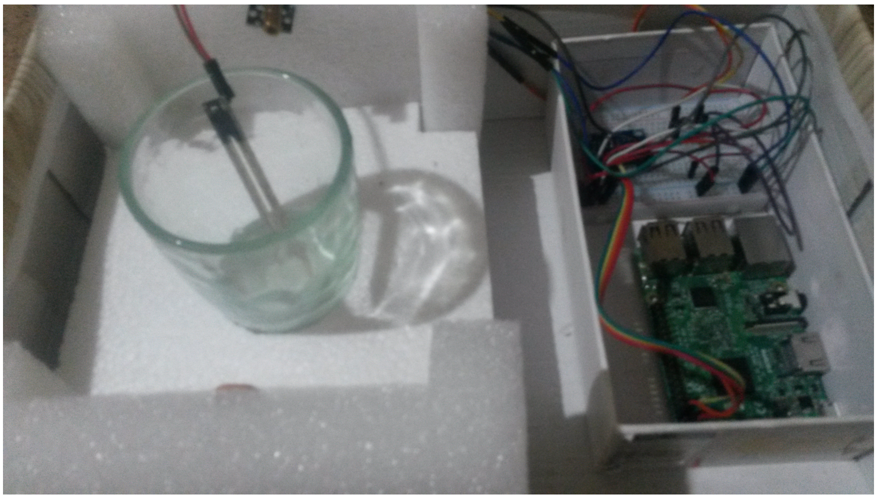


Figure 4.26: Work Environment.

We make connection between Raspberry and computer using **Remote Control Connection** which is Pre-installed on windows to access Raspberry Desktop .

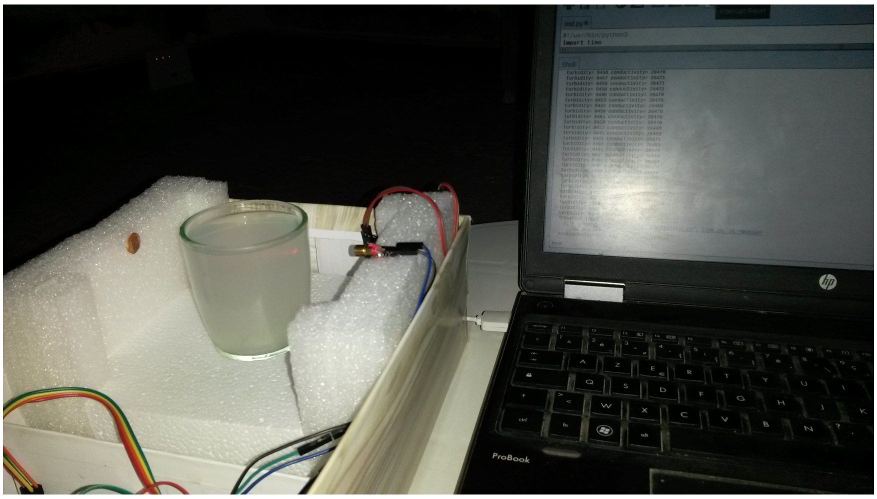


Figure 4.27: Read Sensor Data Using Remote Connection Desktop.

4.3.2 Checking Turbidity

We tested our system on two conditions; on clean water and on turbid water. The results about clean water gives us a range of analog signal that allows us to define the Threshold for water contamination.

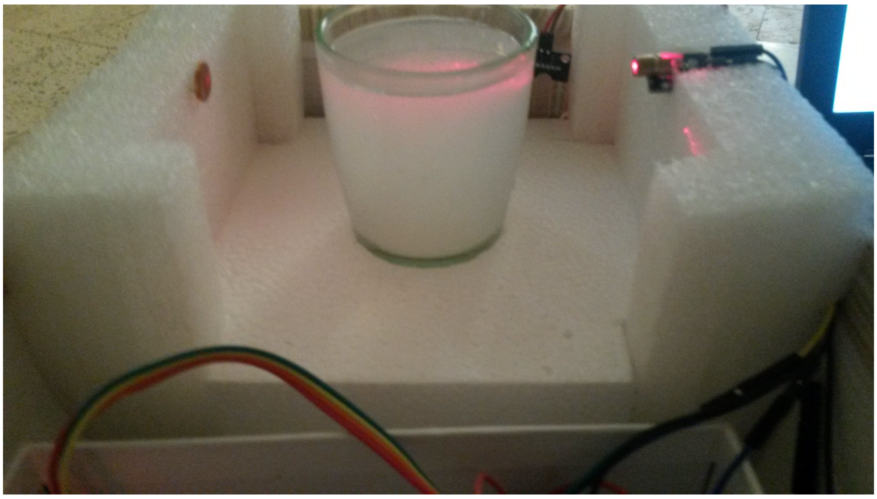


Figure 4.28: Turbid Water Check.

Note that, for increment the level of turbidity we add different quantities of milk to the clean water.

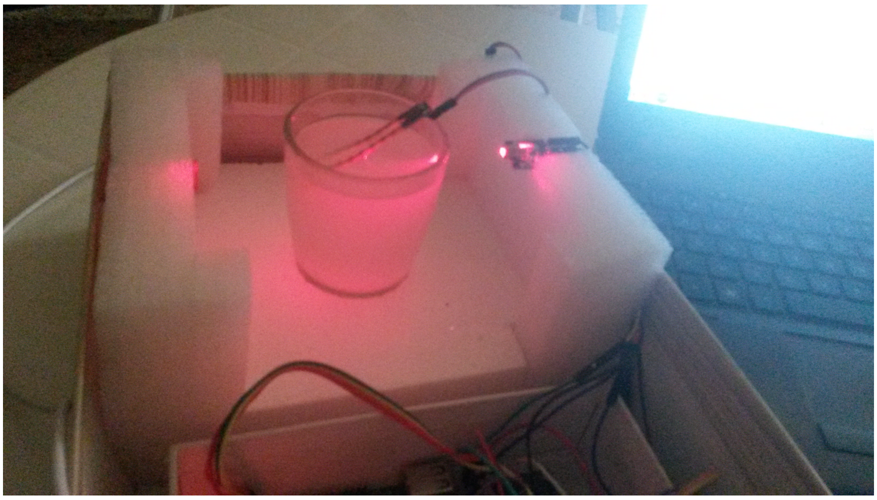


Figure 4.29: Very Turbid Water Check.

4.3.3 Checking Conductivity

In the case of conductivity, the salt is a good option to change the level of water conductivity.

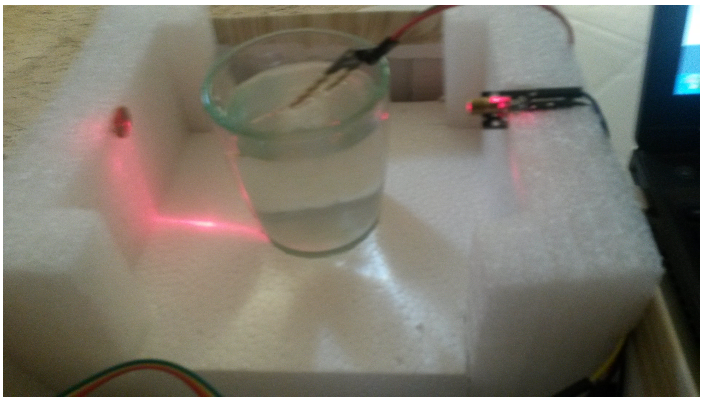


Figure 4.30: Conductivity Testing.

One can check if there is anomaly features of water, the informations about this anomaly are sending to the web site (See Figure 4.16) in parallel with a notification reported in the mobile application (See Figure 4.31).

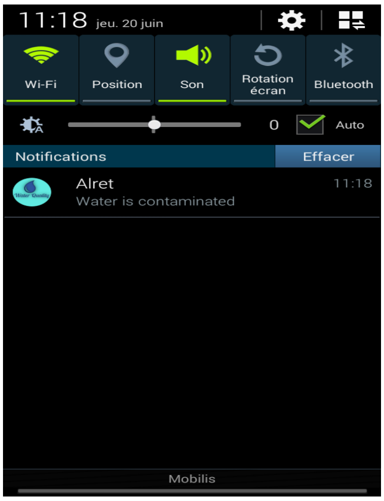


Figure 4.31: Display Notification.

4.4 Conclusion

This project aims to develop a system to monitor the water quality level based on water quality index as a standard practice by department of Environment Algeria (See Annex A). The developed system was successfully detect both conductivity and turbidity levels. Hence, it updating in web page, then it notify users if there is a water contamination.

This chapter presened real time monitoring system of water quality in an IoT environment. for this aim, we based in the concept of smart home and we use a several sensors for measuring physical and chemical parameters of water which are citted in the pervious chapter. In short, the Turbidity Meter simply measures the amount of light coming from the light sender to the light receiver and calculates the water turbidity.

Overall, the system developed offers fast and easy monitoring of drinking water and ensuring the clean water is continuously maintained.

General Conclusion

Failure is success if we learn from it.
Malcolm Forbes
Success is simple. Do what's right, the right way, at the right time.
Arnold H. Glasow

WATER pollution has been an increasing problem over the last few years. Water personal satisfaction may be a standout amongst those primary variables with control well being and the state for sicknesses. For insctane, after the cholera epidemic in Algeria (Blida 2018), the victims inquiring how to build a cheap device to ensure the quality of drinking water. For this purposes of water quality monitoring, we thought the design of a simple monitoring system capable of analyzing a water sample. The objective of this water quality monitoring system using internet of things is to find the quality of the water and sending alarm message to the corresponding authorities or to consumers. We are going to implement this project at home drinking water reservoir. For that we are using an Raspberry board for finding turbidity and conductivity value sensors. Then, we use a web application to have display the observations on water parameters. Finally the user gets a notification about water. Overall, the system developed offers fast and easy monitoring of drinking water and ensuring the clean water is continuously maintained.

As prospects for our work, we propose to improve it by future work in order to obtain more efficient analysis. These future works are as follows:

- Use more sensors for measuring physical and chemical parameters of water.
- Extend this project by sending the sensor data to cloud for global monitoring of water quality.
- Build a sofestic tool and simple use with the aid of this project.

Appendix A

Annex

Official newspaper about quality parameters of human consumption water.
Published on Sunday 7^{th} Joumada El Oula 1435, Corresponding to March 9, 2014.

N° 13 — Dimanche 7 Joumada El Oula 1435

53ème ANNEE — Correspondant au 9 mars 2014

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ANNEXE

Paramètres de qualité de l'eau de consommation humaine

Tableau 1 : paramètres avec valeurs limites

GROUPE DE PARAMETRES	PARAMETRES	UNITES	VALEURS LIMITES
Paramètres chimiques	Aluminium	mg/l	0,2
	Ammonium	mg/l	0,5
	Baryum	mg/l	0,7
	Bore	mg/l	- Eaux conventionnelles : 1 - Eaux déssalées ou déminéralisées : 1,3
	Fluorures	mg/l	1,5
	Nitrates	mg/l	50
	Nitrites	mg/l	0,2
	Oxydabilité	mg/l 02	5
	Acrylamide	µg/l	0,5
	Antimoine	µg/l	20
	Argent	µg/l	100
	Arsenic	µg/l	10
	Cadmium	µg/l	3
	Chrome total	µg/l	50
	Cuivre	mg/l	2
	Cyanures	µg/l	70
	Mercure	µg/l	6
	Nickel	µg/l	70
	Plomb	µg/l	10
	Sélénium	µg/l	10
	Zinc	mg/l	5
	Hydrocarbures polycycliques aromatiques (H.P.A) totaux Fluoranthène, benzo (3,4) fluoranthène, benzo (11,12) fluoranthène, benzo (3,4) pyrêne, benzo (1,12) pérylène, indéno (1,2,3-cd) pyrène,	µg/l	0,2
	benzo (3,4) pyrène	µg/l	0,01
	Benzène	µg/l	10
	Toluène	µg/l	700
	Ethylbenzène	µg/l	300

ANNEXE (suite)

GROUPE DE PARAMETRES	PARAMETRES	UNITES	VALEURS LIMITES
Paramètres chimiques (suite)	Xylènes	µg/l	500
	Styrène	µg/l	100
	Agents de surface régissant au bleu de méthylène	mg/l	0,2
	Epychlorehydrine	µg/l	0,4
	Microcystine LR	µg/l	1
	Pesticides par substance individualisée - Insecticides organochlorés persistants - Insecticides organophosphorés et carbamates - Herbicides - Fongicides - P.C.B - P.C.T - Aldrine - Dieldrine - Heptachlore - Heptachlorépoxyde	 µg/l µg/l µg/l µg/l µg/l µg/l µg/l µg/l µg/l µg/l	 0,1 0,1 0,1 0,1 0,1 0,1 0,03 0,03 0,03 0,03
	Pesticides (Totaux)	µg/l	0,5
	Bromates	µg/l	10
	Chlorite	µg/l	0,07
	Trihalométhanes par substance individualisée : -Chloroforme - Bromoforme - Dibromochlorométhane - Bromodichlorométhane	 µg/l µg/l µg/l µg/l	 200 100 100 60
	Chlorure de vinyle	µg/l	0,3
	1,2-Dichloroéthane	µg/l	30
	1,2-Dichlorobenzène	µg/l	1000
	1,4-Dichlorobenzène	µg/l	300
	Trichloroéthylène	µg/l	20
	Tetrachloroéthylène	µg/l	40
Radionucléides	Particules alpha	Picocuriel/L	15
	Particules béta	Millirems/an	4
	Tritium	Bequerel/l	100
	Uranium	µg/l	30
	Dose totale indicative (DTI)	mSv/an	0,15
paramètres microbiologiques	Escherichia Coli	n/100ml	0
	Enthérocoques	n/100ml	0
	Bactéries sulfitoréductices y compris les spores	n/20ml	0

Tableau 2

Paramètres avec valeurs indicatives

GROUPE DE PARAMETRES	PARAMETRES	UNITES	VALEURS INDICATIVES
Paramètres Organoleptiques	couleur	mg/l platine	15
	Turbidité	NTU	5
	Odeur à 25 °C	Taux dilution	4
	Saveur à 25 °C	Taux dilution	4
Paramètres physico-chimiques en relation avec la structure naturelle des eaux	Alcalinité	mg/l CaCO3	65 pour les eaux déssalées ou déminéralisées (valeur minimale)
	Calcium	mg/l	200
	Chlorure	mg/l	500
	Concentration en ions hydrogène	Unité pH	≥ 6,5 et ≤ 9
	Conductivité à 20 °C	μS/cm	2800
	Dureté (TH)	mg/l en CaCO3	500
	Fer total	mg/l	0,3
	Manganèse	μg/l	50
	Phosphore	mg/l	5
	Potassium	mg/l	12
	Sodium	mg/l	200
	Sulfates	mg/l	400
	Température	°C	25

Décret exécutif n° 14-97 du 2 Joumada El Oula 1435 correspondaut au 4 mars 2014 portant dissolution de l'agence de gestion du système hydraulique de Beni Haroun.

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Le Premier Ministre,

Sur le rapport du ministre des roussources en eau,

Vu la Constitution, notamment ses articles 85-3° et 125 (alinéa 2),

Vu le décret présidentiel n° 13-312 du 5 Dhou El Kaâda 1434 correspondant au 11 septembre 2013 portant nomination des membres du Gouvernement ;

Vu le décret exécutif n° 94-294 du 19 Rabie Ethani 1415 correspondant au 25 septembre 1994 relatif aux modalités de dissolution et de liquidation des entreprises publiques non autonomes et des établissements publics à caractère industriel et commercial ;

Vu le décret exécutif n° 07-337 du 19 Chaoual 1428 correspondaut au 31 octobre 2007 portant création de l'agence de gestion du système hydraulique de Beni Haroun ;

Après approbation du Président de la République ;

Décrète :

Article 1er. — L'agence de gestion du système hydraulique de Beni Haroun, créée par les dispositions du décret exécutif n° 07-337 du 19 Chaoual 1428 correspondaut au 31 octobre 2007 portant création de l'agence de gestion du système hydraulique de Beni Haroun est dissoute.

Art. 2. — La dissolution de l'agence prévue a l'article 1er ci-dessus, donne lieu à l'établissement d'un inventaire quantitatif, qualitatif et estimatif dressé conformément aux lois et règlements en vigueur par une commission dont les membres sont désignés conjointement par le ministre des finances et le ministre chargé des ressources en eau.

Art. 3. — Le présent décret sera publié au *Journal Officiel* de la République algérienne démocratique et populaire.

Fait à Alger le 2 Joumada El Oula 1435 Correspondant au 4 mars 2014.

Abdelmalek SELLAL.

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